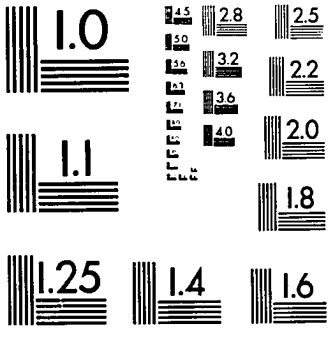
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GRADUATE COLLEGE

THE ASSESSMENT OF CLIMATOLOGICAL IMPACTS ON AGRICULTURAL PRODUCTION AND RESIDENTIAL ENERGY DEMAND

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

By

ELLEN JEAN COOTER

Norman, Oklahoma

1985

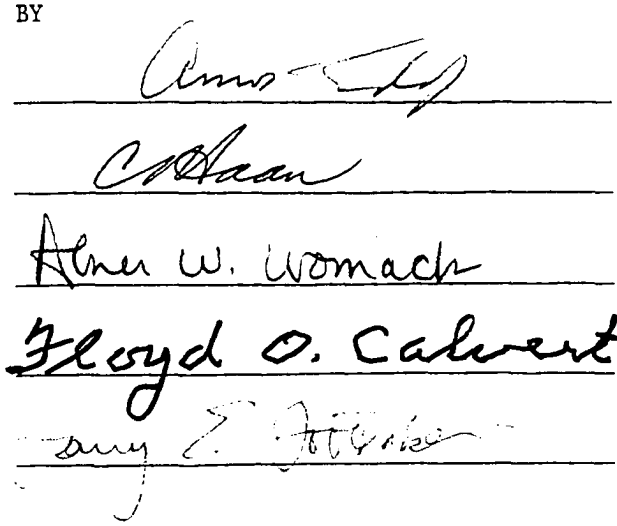
THE ASSESSMENT OF CLIMATOLOGICAL IMPACTS ON

AGRICULTURAL PRODUCTION AND RESIDENTIAL ENERGY DEMAND

A DISSERTATION

APPROVED FOR AN INTERDISCIPLINARY DEGREE

BY



ABSTRACT

The assessment of climatological impacts on selected economic activities is presented as a multi-step, inter-disciplinary problem. The assessment process which is addressed explicitly in this report focuses on 1) user identification, 2) direct impact model selection, 3) methodological development, 4) product development and 5) product communication.

Two user groups of major economic importance were selected for study; agriculture and gas utilities. The broad agricultural sector is further defined as U.S.A. corn production. The general category of utilities is narrowed to Oklahoma residential gas heating demand.

The CERES physiological growth model was selected as the process model for corn production. The statistical analysis for corn production suggests that 1) although this is a statistically complex model, it can yield useful impact information, 2) as a result of output distributional biases, traditional statistical techniques are not adequate analytical tools, 3) the model yield distribution as a whole is probably non-Gausian, particulary in the tails and 4) there appears to be identifiable weekly patterns of forecasted yields throughout the growing season. Agricultural quantities developed include point yield impact estimates and distributional characteristics, geographic corn weather distributions, return period estimates, decision making criteria (confidence limits) and time series of indices. These products were

communicated in economic terms through the use of a Bayesian decision example and an econometric model.

The NBSLD energy load model was selected to represent residential gas heating consumption. A cursory statistical analysis suggests relationships among weather variables across the Oklahoma study sites. No linear trend in "technology-free" modeled energy demand or input weather variables which would correspond to that contained in observed state-level residential energy use was detected. It is suggested that this trend is largely the result of non-weather factors such as population and home usage patterns rather than regional climate change. Year-to-year changes in modeled residential heating demand on the order of 10^6 Btu's per household were determined and later related to state-level components of the Oklahoma economy. Products developed include the definition of regional forecast areas, likelihood estimates of extreme seasonal conditions and an energy/climate index. This information is communicated in economic terms through an input/output model which is used to estimate changes in Gross State Product and Household income attributable to weather variability.

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CONTENTS

ABSTRACT i

ACKNOWLEDGEMENTS iii

Chapter page

I. INTRODUCTION 1

II. PRODUCTION/CONSUMPTION MODEL REVIEW 10

III. A CLIMATE SENSITIVITY ANALYSIS OF THE CERES CORN MODEL 45

INTRODUCTION 45
A FIRST LOOK AT WEATHER IMPACTS 54
Between-Season Weather Impacts 64
Within-Season Weather Impacts 73
STATISTICAL ANALYSIS OF MODELED YIELD/WEATHER RELATIONSHIPS 76
Variance Partitioning 76
Within-Season Variability 86
A Two-Way ANOVA Approach to Within-Season Impact Analysis. 101
AN AGROCLIMATIC ANALYSIS OF CORN GROWING SEASON CONDITIONS: A 1983 U.S. CORN BELT EXAMPLE 132
The 1983 Corn Growing Season: A Climatological Analysis 136
The 1983 Corn Growing Season: An Agrometeorological Analysis 148
AGROCLIMATOLOGICAL PRODUCTS FROM THE CERES CORN MODEL . . 160
Pre-Season Climatological Products 161
Mid-Season Products: Point Estimates 170
Mid-Season Products: A Corn/Weather Index 182
Mid-Season Products: A Bayesian Example 189
The Bayesian Problem 189
Estimations of Mid-Season Forecast Skill 191
Estimation of Forecast Certainty 195
Mid-Season Forecast Value Estimation 202
Modeled Yield Non-Homogeneities and User Products . . . 215

IV. ESTIMATION OF DIRECT IMPACTS OF RESIDENTIAL HEATING ENERGY DEMAND. 225

NBSLD MODEL DESCRIPTION 227
HEATING SEASON WEATHER STATISTICS 230
NBSLD ENERGY USE ESTIMATES 243

MODEL COMPARISONS 255
CLIMATE/ENERGY PRODUCTS 263
SUMMARY 271

V. ECONOMIC APPROACHES TO THE ASSESSMENT OF THE VALUE OF CLIMATOLOGICAL INFORMATION AND IMPACTS 274

VI. SUMMARY 302

BIBLIOGRAPHY 309

Appendix page

A. CERES MODEL RESPONSES TO WEEKLY MAXIMUM TEMPERATURE, MINIMUM TEMPERATURE AND PRECIPITATION VARIABILITY AT SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT. 314

B. STATISTICAL RESULTS FOR MEAN SEASONAL MAXIMUM AND MINIMUM TEMPERATURES AND TOTAL PRECIPITATION AT SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT. 333

C. RAW WEEKLY 1983 RANKS OF MAXIMUM AND MINIMUM TEMPERATURE AND PRECIPITATION AT SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT. 354

D. STATISTICAL RESULTS FOR INPUT SERIES 1 THROUGH 5 (TABLE 15) FOR SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT. 358

E. WEEKLY IMPACTS OF OBSERVED MAXIMUM AND MINIMUM TEMPERATURES AND PRECIPITATION ON MODELED CORN YIELD AT SEVEN SENSITIVITY SITES ACROSS THE U.S.A. CORN-BELT. 393

F. LONG-TERM AND ANNUAL WEEKLY MEAN MODELED YIELD AND FOLLOWING WEATHER YIELD VARIABILITY (1948-1983) AT ROCHESTER, MN. 450

G. PHYSICAL DESCRIPTION OF NBSLD STRUCTURE. 488

H. STATISTICAL SUMMARY OF AVERAGE HEATING SEASON MEAN, MAXIMUM AND MINIMUM TEMPERATURES AND TOTAL HEATING DEGREE DAYS AT FOUR OKLAHOMA SITES. 510

I. SAMPLE OUTPUT FOR ROOM 1, JANUARY 1-2, 1955 AT ALTUS, OKLAHOMA. 527

LIST OF TABLES

Table		page
1.	Comparison of General Model Characteristics (Source: Larsen (1981)).	17
2.	Input-Operating Data for NBSLD.	33
3.	Input-Building Data for NBSLD.	34
4.	Input-Weather Data to NBSLD.	35
5.	An Example of Structure Definition as Given by the GBEA Model.	38
6.	An Example of Hourly Energy Exchanges Produced by the GBEA Model.	39
7.	Quantity of Energy Used for Onfarm-Pumped Irrigation Water(After Sloggett, 1979).	43
8.	Total Cost of Energy for Onfarm-Pumped Irrigation Water(After Sloggett, 1979).	44
9.	Selected Energy Prices in the United States(After Sloggett, 1979).	44
10.	CERES Process Model Plant Functions or Operations.	48
11.	Growth Stages Used in CERES Corn Models.	49
12.	Sample Results of the Modified CERES Model at Peoria, IL.	50
13.	Corn/Weather Impact Seasons for Selected Stations.	63
14.	Summary of 1983 Weather Impacts on Modeled Corn Yields at Peoria, IL.	75
15.	Corn Weather Impact Normalization Schemes.	79
16.	Means, Julian Dates and Standard Deviations of Phenological Stages of Corn Development as Calculated by the CERES Model at Rochester, MN.	85

18. Weekly Impact of All Observed Weather Variables on Modeled Corn Yield at Peoria, IL (Case 1 - Case 5, Table 15). 89

19. Weekly Impact of Observed Maximum Temperature on Modeled Corn Yield at Peoria, IL (Case 2 - Case 5, Table 15). 90

20. Weekly Impact of Observed Minimum Temperature on Modeled Corn Yield at Peoria, IL. (Case 3 - Case 5, Table 15). . . . 91

21. Weekly Impact of Observed Precipitation on Modeled Corn Yield at Peoria, IL. (Case 4 - Case 5, Table 15). 92

22. Summary of Weekly Modeled Yield Sensitivity Analysis for Peoria, IL. 100

23. Contents of the Shaded Column of Figure 35 104

24. Contents of the Shaded Row of Figure 35 105

25. Results of the SAS ANOVA Procedure for Three Two-Way Designs. 110

26. Clustered Years of Pairwise Selected Yields Produced by Leading Weather Time-Series. 128

27. Model Input Corn Variety Specifications. 134

28. Corn Belt Station Locations and Model Input Parameter Values. 135

29. June 1, 1983 Yield Projections. 178

30. July 1, 1983 Yield Projections. 179

31. August 1, 1983 Yield Projections. 180

32. August 15, 1983 Yield Projections. 181

33. Modeled Yield and Random Contingency Tables of Average Planting Week at Rochester, MN. 193

34. Modeled Yield and Random Contingency Tables for Five Weeks Following Average Planting Week at Rochester, MN. 193

35. Modeled Yield and Random Contingency Tables for Pre-Flowering Week at Rochester, MN. 194

36. Modeled Yield and Random Contingency Tables for Post Flowering Week at Rochester, MN. 194

37. Modeled Yield and Random Contingency Tables for End of Linear Grain Fill Week at Rochester, MN. 195

38. Modeled Yield and Gausian Estimated Contingency Tables for Post-Flowering Week at Rochester, MN. 197

39. Row Variance, Modeled Yield and Individual Row Gausian Fit Contingency Tables for Post Flowering Week at Rochester, MN. 197

40. Matrix Variance, Modeled Yield and Simultaneous Row Gausian Fit Contingency Tables for Post-Flowering Week at Rochester, MN. 198

41. Column Variance, Modeled Yield and Individual Column Gausian Fit Contingency Tables for Post-Flowering Week at Rochester, MN. 198

42. Matrix Variance, Modeled Yield and Simultaneous Column Gausian Fit Contingency Tables for Post-Flowering Week at Rochester, MN. 199

43. Modeled Yield and Gausian Estimated Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN. 203

44. Row Variance, Modeled Yield and Simultaneous Row Gausian Fit Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN. 203

45. Matrix Variance, Modeled Yield and Simultaneous Row Gausian Fit Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN. 204

46. Column Variance, Modeled Yield and Individual Column Gausian Fit Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN. 204

47. Matrix Variance Modeled Yield and Simultaneous Column Gausian Fit Contingency Tables for Post Flowering Week and 5 EDF at Rochester, MN. 205

48. Assigned Unit Values to Factors Contributing to Decision Maker Regrets. 206

49. Mid-Season Forecast Categories and Associated Decision Maker Actions. 206

50. Decision Maker Risks Associated With Actions a_1 Through a_5. . 207

51. Decision Maker Regrets Table. 207

52. Original Modeled Yield Contingency Table. 208

53. Joint Probability Table for Baysian Decision Maker. 208

54. Table 53 Normalized by Column. 209

55. Computed Baysian Regrets Table. 211

56. Means and Standard Deviations of Three Clustered Distributions of Mean Forecasted Yields at Weeks 25, 30, and 35. 220

57. Probability Statements Concerning the Likelihood of Mean Forecast, X, Belonging to Forecast Group 1, 2, or 3. . . . 222

58. Weather Input Parameters Required for a Real-Time NBSLD Execution. 229

59. NBSLD Data Sites and Period of Record. 229

60. Largest Differences of Cummulative Frequency Plots of Seasonal Weather Variables Across Five Oklahoma Sites. . . 240

61. Largest Differences of Cummulative Frequency Plots of Daily Weather Variables Across Five Oklahoma Sites. 240

62. Hourly Weather Data for Altus Oklahoma, January 1, 1955. . . . 244

63. Computed Cummulative Probability Values for Use in K-S Tests for Station Period of Record (frequency count[cummulative probability]). 251

64. K-S Critical Values Used in Conjunction with Table 63. 251

65. Summary of K-S Tests of Energy Demand Among Five Oklahoma Sites. 252

66. Seasonal Energy Correlations Between NBSLD Generated Energy Demand and Individual Weather Variables at Five Oklahoma Locations. 253

67. Counties Contained in Each Energy Area Defined in Figure 101. 257

68. Figure 101 Regional Population Weights, 1955-1964 for NBSLD Point Energy Estimates. 258

69. Weighted State Heating Energy Demand(Single Dwelling), 1955-1964 and Reported Residential Heating Energy Demand(all dwellings,gas). 258

70. NBSLD Weighted State Energy Demand and Detrended Reported Energy Demand. 260

71. Population Weighted HDD and AISC Model Estimated State Energy Demand. 262

72. Key to Sectors Used in Oklahoma Input-Output Model. 284

73. Multipliers for a $1 Decrease in Utility Final Demand. 284

74. State-Level Economic Changes Induced by Weather Conditions During December, 1983 (W. Cooter, 1984). 286

75. State-Level Economic Changes Induced by Weather Conditions During December, 1965. 286

76. State-Level Economic Impacts of Winter Heating Season Weather in Oklahoma. 289

77. Use Price Changes Associated with a Corn Supply Change of +100 million Bu. 293

78. Use Price Changes Associated with a Corn Supply Change of -100 million Bu. 293

79. Mean and Standard Deviation of Yield, Production and Production Value for a 1, 20 and 40 Station Network. . . . 294

LIST OF FIGURES

Figure		page
1.	Impact Assessment Overview (Source: OCS (1980)).	4
2.	Research Organization and Flowchart.	6
3.	Generalized TAMW Flowchart (Source: Larsen (1981)).	16
4.	Upper Thermoneutral Temperature for Hogs(Source: Hays, 1983).	20
5.	Bioclimatic Chart for U.S. Moderate Zone Inhabitants (After Olgyay, 1963).	27
6.	NBSLD Calculation Sequence for Hour-by-Hour Heating and Cooling Load of Buildings (After Kusuda, 1976).	32
7.	An Example of an Hourly Loss/Gain Graph Produced by the GBEA Model.	40
8.	Cummulative Probability Plots and Sample D's for Raw, Modeled and Normalized Modeled Data.	53
9.	Time-Series Construction to Examine Weather Impacts on Modeled Corn Yields During Week 24.	56
10.	Time-Series Construction to Examine Weather Impacts on Modeled Corn Yields During Week 25.	56
11.	CERES Model Response to Weekly Maximum Temperature at Peoria, IL.	57
12.	CERES Model Response to Weekly Minimum Temperature at Peoria, IL.	58
13.	CERES Model Response to Weekly Precipitation at Peoria, IL. . .	59
14.	Statistical Results for Mean Seasonal Maximum Temperature at Peoria, IL.	65
15.	Statistical Results for Mean Seasonal Minimum Temperature at Peoria, IL.	66

16. Statistical Results for Total Seasonal Growing Degree Days at Peoria, IL. 67

17. Statistical Results for Total Seasonal Precipitation at Peoria, IL. 68

18. Statistical Results for Input Series 1 Generated Yields. . . . 70

19. Ranking System for Figures 20 - 22. 71

20. Annual Modeled Yield and Season Average Minimum Temperature Ranks at Peoria, IL. 71

21. Annual Modeled Yield and Season Average Maximum Temperature Ranks at Peoria, IL. 72

22. Annual Modeled Yield and Season Total Precipitation Ranks at Peoria, IL. 72

23. Raw Weekly 1983 Ranks of Maximum Temperature, Minimum Temperature and Precipitation at Peoria, IL. 73

24. Smoothed Weekly 1983 Ranks of Maximum Temperature, Minimum Temperature and Precipitation at Peoria, IL. 74

25. Statistical Results for Input Series 2 Generated Yields (see Table 15). 80

26. Statistical Results for Input Series 3 Generated Yields (see Table 15). 81

27. Statistical Results for Input Series 4 Generated Yields (see Table 15). 82

28. Statistical Results for Input Series 5 Generated Yields (see Table 15). 83

29. Time-Series Construction and Series 1-4 Description for Weekly Partitioning of Within Season Yield Variance. 88

30. Weekly Yield Difference Means, Standard Deviations and Ranges at Peoria, IL (Case 1 - Case 5, Table 15, all variables normalized). 95

31. Weekly Yield Difference Means, Standard Deviation and Ranges for Maximum Temperature at Peoria, IL (Case 2 - Case 5, Table 15). 96

32. Weekly Yield Difference Means, Standard Deviation and Ranges for Minimum Temperature at Peoria, IL (Case 3 - Case 5, Table 15). 97

33. Weekly Yield Difference Means, Standard Deviation and Ranges for Precipitation at Peoria, IL (Case 4 - Case 5, Table 15). 98

34. Weather Time-Series Construction for the Two-Way ANOVA Model (after Duchon, 1984). 102

35. 3-Dimensional Array Construction of Modeled Yield Time-Series for the Two-Way ANOVA Model. 103

36. Three Two-Way ANOVA Designs. 106

37. Graphical Representation of and , where: j=leading year and k=following year. 113

38. Weekly Average Grand Mean and Standard Deviation for Leading Weather at Rochester, MN. 115

39. Weekly Average Grand Mean and Averaged Variability for Following Weather at Rochester, MN. 116

40. Composite of Figures 38 and 39. 119

41. Weekly Differences of Preceding and Following Yield Deviations at Rochester, MN (see Eq. 21). 120

42. Long-Term Weekly Mean and 1971 Modeled Yield and Following Weather Yield Variability at Rochester, MN. 123

43. Long-Term Weekly Mean and 1982 Modeled Yield and Following Weather Yield Variability at Rochester, MN. 124

44. Mean Forecasted Yields Attributable to Leading Weather, 1948 - 1983. 127

45. Histogram of Clustered Forecasted Yield Means at Week 27 . . 129

46. Histogram of Clustered Forecasted Yield Means at Week 28 . . 130

47. Map of Model Execution Sites. 133

48. Rankings of the 1983 Corn Growing Season Maximum Temperature. 138

49. Rankings of the 1983 Corn Growing Season Minimum Temperature. 138

50. Rankings of the 1983 Corn Growing Season Precipitation. . . . 139

51. 1983 Weekly Ranked Weather Patterns for Springfield, MO. . . 140

52. 1983 Weekly Ranked Weather Patterns for Dodge City, KS. . . . 141

53. 1983 Weekly Ranked Weather Patterns for Peoria, IL. 141

54. 1983 Weekly Ranked Weather Patterns for Rapid City, SD. . . . 141

55. 1983 Weekly Ranked Weather Patterns for Des Moines, IO. . . . 142

56. 1983 Weekly Ranked Weather Patterns for Indianapolis, IN. . . 142

57. 1983 Weekly Ranked Weather Patterns for Omaha, NB. 142

58. 1983 Weekly Ranked Weather Patterns for Columbus, OH. 143

59. 1983 Weekly Ranked Weather Patterns for Rochester, MN. . . . 143

60. 1983 Corn Belt Meteorological Drought 147

61. 1983 and Long-Term Rochester Weekly Mean Yield and Following Weather Variance. 150

62. 1983 Corn Belt Agricultural Drought 151

63. 1983 Corn Growing Season Weather and Modeled Yields 152

64. Weekly Deviations from Mean Model Yields Attributed to Long-Term Leading, Long-Term Following and 1983 Followig Weather(see Eq. 21). 156

65. Flowering Weather Index for 1983. 159

66. 1983 Flowering Weather Index and Model Predicted Yields. . . 160

67. Likelihood of 1983 Growing Season Temperatures or Warmer and 1983 Growing Season Precipitation or Drier Recurring. 162

68. Likelihood of 1983 or Lower Yields Recurring. 164

69. Probability of State Weighted Flowering Temperatures Recurring. 166

70. Corn Belt Production Hazard Under 1983 Flowering Conditions. 168

71. Weather Time-Series Construction for Yield Distribution Forecasts (After Duchon, 1984). 172

72. Corn Model Yield Statistics 1948-1983. 173

73. F-Test Results Derived from the Leading and Following Variances Graphed in Figure 72. 174

74. The value of Perfect 5-, 15- and 30-day Weather Forecasts During the 1983 Growing Season at Peoria, IL (After Duchon, 1984). 175

75. Modeled Yield Distribution for Period Ending June 1, 1983. . 176

76. Modeled Yield Distribution for Period Ending July 1, 1983. . 176

77. Modeled Yield Distribution for Period Ending August 1, 1983. 177

78. Modeled Yield Distribution for Period Ending August 15, 1983. 177

79. Corn/Weather Index Time-Series 185

80. Response of Independent Pooled Variance to Station Number. . 188

81. Graphed Chi-Square Values versus Time of Mid-Season Forecast. 196

82. Diagram of Gausian Row Fitting Procedure. 200

83. Schematic Illustrating the Sample Bias in the Gausian Fitting Procedure. 201

84. Estimated Bayes Risk at Flowering. 213

85. Value of EDF Flowering 214

86. Hypothetical Distribution of Modeled Corn Years. 216

87. Locations of NBSLD Station Sites. 230

88. Statistical Summary of Mean Heating Season Temperature at Oklahoma City, Oklahoma. 233

89. Statistical Summary of Mean Heating Season Minimum Temperature at Oklahoma City, Oklahoma. 234

90. Statistical Summary of Mean Heating Season Maximum Temperature at Oklahoma City, Oklahoma. 235

91. Statistical Summary of Total Heating Season HDD at Oklahoma City, Oklahoma. 236

92. Time-Series of Heating Season HDD at Oklahoma City, Oklahoma. 238

93. Time-Series of Heating Season Mean Maximum Temperatures. . . 238

94. Time-Series of Heating Season Mean Minimum Temperatures. . . 239

95. Statistical Summary of NBSLD Generated Energy Requirements for Altus, Oklahoma. 245

96. Statistical Summary of NBSLD generated Energy Requirements for Enid, Oklahoma. 246

97. Statistical Summary of NBSLD Generated Energy Requirements for Gage, Oklahoma. 247

98. Statistical Summary of NBSLD Generated Energy Requirements for Oklahoma City, Oklahoma. 248

99. Statistical Summary of NBSLD Generated Energy Requirements for Tulsa, Oklahoma. 249

100. Time-Series of NBSLD Generated Energy Demand at Five Oklahoma Locations. 253

101. Oklahoma Energy Demand Areas. 256

102. Likelihood of December 1983 or Higher Residential Energy Demand Weather. 265

103. Likelihood of December 1965 or Lower Residential Energy Demand Weather 266

104. Time-Series of Monthly Energy/Climate Indices 268

105. Monthly Energy Climate Indices for the 1984/85 Heating Season with Confidence Limits. 271

106. A Simplified Regional Input-Output Table. 277

107. Possible Change in Utility Sector Technology Stemming From Increased Demand During Unusually Cold Winters or Hot Summers. 278

108. Alternative Pattern of Utility Sector Technology Change Stemming From Increased Demand During Unusually Cold Winters. 279

109. Possible Changes in Technologies of Commercial Sectors and Spending Patterns of Households Associated with Unusually Cold Winters or Hot Summers. 280

110. Time-Series of GSP, Household Income and Direct Impacts of Heating Season Weather in Oklahoma. 288

111. Feed Grains (Annual Model) Corn, Sorghum, Oats and Barley (After Womack, et.al., 1982). 291

Chapter I

INTRODUCTION

Climate impact assessment is a relatively new field of endeavor whose primary focus is to identify and quantify aspects of the atmospheric environment which impact on, or interact with, economically important activities. For the purposes of the present study it attempts to determine the economic (in contrast to intrinsic or social) value of climate conditions or fluctuations. Although many atmospheric conditions and processes have seemingly obvious impacts on economic activities, meteorologists and climatologists have only recently attempted to isolate and quantify them. One early attempt was made by Russo for the construction industry (Russo, 1971). Another notable early contribution was Maunder's "The Value of Weather" (1970). The point to be made here is that while major contributions have been made by certain meteorologists and climatologists, climate impact assessment has largely failed to gain the acceptance that has been awarded to, for instance, the field of environmental impact assessment.

There are, of course, exceptions to this generalization, such as the work of Maunder. Although his techniques have received limited use by several U.S.A. agencies within the National Oceanographic and Atmospheric Administration (NOAA), they still have not attained widespread recognition and acceptance from economic or administrative decision makers in the United States. The question can be posed: why

have climatologists not taken up the challenge to establish a new, clearly identifiable and potentially valuable discipline of climate impact assessment? Perhaps a brief considertion of the seemingly kindred discipline of environmental impact assessment could shed light on this issue.

Although both are concerned with environmental phenomena, environmental impact assessment actually bears little resemblence to climate impact assessment. One major difference is that the entire field of environmental impact assessment was born out of legislative necessity. When the Environmental Protection Agency (EPA) was initially empowered in the 1960's and 1970's, a requirement for the completion of Environmental Impact Statements or Environmental Impact Assessments associated with most public works projects was also established. Detailed guidelines were published in the "Federal Register" (Federal Register, 1973). These guidelines spelled out who was to do the assessments, who would evaluate them, and exactly what was to be in them. More than ten years later these are still the basic guidelines in use, and a large group of trained professionals has arisen concerned with the development of products which follow these guidelines to the letter. The basic elements of this discipline are described well in Canter (1977).

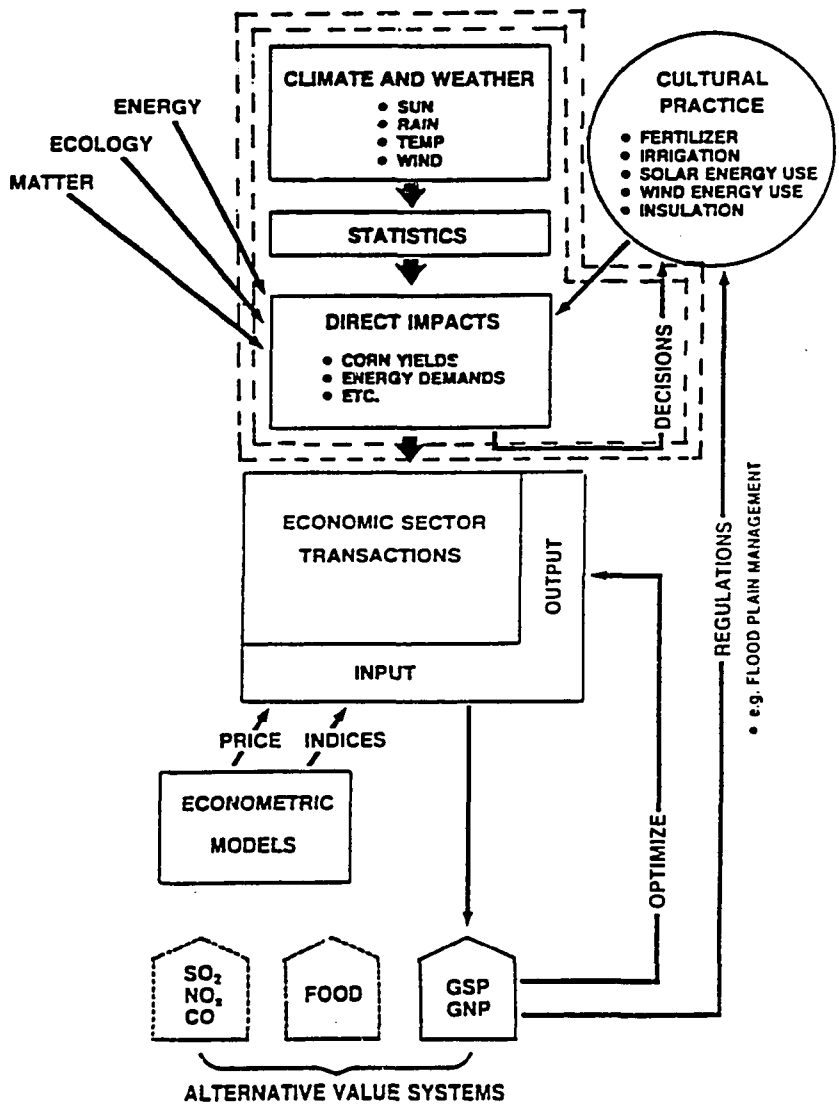
In contrast, climate impact assessment is not legislated. There is no requirement for specific analyses to be performed. There are no legally mandated Climate Impact Assessments. If there is to be a viable field of study called climate impact assessment, climatologists must begin by identifying a user audience or market. Once a market has been

identified, there must be a technically solid product to which some demonstratable value or payoff can be attached. Climatologists cannot establish this value by themselves nor, as in the case of Environmental Impact Assessments, can they have the value of their product defined by the Federal Government.

In spite of these obstacles, one can still establish the basic requirements for a successful climate impact assessment program. Figure 1 is a schematic of such a program. This figure illustrates the way in which meteorological observations, statistics of the observations and a knowledge of weather sensitive aspects of economic production or consumption act as input to numerical estimates of direct weather impacts. Results of the direct impact expressions can be used immediately as tools to assist decision makers involved in weather sensitive activities, or they can be used as input to economic models (inter-industry or econometric) to produce estimates of economy-wide dollar impacts of weather on a broad spectrum of economic activities. A final step is to translate these impacts into alternative value systems (pollution, crop production, etc.), and use this activity-specific information to optimize sectoral production/consumption or assist in the formulation of new regulations or guidelines.

Although it might be desirable to consider each element of Figure 1 in great detail, we have decided to focus on the elements contained within the double lined boxed area. The remaining segments are included in the present project, but in far less detail. A detailed flowchart of the research organization of this report is provided in Figure 2. It can be summarized into five steps: 1) user identification, 2) direct

Figure 1: Impact Assessment Overview (Source: OCS (1980)).

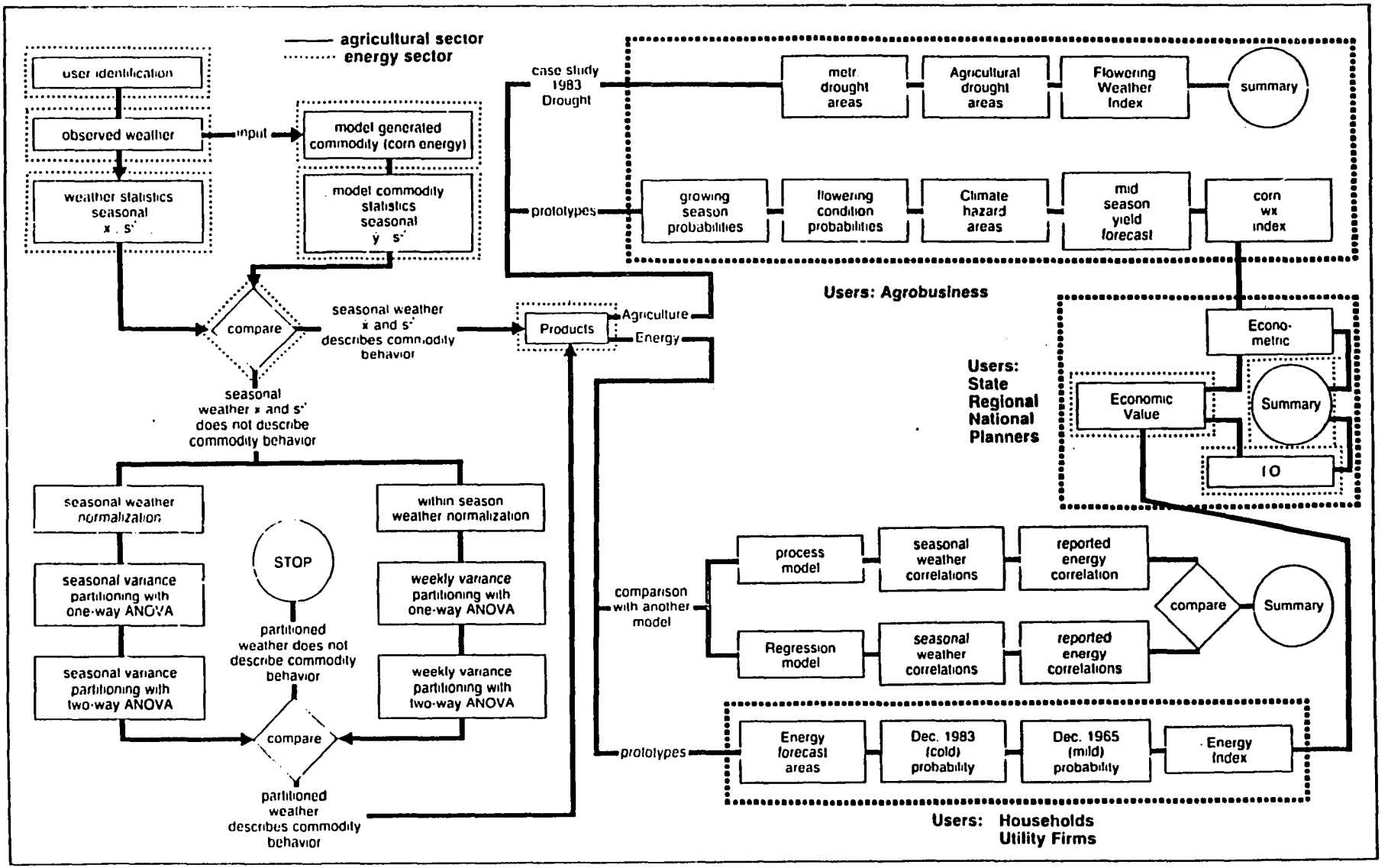


impact model selection, 3) methodological development, 4) product development and 5) product communication.

The first step at the top of Figure 2, user identification, is not explored at great length in this study. In the present case, economic activities which are important at the State (Oklahoma residential gas heating demand) and National (corn-belt regional production) scales were selected. The logic behind this selection is that one would like a significant return on his investment of research time, effort and product development. One assumes the largest returns would be derived either from large-volume markets, markets demonstrating large impacts, or markets making large contributions to the overall economy of the area of interest. In the case of agriculture, the number of potential users may be relatively small, but the activities of this economic sector make large contributions to the overall economy. Also, the potential dollar impact of weather on these sectoral activities is substantial. In the case of gas utilities, the magnitude and dollar value of individual household impacts are usually small relative to those of agriculture, but the number of potential utility product users is many times that of agriculture. Once the general area of economic activity has been selected, various user groups within the sector such as state or national level decision makers, corporations, or individuals can be further identified and developed.

The second portion of Figure 2 represents the development of a basic model methodology which is repeated for both agricultural and utility sectors. This component includes the selection of physical-process models (for crop production and residential gas heating

Figure 2: Research Organization and Flowchart.



consumption), the input of weather data into the model and a statistical analysis of both the input variables (weather and climate) and model-generated results (yield and energy demand distributions). The lower one-half of Figure 2 defines in more detail the components of the statistical anlaysis for corn. Chapter II contains a brief review of physical models available for analysis. Chapter III contains the agricultural model and its statistical evaluation. Chapter IV contains the same treatment for residential heating demand.

The methodology has been designed to yield those products which satisfy the market demand. Agricultural products are discussed in Chapter III, sections 4 and 5. Section 3.4 contains a specific analysis for corn-belt climate impacts during the 1983 drought. Section 3.5 contains a variety of pre-season and mid-season agroclimatological products. Energy-related products and a model comparison are contained in Chapter IV. A model comparison could have been performed for the agricultural sector as well, but such a comparison was considered to represent a more significant contribution to the field of impact assessment if performed only for the energy demand sector at this time.

The final step, valuation, is addressed in two manners. Chapter III, section 4 utilizes Bayesian decision techniques to assess the dollar value of direct weather impacts and product refinements. Chapter V addresses this same issue using more traditional economic language and models. The results include dollar impact value estimates in econometric and inter-industry terms.

There are several elements within the present report that represent unique applications of existing methodologies, interpretation and presentation of model results, and model analysis. This is especially the case with the analysis of an agricultural process model to estimate commodity responses to climate and climate variability. Crop models have been used for many years by many scientists to estimate point and regional crop production. To date, most detailed climatological analyses have utilized statistical regression type models, particularly when making regional impact estimates. Most agronomists, however, would now favor using physical-process models. Those scientists interested in assessing weather impacts have either avoided using process models altogether or have replaced their regression expressions with process models after little detailed analysis of the models' statistical or weather sensitivities. Chapter III, sections 1, 2, and 3 begin to remedy this situation for the CERES maize plant process model (Ritchie and Otter, n.d.). Some comparisons and model analyses had been done previously, but these were largely aimed at validating the model at a single location for a single growing season (see Larsen, 1981). Prior to the present report, no detailed analysis of the model's response to a variable climate had been performed. In the course of this climate sensitivity analysis, insights into the statistical nature of a plant process model are gained. Although Chapter III concludes that we are dealing with a complex statistical system, certain distinct advantages of such a model are explored. Chief among these is the ability to use these models to make mid-season forecasts which can include confidence limits. Although possible in some cases, no operational mid-season crop

forecast which utilizes computer models provides this information at present. This unique feature is explored, applied in a decision theory framework, and economically quantified. Other unique agroclimatological products such as a corn climate hazard map are developed and presented.

Although not quite as "revolutionary" as Chapter III, the energy analysis contained in Chapter IV also makes significant contributions to climate impact assessment. Three major topics are explored: use of a building load model to perform an analysis in space and time of residential energy demands; a performance comparison of a process type energy model and its statistical regression counterpart; and the translation of annual weather impacts into a time series and distribution of heating demand variability impacts on household income and Gross State Product.

Chapter II

PRODUCTION/CONSUMPTION MODEL REVIEW

Climatic impacts upon economic production and consumption patterns have long been noted in a qualitative manner by both economists and climatologists. These impacts may be of a beneficial or detrimental nature. For instance, favorable climatological conditions may permit maximum plant growth and development, increased livestock production, or savings in tillage, harvesting, and other field work operations. Unfavorable conditions can trigger pest or pathogen outbreaks, create the need for supplemental irrigation, drown the crop, or delay various field work operations, all of which can lead to production losses or decreased crop quality. A large body of literature exists which identifies, or quantifies, these and other climate impacts on agricultural and unit utility production and consumption. The discussion that follows will highlight those works which have been important to the development of production models for agricultural commodities such as crops and livestock and residential energy consumption models for utility impact assessment. Later chapters will utilize selected models, to estimate climate impacts on a variety of time and space scales.

One obviously weather sensitive sector of the national economy is agriculture. A major portion of production variability can be attributed to local climatic factors. This sensitivity is usually

manifested in fluctuating yields, rate of weight gain or in variations in the quality of a commodity. These impacts can be assessed in a variety of ways including crop yield models, livestock production models and phenological-calendar models (a general treatment of the development of such modeling techniques over the last two or three decades is given in Maunder, (1973)). The most frequently used tool to assess the impacts of weather variations on the agricultural sector is statistical regression techniques. Simple regression-based models were used to calculate wheat yields as early as 1925 (Fisher, 1925). A modern descendant of such regression models, geared to a particular experimental station location, may be found in Feyerherm (1977a and 1977b).

The application of statistical regression models to larger geographical areas, rather than to individual experimental stations, is a fairly recent development. A number of relatively successful large area regression models were developed in pioneering work by Thompson (1962, 1963a, and 1963b) at Iowa State University. A good background discussion on how regional regression models can be developed and used is contained in Sakamoto (1977). In general, yield models are a combination of linear regression yield expressions fit to a phenological rationale. Such models attempt to provide realistic relationships between the variables in the statistical models and actual, physical mechanisms relating plant growth responses to regional environmental conditions. A discussion of a hard-red spring wheat model developed by LeDuc (1977) will be used as a representative example of a successful regional, statistical regression model.

The goal of LeDuc's research was to predict spring wheat yield for a set of geographic regions by using weekly weather data associated with critical phenological period variables using models of the form:

$$Y = X\beta + \epsilon$$

where: X = a matrix of observed variables

Y = the estimated yield

and ϵ = the unexplained error associated with this linear model.

A particular predictive equation obtained from a sample of data is given in Eq. (1).

$$\hat{Y}_j = a + b*YR + T_j + \sum_{i=1}^{n} c_i*W_{ij} \qquad (1)$$

where: $\hat{Y}_j$ = estimated yield for district j

n = number of weather terms

W_{ij} = weather variables for district j, state i

YR = year - 1950

$T_j = 28*A1_j*\exp((-.001*A2_j*(year - 1920-50*A3_j))^2)$

A1,A2,A3 = constants for a particular state and location

a, b, c_i = parameter estimates

Weather impact variables include various transformations of weekly temperature and precipitation averaged over a Crop Reporting District (CRD). Eddy, E. Cooter and W. Cooter (1979) used a form of this basic modeling approach to assess the economic impacts of weather modification activities on North Dakota spring wheat production during a particular crop-critical stage.

Models similar in form to LeDuc (1977) have been developed for a wide variety of crops and have been utilized in climatic impact assessments by a number of researchers. Two examples dealing with Oklahoma explicitly are W. Cooter (1984) and Uhart (1985). Both authors have used local crop and weather data to develop regression type expressions for point and area changes in crop production resulting from a variety of actual and modeled weather scenarios. Uhart then applies his results to weather impacted decision made through the use of linear progamming, while Cooter carries his estimated impacts through an economic input/output model in order to determine economy-wide indirect as well as direct weather impacts.

A second variety of crop yield model that is rapidly gaining in importance is the physiological or plant process model. Such models have been with us for many years but have, in the past, been overlooked in favor of regression type models. Reasons for this oversight include a high degree of model complexity, a large requirement for computer time and space demands, and extensive input data requirements. With the advent of larger and faster computers as well as improvements in data availability these are no longer such critical limitations. The basic function of these models is to simulate day-to-day physiological growth and development of individual crop plants. Significant work in the area of plant process models has been conducted at the Texas Agricultural Experiment Station at College Station, Texas, among other locations. Two models produced by this group are TAMW (Maas and Arkin, 1980) and SORGF (Maas and Arkin, 1978).

TAMW is a wheat growth and development simulation model for an individual plant. Although the initial version of TAMW was not designed explicitly as a yield model, final yield can be estimated by assuming a modeled culture of individual identical wheat plants in a regularly configured stand. This culture is then made representative of actual cropping situations by assuming that modeled plant characteristics approximate the average of field plant characteristics over a sufficiently large area.

The portion of TAMW that simulates growth and development consists of three submodels. The phenology submodel provides a framework for ordering the plant development of the modeled plant through the growing season. The appearance and subsequent development of the individual shoots of the plant is determined by the tiller production and survival submodel. For those shoots that survive to produce viable heads, the grain formation and filling submodel derives the components of yield. A fourth submodel, which produces a daily soil water balance based on weather conditions and crop status, completes the wheat model.

Major plant growth and development activities simulated in TAMW are shown in the flow chart in Figure 3. There are two main loops in the model computer program. An outer loop determines the environment (temperature, photoperiod and soil moisture conditions) the plant experiences each day. An inner loop calculates the growth and development of each shoot on the plant based on the environmental conditions. Prior to sowing, calculations are performed only in the outer loop, and a soil water balance is maintained (assuming a bare soil surface) for each day weather data are available. The simulation

continues for either a fixed number of days (specified in the initial input data) or until the end of the weather data record is encountered.

Larsen (1981) contains a review and comparison of the TAMW model and another wheat process model developed by J. T. Ritchie (Ritchie and Otter, n.d.). Table 1, a comparison of general model characteristics, has been included to illustrate some basic similarities and differences among process type models which attempt to achieve similar ends. The Larson analysis is of particular interest since a reworked version of the CERES wheat model, designed for maize simulation was selected for consideration in Chapter III. Larson concludes that each model generally performs well. The version of the Ritchie model that Larson analyzed needed work on its soil water, root depth and leaf area index subroutines. More genetic varieties required definition. There were no allowances for nutrient stress, winterkill, insects and disease. Finally, the grain filling rate was judged as too slow and the grain filling duration too long. Although several of these deficiencies have been remedied in the model version used in the remainder of this report, the latter problem with grain fill remains and is further documented by the present analysis.

To this point, all modeling review efforts have been directed towards estimating climatological impacts on field crops. In terms of areal climate impact models another, less thoroughly explored, agricultural sector is livestock production. In Oklahoma, major livestock products center on meat. The primary meat product is beef, but pork, lamb, and poultry also play important economic roles. A review of several state-of-the-art livestock models may be found in

Figure 3: Generalized TAMW Flowchart (Source: Larsen (1981)).

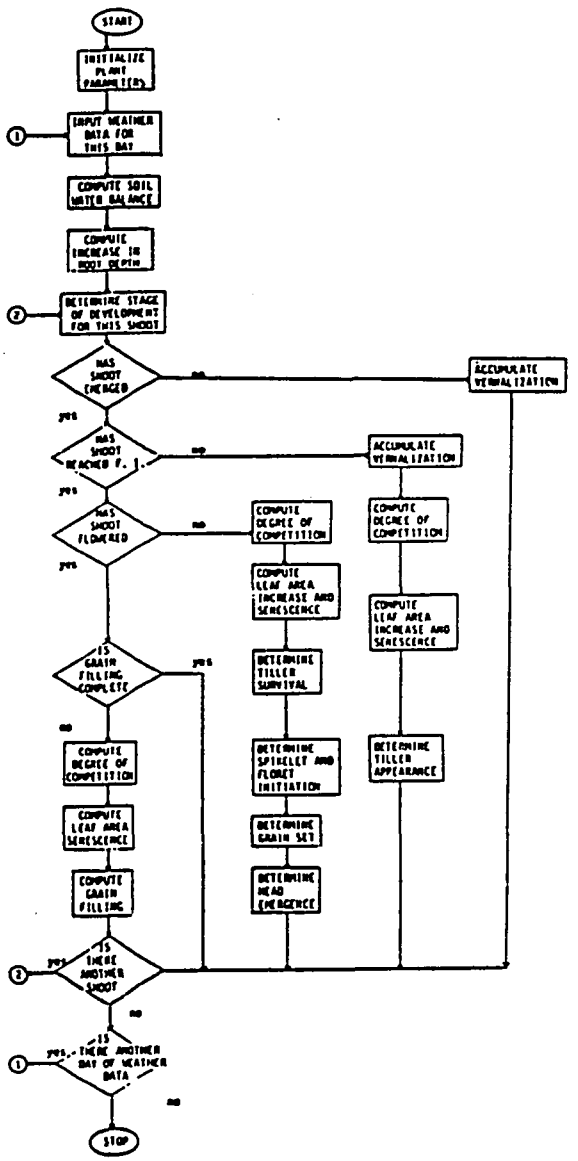


TABLE 1

Comparison of General Model Characteristics (Source: Larsen (1981)).

	Ritchie	TAMW
Program Characteristics	Above ground dry matter simulated on square meter basis. Photosynthesis used to accumulate biomass Fortran about 600 lines of code main, one subroutine, one real function about 2.3 seconds of cpu time on IBM 3033 one main loop makes daily computations	Individual plant is simulated Canopy light interception relations used to adjust for competition among plants Fortran about 950 lines of code main, 14 subroutines, 3 real functions about 4 seconds of cpu time on IBM 3033 two main loops make daily computations and identify individual tillers
Initial Input	Starting date of daily met data Sowing date Seeding density Seeding depth Irrigation data Soil albedo Latitude 9 genetic parameters Upper limit of stage 1 soil evaporation Actual available soil water in each layer of soil profile Max extractable soil water in each layer of soil profile	Starting date of daily met data Sowing date Between row space Within row space Seeding depth Latitude Soil albedo 13 genetic rate or duration functions Upper limit of stage 1 soil evaporation Coefficient of cumulative soil evaporation Actual available soil water in each layer of soil profile Max extractable soil water in each layer of soil profile

Table 1 (continued)

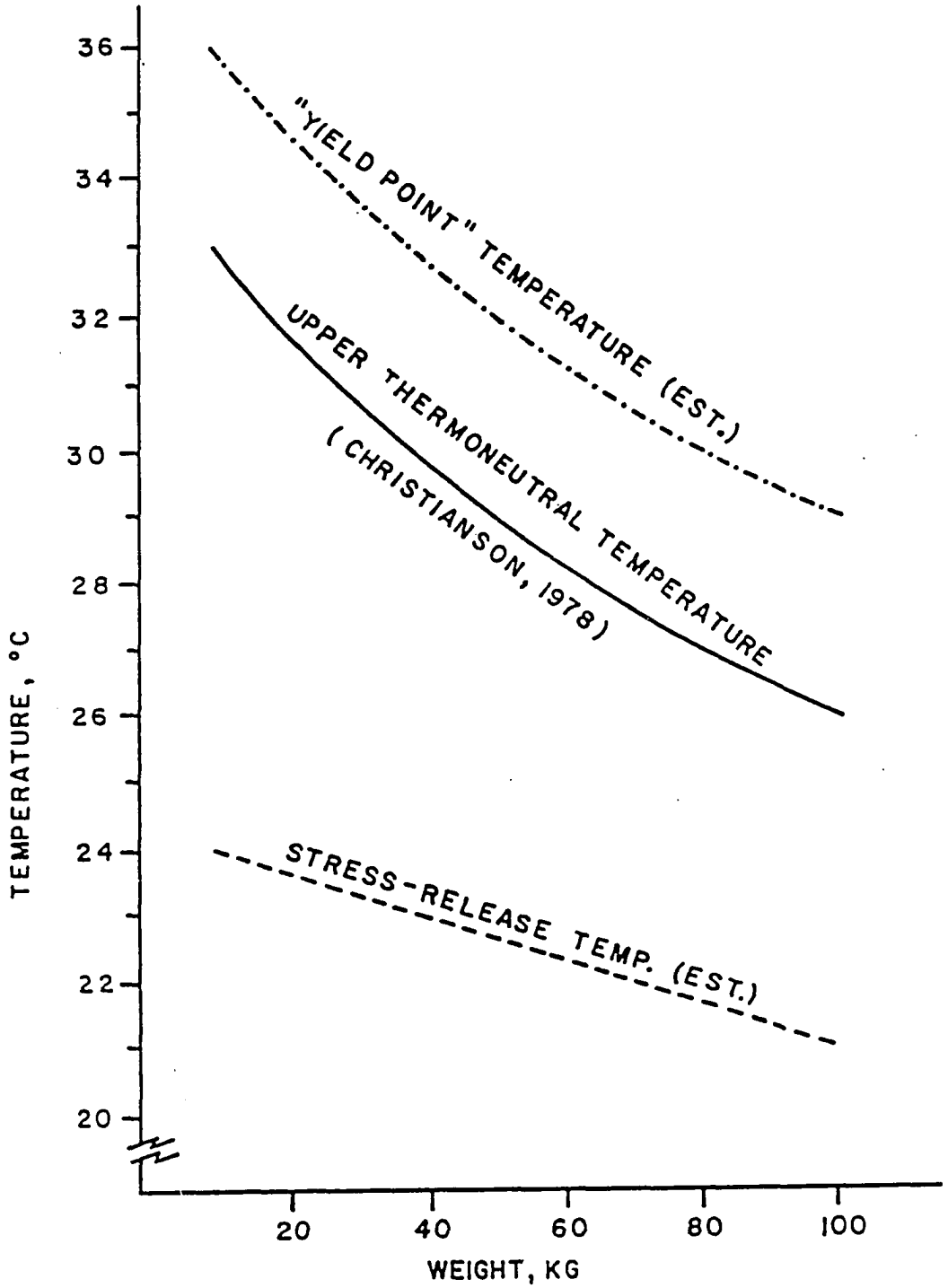
	Ritchie	TAMW
Daily Input	Precipitation Max & min temperature Solar radiation	Precipitation Max & min temperature Solar radiation Snow depth
Phenology	Germination Emergence Floral Initiation Max Floret Number Heading Anthesis Begin Grain Fill Physiological Maturity	Germination Emergence Floral Initiation Terminal Spikelet Heading Anthesis Physiological Maturity
Vegetative Development	LAI Tiller number	Individual leaves Individual tillers LAI
Fruit Development	Floret number Grain number Grain weight	Individual spikelets Floret number Grain number Grain weight

Mignogno (1978). A more thorough discussion of the physical relationships between climate and livestock production is given in Hays (1983). There is a second group of impact relationships for livestock products such as milk and milk products (measured in terms of pounds of butterfat, eggs, or wool). An example of each type of relationship is given below.

When one is dealing with beef cattle, hogs, or other meat animals, rapid weight gain is of primary interest. Therefore, the principle of compensatory growth must be considered. Hahn (1979) discusses the underlying principles and observations of compensatory performance and evaluates that information in terms of shelter selection. Hahn reports that compensatory growth following a suppressed growth period resulting from adverse climatic factors has, in most cases, permitted body size form to return to normally expected levels. Such observations might be expected, particularly following growth suppression caused by hot weather when animals voluntarily reduce feed intake to maintain homeostasis. In most situations, after the stress is removed, the weight is regained. Figure 4 illustrates the principle of compensatory growth and the temperature dependent limit of such growth for hogs. For example, a 60 kg (132.3 lb.) hog will not recover growth while the environmental temperature remains higher than 31.5 degrees C (88.7 F).

A second approach to estimating climate impacts on livestock meat production is to estimate the energy necessary to maintain the animals' metabolic processes. Once this has been done, weight losses or slowing of weight gains associated with metabolic energy deficiencies can be calculated and dollar figures assigned. Ames (1980) developed such a model given by Eq. (2).

Figure 4: Upper Thermoneutral Temperature for Hogs(Source: Hays, 1983).



$$ME_m = aW^{.75} + b\frac{\Delta T}{I} \quad (2)$$

where: ME_m = metabolized energy for maintenance corrected for effective temperature (kcal ME/day)

ΔT = magnitude of cold (C), i.e., difference between animals lower critical temperatures and effective temperature,

I = total insulation ($C/kcal/m^2/day$),

a = coefficient of maintenance requirement for animal in zone of thermoneutrality; kcal ME/day = 127.8 for cattle and sheep and 100 kcal M/day for swine,

b = surface area of animal (m^2)

W = weight of animal (kg).

Milk production is the most frequently studied type of non-meat production. For example, Hahn and Osburn (1969) considered the impact of local environmental conditions on milk production. They report that hot weather causes rapid declines in milk production and feed intake for all cows, although there are individual and breed differences in heat sensitivity. Cold weather is not as detrimental to production, but management problems become a factor below 35 degrees F. In her article submitted to the Oklahoma Climatological Survey Monthly Summary, Thiessen (1985) describes several impacts of cold weather events on dairy operations. First an example is given in which a bulk milk truck could not reach its destination because of hazardous road conditions during a winter storm. The entire load of milk had to be dumped. A second weather impact can result when electrical power to a dairy farm is lost. Permanent damage can be sustained by dairy cows if they can not be milked for an extended period of time. In some cases there might be too many animals to be milked by hand. In others, the animals, now used only to milking by machine, will not tolerate hand milking.

The second major economic sector for which weather impacts will be estimated is gas utilities. Here there are clear within-region meteorological impacts on both utility consumption and production. There are, however, several differences in the way these two types of impacts are usually estimated. Utility production, although often referred to in general, sectoral terms, is very firm specific. Service areas are often broken up or spread over extensive, climatologically heterogeneous regions and managerial practices are not nearly as uniform as within a large winter wheat producing area consisting of different farm firms. Since the intent of the present study is to focus on models that have ready and apparent full sectoral or regional applications while still containing information useful for individual decision maker firms, examples of utility production models will be summarized. There are, however, currently no plans for the use of such models by the author. Utility consumption models, on the other hand, will be discussed on both the level of individual structures and on the level of the residential consumer category.

Utility or energy consumption models usually take one of two forms: statistical regression types which use techniques analogous to those discussed for agriculture, and building load models which are based on physical-engineering criteria. Examples of each utility consumption model type will be presented and briefly discussed. First, a summary consideration of state-of-the-art utility production models will be given.

The utility production model to be considered is one developed in Johnson, McQuigg and Rothrock (1968). This is a load projection model

that takes into account the effects of temperature fluctuations on peak load send-out. The estimated model is of the linear form:

$$L_i = b_{0i} + b_{1i}T_i + b_{2i}X \qquad (3)$$

where: L_i = the estimated hourly peak load

T_i = average daily temperature

X = a dummy variable that separates weekdays from weekends

b_0, b_1, b_2 = parameter estimates

i = subscript indicating the distribution areas

There is no reason why, if the supply data will support it, a similar model could not be developed that specified impacts associated with particular user categories (e.g., industrial, commercial or residential) rather than for all consuming sectors. Other studies describing weather data applications in gas forecasting, the effects of weather on electric utility fuel budgeting, and the use of weather normalizing utility load curves may be found in "The Economic Impact of Climate for the Gas and Electric Utilities Industry" (OCS, 1981). Another summary article containing an extensive literature review dealing with the impact of weather on electricity production is given in Proctor (1980).

An application of a State-level sectoral production model which reflects the influence of climatological factors is in utility regulatory models. An example of such an application may be found in Viren (1981). In his paper "Forecasting Forward Budgets, Rate Case Test Years for Gas and Electric Utilities," Viren investigates the practicality of developing budget models which incorporate forecasted weather information; i.e., he examines the use of predicted climate conditions in models that estimate net revenues of individual utility companies. Viren states,

> "Monthly variations and utility financial conditions are due primarily to changes in weather. Other intra-yearly variations are affected primarily by weather conditions, with the possible exception of random plant outages that exceed the expected."

The model Viren proposed incorporated climate forecast information and/or current weather information to make forecasts of sales, costs, revenues and thus earnings, which would be conditional upon the weather forecast. Knowing the probability distribution of that forecast, expected sales, costs, revenues and earnings position can be computed. As a result, it would be possible to develop models for utility rate cases, budgets, and financial projections which reflect likely weather versus normal weather. The precise form of the model may be found in Viren (1981).

Consumers of gas and electric utilities may be separated into three major categories: residential, commercial, and industrial. Of these, residential demand (or consumption) has proved to be the least affected by such episodic dislocations as strikes, federal regulation changes, allocation system reforms, on-site private energy production, etc. This vastly simplifies the task of model development. It has been projected (Starr, 1971) that by the year 2000, 30% of all natural gas used in the U.S. will be used by the residential sector. Starr projects a similar level of electric power consumption going to residential users. Clearly, any fluctuations in demand from this residential category will have a great impact on overall utility revenue and on the entire economy of a region. Therefore, although only models for residential utility consumption will be considered in the present study, such models probability represent the lion's share of quantifiable climatological

impacts on the energy sector's consumption related activities as a whole.

It has been established by numerous researchers (see the annotated bibliography by McQuigg, 1975) that temperature, often transformed into a heating or cooling degree variable, is an important factor in utility demand. In addition to those which use temperature, several models have been developed that use windspeed, cloud cover, precipitation amount, precipitation form, and visibility as demand estimators. The first energy consumption model to be considered is a statistical regression type developed by Warren and Lehman (1978). For each of nine natural gas consumption regions in the U.S., as defined by the American Gas Association, a data set of quarterly gas consumption and associated divisional average heating degree days was developed. For each regional division, a set of quarterly models was developed of the form:

$$S_q = a_0 + a_1 \bar{Z}_q \qquad (4)$$

where: S_q = estimated quarterly natural gas consumption for division q

a_0, a_1 = parameter estimates

$\bar{Z}_q$ = divisional average heating degree days for a quarter

q = census division region 1 to 9

Given such a set of models, seasonal temperature shifts could be used to predict changes in residential gas consumption. Warren and Lehman proceed to discuss how gas demand could be projected based on extended one or three month forecasts of heating degree days.

The Warren and Lehman model has been continually upgraded and improved since 1978. A more recent version and its application is presented in Warren, et al. (1984). This particular version is

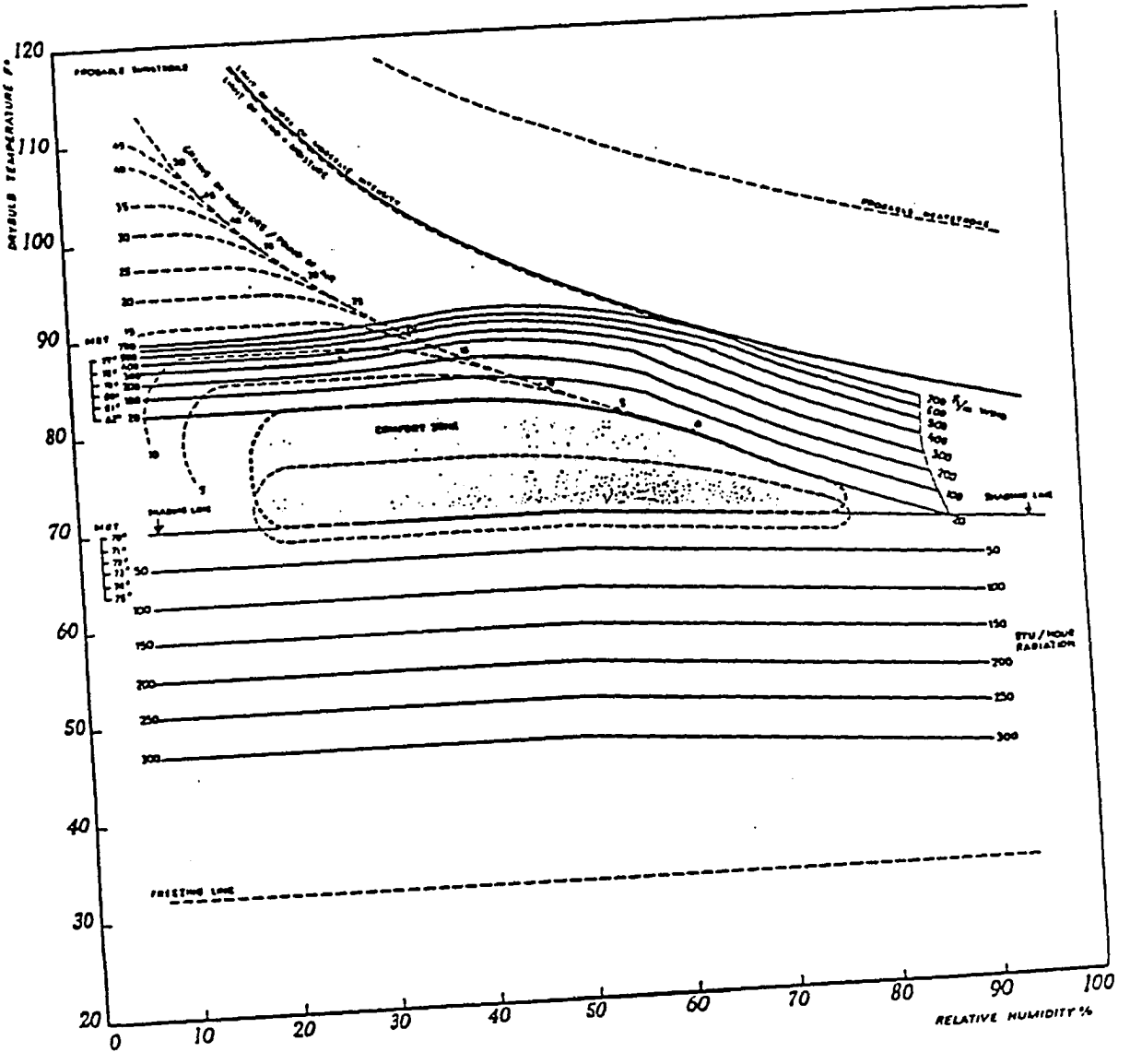
discussed in some detail and is exercised using Oklahoma data in Chapter IV.

Major changes have taken place in consumer behavior since the energy "revolution" of the early 1970's. These major structural and behavioral changes are clearly reflected in the historical data base but can vastly complicate statistical modeling, especially if interest lies in the most recent, and, unfortunately, most volatile, period of time. Furthermore, even if a reliable model can be developed, it is still geared to "normal" or expected behavior. A regression model is also relatively limited in addressing alternative futures involving major changes in building design or lifestyles. An alternative to simple regression models is the building load model. An overview will now be presented on building load modeling approaches.

Building load generally refers to the rate of energy gain or loss through a specified structure. Potentially two types of econo-climatic impacts can be determined by using these models: utility demand changes due to alterations in structural or behavioral patterns given specified climatic conditions and utility demand changes due to climatological variations affecting a given set of structural and behavioral characteristics. In addressing these applications, a brief discussion of some basic load modeling concepts will be given.

Building load calculations were originally performed by architects or engineers to help them design "comfortable" as well as attractive and functional structures. Comfort can be rather rigorously defined in terms of a combination of environmental factors. Olgyay (1963) suggests a rather simple, graphical approach for defining comfort under a wide

Figure 5: Bioclimatic Chart for U.S. Moderate Zone Inhabitants (After Olgyay, 1963).



range of environmental conditions (see Figure 5). In Figure 5 such factors as wind, vapor pressure, evaporation, radiation, dry bulb temperature, and relative humidity are related to a "comfort zone." Any climatic condition that can be represented by its dry-bulb temperature and relative humidity can be plotted on the chart. If the plotted point falls into the comfort zone, one would feel comfortable in the shade. If the point falls outside the comfort zone, environmental modifications are needed. For instance, if the point is higher than the upper perimeter of the comfort zone, air movement is needed. If the temperature is high and humidity low, additional evaporative cooling would be the appropriate tool to maintain comfort. At the lower perimeter of the zone is the line above which shading is needed. Conversely, radiant heat is necessary below the line to counteract lower dry bulb temperatures.

If an environment is not naturally comfortable, there are several alternative actions which can be taken. Structures could be designed and built in a climate sensible fashion; e.g., through installation of storm windows and doors, use of attic fans, proper landscaping, and so forth. Another currently more prevalent response is to rely heavily on the installation of supplemental space heating and cooling units to try to hold the climate at bay through a lavish use of fossil fuels or fossil fuel produced electricity to control interior environments. The increasing shortage of fossil fuel emphasizes the need to reverse this trend and return to traditional climate-sensible building designs as well as to encourge new technologies which exploit solar and wind power. Building load determination models provide a means of assessing both old

and new techniques for attaining the goal of energy efficiency while at the same time achieving comfortable interior living environments.

Although graphs or nomographs such as that shown in Figure 5 are informative, use of additional tables and algorithms is required to arrive at the most climate-sensible structural design. Further, a complete energy flow analysis is a necessary step if an appropriate design is to be achieved, and this depends heavily upon thermal properties such as heat transfer coefficients and resistances of specific building materials. An appealing method would be to use computer implemented building load models, where all the necessary algorithms are built in as subroutines. Three of the many such models currently available, the NBSLD model, the AGNET system's HOUSE program, and the GBEA model, will be discussed.

The National Bureau of Standards Load Determination (NBSLD) model, Kusuda (1976), is in the public domain; i.e., it can be obtained at cost, and is geared to a technically oriented audience interested in minimizing total energy costs for a given structure from an architectural design point of view. The major reason the National Bureau of Standards developed this model was that despite the existence of numerous load programs, most were not adequate for the analysis of building designs where non-conventional or innovative ideas on structures, heating and cooling systems, and control devices were employed. Some of the unique aspects of building and building system design and operation that can be handled by or studied using the NBSLD model are:

1. effect of interior partition walls or floors on the heat storage characteristics of the room,
2. off-peak heating or cooling of buidings to shave the peak heating or cooling demand,
3. evaluation of the indoor thermal environments of various zones (e.g., basements, ground floor rooms, etc.) during an intermediate season, such as spring or autumn, when the heating or cooling requirements for these zones may not be in phase with that of the building as a whole,
4. use of solar energy for heating and cooling buildings as this relates to the thermal storage characteristics of the building,
5. use of attic ventilation to reduce the cooling load since the NBSLD model can accurately predict attic temperatures,
6. effective use of natural air conditioning, such as ventilation, shading, increased ceiling insulation, and the subsequent determination of the requirements for mechanical cooling,
7. effective use of planned ventilation to minimize the building heating load during the winter season and
8. accurate evaluation of indoor comfort conditions based upon air temperature, humidity, and mean radiant temperture.

Figure 6 depicts an overall calculation sequence to attain the hour-by-hour heating and cooling load of buildings. Shown in the double lined boxes are input data to be supplied whereas those in single lined boxes indicate calculations to be performed. The cycle indicators show the iterative cycles for the number of buildings, the number of rooms in a given building, and the number of days for which the calculations are

to be performed. More specific identification of the types of input data needed are listed in Figure 6 and Tables 2, 3, and 4. Output examples and discussion of several runs may be found in E. Cooter(1980).

The NBSLD model also allows for real-time calculations of heating and cooling loads for any length of time. Although a one year simulation might provide some interesting results, the computing costs of such a project would be high. A more reasonable, yet quite informative, effort would be to simulate episodic climate variations such as unusually hot summers or cold winters to estimate their impacts on a given structure. This particular model is further discussed in some detail in Chapter IV. Results for five Oklahoma locations are generated and are compared to those obtained from the Warren model presented earlier.

A second building load determination model is HOUSE, University of Nebraska (1980). HOUSE is accessible through the University of Nebraska's AGNET system and has been designed to be used by the general public to help determine what energy conservation methods could be added to an existing residential structure and to estimate the dollar benefits derived from such measures. HOUSE will estimate the heat loss and costs of heating and cooling a home or office building given the location, inside design temperature, structural dimensions, and the size and specification types for the walls, doors, windows, roof, ceiling, and foundations. Again, a sample coding form and examples of actual runs may be found in E. Cooter (1980). Although HOUSE is somewhat more limited than the NBSLD model in its ability to analyze climatological and technological scenarios, a model of this type might be used

Figure 6: NBSLD Calculation Sequence for Hour by Hour Heating and Cooling Load of Buildings (After Kusuda (1976)).

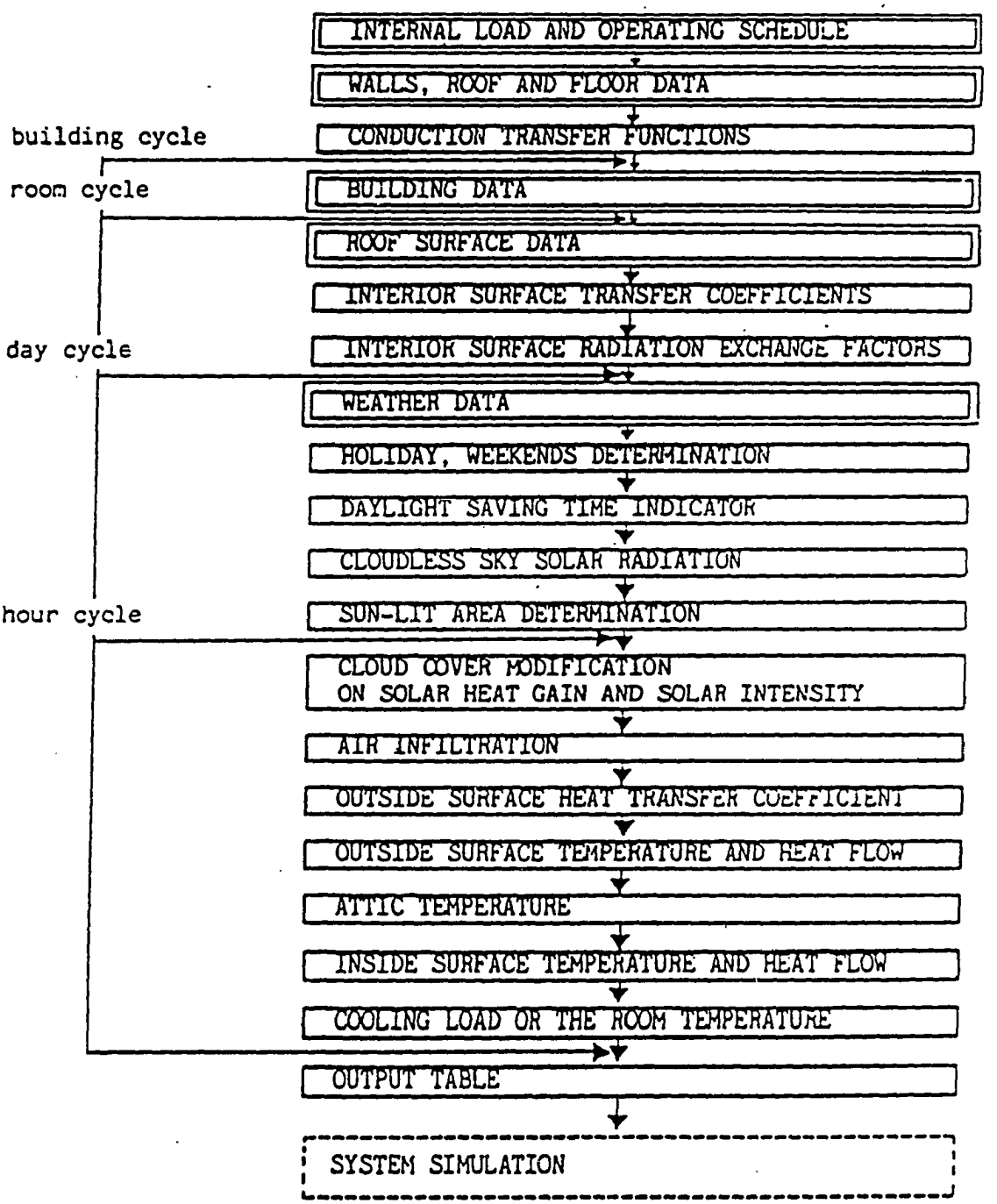


TABLE 2

Input-Operating Data for NBSLD.

o ELECTRIC POWER TO LIGHTS, WATTS PER SQUARE FOOT OF FLOOR (QLITY)
o HOUR BY HOUR LIGHTING SCHEDULE (QLITX)
o ELECTRIC POWER TO EQUIPMENT, WATTS PER SQUARE FOOT OF FLOOR (QEQPX)
o HOUR BY HOUR EQUIPMENT SCHEDULE (QEQUX)
o SUPPLY AIR RATE (CFMS)
o AIR LEAKAGE RATE (CFML)
o SUPPLY AIR TEMPERATURE (TS)

effectively for estimating the impacts of residential-oriented energy conservation programs. For instance, from the information provided by HOUSE, local changes in utility demand due to governmental policies encouraging energy conservation could be estimated. It should be noted, however, that HOUSE works strictly on a seasonal or annual basis, and no monthly or distributional information can be obtained.

A third computerized building load model is written by Micro-Computer Design Tools, Inc. and is called "Graphical Building Energy Analysis," or GBEA (Microcomputer Design Tools, Inc., 1982). GBEA is a commercially produced model available for several brands of 48K micro-computers and is based upon many of the principles of NBSLD. Its major

TABLE 3

Input-Building Data for NBSLD.

- ROOM NUMBER (ROOMNO)
- CEILING HEIGHT (H)
- ROOM LENGTH (L)
- ROOM WIDTH (W)
- NUMBER OF OCCUPANTS (QCU)
- OCCUPANT SCHEDULE (QOCUP)
- WINTER WINDOW OVERALL HEAT TRANSFER COEFFICIENT (UGLAS)
- GROUND FLOOR HEAT TRANSFER COEFFICIENT (UG)
- SUMMER INFILTRATION, AIR CHANGES PER HOUR (ARCHGS)
- WINTER INFILTRATION, AIR CHANGES PER HOUR (ARCHGW)
- TYPE OF HEAT TRANSFER EXPOSURES (ITYPE), ROOFS-WALLS-WINDOWS-DOORS-FLOORS
- TYPE OF RESPONSE FACTORS TO BE USED (IRF), HEAVY/LIGHT: ROOF, EXTERIOR WALLS, CEILING/FLOOR PARTITION
- U VALUE OF THE EXPOSURE (U) (ONLY WHEN RESPONSE FACTOR IS NOT CALCULATED)
- AREA OF THE EXPOSURE (A)
- ORIENTATION OF THE EXPOSURE (AZW), N,E,S,W (ONLY FOR EXTERNALLY EXPOSED SURFACES)
- WINDOW SHADING COEFFICIENT (SHADE)
- SOLAR HEAT ABSORPTION COEFFICIENT FOR THE EXTERIOR SURFACE (ABSP)
- TIME INCREMENT OF TEMPERATURE DATA USED
- PROPERTIES OF BUILDING MATERIALS - THICKNESS - THERMAL CONDUCTIVITY - DENSITY - SPECIFIC HEAT
- NUMBER OF SURFACES IN EACH WALL (NS,NW,NN,NE)

TABLE 4

Input-Weather Data to NBSLD.

- LATITUDE (LAT)
- LONGITUDE (LONG)
- TIME ZONE NUMBER (TZN)
- MONTH (MONTH)
- DAY (DAY)
- ELAPSED DAYS SINCE JANUARY 1 (ELAPS)
- MAXIMUM TEMPERATURE OF THE DESIGN DAY (DBMAX)
- DAILY TEMPERATURE RANGE OF THE DESIGN DAY (RANGE)
- DESIGN INDOOR TEMPERATURE CONDITION (DBIN)
- DESIGN OUTDOOR WET-BULB TEMPERATURE (WBMAX)
- DESIGN INDOOR WET-BULB TEMPERATURE (WBID)
- DESIGN WINTER OUTDOOR TEMPERATURE (DBMWT)
- DESIGN SUMMER GROUND TEMPERATURE (TG)
- DESIGN WINTER GROUND TEMPERATURE (TGW)

advantage over NBSLD is that it is relatively fast and inexpensive to use. It provides a much more detailed energy analysis than HOUSE, and presumably, more accurate. It does lack the retrofit recommendations available with HOUSE but the added detail and accuracy is a fair

exchange. Inputs required include hourly values for total horizontal solar radiation, dry bulb temperature, dew point temperature, wind velocity and a station description. The manufacturer provides this information for a 366 day "typical" (not normalized or mean) year. By using a "typical" year the user can observe the effects of changing sky conditions, relative humidity and precipitation that might otherwise be lost if the data were simply averaged. Documentation concerning the structure of these input files is available from the manufacturer so the user can define his own set of climatological conditions rather than relying exclusively on those provided by the manufacturer. Tables 5 and 6 and Figure 7 are typical GBEA results. Table 5 defines the basic structural design of the building being analyzed. Table 6 is an hourly description of the energy flow components for the selected day. Figure 7 is a graphical presentation of the cumulative energy use in Table 6.

The last model to be considered, presented in ASHRAE (1979), uses a system of tables and simple, repetitive algorithms which, when a given structure has been defined, should adapt easily to computerization. as regards level of complexity, the ASHRAE procedure falls somewhere between the NBSLD and house models. Unlike the house model, it can be easily adapted to calculate daily, monthly, seasonal, or annual loads. Also, unlike the house model, it can take advantage of much more detailed meteorological information than house, such as temperature maxima, minima, and ranges. It also allows for occupancy scheduling, load contributions due to machinery or appliances, ventilation, and infiltration. However, the ASHRAE model is neither as flexible nor as detailed as the NBSLD version. ASHRAE cannot easily calculate hourly

energy loads or use the level of detailed meteorological information that the NBSLD model does. Also, the ASHRAE model is not capable of handling innovative, or extremely complex, structural designs. The major advantages of the ASHRAE model lie in its simplistic, but thorough, treatment of thermodynamic as well as basic design features most commonly found in residential or simple commercial structures. The author has successfully used the ASHRAE model in a number of climate impact related applications.

The first application was "An Energy-Climate Analysis for Oklahoma Residential Structures," (OCS, 1980). In this project, a "typical" Oklahoma residential structure was defined and normal climatic conditions imposed. Several structural as well as behavioral alternatives were considered (e.g., landscaping, structural orientation, extra insulation, and thermostat settings), their loads calculated, and the associated dollar costs for each category estimated. In this case, the climatological impact was represented by the control over the calculated load and, therefore, the associated energy costs of the prevailing external meteorological conditions. A similar, though more detailed, example has been considered by W. Cooter (1984). Here, the same procedure as in the example outlined above is followed but is extended so that regional direct and indirect economic impacts stemming from changes in levels of residential utility consumption are calculated and possible tax and policy implications discussed.

A second type of application of the ASHRAE model is presented in E. Cooter (1981). In this case, the economic impacts of the Oklahoma City urban heat island effect were assessed to estimate the energy cost

TABLE 5

An Example of Structure Definition as Given by the GBEA Model.

```
USE-TYPE  LIVE

FLOOR AREA  1500  SQ FT
CEILING HEIGHT  8  FT

OCCUPANCY PATTERN (0=EMPTY 1=OCCUPIED)
        111111111122222
123456789012345678901234
000111111111111111110000

OCCUPANCY LEVEL=150 SQ-FT/PERS  ACTIVITY LEVEL=500 BTU/PERS/HR
LIGHTING LEVEL=1 WATTS/SQ FT    EQUIPMENT=8 BTU/SQ FT
INFILTRATION=.1 AIR CHANGES/HR  VENTILATION= 10 CU-FT/PERSON/MIN

SOLID SKIN TYPES :
400 SQ FT    R-10    NORTH WALL
150 SQ FT    R-10    EAST WALL
300 SQ FT    R-10    SOUTH WALL
100 SQ FT    R-10    WEST WALL
1500 SQ FT    R-10    ROOF

WINDOW AREAS :
90 SQ FT   R-1  -90-DEG AZ    90-DEG EL   EAST WINDOW
100 SQ FT   R-1  0-DEG AZ    90-DEG EL   SOUTH WINDOW
140 SQ FT   R-1  90-DEG AZ    90-DEG EL   WEST WINDOW
```

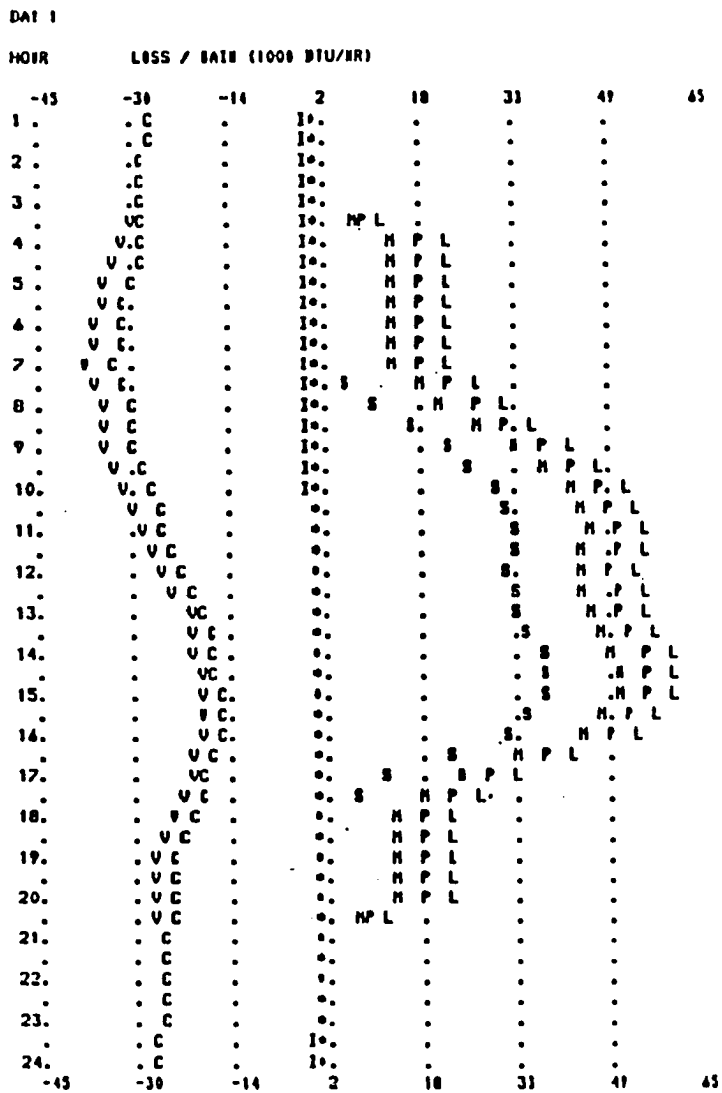
TABLE 6

An Example of Hourly Energy Exchanges Produced by the GBEA Model.

DAY 1

	* * * * * * UNITS ARE 1000-BTU / HOUR * * * * * * *								DEG.	BTU/
	TOTAL	---------- ENERGY FLOW BY SOURCE ----------							F	SQ-FT
HR	NET	SOLAR	COND.	VENT	INFIL	MISC.	OCCUP	LIGHTS	TEMP.	SOLAR
1	-27	0	-27	0	-1	0	0	0	26	0
2	-28	0	-28	0	-1	0	0	0	24	0
3	-30	0	-29	0	-1	0	0	0	23	0
4	-11	0	-28	-5	-1	12	5	4	24	0
5	-13	0	-30	-5	-1	12	5	4	21	0
6	-15	0	-31	-5	-1	12	5	4	19	0
7	-16	0	-32	-5	-1	12	5	4	17	0
8	-4	9	-30	-5	-1	12	5	4	21	13
9	8	21	-30	-5	-1	12	5	4	21	57
10	21	30	-27	-5	-1	12	5	4	26	110
11	26	33	-25	-4	-1	12	5	4	30	158
12	28	32	-21	-4	-1	12	5	4	35	180
13	33	33	-18	-3	-1	12	5	4	41	180
14	39	37	-17	-3	-1	12	5	4	42	158
15	41	37	-16	-3	-1	12	5	4	44	118
16	34	31	-16	-3	-1	12	5	4	44	66
17	11	11	-18	-3	-1	12	5	4	41	13
18	-2	0	-20	-4	-1	12	5	4	37	0
19	-6	0	-23	-4	-1	12	5	4	32	0
20	-6	0	-23	-4	-1	12	5	4	32	0
21	-25	0	-25	0	-1	0	0	0	30	0
22	-26	0	-26	0	-1	0	0	0	28	0
23	-26	0	-26	0	-1	0	0	0	28	0
24	-27	0	-27	0	-1	0	0	0	26	0
COOLING	245	277	0	0	0	204	85	80		
HEATING	-258	0	-579	-62	-18	0	0	0		

Figure 7: An Example of an Hourly Loss/Gain Graph Produced by the GBEA Model.



Interpretation of Figure 2.4

Upper Limit of Area	Lower Limit of Area	Area Represents
C	V	Ventilation (loss)
I	C	Conduction (loss)
*	I	Infiltration (loss)
S	*	Solar (gain)
M	S	Miscellaneous (gain)
P	M	People (gain)
L	P	Lights (gain)

differences exhibited by the same structure located within and outside the urban heat island. Here, economic impacts due solely to changes in environmental rather than behavioral characteristics were assessed. It was concluded that given the estimated 11% benefit to urban heating season purchases, and 4% savings to rural cooling customers, only about 28,000 urban or 42,000 rural customers would be needed to obtain direct household expenditure impacts of more than one million dollars. Therefore, although the effect on each urban or rural household may be small, 11% and 4% respectively, when considered over a SMSA or similar region, the total dollar impacts can easily attain economically significant levels. In order to make the generalization from individual households to regional impacts, many assumptions must be made to keep the calculation burden within manageable levels.

Although agricultural and utility sectoral activities have been treated independently to this point, there are important interactions. For instance, irrigation amounts to approximately 23% of total energy used in on-farm agricultural production (Sloggett, 1979). Further, it has been estimated that in the U.S. during 1974 alone, nearly 20 billion KWh were used to pump and deliver irrigation water for crop production. Although much of the variation in utility demands for irrigation water pumping and delivery may be economic, e.g., fuel costs, crop value, acres in production, etc., a significant amount of variability may be due to climatic influences. For instance, if the time during a critical phenological period is hot and dry, a crop may require additional irrigation applications to guarantee profitable harvests. More energy is required to pump and deliver this additional water. Conversely, if

the previous 1-5 years have been favorably wet over the recharge area of an aquifer, that aquifer may be sufficiently recharged so as to decrease well drawn-down, thus decreasing required pump lift. The result may be lower energy expenditures to pump a consistent quantity of water. Therefore, there is an important, potentially quantifiable, climate impacted linkage between the agriculture and utility sectors.

The year-to-year estimation of these on-farm utility demands is not a simple task. Sloggett (1979) found that in order to quantify these demands it was first necessary to determine: (1) acreage irrigated from groundwater and from pumped surface water, (2) feet of lift required from groundwater and pumped surface water, (3) types of distribution systems used to apply water to fields, (4) types of power units used for pumping, and (5) acre-feet of water applied. Estimates were also obtained for pumping unit efficiency and pressure needed to operate distribution systems. Once these data were estimated, 1974 and 1977 patterns of energy use and expenditures were calculated and examined. Tables 7, 8, and 9 illustrate his results. Sloggett concluded that between 1974 and 1977 the acreage and the cost of energy for on-farm pump irrigation have increased and that few farmers stopped irrigation despite rising energy costs. Although the changes estimated were explained in some part by favorable farm prices, recent history has indicated that such beneficial price levels are often short-lived. As costs associated with pumping continue to make up a significant portion of on-farm crop production expenditures, external influences such as weather should increase in importance. If a state level time series of pumping energy expenditures were to become available, the estimation of

pertinent econoclimate impacts could be made and these would be important to both agriculture and utility sectors. Estimates of changes in these agricultural use patterns due to weather could easily fit into an I/O analysis framework, such as that described in Chapter I. Eventually estimates of the economy-wide repercussions of given climatic events or scenarios could be made. Though that would be intriguing, the present research concentrates on the direct impacts associated with representative segments of the utility and agricultural sectors which form the principle climate sensitive portions of the Oklahoma I/O transaction tables utilized in Chapter V.

TABLE 7

Quantity of Energy Used for Onfarm-Pumped Irrigation Water(After Sloggett, 1979).

Fuel	Unit	1974	1977	Change	Percentage change, 1974 to 1977
		Units of fuel			Percent
Electricity	Bil. kWh	16	19	3	19
Diesel	Mil. gal.	175	350	175	100
Gasoline	do.	65	78	13	20
Natural gas	Mil. MCF	132	149	17	13
LPG	Mil. gal.	238	217	-21	-9

TABLE 8

Total Cost of Energy for Onfarm-Pumped Irrigation Water(After Sloggett, 1979).

Energy	1974	1977	Change	Percentage change, 1974 to 1977
	Million dollars			Percent
Electricity	308	588	280	91
Diesel	62	156	94	152
Gasoline	31	37	6	19
Natural gas	101	187	86	85
LPG	68	73	5	7
Total	570	1,041	471	83

TABLE 9

Selected Energy Prices in the United States(After Sloggett, 1979).

Item	Unit	1973	1974	1975	1976	1977
		Dollars per unit				
Electricity	kWh	0.023	0.027	0.030	0.033	0.035
Diesel	Gal.	.23	.37	.39	.41	.45
Gasoline	do.	.33	.47	.50	.54	.57
Natural gas 2/	MCF	.50	--	--	--	1.50
LPG	do.	.20	.30	.30	.33	.39

1/ Agricultural Statistics, U.S. Dept. of Agr., 1972-77.
2/ Estimated.

Chapter III

A CLIMATE SENSITIVITY ANALYSIS OF THE CERES CORN MODEL

3.1 INTRODUCTION

Portions of the research reported in this document were completed in preparation for a NOAA symposium to be held in Washington, D.C. The overall goal was to use the interdisciplinary expertise of the members of a university consortium to analyze the agroeconomic aspects of an unusual meteorological event. The Oklahoma Climatological Survey (OCS) contribution to this joint consortium effort can be broken into four major tasks:

1. an assessment of the sensitivity or response of corn to climatological variability;
2. the identification of those meteorological patterns which influenced 1983 corn-belt production;
3. the estimation of the likelihood of recurrence of these conditions; and
4. the derivation of econo-climatic products and the use of meteorological forecasts to assist in making influential crop production projections and decisions based on weather sensitive outcomes.

These objectives will be addressed here and in sections 3.2 through 3.6. The upper portion of Figure 2, Chapter I illustrates how these research areas interact and their general content.

Section 3.1 contains a general model description including fixed and variable inputs and subroutine functions. Sample model output is provided. Section 3.2 introduces selected weather time-series and model initialization procedures. Seasonal distributions of weather inputs and associated modeled yield output are discussed and questions concerning their agreement are raised.

The statistical portion of the CERES analysis (section 3.3) is a detailed exploration of weather related variance contained in the model-generated yield time-series using 36 years of observed meteorological data. Extensive parallel analyses dealing with variance partitioning to determine the source and component magnitude of this variability are pursued on seasonal and week-by-week bases. Variance partitioning is explored at three levels of complexity: 1) normalization procedures; 2) a simple one-way ANOVA model; and 3) a more complex two-way ANOVA model. Although no single method adequately addresses all variance partitioning applications for agricultural and meteorological audiences, each technique builds upon the results of its predecessor to evolve a more detailed understanding of the complex statistical nature of weather yield relationships contained in plant process models. This understnading is an essential factor which facilitates the interpretation and application of derived climate information products.

Section 3.4 is an analysis of 1983 corn growing season weather. This analysis examines relationships in space and time of 1983 corn growth and development in the U.S.A. corn-belt. Through this analysis, insight is gained into the adequacy of existing agrometeorological tools. Suggestions are made concerning weather indicators appropriate for unusual growing seasons such as that of 1983.

Section 3.5 carries the suggestions made in section 3.4 a bit further. Maps of specific weather event probability estimates are generated. A method for the development of climate hazard and corn/weather impact maps is discussed. The generation of conditional probability forecasts is suggested, an example illustrating the value of improvements in mid-season corn weather forecasts is developed, and a corn-belt corn/weather index is presented.

Section 3.6 explicitly addresses an issue which will arise throughout Chapter III, modeled yield population non-homogeneities. This section explores and describes the distribution of CERES modeled yields in some detail. An example of the way in which distributional information can be used to develop more informative user products is also presented.

An initial task was to decide how climatologists (viz. non-agronomists), should approach a problem with clearly agronomic underpinnings. First it was decided to use a physiologic plant process computer model to represent corn plant growth and development. The model selected is one developed by Dr. Joe Ritchie and others while working at the USDA-ARS Crop Systems Evaluation Unit (CSEU), Temple, Texas and is called the Crop Environment Resource Synthesis (CERES) model. The version used by OCS was modified at the Assessment Information Services Center (AISC), Columbia MO. Coefficients and algorithms have been developed by these research units for wheat and maize or corn. The computer program contains 15 subroutines which simulate plant physical processes or crop related operations such as irrigation. The basic functions or operations which are included in the

model are given in Table 10. A more detailed description of the modified CERES model may be found in Larrabee and Hodges (n.d.).

TABLE 10

CERES Process Model Plant Functions or Operations.

- A water balance subroutine which calculates:
  a. soil moisture content
  b. water stress
  c. evaporation
  d. root growth
  e. water uptake
  f. soil deficit factors
- Calculation of phenological stages based on energy units: a combination of growing degree days and radiative inputs.
- Plant growth subroutine which calculates:
  a. leaf area
  b. physical plant growth
  c. photosynthesis
- Vernalization subroutine for winter wheat
- Leaf subroutine which estimates the number of leaves and their development
- Damage due to high temperatures
- Damage due to cold temperatures
- A solar radiation simulation routine

Table 11 contains a list of phenological stages calculated by the model. It is on the basis of these stages and their associated dates that the manner in which certain meteorological variables impact final harvested yields are determined. Phenological dates and stages are computed using daily accumulations of thermal units and predetermined

varietal constraints. Knowledge of these dates and stages are important not only to the model, but forecasts of these values could provide important information for planning various farm activities such as tillage, fertilizer applications and harvest contracting. An example of standard model generated output which contains estimated plant yield and dates of phenological stages for Peoria, Illinois given fixed 1983 technology, planting date, bushel test weight, plant variety, soils and other physiologic constants as well as observed daily maximum temperature, minimum temperature and precipitation from 1948-1983 are given in Table 12. Values for the constant factors listed above were provided to OCS (Hodges, personal communication).

TABLE 11

Growth Stages Used in CERES Corn Models.

Stage	Corn
7	Presowing
8	Sowing to germination
9	Germination to emergence (roots, leaves)
1	Emergence to tassel initiation (roots, leaves)
2	Tassel initiation to beginning of linear ear growth (exclusive of grain) (roots, leaves, stems)
3	Linear ear growth to end of vegetative growth (roots, leaves, stem, ear)
4	End of vegetative growth to beginning of linear grain fill (stem, ear)
5	Linear grain fill (stem, grain)
6	End of linear grain fill to physiological maturity

Table 12: Sample Results of the Modified CERES Model at Peoria, IL.

KG/HA = Kilograms per Hectare
BU/AC = Bushels per Acre
G/GRAIN = Grams per Grain
GR/SQM = Grains per Square Metre
PL/SQM = Plants per Square Metre
GR/EAR = Grains per Ear

EMERGE = Emergence date (Julian Days)
TASSLE = Tassle Initiation data (Julian Days)
BEG EAR GROWTH = Beginning of Ear Growth Date (Julian Days)
END VEG GROWTH = End of Vegetative Growth Date (Julian Days)

BEG GR FILL = Beginning of Linear Grain Fill Date (Julian Days)
END GR FILL = End of Linear Grain Fill Date (Julian Days)
MATURE = Maturity Date (Julian Days)

YEAR	KG/HA	BU/AC	G/GRAIN	GR/SQM	PL/SQM	GR/EAR	EMERGE	TASSLE	BEG EAR GROWTH	END VEG GROWTH	BEG GR FILL	END GR FILL	MATURE
48	5926.	94.4	0.2238	2648.	6.	464.5	135	160	188	196	208	242	244
49	4357.	69.4	0.1620	2690.	6.	472.0	132	156	181	187	198	228	230
50	7342.	117.0	0.2498	2939.	6.	515.7	134	154	183	192	205	247	251
51	6912.	110.1	0.2508	2756.	6.	483.5	134	155	188	197	207	245	250
52	4119.	65.6	0.1418	2905.	6.	509.7	133	161	184	193	203	239	241
53	6419.	102.3	0.2109	3043.	6.	533.9	132	157	181	188	200	232	234
54	6068.	96.7	0.1862	3259.	6.	571.7	135	162	185	193	203	236	239
55	2716.	43.3	0.0958	2835.	6.	497.4	134	157	187	193	203	231	232
56	5009.	79.8	0.1714	2923.	6.	512.8	131	154	177	185	197	230	233
57	4162.	66.3	0.1352	3079.	6.	540.1	132	159	185	193	202	234	236
58	4923.	78.4	0.1738	2832.	6.	496.9	132	155	186	195	208	242	246
59	4477.	71.3	0.1504	2977.	6.	522.2	131	155	179	188	198	230	232
60	6638.	105.7	0.2301	2885.	6.	506.2	136	160	190	200	210	246	247
61	6334.	100.9	0.2442	2594.	6.	455.0	133	162	195	204	214	251	253
62	4166.	66.4	0.1489	2798.	6.	490.9	133	150	180	187	199	237	240
63	6524.	103.9	0.1943	3357.	6.	589.0	130	159	189	198	208	250	253
64	4201.	66.9	0.1325	3170.	6.	556.2	129	151	179	186	198	230	232
65	5986.	95.4	0.2027	2953.	6.	518.1	129	150	177	185	198	232	235
66	5271.	84.0	0.1854	2843.	6.	498.8	135	160	185	192	202	241	244
67	9689.	154.4	0.3234	2996.	6.	525.6	137	162	191	201	212	261	264
68	6328.	100.8	0.2442	2591.	6.	454.6	134	163	194	201	213	250	255
69	5513.	87.8	0.2101	2624.	6.	460.4	134	161	189	197	206	243	245
70	6855.	96.5	0.2020	2998.	6.	525.9	131	153	183	192	204	240	242
71	7174.	114.3	0.2342	3063.	6.	537.4	135	160	183	191	204	245	247
72	7061.	112.5	0.2508	2815.	6.	493.9	134	154	185	194	204	242	244
73	6480.	103.2	0.2310	2805.	6.	492.2	134	162	190	199	209	244	245
74	3939.	62.8	0.1355	2907.	6.	510.0	136	159	190	197	208	249	253
75	5861.	93.4	0.1844	3178.	6.	557.5	133	154	180	187	200	234	235
76	7656.	122.0	0.2475	3094.	6.	542.8	134	161	190	197	208	247	251
77	6474.	103.1	0.2412	2684.	6.	470.9	133	151	183	190	199	237	239
78	4606.	73.4	0.1457	3161.	6.	554.5	134	156	184	192	202	238	240
79	7190.	114.5	0.2268	3181.	6.	558.1	129	158	186	195	207	243	245
80	3894.	62.0	0.1312	2969.	6.	520.9	133	157	187	194	202	233	236
81	5047.	80.4	0.1865	2706.	6.	474.7	136	160	187	195	205	243	246
82	3849.	61.3	0.2508	1535.	6.	354.1	131	151	185	192	202	240	243
83	4157.	66.2	0.1264	3290.	6.	577.1	132	162	185	194	203	231	232

A brief consideration of these Peoria results indicates that even with the same planting dates, calculated maturity dates vary across the 36 study seasons from August 17 to September 11. Yields range from 43.3 bu/ac in 1955 to 154.4 bu/ac in 1967. Although it is beyond the scope of this study to comment on the representativeness of the plant physiologic process simulations contained in this model, it is quite appropriate to assess the general distributional correctness of the modeled results, F(x), as compared to reported observations, F(y). The null hypothesis to be tested is that the populations from which the two samples of corn yields have been taken possess the same underlying distribution (Eq. (5)).

$$H_o: F(x) = F(y) \quad . \tag{5}$$

The data set for analysis contains modeled Peoria yields for the period 1948-1975 and USDA-reported central crop reporting district (CRD) values for the same period. Since the natural distribution of yields at Peoria during this period is unknown, a non-parametric test, the Kolmogorov/Smirnov test (K-S test), was selected. The critical D value for a two-sample, two tailed K-S test with $\alpha = .05$ can be computed as in Eq. (6); i.e., there is only 1 chance in 20 that the samples are from the same distribution if the difference between F(x) and F(y) is greater than D_c.

$$D_c = 1.36 \sqrt{\frac{n_1 - n_2}{n_1 * n_2}} \quad . \tag{6}$$

where: D_c = maximum $|F(x) - F(y)|$

n_1 = number in sample x

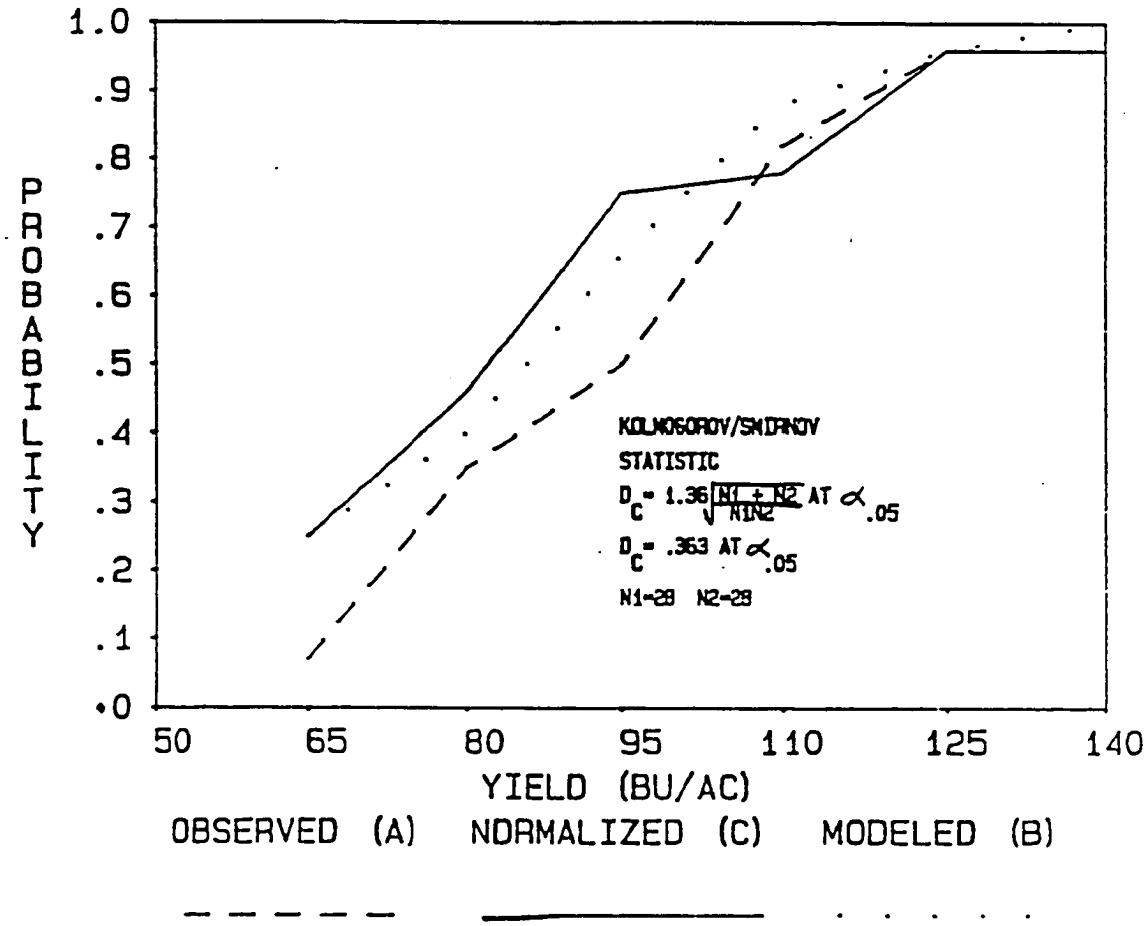
n_2 = number in sample y .

A sample D is found by constructing a cumulative probability distribution for two samples, taking the magnitude of the greatest difference between the two curves and comparing this value to a computed test statistic (see Figure 8, curves A and B).

If model generated and USDA reported yield distributions are to be compared, the presence of a technology trend in the observed data and the assumption of constant technology in the modeled data suggest a potential distributional bias. To test the extent of this bias, two sample D's were constructed; one which retains the bias (curves A and B, Figure 8) and another that has had the modeled means adjusted, or normalized, to the long-term mean of the observed conditions. The normalization procedure consists of finding the reported 28 year mean yield (84.95 bu/ac) and the modeled 28 year mean yield (90.834 bu/ac) and adjusting each modeled value by their ratio (modeled yield * .935).

As defined above, each sample D is the maximum distance between the modeled or normalized modeled and observed curves. Given sample sizes of 28 for cases A and B and 27 for the normalized case, C, the critical D, D_c, is .363 for cases A and B and .367 for case C. Figure 8 illustrates that the largest difference between the normalized modeled and observed yield curves is .09, well within the region of acceptance. When the original modeled yield estimates are used, the largest difference is .25, still within the acceptance region. Therefore, the hypothesis that the populations from which the two samples were taken have the same underlying distributions cannot be rejected. Having

Figure 8: Cummulative Probability Plots and Sample D's for Raw, Modeled and Normalized Modeled Data.



established that there is less than a 5 percent chance of the CERES model inaccurately representing the distribution of annual corn yields, a more detailed examination of modeled corn response to climatic variability will now begin.

3.2 A FIRST LOOK AT WEATHER IMPACTS

Table 12 suggests that the model reacts rather vigorously to something from year-to-year that is not technology, variety, or planting date since these are all held constant. One major source of variability which has not been fixed is weather. If this is the source of such wide variability, then, an examination of corn growing weather conditions would seem in order. First, however, the corn weather impact season at a particular location should be defined (note: a corn weather impact season will not necessarily equal a growing season for corn and will vary from one location to another).

Since Table 12 illustrates that the physiological growing seasons of corn can vary widely, one means of determining a representative weather impact season for a location and crop is to begin with a typical planting date and perturb the daily climate widely throughout the entire calendar year. This process will test the sensitivity of the corn model to small as well as to large variations in daily climatological conditions before, during, and after what would be a conventional growing season (planting to harvest). This process should determine model response to weather conditions other than those under which the model was originally derived.

First a base run must be made against which the impact of climatological perturbations can be compared. This base run is comprised of long-term daily mean values of maximum and minimum temperature and a "representative" year for precipitation. The use of a "representative" precipitation year will preserve a natural rain/no-rain event pattern, whereas a long-term daily mean precipitation time series

would not. Next, independent variations among the temperature and precipitation variables are imposed by adding a constant to each daily temperature value and multiplying each value of precipitation by a constant. This means that days with 0 precipitation remain 0 while non-zero values are increased or decreased by a fixed percent as given in the legend of Figure 13. Since a variation of climate inputs one day at a time will not alter the model estimated yields enough to be of interest, and since arbitrary alteration of long time periods of climatological variables disrupts their natural distributions, alterations were ultimately made in seven day groups. Finally, the model generated biomass calculations of Table 12 are converted to bu/ac by assuming a fixed bushel test weight. Figures 11 - 13 are then constructed.

Figures 9 - 13 illustrate:

1. how the set of time series for the model executions was created,
2. the resultant yield estimates, and
3. the impact seasons.

Figure 9 considers the modeled corn reaction to altering the daily maximum temperature only during Julian Week 24, days 161-167. Prior to and following this 7-day period, base-run values of long-term daily maximum and minimum temperatures and "representative" precipitation are used. This climatological time series (a one-week perturbation of the base run) is then entered as input to the corn process model and a yield is obtained (point A, Figure 11). Next, replace the altered seven days with their original base run values leaving all previous days unchanged. Alter the next group of seven days (168-174): the result is Figure 10.

Figure 9: Time-Series Construction to Examine Weather Impacts on Modeled Corn Yields During Week 24.

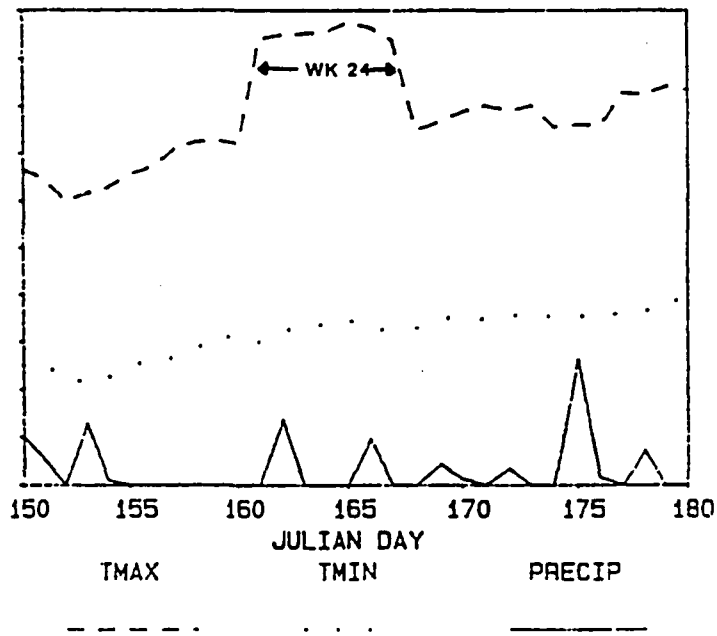


Figure 10: Time-Series Construction to Examine Weather Impacts on Modeled Corn Yields During Week 25.

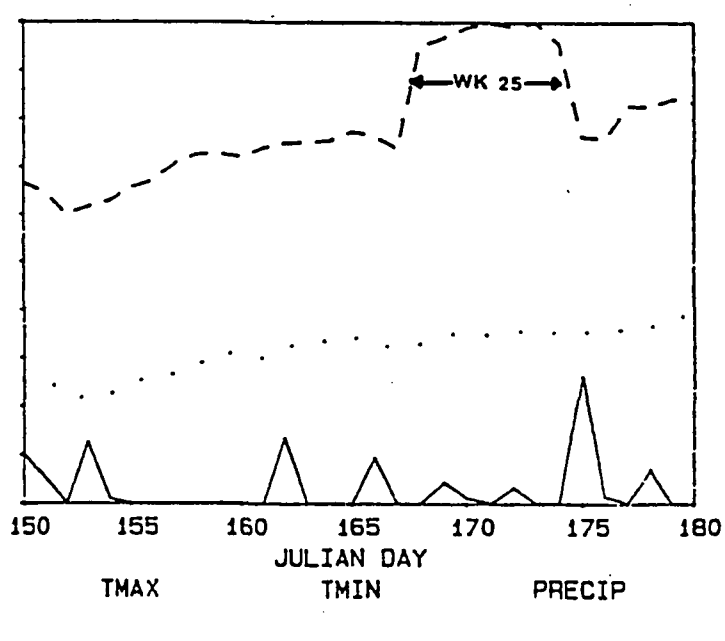


Figure 11: CERES Model Response to Weekly Maximum Temperature at Peoria, IL.

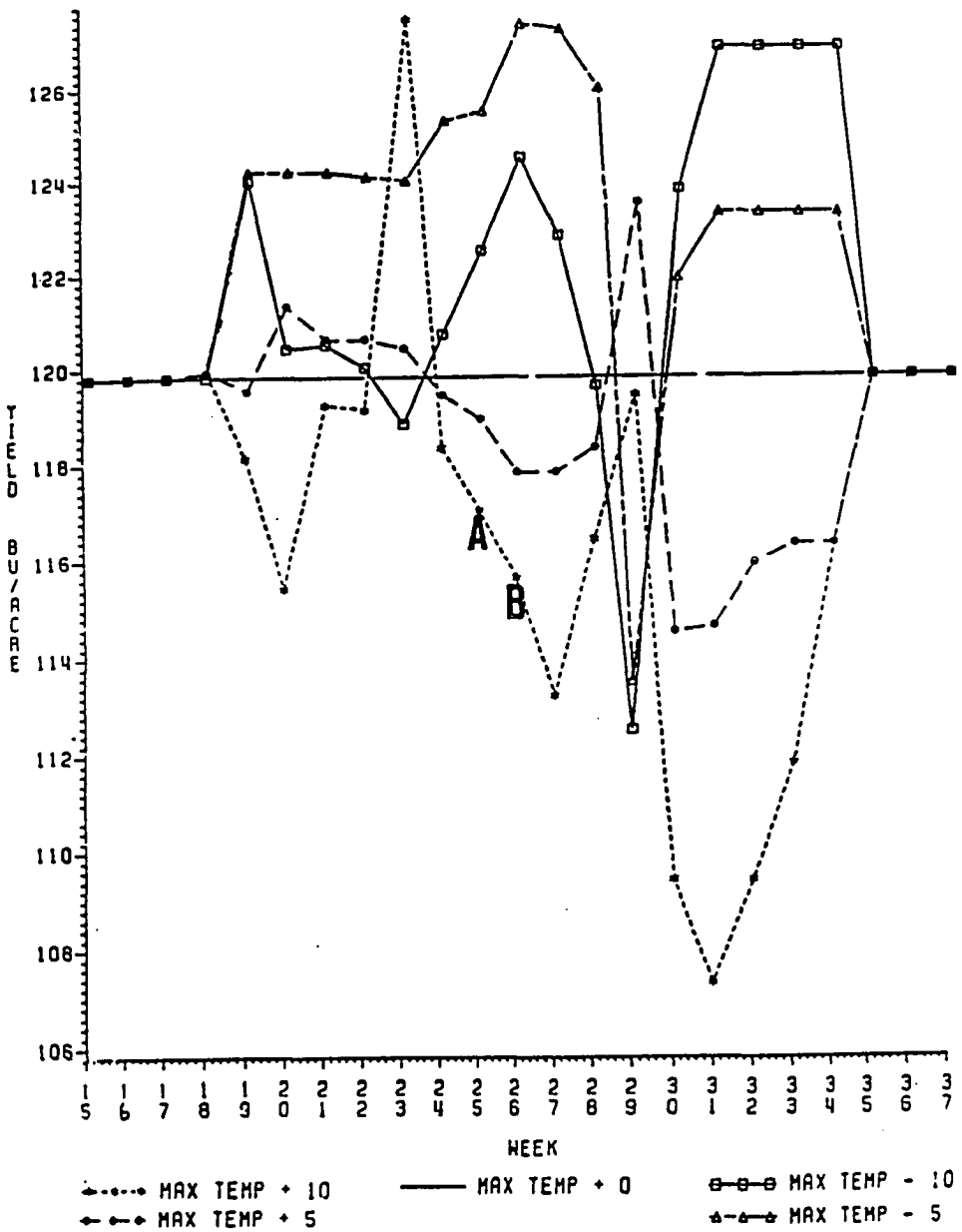


Figure 12: CERES Model Response to Weekly Minimum Temperature at Peoria, IL.

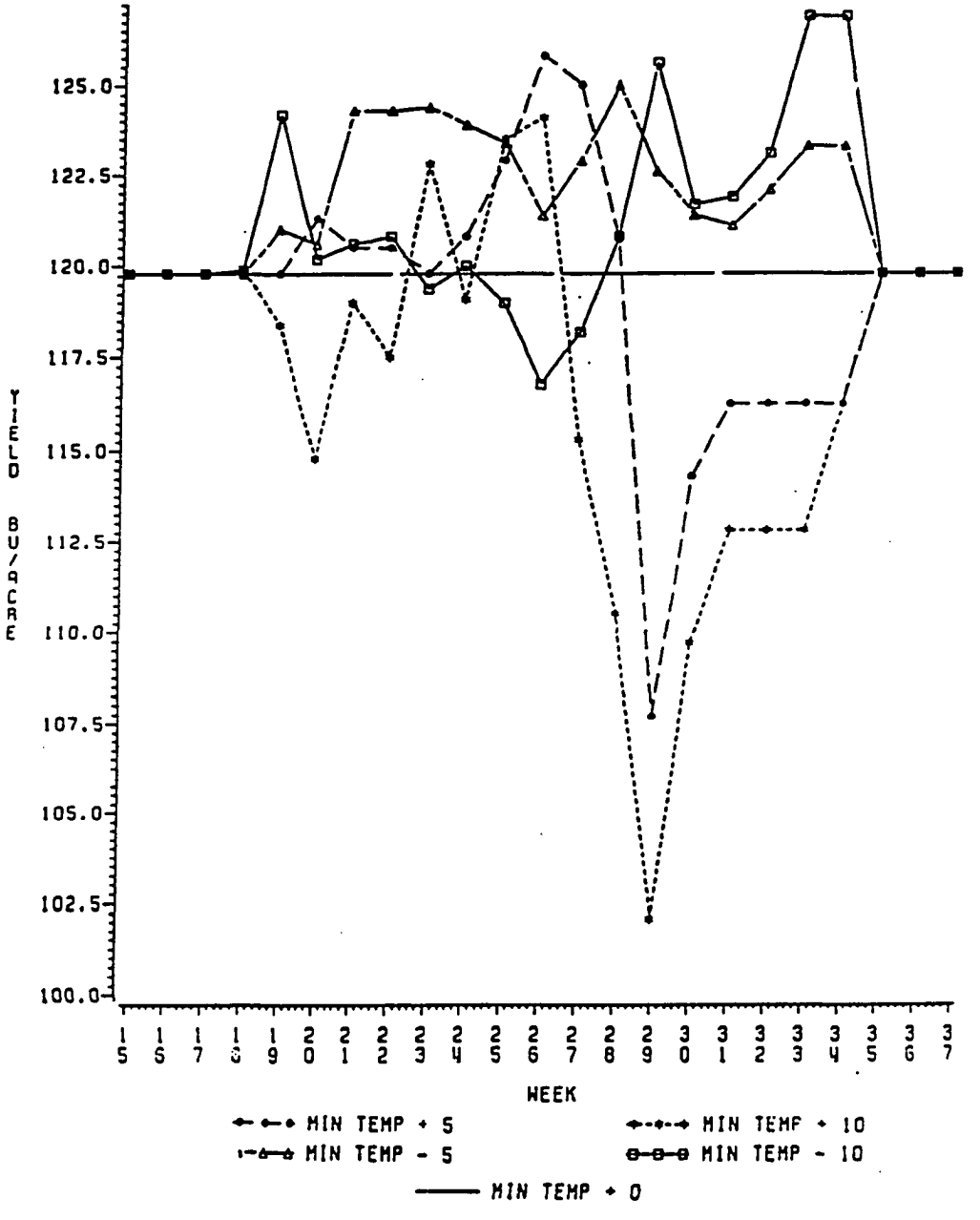
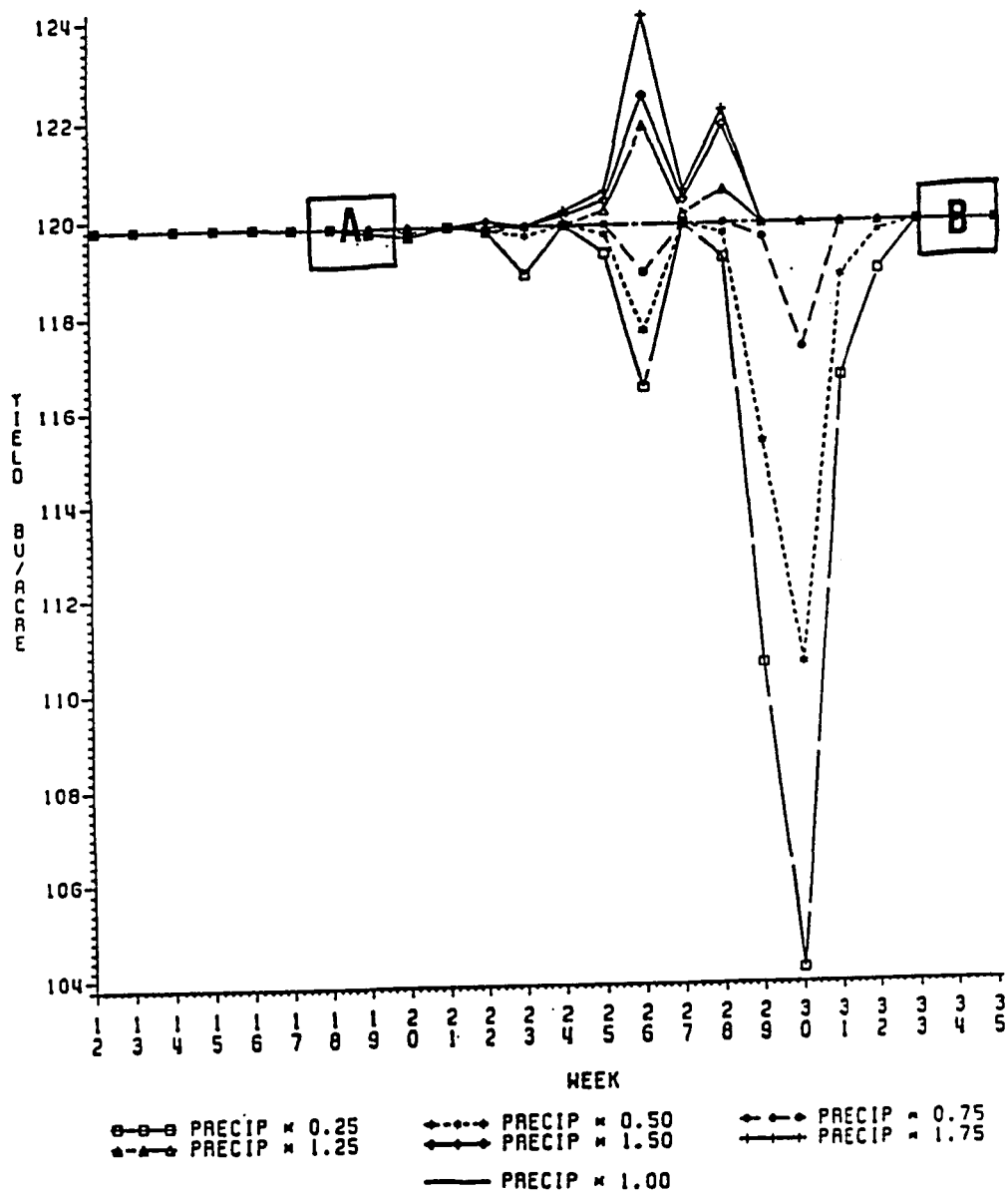


Figure 13: CERES Model Response to Weekly Precipitation at Peoria, IL.



Another yield is calculated (point B, Figure 11). These operations are repeated for each week of the calendar year and then repeated for each variable changed. The legend of Figure 11 describes the range of maximum temperature perturbations. The curve containing points A and B represent the most extreme perturbations. Note that although the three variables required as model input are all treated as though they were independant, it is well known that this is not the case. Therefore, when in each case one weather variable is altered, there is no way of determining how much of the modeled yield response is attributable to the single weather variable being tested, and how much is the result of weather variable interactions. The method described above does permit the pin-pointing in time of those periods of greatest weather sensitivity, regardless of its source.

These operations are performed for minimum temperature and daily precipitation as well (Figures 12 and 13 respectively). What is then defined in time by these graphs is not necessarily a representative agronomic growing season, but a corn weather impact season. This is the period of time during the year when climate impacts levels of final corn (model) production. Impacts might be observed prior to sowing (see area A outlined in Figure 13) which represents the effects of preplant soil moisture on predicted germination and emergence. Impacts may also end prior to physiologic maturity (see area B, Figure 13). Thus the precipitation impact growing season for a representative physiological growing season is from Week 17 through Week 32. The temperature impacts run between Weeks 18 through 34. The latter was redefined to Week 36 to be sure outlier years were included so that the representative corn

weather impact season at Peoria is defined as Julian Weeks 17 through 36.

Figures 11 through 13 also illustrate the model's sensitivity to weather week by week. For instance, in this representative year, the model output contained in Figure 11 illustrates extreme crop sensitivity to changes, high or low, in maximum temperature during Week 31 (blister stage, or beginning of grain fill approximately 12 days after silking). Figure 12 shows the greatest sensitivity of modeled corn yield to high daily minimum temperatures during Week 33 (dough approximately 24 days after silking). Model estimated plant growth during Week 29 (silking, approximately 66 days after emergence) is most sensitive to low minimum temperatures. Figure 13 shows the greatest modeled yield sensitivity to excessive precipitation during Week 25 (start of ear growth, approximately 6 weeks after emergence) and the greatest sensitivity to moisture deficit during Week 30.

Having now summarized these figures individually, can these yield results be generalized across time and space? First, consider across time, or all growing seasons. In realistic terms the answer is no, primarily because of weather variable correlations and distributional instabilities. The greatest source of error lies in the selection of a "typical" precipitation year. Since it is known that yield response to temperature is influenced by moisture availability, precipitation year selection is crucial to the estimation of yield response to temperature. Also, temperature events have been combined which rarely if ever are observed (average daily temperatures) with specific, recorded precipitation events. The likelihood of these two sets of weather

events actually occurring simultaneously is nearly zero. Correlation aside, the precipitation analysis alone could easily contain certain biases as well. For instance, for the use of a "typical" year to be acceptable, it must be assumed that the year is typical not only in terms of precipitation amount, but also in terms of within-season distribution (runs of wet and dry days). Further, as total precipitation is increased or decreased, the distribution of these wet and dry days does not change significantly. Therefore, these graphs represent a useful model exercise to illustrate the range of model response to weather variability unlike that which the model was developed and to set reasonable weather impact seasons. But just as "normal" weather is rarely if ever observed, the likelihood of these plant yield responses being observed during any particular growing season is very small.

Next consider the application of these Peoria results to other locations. It is reasonable to expect that no matter what the location, certain weather extremes would always result in raised or lowered modeled yields. The point in calendar time at which yields begin to be affected by these extremes is largely the result of varietal characteristics and local weather variable relationships between the "normal" temperatures and "typical" precipitation. The point in phenological time that yield is effected by weather extremes should remain consistant within a variety. Thus, although these results may not be generalizable across real time growing seasons at a single location, they should apply across space in phenological time.

These results are confirmed when graphical analyses similar to Figures 11 - 13 are performed at seven other sites across the corn belt; Springfield, Missouri; Omaha, Nebraska; Rapid City, South Dakota; Rochester, Minnesota; Columbus, Ohio; Dodge City, Kansas; and Des Moines, Iowa. The set of three-graph groups corresponding to Figures 11 - 13 for each station is contained in Appendix A. Table 13 contains the weather impacted corn seasons derived from the results in Appendix A for each of the above stations.

TABLE 13

Corn/Weather Impact Seasons for Selected Stations.

Location	Julian weeks	Calendar Dates
Springfield, MO	20-35	May 13 - Aug. 26
Omaha, NB	19-34	May 7 - Aug. 20
Rapid City, SD	19-37	May 7 - Sept. 16
Rochester, MN	20-36	May 13 - Sept. 2
Peoria, IL	17-35	April 24 - Aug. 26
Columbus, OH	19-33	May 7 - Aug. 14
Dodge City, KS	19-34	May 7 - Aug. 20
Des Moines, IO	20-35	May 18 - Aug. 26

One piece of applications information can already be derived from Table 13 . If the model represents a customer who is a corn grower in central Illinois, climate forecasts for the period prior to late April or early May or after mid-September are of little value. Not only is the modeled crop not usually in the field during this period, but also the weather apparently has little influence on the crop when it is in the field. This confirms that the model has been successfully transferred from its development site and variety to another location and growing conditions.

Now that model representative corn weather impact seasons for various geographic locations throughout the corn belt have been determined, growing season climatologies can be produced and estimates of normal and abnormal corn climate conditions can begin. This will be determined by examining between-season and within-season climate variability.

3.2.1 Between-Season Weather Impacts

Begin with between-season comparisons. For each of four variables; maximum temperature, minimum temperature, growing degree days and precipitation, some descriptive statistics are generated, ranking is performed (1948-1983), and frequency histograms are produced. Ranking is performed only on the leading variable. The other three which occur concurrently are then also given. An example for Peoria, Illinois is provided in Figures 14 - 17 . Similar graph sets for the other sensitivity-test locations are located in Appendix B.

From Figure 14 it can be seen that the mean seasonal (Julian Week 17-36) maximum temperature at Peoria is 79.4 degrees, with a range of 6.9 degrees and a standard deviation of 1.8 degrees. The standard deviation as well as the histogram should be used with caution since the population distribution of these seasonal temperatures is unknown. The frequency categories chosen for the histograms are arbitrary and may not reflect the shape of the distribution accurately. The range varies from 75.5 to 82.4 degrees with a sample size of 36 points or seasons. The ranking suggests that the 1983 seasonal mean maximum Peoria temperature was the warmest (36th of 36) on record, 1948-1983. The 1983 seasonal

Figure 14: Statistical Results for Mean Seasonal Maximum Temperature at Peoria, IL.

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1967	76.06	55.50	15.11	2175.5
2	1960	77.20	57.75	21.36	2373.0
3	1950	77.65	57.14	19.41	2360.0
4	1958	77.80	57.54	20.52	2380.0
5	1961	77.88	56.08	13.45	2294.0
6	1948	78.13	57.92	17.77	2419.5
7	1974	78.25	57.63	22.58	2420.5
8	1969	78.47	57.68	16.52	2429.5
9	1972	78.54	57.34	16.01	2417.0
10	1981	78.59	59.72	25.33	2522.5
11	1951	78.79	58.98	14.77	2517.5
12	1976	78.95	55.71	16.95	2354.5
13	1973	79.26	58.95	18.41	2546.0
14	1978	79.40	58.56	14.75	2550.5
15	1979	79.44	57.20	11.50	2460.5
16	1963	79.59	56.45	12.63	2434.5
17	1966	79.72	56.85	14.62	2402.0
18	1971	79.95	56.42	11.83	2441.5
19	1982	80.00	59.50	17.99	2628.5
20	1956	80.09	59.50	18.17	2647.5
21	1948	80.13	58.47	15.32	2567.5
22	1965	80.14	58.89	17.97	2610.5
23	1970	80.35	59.54	19.96	2660.5
24	1954	80.88	60.42	21.95	2743.5
25	1957	80.89	61.18	16.57	2805.0
26	1975	81.08	59.99	20.04	2731.0
27	1980	81.17	60.13	19.69	2644.5
28	1952	81.78	60.27	19.79	2739.0
29	1962	81.92	59.56	12.54	2758.0
30	1964	82.00	59.33	9.91	2715.5
31	1953	82.17	60.72	15.44	2721.5
32	1977	82.43	59.57	16.38	2760.5
33	1955	82.59	61.24	13.41	2768.5
34	1959	82.66	61.92	12.69	2768.0
35	1949	82.89	61.01	11.35	2848.5
36	1983	83.05	61.18	15.50	2492.0

	MEAN	STANDARD DEVIATION
	79.99494444	1.79246449
	MINIMUM VALUE	MAXIMUM VALUE
	76.06000000	83.05000000
	STD ERROR OF MEAN	SUM
	0.29874441	2879.8980000
	VARIANCE	C.V.
	3.21293611	2.241

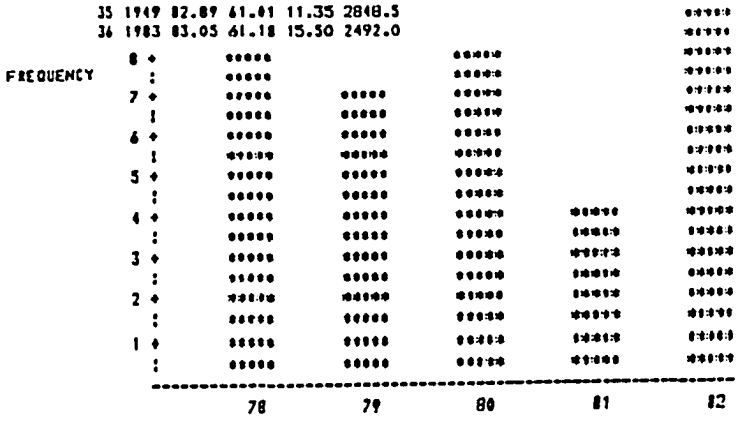


Figure 15: Statistical Results for Mean Seasonal Minimum Temperature at Peoria, IL.

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1967	76.86	55.50	15.11	2175.5
2	1976	78.95	55.71	16.95	2354.5
3	1961	77.88	56.08	13.45	2294.0
4	1971	79.95	56.42	11.83	2441.5
5	1963	79.59	56.45	12.63	2434.5
6	1966	79.72	56.85	14.42	2402.0
7	1950	77.65	57.14	19.41	2340.0
8	1979	79.44	57.20	11.50	2460.5
9	1972	78.54	57.34	16.01	2417.0
10	1958	77.80	57.34	20.52	2380.0
11	1974	78.25	57.65	22.58	2420.5
12	1969	78.47	57.68	14.52	2429.5
13	1960	77.20	57.75	21.36	2373.0
14	1968	78.13	57.92	17.77	2419.5
15	1948	80.13	58.47	15.32	2367.5
16	1978	79.40	58.56	14.75	2550.5
17	1965	80.14	58.89	17.97	2618.5
18	1973	79.26	58.95	18.41	2546.0
19	1951	78.79	58.98	16.77	2517.5
20	1964	82.00	59.33	9.91	2715.5
21	1956	80.09	59.50	18.17	2647.5
22	1982	80.00	59.50	17.99	2628.5
23	1970	80.35	59.54	19.96	2660.5
24	1962	81.92	59.56	12.54	2758.0
25	1977	82.43	59.57	16.38	2769.5
26	1981	78.59	59.72	25.33	2521.5
27	1975	81.08	59.99	20.04	2731.0
28	1980	81.17	60.13	19.69	2644.5
29	1952	81.78	60.27	19.79	2730.0
30	1954	80.88	60.42	21.93	2743.5
31	1953	82.17	60.72	15.44	2721.5
32	1949	82.89	61.01	11.35	2848.5
33	1957	80.89	61.18	16.57	2805.0
34	1983	83.05	61.18	15.50	2492.0
35	1955	82.59	61.24	13.41	2768.5
36	1959	82.66	61.92	12.69	2968.0

	MEAN	STANDARD DEVIATION
	58.77444444	1.72379553
	MINIMUM VALUE	MAXIMUM VALUE
	55.50000000	61.92000000
	STD ERROR OF MEAN	SUM
	0.28721926	2115.8800000
	VARIANCE	C.V.
	2.97147111	2.933

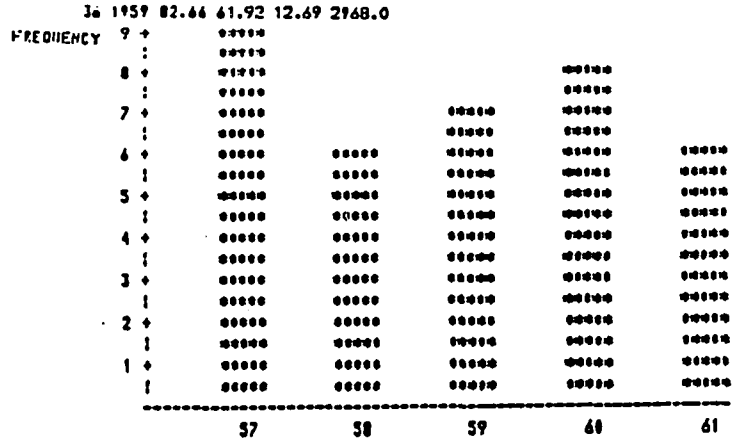


Figure 16: Statistical Results for Total Seasonal Growing Degree Days at Peoria, IL.

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1967	76.06	55.50	15.11	2175.5
2	1961	77.88	54.08	13.45	2294.0
3	1976	78.95	55.71	16.95	2354.5
4	1950	77.65	57.14	19.41	2360.0
5	1960	77.20	57.75	21.36	2373.0
6	1958	77.80	57.54	20.52	2380.0
7	1966	79.72	56.85	14.62	2402.0
8	1972	78.54	57.34	16.01	2417.0
9	1968	78.13	57.92	17.77	2419.5
10	1974	78.25	57.65	22.38	2420.5
11	1969	78.47	57.68	16.52	2429.5
12	1963	79.59	56.45	12.63	2434.5
13	1971	79.95	56.42	11.83	2441.5
14	1979	79.44	57.20	11.50	2460.5
15	1983	83.05	61.18	15.58	2492.0
16	1951	78.79	58.98	14.77	2517.5
17	1981	78.59	59.72	25.33	2522.5
18	1973	79.26	58.95	18.41	2546.0
19	1978	79.40	58.56	14.75	2550.5
20	1948	80.13	58.47	15.32	2567.5
21	1965	80.14	58.89	17.97	2610.5
22	1982	80.00	59.50	17.99	2628.5
23	1980	81.17	60.13	19.69	2644.5
24	1956	80.09	59.50	18.17	2647.5
25	1970	80.35	59.54	19.96	2660.5
26	1964	82.00	59.33	9.91	2715.5
27	1953	82.17	60.72	15.44	2721.5
28	1952	81.78	60.27	19.79	2730.0
29	1975	81.08	59.99	20.04	2731.0
30	1954	80.88	60.42	21.95	2743.5
31	1962	81.92	59.56	12.54	2758.0
32	1977	82.43	59.57	16.38	2760.5
33	1955	82.59	61.26	13.41	2768.5
34	1957	80.89	61.18	16.57	2805.0
35	1949	82.89	61.01	11.35	2848.5
36	1959	82.66	61.92	12.69	2968.0

	MEAN	STANDARD DEVIATION
	2563.87500000	179.20325153
	MINIMUM VALUE	MAXIMUM VALUE
	2175.0000000	2968.0000000
	STD ERROR OF MEAN	SUM
	29.86720859	92239.500000
	VARIANCE	C.V.
	32113.865357	6.990

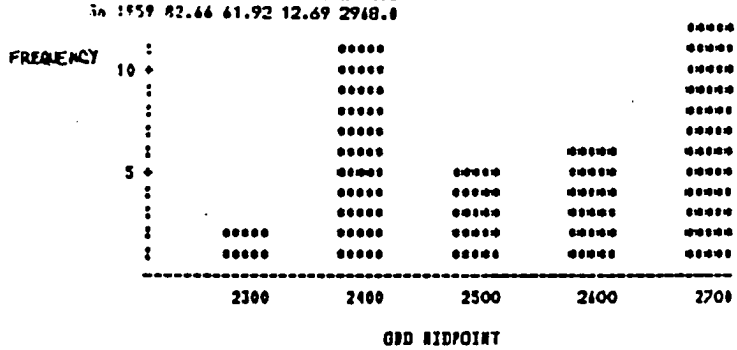
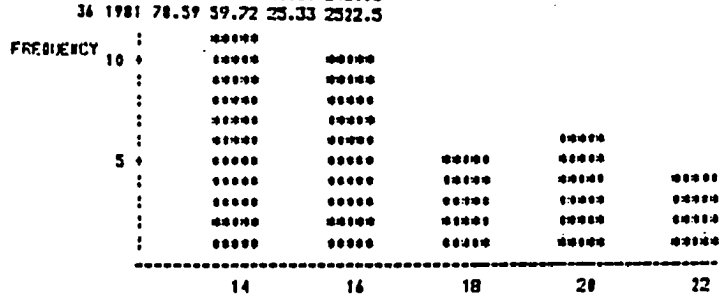


Figure 17: Statistical Results for Total Seasonal Precipitation at Peoria, IL.

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1964	82.00	59.33	9.91	2715.5
2	1949	82.89	61.01	11.35	2848.5
3	1979	79.44	57.20	11.50	2440.5
4	1971	79.95	56.42	11.83	2441.5
5	1962	81.92	59.56	12.54	2758.0
6	1963	79.59	56.45	12.61	2434.5
7	1959	82.66	61.92	12.69	2948.0
8	1955	82.59	61.26	13.41	2768.5
9	1961	77.88	56.08	13.45	2194.0
10	1966	79.72	56.85	14.42	2402.0
11	1978	79.40	58.56	14.75	2558.5
12	1967	76.06	55.58	15.11	2175.5
13	1948	80.13	58.47	15.32	2567.5
14	1953	82.17	60.72	15.44	2721.5
15	1983	83.05	61.18	15.58	2492.0
16	1972	78.54	57.34	16.01	2417.0
17	1977	82.43	59.57	16.38	2760.5
18	1969	78.47	57.48	16.52	2429.5
19	1957	80.89	61.18	16.57	2805.0
20	1951	78.79	58.18	16.77	2517.5
21	1976	78.95	55.71	16.93	2354.5
22	1968	78.13	57.92	17.77	2419.5
23	1965	80.14	58.89	17.97	2610.5
24	1982	80.80	59.50	17.99	2628.5
25	1956	80.09	59.50	18.17	2647.5
26	1973	79.26	58.95	18.41	2546.0
27	1950	77.65	57.14	19.41	2360.0
28	1980	81.17	60.13	19.69	2644.5
29	1952	81.78	60.27	19.79	2730.0
30	1970	80.35	59.54	19.96	2640.5
31	1975	81.08	59.99	20.04	2731.0
32	1958	77.80	57.54	20.52	2380.0
33	1960	77.20	57.75	21.36	2373.0
34	1954	80.88	60.42	21.95	2743.5
35	1974	78.25	57.63	22.58	2420.5
36	1981	78.59	59.72	25.33	2522.5

	MEAN	STANDARD DEVIATION
	16.67194444	3.55817274
	MINIMUM VALUE	MAXIMUM VALUE
	9.91000000	25.33000000
	STD ERROR OF MEAN	SUM
	0.59302879	600.19000000
	VARIANCE	C.V.
	12.66051325	21.342



mean minimum temperature of 60.7 degrees was slightly less extreme: it ranked 34 of 36 (Figure 15); the growing degree days, 2492.0, ranks only 15th highest of 36, as does precipitation (15th driest).

Next, statistical output similar to that generated for weather can be calculated on a time-series of modeled yield results. These values are presented in Figure 18. These are model yields generated on the basis of actual observed temperature and precipitation data. Figure 18 indicates that the "best" corn year at Peoria was 1967, whose weather generated a modeled yield of 154.35 bu/ac. The poorest model corn weather year was 1955, with a yield of only 43.27 bu/ac. The mean yield of the 36 modeled years is 89.62 bu/ac with a standard deviation of 22.72 bu/ac. Weather during 1983, a corn growing season to be considered in far greater detail later, resulted in a modeled yield of 66.23 bu/ac which is the sixth lowest in 36 years.

One method of ascertaining the relationship between the three weather variables and yield is to compare a time-series of ranks. This is done in Figures 20 - 22. Figure 19 illustrates the ranking scales used to construct Figures 20 - 22. From these figures growing season mean maximum and minimum temperatures appear to be negatively correlated with modeled yield and precipitation appears to be positively correlated with yield.

These figures suggest the general relationships of year-to-year yield changes to seasonal weather variables but do not explain why there are yield variations among similarly ranked seasonal weather years. It would be reasonable to expect there to be significant weather impacts taking place on a shorter time scale than those reflected by seasonal

Figure 18: Statistical Results for Input Series 1 Generated Yields.

OBS	YEAR	BUSHELS
1	55	43.27
2	82	61.33
3	80	62.04
4	74	62.75
5	57	65.63
6	83	66.23
7	57	66.30
8	62	66.36
9	64	66.93
10	49	69.42
11	59	71.32
12	78	73.38
13	58	78.43
14	56	79.80
15	81	80.48
16	66	83.98
17	69	87.84
18	75	93.37
19	48	94.42
20	65	95.36
21	70	96.46
22	54	96.68
23	68	100.81
24	61	100.91
25	53	102.27
26	77	103.14
27	73	103.24
28	63	103.93
29	60	105.74
30	51	110.12
31	72	112.49
32	71	114.29
33	79	114.55
34	50	116.97
35	76	121.97
36	67	154.35

MEAN	STANDARD DEVIATION
89.62444444	22.72325800

MINIMUM VALUE	MAXIMUM VALUE
43.27000000	154.35000000

STD ERROR OF MEAN	SUM
3.78710967	3224.4880000

VARIANCE	C.V.
516.34645397	25.354

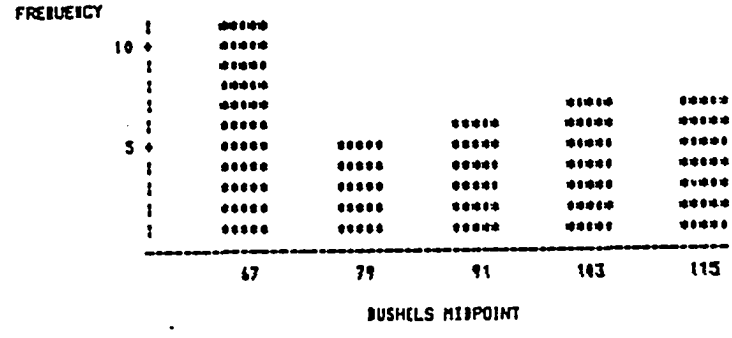


Figure 19: Ranking System for Figures 20 - 22.

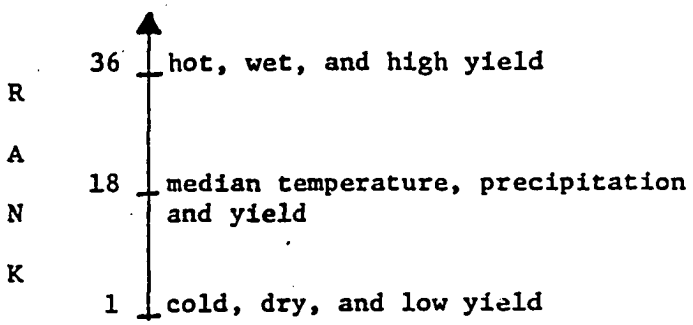
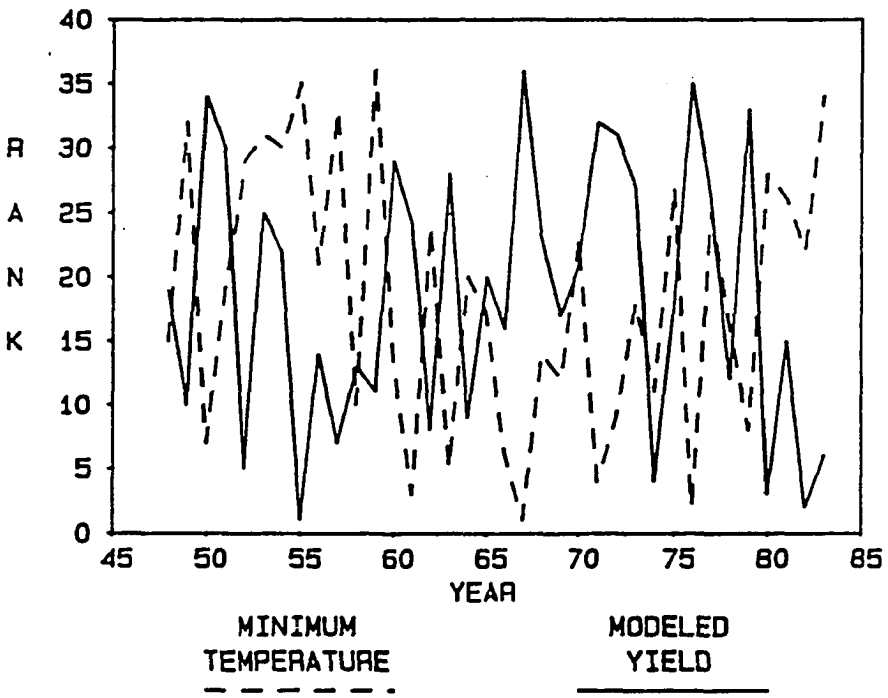


Figure 20: Annual Modeled Yield and Season Average Minimum Temperature Ranks at Peoria, IL.



means or totals. To explore this possibility, consider weekly rankings of weather variables for a particular year, say, 1983.

Figure 21: Annual Modeled Yield and Season Average Maximum Temperature Ranks at Peoria, IL.

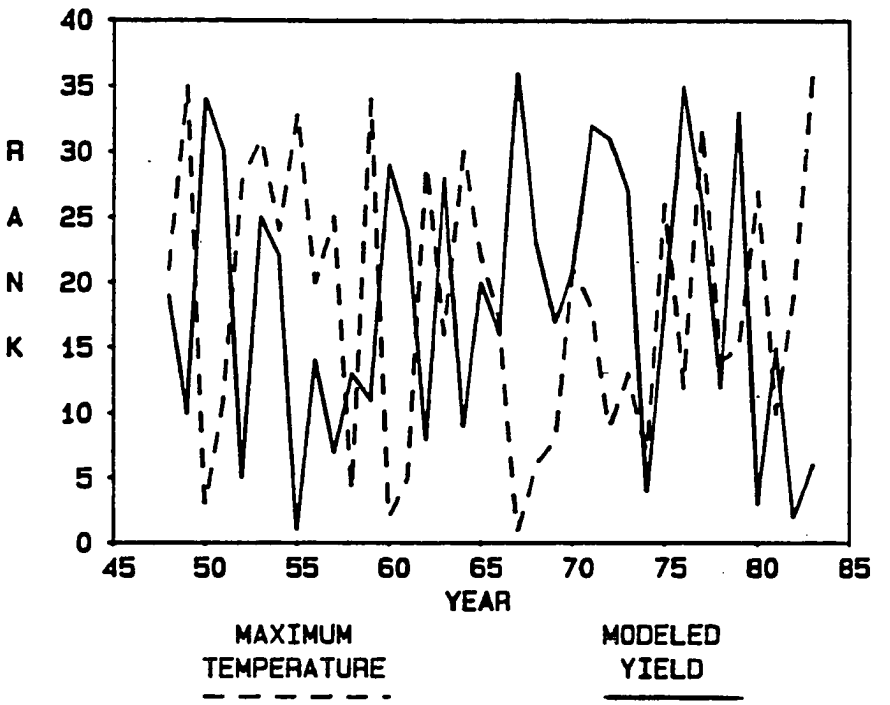
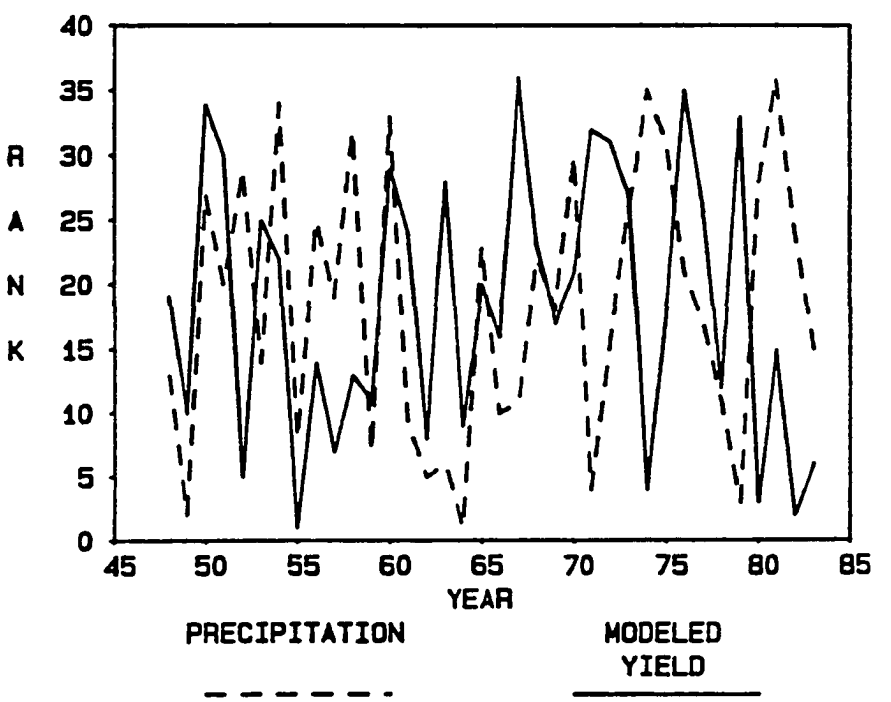


Figure 22: Annual Modeled Yield and Season Total Precipitation Ranks at Peoria, IL.



3.2.2 Within-Season Weather Impacts

Within-season (weekly) conditions across time (1948-1983) can be analyzed in the same way as between seasons. Since some time-series, especially temperature, have pronounced seasonal trends, a graph of weekly 36 year rank provides more information than a simple time series of parameter estimates Figure 23 is a graph showing how each week of the 1983 growing season ranked with respect to its own 36-year history for maximum temperature, minimum temperature and precipitation at Peoria, Illinois. Figure 24 is the same information subjectively smoothed over time. Similar raw ranking (Figure 23 type) graphs for the other seven locations are contained in Appendix C. Smoothed graphs are presented and discussed in Figures 51 - 63.

Figure 23: Raw Weekly 1983 Ranks of Maximum Temperature, Minimum Temperature and Precipitation at Peoria, IL.

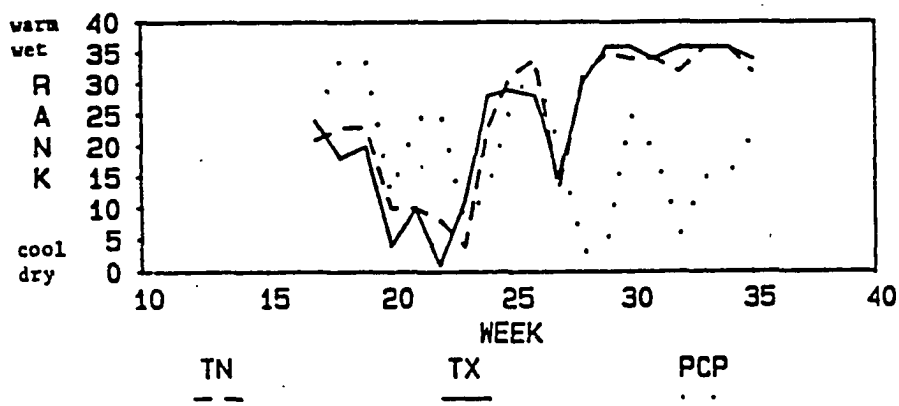
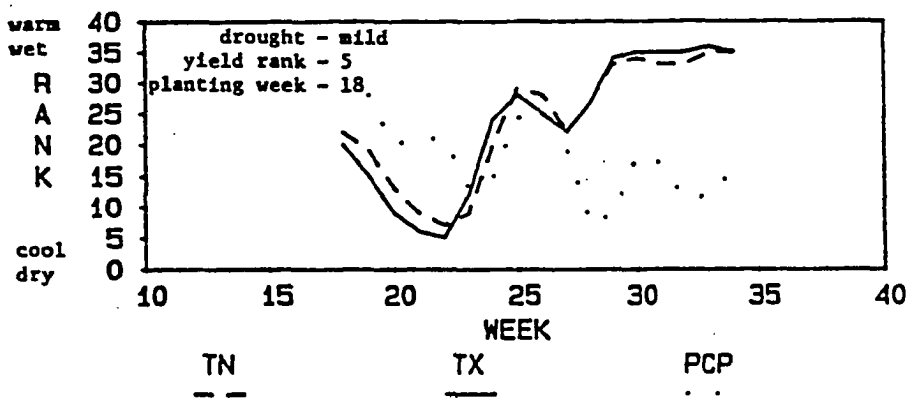


Figure 24: Smoothed Weekly 1983 Ranks of Maximum Temperature, Minimum Temperature and Precipitation at Peoria, IL.



The most unusual feature of Figure 24 is the maximum and minimum temperatures which ranked very high during the latter one-third of the season. During this same time moisture conditions became drier, but precipitation rank did not plummet significantly, suggesting that rainfall patterns were not as abnormal as were those of temperature. If we compare Figure 23 (the raw weekly ranks) to those highly sensitive growth periods highlighted in Figures 11 - 13, Table 14 can be constructed.

This table describes the impact of weather conditions during Julian Weeks 25, 29, 30, 31 and 33 of 1983. The predicted yield responses, positive or negative, are derived from Figures 11 - 13. For example, a high maximum temperature rank (Figure 23) during Julian Week 30 indicates much above normal maximum temperatures. Figure 20 suggests

TABLE 14

Summary of 1983 Weather Impacts on Modeled Corn Yields at Peoria, IL.

Variable	Week	1983 Condition *11-13 Predicted Effect
Precipitation	25	very wet followed by more wet (+)
Minimum temperature	29	slightly cool (+)
Precipitation	30	moderately wet following very dry(--)
Maximum temperature	31	warm following 2 very warm weeks(-)
Minimum temperature	33	very warm (-)

* - yield decrease -- large yield decrease + yield increase ++ large yield increase

that given abnormally high maximum temperatures during week 30, one could expect a decline in potential yield from normal levels. Using this frame of reference, Table 14 suggests that the season began favorably for plant growth and development (Julian Weeks 25 and 29), but deteriorated rapidly during Julian Week 30 and throughout the next several weeks (Julian Weeks 30, 31 and 33), resulting in extremely low yields by harvest time.

It has been established a) that a corn weather impact season can be defined (Table 13), and b) that the CERES model can respond rather dramatically from season-to-season (Table 12). This variability has been related to week-to-week (Figures 11 - 13) real and simulated climate variability. It has also been established that the distribution of these responses is not dissimilar from that of final yield estimates released by the USDA (K-S test, Figure 8). Further, the manner in which modeled yield responds to measures of seasonal weather variability has been noted (Figures 20 - 22).

Even though the analysis just completed provides much information concerning plant model response to variable weather conditions, it still does not tell us to what extent the within-season or the between-season condition is the controlling factor; i.e., is it the overall seasonal condition or one or more short-term within-season "run" of weather that has the greatest influence on final predicted corn yields? The answer to this question can be approached in two ways. The first is to proceed to consider methods of variance partitioning. This procedure is suggested because of the importance of learning more about what makes the model estimated values change from year-to-year to the development of informative user climate products. Methods to partition yield variability are delt with in some detail in section 3.3. A second approach is to take the tools and information that have already been developed and use these to analyze graphically the within-season weather events that determine the final modeled yield outcome. This can be done on a season-by-season basis. Section 3.4 contains such an analysis for the unusual growing season of 1983.

3.3 STATISTICAL ANALYSIS OF MODELED YIELD/WEATHER RELATIONSHIPS

3.3.1 Variance Partitioning

In climatology there are, traditionally, two types of variability which are considered, inter-annual and intra-annual. In the case of agriculture, these become inter-seasonal and intra-seasonal. In the language of statistics, these are represented by between-group and within-group variances. It is this latter approach which the analysis of sections 3.1 and 3.2 suggest might yield some interesting results.

Initially one might assume that a direct application of traditional statistical techniques of variance analysis to model generated yield data would be appropriate, but there are several issues which tend to complicate the analysis. These include model non-linearities and weather variable inter-correlations. The presence of these features indicate that traditional statistical definitions of within and between-group variability may not be applicable. A more general approach will be applied, acknowledging that the results will contain certain anomalies as the result of the effects mentioned above.

If yield variability is to be broken into component parts, additional input time series and associated yield variance information is required, particularly to enable us to examine the within-season variance. As a consequence, five daily weather variable input data sets were created. These input series are described in Table 15.

In series 3, for example, each daily observed value of maximum temperature and precipitation is multiplicatively normalized as defined by Eqs. 7 to 13 and reported values of minimum temperature are left unaltered (as they were observed). Normalization processes can take numerous forms. The most common normalization method is "additive", in which part of the process involves a constant being added or subtracted from each within-year value to obtain the same seasonal mean each year. This would be a valid procedure in the case of daily temperature but would create serious model and physical anomalies in the precipitation data. It is not only the total quantity of water that is important to biological processes, but also its distribution in time. Additive normalization would obliterate natural patterns of wet and dry days and

produce unrealistic estimates of soil moisture availability to crops. Further, the process model cannot cope with a situation where precipitation occurs every day because of sunshine availability assumptions. For these reasons a "multiplicative" rather than "additive" normalization scheme was selected. Since this transformation is non-additive it will also affect the parameter variance.

These operations are performed for each day for each impact season in the time series, 1948-1983. When this has been completed for series 3, the weather data will have a between-season variance of zero except for the contribution made by reported minimum temperature. When these new time series are entered into the CERES yield model a new time series of yield estimates is generated. Figures 25 - 28 are statistical presentations of the yield results for the four remaining time series (series 1 is presented in Figure 18). Figure 26 is the analysis for the minimum temperature input series described above. Similar graph sets for the other seven sensitivity sites are contained in Appendix D.

If inter-variable correlation and non-linear model effects are ignored, the parameter variance associated with input series 3 can be assigned to only between-season minimum temperature. The same can be said for precipitation (Figure 27), maximum temperature (Figure 25), and all variables (Figure 28).

The model expresses the impact of minimum temperatures on between-year yield variance in two ways. First, and probably most significantly, minimum temperature can effect the rate of accumulation of growing degree days (GDD). The model predicts duration of phenological stages on the basis of accumulated GDD or thermal units.

TABLE 15

Corn Weather Impact Normalization Schemes

Input Series	Normalized Variables	Unaltered Variables
1	-	TX_{jk}, TN_{jk}, P_{jk}
2	$\hat{TN}_{jk}$, $\hat{P}_{jk}$	TX_{jk}
3	$\hat{TX}_{jk}$, $\hat{P}_{jk}$	TN_{jk}
4	$\hat{TX}_{jk}$, $\hat{TN}_{jk}$	P_{jk}
5	$\hat{TX}_{jk}$, $\hat{TN}_{jk}$, $\hat{P}_{jk}$	-

The normalization process then takes the form:

$\hat{TX}_{jk}$ = normalized maximum temperature on day j, year k

$$= TX_{jk} * TX_{..}/TX_{.k} \quad (7)$$

$\hat{TN}_{jk}$ = normalized minimum temperature on day j, year k

$$= TN_{jk} * TN_{..}/TN_{.k} \quad (8)$$

$\hat{P}_{jk}$ = normalized precipitation on day j, year k

$$= P_{jk} * P_{..}/P_{.k} \quad (9)$$

$P_{..}$ = season precipitation grand mean (10)

$$= 1/36 \sum_{K=1948}^{1983} P_{.k}$$

$TX_{..}$ = seasonal maximum temperature grand mean (11)

$$= 1/36 \sum_{K=1948}^{1983} TX_{.k}$$

$TN_{..}$ = seasonal minimum temperature grand mean (12)

$$= 1/36 \sum_{K=1948}^{1983} TN_{.k}$$

$GDD_{..}$ = seasonal growing degree day grand mean (13)

$$= 1/36 \sum_{K=1948}^{1983} GDD_{.k}$$

Figure 25: Statistical Results for Input Series 2 Generated Yields (see Table 15).

OBS	YEAR	BUSHELS
1	74	56.98
2	55	57.92
3	69	58.29
4	83	64.74
5	82	68.59
6	64	69.03
7	66	69.66
8	62	70.42
9	57	70.83
10	78	72.78
11	80	74.67
12	69	75.19
13	58	76.21
14	56	84.13
15	52	86.48
16	63	88.59
17	48	94.19
18	59	94.78
19	61	95.28
20	65	97.53
21	68	99.05
22	81	99.07
23	50	100.66
24	60	101.58
25	72	101.77
26	79	103.39
27	67	103.45
28	76	103.59
29	54	106.49
30	75	106.98
31	73	109.05
32	70	109.08
33	51	112.05
34	77	113.40
35	53	113.70
36	71	114.50

MEAN	STANDARD DEVIATION
89.684	18.2617
MINIMUM VALUE	**MAXIMUM VALUE**
56.98	114.50
STD ERROR OF MEAN	**SUM**
3.04366	3228.64
VARIANCE	**C.V.**
333.4996	20.362

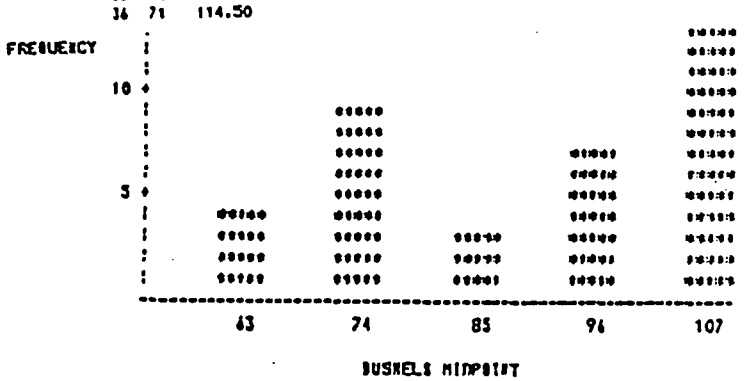


Figure 26: Statistical Results for Input Series 3 Generated Yields (see Table 15).

OBS	YEAR	BUSHELS
1	55	43.71
2	71	51.81
3	80	59.04
4	49	59.29
5	82	61.31
6	57	65.29
7	83	66.62
8	52	70.91
9	78	73.99
10	64	75.65
11	62	76.34
12	56	76.82
13	59	79.74
14	54	88.33
15	69	88.94
16	81	90.70
17	75	92.27
18	65	93.75
19	48	93.96
20	70	94.86
21	50	96.62
22	53	97.20
23	58	97.49
24	60	99.02
25	61	101.16
26	66	104.04
27	77	105.11
28	72	106.44
29	51	107.99
30	68	109.04
31	73	109.17
32	63	114.49
33	76	120.17
34	79	122.43
35	71	131.04
36	67	133.86

MEAN	STANDARD DEVIATION
90.63833333	22.04832984

MINIMUM VALUE	MAXIMUM VALUE
43.71000000	133.86000000

STD ERROR OF MEAN	SUM
3.67472144	3262.98000000

VARIANCE	C.V.
486.12884857	24.326

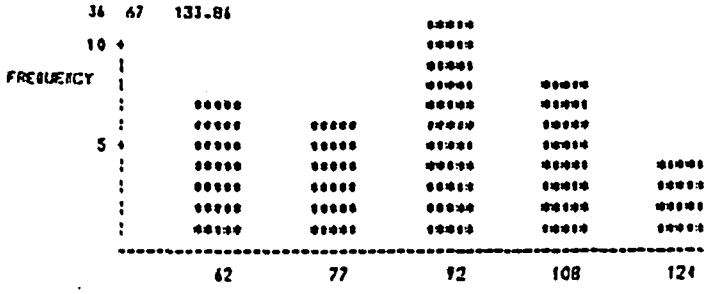


Figure 27: Statistical Results for Input Series 4 Generated Yields (see Table 15).

OBS	YEAR	BUSHELS
1	74	38.54
2	55	57.23
3	58	59.16
4	83	63.18
5	52	64.52
6	82	68.59
7	66	71.08
8	78	71.73
9	57	72.18
10	62	72.43
11	69	73.36
12	61	75.47
13	80	75.78
14	64	76.57
15	56	79.85
16	60	87.81
17	59	88.16
18	68	91.34
19	65	93.56
20	75	94.26
21	48	94.29
22	81	94.58
23	49	96.17
24	72	96.75
25	77	96.97
26	67	97.56
27	73	100.65
28	76	103.23
29	54	104.70
30	50	108.14
31	70	109.50
32	63	110.40
33	51	112.73
34	53	118.93
35	71	122.15
36	79	124.21

MEAN	STANDARD DEVIATION
88.01555556	20.06625190

MINIMUM VALUE	MAXIMUM VALUE
38.54000000	124.21000000

STD ERROR OF MEAN	SUM
3.34437532	3168.5600000

VARIANCE	C.V.
402.65416540	22.719

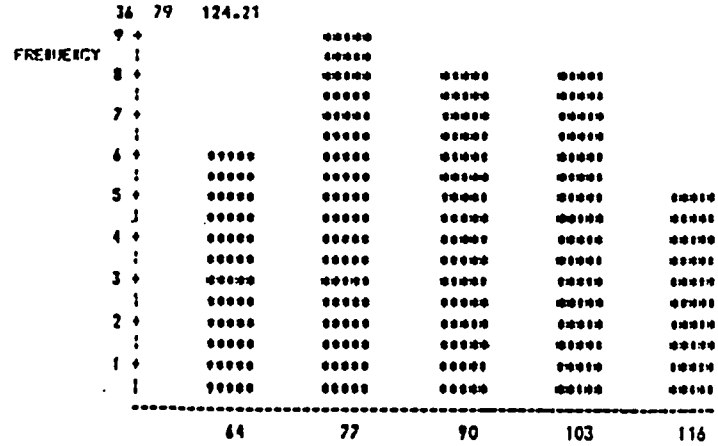
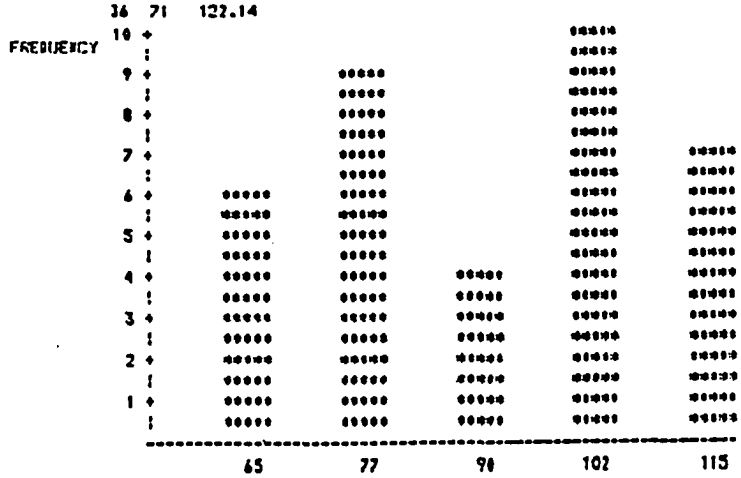


Figure 28: Statistical Results for Input Series 5 Generated Yields (see Table 15).

OBS	YEAR	BUSHELS
1	74	50.27
2	69	58.33
3	55	59.63
4	83	64.38
5	82	68.59
6	66	70.31
7	57	71.05
8	80	71.08
9	78	73.05
10	49	75.18
11	58	76.21
12	62	77.68
13	64	79.62
14	56	80.46
15	52	81.63
16	50	93.83
17	48	94.27
18	65	94.58
19	61	95.12
20	75	96.47
21	60	96.62
22	54	98.84
23	68	99.03
24	81	99.96
25	72	101.79
26	76	105.48
27	67	105.83
28	59	105.90
29	70	107.35
30	73	108.62
31	51	112.76
32	77	113.98
33	79	115.24
34	63	116.33
35	53	120.92
36	71	122.14

MEAN	STANDARD DEVIATION
90.68194444	19.34130086
MINIMUM VALUE	**MAXIMUM VALUE**
50.27000000	122.14000000
STD ERROR OF MEAN	**SUM**
3.22355014	3264.5520040
VARIANCE	**C.V.**
374.0857[illegible]	21.32[illegible]



When the rate of accumulation is slow, certain stages, particularly grain fill, become extended. Protracted early phenological stages can push later stages into periods of traditionally poor weather conditions for corn growth and development, thus lowering yields. Conversely, if grain fill is extended there is no constraint on how great the grain increase can become insofar as this model is concerned. Thus, during cool seasons the model estimated yields can become unrealistically high and, again, variability is increased. An examination of means and variances of model estimated phenological stage dates indicates that maturity dates may vary by more than two weeks about the long-term modeled mean. Single variables, such as minimum temperature can impact model estimated maturity dates by more than a week (see Table 16). This variability is reflected in the modeled yield estimates and their associated variabilities. Although interesting in itself, these results also highlight a problem in the phenological calendar calculation portion of the model. It can be shown from reports of observed phenological stage dates that model date variability should decrease rather than increase with progress through the various stages, i.e., maturity date variability is lower than the dates of earlier phenological stages (Eddy, 1977). Of secondary importance, except at very northerly station sites, low minimum temperatures early in the growing season can result in freeze damage to young plants. The actual importance of this phenomena to between-year variability has not yet been documented.

Maximum temperature is also an important variable to physiological growth and development, but its impact on between-year yield variability

TABLE 16

Means, Julian Dates and Standard Deviations of Phenological Stages of Corn Development as Calculated by the CERES Model at Rochester, MN.

Input Series	Emergence $\bar{E}$	σ_E	Tassel Initiation $\overline{TI}$	σ_{TI}	Begin Ear Growth $\overline{BG}$	σ_{BG}	End Vegetative Growth $\overline{EG}$	σ_{EG}	Begin Grain Fill $\overline{BF}$	σ_{BF}	End Grain Fill $\overline{EF}$	σ_{EF}	Maturity $\bar{M}$	σ_M
1	144	2	166	3	195	4	204	4	215	5	257	14	262	17
2	144	2	166	3	195	3	203	3	215	4	256	5	262	8
3	144	2	166	3	195	3	203	3	215	4	256	8	260	9
4	144	2	166	3	195	4	203	4	214	5	256	10	262	13
5	144	2	166	3	195	3	203	3	215	4	256	5	262	8

where: Input Series 1 = TX, TN, PCP
2 = $\hat{TX}$, $\hat{TN}$, PCP
3 = $\hat{TX}$, TN, $\hat{PCP}$
4 = TX, $\hat{TN}$, $\hat{PCP}$
5 = $\hat{TX}$, $\hat{TN}$, $\hat{PCP}$

See Table 18 and discussion for more detail.

at the seven sensitivity sites appears to be more limited than the impact of minimum temperature. Based on corn physiology, the major impact of high temperatures would take place during flowering which lasts some 2 weeks. During this time impacts such as those which occurred during 1983 can be quite serious. A location that one would expect to suffer chronically from highly variable maximum temperatures and thus, yields, might be Dodge City, Kansas. This location is irrigated and thus any losses due to soil moisture stresses would be mitigated. Although high temperatures and low precipitation often go hand-in-hand, we have been assuming variable independance throughout this analysis. It is most likely that at non-irrigated sites some of the variability attributed only to maximum temperature is actually an artifact of temperature and precipitation interactions. Irrigation

alters the normal inter-relationship between temperature and precipitation and negates the effects of moisture stress. Under these conditions, the maximum temperature effects on yield variability which remain would be limited to those caused by extremely high temperatures, and would exclude those temperature events which create stressful growth conditions only when combined with certain precipitation regimes. In an area such as Springfield, MO, where natural precipitation patterns are allowed to be a more significant contributor to yield variability, the variability in yield attributed to maximum temperatures also increases.

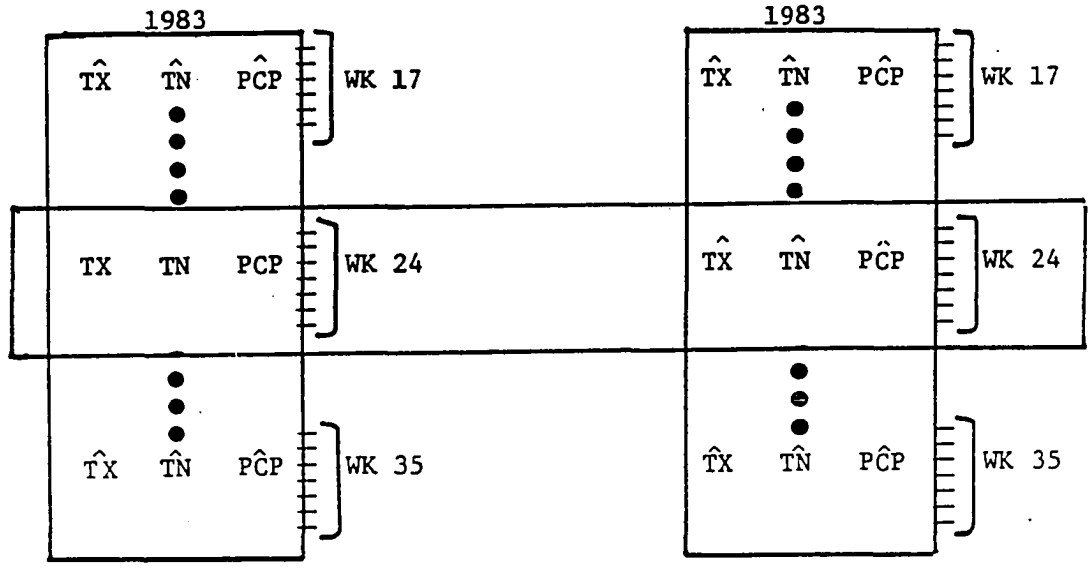
3.3.2 Within-Season Variability

To this point the majority of this analysis has focused on general comparisons of between-season and within-season yield variance. If it is assumed that input series 1 (Figure 18) contains both within-season and between-season variability and that input series 5 (Figure 28) contains only within-season variability, an overall contribution of between-season weather variability (σ_b^2) is 142 $(bu/ac)^2$. This is less than one-half the variability attributed to within-season effects (σ_w^2), 374 $(bu/ac)^2$. A variety of arguments could be suggested to explain this result, including that an incorrect population mean has been removed from our yield sample. A more thorough treatment of this statistical observation will be reserved for later consideration, but given the calculations above, it is concluded that within-season impacts upon yield variance are the more significant of the two effects. In response to this conclusion the nature of the within season impacts implied by Figures 11 - 13 will now be examined.

To obtain the basic weekly yield information for such an analysis, a week-by-week method of data substitution, model computation, and data replacement similar to the first sensitivity analysis described earlier in this chapter (Figures 9 and 10) is required. This time interest focuses on testing estimated yield differences to assess the contribution of individual weeks and variables to overall within-season modeled yield variability. Figure 29 illustrates the input weather time series construction and weekly yield impact computation for Week 24, 1983. The two time series in Figure 29 are identical except during Week 24, when all observed weather variables (input series 1 hereafter referred to as 5.1), are inserted. Each constructed time series is input to the CERES model and two different yields are generated. The output yield difference resulting from the two input weather series is then computed (see Figure 29). This computed difference represents the impact during year YR of observed weather conditions in week WK on modeled yield. The set of these differences over all years for week WK would represent the within-season variance contributed to model yield by week WK weather variability. This set of weekly yield differences between time series 5 (all normalized weather) and the other input time series (1 through 4) at Peoria, Illinois are presented in Tables 18 - 21.

Next consider these tables in closer detail beginning with Table 18. Each entry in the table represents the difference between modeled yield produced by a weather time-series in which all variables for each week have been normalized (input series 5, Table 15), and modeled yield estimated from a time series in which one week of normalized weather has been replaced with observed conditions (see Figure 29). A column in

Figure 29: Time-Series Construction and Series 1-4 Description for Weekly Partitioning of Within Season Yield Variance.



$$*Y^{5.n}_{WK,YR} - Y^{5}_{YR} = \text{Yield impact for week WK}$$

$$*Y^{1}_{24,1983} - Y^{5}_{1983} = 4.8 \text{ bu/ac (Table 18)}$$

where: n= input time series 1-4 (see Table 15 for description),

Y^{5}_{YR}= yield generated by input time series 5, Table 15 for year YR.

Table 18: Weekly Impact of All Observed Weather Variables on Modeled Corn Yield at Peoria, IL. (Case 1 - Case 5, Table 15).

1948	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	-4.6	-4.4	-3.8	-4.1	0.3	0.0	0.0	0.0	0.0	0.0
1949	0.0	2.8	7.7	7.9	7.8	8.0	7.7	7.7	7.0	7.6	-0.3	0.5	-2.2	0.5	-2.1	-4.2	-2.1	-2.1	-2.1
1950	0.0	0.0	2.1	2.6	2.6	2.7	2.9	1.5	1.5	2.1	3.7	1.3	4.9	0.1	-0.5	3.0	0.2	0.0	0.0
1951	0.0	0.0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.3	-0.4	-0.3	-1.0	-1.5	-1.4	-0.1	0.0	0.0	0.0	0.0	0.0
1952	0.0	-0.8	-0.6	-0.7	-0.6	-0.6	-0.5	-0.4	-0.1	-1.2	-1.8	-2.5	-2.2	-3.9	-2.4	-3.6	-1.7	-0.9	-0.1
1953	0.0	0.0	-3.2	-3.2	-0.1	-4.2	-2.3	-4.3	-3.3	-0.4	-5.7	-0.5	-1.1	-3.0	-3.0	-3.3	-3.0	-3.3	-3.4
1954	-0.2	0.0	0.1	6.7	5.7	5.3	5.7	6.0	-0.6	0.8	-0.8	-1.3	7.1	-1.9	-1.8	-1.3	-1.1	-0.4	0.0
1955	0.0	1.0	-0.6	-1.0	-0.3	-1.2	-1.3	-1.6	-2.3	-3.6	-6.3	-3.5	-2.8	-1.5	-1.1	-1.2	-1.2	0.0	0.0
1956	0.0	0.0	-0.3	-0.3	0.0	-0.2	-1.3	0.0	0.4	-0.3	1.8	1.3	0.0	-0.2	-0.6	-0.5	-0.1	0.0	0.0
1957	0.0	0.0	2.1	0.1	0.4	-0.9	0.9	0.7	1.1	-2.9	-1.5	-2.5	-0.5	-1.0	-0.5	-0.4	-0.3	0.0	0.0
1958	0.0	0.0	-6.2	-0.6	-0.6	-6.3	-0.1	0.2	0.1	0.7	1.4	1.5	0.8	1.0	1.1	0.9	0.5	0.2	0.0
1959	0.0	0.0	0.9	-0.2	1.0	0.6	-4.1	1.0	1.2	-4.9	-1.0	-2.3	-7.4	-4.4	-3.0	-0.3	-3.4	-3.3	0.0
1960	0.0	0.0	0.0	2.5	2.4	2.5	2.2	1.9	1.9	1.9	2.1	2.1	2.8	4.1	1.7	1.2	1.1	0.0	0.0
1961	0.0	-0.3	-2.3	-2.3	-2.2	-2.3	-2.3	-2.4	-2.4	-2.5	-2.4	2.9	2.5	0.1	4.5	3.7	3.0	1.4	0.1
1962	0.0	0.0	-3.3	-3.4	-3.3	-3.3	-3.5	-3.8	-4.1	-4.3	-8.0	-5.8	-4.7	-3.2	-2.0	-2.2	-3.0	-3.2	-3.0
1963	0.0	0.0	-9.8	-9.7	-10.0	-9.7	-8.4	-6.6	-6.9	-8.1	-9.6	-11.6	-8.1	-7.6	-4.2	-7.8	-5.9	-1.2	0.0
1964	0.0	0.0	-2.2	-0.2	-0.1	-0.2	-0.1	0.0	2.1	-0.8	-1.1	-6.4	-1.9	-5.2	-0.6	-0.5	0.0	0.0	0.0
1965	0.0	0.0	-2.2	-2.1	-2.1	0.0	0.0	-0.1	0.0	0.3	1.3	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0
1966	0.0	0.3	0.3	0.0	1.5	0.1	1.6	1.2	1.2	3.5	3.3	0.6	0.6	4.5	2.2	1.5	1.1	0.0	0.0
1967	0.0	0.0	-0.3	0.8	1.3	2.1	-2.8	3.2	1.7	4.2	5.2	4.4	4.1	5.0	5.0	3.7	2.7	1.2	0.0
1968	0.0	0.0	-1.6	0.4	0.4	-1.6	-1.6	-1.6	-1.5	-1.5	-1.6	0.2	-0.4	-0.3	0.0	0.0	0.0	0.0	0.0
1969	0.0	-0.1	-0.1	11.3	11.4	11.2	11.4	1.3	1.7	4.0	2.0	4.6	2.6	1.7	1.8	1.8	1.7	1.7	0.0
1970	0.0	0.0	0.2	0.3	0.4	1.1	1.1	-0.3	1.3	1.4	-0.6	0.5	0.7	0.3	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.9	3.0	4.0	4.0	1.6	2.0	-0.6	-1.6	3.5	3.0	4.7	3.1	3.1	3.1	3.1	3.1	0.0
1972	0.0	0.0	-7.2	-6.4	-6.6	0.3	-6.7	-7.0	-6.8	-6.7	-5.9	-6.1	-6.5	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	-6.8	-6.8	-6.8	3.2	-0.1	3.1	0.2	2.6	2.7	3.6	3.1	3.2	3.2	3.2	3.2	0.0
1974	0.0	0.0	-0.2	-0.6	-0.6	-0.7	-0.5	-0.6	-0.1	0.8	1.8	6.4	2.0	0.9	0.2	0.3	0.1	0.0	0.0
1975	0.0	4.2	3.6	2.9	3.6	3.1	-1.0	-1.0	-1.4	0.0	-0.8	-1.0	-0.4	6.3	1.4	0.2	0.0	0.0	0.0
1976	0.0	1.2	1.7	1.1	1.0	1.5	1.0	2.2	1.6	3.5	4.2	4.3	2.1	5.1	4.3	3.0	3.0	1.7	0.0
1977	0.0	0.2	-0.1	-1.2	-1.3	-0.4	-0.7	-1.8	-1.5	-2.1	-1.5	-1.1	-1.9	-1.8	-1.5	-0.8	-0.3	0.0	0.0
1978	0.0	0.0	0.4	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.1	0.0	0.1	0.6	0.3	0.2	0.2	0.2	0.0	0.0
1979	0.0	0.3	3.8	3.8	3.7	3.9	4.9	3.9	3.4	2.8	2.8	-2.2	3.7	2.3	3.5	3.5	3.5	3.5	0.0
1980	0.0	0.0	-0.3	0.6	0.6	-0.4	0.8	0.6	-0.9	-0.1	-0.9	-1.9	3.9	-1.8	-1.1	-1.0	-0.6	-0.1	0.0
1981	0.0	0.0	0.0	4.9	4.6	4.7	0.1	0.1	-0.2	-3.2	-5.0	-2.9	-0.8	-1.4	-1.9	-1.7	-1.3	-0.6	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	-5.3	-5.8	-1.7	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	4.6	4.0	4.3	4.3	4.3	4.8	4.4	-2.1	3.5	0.2	3.0	3.0	-3.0	0.8	0.0	0.0	0.0
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

WEEK

Table 19: Weekly Impact of Observed Maximum Temperature on Modeled Corn Yield at Peoria, IL. (Case 2 - Case 5, Table 15).

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1948	0.0	0.0	0.0	0.0	0.0	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	-4.8	0.2	0.0	0.0	0.0	0.0	0.0
1949	0.0	4.9	3.8	3.0	2.8	2.1	2.5	2.2	5.9	4.3	-3.0	-4.3	-9.9	2.6	-2.1	-2.1	-2.1	-2.1	-2.1
1950	0.0	0.0	0.1	0.2	0.1	0.1	0.3	0.5	-1.2	-3.2	0.6	0.2	0.5	-2.0	-1.3	0.6	-0.8	0.0	0.0
1951	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	-0.1	0.0	-0.1	-0.3	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
1952	0.0	-0.9	-0.9	0.4	-1.0	-1.0	-1.0	-0.9	-3.3	0.6	-2.6	-3.5	-1.5	0.5	-0.5	-2.0	-1.8	-0.9	-0.1
1953	0.0	0.0	0.1	-3.2	-3.2	-3.2	-3.2	-3.3	-3.4	-3.8	-4.7	-4.6	-5.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.4
1954	-0.1	0.0	0.0	5.2	5.3	4.9	5.0	5.2	-1.5	-1.0	-2.0	-1.0	-0.3	-1.6	-2.3	-1.6	-1.4	-0.6	0.0
1955	0.0	0.2	1.2	-0.8	-4.3	-1.7	-4.7	-0.3	-1.6	-1.7	-5.5	-3.7	-1.4	0.0	0.1	-0.3	-0.1	0.0	0.0
1956	0.0	0.0	-0.2	-0.3	-0.3	-0.3	-1.3	0.0	0.4	-0.3	-0.3	-0.2	-0.1	-0.1	-0.6	-0.5	-0.1	0.0	0.0
1957	0.0	0.0	0.8	1.4	0.2	-1.0	0.5	0.5	-2.8	-3.5	-4.0	-2.6	-1.0	-0.5	-0.2	-0.1	-0.3	0.0	0.0
1958	0.0	0.0	-7.4	-7.5	-7.4	-7.6	1.3	1.3	1.5	2.0	3.3	2.5	2.4	2.5	1.9	1.7	1.2	0.4	0.0
1959	0.0	0.0	-0.1	0.1	-0.1	-0.5	-0.6	0.0	0.0	-0.3	-0.6	-3.5	-1.7	-0.4	1.7	1.7	0.2	0.0	0.0
1960	0.0	0.0	0.0	2.0	2.0	1.6	1.8	2.6	1.9	0.7	1.5	2.4	-0.1	-0.4	-1.0	-0.7	-0.3	0.0	0.0
1961	0.0	-0.3	-2.2	-2.2	-0.3	-2.2	-2.2	-2.2	-2.2	-2.3	-2.2	4.9	4.8	1.2	5.4	4.3	3.4	1.6	0.2
1962	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.4	-0.1	0.1	0.2	-1.1	-0.8	0.3	0.5	0.4	0.5	0.3	0.0	0.0
1963	0.0	0.0	-9.9	-9.8	-10.1	-9.8	-9.8	-6.7	-6.9	-8.8	-8.7	-4.8	-5.0	-7.5	-3.7	-1.8	-1.9	-1.4	0.0
1964	0.0	0.0	0.2	0.1	0.1	0.1	0.1	0.1	0.2	-0.6	-0.7	-0.3	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
1965	0.0	0.0	0.0	-2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1966	0.0	0.3	0.3	0.0	-0.4	0.1	-0.4	-0.7	1.2	2.9	3.3	0.5	0.5	4.3	2.3	1.5	1.1	0.0	0.0
1967	0.0	0.0	-0.1	-0.6	-0.4	-0.7	1.7	-1.6	0.0	1.4	3.1	-1.2	2.7	1.8	1.8	1.8	1.8	0.9	0.0
1968	0.0	0.0	-0.2	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	1.5	1.9	1.1	0.0	0.0	0.0	0.0	0.0
1969	0.0	0.0	0.0	1.4	1.4	1.4	1.4	1.6	2.4	2.5	5.2	6.0	5.7	1.5	1.6	1.7	1.7	1.7	0.0
1970	0.0	0.0	0.2	0.3	0.3	-0.7	0.2	-0.3	0.6	0.8	-0.1	-0.3	-0.3	0.4	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.8	3.0	3.1	4.1	1.6	2.0	0.3	-0.6	3.6	4.5	4.8	3.1	3.1	3.1	3.1	3.1	0.0
1972	0.0	0.0	0.0	0.6	0.4	-7.2	0.3	-2.6	0.4	0.6	2.4	-4.7	-5.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	-0.1	-0.1	0.4	0.1	0.6	0.7	0.9	1.0	0.0	-0.1	0.3	0.0	0.0	0.0	0.0
1975	0.0	4.2	4.1	4.2	4.2	4.1	-1.1	-1.1	-1.4	-1.3	-1.0	-1.2	0.0	1.1	1.3	0.6	0.0	0.0	0.0
1976	0.0	1.2	1.2	1.8	1.7	1.8	-0.4	2.7	1.2	3.1	4.4	4.6	2.0	5.5	4.6	3.1	3.2	1.9	0.0
1977	0.0	0.0	0.0	0.2	0.2	-0.4	-0.4	-0.5	-0.8	-0.4	-1.3	-1.3	-0.9	-0.5	-0.8	-0.4	-0.7	-0.4	0.0
1978	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	0.2	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	3.8	3.8	3.8	3.9	4.7	3.7	3.0	2.9	4.2	3.7	3.2	3.5	3.5	3.5	3.5	3.5	0.0
1980	0.0	0.0	-0.7	-0.4	-0.3	-1.2	0.2	-0.4	-1.5	-1.2	-2.3	-2.7	0.9	-1.0	-1.1	-1.3	-0.7	-0.1	0.0
1981	0.0	0.0	0.0	0.7	-1.0	-1.0	-0.9	-1.0	-1.3	-2.7	-4.4	-3.5	-3.9	-1.4	-1.4	-1.3	-1.0	-0.4	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	-5.3	-5.8	-1.7	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	-0.6	0.0	-0.1	0.0	2.4	4.3	-0.9	4.5	2.2	5.1	3.4	4.8	5.1	2.3	-0.5	1.0	0.0	0.0

WEEK

Table 20: Weekly Impact of Observed Minimum Temperature on Modeled Corn Yield at Peoria, IL. (Case 3 - Case 5, Table 15).

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1948	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1949	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1950	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.0	4.5	0.1	0.0	1.8	0.0	0.0	0.0
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1952	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.3	0.0	1.4	1.3	0.5	0.3	0.3	0.0	0.0	0.0	0.0
1953	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.3	0.0	-0.1	-1.2	0.0	0.0	0.0
1954	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.1	1.1	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0
1955	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	-0.7	-0.2	0.0	0.0	0.0	0.0	0.0
1956	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	2.1	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-3.2	-0.4	-0.5	-2.8	-0.6	-0.1	-0.7	0.0	0.0	0.0
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.3	0.6	0.0	3.7	1.2	0.4	0.3	0.0	0.0
1961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.0	-2.3	-0.9	0.0	0.0	0.0	0.0	0.0	0.0
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.7	-12.1	-3.8	-0.2	-0.9	-6.8	-4.8	0.0	0.0
1964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.5	-5.8	0.0	-3.9	0.0	0.0	0.0	0.0	0.0
1965	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.4	1.4	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.3	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1967	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1970	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.2	0.1	0.6	0.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.9	-1.1	0.0	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.1	0.0	0.0	0.0	-0.1	-0.3	0.0	0.1	5.1	1.6	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.9	0.5	0.3	0.1	6.4	1.2	0.3	0.0	0.0	0.0
1977	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	-0.1	0.0	-0.1	-0.1	0.0	0.0	-0.1	-0.4	-1.7	-4.0	0.0	-0.8	0.0	0.0	-0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	-0.1	2.8	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	-1.0	-0.2	0.0	0.0	0.0	0.0

WEEK

Table 21: Weekly Impact of Observed Precipitation on Modeled Corn Yield at Peoria, IL. (Case 4 - Case 5, Table 15).

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1948	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1949	0.0	4.9	7.0	7.5	7.4	7.6	7.4	7.6	7.8	3.4	15.0	8.3	12.4	2.6	-2.1	-2.1	-2.1	-2.1	-2.1
1950	0.0	0.0	0.3	0.1	0.0	0.0	0.1	-3.9	-0.4	1.3	-1.5	1.1	0.1	1.9	1.0	0.4	1.0	0.0	0.0
1951	0.0	0.0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.8	-1.2	-1.1	-0.1	0.0	0.0	0.0	0.0	0.0
1952	0.0	-0.9	-0.8	-1.0	-0.9	-0.9	-0.8	-0.8	-1.5	-2.3	-1.5	-1.9	-3.0	-3.1	-2.1	-1.5	0.2	0.0	0.0
1953	0.0	0.0	-3.3	-3.2	-3.2	-3.2	-3.2	-3.2	-3.1	-3.0	-2.2	-5.6	-4.7	-5.9	-4.7	-4.0	-3.9	-4.3	-3.4
1954	0.0	0.0	0.0	4.8	5.2	5.2	5.0	5.3	0.6	0.2	0.0	-0.5	-0.4	-1.1	-0.8	0.3	0.2	0.2	0.0
1955	0.0	0.9	1.2	-1.0	-1.1	-1.1	0.7	-0.1	-0.7	-1.3	-1.6	-2.5	-1.3	-0.3	-1.0	-0.9	0.0	0.0	0.0
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
1957	0.0	0.0	2.0	0.2	0.3	0.3	0.4	0.3	0.2	0.0	-0.2	-0.4	-0.6	-0.5	-0.2	-0.3	-0.1	0.0	0.0
1958	0.0	0.0	-6.2	-6.9	-6.9	-6.7	0.1	-0.8	-0.8	-0.7	-0.7	-0.9	-1.5	-1.4	-0.3	-0.7	-0.6	-0.1	0.0
1959	0.0	0.0	-0.1	0.0	0.0	-0.1	-0.1	-0.2	-0.3	-0.7	-1.2	-0.3	-0.4	-1.1	-1.8	-1.3	-0.2	0.0	0.0
1960	0.0	0.0	0.0	1.5	2.0	1.6	2.1	1.9	2.0	1.9	2.4	-0.8	1.3	1.1	1.5	1.1	1.2	0.0	0.0
1961	0.0	-0.3	-2.2	-2.1	-2.1	-2.2	-2.2	-2.2	-2.2	0.1	-2.3	-1.9	-1.7	-1.5	-0.4	-0.4	-0.7	-0.3	-0.1
1962	0.0	0.0	-3.2	-3.4	-3.1	-3.2	-3.3	-3.7	-4.2	-4.7	-2.4	-2.9	-4.2	-3.7	-2.3	-2.7	-3.2	-3.2	-3.6
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.2	0.1	0.1	-0.4	0.4	0.0
1964	0.0	0.0	0.2	-0.3	-0.2	-0.3	-0.2	-0.1	1.8	-0.3	-0.2	-0.4	-1.9	-0.5	-0.6	-0.4	0.0	0.0	0.0
1965	0.0	0.0	-2.2	-2.2	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
1966	0.0	0.0	0.0	0.3	0.2	0.3	-0.1	-0.1	-0.1	-1.2	-0.1	0.1	0.1	0.3	-0.1	0.0	0.0	0.0	0.0
1967	0.0	0.0	-0.2	-0.3	1.0	1.3	0.5	-3.9	-1.0	0.1	0.6	1.3	0.9	-1.7	-0.9	-0.5	-0.5	-0.4	0.0
1968	0.0	0.0	0.4	-0.2	-0.2	0.5	0.2	-0.2	-1.6	-1.7	-1.6	-1.4	-0.2	-1.4	0.0	0.0	0.0	0.0	0.0
1969	0.0	0.0	0.0	1.4	1.4	1.2	1.4	1.5	1.5	1.3	1.4	-1.8	15.8	1.9	1.9	1.8	1.7	1.7	0.0
1970	0.0	0.0	2.2	0.3	0.3	0.3	0.3	0.2	0.1	0.0	-0.1	-0.1	-0.1	-0.2	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.6	0.4	0.5	0.3	0.4	0.4	0.2	-0.7	-8.7	-7.7	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	-6.8	-6.8	-9.1	-9.1	3.2	3.1	3.1	3.2	3.1	2.9	3.8	3.1	3.2	3.2	3.2	3.2	0.0
1974	0.0	0.0	-0.1	-0.5	-0.5	-0.5	-0.6	-0.6	-0.6	0.2	0.5	0.6	1.2	0.9	0.0	0.3	0.0	0.0	0.0
1975	0.0	4.2	2.7	4.2	4.1	4.2	-1.0	-0.9	-1.3	-1.9	-1.4	-1.0	-0.5	-1.2	-1.2	-0.7	0.0	0.0	0.0
1976	0.0	0.0	1.2	0.8	0.8	0.8	-0.3	-0.6	-0.3	-0.8	-0.9	-0.6	0.2	-0.3	-0.4	-0.2	-0.2	-0.2	0.0
1977	0.1	0.1	-0.4	0.3	-0.6	0.4	0.0	-0.7	-0.2	-0.7	-2.2	-1.7	-1.7	-1.2	-1.3	-0.3	0.4	0.4	0.1
1978	0.0	0.0	0.4	-0.1	-0.2	-0.2	-0.2	-0.3	-0.6	-0.8	-0.7	0.0	0.6	0.4	0.2	0.2	0.2	0.0	0.0
1979	0.0	0.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.9	3.7	3.7	3.9	3.5	3.5	3.5	3.5	3.5	0.0
1980	0.0	0.0	-0.7	-0.4	-0.3	-0.2	0.9	0.2	0.4	0.7	1.0	0.2	-0.2	-0.7	-0.4	0.4	0.2	0.0	0.0
1981	0.0	0.0	4.8	4.5	4.5	4.3	4.8	-0.1	-0.5	-1.4	-1.8	-0.8	-0.9	-0.3	-0.4	-0.4	-0.3	-0.2	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	-0.6	4.4	5.2	4.2	4.2	4.3	-0.8	4.3	5.7	2.8	3.7	-1.8	-1.4	-1.9	-0.4	-0.7	0.0	0.0

WEEK

Table 18 represents the impact on modeled yield of observed weather versus normalized conditions during one week across all years where the input weather variables for each year, k, are defined by Eqs. 7 through 9. Each row represents the week-by-week impact of observed weather conditions on modeled yield for a particular year. Tables 19 - 21 contain similar information on an individual variable basis. Consider the yield differences for 1983 contained in Table 18. The largest positive difference at Peoria during 1983, 4.8 bu/ac, occurs at Week 24. One interpretation is that during this week the observed values of maximum temperature, minimum temperature and precipitation were worth 4.8 bu/ac over normalized weather conditions. The most negative 1983 impact at Peoria occurred during Week 31, when observed weather conditions would have generated a loss of 3.0 bu/ac over that produced under normalized seasonal weather.

The sum of the estimated model differences between observed and normalized weather across the 1983 growing season in Table 21 is 31.8 bu/ac. This is far from the -.15 bu/ac yield difference found for 1983 from Figure 18 (yield under observed weather) and Figure 28 (yield under normalized weather). This discrepancy between analyses provides some important information concerning weather variable relationships and their transformation into plant growth and development.

Each weather time series possesses a unique degree of autocorreltaion which we have translated into a single yield forecast. When we alter the weather autocorrelation, it is reflected in our yield forecasts. Figures 18 and 28 were constructed by altering every daily weather value in the seasonal time series, thus preserving any existing

autocorrelation. Tables 18 - 21 were constructed by altering one week of weather at a time and, thereby, altering the variable relationships. When we try to compare forecasts from the time series given in Figures 18 and 28 to, for instance, those in Table 18, 1983, we are actually comparing yield estimates resulting from 21 uniquely correlated weather time series (all normalized, all observed, and 19 time series of normalized weather altered one week at a time). The results given above suggest the large degree to which a one week weather impact as reflected in a yield forecast, can depend on preceding and following weather events (the time series autocorrelation). This aspect of the present analysis will be discussed in greater detail in later portions of this Chapter.

If one sums the yield deviations in Tables 18 - 21 across time and plots them, a synopsis of 36 possible weather scenarios (growing seasons) and their associated yield responses can be postulated (see Figures 30 - 33). Figures 30 - 33 were constructed by finding the mean deviation from normal for each week in Tables 18 - 21. The standard deviation for each column about this mean is calculated. Values that lie beyond 3 standard deviations are flagged, eliminated and the mean and standard deviation recalculated.

Consider Figure 30 and note that the mean line, labeled M, is not constant from one week to the next. It should not necessarily be expected that the distribution of differences in output from a non-linear model to possess a constant mean of zero. The deviations plotted in Figures 30 - 33 are not deviations about normal yields but, rather, deviations produced using normalized-weather generated yields. As

Figure 30: Weekly Yield Difference Means, Standard Deviations and Ranges at Peoria, IL (Case 1 - Case 5, Table 15, all variables normalized).

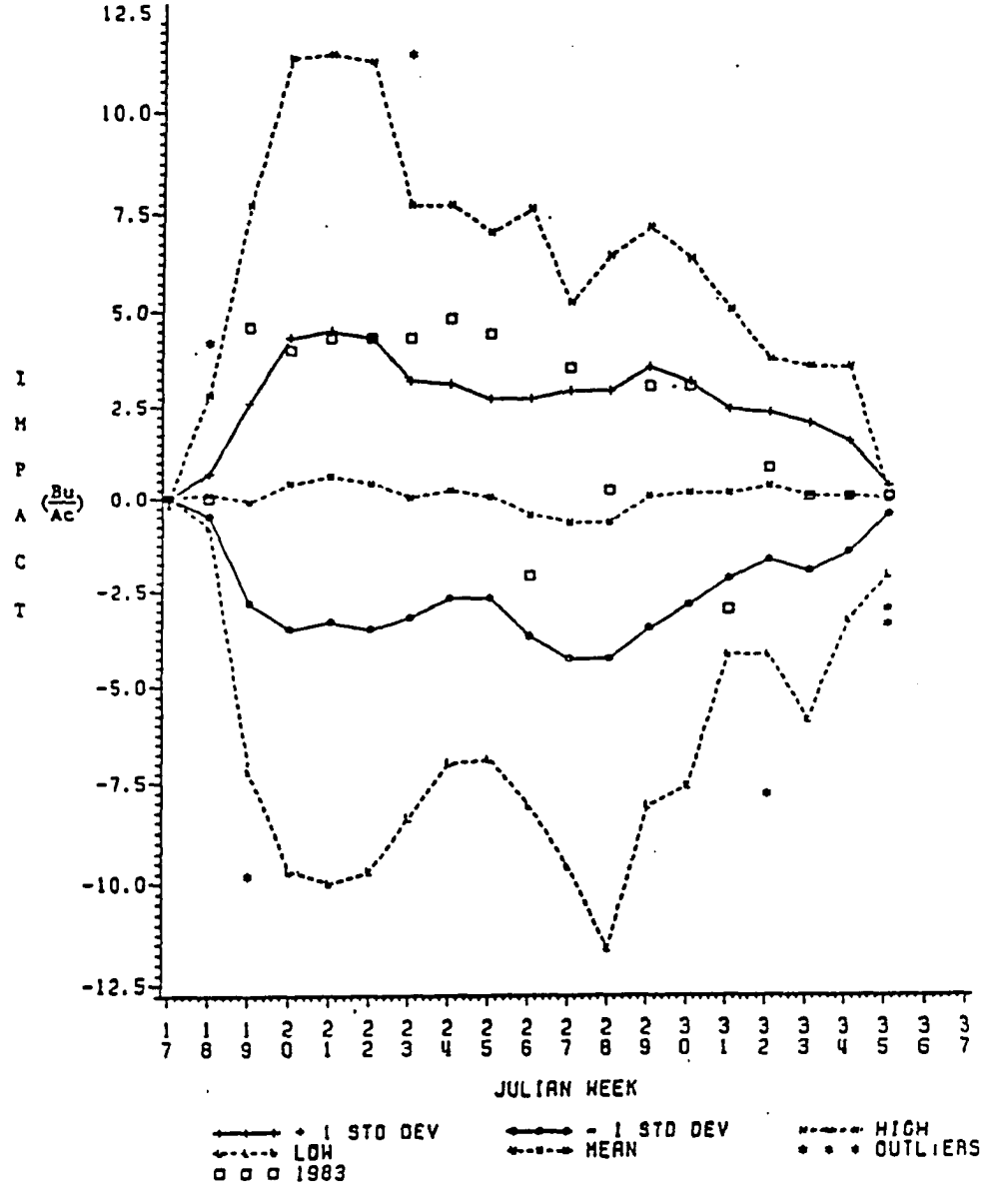


Figure 31: Weekly Yield Difference Means, Standard Deviation and Ranges for Maximum Temperature at Peoria, IL (Case 2 - Case 5, Table 15).

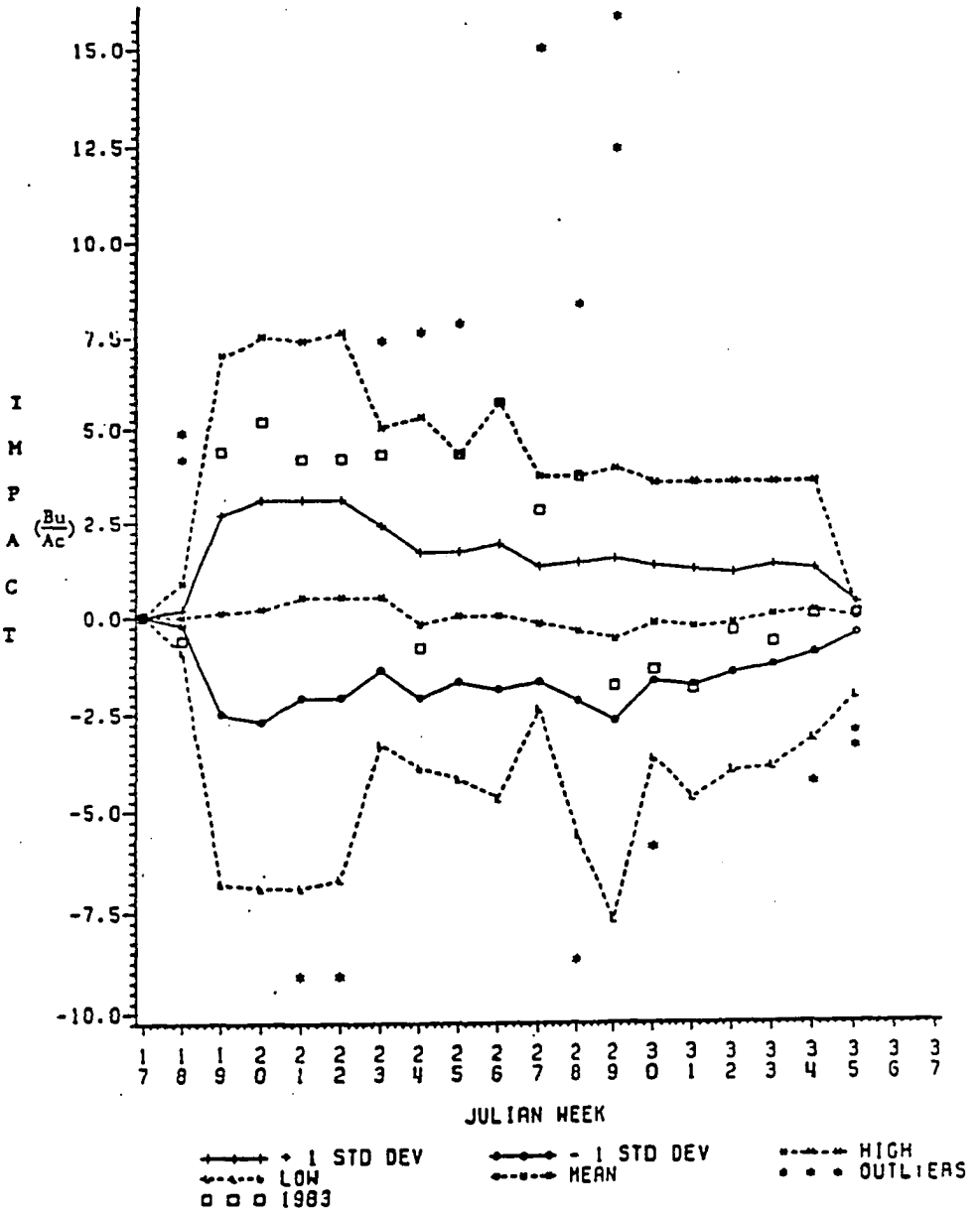


Figure 32: Weekly Yield Difference Means, Standard Deviation and Ranges for Minimum Temperature at Peoria, IL (Case 3 - Case 5, Table 15).

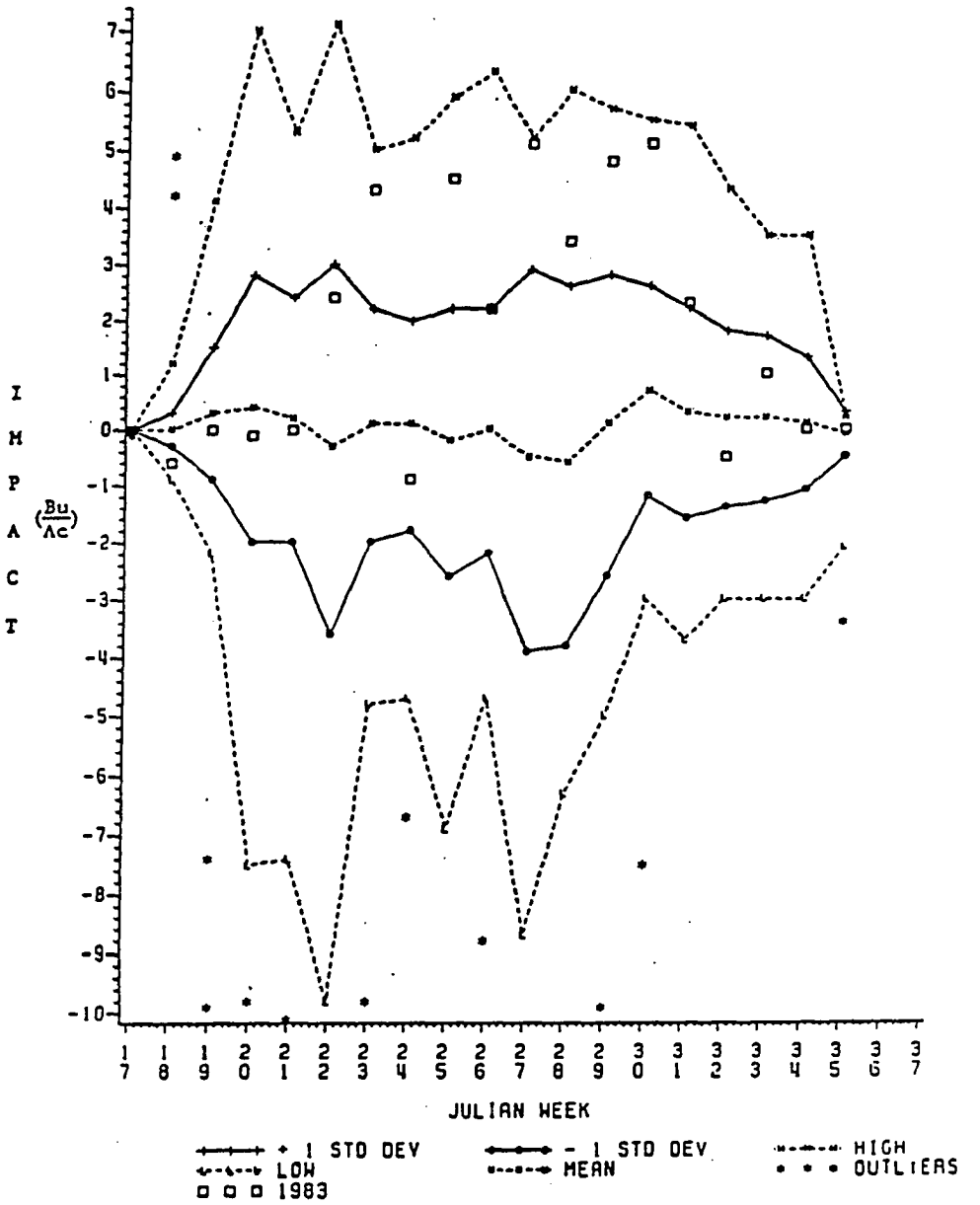
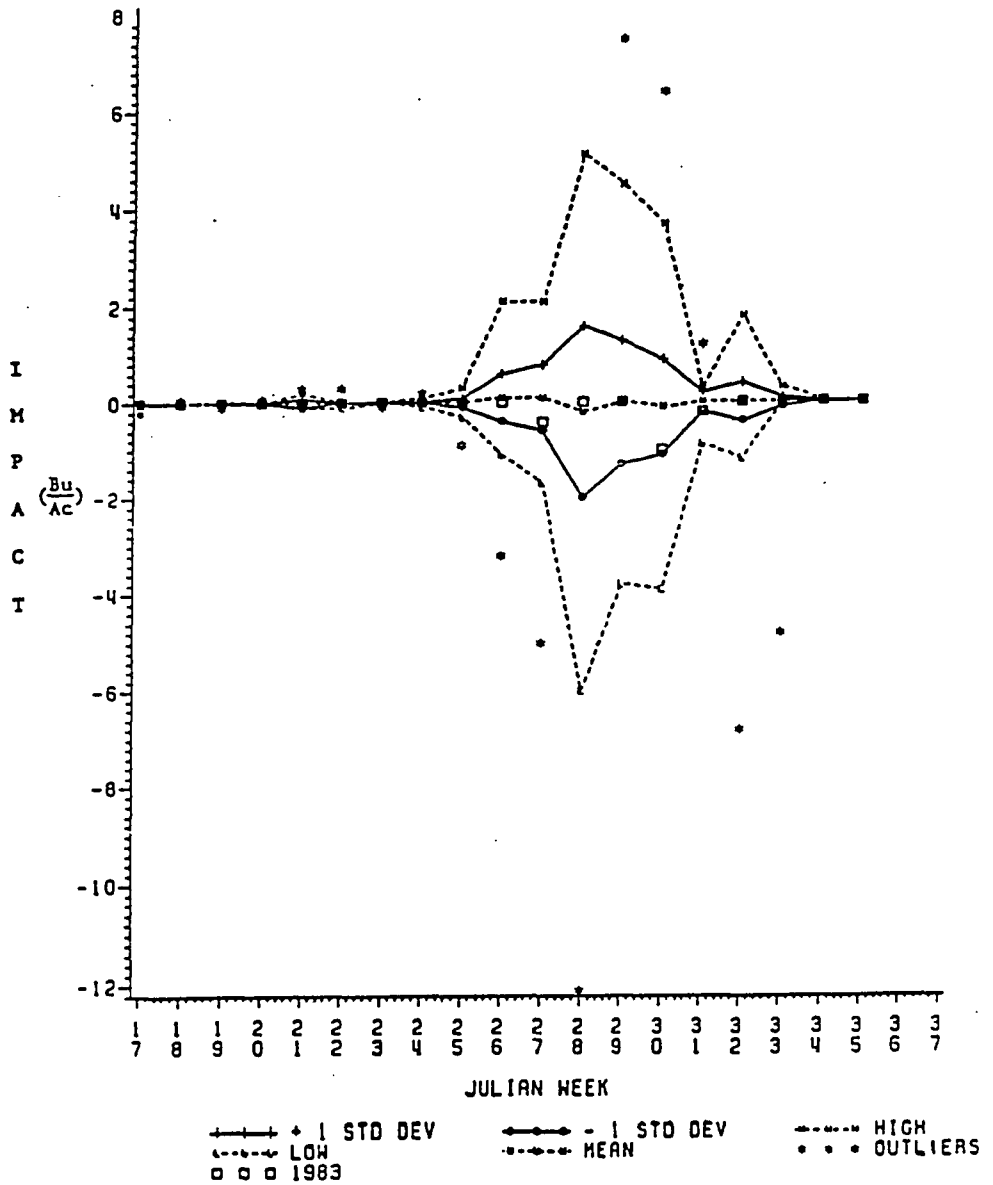


Figure 33: Weekly Yield Difference Means, Standard Deviation and Ranges for Precipitation at Peoria, IL (Case 4 - Case 5, Table 15).



discussed earlier, this means that the seasonal average weather is "normal" but the within-season patterns from year-to-year will produce yields from some unknown parent population. Also, as discussed previously, the open boxes which represent the 1983 row from Table 18, are not distributed about the seasonal weather produced yield difference of -.15 bu/ac (see Figures 18 and 28) because each yield difference is generated by a slightly different weather time series. If the model were not non-linear and if its calculations were independent of preceding and following weather conditions, we would expect the distribution of boxes to be centered on the -.15 bu/ac mean.

It is important to note that the absolute magnitude of yield difference is not nearly as informative as its relative importance to other weekly impacts and other variables. The interpretation of the numeric values is difficult to make because of complicating issues such as model non-linearity and variable correlation. What can be inferred are the weather-sensitive model weeks and the relative impacts of individual variables on yield. Tables 18 - 21 and Figures 30 - 33 for the other given sensitivity test sites are contained in Appendix E. The weekly results for Peoria are provided in Table 22 .

An initial analysis of corn model response to within-season weather variability has now been completed. In addition to those findings in sections 3.2.1 and 3.2.2, the graphs and tables in sections 3.3.1 and 3.3.2 have served to illustrate the impact of model non-linearities, inter-variable correlation and the selection of a normalization scheme for weather variability simulation. Our results have suggested that the model responds differently to weather at different geographic locations,

TABLE 22

Summary of Weekly Modeled Yield Sensitivity Analysis for Peoria, IL.

Sensitive Week(s)	Observed Variable Substituted	Standard Deviation Range During Sensitive Week(s)	Average Weekly Standard Deviation Across Sensitive Weeks
		Bu/Ac	Bu/Ac
20-22	All	+4.0 to -3.25	2.0
27-29	All	+4.0 to -3.25	
28	PCP	± 2.0	.5
22	TN	+3.0 to -3.5	1.5
27-28	TN	+2.8 to -3.8	
19-22	TX	+2.75 to -2.5	1.75
29	TX	+1.5 to -2.5	

e.g., preciptiation is a larger contributor to within-season variance at a non-irrigated site in Missouri than at an irrigated site in Kansas. The impact of weather variability on the timing of phenological stages was considered. Week-by-week yield difference graphs have facilited the quantification of independant (assumed) impacts of weather variables given actual weather observations rather than the less realistic results generated by the mechanical perturbations in Figures 11-13. Table 22 summarizes the results and refines the initial impressions of corn model sensitivity to weekly weather variability at Peoria, IL. Those sensitive Julian Weeks are 19-22 and 27-29. The methods developed in this section resulted in yield variability estimates during these weeks of one standard deviation equal to 2.0 bu/ac.

3.3.3 A Two-Way ANOVA Approach to Within-Season Impact Analysis.

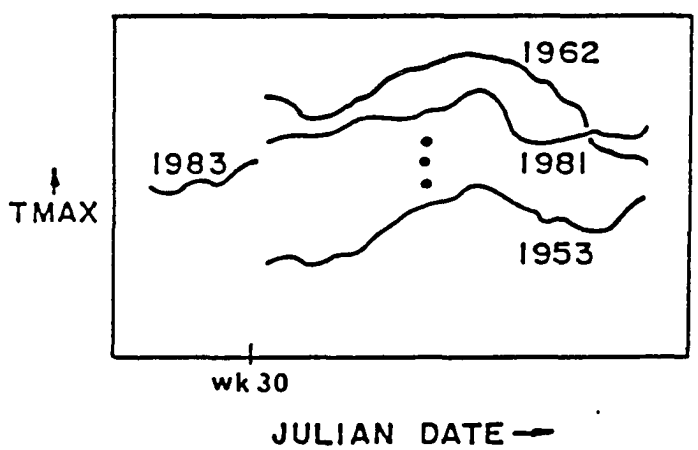
Although these latter graphs and tables illustrate several interesting points, notice the magnitude of yield impacts that are presented. They appear to represent modeled yield differences between corn growth under independent weekly observed and normalized weather, but do not address more sizable differences in corn yield from year-to-year. At Peoria, for instance, this between-year variability is on the order of 20-30 bu/ac. It would seem that our definitions of between- and within-year variability which assume independence are inadequate to explain the complex weather/plant relationships contained in the CERES model. We should, then, reconsider the possible non-model sources of yield variability. For this discussion the analysis location has been moved from Peoria, Illinois to Rochester, MN. Although different corn varieties, planting dates, etc., are used, the same partitioning problems encountered in the Peoria data can be noted at Rochester(see Sections 3.3.1 and 3.3.2).

One reason that weather data normalization was originally performed was to generate multiple realistic weather scenarios that could be played through the model so that distributions of output yields could be generated and analyzed. The method isolated a single week but could alter the natural week-to-week autocorrelation of the input data. If it is a series of "runs" of weather events rather than a single week that controls the lion's share of yield variability, the above method of time-series generation is inadequate.

Assume that the impact of particular weeks on yield is still to be considered. This impact is not independent but, rather, is influenced

by those events preceding and following them. In this way three distinct sources of within-season variability can be defined, that resulting from weather runs preceding the week of interest, that resulting from runs of weather following the week and that resulting from combining the two weather time-series. To generate yield outcomes ameniable to this type of analysis, time series were generated as illustrated in Figure 34.

Figure 34: Weather Time-Series Construction for the Two-Way ANOVA Model (after Duchon, 1984).



In Figure 34 observed data for a specific year are used from January first until the week of interest, Week 30. Then, observed weather for all 36 years are appended one year at a time. This procedure is repeated for each of the 36 years of available data. The resulting data set is used to produce a three-dimensional matrix of modeled yields as illustrated in Figure 35.

Figure 35: 3-Dimensional Array Construction of Modeled Yield Time-Series for the Two-Way ANOVA Model.

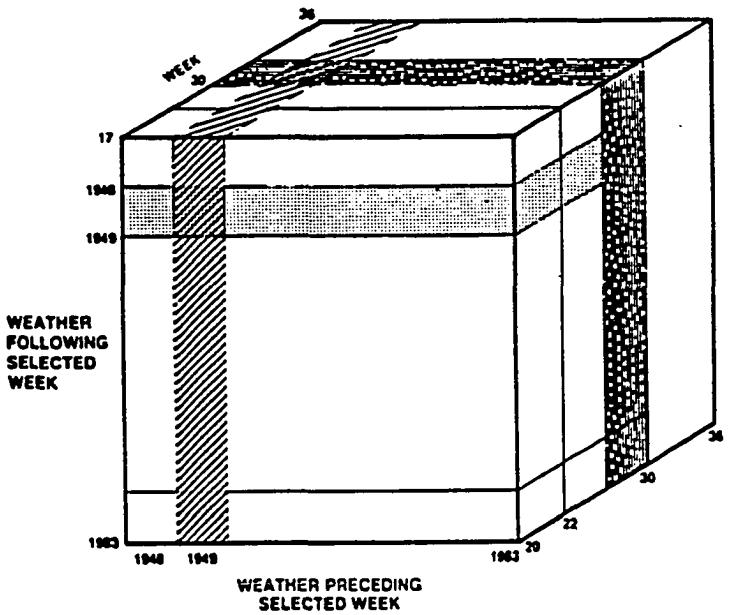


Table 23 contains the entries in the shaded column of the data matrix. This table suggests that given 1949 weather to Week 30 followed by 1948 weather for the remainder of the model determined growing season, the model generates an estimated yield of 77.5 bu/ac. Further down the column, if 1949 data were used from January 1 through Week 30 followed by 1970 weather for the remainder of the model determined growing season, an estimated yield of 104.6 bu/ac is obtained. Therefore, if during 1949, 1970 weather had occurred after Week 30, an improvement of 10.8 bu/ac could have been expected over yields generated by observed 1949 weather. Table 24 contains the data in the shaded row of Figure 35. From Table 24 we can make a statement concerning the way yields change week-by-week as more and more

TABLE 23

Contents of the Shaded Column of Figure 35

Preceeding Weather (wk 30) Year	Following Weather Year	Week 30 Predicted Yield (bu/ac)
49	48	77.5
49	49	93.8
49	50	90.5
49	51	85.1
49	52	85.2
49	53	108.3
49	54	67.4
49	55	63.1
49	56	92.1
49	57	91.8
49	58	67.6
49	59	76.2
49	60	69.5
49	61	86.1
49	62	64.1
49	63	74.2
49	64	60.5
49	65	90.5
49	66	84.1
49	67	94.5
49	68	98.9
49	69	115.8
49	70	104.6
49	71	65.4
49	72	85.7
49	73	96.0
49	74	68.6
49	75	71.5
49	76	68.0
49	77	77.1
49	78	61.1
49	79	81.9
49	80	63.4
49	81	85.3
49	82	75.5
49	83	56.1

information is added. For instance, if 1949 data are used from January 1 to Week 20, then followed by 1949 data, an estimate of 93.8 bu/ac is obtained. If 1950 data are used January 1 to Week 20, then followed by

1949 an estimate of 90.9 bu/ac is obtained. Proceding across the row, if 1978 data were used January 1 to Week 20 and 1949 data used thereafter, a yield estimate of 48.0 bu/ac is estimated.

TABLE 24

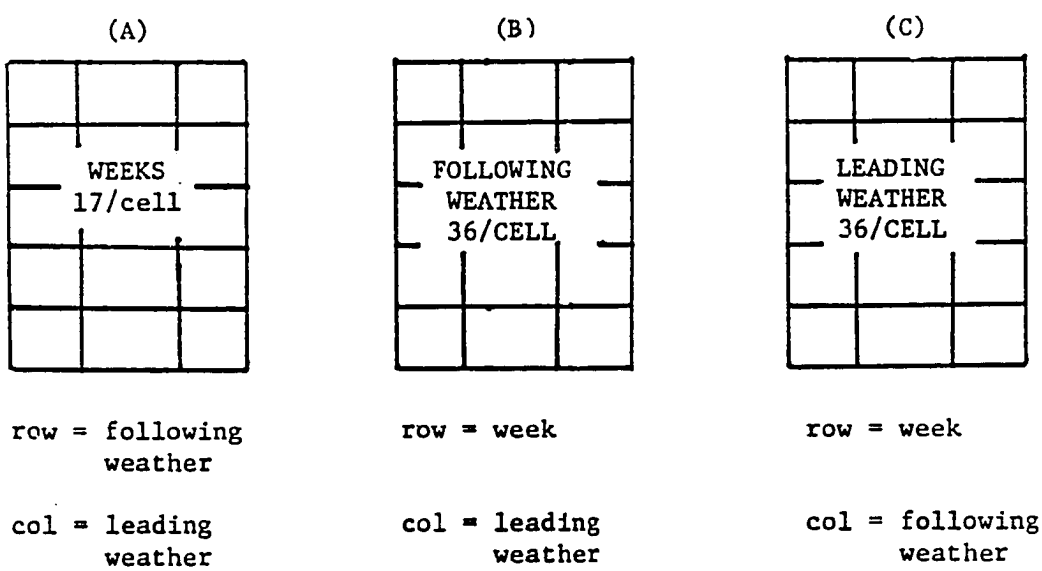
Contents of the Shaded Row of Figure 35

Preceding Weather Year	Modeled Yield Using Week 20 as a Time-Series Breakpoint (bu/ac)	Preceding Weather Year	Modeled Yield Using Week 20 as a Time-Series Breakpoint (bu/ac)
1948	83.3	1949	93.8
1950	90.9	1951	82.1
1952	85.9	1953	93.9
1954	89.4	1955	62.5
1956	98.2	1957	60.5
1958	90.2	1959	97.8
1960	79.5	1961	89.5
1962	77.6	1963	85.2
1964	84.4	1965	81.6
1966	68.7	1967	98.1
1968	70.3	1969	69.3
1970	91.3	1971	101.1
1972	87.7	1973	88.6
1974	78.5	1975	73.4
1976	95.5	1977	78.8
1978	48.0	1979	96.5
1980	82.0	1981	74.5
1982	63.8	1983	88.2

We now have a large data set (22032 values) with three rather clearly defined sources of variability that can be tested (leading weather, following weather and weather time series break-point). This suggests that a two- or three-way fixed effects ANOVA model might be used. A two-way rather than a three-way ANOVA model was selected because of design limitations. If a three-way model is used there is only one observation in each experimental cell. Consideration of the

variance analysis statistics produced under such a design would be virtually meaningless. By using a two-way rather than three-way design the three-way cross-effects term cannot be evaluated, but by constructing several two-way designs it is possible to examine all other main and cross effect terms. The three two-way experimental designs which allow this analysis are presented in Figure 36. In each case the main effects are represented by corn-weather year or Julian Week numbers (1948-1983 and 17-35) and the response variable is a modeled yield value.

Figure 36: Three Two-Way ANOVA Designs.



The first design (A) would address "Given the leading and following weather, what is the contribution to yield variability of the time within the growing season at which a following corn-weather "forecast"

is made?" The second design (B) addresses "Given the leading weather and time series break date what is the variance contribution of the following weather to modeled yield variability?" The last design (C) addresses, "Given the following weather and the time series break week, what is the variance contribution of the leading weather to modeled yield variability?"

The Statistical Analysis System (SAS) ANOVA procedure was chosen to perform the analysis. Since we suspect that in addition to row and column effects there may also be interaction effects, the SAS ANOVA "model statement" is defined by the expression below (see SAS Institute Inc., 1982).

$$\text{Yield} = \text{row column row*column} \tag{14}$$

More explicitly, the variance expression created by this statement would have the form:

$$SST = SSW + SSA + SSB + SSAB \tag{15}$$

where:

$$SST \equiv \Sigma\Sigma\Sigma_{i} (X_{ijk} - \bar{X}_{...})^2$$

$$SSW \equiv \Sigma\Sigma\Sigma (X_{ijk} - \bar{X}_{.jk})^2$$

$$SSA = IK\Sigma_{j} (\bar{X}_{.j.} - \bar{X}_{...})^2$$

$$SSB \equiv IJ\Sigma_{k} (\bar{X}_{..k} - \bar{X}_{...})^2$$

$$SSAB \equiv I\Sigma\Sigma_{kj} (\bar{X}_{.jk} - \bar{X}_{.j.} - \bar{X}_{..k} + \bar{X}_{...})^2$$

$$\bar{X}_{.jk} = \Sigma X_{ijk}/I$$

$$= \text{mean of the jkth cell}$$

$$\bar{X}_{.j.} = \Sigma\Sigma_{ki} X_{ijk}/IK$$

$$= \text{mean of the jth level of A}$$

$\bar{X}_{..k} = \sum\sum_{ji} X_{ijk}/IJ$

= mean of the kth level of B

$(\bar{X}_{.jk} - \bar{X}_{.j.} - \bar{X}_{..k} + \bar{X}_{...})$ = a combination of the jth level of A and kth level of B

X_{ijk} = is a model generated yield.

Restrictions and assumptions of this model include:

1) $\sum_j \alpha_j = 0$, $\sum_k \beta_k = 0$ and $\sum_j \alpha\, \beta_{jk} = \sum_k \alpha\, \beta_{jk} = 0$

for $N_{jk} = I$

where: α_j = type one error

β_k = type two error

2) $e_{ijk} \overset{d}{\sim} NID\ (0, \sigma_e^2)$.

The model error is independent, normally distributed with mean zero and variance σ^2 and there is equality of variance. The equality of error variance is assumed for all cells in the design.

Table 25 contains the results of the SAS ANOVA analysis. This table also includes F-test results. In this case we are using the F (a ratio of two Chi-Square's) as a test of the equality of means. The F-tests take the form:

$$F_A = MSA/MSW \overset{d}{\sim} F_{J-1,\ JK(I-1)} \qquad (16)$$

$$F_B = MSB/MSW \overset{d}{\sim} F_{K-1,\ JK(I-1)} \qquad (17)$$

$$F_{AB} = MSAB/MSW \overset{d}{\sim} F_{(J-1)(K-1),\ JK(I-1)} \qquad (18)$$

where: MSA = mean square of A

= SSA/J-1

MSB = mean square of B

= SSB/K-1

MSAB = mean square of interaction

= SSAB/JK - J - K+1

MSW = mean square within group

= SSW/IJK - JK .

The hypothesis are of the general form:

$$H_0^A: \mu_J = \mu$$

$$H_0^B: \mu_K = \mu$$

$$H_0^{AB}: \alpha\ \beta_{JK} = 0 \ .$$

These hypotheses are essentially independent and any one of them could be true while the others are not.

Begin by considering case A. First we find that if we assume SST = SSW + SS_{lead} + SS_{follow} + $SS_{lead*follow}$, about 58 percent of the modeled yield variability can be explained by leading weather, following weather, and interaction effects. This leaves 42 percent of the variability to be attributed to within-cell effects. The within-cell sum of squares and the following weather sum of squares are about the same, but the following weather sum of squares is more than twice as large as the preceding weather sum of squares. As defined by equations 16-18, the F statistics in Table 25 are testing hypotheses of equality of means between the main or interactive effects and within cell group means Since the probability of calculating an F- statistic larger than those computed in case A is at most .03, the hypothesis of equality of the mean of yield outcomes attributable to leading and following weather

TABLE 25

Results of the SAS ANOVA Procedure for Three Two-Way Designs.

A) SAS Model Statement: Y = leading weather following weather lead*follow

Sum of Squares				PR > F
SST	= 10338775.6			
SSW	= 4387283.7			
SS_{lead}	= 1618504.7	F_{lead}	= 218.56	.0001
SS_{follow}	= 4053481.4	F_{follow}	= 547.38	.0001
$SS_{lead*follow}$	= 279505.7	$F_{lead*follow}$	= 1.08	.0323

B) SAS Model Statement: Y = leading weather week follow*week

Sum of Squares				PR > F
SST	= 10338775.6			
SSW	= 6807128.2			
SS_{lead}	= 1618504.7	F_{lead}	= 145.51	.0001
SS_{week}	= 3606.3	F_{week}	= .71	.7875
$SS_{lead*week}$	= 1909536.4	$F_{lead*week}$	= 10.73	.0001

C) SAS Model Statement: Y = following weather week lead*week

Sum of Squares				PR > F
SST	= 10338775.6			
SSW	= 4542407.1			
SS_{follow}	= 4053481.4	F_{follow}	= 546.13	.0001
SS_{week}	= 3606.2	F_{week}	= 1.06	.3853
$SS_{follow*week}$	= 1739280.8	$F_{follow*week}$	= 14.65	.0001

or their interactive effects and within cell means is rejected. The F-test also suggests that the variables in the interaction term are correlated.

Next, we will expand our discussion to include models B and C. From Table 25 we can see that although the total sum of squares remains constant across the three examples, the sum of squares of the interaction terms is larger in B and C than in A. The F-values are, in turn, much larger (see Eq. 21). This indicates that there is a stronger correlation between leading weather and the time series break date, and following weather and the time series break date, than between leading and following weather (model A interaction term).

In case C the distribution of the variability among effects is quite similar to case A. Slightly less than 58 percent of variability is explained by the main effects and interactive effect. The variability explained by the point at which the time series is split is small compared to that of the following weather. The interaction effect is fairly substantial as might be expected. It is more likely that a closely related point in time and a time series will interact than two extended time series which span a relatively long interval. Applying the same hypothesis testing explanation here as for case A, the F-tests indicate that the distribution of yield means attributed to the following weather and interaction effects are significantly different from within cell means, but a similar break point effect hypothesis of equality of means (yield population and within cell means) cannot be rejected.

The results of model B verify those of model C in terms of sources of variability. Both models, B and C, suggest that more yield variance is attributable to following weather than leading weather. A graphical explanation is given below, but several model design effects should also be noted. First, this variance bias could be the result of our selection of growing season. Second, this result could indicate greater variance in the input weather data as the growing season progresses, that is, more transient weather patterns occur in space and time as we move into the summer months than in the spring. Finally, this increase in variability could be produced by the model itself if a large number of critical physical processes are modeled to take place latter in the growing season than early in the year.

These points as well as the discrepancy in variability contribution by leading and following weather in case A can be pursued by condensing some of the information in the time series (Figure 35) down to weekly means and standard deviations and then plotting them. Using case A as a base of definition, begin by defining SS_{lead}. Using Figure 35, recall that the statistical expression for this "column" effect is:

$$IJ\sum_{k}(x_{..k} - \bar{x}_{...})^2 \qquad (19)$$

where: I = number of observations per cell, 17,

J = number of rows, 36,

K = column, k = 1 to 36.

The previous analysis and Eq. (19) considers all weeks collectively, somewhat analagous to the earlier, seasonal approach. Yet, the effect to be examined expresses itself at some point within each season.

Therefore, redefine Eq. (19) so that the original SS_{lead} is partitioned among the 17 growing season weeks. Equation (19) then becomes:

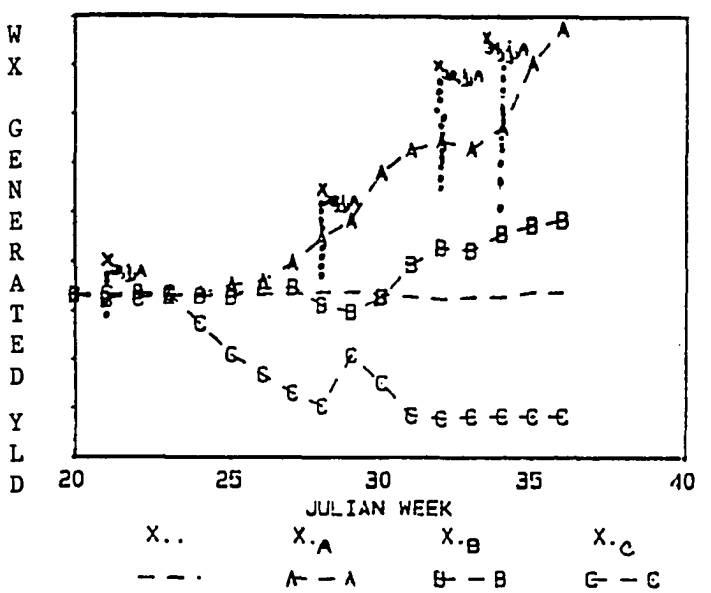
$$\sum_{k}^{J}(x_{.k} - \bar{x}_{..})^2 \qquad (20)$$

where: J = 1 to 36 years of following weather,

k = 1 to 36 years of leading weather.

From the matrix (Figure 35), each week for each leading year has 36 possible outcomes. A weekly mean for leading year Y_1 contains 36 points. There is a possibility of 36 leading years (X_1 to X_{36}). Thus, a leading year weekly mean is the average of 36 leading year average outcomes (see Figure 37).

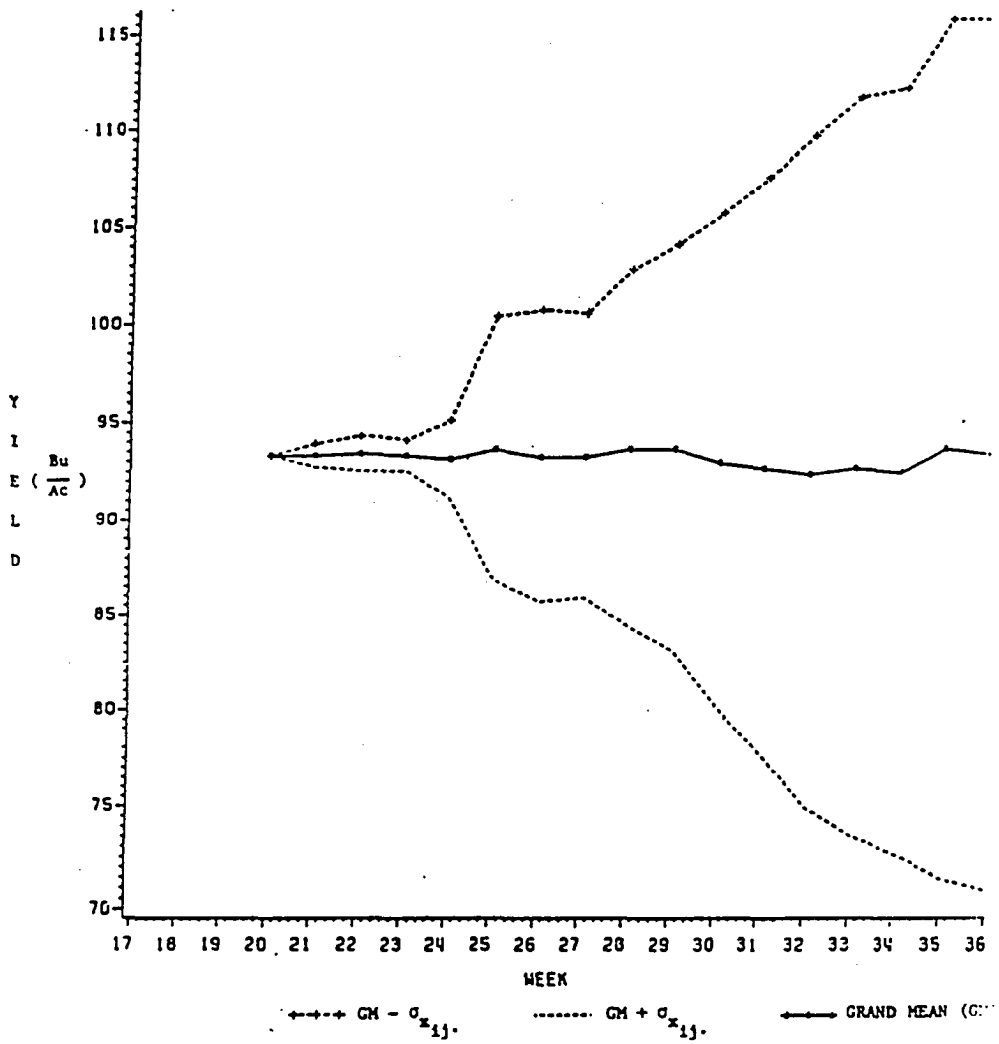
Figure 37: Graphical Representation of $X_{\bullet k}$ and $X_{\bullet\bullet}$, where: j=leading year and k=following year.



Another way of considering this operation is to find the mean of each of 36 columns for a given week. Then find the grand leading mean across these annual means. Figure 38 contains this weekly grand leading weather mean and the variability of the annual means about this value. Since, for a given week across leading years all following time series are the same, that is, the same set of outcomes is applied to each leading year, the only factor generating variability from one year to the next is the leading weather. Therefore, the variability values graphed in Figure 38 represents the effects of leading weather on yield outcome. These values of weekly variability are what generate the SS_{lead} in case A, Figure 36.

Next, consider how one would represent the weekly variability that goes into SS_{follow} (Figure 39). If we return to the earlier development for SS_{lead}, each week of each year has 36 possible yield outcomes. As earlier, a mean based on these 36 points can be computed. A variability about this first mean can also be estimated. Since the only difference between one yield outcome and another for a given week is the weather time series which follows the week, this variability can be attributed to following weather. Similar mean and variability estimates can be made for each of the 36 leading years. A grand mean of these means can be computed as before, but this time, consider the average of the variability about each of the means going into the grand, i.e., the grand mean line looks the same in both Figures 38 and 39, but the variabilities are different. The variability in Figure 39 represents the average following weather impact on yield for each week. The weekly variability represented in Figure 39 is based on the elements of SS_{follow} in case A, Figure 36.

Figure 38: Weekly Average Grand Mean and Standard Deviation for Leading Weather at Rochester, MN.

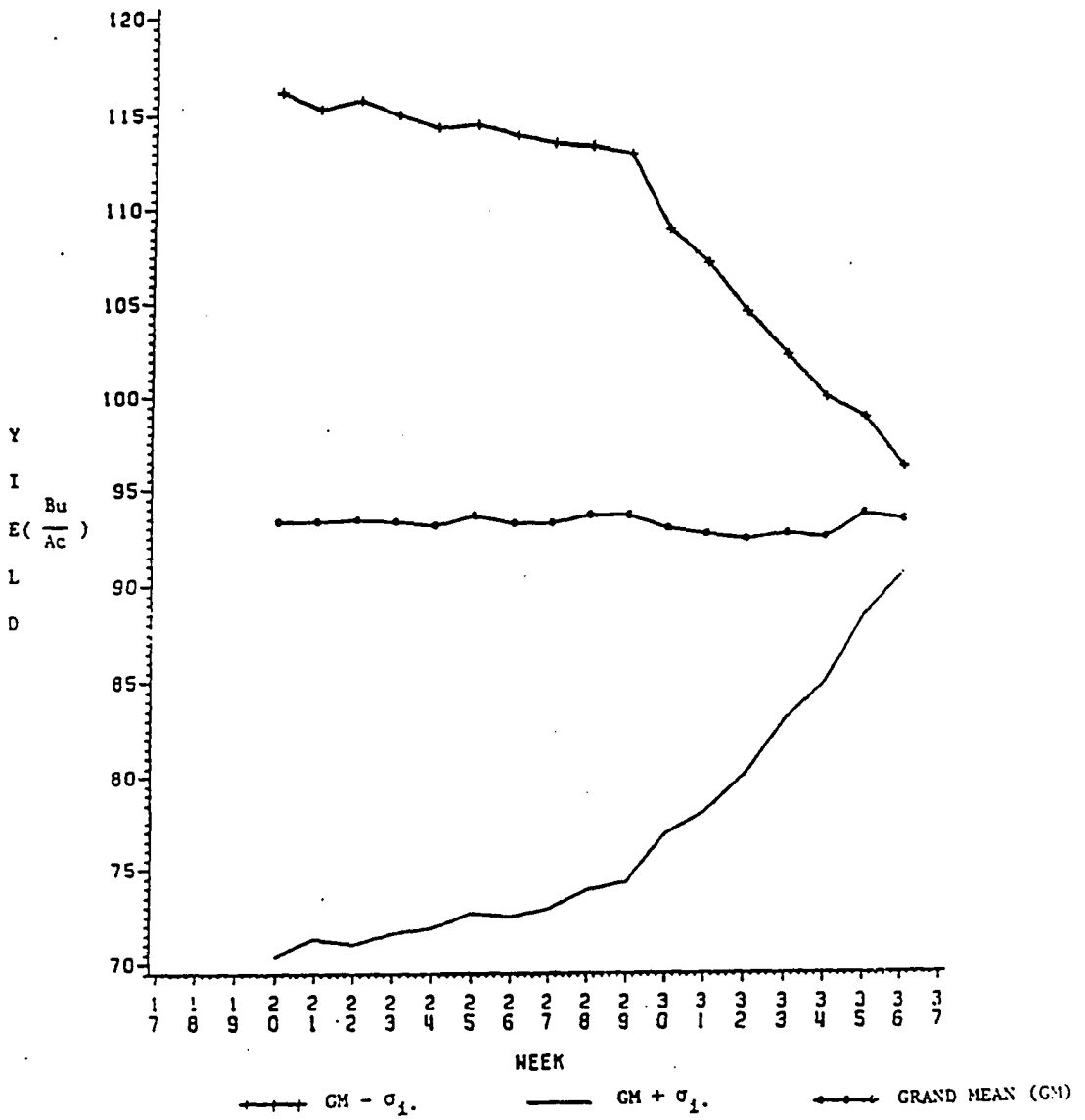


where: $\sigma^2_{x_{ij}.}$ = variance of the 36 $x_{ij}.$ means

$x_{ij}. = (\sum_{k=1}^{36} x_{ijk})/36$, for a given week, i,

and leading weather year, j. This mean has associated with it variance σ^2_{ij} .

Figure 39: Weekly Average Grand Mean and Averaged Variability for Following Weather at Rochester, MN.



where: $\sigma^2_{i.}$ = the average of the 36 σ^2_{ij} 's

$= (\sum_{j=1}^{36} \sigma^2_{ij})/36$, for a given week, i,

and leading weather year, j.

The background has now been developed to address the question: why, in case A, is the variability due to the following weather larger than that due to leading weather? Figure 40 is a composite of Figures 38 and 39. From Figure 40 it can be noted that the variability attributable to leading weather increases relatively smoothly until the last two weeks (35-36), when it has reached the same magnitude as the variability with which the following weather begins. Variability due to following weather maintains a fairly large magnitude until week 29 and then declines fairly rapidly after this point. The result is that because variability attributable to following weather remains larger longer than variability resulting from leading weather, the SS_{follow} will be greater than the SS_{lead}.

This analysis can be taken one step further. Next consider how yield deviations attributable to the effects discussed earlier change from one week to the next. The mean deviation difference each week is computed as given in Eq. (21).

$$DIF_i = |A_i|^{1/2} * B \qquad (21)$$

where: DIF_i = mean deviation difference (bu/ac)

$$(\text{Long-term})A_i = \left(\sum_{k=1}^{36} \sum_{j=1}^{36} (Y_{ijk} - Y_{i..})^2/JK \right)$$

$$- \left(\sum_{k=1}^{36} \sum_{j=1}^{36} (Y_{(i-1)jk} - Y_{(i-1)..})^2/JK \right)$$

(a single year) $A_i = A_{ik}$

$$A_{ik} = \left(\sum_{j=1}^{36} (Y_{ijk} - Y_{i.k})^2/J \right) - \left(\sum_{j=1}^{36} (Y_{(i-1)jk} - Y_{(i-1).k})^2/J \right)$$

Y_{ijk} = Yield associated with week i, following weather j leading weather k.

i = week

j = following weather (j=1 to J)

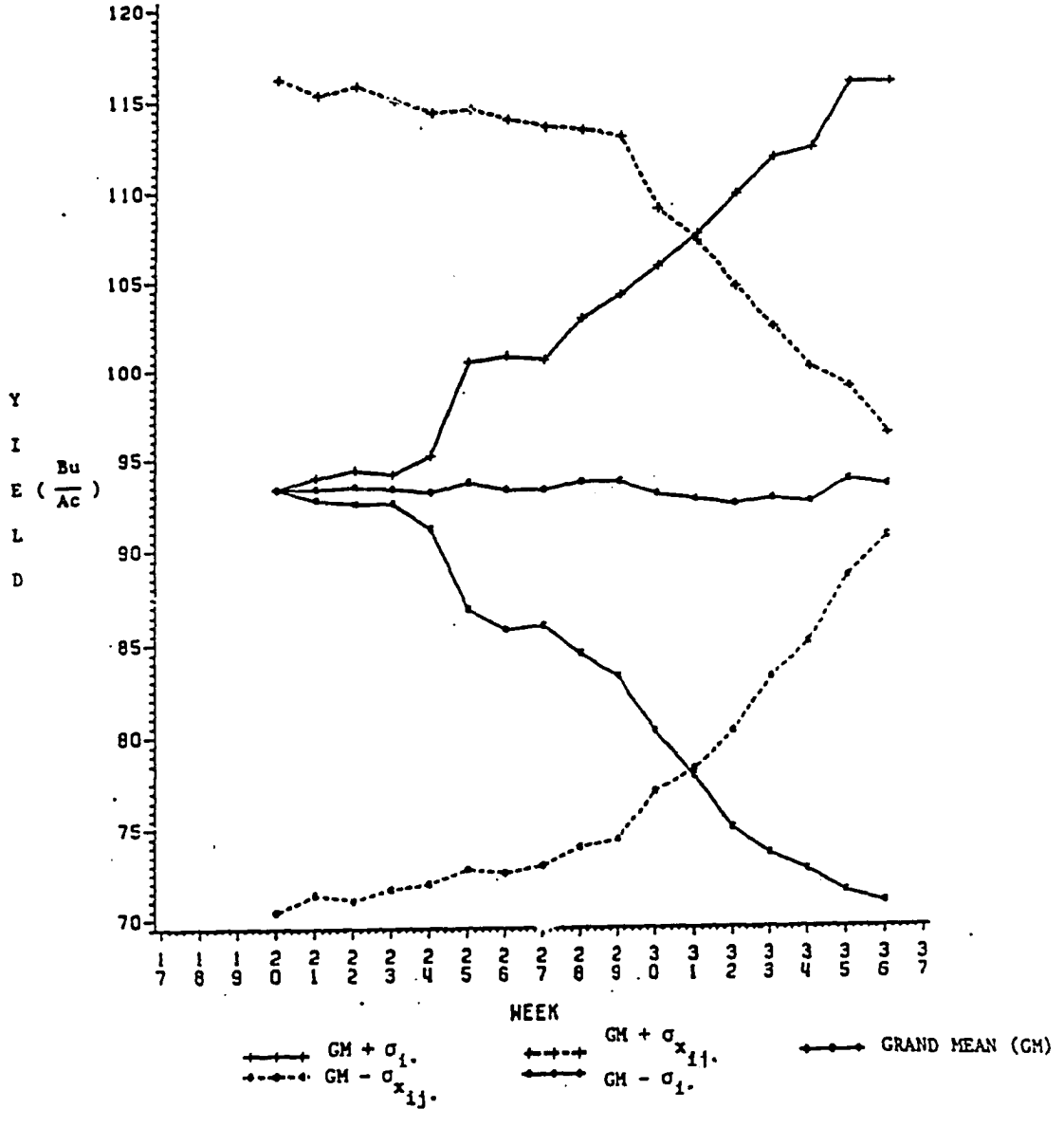
k = leading weather (k=1 to K).

B = 1 or -1 to agree with the sign of A_i

These changes can be attributed to the impact on modeled yield of breaking the weather time series at a particular week. The result is a change in variability between consecutive weeks. Note that these differences are based on the entire set of individual observations (Y_{ijk}'s), not on the means represented in Figure 40. Thus Figure 41 cannot be visually computed from Figure 40.

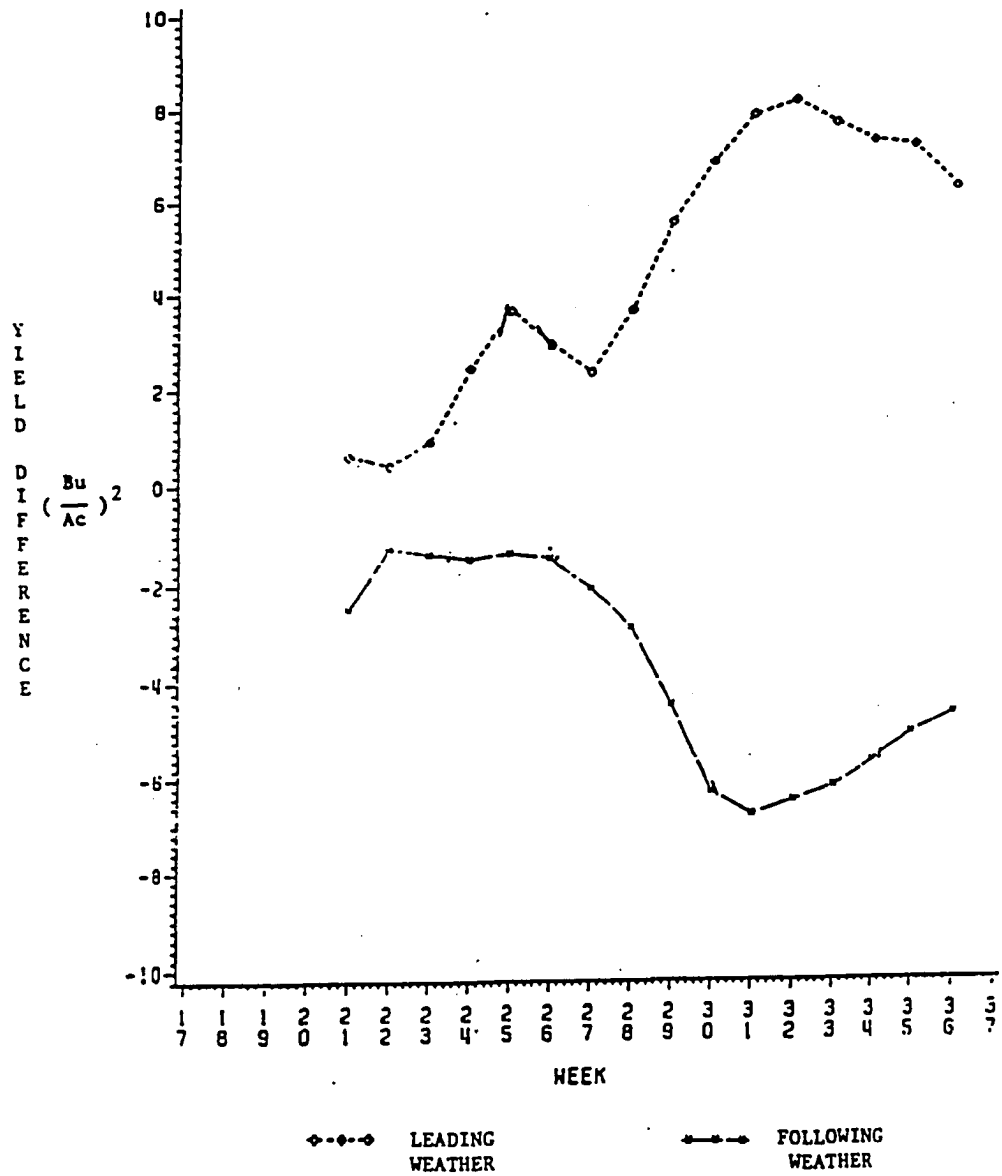
Consider the curves in Figure 41 in more detail. Both curves change slowly early in the growing season. The size of the slope (rate of change) rather than the sign of the differences is of greatest interest. A steep slope and large value (absolute) indicates that something in the weather is forcing the model to a stable solution (following weather) or further decreasing the stability at the beginning of the year (leading weather). From this graph for Rochester, MN (Figure 41) it can be said that the most important following weather events forcing the model to a solution seem to occur between Julian Weeks 30 and 33. Although another maxima in leading weather variability occurs at Julian Week 22, it is not reflected in the following weather variability and so will be attributed to the magnitude of numbers being

Figure 40: Composite of Figures 38 and 39.



(see Figures 38 and 39)

Figure 41: Weekly Differences of Preceding and Following Yield Deviations at Rochester, MN (see Eq. 21).



subtracted so early in the season (when values are large, a small percent change can appear as large absolute differences). Weather appears to be least important between Julian Weeks 21 and 24. These variability estimates are crucial to the ability to place confidence limits on a yield forecast. The ability to determine confidence limits is possible with a relatively continuous, process type model and impractical for the second-generation yield forecast models presently employed by most organizations. The logic and use of such confidence intervals will be presented and discussed in the products portion of this report.

The preceding statement suggests the manner in which model generated yield results can be used to make agrometeorological forecasts and products of optimal value for a specific area. Through the process model, Figures 40 and 41 relate crop phenological information to calendar time. The calendar time of sensitive crop stages indicated on these figures are averages of calculated year-to-year phenology for the area, but this generalization can relieve the forecaster from making repetative phenological calculations and can provide information for long-term planning projects. For example, at Rochester, MN, Figure 41 would tell a forecaster that the most critical forecast period is usually Weeks 31 through 33. Maps or estimates of an area's yield hazard resulting from weather could be based on distributions of conditions during this period. Although this will not always correspond exactly with a critical phenological stage such as flowering, it should, on the average, be quite close.

In addition to general forecast and product information, these graphs can be used for post-season analysis. Take, for example, a high model-yield year (1971) and a low model yield year (1982) at Rochester. Begin with the 1971 growing season Figure 42. From Figure 42 it can be seen that the general slope of the expected yield is upward, indicating good growing conditions throughout the year. The period of most rapid increase is between Julian Weeks 28 and 32. Weather conditions during this time were moderately cool and damp with total precipitation amounting to 2.57", mean maximum temperature of 77.6 degrees and a mean minimum temperature of 54.6 degrees. Flowering is estimated to occur during Julian Weeks 29 and 30. There is a slight yield decline forecast between Julian Weeks 32 and 34 when weather became warmer and drier but the modeled yield forecasts recover later. As is typical with this model in relatively cool, damp years, the grain filling period extends beyond mid-September and so the final yield of 118 bu/ac is not completely represented by the figure.

Next consider 1982 (Figure 43) a relatively poor growing season. The trend in yield is in the opposite direction to that of 1971. In 1982 there is a steady decline in forecast yields with the steepest decline taking place between Julian Weeks 28 and 32. Weather conditions during these weeks were quite warm and moderately wet. Total precipitation amounted to 3.85", mean maximum temperature was 82.1 degrees and mean minimum temperature was 61.6 degrees.

A comparison of the two growing seasons suggests an interesting relationship between temperature, precipitation and modeled yield. Between Weeks 28 and 32, 1982 had 1.28 inches more precipitation than

Figure 42: Long-Term Weekly Mean and 1971 Modeled Yield and Following Weather Yield Variability at Rochester, MN.

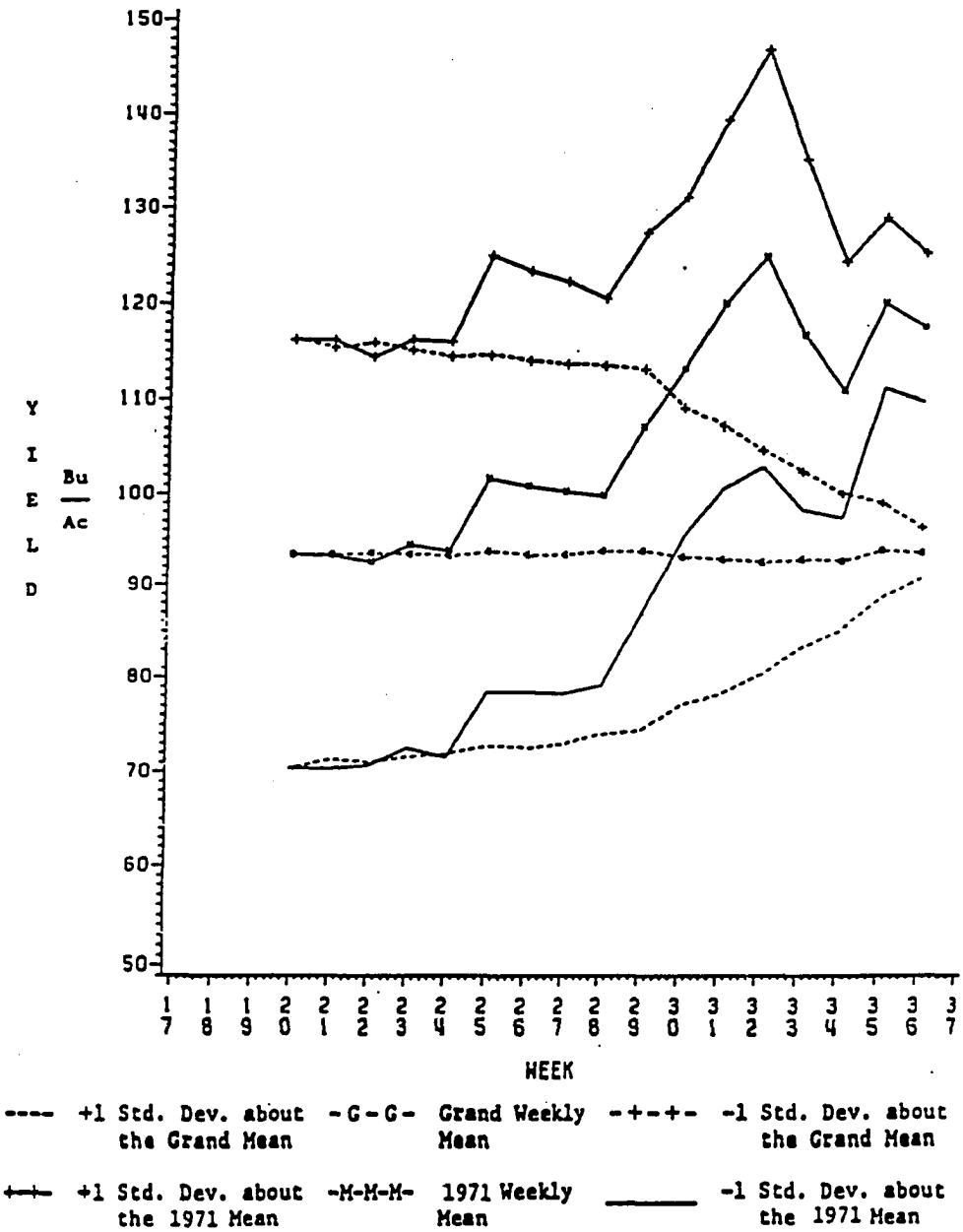
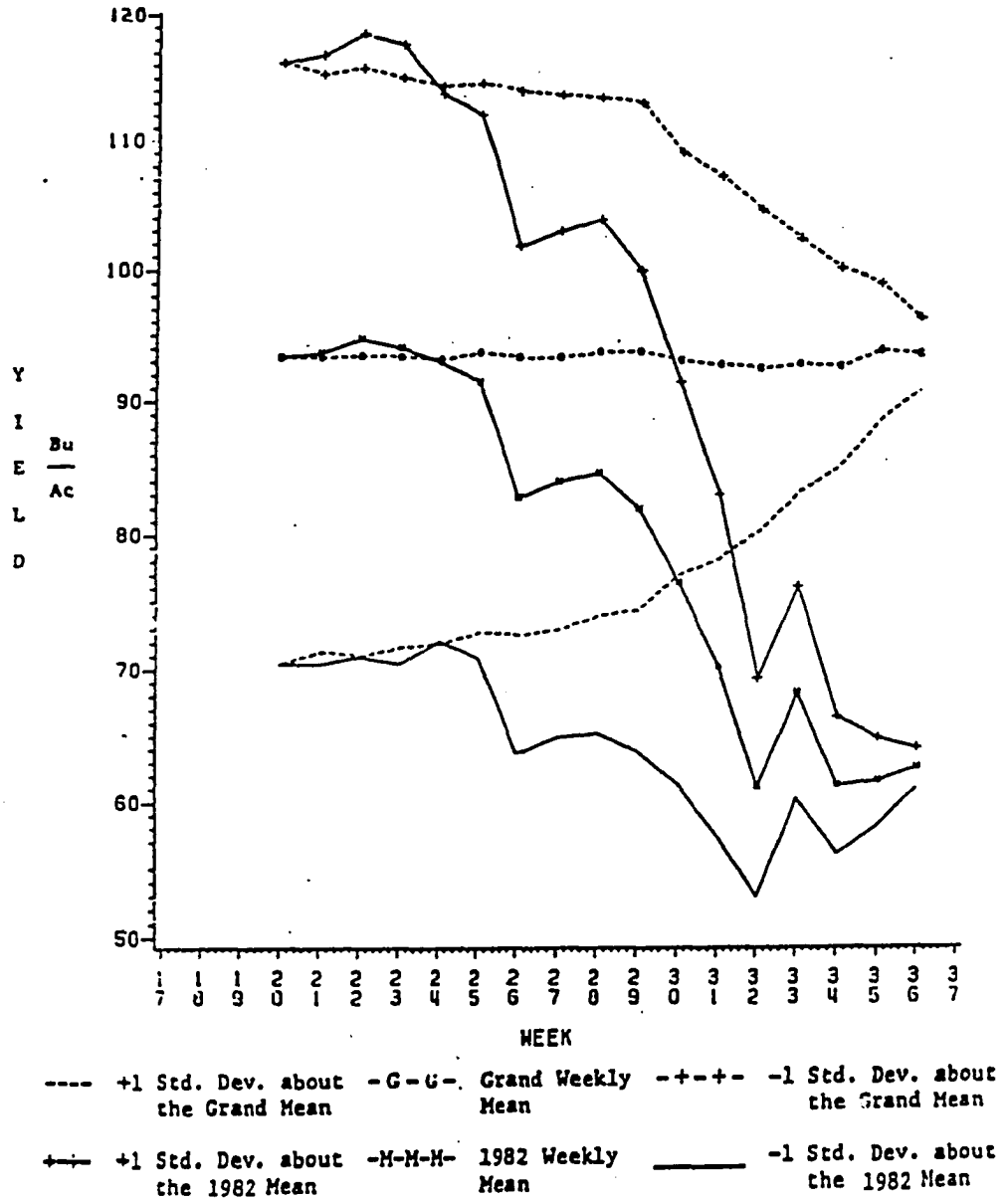


Figure 43: Long-Term Weekly Mean and 1982 Modeled Yield and Following Weather Yield Variability at Rochester, MN.



1971, its mean maximum temperature was 4.6 degrees warmer than 1971, and its mean minimum temperature was 7 degrees warmer than in 1971. What this would indicate is that even though moisture supplied in 1982 was higher than 1971, it was not sufficient to keep pace with the increased demand resulting from higher temperatures, or, that in spite of adequate moisture, the detrimental effects of high temperatures and lower preceding precipitation prevailed. The latter year, 1982, bears many similarities late in the season to 1983 which will be considered in greater detail in section 3.4. Similar graphs for the remaining 35 years may be found in Appendix F. This suggests that perhaps other quantifiable similarities exist within the corn-weather time series.

If an analysis were to be performed for each season, certain clustering characteristics of within-season changes in yield outcome patterns could be noted. This can be formalized by a computerized comparison the 36-year graph sets in Appendix F. An ability to group outcomes (or cluster patterns) would be of interest to forecasters and climatologists and would enhance their ability to produce useful products for their users. In the case of weather forecasters, yield outcome groupings could suggest new forecast or synoptic categories that would result in more valuable longer-range categorical forecasts for corn producers. Traditional synoptic categories may be inappropriate since several different weather patterns could result in similar yield outcome patterns as long as conditions at particular times are consistent. On the other hand, a series of synoptic conditions which might appear similar to the meteorologist could result in quite different yield outcomes.

First, consider looking for groupings using a simple visual approach. Rather than considering following weather patterns which would be unkown in an actual forecast situation, first visually scan for groupings in the leading weather patterns. If the leading weather counter-part of the time series of means contained in Appendix F are graphed together, Figure 44 can be generated. Horizontal lines have been drawn to suggest possible growing season groupings. A more rigorous method of looking for groups of weather outcomes (yields) is through statistical cluster analysis procedures. A less complex (as well as less informative) alternative is the use of pairwise t-tests. The results of such comparisons would be far from conclusive but could be suggestive for future, more detailed analysis.

When comparing more than two means, an ANOVA F-test tells you if some means are significantly different from each other, but it does not immediately tell you which means differ from other means. Multiple comparison methods (also called mean separation tests) are needed to yield more detailed information about the differences among the means.

Since numerous pair-wise comparisons are involved, a method which controls the maximum experimentwise error rate (MEER) under any complete or partial null hypothesis is desirable. The Bonferroni (or Dunn's) t-test is such a statistic. Bonferroni t-tests with MEER $\alpha \leq .05$ and equal cell size declares two means to be significantly different if:

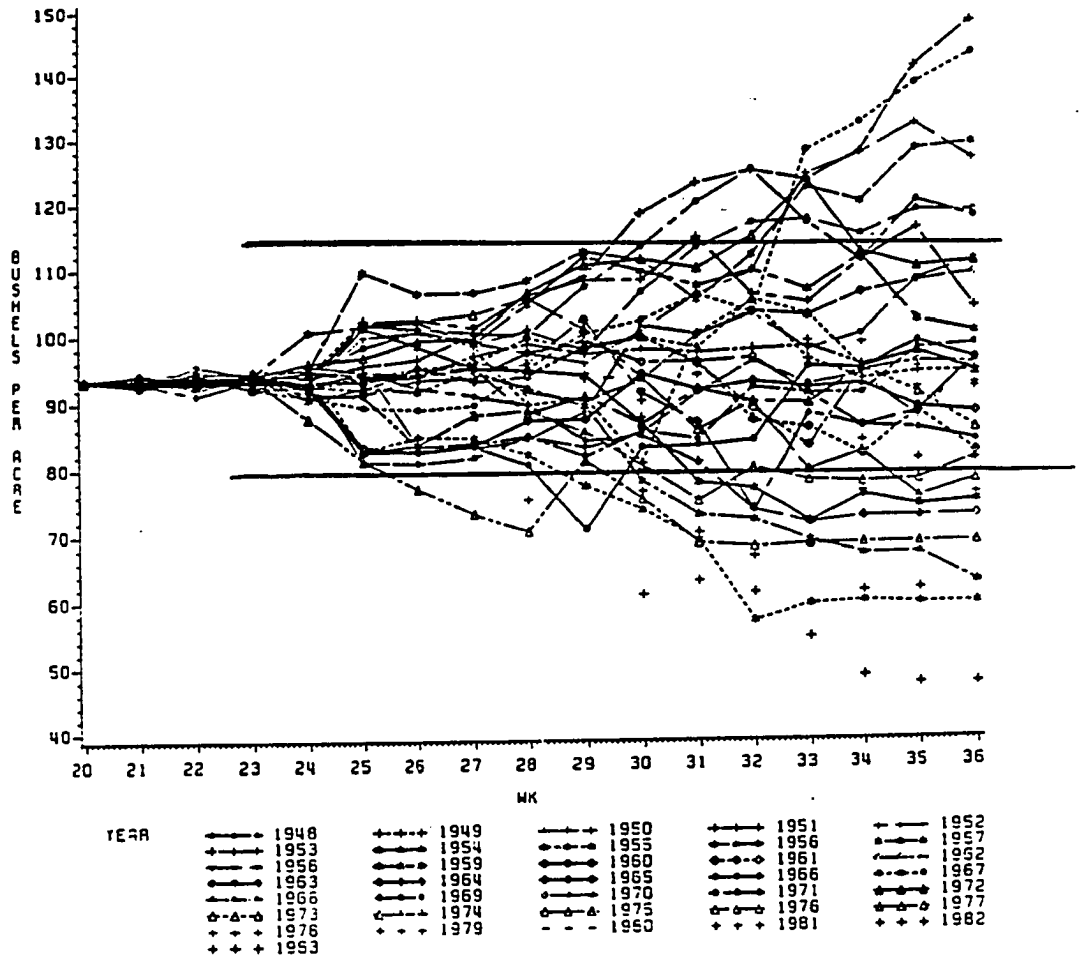
$$|\bar{y}_i - \bar{y}_j| \geq t(\varepsilon;\nu)s(2/n)^{1/2} \qquad (22)$$

where: $\varepsilon = \alpha/(k-(k-1)/2)$ for k cell means,

ν = degrees of freedom,

s = root mean square error,

Figure 44: Mean Forecasted Yields Attributable to Leading Weather, 1948 - 1983.



n = cell size.

$\bar{y}_i$ = cell mean for cell i,

$\bar{y}_j$ = cell mean for cell j.

When this analysis option is run under SAS, the results contained in Table 26 are obtained.

TABLE 26

Clustered Years of Pairwise Selected Yields Produced by Leading Weather Time-Series.

(1)	50	56								
(2)	56	71	52	67	72	70				
(3)	71	52	67	72	70	53	59			
(4)	79	62	51	58	73	49	65	63		
(5)	51	58	73	49	65	63	77	81	61	76
(6)	65	63	77	81	61	76	80	60	69	
(7)	63	77	81	61	76	80	60	69	68	
(8)	61	76	80	60	69	68	66			
(9)	76	80	60	69	68	66	48			
(10)	80	60	69	68	66	48	64	54		
(11)	66	48	64	54	74					
(12)	74	57	78	83						
(13)	57	78	83	82						
(14)	83	82	75							
(15)	82	75	55							

As in the case of Figure 44, suggestive groups of corn weather years are delineated in Table 26. In general, yields associated with these weather groupings range from high (group 1) to low (group 15). Each cluster represents corn weather years whose resultant mean yields are not statistically dissimilar. If the yield estimates associated with the weather series years in Table 26 are plotted in categories of width equal to the smallest detectable yield difference during growing season weeks 27 and 28, Figures 45 and 46 can be constructed. These figures are another strong indication that the model yield population is non-homogeneous and, possibly, non-Gausian.

Having suggested and somewhat substantiated the hypothesis of a non-homogeneous yield population, findings of Section 3.3 will be summarized and a specific agroclimatic analysis for the corn belt will be explored Yield population non-homogeneity will appear again in section 3.5.4 and is explicitly addressed in Section 3.5.5.

Figure 45: Histogram of Clustered Forecasted Yield Means at Week 27

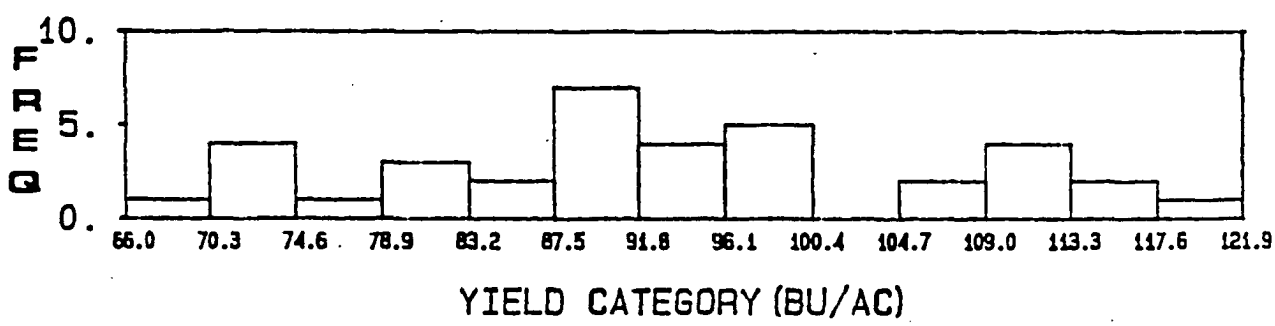
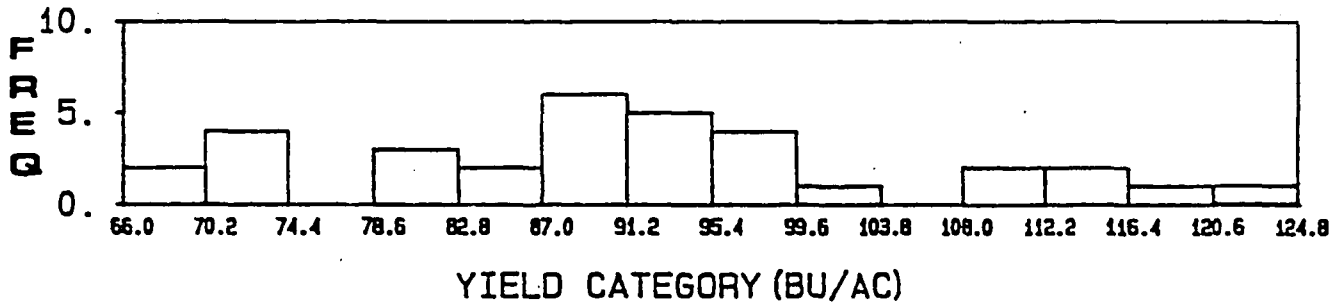


Figure 46: Histogram of Clustered Forecasted Yield Means at Week 28



SUMMARY OF A STATISTICAL ANALYSIS OF THE CERES CORN YIELD MODEL APPLIED TO A GEOGRAPHIC POINT

1. Within-year and between-year variability in model estimated yields can be directly related to variability in one or more correlated weather variables.
2. This variability can be partitioned into a variety of within- and between-growing season effects in a variety of ways.
3. Since weather is put through a model which generates one annual number per site (output is always dependent on an entire growing season), it is difficult to isolate between-season and within-season weather effects.
4. A traditional ANOVA approach is a useful tool but does not adapt directly to these model results as a result of model non-linearities and input variable inter- and auto-correlations. Therefore, the results must be interpreted carefully.
5. Physical and model constraints restrict the choice of data normalization procedures and may result in further complication of the analysis process and results.

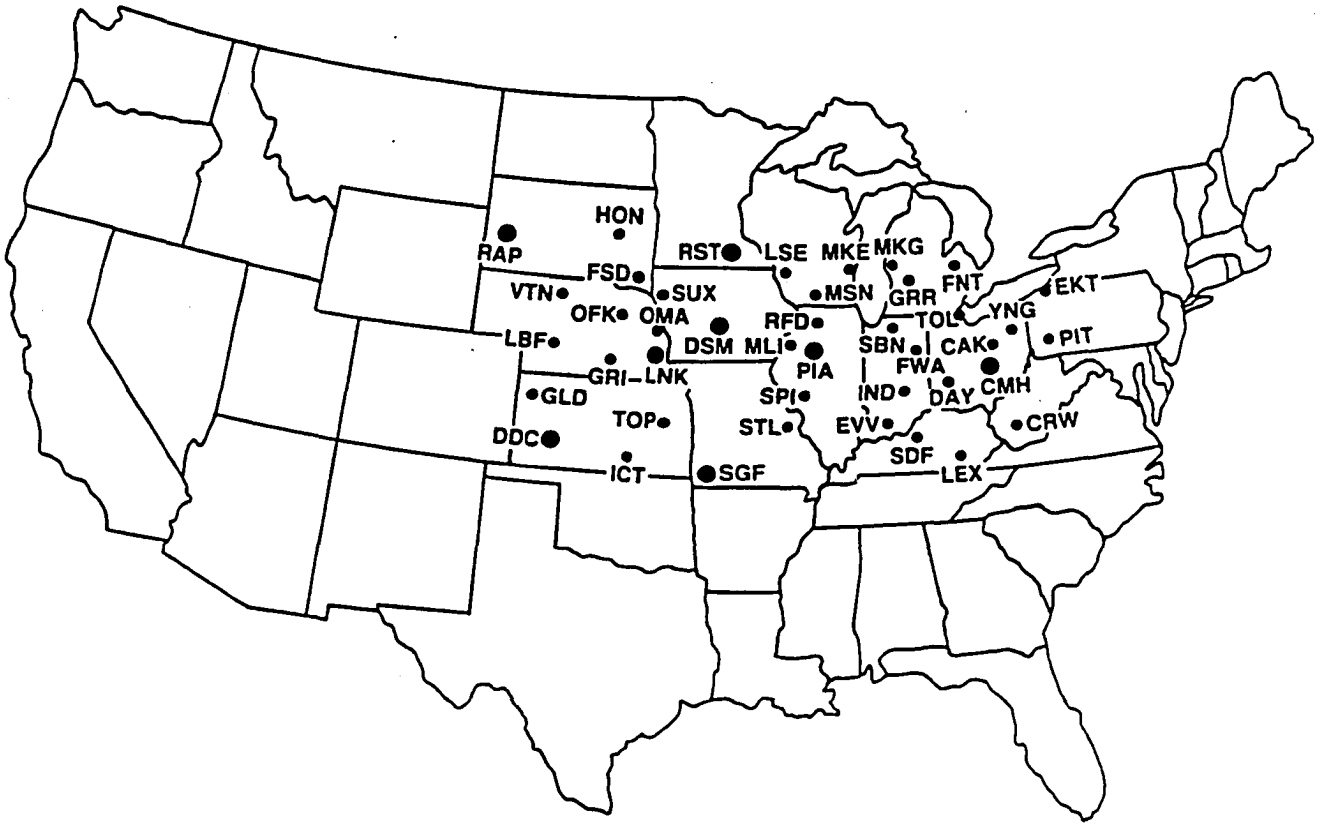
6. In spite of and because of Items 3, 4 and 5, within-season impacts are highlighted and sensitive periods can be identified.
7. Because of 6, information can be deduced by the climatologist/meteorologist so that better products, products which contain more information and greater value, can be produced.
8. As a result of 4, a general statement concerning the likelihood of return of "the summer of 1983" makes little simple statistical sense; however, some inferences can be drawn. The process model does allow the meteorologist to pin-point the major factor or factors contributing to crop failures about which probabilistic statements can be made.
9. Use of a two-way ANOVA model permits partitioning of contributions of within yield variability into leading weather effects and forecasted weather effects.
10. There appears to be more "information" in succeeding weather effects than leading weather effects.
11. The majority of yield variability comes from "runs" of weather rather than isolated week-by-week cases. The weather is highly correlated in time. This correlation is magnified when it is transformed into yield.
12. Climatologies which offer simple monthly or weekly means and standard deviations to the agronomist are inadequate.
13. There seem to be identifiable weather impact patterns in modeled yield and variability that could, potentially, be used in categorical agrometeorological forecasts and other user services.

14. Under the 2-way ANOVA layout, the process model output lends itself to the production of "skillful" conditional forecasts to which confidence limits can be assigned (see Section 3.5).

3.4 AN AGROCLIMATIC ANALYSIS OF CORN GROWING SEASON CONDITIONS: A 1983 U.S. CORN BELT EXAMPLE

The CERES model was originally tested by the author for Peoria, Illinois and later the tests were applied to seven other stations across the corn-belt. Then, by generalizing from these eight detailed studies, the model was used at other locations. Figure 47 is a map containing the sites of the other model executions. Each small dot indicates a location at which the process model was executed. Large dots indicate sites for which a sensitivity analysis was done as well. The model requires certain information as input parameters. Some, such as technology are fixed for all sites. Others, such as the weather, crop variety and cultural practice are site-specific. Table 27 contains the specifications of the seven corn varieties used and their characteristics. Two of the five are known varieties, the other five were "created" by calibrating the model output to reported yields and harvest dates under the guidance of agronomist Dr. Tom Hodges of AISC, Columbia, MO. Table 28 is a list of the weather stations within the corn-belt at which the model was run. The other items in Table 28 indicate the variety used, typical planting date, whether irrigation was used, and the model-generated harvest dates and yields which were calculated while assuming long-term normal daily temperatures and using a "representative" precipitation year for each station.

Figure 47: Map of Model Execution Sites.



The detailed Peoria and Rochester cases discussed in section 3.3 demonstrate that weather variability plays an important role in final modeled corn yield estimates at a point. The next extension is an examination of regional meteorological and agrometeorological patterns.

TABLE 27

Model Input Corn Variety Specifications.

Variety	P1M/1	P1D/2	P6/3	G2/4	G5/5
B73 x M017	172.	.700	700.	.060	8.5
P10 3780	204.	.000	600.	.060	6.6
6	204.	.000	550.	.060	6.6
7	170.	.000	500.	.060	6.6
8	155.	.000	475.	.060	6.6
9	204.	.000	600.	.060	5.5
10	172.	.700	700.	.060	6.0

/1 Accumulated degree days to point where the crop is sensitive to photoperiod.

/2 Genetic-specific coefficient that determines sensitivity to day length.

/3 Thermal time or summation of heat units between beginning of grain fill and maturity.

/4 Genetic-specific constant related to the number of grains produced - grains/gram.

/5 Genetic-specific constant for winter hardiness, or freez susceptibility.

TABLE 28

Corn Belt Station Locations and Model Input Parameter Values.

Station Name	Lat	Variety	Plant Date	Y/N Irr?	Impact Season	Maturity Date	Yield	Representative PCP Year
Springfield, MO	37.23°	01	135	N	20-35	247	92.2	1967
St. Louis, MO	38.75°	01	135	N	20-35	243	96.1	1973
Dodge City, KS	37.77°	10	136	Y	20-35	242	121.3	1957
Goodland, KS	39.37°	09	135	Y	20-35	252	126.8	1958
Topeka, KS	39.07°	01	125	N	20-35	241	85.2	1974
Wichita, KS	37.65°	01	130	Y	20-35	234	95.0	1967
Grand Island, NE	40.97°	03	130	Y	19-34	243	133.0	1960
Lincoln, NE	40.85°	03	130	Y	19-34	239	126.6	1956
Norfolk, NE	41.98°	09	132	Y	19-34	248	118.2	1957
North Platte, NE	41.13°	03	130	Y	19-34	260	166.8	--
Omaha, NE	41.30°	03	130	Y	19-34	238	125.0	1969
Valentine, NE	42.87°	09	132	Y	19-37	256	133.1	1957
Huron, SD	44.38°	06	135	N	19-37	266	94.3	1955
Rapid City, SD	44.05°	07	140	N	19-37	254	78.2	1972
Sioux Falls, SD	43.58°	03	130	N	19-37	260	102.4	1954
Rochester, MN	43.92°	07	135	N	20-36	265	107.4	1971
Des Moines, IA	41.53°	06	133	N	19-34	245	126.8	1965
Sioux City, IA	42.40°	03	135	N	19-34	250	83.1	1974
LaCrosse, WI	43.87°	07	140	N	20-36	249	80.2	1955
Madison, WI	43.13°	07	135	N	20-36	260	112.6	1967
Milwaukee, WI	42.95°	07	135	N	20-36	267	97.3	1974
Moline, IL	41.45°	03	130	N	17-35	248	128.0	1959
Peoria, IL	40.67°	03	124	N	17-35	242	119.8	1967
Rockford, IL	42.20°	03	129	N	17-35	262	117.5	1970
Springfield, IL	39.83°	01	135	N	17-35	250	110.5	1967
Lexington, KY	38.03°	03	130	N	20-35	239	90.4	1972
Louisville, KY	38.13°	01	130	N	20.35	240	96.9	1969
Evansville, IN	--	--	--	-	--	--	--	--
Ft. Wayne, IN	41.00°	03	128	N	19-33	256	97.4	1972
Indianapolis, IN	39.73°	03	127	N	19-33	243	118.1	1971
South Bend, IN	41.70°	06	128	N	19-33	255	117.7	1971
Flint, MI	42.97°	08	135	N	20-36	255	114.2	1970
Grand Rapids, MI	42.88°	07	135	N	20-36	255	117.4	1968
Muskegon, MI	43.17°	08	135	N	20-36	270	122.0	1968
Akron, OH	40.92°	07	145	N	19-33	262	101.3	--
Columbus, OH	40.00°	07	127	N	19-33	233	108.7	1971
Dayton, OH	39.90°	01	125	N	19-33	251	148.9	1971
Toledo, OH	41.60°	07	135	N	19-33	250	106.4	1972
Youngstown, OH	41.27°	08	145	N	19-33	268	128.3	1965
Erie, PA	42.08°	08	140	N	19-33	262	98.8	--
Pittsburg, PA	40.50°	06	135	N	19-33	261	110.8	--
Charleston, WV	38.37°	03	135	N	19-33	247	120.0	--

3.4.1 The 1983 Corn Growing Season: A Climatological Analysis

Consider two meteorological analyses of the corn growing season of 1983. No qualitative statement concerning the positive or negative impacts of these conditions on corn production is mentioned since, until an analysis of 1983 corn model results has been undertaken, such statements would be speculative. The term meteorological drought is used throughout these analyses. It is used here to define conditions exhibiting high temperatures and mild, moderate, or severe moisture deficit conditions.

The first analysis found in Wendland et. al. (1984) is a general one which includes corn production impacts but does not deal with them exclusively. A short excerpt from this article summarizes both the meteorological and economic impacts of this summer event.

> "Whereas June temperature was near normal across the region, July and August tempertaures were generally higher than the 1951-80 normal, with anomalies of +2 degrees C common, and some August anomalies representing a departure greater than 4 standard deviations. Cooling degree days were 50% greater than normal over about 1/3 of the 12 state area(the midwest).
>
> Precipitation was mixed over the area in June, with the greatest anomalies (ca. 200% of normal) in Illinois, Iowa, Minnesota, and Nebraska. July and August precipitation anomalies were similar to each other, and generally negative. Twenty-five percent of normal precipitation was not uncommon. Indeed, two stations in Nebraska and Missouri recorded no precipitation in August.
>
> The impact of high temperatures and low rainfall resulted in substantially less corn and bean yields than expected, but yields of wheat in Kansas, and corn in Wisconsin were greater than last summer. Electrical demand was generally higher than one year earlier, with increases of +15% to +25% common, and 60% greater this July than July 1982 in South Dakota.
>
> New climatological records of high temperatures, low rainfall, and number of days with high temperatures were established and reestablished during the summer, primarily in the southwestern Upper Midwest."

This summary provides a good overview of 1983 conditions, but now a slightly different meteorological and impact presentation directed exclusively at corn production will be developed. Weather parameter ranks rather than anomalies will be used to describe geographic patterns. CERES model output will be used to pin-point the most agriculturally important meteorological conditions during the growing season in the agrometeorological portion of the analysis.

Figures 48 - 50 were constructed to present a regional perspective for the 1983 corn impact season. Since the corn-belt extends over a large geographic area with many local variations, rank of 1983 weather over 36 years at a site, rather than absolute variable values have been mapped. In all cases the variables have been ranked from large parameter values (rank= 36), warm or wet, to small parameter values (rank=1), cool or dry.

Figure 48 illustrates the 1983 rank of the seasonal mean daily maximum temperatures using information generated at each point listed in Table 28 The most extreme high temperatures occurred in the northern one-third of Missouri, the northern one-half of Illinois and the southeastern quarter of Iowa. In these areas, the 1983 corn impact season ranked within the warmest 2 in the past 36 years. Moderately high season temperatures cover all of Illinois and Indiana and most of Kentucky, Iowa and Missouri. Parts of Kansas and Wisconsin are also involved.

Figure 49 illustrates the minimum temperature rankings for the 1983 corn belt impact season. The most obvious difference between figures 48 and 49 is in the rank patterns. The season mean high temperature ranks

Figure 48: Rankings of the 1983 Corn Growing Season Maximum Temperature.

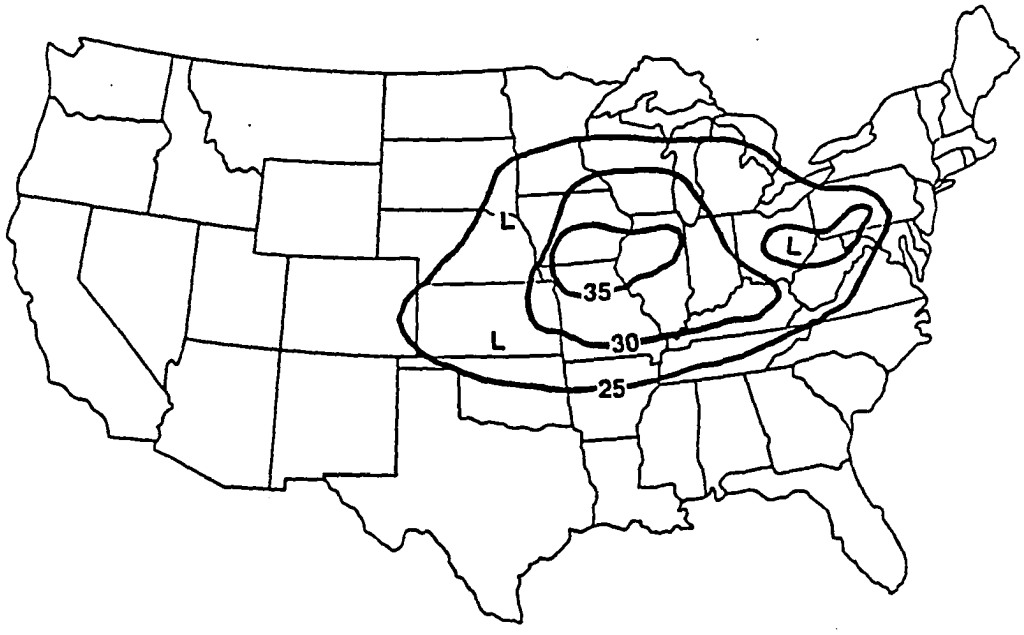


Figure 49: Rankings of the 1983 Corn Growing Season Minimum Temperature.

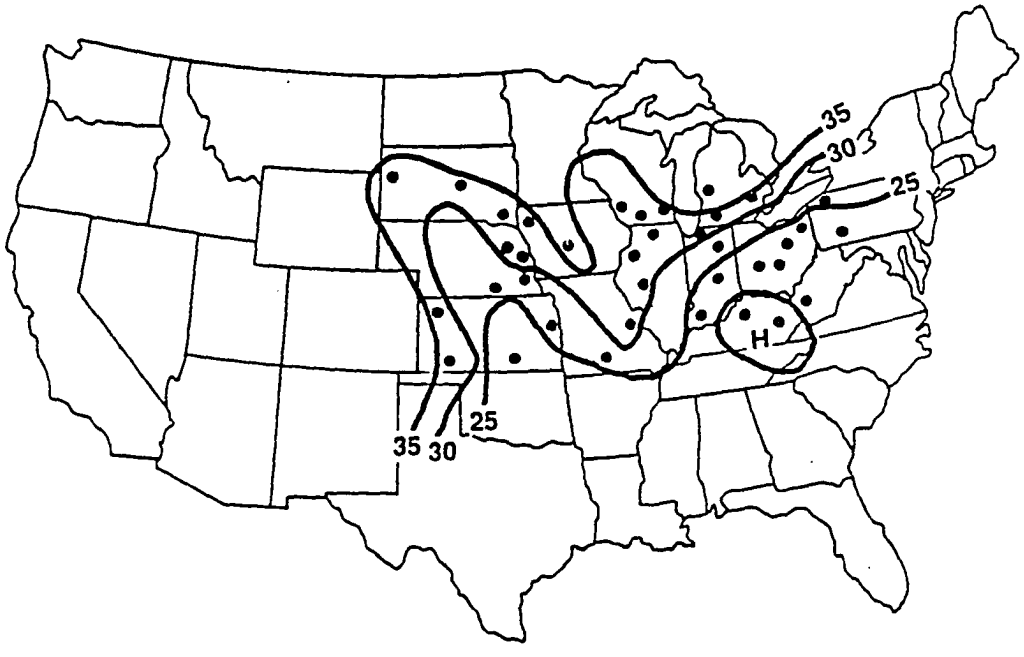
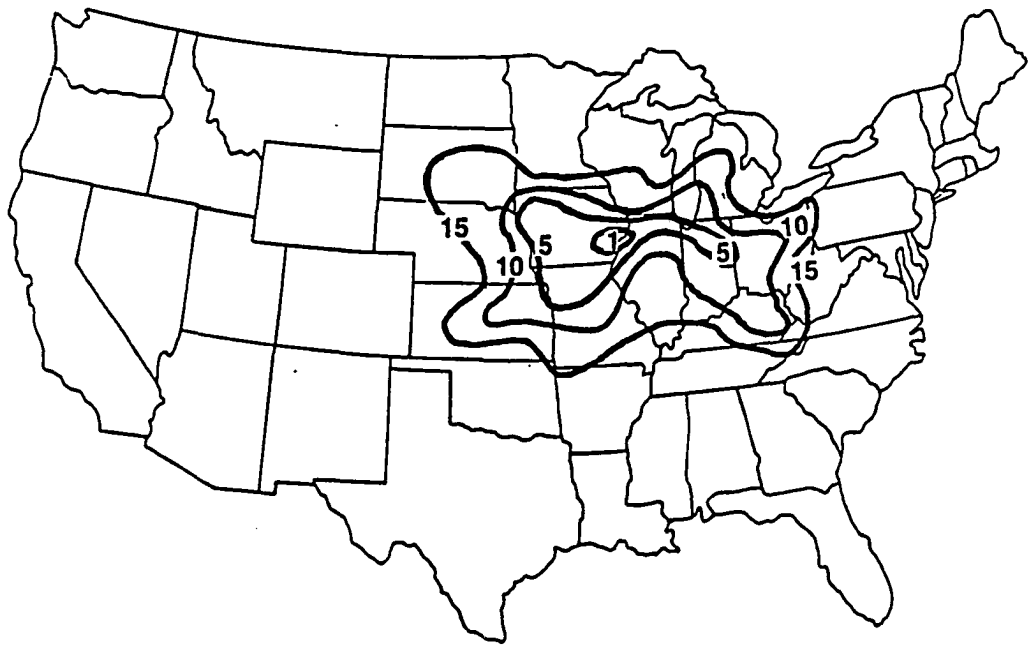


Figure 50: Rankings of the 1983 Corn Growing Season Precipitation.

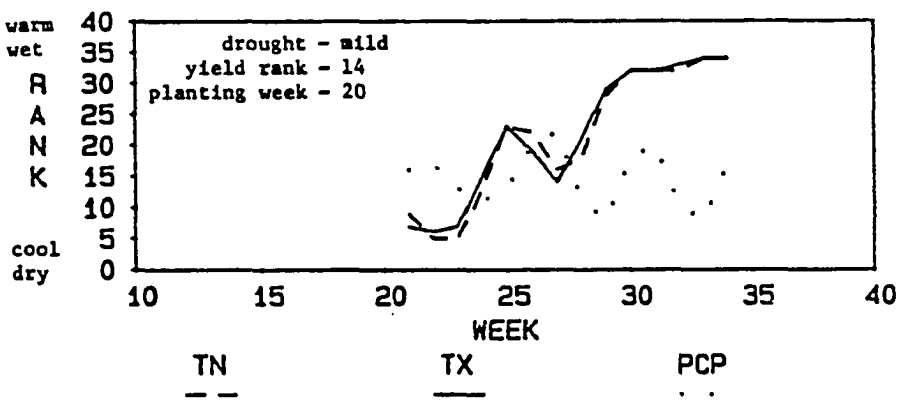


map into more or less concentric circles while the minimum temperature ranks exhibit more of a north-northwest to south-southeast gradient. The most extreme temperature rankings occur in the northern to central portion of the corn-belt.

Figure 50 gives the precipitation rankings for the 1983 corn-belt impact season. The seasonal precipitation pattern, as in the case of maximum temperatures, can be delineated by closed contours. There is a clear minimum rainfall area indicated by low rank values located in southeastern Iowa. This area experienced 36 year low rainfall in 1983. The area of next greatest stress, ranked within the driest five precipitation years, stretches east and west of ths location through central and southern Iowa, northern Missouri, northern Illinois and the northern one-third of Indiana. The pattern continues to spread elliptically east and west with a lesser north to south component through the other ranking categories.

The previous discussion has served to orient the reader regionally. But, as suggested earlier, total seasonal weather influences the estimation of corn yields to a small degree compared to within-season corn weather effects. An examination of within-season ranking patterns, then, would seem appropriate. Figures 51 - 59 are smoothed representations, similar to that already presented for Peoria, Illinois for the eight sensitivity sites(see Figure 47). These figures (51 - 59) were combined with Figures 48 through 50 to define the drought severity areas illustrated in Figure 60. The discussion which follows will refer to each station's classification on this figure as well as listing the 1983 estimated yield rank from Figure 62.

Figure 51: 1983 Weekly Ranked Weather Patterns for Springfield, MO.



Figures 54 and 58 are sensitivity analysis stations which lie outside the areas defined as those suffering meteorological drought. The two graphs have some similarities and some differences. The major similarity is seen in the rank patterns of maximum temperatures. Some similarity is also seen in the minimum temperature ranking patterns, but

Figure 52: 1983 Weekly Ranked Weather Patterns for Dodge City, KS.

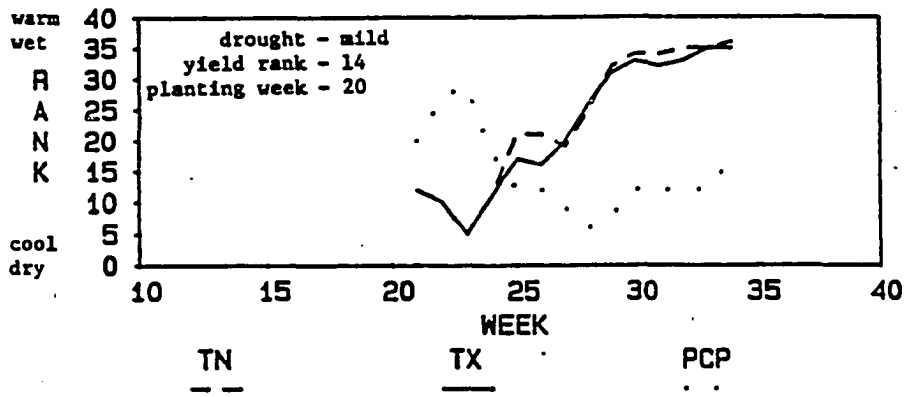


Figure 53: 1983 Weekly Ranked Weather Patterns for Peoria, IL.

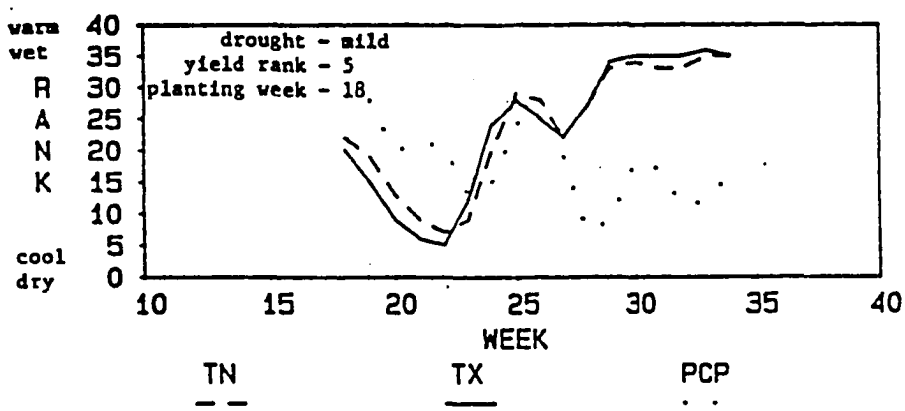


Figure 54: 1983 Weekly Ranked Weather Patterns for Rapid City, SD.

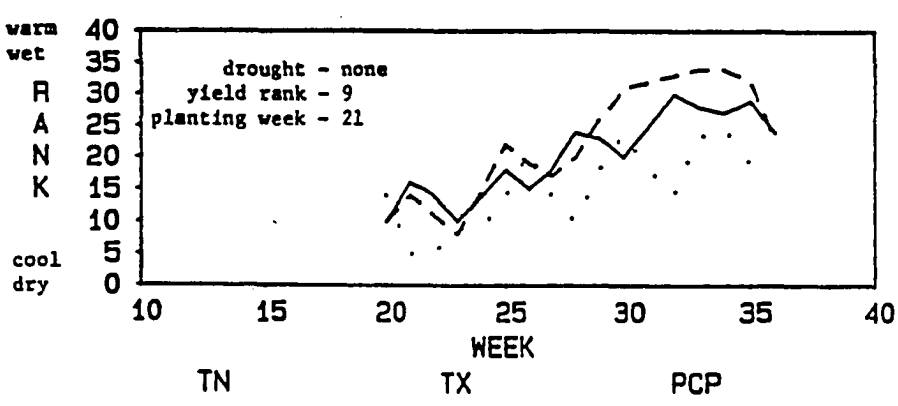


Figure 55: 1983 Weekly Ranked Weather Patterns for Des Moines, IO.

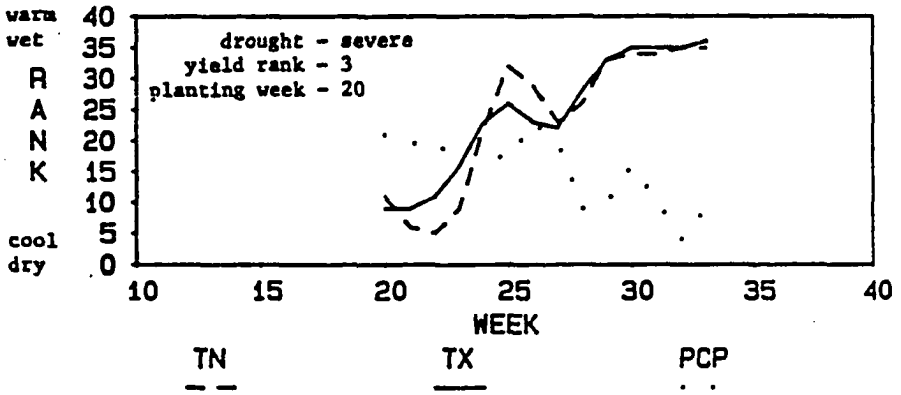


Figure 56: 1983 Weekly Ranked Weather Patterns for Indianapolis, IN.

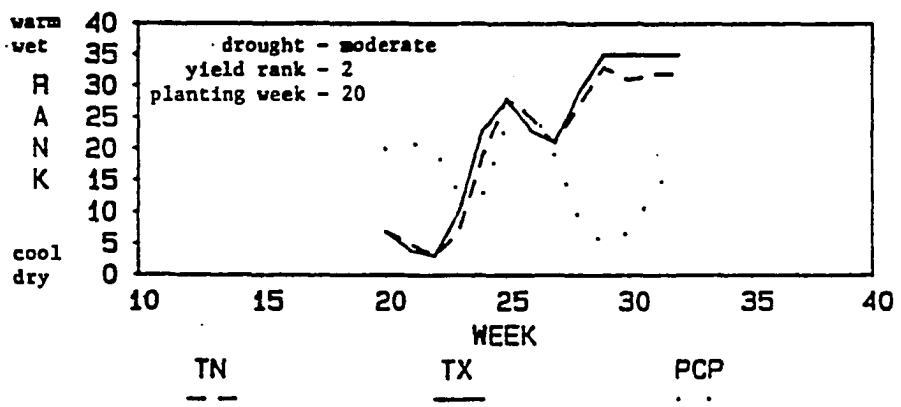


Figure 57: 1983 Weekly Ranked Weather Patterns for Omaha, NB.

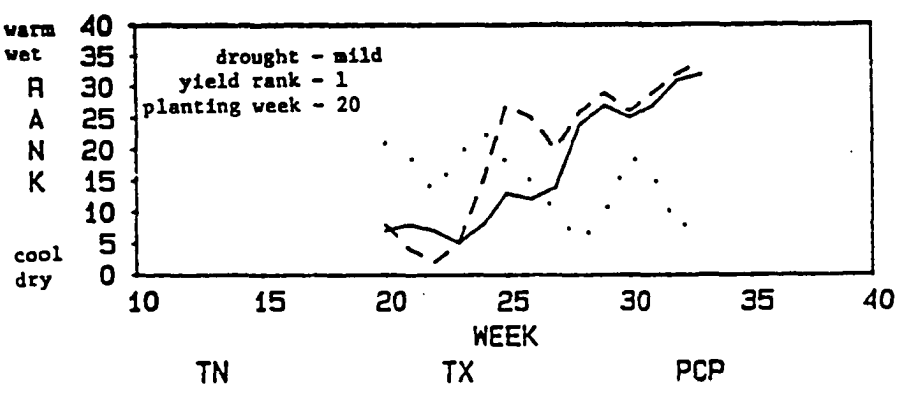


Figure 58: 1983 Weekly Ranked Weather Patterns for Columbus, OH.

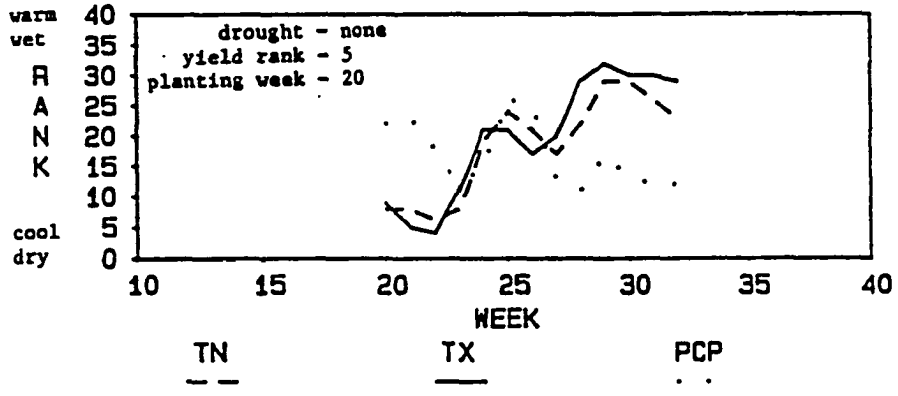
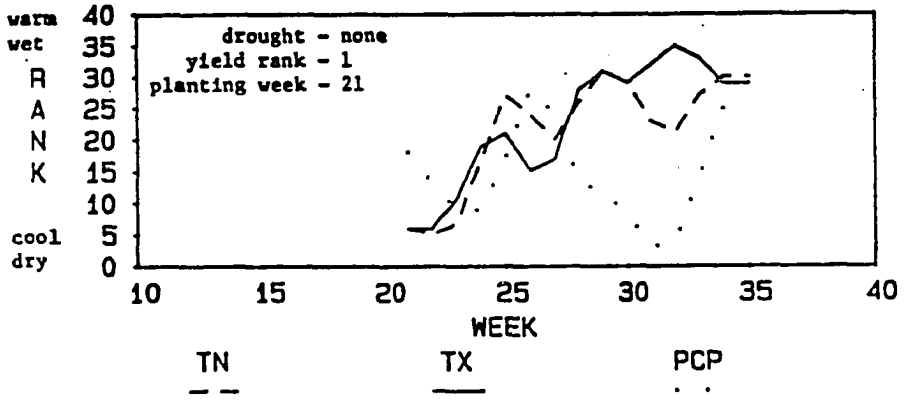


Figure 59: 1983 Weekly Ranked Weather Patterns for Rochester, MN.



not to such a great extent. The major difference between the two locations is the pattern of precipitation ranks. Rapid City is somewhat unique in the station set 51 - 59 in that it becomes wetter as the summer progresses. Columbus, Ohio, on the other hand, has a pattern similar to that of Peoria, Illinois, a mild drought case. This is not unexpected since Columbus lies quite close to these impacted areas, much more so than Rapid City. Using pattern comparison then, it can be noted that the major difference between areas of "no meteorological drought"

and "mild meteorological drought" is in the presence or absence of persistent high temperatures at the end of the impact season, not so much in a particular mid- or low-ranking precipitation pattern.

The next, and largest group of stations are Figures 51, 52, 53, 57, 59. These stations also have similar patterns which have been classified as mild meteorological drought. Peoria, Illinois, which was discussed in detail earlier falls into this group. All exhibit rapidly increasing maximum and minimum temperature patterns and static or declining precipitation ranks. Springfield in particular is a border site in that precipitation declines rapidly enough to warrant its placement in the next most severe category, but temperatures remain ranked slightly lower than at other locations.

Figure 56, Indianapolis, IN, is not one of our sensitivity stations but is useful to demonstrate the within year pattern characteristics of the next most severe meteorological drought category, moderate. Indianapolis exhibits much the same maximum temperature ranking pattern as the severe meteorological drought case (see Des Moines discussion below), but the minimum temperature and precipitation patterns differ significantly. Most notably, the minimum temperatures modify slightly the later portion of the impact season and precipitation begins to increase. Except for the final increase, the precipitation pattern is quite similar to that of Des Moines.

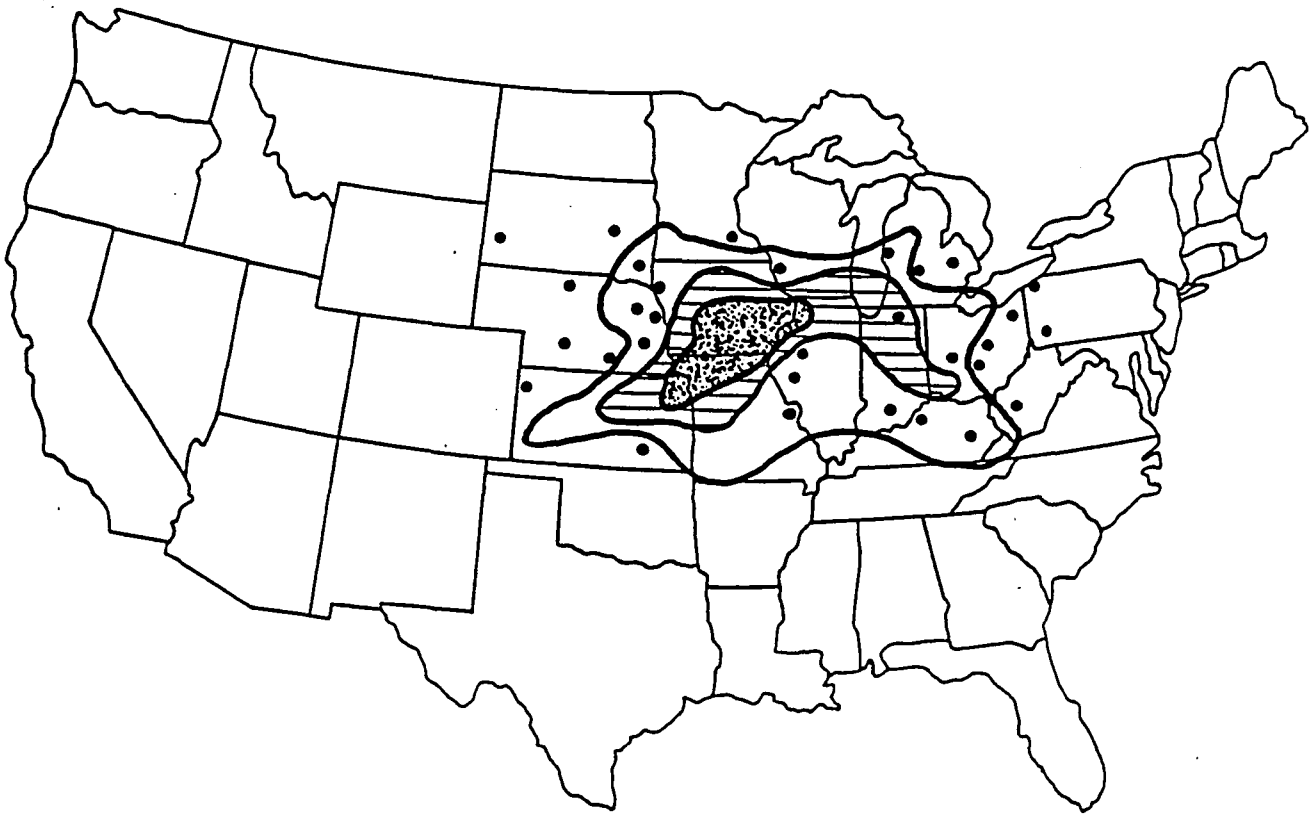
The final sensitivity station to be considered is Des Moines, Iowa. This station pattern should represent the most severe weather conditions experienced in the corn-belt during 1983. The precipitation rank pattern is not too dissimilar to the mild and moderate cases but is

shifted about five ranks lower. The major difference lies in the temperature pattern. The maximum temperatures reach their high extremes and remain there for five weeks (ranks 35 or 36). Most mild meteorological drought sites reach these peaks but then fluctuate until week 34. Des Moines also serves to point out another reason to consider both seasonal and weekly ranking. The Des Moines impact season ranks as third driest in 36 years. An examination of within season weekly rankings indicate an average rank of about 15. This suggests that weather-weeks considered in isolation may not indicate moisture problems, but "runs" of weather can result in devestating economic outcomes. Thus, the "runs" within Des Moines Weather patterns, i.e. a prolonged period of unusually high temperatures (five weeks) and a period lasting nearly the entire impact season of precipitation deficit, typify the severest extent of the 1983 meteorological drought.

Figure 60 represents a composite of Figures 48 - 50 and pattern similarities in Figures 51 - 59. It can be noted from Figure 60 that an area of severe meteorological drought extends over much of southern Iowa, the northern quarter of Missouri, a small portion of Illinois and the northeastern corner of Kansas. Moderate meteorological drought extends further east across the northern third of Illinois and all but southwestern Indiana. Moderate meteorological drought also extends further north in Iowa, slightly west in Kansas and includes the northern one-half of Missouri. In general, most areas of the corn-belt experienced at least mild meteorological drought during 1983. The exceptions being northwestern Kansas, the western two-thirds of Nebraska, most of South Dakota, Minnesota, Wisconsin and Michigan.

These results agree with a generalized composite of weekly Crop Moisture Index values published in the "Weekly Weather and Crop Bulletin" (USDA/SRS) between June and September, 1983.

Figure 60: 1983 Corn Belt Meteorological Drought



PRECIPITATION RANK < 5
AND TEMPERATURE RANK > 35 — SEVERE CORN DROUGHT

PRECIPITATION RANK < 10
AND TEMPERATURE RANK > 30 — MODERATE CORN DROUGHT

PRECIPITATION RANK < 15
AND TEMPERATURE RANK > 25 — MILD CORN DROUGHT

1983
CORN BELT
DROUGHT
(meteorological)

3.4.2 The 1983 Corn Growing Season: An Agrometeorological Analysis

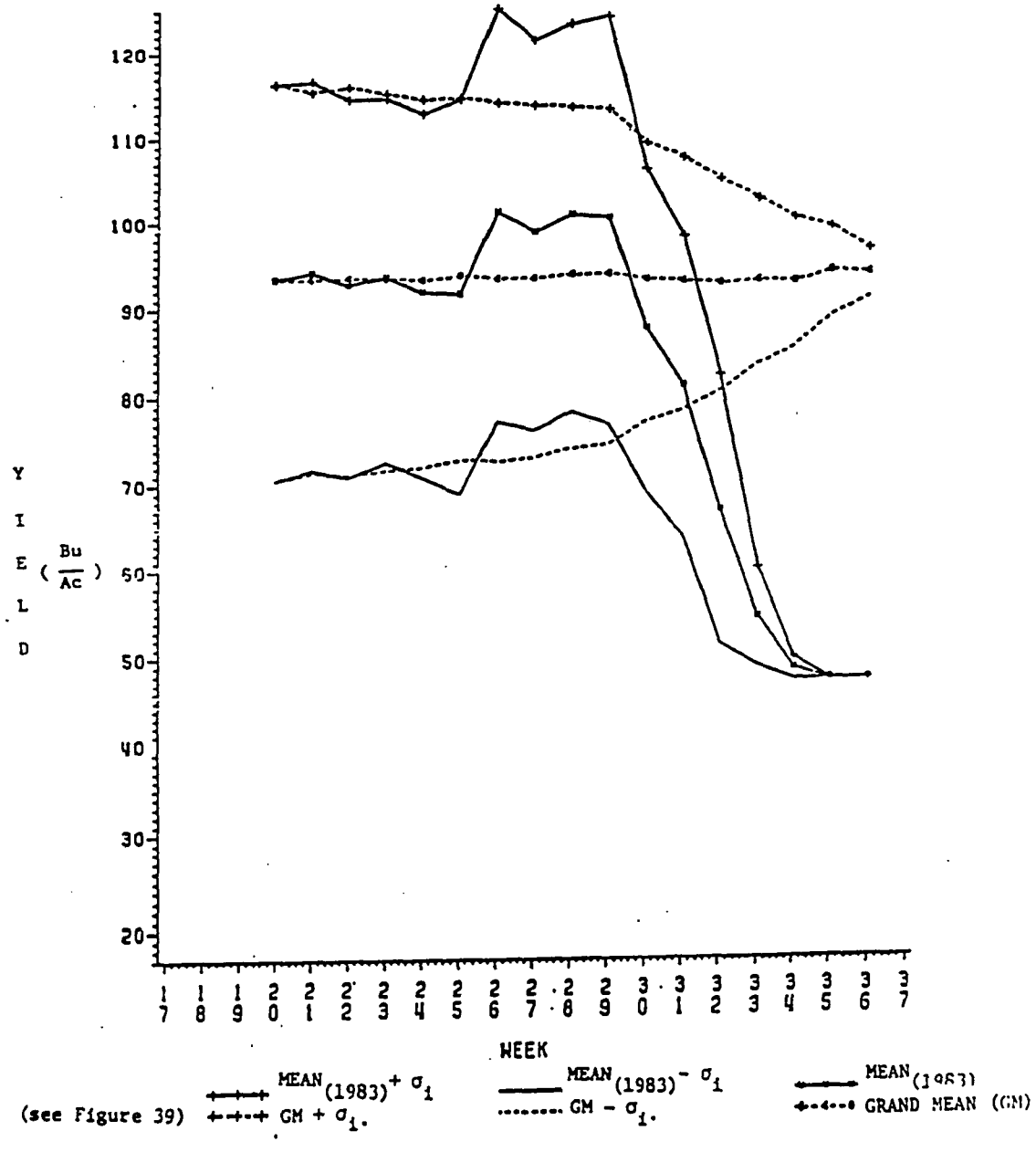
The next, and possibly most important step, is to link the meteorological analysis to agricultural output. One way is to consider graphs such as those described in the two-way ANOVA portion of Chapter III. Figure 61 contains the 36-year weekly mean modeled yield at Rochester, MN, the long-term variability about that mean due to subsequent weather and a corresponding set of lines specifically for 1983. The 1983 mean weekly yield is produced using the average of 1983 weather from January 1 to each week during the growing season followed by reported weather conditions for the remainder of the season for each of 36 possible growing seasons. The standard deviation lines represent the variability about each weekly mean. The graph indicates two specific periods of interest. The first is the period covering Julian Weeks 25-29. Referring to the graphs of within-season weather variable rank (Figures 51 - 59) for Rochester, it can be seen that this is a period of increasing temperatures and drying conditions. This follows a period of very cool, quite moist conditions. It could be suggested that the warming conditions during this time were not detrimental because of adequate moisture reserves, late occurence of flowering due to cool, early season conditions, and the failure to surpass certain critical temperature thresholds prior to week 30. Figure 61 indicates a rapid decline in yield between weeks 29 and 33. Again, Figure 59 suggests that both maximum and minimum temperatures were extremely warm and precipitation conditions were quite dry. Figure 61 shows a slight slowing of yield decline during weeks 33-35. This corresponds with a slight lowering of extremely warm temperatures in addition to being

beyond the physiological point of greatest suceptability to extremes of heat.

Also of considerable interest is the relationship between weather and yield on a regional basis. To accomplish this a ranking map of model generated yields, constructed in a manner similar to Figures 48 - 50 has been drawn (see Figure 62). In Figure 62, a low number represents a low relative (model) yield at a particular location. A higher value represents a larger relative yield per acre at a location. Figure 63 is a comparison of Figures 60 and 62. Rather than the most greatly impacted area simply becoming larger in Figure 63 than Figure 62, as might at first be anticipated, the entire impact area has shifted northward and expanded westward. Although somewhat surprising, this difference could have been anticipated from the earlier analysis of the components of variance at Peoria and Rochester. Figure 63 was constructed from impact season values of temperature and precipitation. As discussed earlier, the majority of yield variability is explained by correlated within-season weather patterns. The observation that the 1983 growing season values were not more informative is surprising only from the point of view of a meteorological definition of drought.

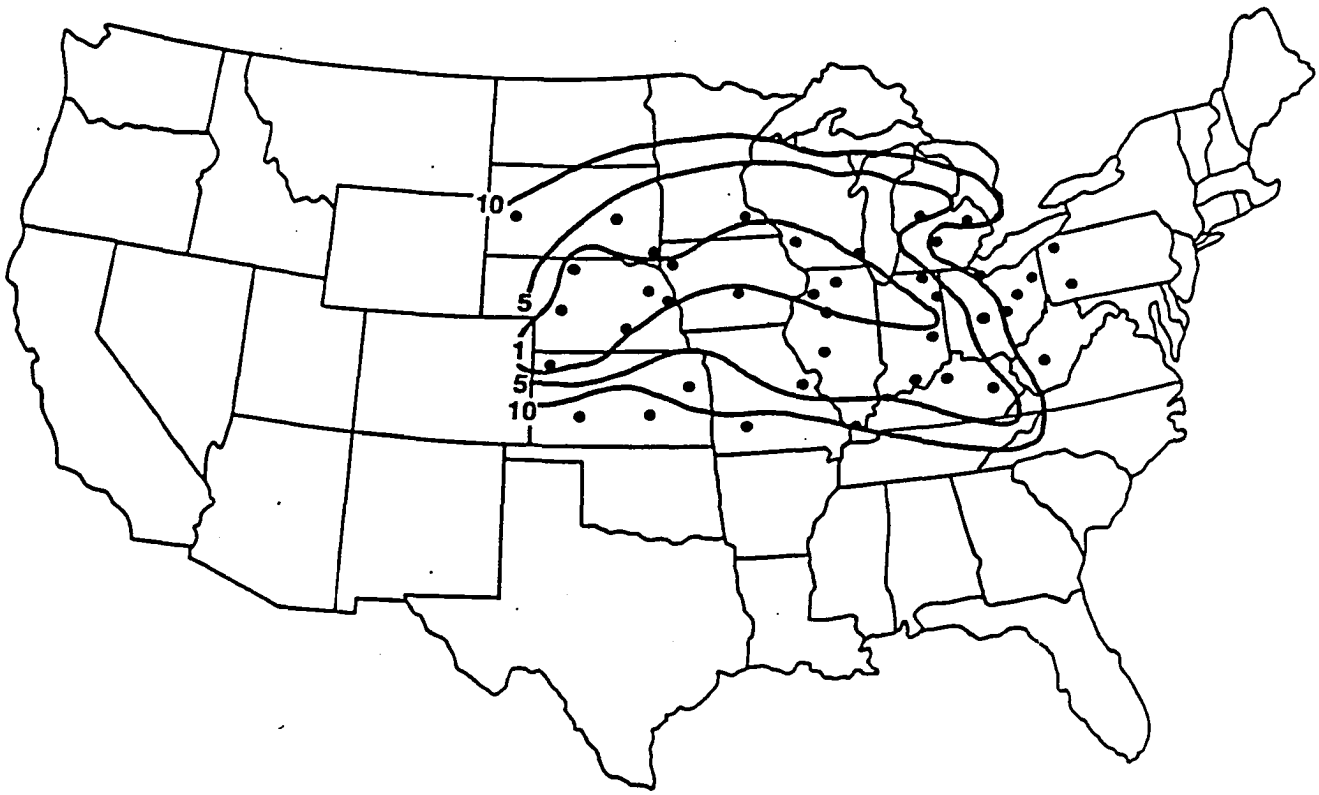
At the Figure 63 severe drought locations, moisture deficits and temperature extremes exist for prolonged periods of time. Yet, this does not appear to have a direct bearing, even in a lagged time sense on final corn yield. Therefore, it can be concluded that the modeled yield impacts used in this analysis are the result of an agricultural drought, or some very brief phenomena lasting for only a short period of time rather than the meterological drought defined by Figure 60. If this is

Figure 61: 1983 and Long-Term Rochester Weekly Mean Yield and Following Weather Variance



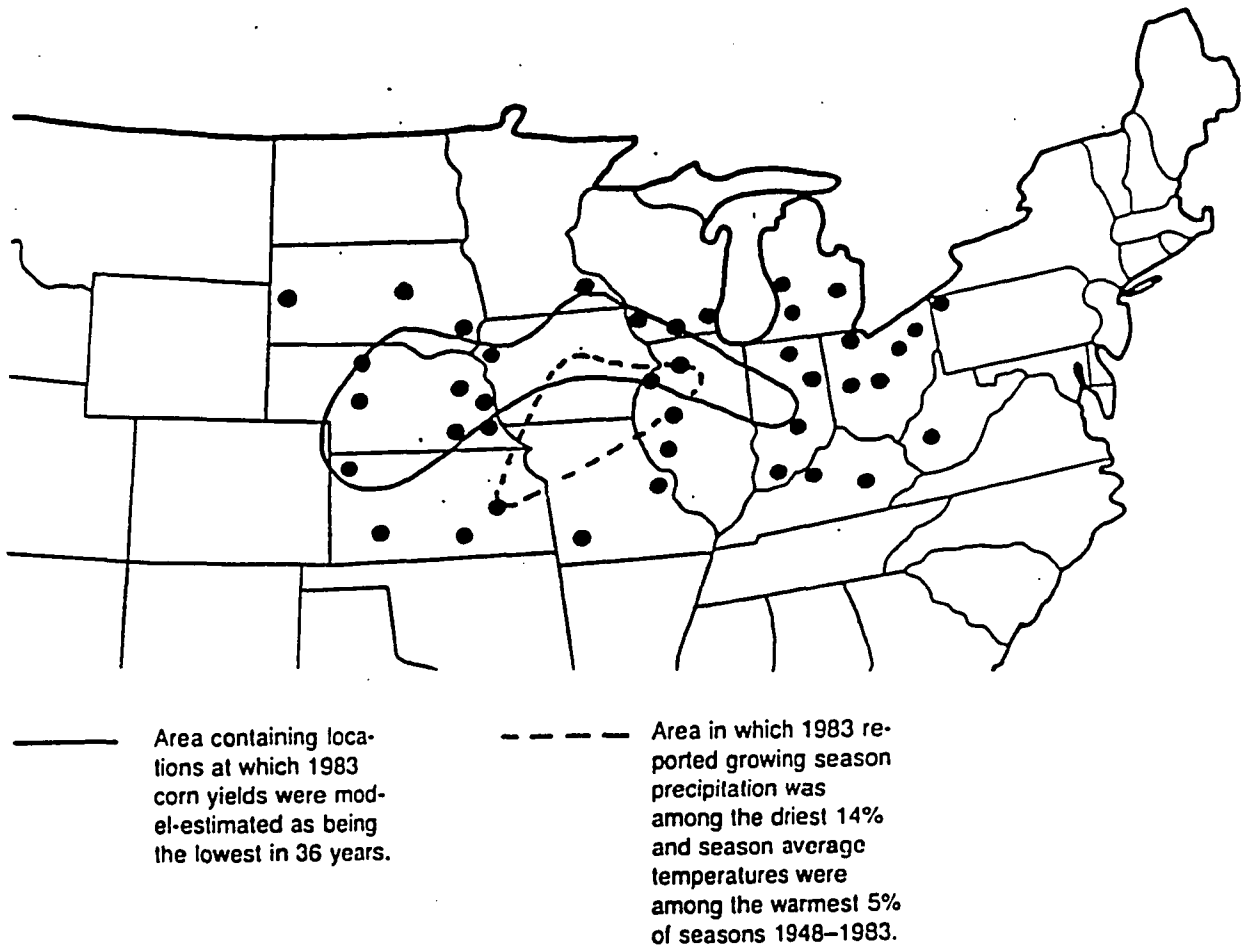
(see Figure 39)

Figure 62: 1983 Corn Belt Agricultural Drought



the case, Figure 63 also provides information concerning the value of the way in which many meteorologists presently address handle agricultural drought. One widely used measure of agricultural drought is the Crop Moisture Index. This is meant to be a responsive agriculturally oriented index calculated on a week by week basis. Although calculated for a crop reporting district rather that a specific location, the overall drought severity patterns generated by the two methods (CMI and season rankings) agree. Thus, there seems to be a gap between what the meteorologist might think of as an agricultural product and a product containing real agricultural information. The observation that an index indicated that plants should be under stress is of general

Figure 63: 1983 Corn Growing Season Weather and Modeled Yields



interest but what would seem of most value is how the plant is reacting to the stress at any particular time. CERES model output indicates that the fact that more southerly areas were under more severe and prolonged meteorological stresses than northern areas had little impact on the modeled yields. When the greatest crop stresses occurred in the south and east, the model predicted that the corn plants were already past their critical stages and so, although negatively impacted, they were not affected as much as the northern and western plains areas. One

alternative to these traditional and apparently less than optimal ways of presenting meteorological data would be to produce crop specific and phenologically sensitive crop/weather products. Perhaps something as simple as overlaying a graph of reported (or model estimated) crop stage onto the traditional CMI maps or weighting CMI by a reported percent of crop in certain known critical crop stages could be done. The basis for these suggestions, some meteorlogical forecast value implications and other agro-meteorological information products will be discussed in the sections which follow.

Before leaving this portion of the report, there are some pertinent observations that can be made concerning the response of this process model to climatological impacts. The process model used appears to be a state-of-the art agronomic product. The analyses which were performed indicate that although the yield means are shifted over time, the model tracks the reported small area yields well. A Kolmogorov/Smirnov test verifies that there is no significant difference between the distribution of modeled and observed corn yields. The model responds to temperature variations throughout the growing season, but its response to variations in precipitation seem to be more limited in time. The option to simulate freeze damage operates quite well, but a corn blight or other climate influenced pathogen infestation subroutine might prove an important addition. There are some difficulties found when the point model is used to represent an area. One problem stems from the selection of model constants such as plant variety and soil type. In this research all corn is assumed to be grown on sandy loam soil. Although this is the soil type of choice for corn, often there is none

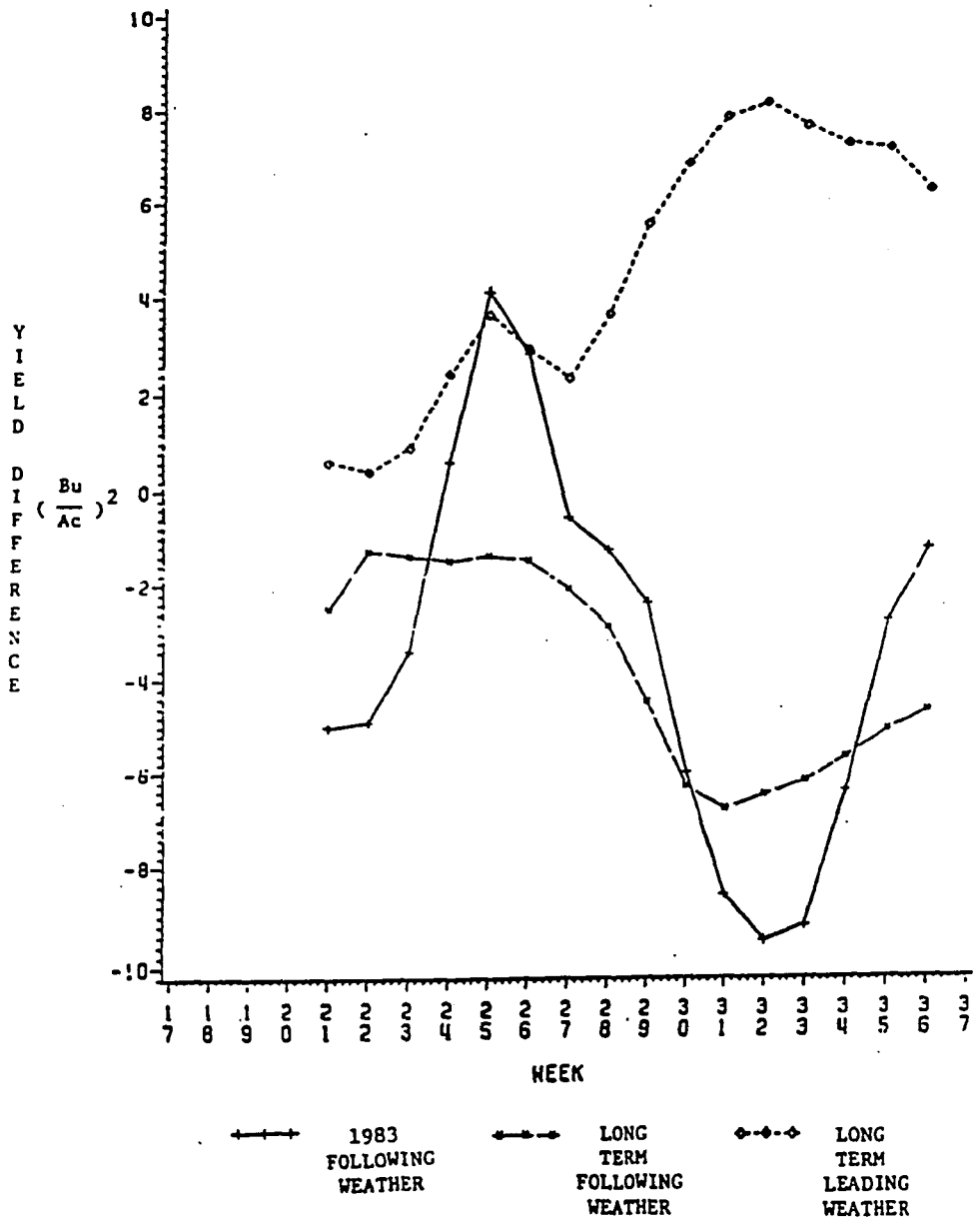
available to use. Additional problems arise when one is considering areas where dryland and irrigated agriculture are practiced side-by-side. Although considerable care should be used when applying the results of the model to other locations or to crop years other than 1983, the model distribution does appear to track reality so that its use as a crop growth indicator but not as an absolute yield forecast would be in order.

One reason that this model readily lends itself to area estimates is that it is driven more by temperature than by precipitation conditions. Aside from dramatic geographic influences, temperature exhibits much larger scale or smoother distributions in space than does precipitation. Thus, errors in precipitation estimates result in smaller errors in area-analyzed model yields than if a more moisture sensitive model were used. Still, an extremely critical issue is the selection of accurate, representative stations and their geographical density. Although in the past decisions concerning station selection were based on largely personal knowledge of the area or by trial and error, statistical techniques have been developed specifically for use in network design. The objective of these techniques is to determine the smallest number of stations needed to replicate accurately the phenomenon that is to be studied. The only criterion is that it be possible to describe the phenomenon numerically. The mathematical results then can be applied to existing networks or in the consideration of future network sites. Further information concerning these methods and their practical application may be found in Eddy, Panturat and Avara (1984).

Only selected crop growth factors have been considered in the analysis performed to date. One factor which was not considered in detail was the impact of planting date. From a few preliminary examples it would appear that, especially in borderline corn growing areas, a delay in planting date by as little as one week can mean the difference between harvesting a crop and having insufficient heat units to mature a crop at all. A far more detailed analysis of this issue may be found in Dillon and Gwin (1976). This factor should receive further attention in future studies.

In addition to allowing agrometeorological analyses of economically important events such as the 1983 corn growing season, the information provided by this model and a climatological data set can be used by meteorologists making agricultural forecasts in at least two major areas, type of forecast made, and time of year of concentrated forecasting effort. At present the Climate Analysis Center issues a number of mid- and long-range forecasts for the United States. Although major improvements are constantly being made on all forecasting scales, funds for such improvements are limited. If one were interested in making agricultural forecasts, it would be helpful to know which time-frame (forecast) was of greatest economic value. In this case value is defined as a decrease in uncertainty of yield estimate. Consider the week-to-week variability differences at Rochester, MN illustrated in Figure 64 and the statistical results presented earlier. First, within season weather patterns (runs) generate far more final yield variability than the growing season taken as a whole. In 1983 it was the weather between weeks 27 and 33 that was of greatest importance. Of these

Figure 64: Weekly Deviations from Mean Model Yields Attributed to Long-Term Leading, Long-Term Following and 1983 Following Weather (see Eq. 21).



weeks, Weeks 30 to 34 impacted yield variability more than normally expected. And of those five weeks, Week 32 was the most important. This would indicate that in 1983 at least, a skillful categorical forecast of perhaps 60 days length issued at Week 26 would have been quite valuable. A valid 30-day forecast issued at Week 28 would have been extremely valuable because by mid-July corn growers know if they are in trouble but have no way of turning a forecast of above normal temperatures into an additional gain or loss of X bu/ac. A skilled valid 20 day forecast for the period of Weeks 31-33 would have had the most economic value during 1983 in terms of determining the final yield outcome (see also Duchon, 1984).

Yet, "skillful" long-range forecasts still have an important place in this example. For instance, many on-farm decisions require extensive lead times. Skillful forecasts of simply normal, above normal, or below normal conditions can be quite beneficial (see section 3.3). Also, the model always requires weather information for the entire growing season. Once day-by-day forecasts are no longer "skillful", forecasts which contain statistical skill over random guesses (conditional probability forecasts) could prove very valuable.

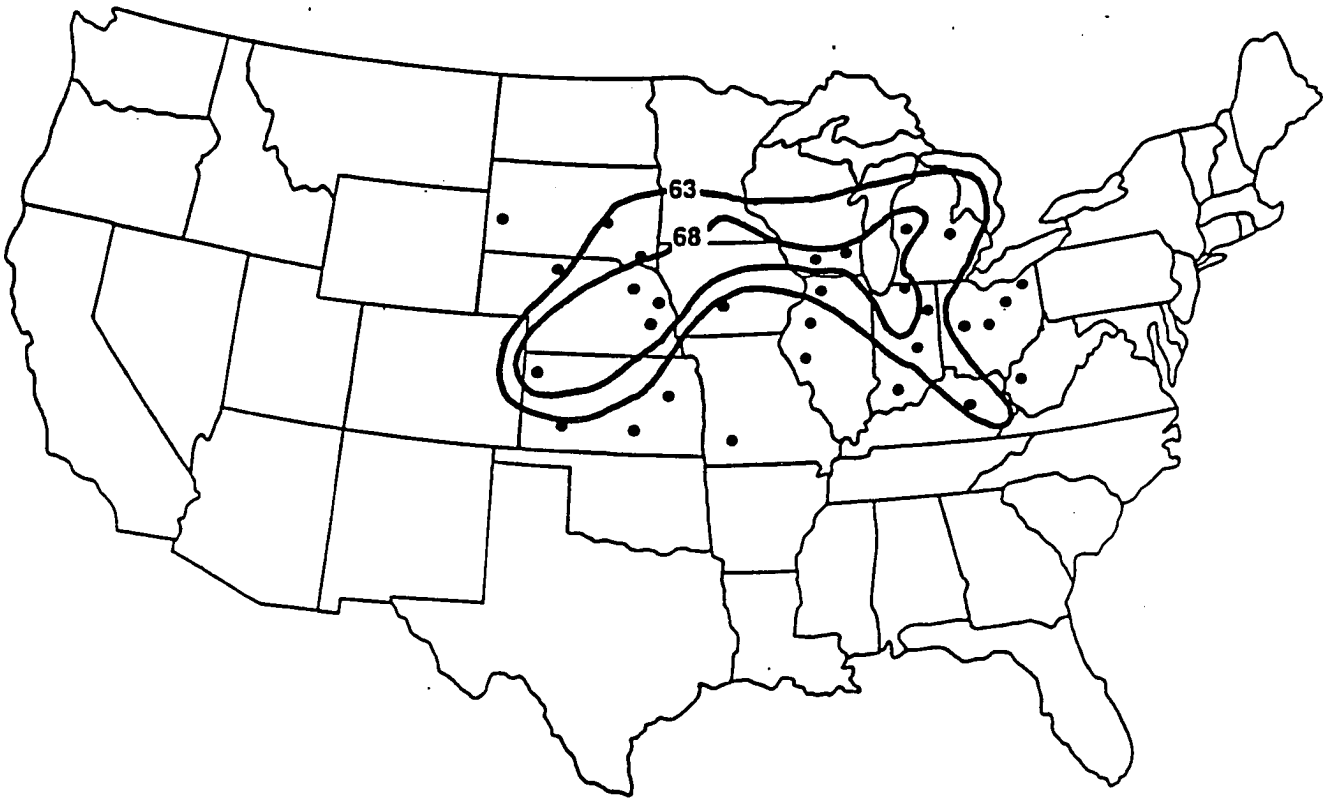
A second use of the modeled output refines the cost/benefit statement made above even further. Of course forecast personel time and efforts directed towards corn weather forecasts could be minimized during the "off" season, but an even more exact statement can be made. Sensitivity analyses show that slight to moderate corn impacts occur at Peoria throughout the impact season, but by far and away the largest impacts (the most critical forecast times) Julian Weeks 25-31 for

precipitation, Julian Weeks 26-29 for minimum temperature and Julian Weeks 18-24 and 28-31 for maximum temperature. If agricultural forecasts for these periods can be improved, they will result in the greatest economic benefits. This information, if related to plant phenology, can be expanded to a regional scale.

Figure 65 is a rank map, similar to those generated earlier in this report. This Figure indicates that during 1983 if correct flowering weather rank only (not absolute maximum and minimum temperatures) had been forecasted during Weeks 27, 28, or 29 depending on corn variety and location, then much of the impact area delineation error noted in Figure 63 would have been eliminated (see Figure 66).

Although it is unrealistic to imagine that this particular stage and these particular weeks will always be the determining factors, Figure 66 does serve to illustrate the fact that a knowledge of the customer's needs and sensitivities, in this case corn during flowering, can result in a far more informative and valuable product than an uninformed application of meteorological principles and definitions. A much more detailed discussion concerning the potential value of corn weather forecasts is discussed in Duchon (1984). A more detailed discussion concerning the development and use of statistical probability forecasts of modeled corn yield at a point and over a region is presented in section 3.5.

Figure 65: Flowering Weather Index for 1983.

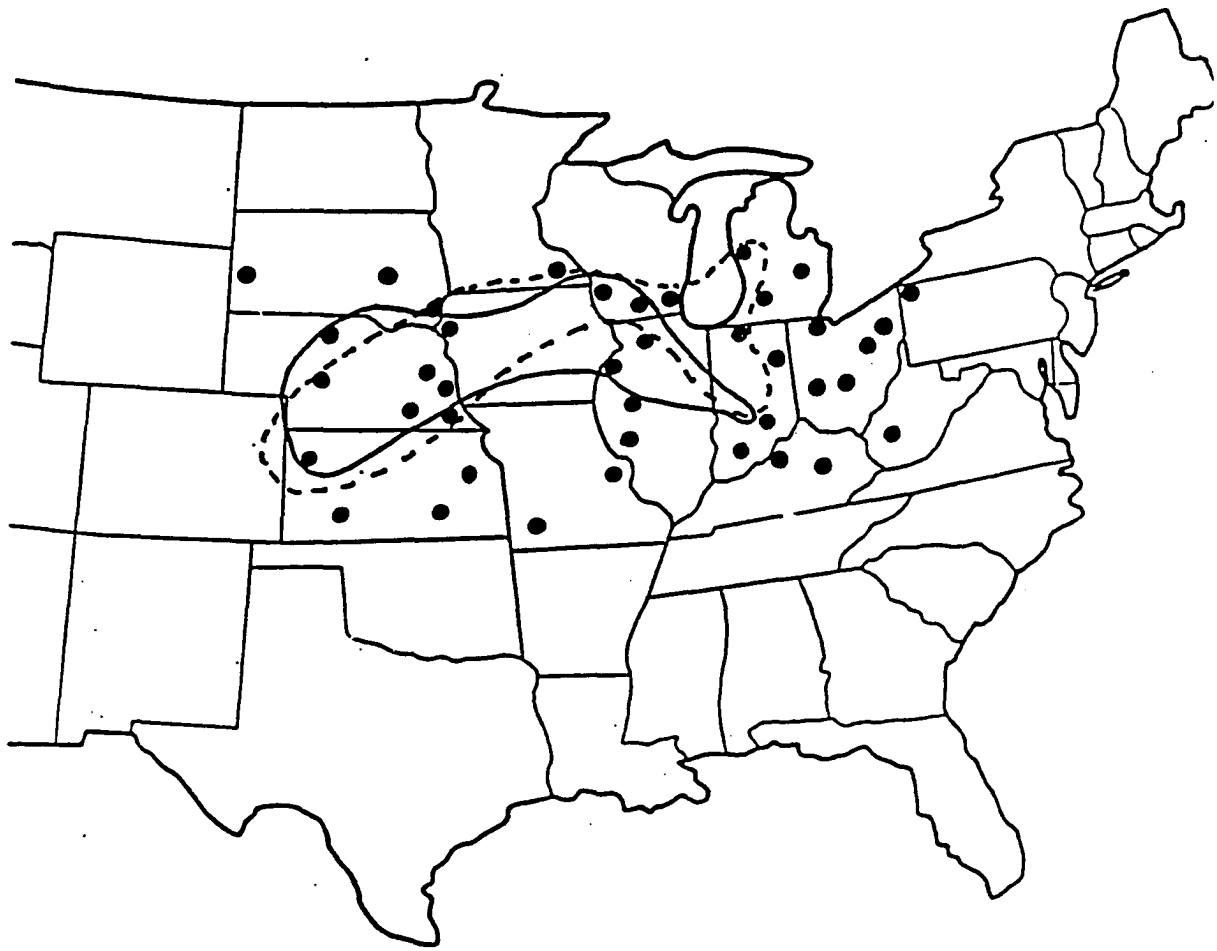


Index = $Rank_{TX}$ + $Rank_{TN}$ during flowering

where: flowering (varieties 1 and 9) = (Julian Day of the end of vegetative growth)/ 7

flowering (all others) = (Julian Day of the end of vegetative growth - 7 days)/ 7

Figure 66: 1983 Flowering Weather Index and Model Predicted Yields.



——— Area containing locations at which 1983 corn yields were model-estimated as being the lowest in 36 years.

– – – – Area in which a flowering temperature index, a combination of maximum and minimum temperatures, indicates the 36-year extreme conditions during 1983.

3.5 AGROCLIMATOLOGICAL PRODUCTS FROM THE CERES CORN MODEL

Results produced by the CERES model as well as through the analyses performed in sections 3.3 and 3.4 suggest a variety of econoclimatic products; e.g., climate products which can possess value and address a sector of economic activity such as agriculture. Several examples of

such products will be presented and discussed. All have been produced using observed input data and crop models that are in hand and operational. This is not to say that each product has significant value in its present form. Some items, the corn/weather index for instance, need substantial refinement. The basic idea or methodology is sound, but improvements in the quality, reliability and stability of the results are necessary. Others, such as the likelihood or recurrence maps, contain sufficient accuracy to be of value as they stand. Many of these products focus on answering questions raised by such anomalous events as the 1983 corn growing season.

3.5.1 Pre-Season Climatological Products

One question that might be raised is, "How unusual were 1983 corn growing season weather conditions?" From a climatologist's perspective one product could be represented by Figures 48 - 50. Assuming independence, this summary provides information about how extreme each individual climate variable was, but does not provide information about how often the specific combination of interrelated growing season variables are encountered. One answer can be generated by first calculating state planted acreage, which will be used to compute weighted seasonal averages of maximum temperature, minimum temperature and precipitation. If the frequency of individual station reported growing season conditions that are as warm or warmer and as dry or drier than the regional values are determined, the point weighted values can be transformed into probability estimates. An example of such a product is Figure 67.

Figure 67: Likelihood of 1983 Growing Season Temperatures or Warmer and 1983 Growing Season Precipitation or Drier Recurring.

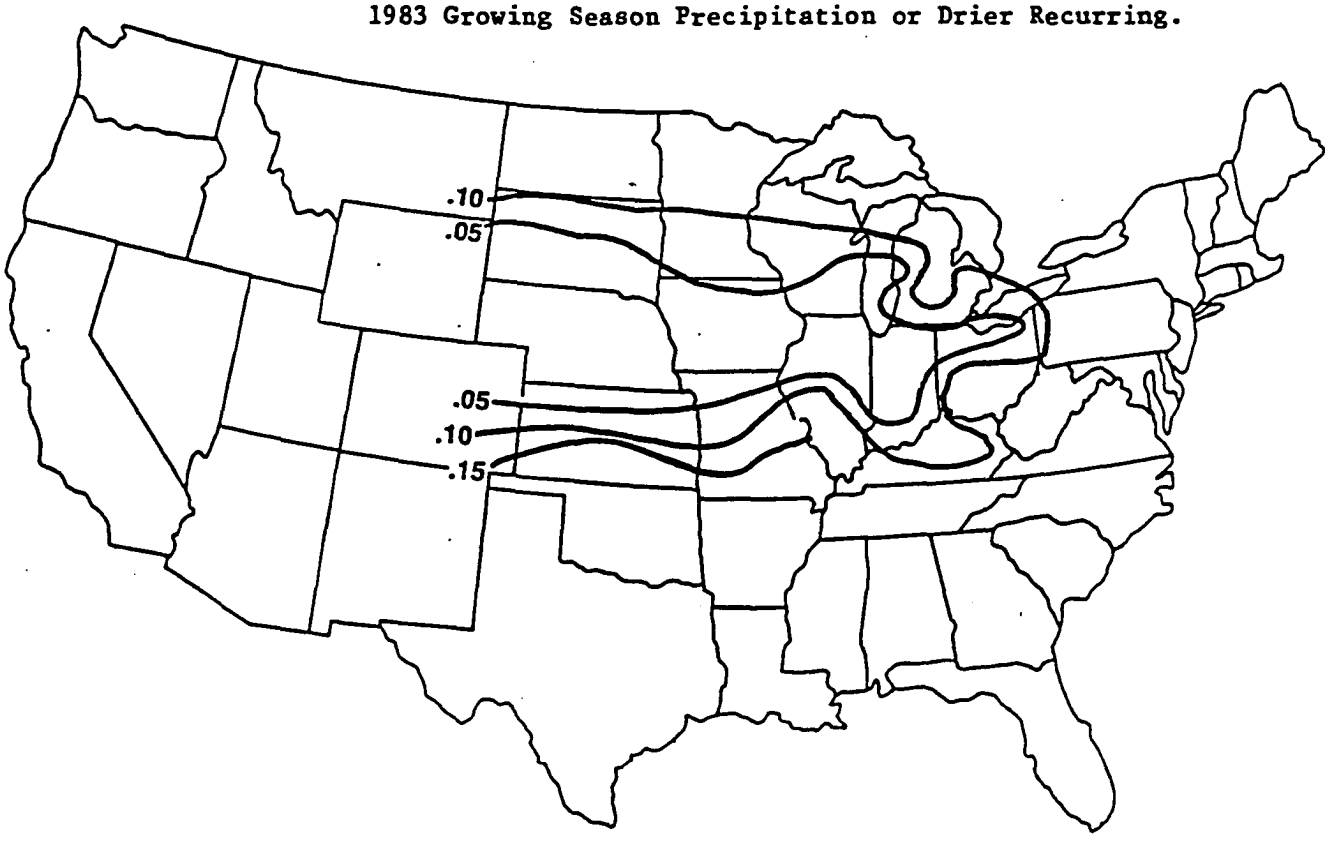


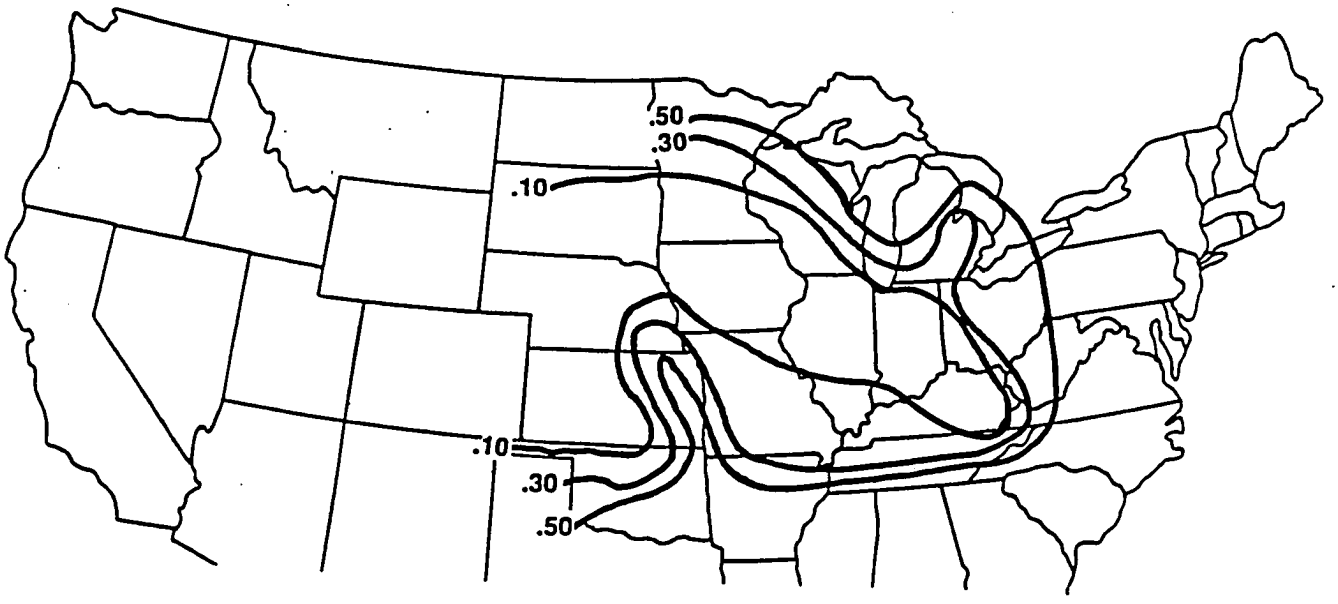
Figure 67 illustrates that 1983 growing season weather conditions were most unusual in the central portion of the corn-belt, extending from eastern Ohio to western South Dakota and Nebraska. 1983 possessed the warmest and driest growing season in 36 years of weather records at 20 of 22 stations in the area with the lowest recurrence frequencies. The southern portion of the corn-belt experienced stressful, but less unusual, weather during 1983 with these or more severe (hotter or drier), conditions reported slightly more often than 5 in 20 years at Dodge City and Wichita Kansas.

Of interest to climatologists is that the majority of variability (i.e., yield impact) lies within the growing season. It has also been

noted that due to the correlated nature of weather variables, consideration of within-year climate variability becomes very difficult. Further, if the customers were climatologists, Figure 67 might suffice, but more likely the customer is someone interested in crop productivity. More precisely, he would be interested in low yield occurences regardless of whether these were due to 1983 patterns or to other weather phenomena. Both requirements can be met through the use of the CERES process model. The model converts correlated within-season weather patterns into meaningful information and, simultaneously, allows one to express the model results in terms of an impact that is of interest to the customer. The process of finding area averages and counting values as low or lower than these, is used in Figure 68 for yields as it was for the weather variables displayed in Figure 67. It is important to note that no emphasis is placed on actual yield values; i.e., no statement depends on the absolute correctness of the model predicted value. Since the resultant product is soley dependant on the yield distribution which has already been demonstrated to be not dissimilar from reality, the product should be valid. Further, the customer is interested in the general category of low yields, not only those generated by conditions similar to those of 1983. The acreage weighting method described above would also meet this requirement. The final product is given by Figure 68.

Figure 68 exhibits an interesting pattern which loosely resembles Figures 67 (yield ranks) and 65 (flowering index). This is not surprizing since an extremely low or high yield rank as used in Figures 67 and 65 would be associated with a small likelihood of recurrence of a

Figure 68: Likelihood of 1983 or Lower Yields Recurring.

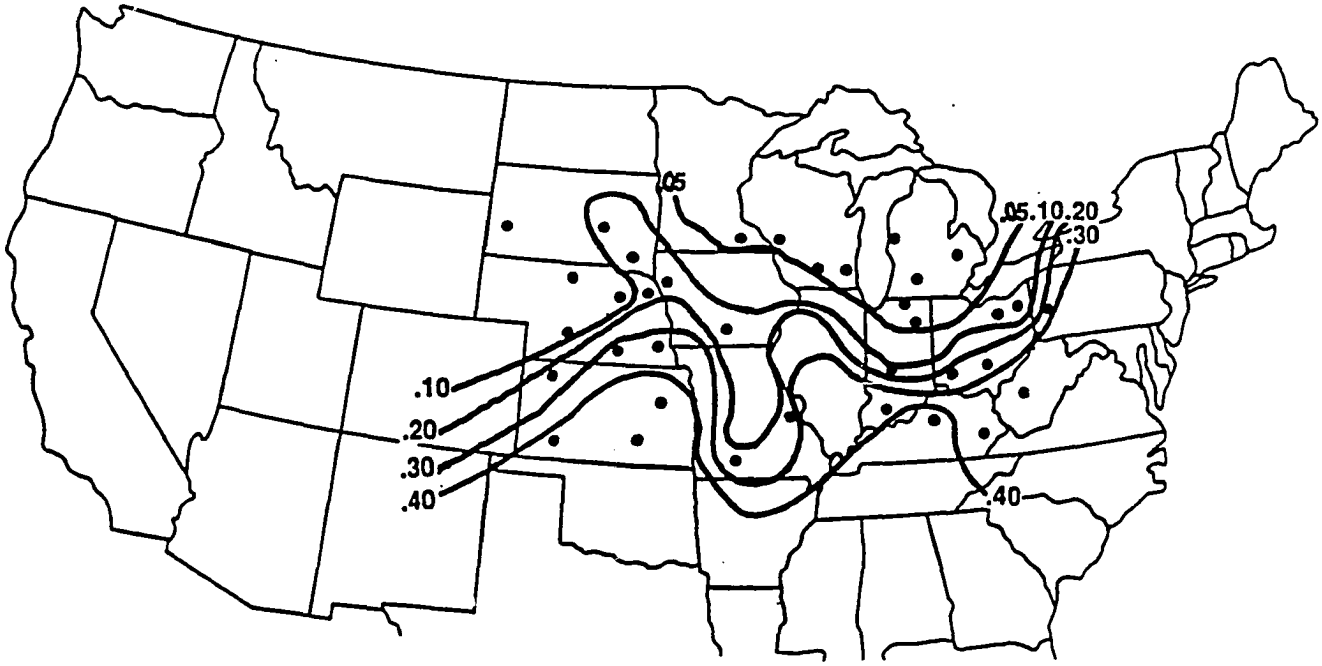


more extreme value. Though similar, the information contained in Figure 68 is not an exact repetition of the earlier maps. For instance, the station frequency counts were taken by comparing a point value to the average of many points in an area rather than a single station. Also, rather than saying "1983 yields ranked 5 out of 36 years at Peoria, Illinois", we can say, "yields as low or lower than those achieved during the 1983 growing season can be expected 10 or fewer times in every 100 years in the northern two-thirds of Illinois." The actual weighted results at Peoria indicate that only three percent of the time would one expect these or lower yields. This illustrates the difference between an unweighted likelihood (5/36 or 14%) versus a regionally weighted likelihood, 3%.

Next, reconsider Figure 66. This figure establishes that for 1983, the pattern of a combination of maximum and minimum temperature ranks during flowering echo the geographic pattern of model predicted yield rankings. This observation can be transformed into addtional agro-information products. Mean weekly flowering temperatures for 1983 were found at each station studied in the corn-belt. Each station-area contribution to its state total planted acreage is determined. The station 1983 flowering temperature is then multiplied by the surrounding area's percent contribution to state planted corn acreage. All weighted station temperatures in the state are then summed to obtain a weighted 1983 state flowering temperature. One can then return to the station data and find how many times in the past this 1983 state weighted flowering temperature was exceeded at a location within the state. A probability is computed (frequency/total seasons). These values are plotted in Figure 69.

The results in Figure 69 suggest that the likelihood of 1983-type flowering temperatures, which were quite warm, decreases as one moves northwards and eastward. The greatest likelihood of the occurrence of 1983 type flowering conditions exists at Wichita Kansas, .51. The smallest likelihood of occurrence is in the northern one-quarter of the corn-belt. 1983-type conditions occurred for the first time in 36 years in portions of Wisconsin, Michigan, Northern Indiana, and Northern Ohio. For local decision makers this map indicates that it is a common problem in Kansas that could result in frequent, significant uncertainty in yield outcomes in spite of the presence of irrigation. For local decision makers in Wisconsin it says that 1983-type flowering conditions

Figure 69: Probability of State Weighted Flowering Temperatures Recurring.



are a significant but rare event and should not dominate year-to-year farm management decisions.

If statements concerning the use of this information by regional or national decision makers are needed, other factors must be considered. For instance, those areas most frequently impacted by adverse flowering weather conditions may contribute little to U.S.A. corn production variability because of their small contribution to overall corn-belt production or because of their use of heat tolerant corn varieties. Areas which represent significant portions of corn-belt production but have not experienced these weather conditions in a 36-year period of record can impact significantly corn-belt production only in rare cases. Of primary interest are those areas which possess non-trivial probabilities of occurence and normally contribute significantly to production.

The weather has already been weighted to represent a location's relative importance to state production. Determine the importance of weather conditions at a particular location in a State to overall corn-belt production can be determined by weighting each station's event probability by the state proportion of total corn-belt planted acreage.

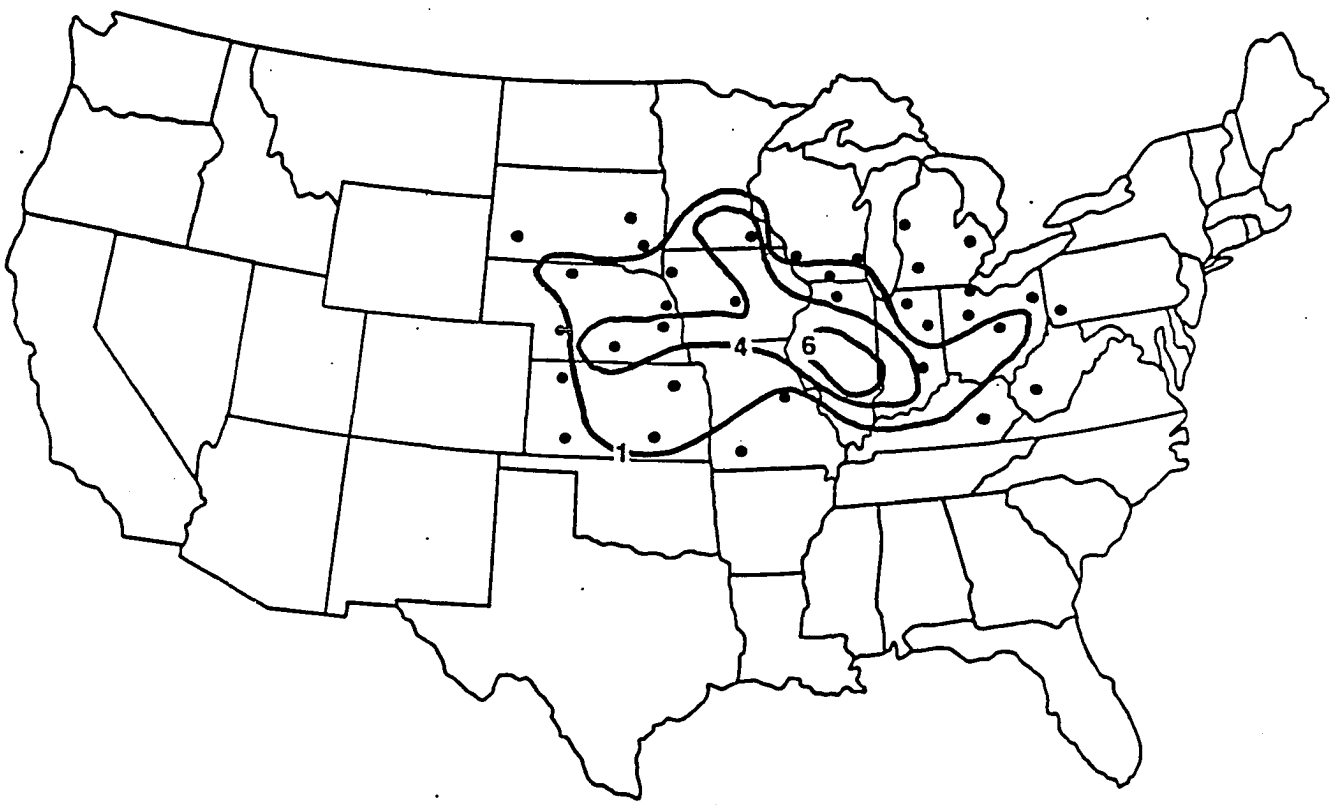
$$[prob_{flower} * (\text{state planted acreage/total acres})]. \quad (23)$$

Since flowering weather probability includes (local acres/ state acres), state acres cancel and local acres/total acres remain. The numbers that are generated represent the importance of the weather for a location or small area to total corn-belt production. Small values are generated by 1) small probabilities of the event occurring, or 2) small contribution by a state to corn-belt production. The smallest values are for those locations having a small probability and small production contribution or an event probability at the location being zero. Larger values represent 1) larger probabilities of occurence, or 2) larger contributions to corn-belt production by the state. The largest values represent areas where event probabilities are relatively large (e.g., greater than .2) and significant production takes place. Mapped values can be interpreted as indicating areas of impact hazards significant to U.S.A. corn production, not to just a single location or crop reporting district. Figure 70 contains these values. Figure 70 indicates the most significant U.S.A. corn production hazard areas for adverse flowering conditions. These are:

- Central and Southern Illinois

- Southern Indiana
- Southern Minnesota
- Southeastern Nebraska
- A large part of Iowa

Figure 70: Corn Belt Production Hazard Under 1983 Flowering Conditions.



Note: Larger values indicate areas which make significant contributions to corn-belt production planted acreage and have also experienced detrimental flowering conditions a significant number of times in the past.

This map is a preliminary product which portrays the impact hazard to U.S.A. corn-belt production resulting from weather at a location

(the degree to which the conditions impact corn yield) attributable to 1983-type flowering weather conditions. It does not reflect the severity of impact at a location; only those areas which are most likly to experience 1983-type conditions and contribute to national production significantly. Thus, not only is the forecast of flowering temperatures critical but, economically, it is even more important to forecast correctly for those areas listed above so that the most valuable information to regional and national decision makers can be provided.

To obtain a more complete product that would include consideration of the magnitude of impact of the weather on yield as well as the hazard of impact to U.S.A. corn production, one might calculate and map a value such as that suggested below:

$$\begin{bmatrix}\text{deviation of 1983 yield at a point from its long-term normal}\end{bmatrix} * \begin{bmatrix}\text{probability of 1983 flowering weather conditions at a location weighted by corn-belt planted acreage}\end{bmatrix} \quad (24)$$

This operation should generate a map of U.S.A. corn production impact areas under 1983-type flowering conditions. Note that the difference between this product and the hazard product is that hazard represents weather only. Corn production is represented only by normal contribution to USA corn production in terms of area, not yield. The impact product includes yield explicitly.

The products presented so far have focused on isolating predictable meteorological parameters and their spatial distributions which affected

the 1983 corn yield in the U.S.A. corn-belt. The primary use of these items might be in: 1) highlighting climate impacts, 2) suggesting geographical and temporal scales that would result in the greatest economic benefits from improved agricultural forecasts and 3) assisting investors, planners and local farmers in the evaluation and potential redesign of their present management or investment strategies.

3.5.2 Mid-Season Products: Point Estimates

A second major category of product is one which provides information for use in mid-season production forecasts. Two agro-climate products which address these users will be presented.

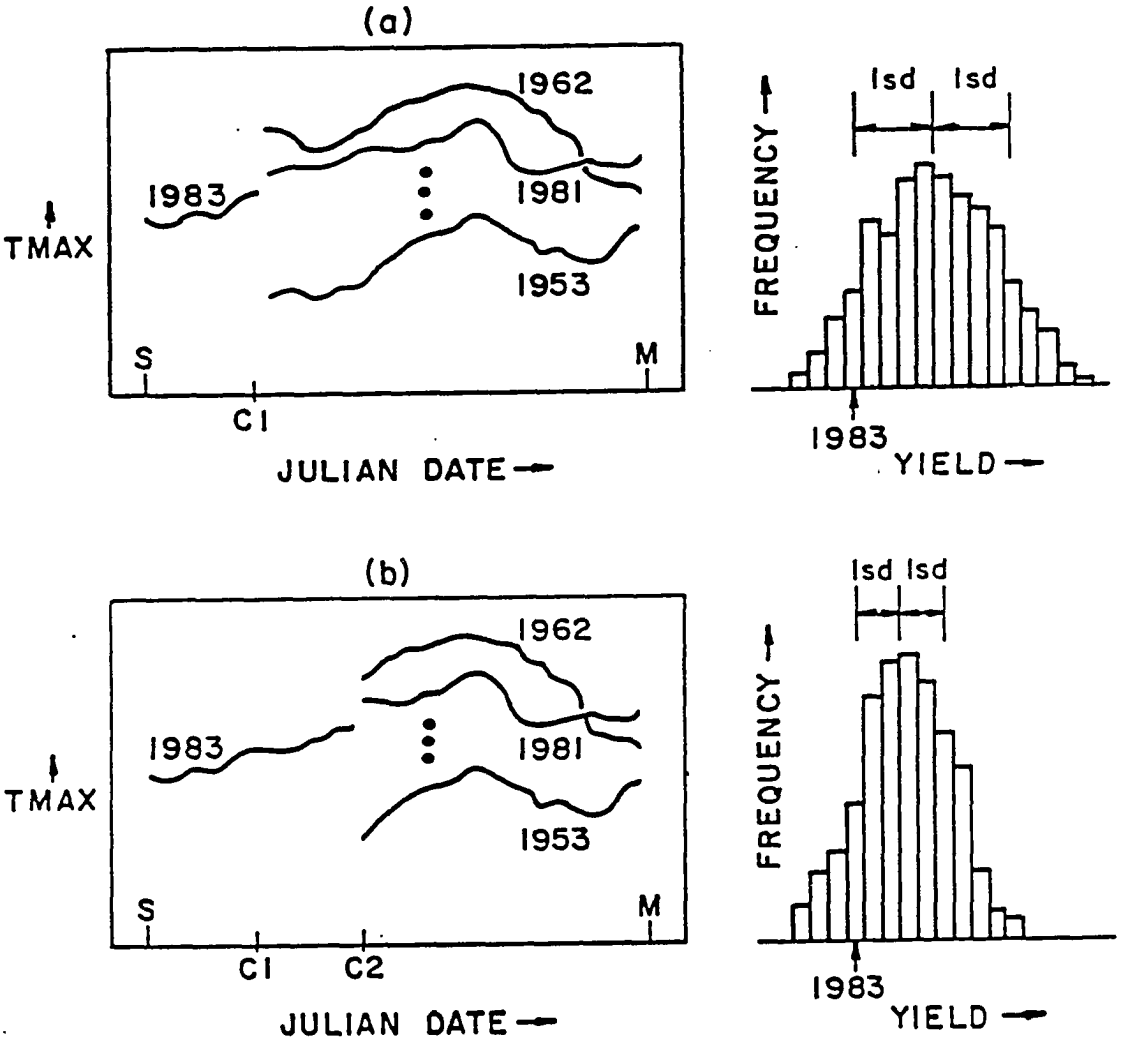
The first mid-season forecast product provides distributions of expected yields based upon time-series of the current season's antecedent data to any specified date and a set of possible succeeding weather outcomes from past climatological history (see Figure 71). Through various averaging procedures described in section 3.3, weekly mean yield variability due to the run of weather prior to a specified week, and the yield variability due to the run of weather following a specified week can be determined (see Figure 72). Agricultural forecasters are interested primarily in the effect of the "following" weather. The question then can be raised "at what point does a weather forecast become of value?", where value is defined as a significant difference between yield variance based on preceding weather and that associated with following weather. One way of determining the point beyond which forecasts will have a statistically significant value is to construct a series of F-tests where the F statistic is defined as the

ratio of the variance of estimated yields due to leading weather to the variance of estimated yields due to following weather. The critical F value, $F_{.05}$ (35,35) for the hypothesis

$$H_o : \sigma^2_{lead} = \sigma^2_{follow} \tag{25}$$

is 1.775. Figure 73 illustrates the F-ratio curve by week. Figure 73 suggests that a forecast of weather and weather variability which possesses a higher likelihood of being correct than a random guess (a skilled forecast) made after Julian Week 31 would result in a model yield estimate whose error variance was significantly less than that due to preceding weather events, i.e., as the growing season progresses, forecast errors become smaller and smaller. This leads to the important result that the yield estimated by the model after Week 31 is significantly different from that associated with the early season "climatologically expected" mean yield. Insofar as it is an unbiased estimate of the final yield (and it is, approximately) then the post-Week 31 estimate is a significant improvement on the pre-Week 31 estimates. Duchon (1984) carries this analysis further by construcing Figure 74. This figure illustrates the value of 5, 15, and 30 day forecasts at Peoria, IL. In this case, value is defined as the degree of modeled yield variance reduction. From Figure 74 we can see that a thirty day forecast has maximum value if made about July 10. A 15 day forecast has maximum value if made about July 20. A 5 day forecast has maximum value if made at the end of August. All these forecasts would focus on the flowering period. Therefore, at Peoria, Illinois the most telling crop/climate relationships occur at or during flowering, and

Figure 71: Weather Time-Series Construction for Yield Distribution Forecasts (After Duchon, 1984).



Schematic diagrams of TMAX at a station for 1983 up to forecast times C1 (a) and C2 (b) after which TMAX from other years is spliced in. The distribution of yields is shown to the right.

Figure 72: Corn Model Statistics 1948-1983.

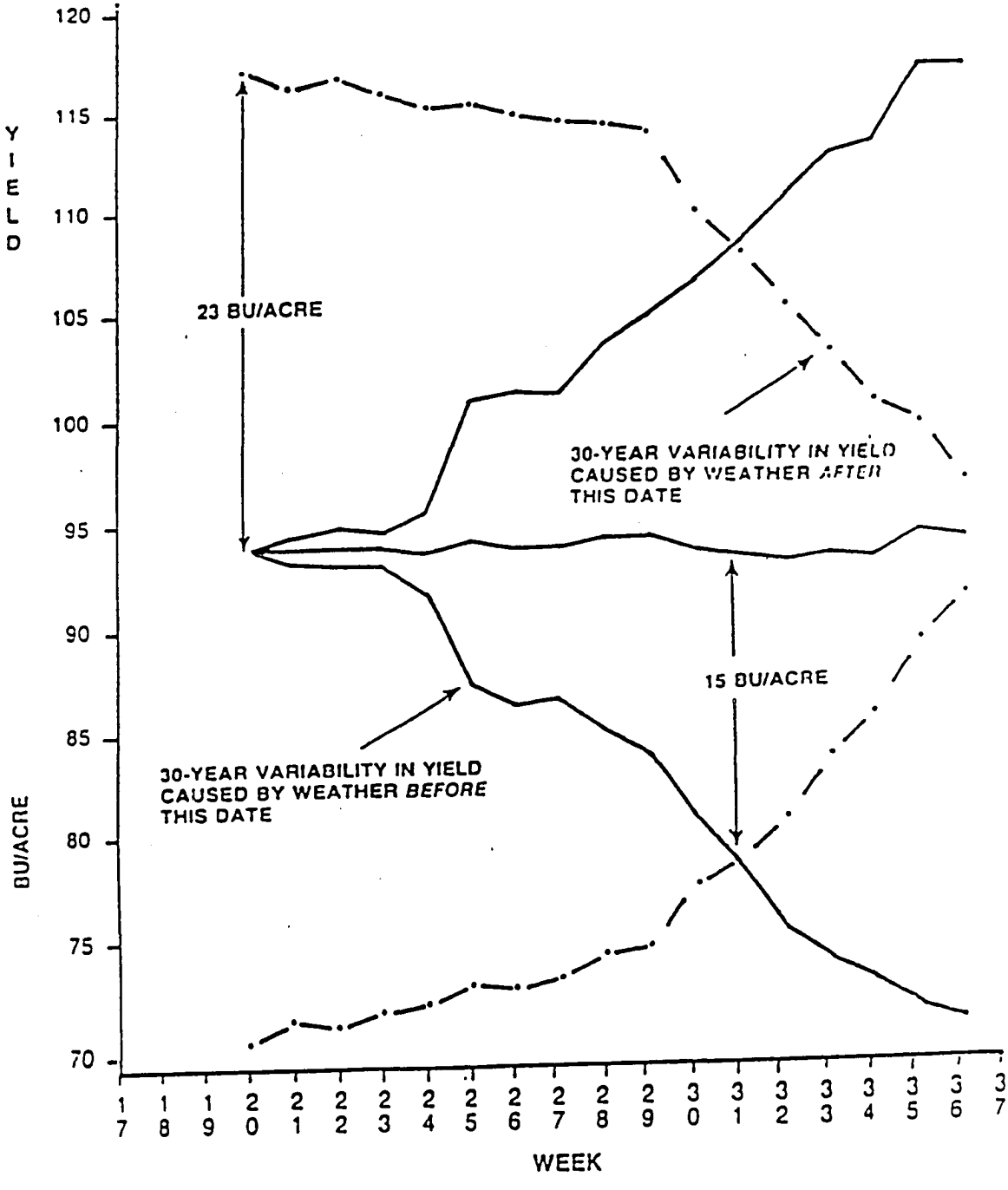
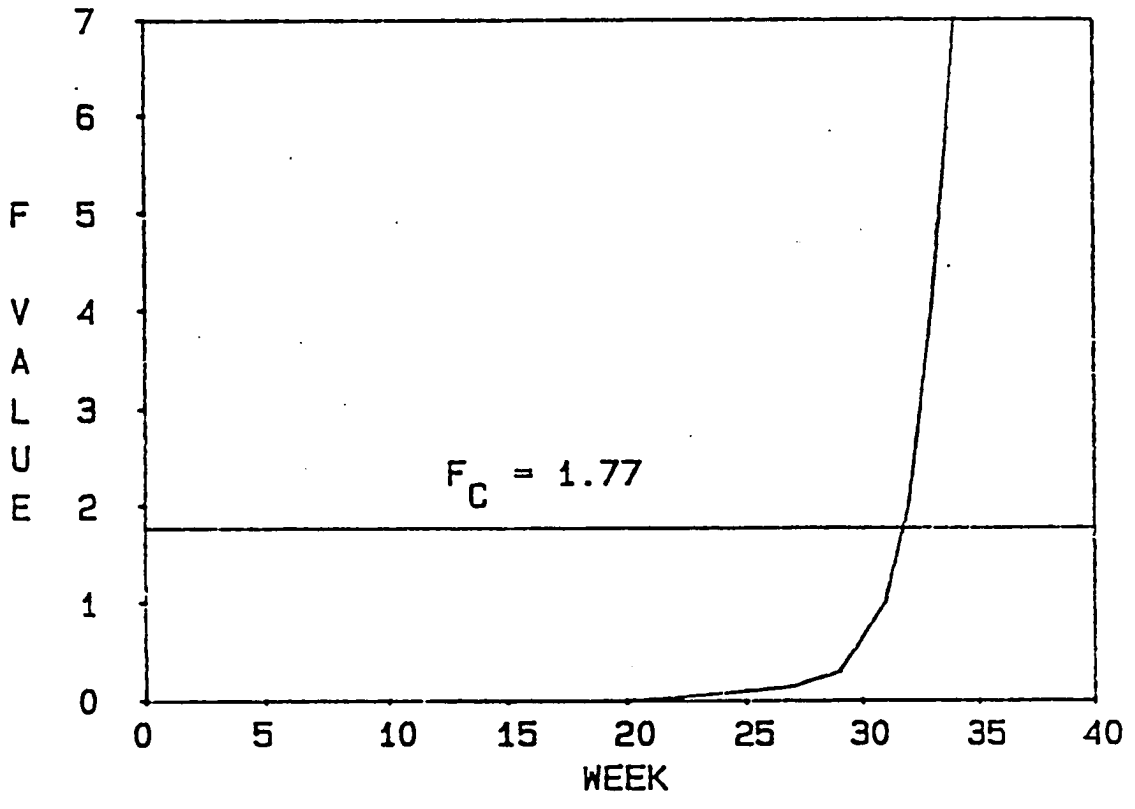
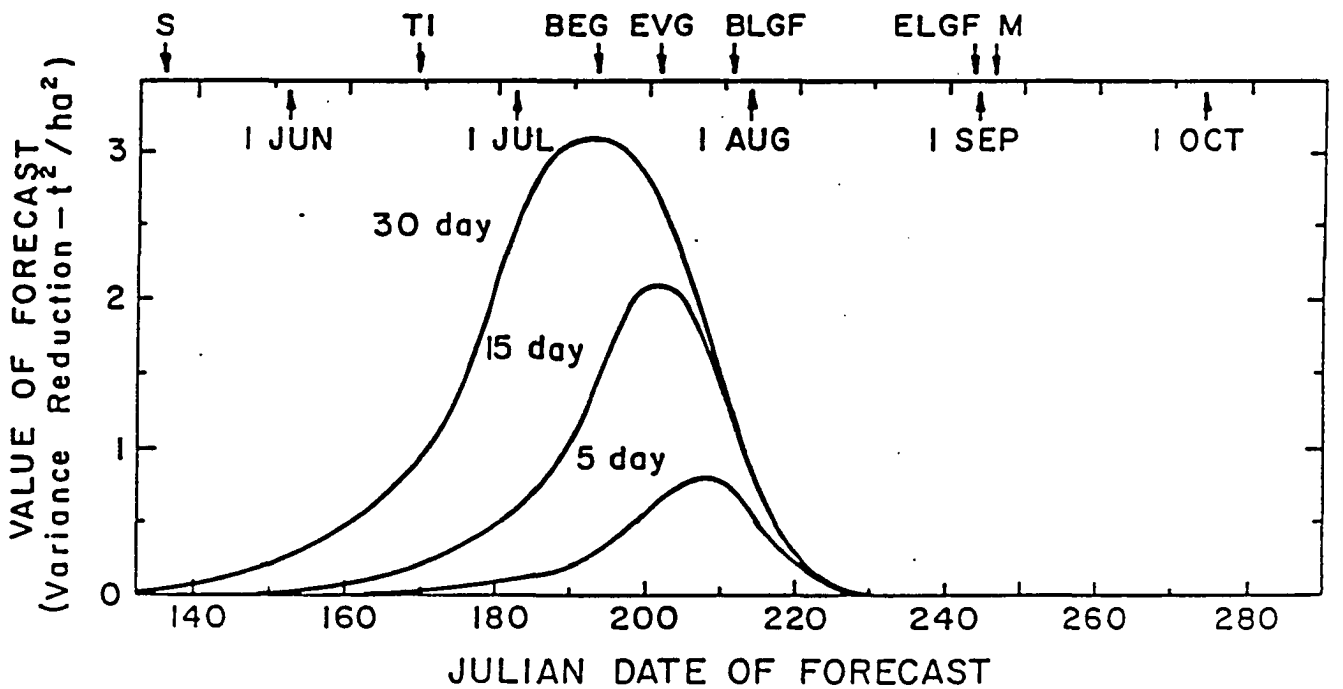


Figure 73: F-Text Results Derived from the Leading and Following Variances Graphed in Figure 72.



forecasts which include this period would contain the greatest potential value of any made throughout the growing season. Figures 75 - 78 are drawn from histograms of Rochester, Minnesota estimated yields and illustrate more clearly the decrease of variance in yield estimates throughout the year. Estimated yield categories were fixed at one

Figure 74: The Value of Perfect 5-, 15- and 30-day Weather Forecasts During the 1983 Growing Season at Peoria, IL (After Duchon, 1984).



standard deviation intervals to facilitate the fromulation of probabilistic interpretations of the results. A Gausian distribution has been sketched over these histograms for the sake of illustration only. Further analysis presented later in this chapter suggests that the distribution is somewhat non-Gausian, particularly in the tails. Accepting this assumption for the time, however, the discussion accompanying Figures 75 - 78 suggest how such graphs might be interpreted.

Assume that at the start of the 1983 season yield forecasts were requested at one-month intervals, i.e., at June 1, July 1, August 1, and

Figure 75: Modeled Yield Distribution for Period Ending June 1, 1983.

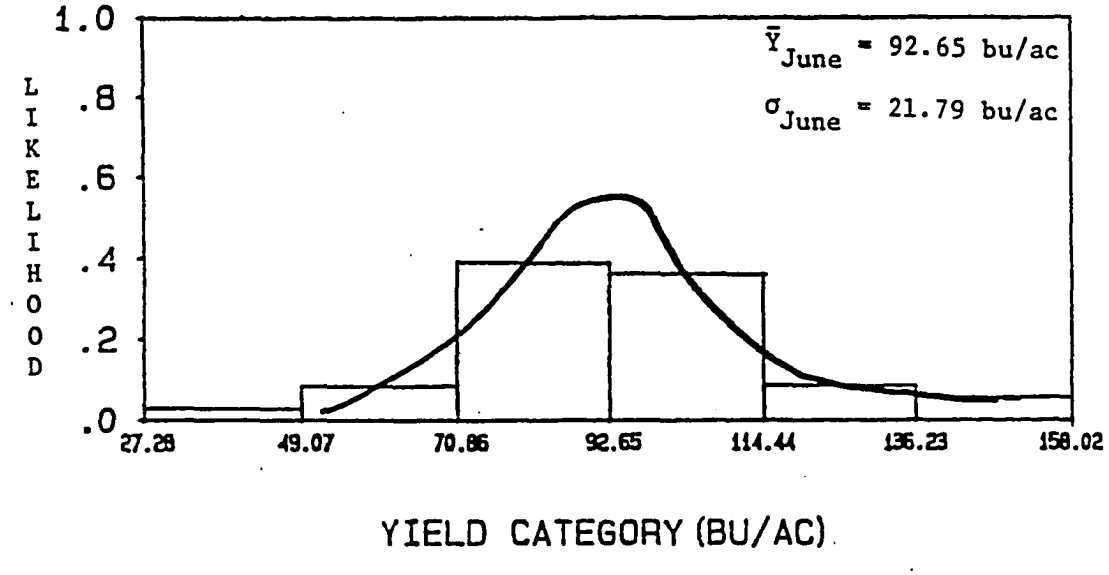
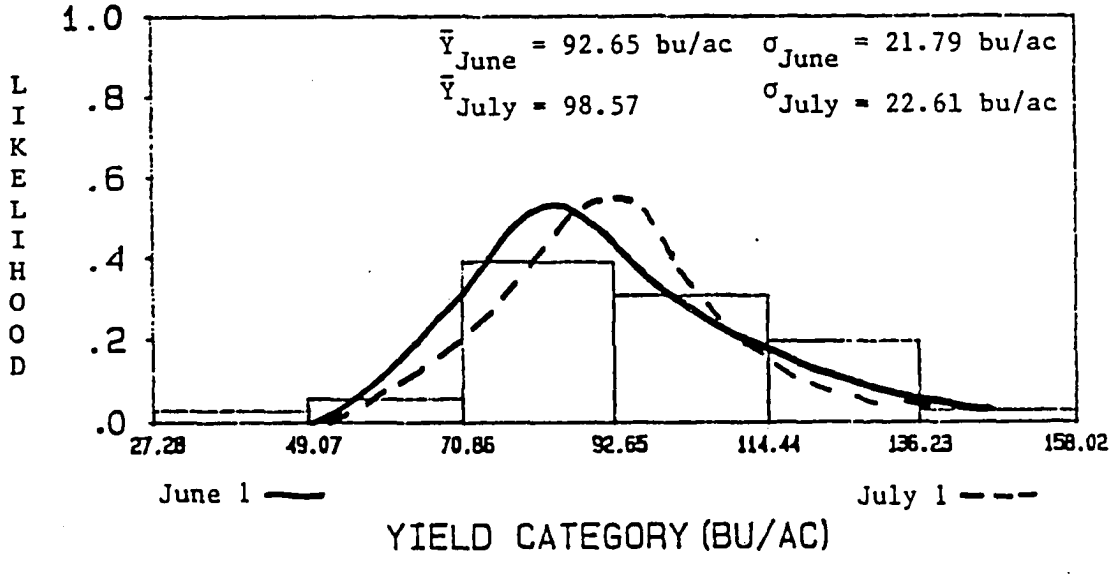


Figure 76: Modeled Yield Distribution for Period Ending July 1, 1983.



September 1. The planting date at Rochester will be Julian Day 135, or

Figure 77: Modeled Yield Distribution for Period Ending August 1, 1983.

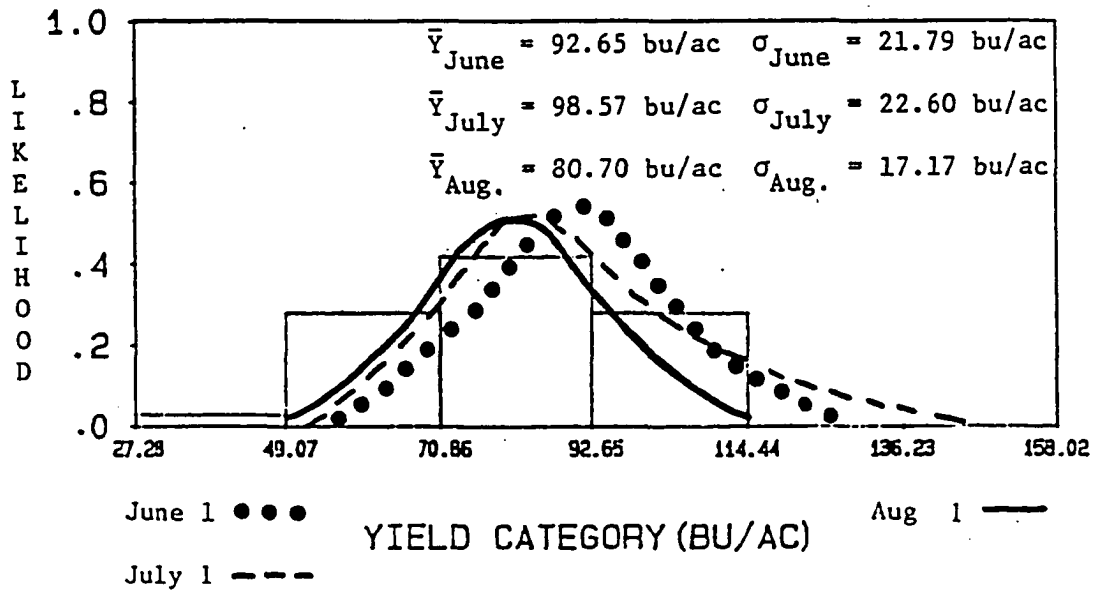
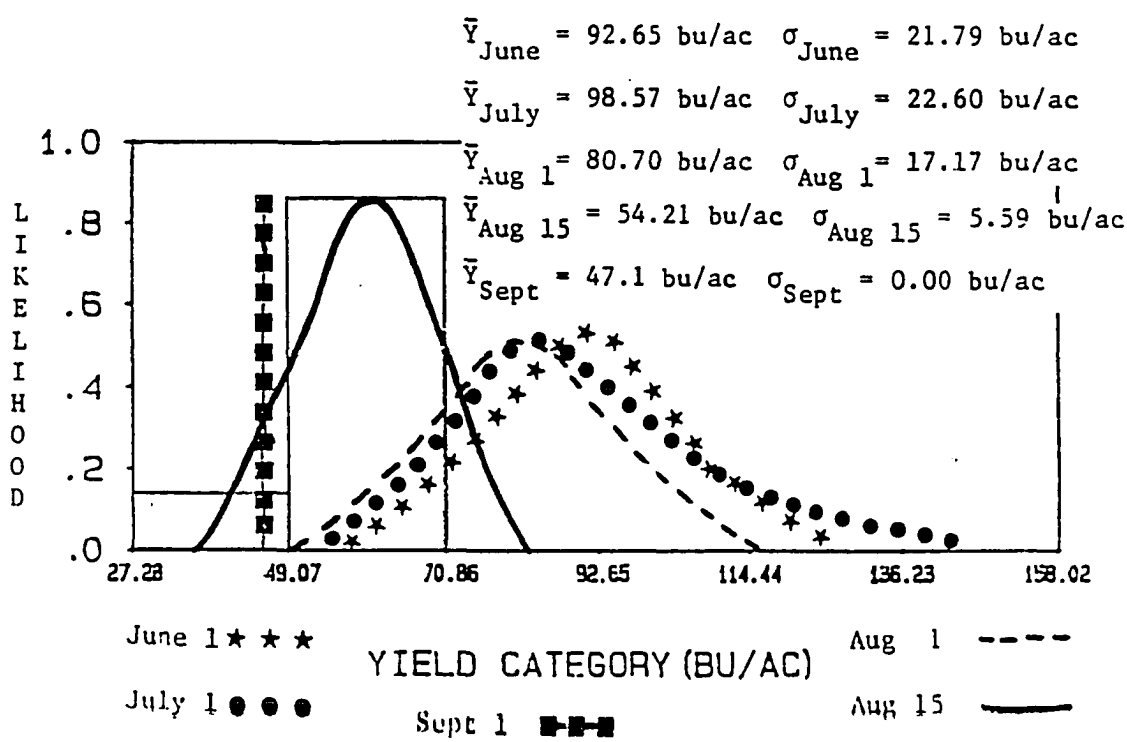


Figure 78: Modeled Yield Distribution for Period Ending August 15, 1983.



May 14. Figure 75 illustrates that given 1983 weather from January 1 through May 31, followed by the substitution of reported weather conditions at Rochester for each of the other 35 growing seasons for the remainder of 1983, a mean modeled yield of 92.65 bu/ac and standard deviation of 21.79 bu/ac is estimated A probabilistic interpretation would be that as of June 1, there was a fifty-percent chance of final harvested yield being greater than 92.65 bu/ac and a fifty-percent chance that it would be below 92.65 bu/ac (recall the Gausian distribution assumption). The probabilistic statements in Table 29 be generated from Figure 75.

TABLE 29

June 1, 1983 Yield Projections.

Likelihood	Yield Range
2.8%	27.28 - 49.09 bu/ac
8.3%	49.09 - 70.86 bu/ac
38.9%	70.86 - 92.65 bu/ac
36.1%	92.65 - 114.44 bu/ac
8.3%	114.44 - 136.23 bu/ac
5.6%	136.23 - 158.02 bu/ac

Table 29 suggests that given the 1983 growing season to June 1, the most likely (75 percent) range of yields lie between 70.86 - 114.44 bu/ac. The most likely yield category was 70.86 - 92.65 bu/ac, representing 38.9 percent of possible modeled outcomes. Projections made using this method on June 1, 1983, would indicate only a small likelihood of very low yields, i.e., of 27.28 - 49.09 bu/ac.

If the estimation procedure is repeated using observed 1983 data to July 1 (Figure 76) a slightly different answer is obtained.

TABLE 30

July 1, 1983 Yield Projections.

Likelihood	Yield Range
2.8%	27.28 - 49.09 bu/ac
5.6%	49.09 - 70.86 bu/ac
38.9%	70.86 - 92.65 bu/ac
30.6%	92.65 - 114.44 bu/ac
19.4%	114.44 - 136.23 bu/ac
2.8%	136.23 - 158.02 bu/ac

Table 30 indicates an upward shift in expect modeled yields, primarily in the relatively high category 114.44 - 136.23 bu/ac. The likelihood of this yield range has more than doubled from the June 1 level and accounts for the majority of the increase in in mean modeled yield to 98.57 bu/ac. These increases are not unexpected since up until this time the 1983 corn crop was experiencing very favorable growing season conditions. The unexpected aspect of these results is an increase in the variance of the predicted yield. Normally, one would expect that as more and more observed growing season conditions are utilized by the model, the modeled yield distribution would narrow. This same phenomenon, an increase in mid-season modeled yield uncertainty, is documented for Peoria, Illinois in Duchon(1984). If we assume that these values are measures of random variances, then a model estimated yield variance increase at any point in the growing season is far less surprising than a nearly smooth decrease in variance noted here

and in Duchon(1984). What makes this increase interesting is that it occurs at nearly the same point in time at two geographically dissimilar locations, a very unlikely event if both samples were random. The cause of this variance increase is unknown, but three possibilities will be offered. These include: 1) these weeks represent a transition point in meteorological patterns from fairly unstable spring temperatures and rainfall regimes to more stable summer ones, 2) there is a tendency for the distribution of the occurence of phenological stages to become more stable temporarily at mid-season and 3) model imposed variance. Although which factor or factors results in the variance pattern reported here cannot be pin-pointed at this time, it poses an interesting question for future investigations.

The next model yield forecast to be made would include 1983 data through the end of July and possible outcomes thereafter (Figure 77). It is in this distributional forecast that the effects of 1983 hot, dry summer conditions can first be seen. Table 31 illustrates the new projections.

TABLE 31

August 1, 1983 Yield Projections.

Likelihood	Yield Range
2.8%	27.28 - 49.09 bu/ac
27.8%	49.09 - 70.86 bu/ac
41.7%	70.86 - 92.65 bu/ac
27.8%	92.65 - 114.44 bu/ac
0	114.44 - 136.23 bu/ac
0	136.23 - 158.02 bu/ac

The mean predicted yield has dropped to 80.7 bu/ac. The standard deviation has dropped as one might expect, but the distribution still tends to be fairly optimistic, with almost 42 percent of possible modeled outcomes falling in the 70.86 - 92.65 bu/ac range. A significant change is the increase to 28 percent of the next lower category, 49.09 - 70.86. The distribution is now 72 to 28 in favor of yields equal to or below the original, early season prediction of 92 bu/ac.

Clearly something significant is happening within the climate/yield system. In order to monitor more closely these changes, an additional mid-August projection could be requested (Figure 78). Table 32 presents the bleak, late season results.

TABLE 32

August 15, 1983 Yield Projections.

Likelihood	Yield Range
13.9%	27.28 - 49.09 bu/ac
86.1%	49.09 - 70.86 bu/ac
0	70.86 - 92.65 bu/ac
0	92.65 - 114.44 bu/ac
0	114.44 - 136.23 bu/ac
0	136.23 - 158.02 bu/ac

Table 32 paints a decidedly poor yield picture. Although the distribution predicts a yield in the range of 49.09 - 70.86 bu/ac as the most likely, it is not far from the final 1983 yield estimate of 47.01 bu/ac. By August 15 the mean modeled yield has dropped to 54.21 bu/ac and the error standard deviation has dropped to 5.59 bu/ac. Far more

confidence can be placed in a model yield estimate made using observed data from January 1 to August 1 than from January 1 to July 1.

By September 1 most corn growth has been completed and the majority of climate impacts have been incorporated into final plant production. The estimated final harvested yields are all 47.01 bu/ac, with the model error estimates at zero.

These methods can be repeated more or less frequently throughout a growing season depending on their value to the user. Daily outputs would not be recommended since it has been determined earlier in this report that day-by-day model impacts are quite small. Model yield distributions produced on a weekly or 14-day schedule might prove more informative.

3.5.3 Mid-Season Products: A Corn/Weather Index

The next issue to be addressed is how one provides mid-season yield forecast estimates such as those just presented, which contain uncertainty limits over an area rather than a point. This proposition will be approached as a two step process. First, a national level mid-season product will be developed, and then problems associated with pooling point data sets with different distributional variances into a single regional value will be addressed.

The first mid-season forecast product to be presented is a national Corn/Weather Index. The requirements for such an index include that: 1) it should reflect acurately the relative contribution of different geographic locations to national level production, 2) it should be essentially technology free, 3) should provide for frequent updating, 4) be simple to execute, and 5) not resemble actual yield too closely.

This latter requirement is essential due to the nature of the predictive model and the need for effective output communication. The model cannot predict observed yield. Corn yield is determined given 1983 technology and cultural inputs, but not the impacts of pests, diseases, hail, or other such episodic events. It would be very misleading to imply that the absolute value of model predicted yield was a comprehensive forecast. The index will provide a tool for assessing at mid-season the degree to which weather is affecting the current year's corn production. If a time-series of indices have been produced, then a visual comparison between the current season's crop status and previous season's status at the same time in the season can be made. This approach has been proven to be an effective means of communicating econoclimatic information in New Zealand (see Maunder, 1979). A description of the construction of such a mid-season index is presented below.

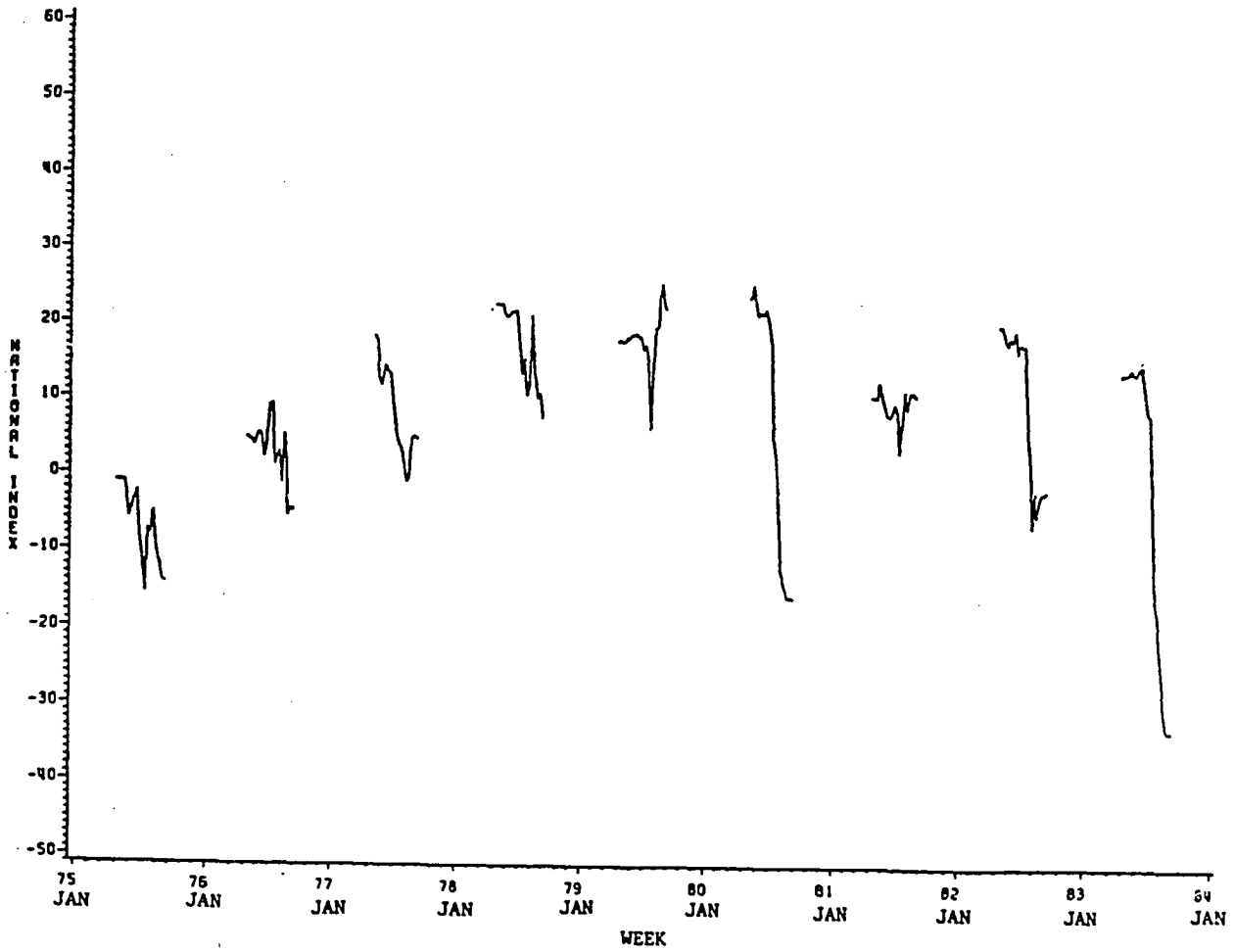
The CERES model is run at each of the 42 network sites beginning with January 1 of each year. The forecast period is defined as begining during Julian Week (JW) 17, the later portion of April. This "running start" is to assure the model includes the effects of pre-planting moisture conditions. In the case of 1962 for example, observed conditions from January 1 to JW 17 are used, then a forecast is made for the remainder of the season. The best climatological forecast would be the technique described in section 3.3.3 and Figure 81. This would provide a distribution of possible outcomes at JW 17 such as illustrated by Figures 85-88. Although this would be the best method, it is also the most expensive to initialize. Once the original 36 X 36 X 17 matrix as in Figure 36 has been constructed, the expense is less extreme. The

generation of this original matrix for each of the 42 stations in this corn-belt network would be prohibitively expensive for the illustrative purposes of this presentation. Another alternative is the use of analog years. This would serve to reduce the expense and would also reduce the statistical confidence in the results by decreasing degrees of freedom from, for example, 34 to 4. Analog years might be acceptable if they can be shown to contain significant statistical information (see section 3.5.5). An alternative forecast, selected for its ease of computation and illustrative capability, is one that completes the growing season with long-term mean maximum and minimum temperatures and normalized precipitation for the previous year. After these weather time-series have been input to the model for each week of the growing season for each station site, the station mean yield is subtracted from the modeled yield. This is to minimize the resemblance of the model result to actual yield. Figure 79 is a time series of weekly corn/weather indices as described above.

Positive values on Figure 79 indicate good corn growing weather, negative values indicate poor corn growing weather. Figure 79 indicates improving overall corn growing season weather through the 1979 growing season. 1980 is indicated as being disastrous, as is 1983.

During 1983, index forecasts made through Week 24 (June 10, 1983) indicate favorable corn-weather and prospects for a good, though not outstanding, harvest (index values of about 16). The first sign of trouble (yield decline) is forecast begining JW 25(June 17) when the index begins to drop. Negative seasonal impacts, that is, yields lower than average, are predicted beginning in Week 29 (July 15). The final

Figure 79: Corn/Weather Index Time-Series



forecast, made at the end of the growing season, -32.7 indicates an appropriately dismal outcome.

These predictive index values can be useful, but it cannot be too strongly emphasized that their value can be greatly increased by the inclusion of statistically defensible confidence limits, or estimates of the quality of the forecasts. This brings up again the issue of area pooled variances and methods of assessing the value of decreased uncertainty in mid-season yield forecasts.

There are two types of pooled variances which could be applied to our corn-belt example. The first is when independent data are pooled. In this case the variance is given by Eq. (26).

$$\sigma_{\bar{y}}^2 = \sigma^2/\nu_e \tag{26}$$

where: $\sigma_{\bar{y}}^2$ = variance of the pooled data

σ^2 = population variance,

ν_e = effective degrees of freedom.

$$\nu_e = n \left\{1 + \frac{2}{n} \sum_{\tau=1}^{n-1} (n - \tau)\, R\,(\tau)\right\}^{-1} \tag{26a}$$

where: n = number of points to be pooled,

τ = estimated average station separation distance.

Under the assumption of independent observations $R(r)=0$ for all $r \neq 0$, and $\gamma_E = n$. Thus Eq. (26) becomes Eq. (27) (Eddy, Duchon, Almazan, 1968).

$$\sigma_{\bar{y}}^2 = \sigma^2/n \tag{27}$$

If independence were the case, Figure 80 would illustrate the relationship between independent sample mean variance and sample size. Since our station network consists of 42 station sites, if our station yields were independent and a population variance of $(15 \text{ bu/ac})^2$ is assumed (see Figure 72), variance about the corn-belt sample mean yield at Week 31 could be reduced to $(15)^2/42.$ or $(5.357 \text{ bu/ac})^2$, or a standard deviation of 2.314 bu/ac.

On the other hand, it is already known from earlier statistical analyses that weather (and consequently estimated yields) is correlated in space and time. Even so, a pooled variance can still be estimated. If we assume a first order Markov process (Eq. 28), Eq. (29) can be used to estimate Eq. (26a).

$$R(\tau) = \rho(1)^{\tau} \tag{28}$$

$$\sigma_{pooled} = \frac{\sigma_y}{\sqrt{n}} \sqrt{\left[\frac{1 + \rho(1)}{1 - \rho(1)}\right]} \tag{29}$$

where: $\rho(1)$ = lag 1 correlation coefficient,

= the correlation across the average spacing between sites,

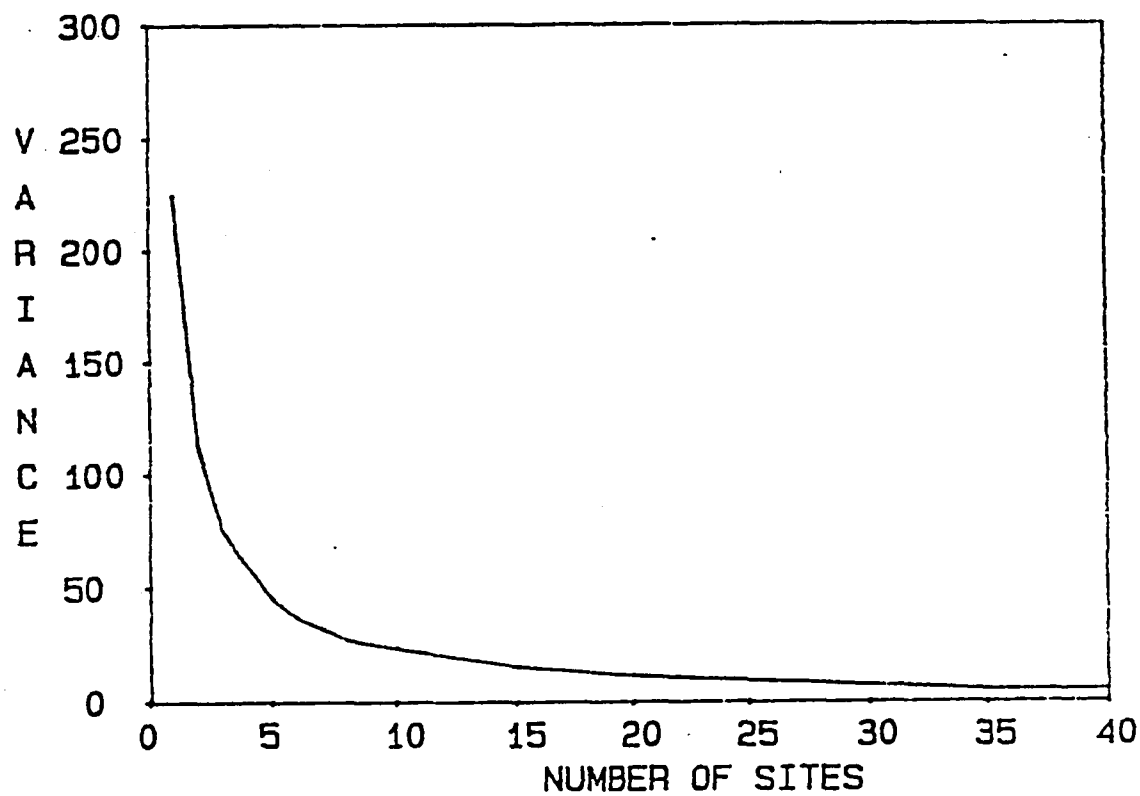
n = number of stations (sites),

where: ν_e = effective degrees of freedom

$$= \left(N/\frac{1 + \rho(1)}{1 - \rho(1)}\right)^{1/2} .$$

A complete discussion of these statistics can also be found in Eddy, Duchon and Almazan (1968).

Figure 80: Response of Independent Pooled Variance to Station Number.



An increased certainty in mid-season yield forecasts can be of immense economic importance. The example which follows will illustrate how one could determine the economic value of 1) the information already derived from the CERES model, 2) improvements in the confidence of mid-season yield forecasts and 3) lowering of regional mid-season forecast variability with 40 degrees of freedom to 2.314 bu/ac.

3.5.4 Mid-Season Products: A Bayesian Example

The purpose of the example which follows is to establish a methodology which will lead to the potential dollar value of improved mid-season regional yield forecasts where improvement is dependent upon increased confidence in these forecasts. More precisely, an estimate of the economic value of decreasing uncertainty in forecasted yield by approximately 85 percent (from 15 bu/ac to 2.314 bu/ac) will be attempted. This will be accomplished by considering a hypothetical Baysian decision maker. In the process of getting from the development of the Bayesian problem to the actual value estimate, the methodology associated with pooling of yield variances and the approximation of yield distributions at various points in the growing season for a number of sampling network densities will be explored.

3.5.4.1 The Bayesian Problem

Consider a national governmental policy to be the maintainance of stable corn prices. This stability is to be achieved by the government purchasing corn from the marketplace or selling corn from its stores; i.e., removing or injecting grain into the marketplace. To facilitate this operation, grain storage facilities are available at a fixed cost. The goal of the government is to maintain stores such that market supplies can meet export and domestic demands but such that no "glut" of grain occurs in the market which would induce lower prices and require subsidy payments to be made directly to the farmers. If foreign and domestic market requirements exceed domestic production and the government's storage of grain is low, a penalty is paid in the form of

the necessity to import corn, and, possibly, to make disaster payments to farmers if yields are excessively low. If too much grain is on the market and government stores are full, the price will drop and subsidies must be paid. The decision framework then, consists of specific sets of buying and selling actions to maintain a certain target price associated with specific states of nature: in this case, harvested yields. It is assumed that for all yield levels there is a pre-determined (but unknown) buy/sell action that will exactly achieve the government target price and meet all market demands.

What has just been described can be formulated as a Bayesian decision theory problem. Regrets rather than losses are used because even when the buy/sell strategy selection is correct, there always remain fixed storage costs. These costs exist whether grain is actually stored or not. This minimum loss is unavoidable; thus one regrets only the portion of an actual loss in excess of the unavoidable storage costs (loss). The "states-of-nature", θ_i's, are the categories of modeled harvested yields. The actions, a_j's, are buy/sell actions based on forecasts of end of season yields made at a particular point in time. The actions are taken on the basis of mid-season forecasted model yield categories z_j.

Because of the modeling work already completed, our decision maker knows that there is a distribution of harvested yields associated with his set of buy and sell actions. With these a priori probability estimates in hand, a set of weighted average expected regrets can be generated. The smallest of these is called the a priori Bayes risk, and the action which leads to this smallest weighted average expected regret (the Bayes Risk) dictates the Bayes strategy (Eddy and Shannon, 1975).

3.5.4.2 Estimations of Mid-Season Forecast Skill

Next the question could be asked: "If skilled mid-season forecasts could be made, would they be of value to our decision maker were he to use them before taking his buy or sell actions?"

Before this question is addressed, consider the following features of skilled model-produced yield forecasts. Each end of season estimate has associated with it a number of mid-season yield forecasts. These mid-season forecasts are contained in the 36 by 36 by 17 forecast matrix described earlier. For the duration of this example, z_j will be used to refer to a category of these forecasts at a point in time. A logical starting point would be to determine when these mid-season forecasts possess a predetermined level of "skill"; i.e., the contingency table of mid-season forecasted yield estimates differs at a given level of significance from a table of random estimates. An F-statistic has already been used to answer this question in one way, but in the present example a Chi-Square test will be more informative. The Chi-Square test is of the form given in Eq. (30).

$$\chi^2(M) = \sum_{i=1}^{RC} \frac{(O_i - E_i)^2}{E_i} \tag{30}$$

where: M = degrees of freedom, (row-1) * (column-1)

= 16,

O_i = observed count in category i,

E_i = expected count in category i,

R = number of rows, 5,

C = number of columns, 5.

The expected count (no-skill case) in the random contingency table is generated by the expression given in Eq. (31).

$$f(\theta_i, z_j) = f(\theta_i) * f(z_j) * N \qquad (31)$$

where: N = number of mid-season forecasts in the sample,

$$f(\theta_i) = [\sum_{j=1}^{5} (\theta_i, z_j)]/N$$

$$f(z_j) = \sum_{i=1}^{5} (\theta_i, z_j)/N$$

This comparison of skill and no-skill matrices can be performed for several points in time. For instance: planting (Week 20), mid-season (Week 25), flowering (Week 29), beginning of linear grain fill (Week 31), and end of linear grain fill (Week 35). Tables 33 - 37 contain the input contingency tables at each point in time listed above, their associated computer generated no-skill or random matrix and the associated Chi-Square test value. Figure 81 is a graphical presentation of these results. The horizontal line in Figure 81 represents Chi-square $\chi^2(16)=26$, the point of rejection/acceptance of the hypothesis that the two contingency tables were taken from similar populations. From this figure it can be concluded that "skilled" forecasts can be made beginning at week 26, the point at which the critical Chi-square is surpassed. This point of "skill" differs from that found in Figure 73 because Figure 73 is based on the uncertainty in a 36 by 36 matrix of all possible outcomes. It follows, then, that by careful selection of categories and limits, a product can be obtained which allows one to make an earlier "skillful" mid-season forecast than if the entire data matrix were used. This is important because the earlier a "skilled" forecast can be obtained, the more valuable the product.

TABLE 33

Modeled Yield and Random Contingency Tables of Average Planting Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
S O N	65-75 bu/ac	29.00	37.00	50.00	32.00	34.00	182.00
	75-85 bu/ac	22.00	37.00	40.00	29.00	29.00	157.00
	85-95 bu/ac	49.00	68.00	86.00	55.00	50.00	308.00
	95-105 bu/ac	21.00	37.00	35.00	29.00	35.00	157.00
	105-115 bu/ac	23.00	37.00	42.00	34.00	32.00	168.00
	TOTAL	144.00	216.00	253.00	179.00	180.00	972.00
	(Random Matrix)						
S O N	65-75 bu/ac	26.76	40.44	47.37	33.52	33.70	182.00
	75-85 bu/ac	23.26	34.89	40.87	28.91	29.07	157.00
	85-95 bu/ac	45.63	68.44	80.17	56.72	57.04	308.00
	95-105 bu/ac	23.26	34.89	40.87	28.91	29.07	157.00
	105-115 bu/ac	24.89	37.33	43.73	30.94	31.11	168.00
	TOTAL	144.00	216.00	253.00	179.00	180.00	972.00
CHI-SQUARE = 5.42							

TABLE 34

Modeled Yield and Random Contingency Tables for Five Weeks Following Average Planting Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
S O N	65-75 bu/ac	37.00	52.00	47.00	25.00	23.00	184.00
	75-85 bu/ac	22.00	54.00	32.00	29.00	29.00	166.00
	85-95 bu/ac	48.00	97.00	74.00	47.00	53.00	319.00
	95-105 bu/ac	20.00	49.00	28.00	33.00	31.00	161.00
	105-115 bu/ac	22.00	40.00	32.00	37.00	35.00	166.00
	TOTAL	149.00	292.00	213.00	171.00	171.00	996.00
	(Random Matrix)						
S O N	65-75 bu/ac	27.53	53.94	39.35	31.59	31.59	184.00
	75-85 bu/ac	24.83	48.67	35.50	28.50	28.50	166.00
	85-95 bu/ac	47.72	93.52	68.22	54.77	54.77	319.00
	95-105 bu/ac	24.09	47.20	34.43	27.64	27.64	161.00
	105-115 bu/ac	24.83	48.67	35.50	28.50	28.50	166.00
	TOTAL	149.00	292.00	213.00	171.00	171.00	996.00
CHI-SQUARE = 21.22							

TABLE 35

Modeled Yield and Random Contingency Tables for Pre-Flowering Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
S O N	65-75 bu/ac	37.00	51.00	32.00	36.00	27.00	183.00
	75-85 bu/ac	30.00	48.00	35.00	32.00	18.00	163.00
	85-95 bu/ac	43.00	66.00	83.00	79.00	38.00	309.00
	95-105 bu/ac	19.00	28.00	30.00	39.00	22.00	138.00
	105-115 bu/ac	16.00	29.00	43.00	29.00	38.00	155.00
	TOTAL	145.00	222.00	223.00	215.00	143.00	948.00
	(Random Matrix)						
S O N	65-75 bu/ac	27.99	42.85	43.05	41.50	27.60	183.00
	75-85 bu/ac	24.93	38.17	38.34	36.97	24.59	163.00
	85-95 bu/ac	47.26	72.36	72.69	70.08	46.61	309.00
	95-105 bu/ac	21.11	32.32	32.46	31.30	20.82	138.00
	105-115 bu/ac	23.71	36.30	36.46	35.15	23.38	155.00
	TOTAL	145.00	222.00	223.00	215.00	143.00	948.00
CHI-SQUARE = 37.75							

TABLE 36

Modeled Yield and Random Contingency Tables for Post Flowering Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
S O N	65-75 bu/ac	85.00	39.00	27.00	21.00	9.00	181.00
	75-85 bu/ac	33.00	47.00	44.00	38.00	9.00	171.00
	85-95 bu/ac	27.00	62.00	105.00	89.00	56.00	339.00
	95-105 bu/ac	14.00	37.00	37.00	48.00	31.00	167.00
	105-115 bu/ac	17.00	19.00	36.00	35.00	45.00	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00
	(Random Matrix)						
S O N	65-75 bu/ac	31.54	36.56	44.62	41.40	26.88	181.00
	75-85 bu/ac	29.80	34.54	42.16	39.11	25.40	171.00
	85-95 bu/ac	59.07	68.47	83.58	77.53	50.35	339.00
	95-105 bu/ac	29.10	33.73	41.17	38.20	24.80	167.00
	105-115 bu/ac	26.49	30.70	37.47	34.76	22.57	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00
CHI-SQUARE = 203.9							

TABLE 37

Modeled Yield and Random Contingency Tables for End of Linear Grain Fill Week at Rochester, MN.

YIELD FORECAST CATEGORY

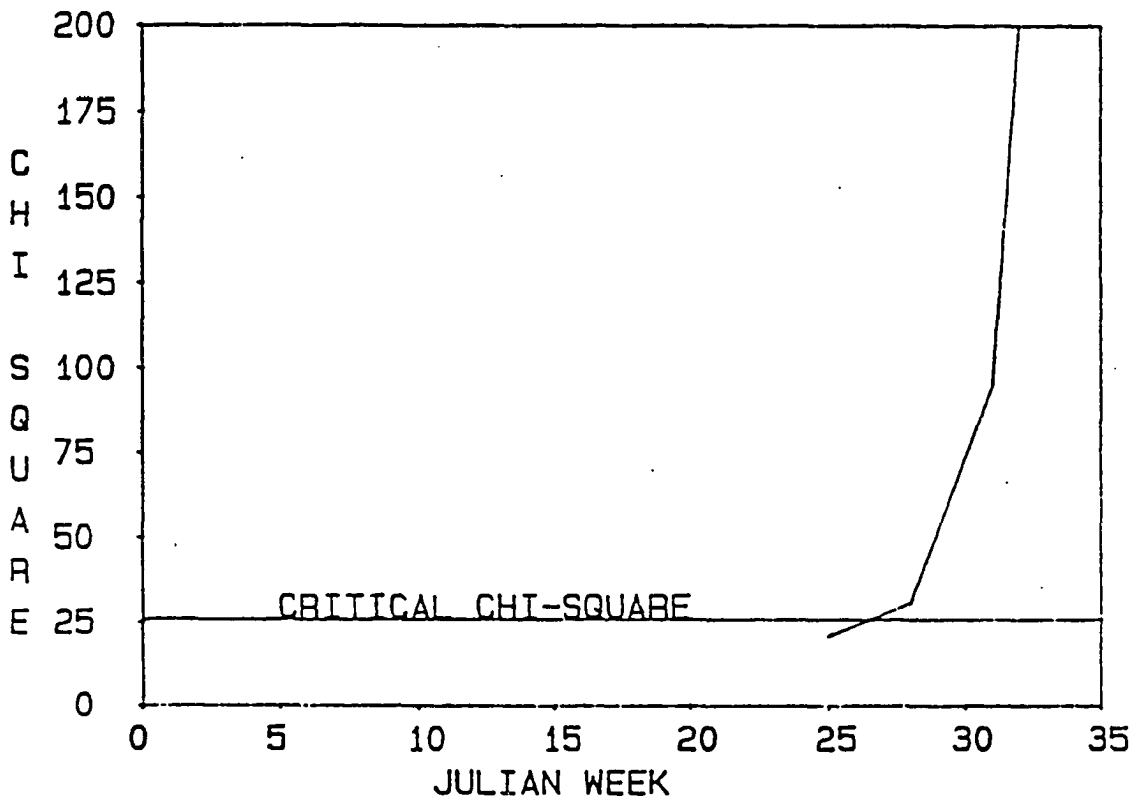
	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
S	65-75 bu/ac	119.00	9.00	0.00	0.00	3.00	131.00
	75-85 bu/ac	18.00	129.00	54.00	3.00	0.00	204.00
O	85-95 bu/ac	0.00	31.00	190.00	61.00	6.00	288.00
	95-105 bu/ac	0.00	7.00	45.00	113.00	34.00	199.00
N	105-115 bu/ac	22.00	2.00	1.00	32.00	77.00	134.00
	TOTAL	159.00	178.00	290.00	209.00	120.00	956.00
	(Random Matrix)						
	65-75 bu/ac	21.79	24.37	39.74	28.64	16.44	131.00
S	75-85 bu/ac	33.93	37.98	61.88	44.60	25.61	204.00
	85-95 bu/ac	47.99	53.62	87.36	62.96	36.15	288.00
O	95-105 bu/ac	33.10	37.05	60.37	43.51	24.98	199.00
N	105-115 bu/ac	22.27	24.95	40.65	29.29	16.82	134.00
	TOTAL	159.00	178.00	290.00	209.00	120.00	956.00
	CHI-SQUARE = 1468.04						

3.5.4.3 Estimation of Forecast Certainty

Now that a skilled forecast season has been located, one would like to determine the effect of increasing regional forecast certainty at a point in time, i.e., pooling estimates at N independent sites across the corn-belt: n=5, 10, 20, 25, 30, 100. If the underlying distribution of our modeled yields could be specified, a complete station covariance matrix can be computed. In the present case the underlying distribution is unknown and the empirical covariance determination is beyond the scope of the present study. Meaningful results can still be achieved by making certain assumptions concerning these computational elements.

To test the value of decreased uncertainty of forecasted yield categories, some method of contingency table estimation must be used. One method is to assume that the distribution of yields in these

Figure 81: Graphed Chi-Square Values versus Time of Mid-Season Forecast.



categories can be described by some known statistical distribution. Since changes in modeled yield variance are of primary interest, a logical selection would be a distribution effectively described by σ^2, such as the Gaussian distribution. A computer program was utilized to perform these estimates, and sample output are presented in Tables 38 - 42.

TABLE 38

Modeled Yield and Gausian Estimated Contingency Tables for Post-Flowering Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	85.00	39.00	27.00	21.00	9.00	181.00
S	75-85 bu/ac	33.00	47.00	44.00	38.00	9.00	171.00
O	85-95 bu/ac	27.00	62.00	105.00	89.00	56.00	339.00
	95-105 bu/ac	14.00	37.00	37.00	48.00	31.00	167.00
N	105-115 bu/ac	17.00	19.00	36.00	35.00	45.00	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00
	(Random Matrix)						
	65-75 bu/ac	31.54	36.56	44.62	41.40	26.88	181.00
S	75-85 bu/ac	29.80	34.54	42.16	39.11	25.40	171.00
O	85-95 bu/ac	59.07	68.47	83.58	77.53	50.35	339.00
	95-105 bu/ac	29.10	33.73	41.17	38.20	24.80	167.00
N	105-115 bu/ac	26.49	30.70	37.47	34.76	22.57	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00

CHI-SQUARE = 203.9

TABLE 39

Row Variance, Modeled Yield and Individual Row Gausian Fit Contingency Tables for Post Flowering Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	85.00	39.00	27.00	21.00	9.00	181.00
S	75-85 bu/ac	33.00	47.00	44.00	38.00	9.00	171.00
O	85-95 bu/ac	27.00	62.00	105.00	89.00	56.00	339.00
	95-105 bu/ac	14.00	37.00	37.00	48.00	31.00	167.00
N	105-115 bu/ac	17.00	19.00	36.00	35.00	45.00	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00
	(Random Matrix)						
	65-75 bu/ac	88.30	37.07	35.53	16.13	5.37	181.00
S	75-85 bu/ac	39.80	43.78	39.80	29.30	17.71	171.00
O	85-95 bu/ac	39.41	79.70	100.78	79.70	39.41	339.00
	95-105 bu/ac	19.62	29.72	38.12	41.42	38.12	167.00
N	105-115 bu/ac	15.55	23.85	32.37	38.87	41.34	152.00
	TOTAL	181.18	234.31	246.65	205.69	142.16	1010.00

CHI-SQUARE = 49.44

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
17.82	2.00	12.39	26	1	1	1	5
22.38	2.00	6.70	22	2	2	1	5
15.11	2.00	13.01	61	3	3	1	5
24.54	2.00	6.00	22	4	4	1	5
28.60	2.00	3.67	33	5	5	1	5

TABLE 40

Matrix Variance, Modeled Yield and Simultaneous Row Gausian Fit Contingency Tables for Post-Flowering Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	85.00	39.00	27.00	21.00	9.00	181.00
S	75-85 bu/ac	33.00	47.00	44.00	38.00	9.00	171.00
O	85-95 bu/ac	27.00	62.00	105.00	89.00	56.00	339.00
	95-105 bu/ac	14.00	37.00	37.00	48.00	31.00	167.00
N	105-115 bu/ac	17.00	19.00	36.00	35.00	45.00	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00
	(Random Matrix)						
	65-75 bu/ac	60.03	53.38	37.54	20.87	9.18	181.00
S	75-85 bu/ac	40.53	45.58	40.53	28.50	15.85	171.00
O	85-95 bu/ac	52.61	74.82	84.14	74.82	52.61	339.00
	95-105 bu/ac	15.48	27.84	39.59	44.52	39.57	167.00
N	105-115 bu/ac	7.71	17.53	31.52	44.83	50.41	152.00
	TOTAL	176.36	219.15	233.32	213.54	167.64	1010.00

CHI-SQUARE = 67.99

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
20.64	2.00	11.01	22	1	5	1	5

TABLE 41

Column Variance, Modeled Yield and Individual Column Gausian Fit Contingency Tables for Post-Flowering Week at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	85.00	39.00	27.00	21.00	9.00	181.00
S	75-85 bu/ac	33.00	47.00	44.00	38.00	9.00	171.00
O	85-95 bu/ac	27.00	62.00	105.00	89.00	56.00	339.00
	95-105 bu/ac	14.00	37.00	37.00	48.00	31.00	167.00
N	105-115 bu/ac	17.00	19.00	36.00	35.00	45.00	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00
	(Random Matrix)						
	65-75 bu/ac	66.80	39.77	43.64	17.61	9.53	177.36
S	75-85 bu/ac	57.07	43.91	78.29	28.87	19.32	227.45
O	85-95 bu/ac	35.58	39.77	95.13	38.83	31.98	241.27
	95-105 bu/ac	16.18	29.55	78.29	42.86	43.29	210.17
N	105-115 bu/ac	5.37	18.01	43.64	30.83	47.88	153.73
	TOTAL	181.00	171.00	339.00	167.00	152.00	1010.00

CHI-SQUARE = 199.32

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
17.82	1.00	14.99	26	1	5	1	1
22.47	1.00	10.59	24	1	5	2	2
16.02	1.00	25.74	42	1	5	3	3
22.47	1.00	23.04	12	1	5	4	4
22.26	1.00	12.98	27	1	5	5	5

The first step in this approximation is to test the original

TABLE 42

Matrix Variance, Modeled Yield and Simultaneous Column Gausian Fit Contingency Tables for Post-Flowering Week at Rochester, MN.

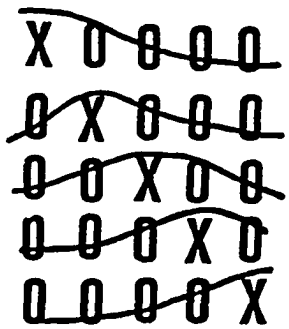
YIELD FORECAST CATEGORY

		65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
(Input Matrix)							
S	65-75 bu/ac	85.00	39.00	27.00	21.00	9.00	181.00
	75-85 bu/ac	33.00	47.00	44.00	33.00	9.00	171.00
O	85-95 bu/ac	27.00	62.00	105.00	89.00	56.00	339.00
	95-105 bu/ac	14.00	37.00	37.00	48.00	31.00	167.00
N	105-115 bu/ac	17.00	19.00	36.00	35.00	45.00	152.00
	TOTAL	176.00	204.00	249.00	231.00	150.00	1010.00
(Random Matrix)							
S	65-75 bu/ac	56.81	53.24	38.53	21.24	9.15	178.78
	75-85 bu/ac	50.97	59.13	52.79	35.90	19.08	217.83
O	85-95 bu/ac	37.20	53.24	58.64	49.19	32.25	230.52
	95-105 bu/ac	22.01	38.86	52.79	54.64	44.18	212.48
N	105-115 bu/ac	10.56	22.99	38.53	49.19	49.07	170.35
	TOTAL	177.36	227.45	241.29	210.17	153.73	1010.00
CHI-SQUARE = 149.53							

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
21.83	1.00	16.84	20	1	5	1	5

contingency table, in this case flowering, against a "no-skill" or random matrix. Elements of such a matrix can be calculated from the expression given in equation (31). The calculated skill score, or Chi-square result, is a value of 203.9, indicating a relatively significant degree of "skillfulness" over random guesses in the original contingency table. The next step is to fit the known Gaussian distribution to the original contingency table, centered on the diagonal (see Figure 82) one row at a time (Table 39). Then perform another Chi-Square test to see how well our fit has done. Table 39 gives this first Gausian aproximation and a Chi-Square value of 49.44 is computed. $\chi^2_{c(16)=26.09}$ and so the hypothesis that the two yield samples were drawn from similar populations, that is, there is no sample bias cannot be accepted. Next consider where this bias comes from. First examine the variance across

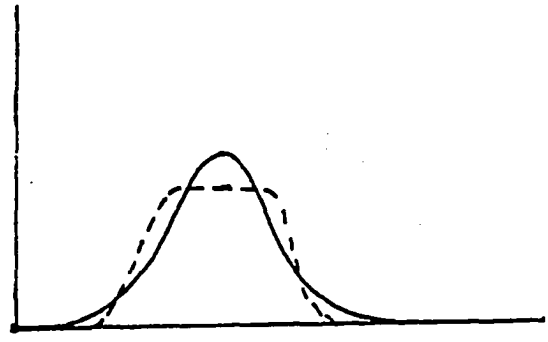
Figure 82: Diagram of Gausian Row Fitting Procedure.



forecast categories of modeled yield outcomes in Table 39. The largest and probably most significant variance, 28.6, resides in the distribution of yields in the last row of the contingency table, the highest yield category of this table. This again highlights a model bias that has been mentioned several times in this report; that of a vast overestimation of yield under certain types of climatic conditions, most often a cool growing season. The bias is likely even greater than reflected here since in cases of extremely cool growing seasons, the yield sample was stopped prior to the end of grain fill and maturity. The changes in magnitude and significance of variance from row-to-row of the table could well be a funciton of yield category and width selection. Another source of bias can be noted within the body of the table. Remember that a Gaussian curve centered on the diagonal element is begin fit. If the fitted matrix is considered, it can be noted that the distribution is flattened. The result is illustrated in Figure 83. A centered Gausian distribution has been created to approximate a

slightly flattened, less than Gausian distribution, therefore, there is a bias in the distribution of the modeled contingency table. That the approximation is not perfect and in what way has now been established, but this is somewhat beside the point. Of primary concern is the generation of a matrix that is at least close to the original, possesses "skill" and which can be statistically described with some confidence because its distribution is known. What remains, then is to see wheather skill was lost or gained through the approximation.

Figure 83: Schematic Illustrating the Sample Bias in the Gausian Fitting Procedure.



Before calculating this Chi-Square an additional Gausian fit is performed, this time in two-dimensions, i.e., all rows at once (Table 40). This means that the distribution will be centered on the diagonal of each row as well as down the vertical diagonal. In this case the peak of the distribution will be element (3,3). When this doubly fit table is compared to a random table, a Chi-Square of 67.99 is computed.

Next repeat the fitting procedure on this new row fitted matrix by columns (Table 41). When one column at a time is fit, one finds a different distribution of variance across the columns than the rows. All columns have large values, but also large errors. This means that within a forecast category, there is no marked bias in the modeled outcomes or states of nature. Finally, perform a Gaussian fit across all columns simultaneously (Table 42). It is this modeled contingency table which will be used to find the Bayes strategy and associated risk.

3.5.4.4 Mid-Season Forecast Value Estimation

Now return to the original purpose of this modeling exercise. Since a contingency table with a known distribution has been derived, the the characteristics of the distribution can be altered to simulate the effects of decreasing uncertainty in mid-season regional forecast categories due to increases in effective degrees of freedom of our sample. Since, realistically, one cannot alter the distribution of final yield outcomes, alterations will be performed during the forecast category (row) fit only. The last simultaneous column fit will, however, continue to be used for the Baysian calculations. The second of eight flowering week iterations (1, 5, 10, 20, 25, 30, 100, 150), based on 5 effective degrees of freedom (EDF, or the number of independent sites) is shown in Tables 43 through 47. A comparison of the variance of the matrix assuming 1 EDF (the original unmodeled case, Table 42), and 5 EDF (Table 47) indicates a decrease in uncertainty from 21.83 bu/ac to 9.79 bu/ac.

TABLE 43

Modeled Yield and Gausian Estimated Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	109.24	60.75	10.44	0.56	0.01	181.00
S	75-85 bu/ac	42.97	77.28	42.97	7.39	0.39	171.00
O	85-95 bu/ac	14.07	81.84	147.18	81.84	14.07	339.00
	95-105 bu/ac	0.38	7.22	41.97	75.47	41.97	167.00
N	105-115 bu/ac	0.01	0.47	8.77	51.01	91.74	152.00
	TOTAL	166.68	227.55	251.33	216.27	148.18	1010.00
	(Random Matrix)						
	65-75 bu/ac	29.87	40.78	45.04	38.76	26.56	181.00
S	75-85 bu/ac	28.22	38.53	42.55	36.62	25.09	171.00
O	85-95 bu/ac	55.94	76.37	84.36	72.59	49.74	339.00
	95-105 bu/ac	27.56	37.62	41.56	35.76	24.50	167.00
N	105-115 bu/ac	25.08	34.24	37.82	32.55	22.30	152.00
	TOTAL	166.68	227.55	251.33	216.27	148.18	1010.00
	CHI-SQUARE = 926.41						

TABLE 44

Row Variance, Modeled Yield and Simultaneous Row Gausian Fit Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	109.24	60.75	10.44	0.56	0.01	181.00
S	75-85 bu/ac	42.97	77.28	42.97	7.39	0.39	171.00
O	85-95 bu/ac	14.07	81.84	147.18	81.84	14.07	339.00
	95-105 bu/ac	0.38	7.22	41.97	75.47	41.97	167.00
N	105-115 bu/ac	0.01	0.47	8.77	51.01	91.74	152.00
	TOTAL	166.68	227.55	251.33	216.27	148.18	1010.00
	(Random Matrix)						
	65-75 bu/ac	108.17	61.14	11.04	0.64	0.01	181.00
S	75-85 bu/ac	43.36	75.59	43.36	8.18	0.51	171.00
O	85-95 bu/ac	15.53	82.27	143.41	82.27	15.53	339.00
	95-105 bu/ac	0.50	7.99	42.35	73.82	42.35	167.00
N	105-115 bu/ac	0.01	0.53	9.27	51.34	90.84	152.00
	TOTAL	167.57	227.52	249.43	216.25	149.27	1010.00
	CHI-SQUARE = 0.77						

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
9.63	2.00	0.58	61	1	1	1	5
9.04	2.00	0.87	61	2	2	1	5
9.04	2.00	1.94	61	3	3	1	5
9.04	2.00	0.85	61	4	4	1	5
9.63	2.00	0.48	61	5	5	1	5

To use these Baysian techniques a value system for our decision

TABLE 45

Matrix Variance, Modeled Yield and Simultaneous Row Gausian Fit Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	109.24	60.75	10.44	0.56	0.01	181.00
S	75-85 bu/ac	42.97	77.28	42.97	7.39	0.39	171.00
O	85-95 bu/ac	14.07	81.84	147.18	81.84	14.07	339.00
	95-105 bu/ac	0.38	7.22	41.97	75.47	41.97	167.00
N	105-115 bu/ac	0.01	0.47	8.77	51.01	91.74	152.00
	TOTAL	166.68	227.55	251.33	216.27	148.18	1010.00
	(Random Matrix)						
	65-75 bu/ac	107.18	61.48	11.60	0.72	0.01	181.00
S	75-85 bu/ac	43.36	75.59	43.36	8.18	0.51	171.00
O	85-95 bu/ac	15.53	82.27	143.41	82.27	15.53	339.00
	95-105 bu/ac	0.50	7.99	42.35	73.82	42.35	167.00
N	105-115 bu/ac	0.01	0.61	9.75	51.63	90.01	152.00
	TOTAL	166.58	227.93	250.47	216.62	148.40	1010.00
	CHI-SQUARE = 1.05						

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
7.04	2.00	1.21	61	1	5	1	5

TABLE 46

Column Variance, Modeled Yield and Individual Column Gausian Fit Contingency Tables for Post-Flowering Week and 5 EDF at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	109.24	60.75	10.44	0.56	0.01	181.00
S	75-85 bu/ac	42.97	77.28	42.97	7.39	0.39	171.00
O	85-95 bu/ac	14.07	81.84	147.18	81.84	14.07	339.00
	95-105 bu/ac	0.38	7.22	41.97	75.47	41.97	167.00
N	105-115 bu/ac	0.01	0.47	8.77	51.01	91.74	152.00
	TOTAL	166.68	227.55	251.33	216.27	148.18	1010.00
	(Random Matrix)						
	65-75 bu/ac	111.40	44.66	3.34	1.60	0.00	161.01
S	75-85 bu/ac	57.88	64.16	69.89	12.61	0.34	206.88
O	85-95 bu/ac	9.30	44.66	192.52	43.52	7.69	297.69
	95-105 bu/ac	0.42	15.06	69.89	65.75	50.19	201.31
N	105-115 bu/ac	0.01	2.46	3.34	43.52	93.78	143.11
	TOTAL	181.00	171.00	339.00	167.00	152.00	1009.99
	CHI-SQUARE = 154.52						

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
8.97	1.00	7.92	45	1	5	1	1
11.75	1.00	19.38	27	1	5	2	2
7.02	1.00	26.98	14	1	5	3	3
11.01	1.00	18.15	37	1	5	4	4
8.74	1.00	4.74	50	1	5	5	5

maker must be defined. An examination of government costs associated

TABLE 47

Matrix Variance Modeled Yield and Simultaneous Column Gausian Fit Contingency Tables for Post Flowering Week and 5 EDF at Rochester, MN.

YIELD FORECAST CATEGORY

	(Input Matrix)	65-75 bu/ac	75-85 bu/ac	85-95 bu/ac	95-105 bu/ac	105-115 bu/ac	TOTAL
	65-75 bu/ac	109.24	60.75	10.44	0.56	0.01	181.00
S.	75-85 bu/ac	42.97	77.28	42.97	7.39	0.39	171.00
O	85-95 bu/ac	14.07	81.84	147.18	81.84	14.07	339.00
	95-105 bu/ac	0.38	7.22	41.97	75.47	41.97	167.00
N	105-115 bu/ac	0.01	0.47	8.77	51.01	91.74	152.00
	TOTAL	166.68	227.55	251.33	216.27	148.18	1010.00
	(Random Matrix)						
	65-75 bu/ac	93.24	52.92	15.16	0.79	0.02	162.13
S	75-85 bu/ac	55.33	89.18	72.55	10.76	0.76	228.58
O	85-95 bu/ac	11.56	52.92	122.27	51.49	10.28	248.51
	95-105 bu/ac	0.35	11.06	72.55	86.78	49.13	220.41
N	105-115 bu/ac	0.02	0.31	15.16	51.49	82.88	150.36
	TOTAL	161.01	206.83	297.69	201.31	143.11	1009.99
	CHI-SQUARE = 84.62						

SIG	1=COL;2=ROW	ERRR	ITER	IBOT	ITOP	JBOT	JTOP
9.79	1.00	14.38	27	1	5	1	5

with regulating corn production and sales can be found in the "Feed Outlook and Situation Report" (USDA, 1984). The major factors provided are import costs, support price expenditures and disaster payments. For the sake of argument, assign unit values to each of these factors (see Table 48).

As outlined earlier, there is a set of yield forecasts made at a certain point in time associated with each category of final modeled yield outcome. There are predetermined but unspecified buy/sell strategies the government has developed which depend on the category forecast. These actions are summarized in Table 49. The matrix in Table 50 illustrates the government risks incurred when action a_j is taken based on a forecast of category z_j, and harvested yield in category θ_i is observed.

TABLE 48

Assigned Unit Values to Factors Contributing to Decision Maker Regrets.

Effect	Value	Effect	Value	Effect	Value
Low import level	1	Little support price	1	Small disaster payment	1
Moderate import level	2	Moderate support price	2	Moderate disaster payment	2
High import level	3	High support price	3	Large disaster payment	3
Very high import level	4	Very high support price	4	Very large disaster payment	4
Highest import level	5	Highest support price	5	Highest disaster payment	5

TABLE 49

Mid-Season Forecast Categories and Associated Decision Maker Actions.

Forecast Category (Z_j)	Government Action (a_j)
65-75 bu/ac	Large government sales to market
75-85 bu/ac	Moderate government sales to market
85-95 bu/ac	No buy/no sell
95-105 bu/ac	Moderate government purchase from market
105-115 bu/ac	Large government purchases from market

When Table 48 is combined with Table 50, the risks or regrets table presented as Table 51 is derived.

The basic information is now in hand to calculate the Bayes risk and, consequently to determine the value of increased certainty in the forecast categories. The determination of the Bayes risk and strategy for the observed data case at flowering will be followed as an example. Begin with the contingency table given as Table 52.

TABLE 50

Decision Maker Risks Associated With Actions a_1 Through a_5.

Actions / SON	Large Government Sales a_1	Moderage Government Sales a_2	No Buy No Sell a_3	Moderate Government Purchase a_4	Large Government Purchase a_5
Very Low Yields θ_1	Correct Action	Moderate Disaster Payments	Moderate Disaster + Moderate Imports	High Disaster + High Imports	High Disaster + Higher Imports
Low Yields θ_2	Moderate Disaster	Correct Action	Small Imports + Disaster	Moderate Imports	High Imports
Average Yields θ_3	Large Supports	Moderate Supports	Correct Action	Moderate Imports	Large Imports
Above Average Yields θ_4	Higher Supports	High Supports	Moderate Supports	Correct Action	Moderate Imports
Much Above Average Yields θ_5	Highest Supports	Higher Supports	High Supports	Moderate Supports	Correct Action

TABLE 51

Decision Maker Regrets Table.

		ACTIONS				
		a_1	a_2	a_3	a_4	a_5
SON	θ_1	0	2	4	6	7
	θ_2	2	0	3	2	3
	θ_3	3	2	0	2	3
	θ_4	4	3	2	0	2
	θ_5	5	4	3	2	0

TABLE 52

Original Modeled Yield Contingency Table.

		FORECASTS					
		Z_1	Z_2	Z_3	Z_4	Z_5	
	θ_1	85	39	27	21	9	181
	θ_2	33	47	44	38	9	171
S	θ_3	27	62	105	89	56	339
O	θ_4	14	37	37	48	31	167
N	θ_5	17	19	36	35	45	152
		176	204	249	231	150	1010

Next, find the joint probabilities associated with this table as given by Eq. (32) and Table 53.

$$\hat{p}(\theta_i, z_j) = f(\theta_i, z_j)/N \ . \tag{32}$$

TABLE 53

Joint Probability Table for Baysian Decision Maker.

		FORECASTS					
		Z_1	Z_2	Z_3	Z_4	Z_5	$P(\theta_i)$
	θ_1	.084	.038	.027	.021	.009	.179
	θ_2	.033	.046	.043	.038	.009	.169
S	θ_3	.027	.061	.104	.088	.055	.335
O	θ_4	.014	.037	.037	.047	.031	.166
N	θ_5	.017	.019	.036	.035	.044	.151
	$P(Z_j)$	.175	.201	.247	.229	.148	

Normalize each element of this joint probability table by column as given in Eq. (33) in order to obtain $p(\theta_i|z_j)$.

$$p(\theta_i|z_j) = p(z_j, \theta_i)/p(z_j) \quad . \tag{33}$$

The values in Table 54 are then computed.

TABLE 54

Table 53 Normalized by Column.

		SON						
		θ_1	θ_2	θ_3	θ_4	θ_5	$\Sigma P(\theta_i/Z_j)$	$P(Z_j)$
FORECASTS	Z_1	.48	.189	.154	.080	.097	1	.175
	Z_2	.189	.229	.303	.184	.095	1	.201
	Z_3	.109	.174	.421	.150	.146	1	.247
	Z_4	.092	.166	.384	.205	.153	1	.229
	Z_5	.061	.061	.372	.209	.297	1	.148

The final Bayes strategy can now be determined. From Table 54 there are 3125 possible strategies (Eq. 34).

$$N_s = (\text{number of actions})^{(\text{number of predictions})} \quad . \tag{34}$$

where: N_s = number of possible solutions.

The regrets associated with each of these 3125 strategies can be calculated as given below:

$$R_q = \sum_{i=1}^{5} \left[\sum_{j=1}^{5} p(z_j|\theta_i) * R(\theta_i, a(z_j)) \right] * p(\theta_i) \qquad (35)$$

where: $p(z_j|\theta_i)$ = probability of forecast z_j give state of nature i,

$R(\theta_i, a(z_j))$ = the regret associated with state of nature, i, and action, a, of forecast z_j,

$p(\theta_i)$ = probability of state of nature i.

Eddy and Shannon (1975), however, have demonstrated that one need only consider 25 outcomes (Eq. 36) enumerated by Eq. (37).

$$N_s = \text{(number of actions} * \text{(number of predictions)} . \qquad (36)$$

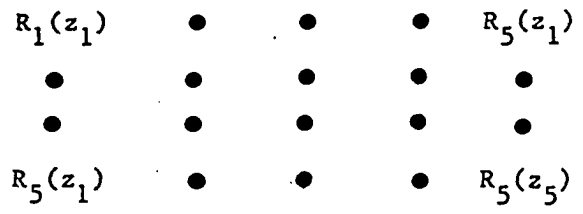
$$R_i(a_j) = \left[\sum_{i=1}^{5} p(\theta_i|z_j) * R(\theta_i, a(z_j)) \right] * p(z_j) \qquad (37)$$

where: $p(\theta_i|z_j)$ = probability of state of nature i given forecast z_j,

$p(z_j)$ = probability of forecast z_j,

$R(\theta_i, a(z_j))$ = as in Eq. (35).

Using the portion of Eq. (37) enclosed in square brackets, a matrix will result of the form:



where: $R_1(z_5)$ denotes the expected regret from taking action a_1 when z_5 is determined (see table 55) .

TABLE 55

Computed Baysian Regrets Table.

	a_1	a_2	a_3	a_4	a_5
R_1	1.645	2.578	2.941	3.069	3.559
R_2	1.896	1.916	1.944	2.179	2.681
R_3	2.94	2.096	1.450	1.735	1.736
R_4	3.76	2.388	2.136	1.958	1.826
R_5	4.549	3.287	5.548	2.704	2.144

Locate the smallest risk value in each column. The set of actions associated with these smallest risks is the Bayes strategy. In this example the Bayes strategy, S_B is a_1 , a_2 ,a_3 ,a_3 ,a_3 . Multiply each of these actions by the appropriate $P(z_j)$ (Table 53). It can then be said that under this optimal i.e.; minimum risk/regret strategy, a Bayes risk value, R_B of 1.685 is computed. This value represents the long-term expected risk given the model forecast yield distribution, i.e., over the long-term our decision maker could expect to lose 1.685 units. This is compared to a loss under the "no-skill" matrix forecast of 2.39.

The use of a "skilled" forecast matrix has saved the decision maker .71 units or, has decreased his risk by approximately 30 percent.

In order to estimate the value of decreasing the uncertainty in mid-season forecasts of yield category, these same solution procedures are followed for each of the Gausian modeled contingency tables. The solid line in Figure 84 is a graphical representation of the way the Bayes risk responds to effective degrees of freedom, or, increases in certainty. Assume that the maximum risk exists with the use of 1 EDF. The curve decreases with EDF until, at EDF = 100, the risk is essentially 0, i.e., the estimate is correct. To obtain a value curve for these results, take the difference between the Gaussian modeled R_B = 1.842 for EDF = 1 and R_B at the various levels of EDF. Figure 85 can then be constructed. Figure 85 indicates the majority of increased value, i.e., decreased risk, occurs with EDF's between 2 and 40. Beyond 40 EDF there is some improvement, as illustrated in Figure 84, but it is relatively insignificant.

The final step would be to translate the EDF information into the required number of point (area) yield estimates. This would require the development of a complete covariance matrix, which is beyond the scope of the present study. An example and application may be found in Eddy, Avara, and Panturat (1984). But, if a model for interstation correlation is assumed, the number of stations required to achieve this EDF can be estimated by Eq. (38).

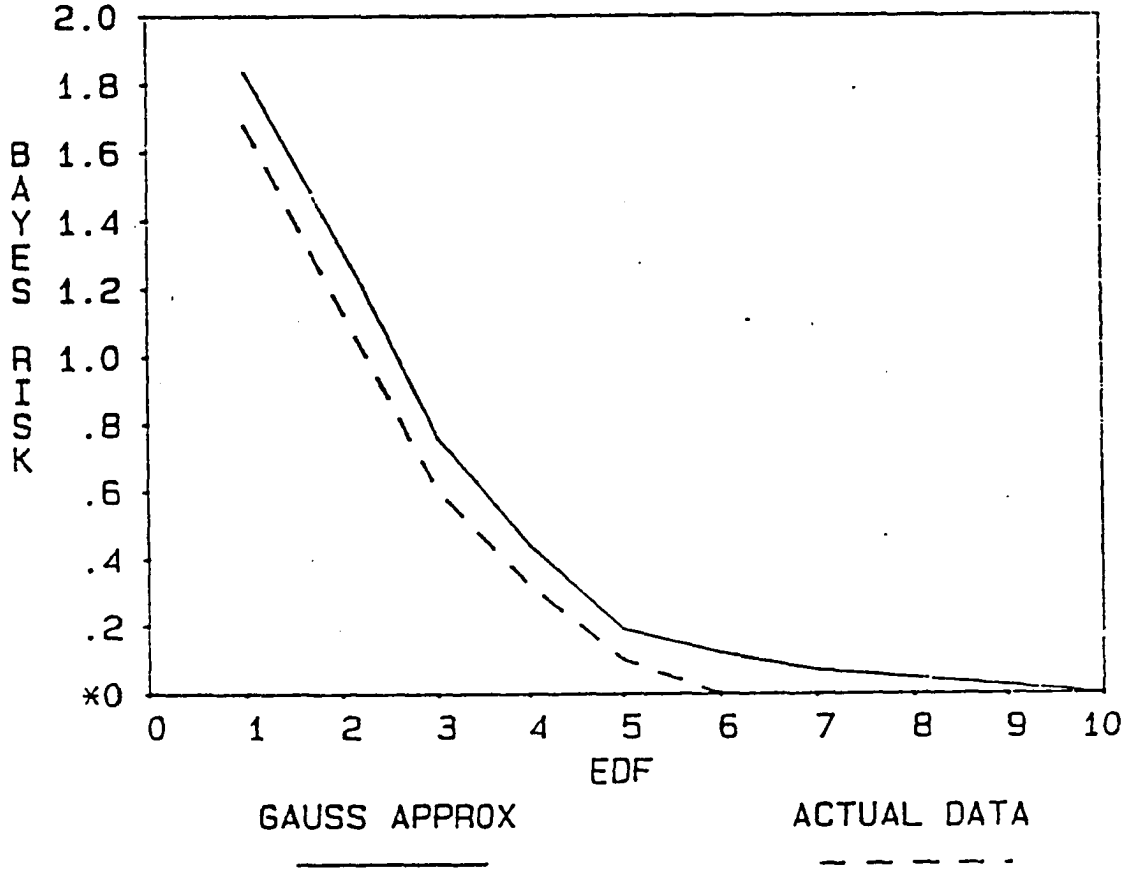
$$N_a = [(1 + \rho)/(1 - \rho)]N_e \qquad (38)$$

where: N_a = actual station number,

N_e = effective station number,

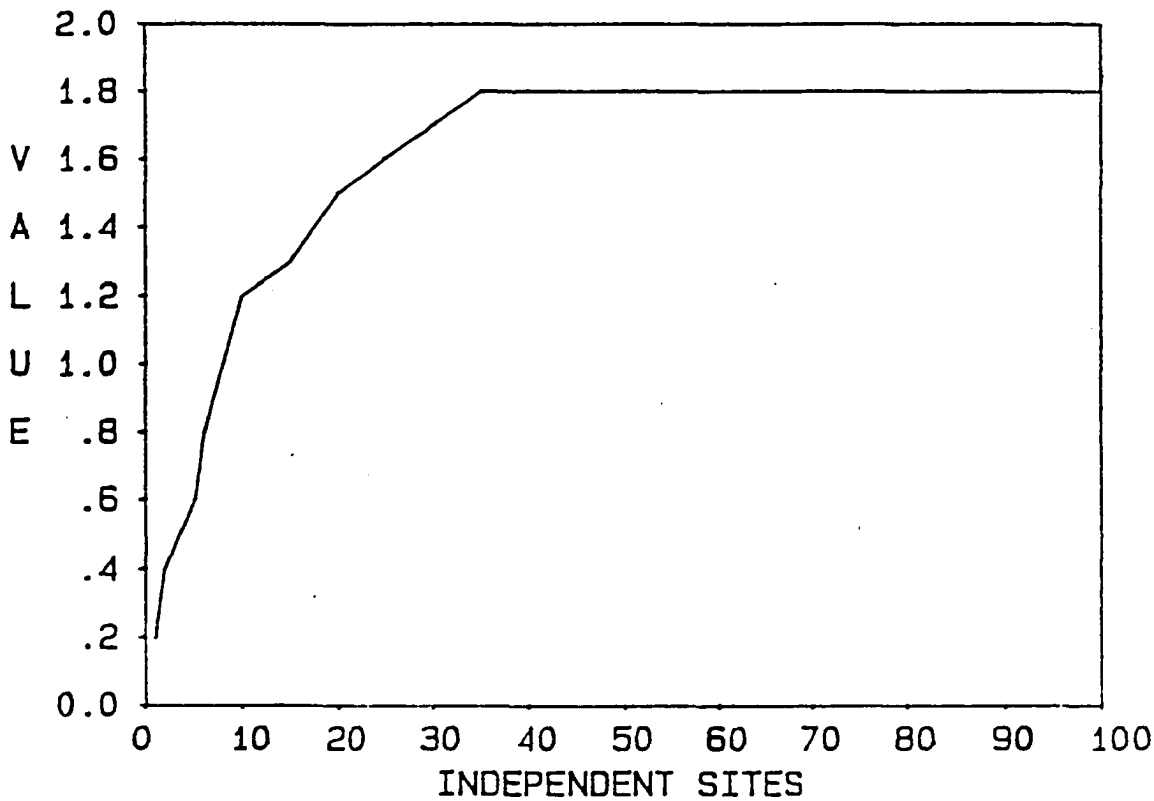
ρ = interstation correlation.

Figure 84: Estimated Bayes Risk at Flowering.



For example, assuming a value of $\rho = .7$, the greatest increase in yield forecast value would be achieved with between 11 and 227 stations. Assuming $\rho = .7$ was correct for the present 42 station network, which it most likely is not, this translates into 7.4 EDF. These EDF result in a variance of $(5.47 \text{ bu/ac})^2$ and a Bayes risk reduction of about 1.0 (46%). Even so, Figure 85 suggests that 7.4 EDF are still somewhat suboptimal for this particular Bayes construction.

Figure 85: Value of EDF Flowering



The above results permit the estimation that a decrease in mid-season forecast uncertainty of, say, 40 percent, results in a Bayes Risk decrease of 90 percent, and that this estimate is probably conservative. With more than 2000 cooperative stations in the 14 state area defined as the corn-belt, the point of minimum risk developed in this example, 50 EDF, should be achieved easily. The only constraint is the degree of monetary investment, which could be quite sizable. On the other hand, the magnitude of investment involved in these decisions is on the order

of billions of dollars. The challange is to develop a well thought-out plan of action to achieve these risk reductions.

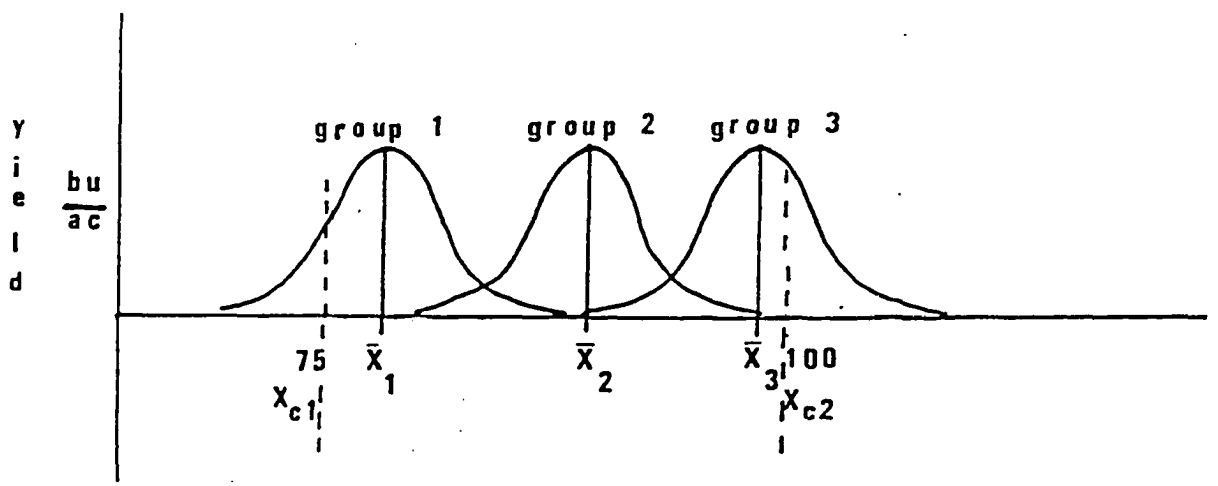
To conclude this portion of research, consider the implications of these computed results developed under a Bayesian framework to the mid-season National Corn/Weather Index presented earlier. To create an unlimited number of site specific forecast matrices which reasonably forecast mid-season yield uncertainty is prohibitively expensive. A methodology has been suggested capable of keeping this cost to a minimum. If a complete covariance matrix for the station network is developed, including the user's requirements for estimate accuracy, a minimum number of stations could be statistically selected and their forecast matrices computed. As indicated by the Bayes case, a moderate reduction in forecast uncertainty could generate significant user savings. The results computed as a prelimiary index using a poor forecasting technique indicate that this product could be well worth the future investment of time and money.

3.5.5 Modeled Yield Non-Homogeneities and User Products

By this point in the analysis, it is apparent that the modeled yield population is non-homogeneous. This has been suggested both visually (Figure 44) and statistically (section 3.5.4.2), and has been identified in rough statistical terms (Table 26). Although this population characterisitc tends to complicate statistical analysis, it also facilitates the making of probabilistic statements which can contribute to the general applicability of user products. Before such probabilistic statements can be made, the nature of the non-homogeneity must be defined more clearly.

Refer back to the histogram of yields in Figure 45. These are not individually modeled yields, but row means from design B, Figure 36. Thus, each week there is a distribution consisting of 36 means about a central mean. From earlier work it is assumed that there are three such distributions which look something like Figure 86. By inspection of Table 26 (a composite of all weeks; i.e. column effects in each row), a reasonable a priori probability statement would be .17, .58, .25. That is, 17% of the time a yield forecast will be less than 78 bu/ac, 58% of the time a yield forecast will lie between 78 and 100 bu/ac and 25% of the time a forecasted yield will be greater than 100 bu/ac.

Figure 86: Hypothetical Distribution of Modeled Corn Years.



If it is assumed that each of these three sets of means are drawn from a Gausian distribution, a more accurate measure of yield forecast probability can be made. For instance, assume some critical value X_{c_1} which lies between distribution 1 and distribution 2. Likewise, assume some critical value X_{c_2} which lies between distributions 2 and 3. The

probability of the mean of a set of 36 yield forecasts, X, belonging to group 1 given that $X<X_{c_1}$ is given by Eq. (39). The probability of this forecast mean belonging to group 3 given that $X>X_{c_2}$ is given by Eq. (40). The likelihood of mean forecast X belonging to group 2 given it is between X_{c_1} and X_{c_2} is presented in Eq. (41).

$$p(x\ni 1,i|x<x_{c_1},i) = \frac{\left[\int_{-\infty}^{x_{c_1}} e^{\frac{-1}{2}\frac{(x-\bar{x}_1)^2}{\sigma_1^2}} dx\right] p(1)}{\sum_{j=1}^{3}\left[\int_{-\infty}^{x_{c_1}} e^{\frac{-1}{2}\frac{(x-\bar{x}_j)^2}{\sigma_j^2}} dx\right] p(j)} \tag{39}$$

where: $p(x\ni 1,i|x<x_{c_1})$ = the probability of the mean mid season yield forecast x being in group 1 during week i, given that the forecast is less than a critical value, x_{c_1},

$\bar{x}_j$, σ_j = the mean and standard deviation of the distribution of mean yield forecasts belonging to group j,

p(j) = the <u>a priori</u> probability of a mean yield forecast being in forecast group j,

j = forecast group (See Figure 86).

i = forecast week

$$p(x\ni 3,i|x>x_{c_2}) = \frac{\left[\int_{x_{c_2}}^{\infty} e^{\frac{-1}{2}\frac{(x-\bar{x}_3)^2}{\sigma_3^2}} dx\right] p(3)}{\sum_{j=1}^{3}\left[\int_{-\infty}^{x_{c_1}} e^{\frac{-1}{2}\frac{(x-\bar{x}_j)^2}{\sigma_j^2}} dx\right] p(j)} \tag{40}$$

where: $p(x\ni 3,i|x>x_{c_2})$ = the probability of a mid-season forecast, x, being in forecast group 3 during week i, given that x is greater than some critical forecast, x_{c_2}

others as in Eq. (39).

$$p(x\ni 2,i|x_{c_1}<x<x_{c_2}) = 1 - p(x\ 1|x\leq x_{c_1}) - p(x\ 3|x\geq x_{c_2}) \qquad (41)$$

where: $p(x\ni 2,i|x_{c_1}<x<x_{c_2})$ = the probability of a mid-season mean yield forecast, x, belonging to group 2 during week i, given x is between two critical forecast values, x_{c_1} and x_{c_2},

others as in Eqs. (39) and (40).

There are a number of ways in which this information could be provided to users. The illustration which follows is a simple example of one such method.

Assume that the user is a commodity broker with many years of experience. He knows that when USDA corn yield estimates are 75 bu/ac or less he should buy and when they are equal to or above 100 bu/ac he should sell. These estimates are rather widely spread through time but an agroclimatologist will provide him with yield information every week.

The earlier he can project market turns or "beat" the USDA estimates, the larger the Broker's profits. The broker asks the climatologist to provide him with information concerning the liklihood of model forecasted yields falling above 100 or below 75 bu/ac. The climatologist can produce this information on a week by week basis, but cannot recommend an action unless he knows the Broker's decision criteria. That is, how confident must he be in the yield category forecast before an action is taken. The climatologist can release the information as a simple probability statement and let the broker decide his actions himself, or, if provided with the broker's decision critera, the climatologist can make buy/sell recommendations. By way of illustration, the calculations necessary to make a probabilistic statement concerning yield group identity will be performed at three times during the growing season.

First, to restate the user's question, a broker fixes his critical yield limits at 75 and 100 bu/ac. Each week he would like to know, given a yield forecast mean of X<75bu/ac, what is the likelihood that it belongs to group 1, group 2 or group 3. This premise is stated in probabilistic terms in Eq. (42).

$$P(A|B) \tag{42}$$

where: $P(A|B)$ = the probability of A given B,

A = group 1 in week i,

B = Y < 75 bu/ac.

From Bayesian decision theory we know:

$$P(A|B)P(B) = P(B|A)P(A), \text{ and} \tag{43}$$

$$P(A|B) = P(B|A)P(A)/P(B) \tag{44}$$

By use of the z-statistic and a table of normal deviates, we can compute $P(B \mid A)$. Values of $\bar{X}$ and σ^2 for each group

$$P(B|A) = P(Z < \frac{x-\bar{x}_j}{\sigma_j}) \tag{45}$$

where: $P(B|A)$ = probability a forecast, x, where $x < 75$ bu/ac given that we are in group j at week i,

Z = Z statistic,

$\bar{x}_j$, σ_j = mean and standard deviation of group j.

for each sample week are given in Table 56. We have already defined our a priori probabilities of being in group 1, P(A), group 2, P(C) or group 3, P(D). We still do not know the a priori probability of a yield less than 75 bu/ac, P(B). Intuitively this would be the number of mean forecasts less than 75 bu/ac given being in group 1 plus the number of

TABLE 56

Means and Standard Deviations of Three Clustered Distributions of Mean Forecasted Yields at Weeks 25, 30, and 35.

	$\bar{X}_1$	σ_1	$\bar{X}_2$	σ_2	$\bar{X}_3$	σ_3
Week 25	88.5	5.19	92.75	6.18	99.23	5.55
Week 30	75.15	8.51	91.19	6.68	108.72	5.53
Week 35	63.05	9.57	89.87	9.92	122.54	12.98

mean forecasts less than 75 bu/ac given being in group 2 plus the number of mean forecasts less than 75 bu/ac given being in group 3 divided by the total number of sample means. This can be expressed by Eq. (46).

$$P(B) = [P(B|A)f(A)+P(B|C)f(C)+P(B|D)f(D)]/36. \quad (46)$$

where: $P(B)$ = probability of $x < 75$ bu/ac,

$f(A), f(C), f(D)$ = frequency of forecasts in group A, C, or D (1, 2, or 3),

others as in Eq. (42).

All the information has now been assembled to compute a complete probability statement for each example week. The results of these computations are given in Table 57 and a discussion of its interpretation follows.

Table 57 is interpreted as:

1. Given a mean yield forecast of less than 75 bu/ac, the probability of being in group 1 during week 25 is .084.
2. Given a mean yield forecast of less than 75 bu/ac, the probability of being in group 2 during week 25 is .553.
3. Given a mean yield forecast of less than 75 bu/ac, the probability of being in group 3 during week 25 is .362.
4. etc.

The other probability group statements contained in Table 57 can be constructed in a similar manner. In general, there is a rather impressive ability to discriminate mid- and high-yield groups as early

TABLE 57

Probability Statements Concerning the Likelihood of Mean Forecast, X, Belonging to Forecast Group 1, 2, or 3.

	Week 25	Week 30	Week 35	Group Probs.
|X<75)	.084	.948	.794	
P(wk,#1|75<X<100)	.904	.037	.166	P(1) = 1.0
|X>100)	.012	.015	.040	
|X<75)	.553	.052	.207	
P(wk,#2|75<X<100)	.063	.672	.411	P(2) - 1.0
|X>100)	.384	.276	.382	
|X<75)	.362	.001	.0002	
P(wk,#3|75<X<100)	.034	.292	.423	P(3) = 1.0
|X>100)	.604	.707	.577	

in the growing season as week 25. This is impressive when the tangled mass of forecast time-series in Figure 44 are considered at this date (week 25). Also as suggested by Figure 44, by week 30, clear statements concerning forecast group identity can be made. The most certain statement that can be made from Week 30 in Table 57 concerns the probability of the final outcome being in group 1 (low yields). Table 57 indicates that given a yield forecast made at Week 30 of 75 bu/ac or less, there is a 9.5 in 10 chance that the final model outcome will fall into the low yield group. Given a forecast of between 75 and 100 bu/ac at Week 30, there is a nearly 7 in 10 chance that the final model outcome will fall into group 2 (middle range yields). Given a forecast

of greater than 100 bu/ac, there is a 7 in 10 chance of the final model outcome belonging to group 3 (high yield). In most cases, these values represent an improvement over the estimates made at Week 25. In most cases at Week 30, there is clearly 1 most probable outcome. At Week 25, with the exception of group 1, mid-range forecasts, the likelihood estimates for each possible outcome group are much closer together.

By Week 35 a situation where the likelihoods are more evenly distributed among outcome groups has been achieved. There are still indications of preferred outcome groups, but the likelihood of making an error in forecast group is much higher. This "smearing" effect during Week 35 is not unexpected given the quantitative knowledge of yield variance behavior and qualitative information in Figure 44 This effect, then, should be considered to be noise and decisions made based upon week 30 criteria would still be valid.

This concludes the present example of uses of known population non-homogeneities. Another use of the information presented in this example is in the selection of analog corn-weather years for senario computations. For example, in the case of a mean forecast yield less than 75 bu/ac at week 30, those years whose means cluster in group 1 might be selected (1955, 1957, 1975, 1978, 1982 and 1983). In the case of a mean yield forecast during week 25 greater than 100 bu/ac, a combination of 6 randomly selected years from group 3(high-yields) and 4 from group 2 (mid-yields) might be utilized.

There are a number of other ways that this type of cluster information can be utilized. For instance, optimal critical values which best seperate the three distributions could be determined using

multiple discriminant analysis. These critical values would then be fixed across all time and the likelihood of being in each group determined. The most important point of the example and analysis contained in the present section is the quantification of suspected population non-homogeneities and the practical exploitation of this additional information to refine confidence limit statements made in earlier portions of this Chapter which assume a single, homogeneous distribution. A second major point of the discussion just completed is the development of a method which allows for the logical selection of representative corn-weather analog years for senario illustrations.

Relating what has been accomplished in Chapter III to Figurel, Chapter 1; this chapter has illustrated the way in which sensitivity analyses of a direct impact plant process model can give results which can then be utilized in case studies and in the development of products of definable value to an identified user group (alternative value systems). The process was carried even further through the flowchart of Figure 1, out of the double lined box and into the relm of decision making. The remaining portions of Figure 1, economic modeling, will be addressed in Chapter V. Before proceding to this further analysis, a parallel but streamlined analysis for an energy process-type model following the steps contained in the double lined box of Figure 1 will be explored.

Chapter IV

ESTIMATION OF DIRECT IMPACTS OF RESIDENTIAL HEATING ENERGY DEMAND.

A second area of economic activity which can be affected directly by weather is domestic energy use. In general it is much more practical to discuss direct weather impacts on households than industry-wide impacts because, except in a few extreme cases, the utility industry has insulated itself to a considerable extent against weather associated energy emergencies. Companies organize themselves into grids or cooperatives such that climate impacts are minimized. Household budgets on the other hand, are far more susceptible to the impacts of transient climatological extremes. The dollar value of those impacts can be assessed through the use of an economic model such as that discussed in Chapter V below.

This development of climate impact techniques for energy demand will follow much the same pattern as for agriculture in Chapter III, but with a streamlined and simplified statistical approach to the analysis of sources of variability in heating season weather and model predicted energy use. A large portion of this chapter focuses on using heating season weather information in a process-type energy model. This is an essential part of the direct impact analysis since a weather sensitivity analysis of an energy load process model has never been performed. The analysis performed is not exhaustive, rather the goal is to pin-point those weather variables which, when transformed by the model, explain

the majority of predicted and observed residential heating energy demand. This will not only illustrate the statistical nature of the model but will also suggest appropriate user products.

Another aspect of direct climate impact modeling is model selection. Chapter II describes several types of impact models including statistical regression models. Statistical regression models currently remain the dominant method of direct impact estimation, particularly in the area of energy supply/demand forecasting. The present analysis addresses this by comparing the performance of a regression-type model and a process-type direct impact model under Oklahoma heating season weather. A similar analysis could have been performed for the agricultural model described in Chapter III, but it was decided to illustrate the comparison procedure for only the energy case.

Once the statistical and process model comparison has been completed, sample products designed for use by households and utility firms are developed. The sample products include the suggestion of geographic energy use areas, the estimation of the likelihood of mild and severe heating season weather, and an energy use index. Applications of the latter product to estimate the dollar impacts of heating season weather on aspects of the Oklahoma economy are explored in Chapter V.

4.1 NBSLD MODEL DESCRIPTION

As in the case of direct agricultural impacts, there are two basic types of energy demand impact models. The most prevalent is a regresssion type model which can contain coefficients reflecting the effects of weather, energy costs and use-patterns on domestic demand. Warren, LeDuc and Hock (1984) give such a model. It is similar in form and function to the second-generation yield models mentioned earlier in this report. It is primarily designed to provide areal estimates of energy demand.

The second model type is a load determination model, NBSLD (Kusuda, 1976). This model is very similar in form and function to the CERES corn process model. NBSLD is designed to model the physical processes of heat exchanges within and among structural components. It makes an energy use estimate at a point location. It is free from the effects of technology and price since it is purely physical. There are no assumptions made by the model concerning mechanical efficiencies of heating systems. The model estimates energy exchanges among structural materials with no consideration of how these exchanges might be mitigated. The structural components are held constant in time and space so the only factor stimulating energy demand changes is the local external weather. A description of NBSLD model components and structural input requirements has been provided in Chapter II.

The NBSLD "process" model will be defined for five locations across Oklahoma and will be applied using some simple statistical analyses of weather variable input and model outut. The AISC energy model will then be developed for the State of Oklahoma. Aggregate NBSLD results will be

defined for the State, and results from the two models will be compared in general terms.

The first model to be considered in some detail is the National Bureau of Standards Load Determination model (NBSLD). This model offers the option of using "design day" weather conditions or actual hourly reports. When design day data are used, this model simulates the majority of required weather data from a few basic input parameters. An hour-by-hour analysis performed with observed rather than simulated data requires far more detailed weather input. Table 58 provides a list of the required information. The original data were obtained from the National Environmental and Satellite Data Information Service (NESDIS) at Ashville, North Carolina. These data (format TD 1440) were reprocessed, edited and reformatted into an hourly data format (McDonald, et.al, 1983). The stations used for Oklahoma, their periods of record, and their locations are given in Table 59 and Figure 87. Missing data were a problem at the non-first order meteorological sites. Although more sophisticated methods were considered, it was decided to use long-term hourly means for each calendar day to approximate data prior to January 1, 1965. After January 1965 all station observations were digitized with a resolution of once every three hours. In these cases the 3-hourly observations were duplicated in the off-hour periods to avoid unnecessary inconsistencies in the time-series. If a 3-hourly observation was missing, long-term hourly means for the calendar day were substituted.

The physical characteristics of the house are described in Appendix G. These include the occupancy schedule as well as materials and their

TABLE 58

Weather Input Parameters Required for a Real-Time NBSLD Execution.

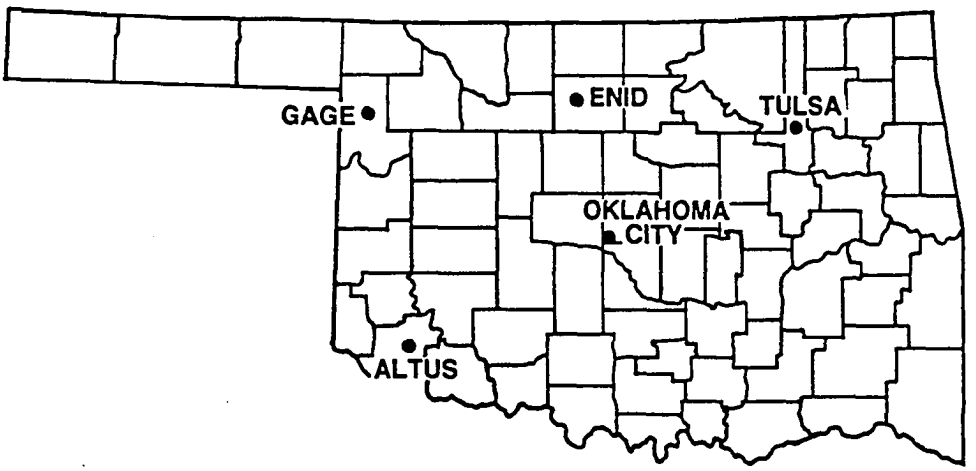
Parameter	Units
Dry Bulb Temperature	°F
Dew Point Temperature	°F
Wet Bulb Temperature	°F
Wind Velocity	Knots
Barometric Pressure	Inches
Total Cloud Cover	Tenths
Total Opaque Cloud Cover	Tenths
Year	-
Month	-
Day	-
Hour	-

NBSLD Data Sites and Period of Record.

Station	Period of Record
Altus	8/53 - 12/70
Enid	1/49 - 12/70
Gage	7/48 - 12/64
Oklahoma City	1/45 - 12/81
Tulsa	7/48 - 12/81

thermal characteristics for each room. Consideration was given to documenting and then developing a "typical" Oklahoma structure. Although this would lend a greater degree of realism to our results, this detail was determined unnecessary for the present project. We are most interested in the variability of energy requirements produced by weather variability. There are, of course many aspects of structural composition that will effect this response variability but these details are most likely of greater importance to the mean and absolute energy prediction than to an assessment of seasonal variability. To summarize:

Figure 87: Locations of NBSLD Station Sites.



the structure contains 1654 square feet of living space comprised of three bedrooms, 1 3/4 baths, kitchen and living room. The construction is "tight" with 4 inches of blown insulation in the ceiling.

4.2 HEATING SEASON WEATHER STATISTICS

The first task is to determine the period of interest over which the NBSLD model will be run. In Oklahoma this is the heating season which extends between October 1 and May 1, with October and April being transition months during which cooling as well as heating may be required. By rigidly fixing this season, we will miss some unusually cool early Falls and late Springs, but October 1 to May 1 will capture

the majority of most heating season impacts. One measure of a heating season is the heating degree day (Eq. (47)). The distribution of the degree day units can be used to define a "season".

$$\text{Heating Degree Days} = \text{HDD} = 65 - ((\text{maximum temperature} + \text{minimum temperature})/2) \quad (47)$$

This expression assumes that heat is required when exterior mean daily temperatures fall below 65 degrees. This "base" is merely a consensus figure, and arguments on behalf of various other bases could be made. In this study, however, 65 degrees is assumed for a base.

Once the heating season has been determined, seasonal climatologies of energy related variables can be generated. This type of analysis on the hourly data has not been performed because there is some doubt as to the meaning of seasonal hourly averages of some variables such as cloud cover or barometirc pressure. Some meaningful values such as 24-hour maximum and minimum temperatures and 24-hour mean temperature can be computed. A brief comparison at Oklahoma City of these values based on hourly and 24-hour observations indicates reasonable correspondence. The major difference between the two time scales would be in HDD since it is linked closely with time. Although it is assumed that HDD are included implicitly in the NBSLD model, they do not appear explicitly. Therefore, a statistical presentation of daily (24-hour) temperature and HDD data which contains rankings, histograms, means and standard deviations for the period corresponding to that of the hourly data was

created. A sample set has been provided in Figures 88 - 91. Statistics for the remaining four stations are provided in Appendix H. In each example only the variable for which the figure is titled has been ranked. The other variables which occur ccoincidentally with the ranked parameter are then also provided. In the case of Figure 88, Mean Heating Season Temperature at Oklahoma City has been ranked from coolest to warmest. The coolest season occurred during 1959 and 1960. The maximum and minimum temperatures and total HDD which also ocurred during 1959 and 1960 are then also provided.

First consider the seasonal energy climatology discussion focusing on Oklahoma City, depicted in Figures 88 - 91. Comparing Figure 89 to 90, it can be seen that much less variance resides in minimum temperature than maximum temperature, approximatley 64 percent less. This large discrepancey might at first seem suspicious but can easily be explained. Maximum temperatures are largely determined by levels of incoming solar radiation and surface characterisitics. Anything that might impact the surface interception of this energy such as cloudiness, rain, particulate pollution, etc., could radically impact observed values of maximum temperature. Minimum temperature, on the other hand, is primarily controlled by the rate of heat released from the surface and its transfer upwards through the atmosphere. Although heat transfer properties of the soil, soil moisture, and low level cloudiness can impact these minimum temperature values, such impacts are on a much smaller scale than those factors effecting maximum temperatures. Thus, the variance in daily minimum temperatures and seasonal minimum temperatures is much less than that of maximum temperatures.

Figure 88: Statistical Summary of Mean Heating Season Temperature at Oklahoma City, Oklahoma.

1	59	60	55.3	35.4	45.4	4207.0
2	78	79	56.6	34.4	45.5	4242.5
3	57	58	55.0	36.3	45.6	4138.5
4	72	73	55.1	36.7	45.9	4191.5
5	77	78	57.1	35.2	46.2	4112.0
6	69	70	57.8	35.2	46.5	4014.5
7	55	56	59.1	34.6	46.8	3952.5
8	48	49	57.9	36.5	47.2	3867.0
9	61	62	57.7	36.6	47.2	3885.0
10	68	69	57.9	36.5	47.2	3896.5
11	76	77	59.8	34.8	47.3	3858.0
12	58	59	59.0	35.8	47.4	3880.5
13	64	65	59.1	36.2	47.6	3812.0
14	67	68	58.2	36.9	47.6	3797.5
15	70	71	59.6	35.6	47.6	3746.5
16	81	82	58.9	36.2	47.6	3775.5
17	74	75	58.4	37.1	47.8	3751.0
18	79	80	59.8	35.7	47.8	3771.5
19	56	57	57.9	38.2	48.0	3725.0
20	51	52	59.4	37.5	48.5	3601.0
21	62	63	60.3	37.3	48.8	3684.0
22	50	51	61.4	36.8	49.1	3143.5
23	60	61	60.1	38.2	49.1	3551.5
24	52	53	60.5	37.8	49.2	3346.0
25	63	64	61.4	37.4	49.4	3418.0
26	71	72	61.0	38.2	49.6	3405.0
27	54	55	61.9	38.0	49.9	3428.0
28	49	50	61.9	38.1	50.0	3177.5
29	65	66	61.1	39.2	50.1	3249.0
30	73	74	61.8	38.4	50.1	3289.0
31	80	81	63.0	37.8	50.4	3277.0
32	53	54	61.7	39.3	50.5	3113.5
33	66	67	63.4	39.1	51.2	3114.0
34	75	76	64.4	38.5	51.5	3083.5

MEAN	STANDARD DEVIATION
48.22352941	1.67061209
MINIMUM VALUE	**MAXIMUM VALUE**
45.40000000	51.50000000
STD ERROR OF MEAN	**SUM**
0.28650761	1639.6000000
VARIANCE	**C.V.**
2.79014474	3.464

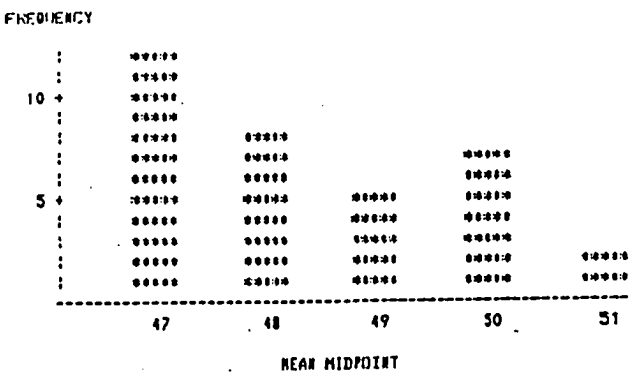


Figure 89: Statistical Summary of Mean Heating Season Minimum Temperature at Oklahoma City, Oklahoma.

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	57	58	55.0	34.3	45.6	4138.5
2	72	73	55.1	34.7	45.9	4193.5
3	59	60	55.3	35.4	45.4	4207.0
4	78	79	56.6	34.4	45.5	4242.5
5	77	78	57.1	35.2	46.2	4112.0
6	61	62	57.7	36.6	47.2	3885.0
7	69	70	57.8	35.2	46.5	4014.5
8	48	49	57.9	36.5	47.2	3847.0
9	56	57	57.9	38.2	48.0	3725.0
10	68	69	57.9	36.5	47.2	3896.5
11	67	68	58.2	36.9	47.6	3797.5
12	74	75	58.4	37.1	47.8	3751.0
13	81	82	58.9	36.2	47.6	3775.5
14	58	59	59.0	35.8	47.4	3810.5
15	55	56	59.1	34.6	46.8	3932.5
16	64	65	59.1	36.2	47.6	3812.0
17	51	52	59.4	37.5	48.5	3681.0
18	70	71	59.6	35.6	47.6	3746.5
19	76	77	59.8	36.8	47.3	3858.0
20	79	80	59.8	35.7	47.8	3773.5
21	60	61	60.1	38.2	49.1	3551.5
22	62	63	60.3	37.3	48.8	3684.0
23	52	53	60.5	37.8	49.2	3546.0
24	71	72	61.0	38.2	49.6	3405.0
25	65	66	61.1	39.2	50.1	3249.0
26	50	51	61.4	36.8	49.1	3583.5
27	63	64	61.4	37.4	49.4	3618.0
28	53	54	61.7	39.3	50.5	3313.5
29	73	74	61.8	38.4	50.1	3289.0
30	49	50	61.9	38.1	50.0	3177.5
31	54	55	61.9	38.0	49.9	3428.0
32	80	81	63.0	37.8	50.4	3277.0
33	66	67	63.4	39.1	51.2	3114.0
34	75	76	64.4	38.5	51.5	3003.5

	MEAN	STANDARD DEVIATION
	59.51470588	2.31204125
	MINIMUM VALUE	MAXIMUM VALUE
	55.00000000	64.40000000
	STD ERROR OF MEAN	SUM
	0.39651180	2023.5000000
	VARIANCE	C.V.
	5.34553476	3.885

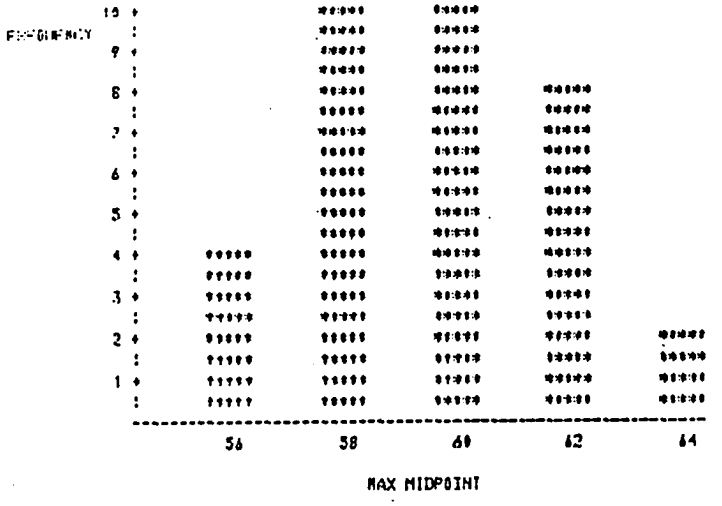


Figure 90: Statistical Summary of Mean Heating Season Maximum Temperature at Oklahoma City, Oklahoma.

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	78	79	56.6	34.4	45.5	4242.5
2	55	56	59.1	34.6	46.8	3952.5
3	76	77	59.8	34.8	47.3	3858.0
4	69	70	57.8	35.2	46.5	4014.5
5	77	78	57.1	35.2	46.2	4112.0
6	59	60	55.3	35.4	45.4	4207.0
7	70	71	59.4	35.6	47.6	3746.5
8	79	80	59.8	35.7	47.8	3771.5
9	58	59	59.0	35.8	47.4	3880.5
10	64	65	59.1	36.2	47.6	3812.0
11	81	82	58.9	36.2	47.6	3775.5
12	57	58	55.0	36.3	45.6	4138.5
13	48	49	57.9	36.5	47.2	3867.0
14	48	49	57.9	36.5	47.2	3896.5
15	61	62	57.7	36.6	47.2	3865.0
16	72	73	55.1	36.7	45.9	4113.5
17	50	51	61.4	36.8	49.1	3143.5
18	67	68	58.2	36.9	47.6	3797.5
19	74	75	58.4	37.1	47.8	3751.0
20	62	63	60.3	37.3	48.8	3684.0
21	63	64	61.4	37.4	49.4	3618.0
22	51	52	59.4	37.5	48.5	3601.0
23	52	53	60.5	37.8	49.2	3546.0
24	80	81	63.0	37.8	50.4	3277.0
25	54	55	61.9	38.0	49.9	3428.0
26	49	50	61.9	38.1	50.0	3177.5
27	56	57	57.9	38.2	48.0	3725.0
28	60	61	60.1	38.2	49.1	3551.5
29	71	72	61.0	38.2	49.6	3485.0
30	73	74	61.8	38.4	50.1	3289.0
31	75	76	64.4	38.5	51.5	3001.5
32	66	67	63.4	39.1	51.2	3114.0
33	65	66	61.1	39.2	50.1	3249.0
34	53	54	61.7	39.3	50.5	3113.5

MEAN	STANDARD DEVIATION
36.92647059	1.35899000
MINIMUM VALUE	**MAXIMUM VALUE**
34.40000000	39.30000000
STD ERROR OF MEAN	**SUM**
0.23304486	1255.5000000
VARIANCE	**C.V.**
1.84685383	3.680

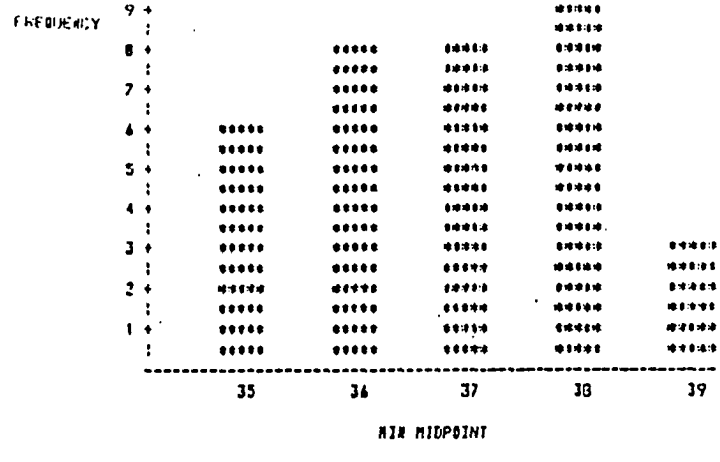
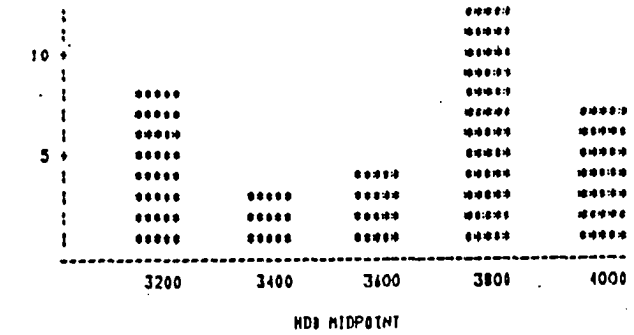


Figure 91: Statistical Summary of Total Heating Season HDD at Oklahoma City, Oklahoma.

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	75	76	64.4	38.5	51.5	3003.5
2	53	54	61.7	39.3	50.5	3113.5
3	66	67	63.4	39.1	51.2	3114.0
4	50	51	61.4	36.8	49.1	3143.5
5	49	50	61.9	38.1	50.0	3177.5
6	65	66	61.1	39.2	50.1	3249.0
7	80	81	63.0	37.8	50.4	3277.0
8	73	74	61.8	38.4	50.1	3289.0
9	52	53	60.5	37.8	49.2	3346.0
10	71	72	61.0	38.2	49.6	3405.0
11	54	55	61.9	38.0	49.9	3428.0
12	60	61	60.1	38.2	49.1	3551.5
13	51	52	59.4	37.5	48.5	3601.0
14	63	64	61.4	37.4	49.4	3618.0
15	62	63	60.3	37.3	48.8	3684.0
16	56	57	57.9	38.2	48.0	3725.0
17	70	71	59.6	35.6	47.6	3746.5
18	74	75	58.4	37.1	47.8	3751.0
19	79	80	59.8	35.7	47.8	3773.5
20	81	82	58.9	36.2	47.6	3775.5
21	67	68	58.2	36.9	47.6	3797.5
22	64	65	59.1	36.2	47.6	3812.0
23	76	77	59.8	34.8	47.3	3858.0
24	48	49	57.9	36.5	47.2	3867.0
25	58	59	59.0	35.8	47.4	3880.5
26	61	62	57.7	36.6	47.2	3885.0
27	68	69	57.9	36.5	47.2	3896.5
28	55	56	59.1	34.6	46.8	3952.5
29	69	70	57.8	35.2	46.5	4014.5
30	77	78	57.1	35.2	46.2	4112.0
31	57	58	55.0	36.3	45.6	4138.5
32	72	73	55.1	36.7	45.9	4193.5
33	59	60	55.3	35.4	45.4	4207.0
34	78	79	54.6	34.4	45.5	4242.5

MEAN	STANDARD DEVIATION
3665.55882353	352.80990600
MINIMUM VALUE	**MAXIMUM VALUE**
3003.5000000	4242.5000000
STD ERROR OF MEAN	**SUM**
60.50439970	124629.00000
VARIANCE	**C.V.**
124474.82927	9.625

FREQUENCY



Figures 92 - 94 are graphical presentations of Figures 88 - 91. The smooth curves represent a subjective filtering of the data. There is essentially no trend in time for minimum temperature, a gently undulating curve in maximum temperature and a slightly larger amplitude wave whose pattern is the inverse of maximum temperature in seasonal heating degree days. Both maximum temperature and HDD possess slight upward trends. The long-term statistical significance of such trends, however, is doubtful. The heating degree day pattern is an inverse of maximum temperature since increased natural warmth decreases the need for heat supplements, represented by HDD. If the apparent trends were truly significant, one would expect the HDD trend to be in the opposite sense of one in maximum temperature. An exception to this generalization would be where the daily maximum temperature distribution or variance is changing through time. It is known that some geographic variability in observed energy use exists. Assume that the portion of this variability not resulting from technological changes will be represented in the NBSLD model output. The next step is to determine the amount of this variability which is attributable to the weather input and how much may be the result of model amplifications. To help accomplish this task, consider the distribution of weather and weather variability at other locations across the State.

If mean minimum temperatures at these locations are considered, a fairly small range, 31.17 to 17.55, and a very small spread in standard deviation, 1.061 to 2.306 among sites can be noted. At best it would appear that the only stations significantly different from the others are: Gage, with mean 31.17, range 29.4 to 33.7, and standard deviation

Figure 92: Time-Series of Heating Season HDD at Oklahoma City, Oklahoma.

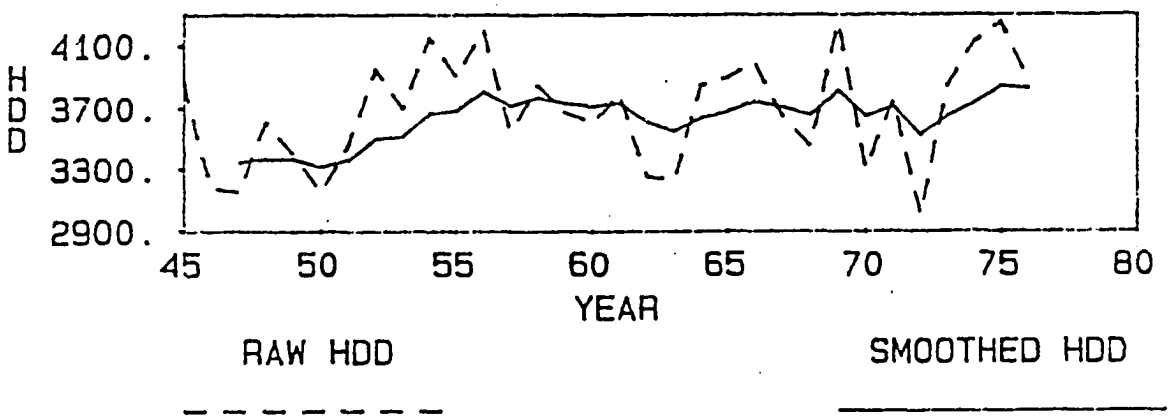
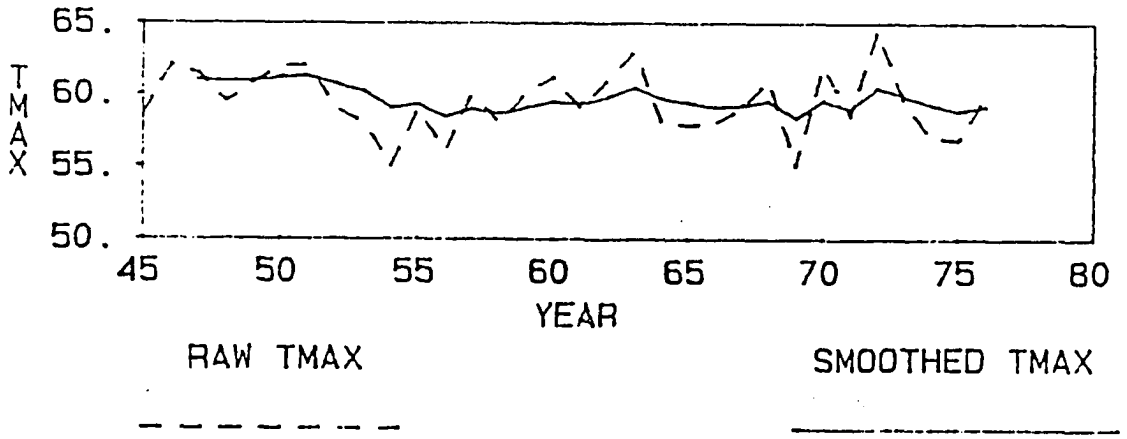
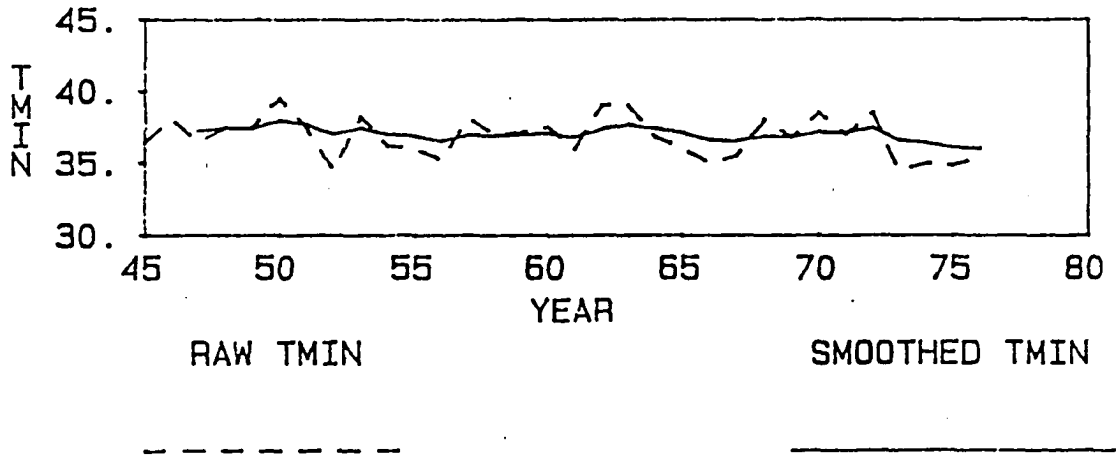


Figure 93: Time-Series of Heating Season Mean Maximum Temperatures.



1.997; and Altus, with mean 37.547, range 34.6 to 40.2 and standard deviation 1.961. This hypothesis is verified with the development of formal K-S statistics for the 34 year period 1948-1981. A 34-year period rather than those given in Table 59 was used so that K-S results would not be biased by comparisons of weather from two dissimilar

Figure 94: Time-Series of Heating Season Mean Minimum Temperatures.



periods of time. The results of all seasonal K-S statistics are summarized in Table 60. In summary, Gage and Altus are always dissimilar in some element from Oklahoma City, Enid, and Tulsa. They are also dissimilar from each other. Based on this analysis, heating season weather in Oklahoma can be divided into at least three distinct heating regions: Northwest (defined by the area surrounding Gage), Southwest (defined by the area surrounding Altus) and the remaining eastern two-thirds of the state (defined by Oklahoma City, Enid, and Tulsa). The potential exists for a fourth heating weather district in southeastern Oklahoma, but since sufficient hourly data for NBSLD model operations were not available, this area was not included in our analysis. These K-S results imply that the distribution of the seasonal energy use estimates should also break up into three statistically identifiable groups.

One question that arises, particularly in the case of HDD which is a cumulative rather than an averaged variable, is "Do these

TABLE 60

Largest Differences of Cummulative Frequency Plots of Seasonal Weather Variables Across Five Oklahoma Sites.

	Maximum Temperature	Minimum Temperature	Mean Temperature	HDD
Altus/Gage	*	*	*	*
Altus/Oklahoma City	*	-	*	*
Altus/Tulsa	*	-	*	*
Altus/Enid	*	-	*	*
Gage/Oklahoma City	-	*	*	*
Gage/Tulsa	-	*	*	*
Gage/Enid	-	*	*	*
Oklahoma City/Tulsa	-	-	-	-
Oklahoma City/Enid	-	-	-	-
Tulsa/Enid	-	-	-	-

Note: $D_c = .3298$

* = reject $H_o: \mu_1 = \mu_2$

TABLE 61

Largest Differences of Cummulative Frequency Plots of Daily Weather Variables Across Five Oklahoma Sites.

	Maximum Temperature	Minimum Temperature	Mean Temperature	HDD
Altus/Gage	*	*	*	*
Altus/Oklahoma City	*	-	*	*
Altus/Tulsa	*	-	*	*
Altus/Enid	*	-	*	*
Gage/Oklahoma City	-	*	*	-
Gage/Tulsa	-	*	-	-
Gage/Enid	-	*	-	-
Oklahoma City/Tulsa	-	-	-	-
Oklahoma City/Enid	-	-	-	-
Tulsa/Enid	-	-	-	-

Note: $D_c = .1320$

* = reject $H_o: \mu_1 = \mu_2$

relationships hold true on a within-season basis?" A K-S analysis similar to that performed on the 34 seasonal values was performed on 213 long-term daily mean values of maximum temperature, minimum temperature, mean temperature and HDD. The results are summarized in Table 61. In brief, the patterns of significant differences are similar to those contained in Table 60 except in the case of mean daily temperatures and HDD. In a daily analysis only Altus, in southwestern Oklahoma, would appear to have different heating season weather from the others. Two lines of argument were explored to account for these discrepancies between seasonal and daily mean temperature and HDD distributions. One physical explanation is that the correlation between coincident minimum and maximum daily temperatures is different at Altus than at other locations across the State, and the seasonal difference at Gage is due to a difference in mean value of the daily mean and not in the way high and low temperatures occur together. This hypothesis can be explored by performing simple correlation tests between maximum and minimum temperature at each point. The results of these correlation computations produce R^2 values that are identical in all cases to two significant figures.

A second hypothesis is that due to Altus' position in the far southwestern corner of the State, there might be slight lag in the temperature response to synoptic patterns not apparent at other Oklahoma sites. Simple correlations between individual variables and sites were constructed. Again the correlations are all quite high and they are identical to two significant figures. Neither of these results support either hypothesis and so further investigation at a later time is recommended.

The discrepency between Tables 60 and 61 is of interest from two points of view: the statistical and the applications. Statistically one would expect that as time resolution increases, diversity would also increase. This does not appear to be the case. The reason might be found in the use of means rather than true daily values; the increased sample size could be overcoming increased natural variance increases or, since daily values are known to be distributed far from Gaussian, the correlation significance could be unreliable.

From an applications point of view, the tabled differences could have serious implications. For instance, for long-term planning projects, quarterly or seasonal energy demand estimates are reasonable and, as suggested earlier, could use our three distinct energy use districts. Fuel routing, on the other hand, is highly dependent on day-to-day synoptic changes. Table 61 would suggest that at best there are only two use districts in the State and further disaggregation would be wasted effort. However, since routing decisions are highly sensitive to existing and predicted weather conditions and the costs associated with routing changes represent a significant portion of a utility's expenses, it is important to understand the physical characteristics of these areas if the meteorological forecasts can be more closely tailored to the user's specific needs.

4.3 NBSLD ENERGY USE ESTIMATES

The next step is to relate these data directly to Oklahoma heating season energy use. This is done through the use of hourly weather data as input to the NBSLD energy load model. Table 62 contains an example of 24-hours of observations at Altus, Oklahoma, January 1, 1955. The original structure of the model does not allow for very efficient use of time-series data even though documentation states that this is a viable option. The program operates on one room of the structure at a time for the entire weather time series. This requires a weather data tape rewind for each room (7 in this example). This process of room rewinds must be repeated for each analysis year. Thus there is significant wear on computer tape and inefficient

use of computer time. If, in the future, the model were to be used on an operational basis, computer expenses could most likly be greatly decreased by program restructuring. An example of model output for one room for one day and the final total energy use for the room for the first two days of January, 1955, at Altus Oklahoma is given in Appendix I. Obviously there is the potential for a great deal of output. It was determined that for the purposes of the present study this degree of detail was unnecessary and the program was adjusted accordingly.

After the NBSLD was run for the period of hourly data record, statistical output and graphs similar to those generated for the weather variables were created. Figures 95 - 99 contain the rankings, histograms and descriptive statistics for the five hourly weather sites. Figure 100 is a time series graph of the generated energy requirement data.

Table 62. Hourly weather data for Altus, Oklahoma, January 1, 1955 used at input to the NBSLD Model.

Hour	Array Row Number	Dry Bulb Temp(°F)	Dew Point Temp(°F)	Wet Bulb Temp(°F)	Wind Speed (mph)	Barometric Pressure (IN of H_S)	Total Cloud Amount (.1%)	Opaque Cloud Cover (.1%)	Year	Month	Day
1	5	42	32	38	8	28.22	6	6	55	1	1
2	6	41	33	38	0	28.22	4	4	55	1	1
3	7	41	32	37	7	28.24	5	5	55	1	1
4	8	40	33	37	6	28.26	7	5	55	1	1
5	9	37	32	35	7	28.27	10	8	55	1	1
6	10	37	32	35	5	28.28	10	7	55	1	1
7	11	38	31	35	5	28.31	8	3	55	1	1
8	12	36	30	34	3	28.33	8	2	55	1	1
9	13	35	30	33	0	28.38	9	3	55	1	1
10	14	39	32	36	6	28.41	5	3	55	1	1
11	15	47	31	40	5	28.44	1	1	55	1	1
12	16	50	32	42	0	28.44	0	0	55	1	1
13	17	54	35	45	0	28.44	0	0	55	1	1
14	18	57	39	48	0	28.44	1	1	55	1	1
15	19	59	39	49	0	28.43	3	2	55	1	1
16	20	60	38	49	0	28.44	1	1	55	1	1
17	21	59	44	51	0	28.47	1	1	55	1	1
18	22	53	46	49	0	28.48	1	1	55	1	1
19	23	46	41	44	0	28.52	1	1	55	1	1
20	24	42	39	40	0	28.53	1	1	55	1	1
21	25	41	36	39	0	28.53	0	0	55	1	1
22	26	39	35	37	0	28.53	0	0	55	1	1
23	27	37	34	36	0	28.54	0	0	55	1	1
24	28	39	31	36	0	28.53	0	0	55	1	1

Figure 95: Statistical Summary of NBSLD Generated Energy Requirements for Altus, Oklahoma.

SEASONAL HEATING (BTUS * 10**7) FOR ALTUS

OBS	YEAR1	YEAR2	HEAT
1	54	55	5.3413
2	60	61	5.7894
3	66	67	5.8025
4	56	57	5.8184
5	65	66	5.8454
6	55	56	5.9169
7	64	65	6.2994
8	58	59	6.3284
9	67	68	6.3393
10	62	63	6.3527
11	63	64	6.3666
12	68	69	6.4811
13	69	70	6.5324
14	57	58	6.5348
15	59	60	6.8996
16	61	62	7.0372

MEAN	STANDARD DEVIATION
6.23608750	0.44248605
MINIMUM VALUE	**MAXIMUM VALUE**
5.34130000	7.03720000
STD ERROR OF MEAN	**SUM**
0.11062151	99.77740000
VARIANCE	**C.V.**
0.19579391	7.096

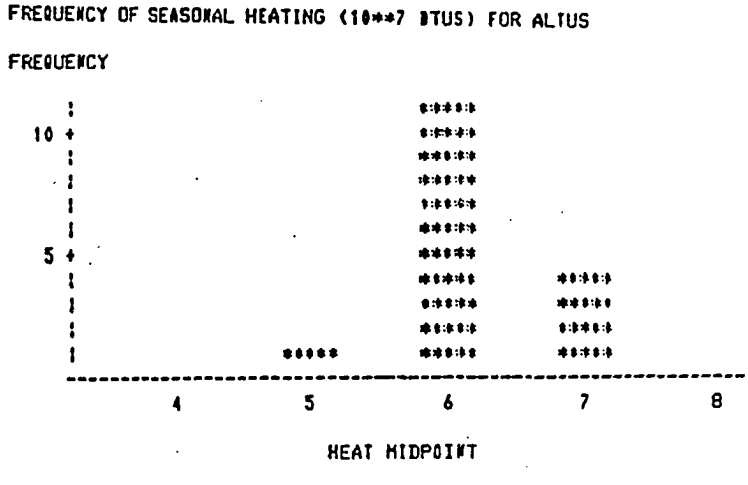


Figure 96: Statistical Summary of NBSLD generated Energy Requirements for Enid, Oklahoma.

SEASONAL HEATING (BTUS *.10**7) FOR ENID

OBS	YEAR1	YEAR2	HEAT
1	53	54	6.6815
2	54	55	6.7923
3	52	53	6.7966
4	56	57	7.0163
5	49	50	7.0794
6	66	67	7.0799
7	65	66	7.1471
8	60	61	7.2934
9	62	63	7.3666
10	63	64	7.5123
11	58	59	7.6058
12	55	56	7.6133
13	57	58	7.6374
14	67	68	7.6758
15	51	52	7.6816
16	69	70	7.7414
17	68	69	7.7764
18	64	65	7.8007
19	61	62	7.9641
20	50	51	8.0407
21	59	60	8.4547

MEAN	STANDARD DEVIATION
7.46574286	0.45548630
MINIMUM VALUE	**MAXIMUM VALUE**
6.68150000	8.45470000
STD ERROR OF MEAN	**SUM**
0.09939526	156.78060000
VARIANCE	**C.V.**
0.20746727	6.101

FREQUENCY OF SEASONAL HEATING (10**7 BTUS) FOR ENID

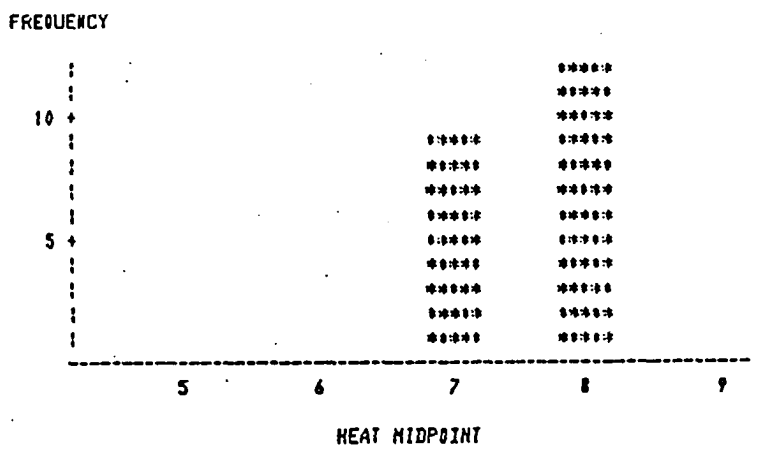


Figure 97: Statistical Summary of NBSLD Generated Energy Requirements for Gage, Oklahoma.

SEASONAL HEATING (BTUS * 10**7) FOR GAGE

OBS	YEAR1	YEAR2	HEAT
1	53	54	7.2189
2	54	55	7.5778
3	52	53	7.7075
4	49	50	7.8020
5	62	63	7.8650
6	56	57	8.1825
7	51	52	8.1857
8	60	61	8.2428
9	63	64	8.3724
10	55	56	8.4387
11	57	58	8.5800
12	50	51	8.7005
13	61	62	8.7339
14	58	59	8.7775
15	59	60	9.3753

MEAN	STANDARD DEVIATION
8.25070000	0.55472939
MINIMUM VALUE	**MAXIMUM VALUE**
7.21890000	9.37530000
STD ERROR OF MEAN	**SUM**
0.14323051	123.76050000
VARIANCE	**C.V.**
0.30772470	6.723

FREQUENCY OF SEASONAL HEATING (10**7 BTUS) FOR GAGE

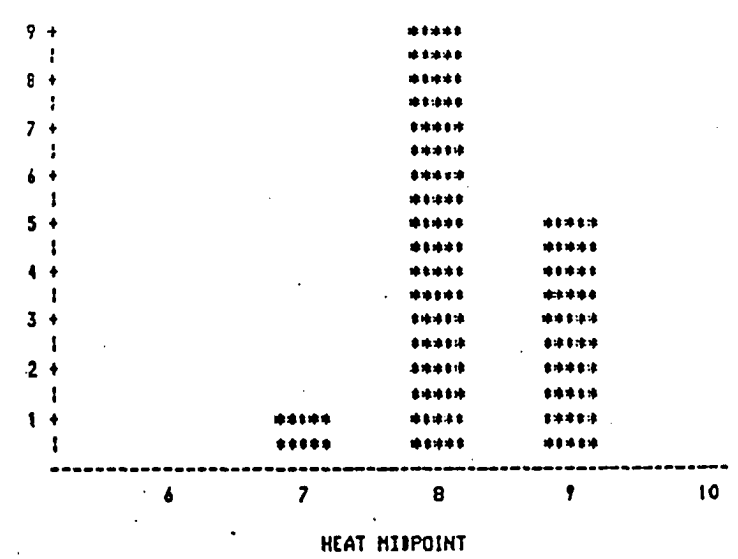


Figure 98: Statistical Summary of NBSLD Generated Energy Requirements for Oklahoma City, Oklahoma.

SEASONAL HEATING (BTUS * 10**7) FOR OKC

OBS	YEAR1	YEAR2	HEAT
1	75	76	5.9731
2	66	67	6.0149
3	65	66	6.0558
4	73	74	6.4376
5	45	46	6.5315
6	71	72	6.5858
7	53	54	6.6808
8	52	53	6.8256
9	49	50	6.8535
10	54	55	6.8653
11	60	61	7.0394
12	67	68	7.1803
13	51	52	7.2171
14	68	69	7.2694
15	79	80	7.3266
16	76	77	7.3277
17	63	64	7.3443
18	74	75	7.3538
19	56	57	7.3927
20	62	63	7.4127
21	70	71	7.4259
22	69	70	7.4347
23	46	47	7.4797
24	64	65	7.7083
25	61	62	7.7974
26	48	49	7.8343
27	50	51	7.9242
28	47	48	7.9294
29	58	59	7.9514
30	55	56	7.9789
31	57	58	8.0336
32	72	73	8.1286
33	77	78	8.3253
34	59	60	8.4909
35	78	79	8.6608

MEAN	STANDARD DEVIATION
7.33813429	0.68312095
MINIMUM VALUE	**MAXIMUM VALUE**
5.97310000	8.66080000
STD ERROR OF MEAN	**SUM**
0.11546851	256.83470000
VARIANCE	**C.V.**
0.46665423	9.309

FREQUENCY OF SEASONAL HEATING (10**7 BTUS) FOR OKC

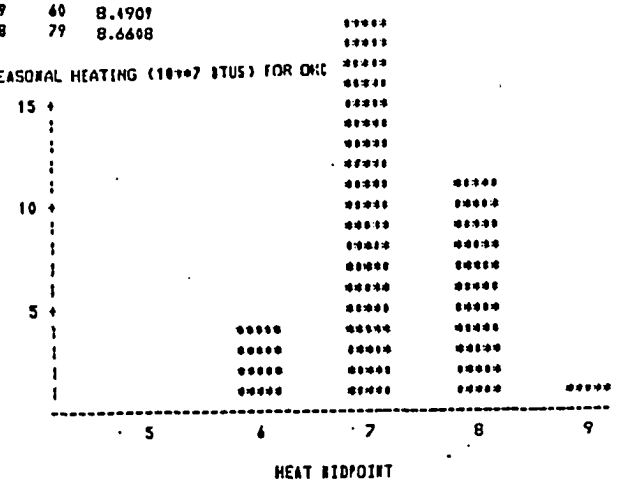


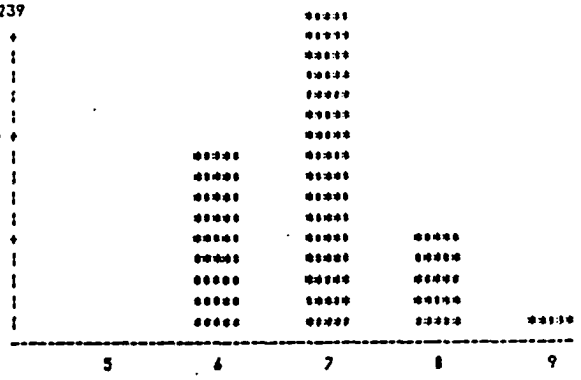
Figure 99: Statistical Summary of NBSLD Generated Energy Requirements for Tulsa, Oklahoma.

SEASONAL HEATING (BTUS * 10**7) FOR TULSA

OBS	YEAR1	YEAR2	HEAT
1	75	76	6.0268
2	71	72	6.1388
3	53	54	6.1815
4	65	66	6.2438
5	73	74	6.2516
6	54	55	6.2689
7	49	50	6.4481
8	52	53	6.4779
9	56	57	6.4834
10	79	80	6.5736
11	66	67	6.6686
12	60	61	6.6712
13	58	59	6.8161
14	70	71	6.9980
15	51	52	7.0096
16	63	64	7.0384
17	57	58	7.1126
18	55	56	7.2141
19	74	75	7.2481
20	62	63	7.2791
21	67	68	7.3054
22	64	65	7.3346
23	72	73	7.4305
24	76	77	7.4308
25	68	69	7.4828
26	69	70	7.5627
27	50	51	7.6244
28	59	60	7.8890
29	61	62	8.1883
30	78	79	8.2813
31	77	78	8.7239

MEAN	STANDARD DEVIATION
7.04625484	0.67718953
MINIMUM VALUE	**MAXIMUM VALUE**
6.02680000	8.72390000
STD ERROR OF MEAN	**SUM**
0.12162683	218.43390000
VARIANCE	**C.V.**
0.45858566	9.611

FREQUENCY OF SEASONAL HEATING (10**7 BTUS) FOR TULSA



From these figures one finds that Gage, in northwestern Oklahoma, has the largest mean heating energy requirements. Altus, in southwestern Oklahoma, has the smallest heating season energy requirements. Oklahoma City has the largest standard deviation, or largest variance, in heating energy use. In addition, central Oklahoma constitutes the major population center of the State. When population is combined with high demand variability due to weather, central Oklahoma becomes a major influence in state level energy demand changes attributable to weather variability. As one might expect from the standard deviation figures, a structure located in Oklahoma City has the largest seasonal range in weather related energy demand: 12.929×10^7 BTU's. Altus has the smallest seasonal range: 1.6959×10^7BTU's.

As in the case of the weather variables, K-S tests can be performed to determine the significance of this geographic distribution. Graphs were not constructed but probability difference estimates were taken directly from Table 63. Equation (6) was used to determine the appropriate critical values for each station pair(see Table 64). The results of these tests are presented in Table 65. The results of this non-parametric test yield the same distributional results as Table 60 ,that is, there appear to be three distinct heating energy use regions in the State.

Figure 100 is the time series representation of the data in Figures 95 - 99 . Although some of the shorter time series such as Altus and Gage may appear to have upward trends, the longer time series stations seem to indicate a more or less stationary mean with a fairly long amplitude wave about it. Winters of note would include 1959/60, 1977/78

TABLE 63

Computed Cummulative Probability Values for Use in K-S Tests for Station Period of Record (frequency count[cummulative probability]).

Energy Demand 10^7 BTU	Period of Record / Station Name / Category	15 Gage	16 Altus	21 Enid	31 Tulsa	35 OKC
	5.1 - 6.0	0[0]	6[.375]	0[0]	0[0]	1[.028]
	6.1 - 7.0	0[0]	9[.9375]	3[.1428]	14[.4516]	9[.2857]
	7.1 - 8.0	5[.333]	1[1.0]	16[.9048]	14[.9032]	20[.8571]
	8.1 - 9.0	9[.933]	0[1.0]	2[1.0]	3[1.0]	5[1.0]
	9.1 - 10.0	1[1.0]	0[1.0]	0[1.0]	0[1.0]	0[1.0]

TABLE 64

K-S Critical Values Used in Conjunction with Table 63.

Station Pair	D_c
Gage/Altus	.4887
Gage/Enid	.4597
Gage/Tulsa	.4277
Gage/Oklahoma City	.4197
Altus/Enid	.4513
Altus/Tulsa	.4186
Altus/Oklahoma City	.4104
Enid/Tulsa	.3843
Enid/Oklahoma City	.3753
Tulsa/Oklahoma City	.3354

and 1978/79. These appear to be particulary cold seasons with

TABLE 65

Summary of K-S Tests of Energy Demand Among Five Oklahoma Sites.

Station Pair	+K-S Result
Altus/Gage	*
Altus/Oklahoma	*
Altus/Tulsa	*
Altus/Enid	*
Gage/Oklahoma City	*
Gage/Tulsa	*
Gage/Enid	*
Oklahoma City/Tulsa	-
Oklahoma City/Enid	-
Tulsa/Enid	-

+ An * indicates that the hypothesis of H_o: $F(x_1) = F(x_2)$ is rejected.

An - indicates that the hypothesis of H_o: $F(x_1) = F(x_2)$ is accepted.

correspondingly high heating demands. Warm winters include 1945/46, 1949/50, 1965/66, and 1975/76. A visual comparison of Oklahoma seasonal averages (Figures 92 - 94) with energy demand indicate they are significantly correlated. Simple correlations were run between the weather variables and model estimated energy demand. This was to verify the visual analysis and to pin-point which variables would provide the most information when included in energy related climate products. The correlation results are given in Table 66. Table 66 suggests there is greater meteorological diversity reflected in energy demand than in the weather variables themselves. There are two possible reasons other than variable time periods for these differences. One additional source of variability is that weather variables not considered in the earlier statistical analysis, but used as model inputs, are more significant

Figure 100: Time-Series of NBSLD Generated Energy Demand at Five Oklahoma Locations.

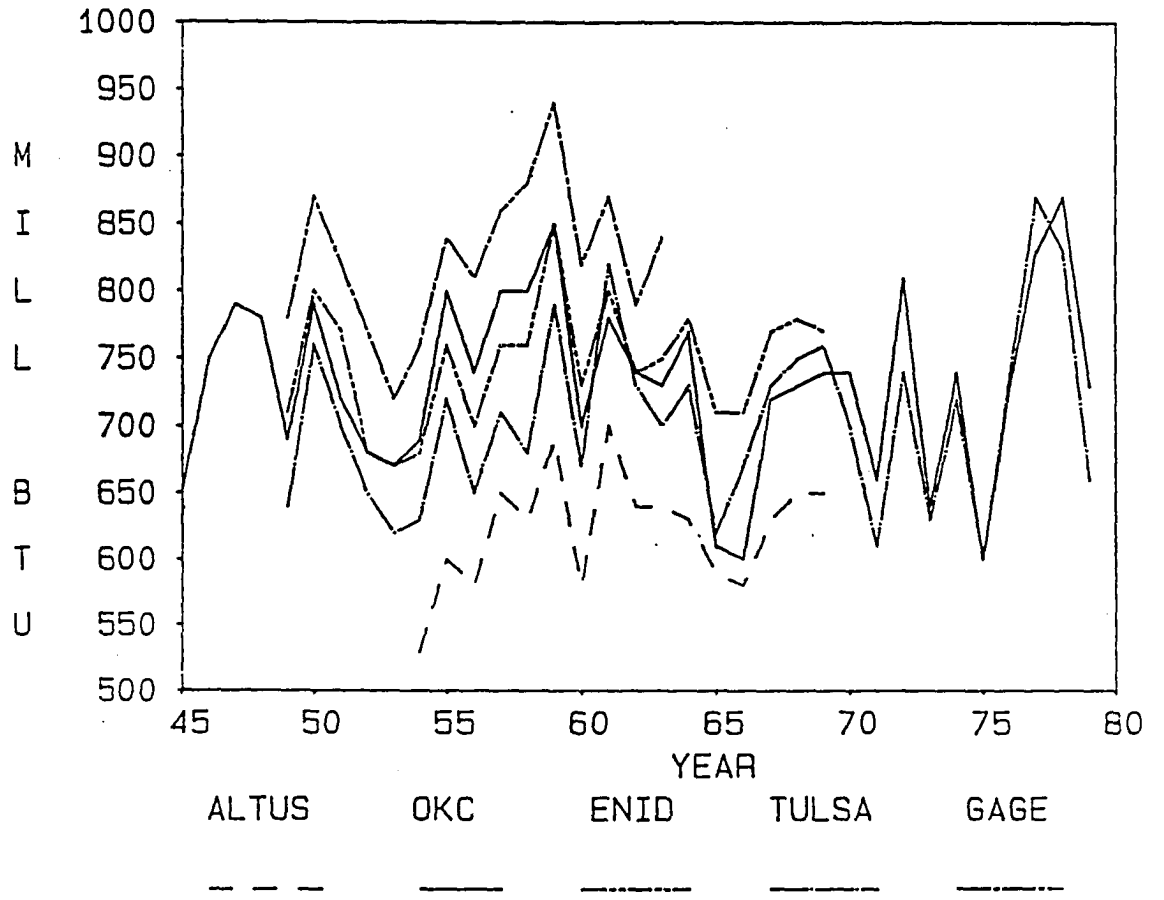


TABLE 66

Seasonal Energy Correlations Between NBSLD Generated Energy Demand and Individual Weather Variables at Five Oklahoma Locations.

Location	Maximum Temperature	Minimum Temperature	Mean Temperature	Heating Degree Days
Oklahoma City	-.81773	-.81290	-.89406	.84530
Tulsa	-.77427	-.85902	-.90773	.93283
Altus	-.59801	-.72773	-.75467	.80125
Enid	-.71662	-.78308	-.80899	.82684
Gage	-.72083	-.78552	-.87726	.87271

variance contributors than originally thought. These variables are wind speed, barometric pressure, dew point temperature, wet bulb temperature, and measures of cloudiness. The second possibiltiy is that as with the agricultural model case, model non-linearities are creating mixed statistical signals at a specific location. And thirdly, inter- and auto-correlated data have been combined into a single value. The exact impact of this correlation on model behavior is unknown but could be determined at a later time. What is of most interest at present are the predictive implications of these results in terms of forecasting energy demand variability.

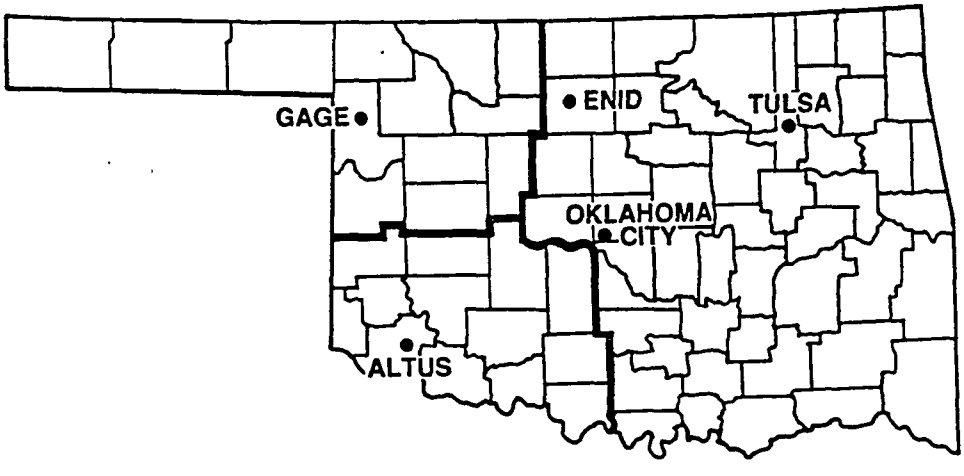
1. The NBSLD model is internally consistant and maintains geographic relationships across areas but may alter relationships among input variables at a point as a result of model non-linearieties, input data correlations and other input variables not included in our statistical analysis.
2. Meterological factors such as relative humidity, wind and cloud cover can play a significant part in energy demand prediction as suggested by models presented in Barnett (1973), Barr and Gunderson (1962) and Leffler (1972) among many others and should be more thoroughly investigated.
3. Based on HDD alone, the most common energy predictor in statistical regression models, 80 to 90 percent of total energy use variability can be explained. This is fairly low compared to what many researchers would propose. The poor degree of explanation may result from the highly correlated nature of the input weather variables.

4.4 MODEL COMPARISONS

At this point a comparison between process model type output and reported residential demand could be made if demand figures were available on a small enough scale. Unfortunately, only state level demand figures are available. Thus, the next step was to aggregate the detailed point estimates to the larger state level. As in the agricultural example, this can be accomplished through the use of weighting factors. There are several possibilities for selecting weighting factors. One is to use population. Another weighting factor could be the number of residential heating customers. Customer information, unfortunately, is available only on the State level. There are other possible weights such as the number of single family dwellings, but for the purposes of this project, population will be used to determine the weights. Energy areas defined by Figure 101 were utilized. Table 67 contains a list of the counties contained in each region. Table 68 contains the three regional weights for the 10 year period common to all the hourly weather data sites.

To obtain a weighted energy value for regions I and II (Figure 101), simply multiply the calculated energy value at Altus or Gage by the appropriate weight (Table 68). Region III contains three weather sites, and so a weighted value could be obtained several ways. One would be to divide the region into sub-regions, each containing only one weather station, finding the population contribution of each sub-region to the entire region and obtaining a weighted regional value. Another method, which will be employed here, is to average the three weather sites energy demand estimates and multiply the average by the

Figure 101: Oklahoma Energy Demand Areas.



appropriate weight. This should produce reasonable results without loosing a significant amount of information since it has already been determined that the stations are not statistically dissimilar. When these operations are performed, Table 69, Weighted State Energy Demand for a single structure, 1955 - 1964, is produced.

Table 69 also contains reported State level use of natural gas for all residential structures. These values are derived from those contained in GAS FACTS, 1954-1963. The actual reported values were in millions of Therms per year. First the values were transformed into BTU's by multiplying by 10^5. Next, a "season" needed to be defined. The first assumption was that the bulk of wintertime residential natural gas sales are for space heating purposes. This is not unrealistic for Oklahoma. The next assumption was that, for instance, 121 days(Jan, Feb, Mar, Apr)/213 days(entire season) or .568 of the 1951 gas sales

TABLE 67

Counties Contained in Each Energy Area Defined in Figure 101.

(I) Northwest:

Cimarron	Dewey	Blaine	Texas	Woodward
Beaver	Woods	Harper	Major	Ellis
Alfalfa	Roger Mills	Custer		

(II) Southwest:

Beckham	Cotton	Harmon	Washita	Comanche
Caddo	Tillman	Grady	Kiowa	Stephens
Greer	Jefferson	Jackson		

(III) Central and Eastern:

Grant	Lincoln	Marshall	Garfield	Pottawatomie
Coal	Kay	Creek	Atoka	Noble
Okfuskee	Bryan	Kingfisher	Seminole	Osage
Canadian	Garvin	Pawnee	Logan	Murray
Washington	Oklahoma	Carter	Tulsa	Cleveland
Love	Nowata	McClain	Pontotoc	Rogers
Payne	Johnston	Wagoner	Craig	Cherokee
Mayes	Haskell	Ottawa	Sequouah	Delaware
Adair	Okmulgee	Latimer	Hughes	Pushmataha
Muskogee	Choctaw	McIntosh	LeFlore	Pittsburg
McCurtain				

contributed to 1950/51 heating season sales and 92 days(Oct, Nov, Dec)/213 days(entire season) or .43 of the 1950 gas sales contributed to the 1950/51 heating season sales. The sum of these two fractions are the "adjusted" observed values of gas sales, i.e., demand in 10^{13} BTUs.

The next issue to be considered is whether the weighted NBSLD output can be used to reflect changes in reported sales attributable to weather. At this point one would not expect the "fixed technology" model to predict demand in absolute terms. However, if the weighted

TABLE 68

Figure 101 Regional Population Weights, 1955-1964 for NBSLD Point Energy Estimates.

Heating Season	Region 1	Region 2	Region 3
1954/1955	.05879	.13567	.80566
1955/1956	.05604	.13555	.83012
1956/1957	.05453	.13319	.81267
1957/1958	.05394	.13405	.81242
1958/1959	.05436	.13742	.80820
1959/1960	.05299	.13447	.81254
1960/1961	.05301	.13740	.80958
1961/1962	.05303	.14026	.80670
1962/1963	.05311	.14017	.80672
1963/1964	.05287	.13985	.80728

TABLE 69

Weighted State Heating Energy Demand(Single Dwelling), 1955-1964 and Reported Residential Heating Energy Demand(all dwellings,gas).

Season	Weighted (10^7 Btu's)	Reported (10^{13} Btu's)
1954/1955	6.5216	5.0071
1955/1956	7.6020	5.3426
1956/1957	6.8796	5.5867
1957/1958	7.5093	5.7898
1958/1959	7.3822	6.0646
1959/1960	8.1510	6.2179
1960/1961	6.9005	6.1421
1961/1962	7.8903	6.3376
1962/1963	7.2399	6.4445
1963/1964	7.2248	6.4593

NBSLD values do track year by year changes well, other adjustments to account for prices and use patterns can be added at a later date. The appropriate statistic to test the hypothesis of agreement in year-to-year estimates would be simple correlation. But before this statistic is obtained a very distinct upward trend in reported energy use can be noted. This would tend to bias severly any statistical comparison. In response, a trend in reported energy use is calculated and is given in Eq. (48).

$$Y = .15604727\ X - 3.34559273 \qquad (48)$$

where: Y = energy demand in 10^7 BTU's,

X = season year, 55 to 64.

This expression was derived using the SAS GLM procedure. This procedure also calculated a model F-statistic of 88.55 and and R^2 of .917138. This means that the trend alone predicts nearly 92 percent of the variance in reported gas energy demand. If it is assumed that the trend represents non-weather impacts such as cultural practices and population growth (since there is no indication of a significant trend in the weather data) that leaves 8 percent of demand variance to be explained other factors such as weather. To test how well the NBSLD output predicts this weather variability, a correlation was run between weighted NBSLD energy demand and deviations from the calculated trend value. The data to be compared then become those given in Table 70. The simple correlation results yield in an R^2 of .6792. This means that almost 68 percent of the remaining 8 percent of demand variance is

explained by weather as reflected in NBSLD output. This would seem to indicate that this type of model is of value in predicting energy demand changes produced by weather. To obtain State level demand (10^{13} Btu's) estimates, multiply the single household estimate by the number of gas households in the State. The next step is to perform the same type of comparison between reported energy demand and a regression type model already in use.

TABLE 70

NBSLD Weighted State Energy Demand and Detrended Reported Energy Demand.

Season	NBSLD (10^7 Btu's)	Detrended Observations (10^7 Btu's)
1954/1955	6.5216	-.2299033
1955/1956	7.6020	-.0504505
1956/1957	6.8796	.0376023
1957/1958	7.5093	.0846551
1958/1959	7.3822	.2034079
1959/1960	8.1510	.2006607
1960/1961	6.9005	-.0311865
1961/1962	7.8903	.0082663
1962/1963	6.3037	-.0408809
1963/1964	7.2248	-.1821281

Begin with the expression given in Eq. (49) which was developed by Warren, LeDuc and Hock (1984) for application to the West South Central Power Region of the United States.

$$S = a_0 + a_1 z + a_2 p' \qquad (49)$$

where: S = energy consumed by customer during the time period 10^6 BTU's

a_0 = energy for non-heating use, i.e., cooking and water heating. for an individual customer a_o is expected to be non-negative.

$a_1 z$ = energy used as a function of weather. Z is the amount of HDD (base 65 degrees) in the period and a is the rate of use per HDD and is in units of 10^3 HDD. As the weather gets colder Z and S increase, a is expected to be positive. This value, HDD is weighted by...

$a_2 p'$ = energy used as a function of the per unit price (price index), p' of the energy. As price increases use is expected to decrease so a_2 is expected to be negative.

Coefficients were estimated from data during the heating seasons 1971-72 to 1979-1980 and are given below

$a_0 = 14.635$ (10^6 BTU's)
$a_1 = 20.389$ (10^6 BTU/10^3 HDD)
$a_2 = -3.681$ (10^6 BTU's)
$p' = .73$ (assumed)

Table 71 contains a set of population weighted HDD's(NCDC,1981) and the resulting estimate of per customer energy demand.

It is these values, sales/customer, that will be correlated with the detrended reported gas sales as was the case with the NBSLD generated estimates. Again one is trying to model year-to-year changes. The AISC model in the form presented in equation (26) is also a fixed technology type expression since there is no trend with time, but normally there would be some movement due to price changes which have been ignored in this case. When the simple correlation is run, one finds that the AISC model explains .71 of the unexplained 8 percent of the variance in the reported sales data. This is a relatively small

TABLE 71

Population Weighted HDD and AISC Model Estimated State Energy Demand.

Season	Population Weighted HDD	AISC Model Estimated (BTU X 10^7) Sales/Customer
54/55	3113	7.5418
55/56	3520	8.3717
56/57	3390	8.1067
57/58	3815	8.9732
58/59	3520	8.3717
59/60	3954	9.2566
60/61	3378	8.0822
61/62	3743	8.8264
62/63	3433	8.1943
63/64	3460	8.2494

improvement over the NBSLD estimates, which could be attributed to a variety of factors. One unknown effect is small sample size. Ten years is hardly a full model exercise. The impact on the relationship between AISC modeled output and reported gas demand can be tested, but adequate data are not available to test the NBSLD output. It is expected, however, that neither AISC nor NBLSD estimates would do as well since the decade of the 1970's witnessed violent fluctuations in price and availability of natural gas. This means that the calculated trend line would not be as good a fit and more of the detrended year-to-year variations in energy sales could be the consequence of factors other than weather.

Finally, in some cases substantial portions of the hourly data were missing. A different interpolation method to fill in these missing data could lead to different NBSLD output. 24-hour means and extremes should

remain the same, but since the NBSLD performs 24, one-hour calculations rather than a single calculation per day, there could be significant differences.

The arguments in favor for and against each model is much the same for energy as in the agricultural case. One would not necessarily expect the process energy model to perform better in terms of variance explanation than the regression model since variance explanation is what regression is designed to do best. Some valid issues for consideration are how responsive the model is to weather (i.e., can the weather effects be readily isolated from non-weather factors), its physical representativeness, its flexibility in space and time and general applicability. What the results indicate is that both models do a good job in reflecting the modeled phenomena. Still, for detailed econo-climatic analysis, where an assessment of only the direct impacts due to weather at periodic intervals with economic models providing the intersectoral detail, and inclusion of confidence limits on forecasted estimates is desired, the future may lie with the process type model.

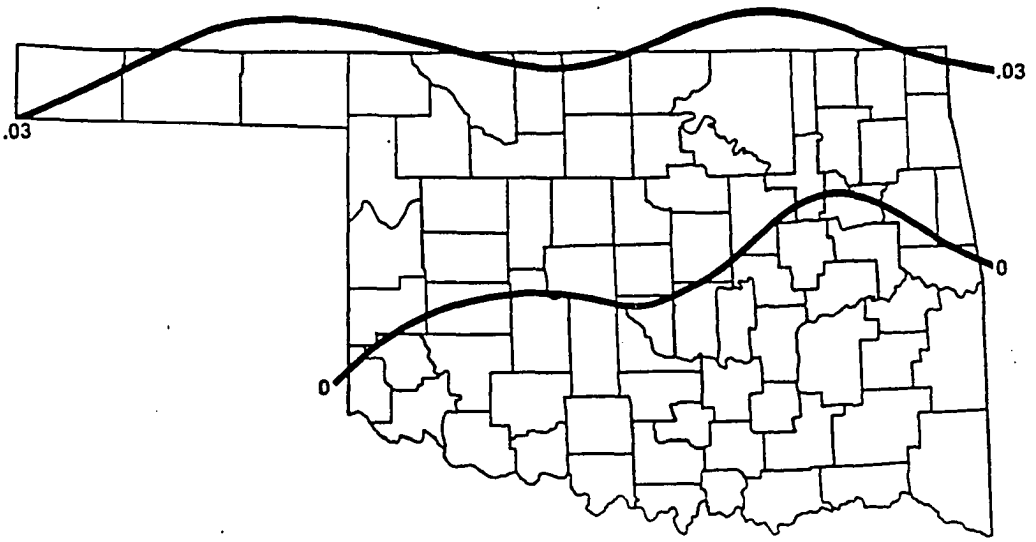
4.5 CLIMATE/ENERGY PRODUCTS

Proto-type products similar to those developed in Chatper III for corn production can be formulated for Climate/Energy relationships. One product, Climate/Energy regions, has already been formulated and is presented in Figure 101. Figure 101 suggests a macro-scale grouping of Climate Division areas that reflect the geographic variability in energy use identified in the previous section. Such a product would minimize the number of demand computations needed by an energy firm to determine future energy needs and distribution schemes.

A second product is a recurrence estimate of heating demand extremes similar to those generated in Chapter III. Two examples have been computed for December across Oklahoma. A mild (1967) and an extremely cold winter case (1983) were selected. Earlier, weather correlation results indicated that HDD is usually a good predictor of energy demand and so will be utilized as an indicator of the general magnitude of actual energy use. A state average number of HDD was computed and the number of times this quantity was exceded (in the cold case), was not met (in the mild case) are counted at individual points across the State. Counts were divided by the totals to get likelihood estimates at each point.

Figure 102 represents the likelihood of December 1983 or higher residential heating demand weather (HDD). Each station used in the analysis was compared to a state average value of 1192 HDD. The population weighted value for this month utilized elsewhere in this report was 1144 HDD. The climatologically expected value for December is 747 HDD. Clearly this is an example of an abnormally high heating energy demand month. When likelihood values are computed for this event as just described, the state divides neatly into two areas, those which had never experienced these conditions (the area below the line) and those areas at which one would expect December 1983 levels of energy demand 3 years in 100. The highest likelihood is in the eastern portions of west-central Oklahoma, .04 or 4 times in 100 years. This product would tell a utility planner that these demands are highly unlikely and, unless his losses incurred in such a situation were substantial, need not be included in his normal planning procedures. To the household, the results presented in Figure 102 mean that there is at

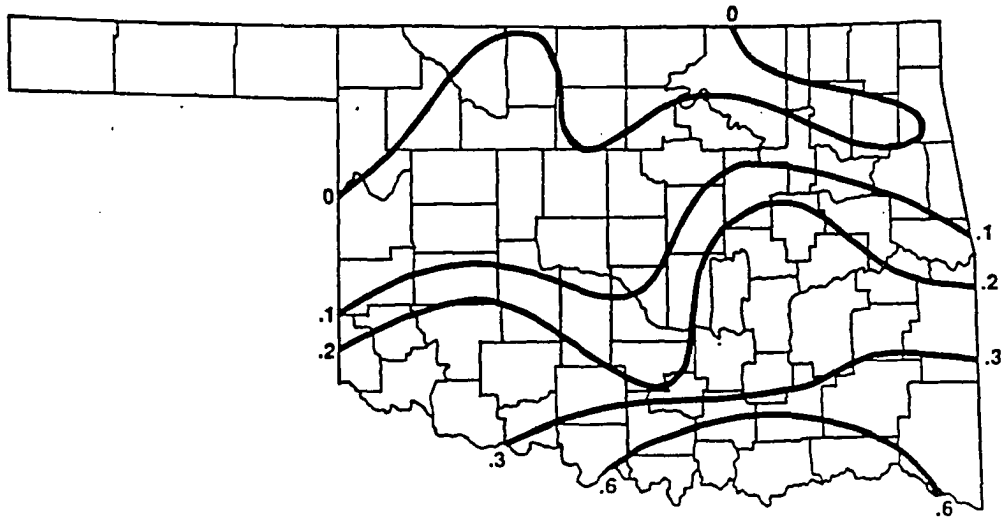
Figure 102: Likelihood of December 1983 or Higher Residential Energy Demand Weather.



most a 4 in 100 chance that his utility bill will be as high as during December, 1983 (assuming fixed energy prices). It is common for utility companies to reassess their rate structures based upon recent weather records. This example illustrates that the selection of weather years used in these evaluations is critical. If December 1983 was to be used in rate assessment situations, misleading conclusions concerning future structuring would most likely result.

Figure 103 represents the likelihood of December 1965 or lower residential heating demand weather. Each station used in this analysis was compared to a state average value of 624 HDD. The population weighted value for this month used elsewhere in this report was 557 HDD. Again the climatologically expected value for December is 747 HDD. This, then, is an example of a mild December with lower than normal

Figure 103: Likelihood of December 1965 or Lower Residential Energy Demand Weather

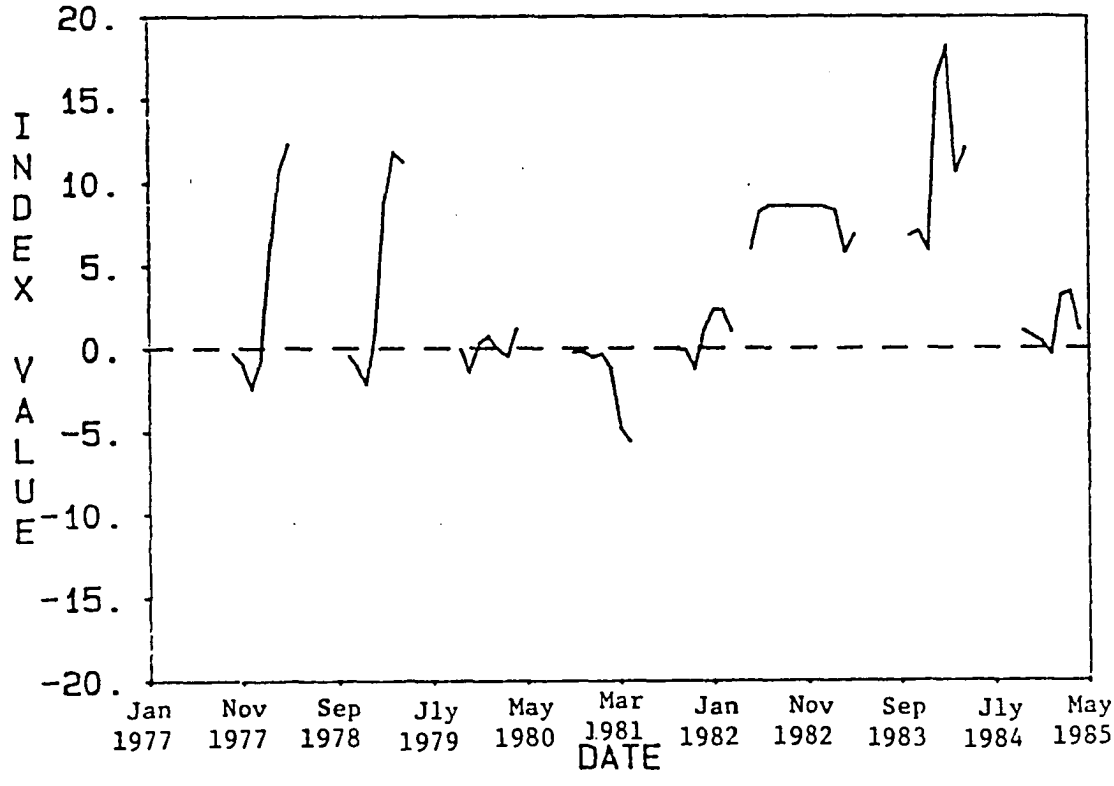


expected heating energy demand. December 1965 was uniquely mild for approximately the northern one-quarter of the State. This level of HDD becomes increasingly more common as one moves southwards until the likelihood is higher than .50 that these conditions will be observed in southernmost Oklahoma. Conditions such as those of December, 1965, can be expected about 1 in 10 years in the northern one-half of the State. These December conditions are most common in the southernmost portion of the eastern area of the State. The greatest likelihood, .7 or 7 in 10 years, occurs in this region. A comparison of Figures 102 and 103 suggests that while extremely cold winters affect large portions of the State, unusually mild winters are more local in nature and thus affect a smaller service area.

The final climate energy product developed in this research is a climate/energy index. This index is presented in two forms. The first is a time-series of monthly forecasts for eight heating seasons. The second presentation is a graph of monthly energy forecasts for the 1984/85 heating season in Oklahoma, including confidence limits. First consider the time-series presentation, Figure 104.

Figure 104 was constructed in a manner quite similar to the agricultural index in Chapter III. Observed population weighted monthly State HDD conditions are computed until "present". These are used with the AISC model to project energy requirements for a full season, and thus a "forecast" of HDD for the remainder of the heating season is required. For the sake of illustration, long-term average HDD conditions were used as the forecast. When this season total HDD is put into the AISC model, an estimate of seasonal energy demand for the current year is obtained. If the long-term average seasonal heating demand is estimated and the difference between it and projections for the present year are determined, one has a comparison of projected energy requirements to long-term normal conditions. One might expect with the forecast method described that difference estimates would lie close to zero until rather late in the heating season. On the contrary, even with this crude forecast method, forecasts as early as October 1 during the 1982/83 and 1983/84 heating season appear to contain significant information. Detailed analyses could be performed on these data to ascertain at what point in the season statistical forecast "skill" is established. A visual estimate would suggest the pivitol months to be December and January. This could be refined further if weekly rather than monthly forecasts were made. Some seasons do not

Figure 104: Time-Series of Monthly Energy/Climate Indices



settle towards their final outcomes until February or March (1980/81 and 1981/82) while others experience rather decisive events as early as October (1982/83). There appears to be a sine-wave pattern in the eight seasons graphed, but from the earlier analysis of longer energy demand time-series which indicate no significant energy use trend, one can conclude that while significant within the graphed sample, such a pattern is not statistically significant over time.

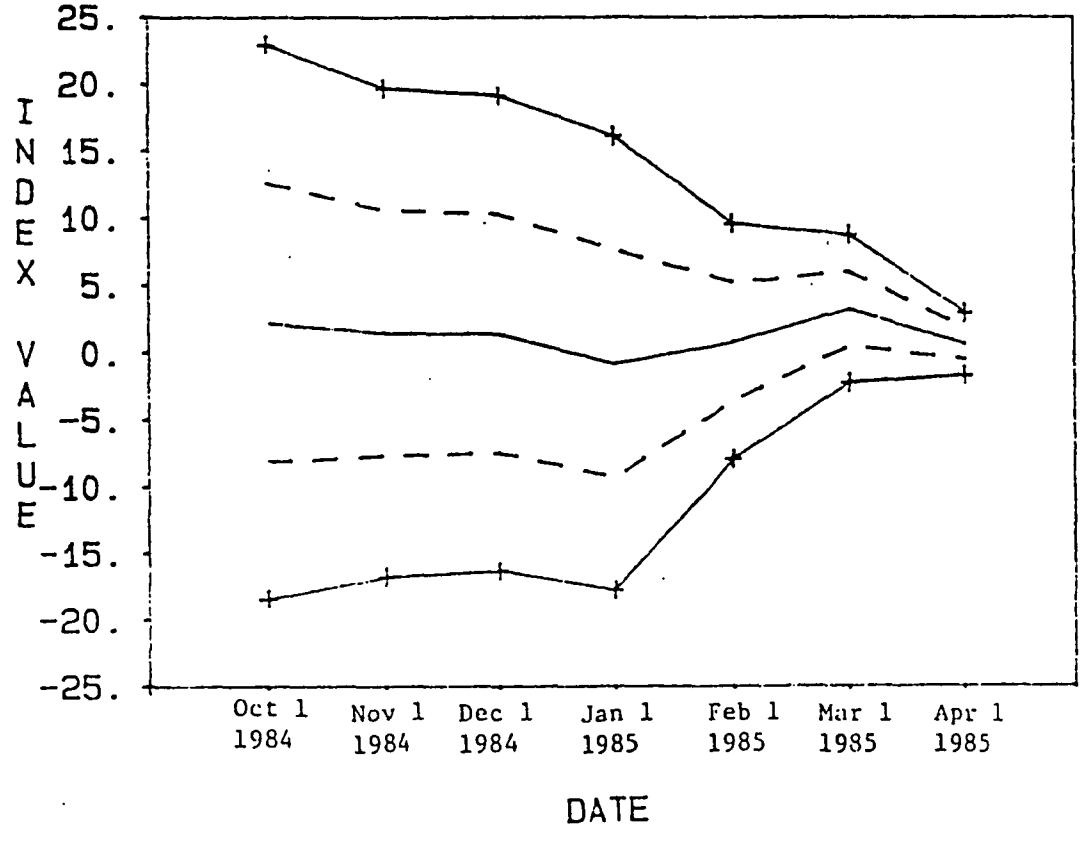
If proved reliable, energy demand related information could be derived from an index such as that in Figure 104. For instance, a utility company would need to plan its power plant operations several months in advance in order to be certain that it would have sufficient fuel at the lowest possible price. The 1983/1984 index suggests above average energy demand. Fuel orders could then be placed in advance based on the recommendation of the index. But just how accurate is the index? How much of a chance is there that actions taken on the suggestion of the index are incorrect? Figure 104 does not provide enough information to answer this question. To do so would require the establishment of a distribution of outcomes. If confidence limits were to be defined, then the likelihood of a particular index or range of index values being realized at the end of the season could be determined. The "best" fuel strategy for a particular utility activity could then be ascertained through a risk analysis procedure similar to that completed earlier for corn. Figure 105 has been constructed to illustrate the use of confidence limits on a State level energy Index.

Figure 105 illustrates month-by-month energy demand forecasts for the State of Oklahoma for the 1984/85 heating season. The major difference between this figure and Figure 104 is the forecast method, which permits the computation of confidence limits about the energy forecasted values. The forecast technique computes 30 HDD forecasts each month using methods similar to those of the crop forecasts, that is, using real data for the current year to the forecast date, then completing the season with each of the previous 30 year's HDD. The result is a sample of 30 seasonal energy demand estimates for a point in

time for which a mean and a standard deviation can be computed. Using this technique, a set of confidence limits which become smaller as the season progresses can be found. The same question can be raised here as in the agricultural case: "How much is it worth to decrease these limits by increasing the sampling density going into the state weighted HDD and how many stations or area estimates would be required to reach an acceptable level of forecast certainty?" Techniques similar to those in Chapter III could be used to answer these questions, but will not be pursued at this time.

Consider a specific forecast on Figure 105, for December 1. The 30 possible forecasts constructed for this date result in an expected seasonal demand of 1.39 X 10^6 Btu's above normal. If one assumes a Gausian distribution for the 30 year sample, Figure 105 suggests that there is a 66 percent chance of energy use being between 10.25 X 10^6 Btu's above and 7.47 X 10^6 Btu's below expected demand. There is a 95 percent chance of seasonal energy demand being between 19.11 X 10^6 Btu's above and 16.33 X 10^6 Btu's below expected demand. Further consideration of methods to decrease mid-season energy forecast uncertainty would most likely be necessary for this product to provide information of significant value to utility firms and energy planners.

Figure 105: Monthly Energy Climate Indices for the 1984/85 Heating Season with Confidence Limits.



4.6 SUMMARY

The analysis just completed has focused on the quantification of the direct impacts of weather on residential heating energy demand. This has been accomplished through the use of regression and process-type models. In order to understand the way in which the process-type model transforms weather into energy demand, climatological as well as modeled energy demand statistics were constructed. When compared, these two sets of information suggest similar geographic energy demand areas

(Figure 101), but the process model appears to transform the geographic inter-relationships among the input weather variables. This could be the result of model non-linearities or the use of several correlated weather variables as input to the model.

The NBSLD model indicates that average seasonal household heating energy demands range from 6.23×10^7 Btu's at Altus to 8.25×10^7 Btu's at Gage with standard deviations on the order of 10^6 Btu's per season. An analysis of the modeled point energy demand estimates indicates no significant weather related trends or cyclic patterns similar to those contained in reported household heating energy use. A comparison of State level modeled results to state level detrended reported energy demand supports the hypothesis that the process model is capable of representing areal demand. A technology related trend explains 92 percent of observed demand time-series variability. The process model explains 68 percent of the remaining weather related variability contained in the observed demand time-series. A comparison of process model demand estimates to those of regression type model in current use by AISC, Columbia, MO, suggests that both model types are equally good predictors of direct weather impacts on areal energy demand. The major difference is that the regression model is tied to technology and cultural practices while the process model is purely physical and thus is essentially technology and use pattern free.

The final step, which parallels the agricultural sector impact development of Chapter III, is the suggestion of proto-type products. Those products discussed include energy demand forecast areas (Figure 101), extreme event likelihood maps (Figure 102 and 103), and a

climate/energy index. Although Figure 101 and its accompanying statistics suggest that only three to four regions are necessary to describe the geographic distribution of energy demand across the State, the uncertainty results of Figure 105 suggest significantly more areas or sites are needed (more than nine climate divisions) to forecast actual energy demand within acceptable limits. That is, if State energy demand were to be disaggregated, there would only be four statistically distinct groups of values. But to obtain a mid-season State level demand forecast with an acceptable level of statistical certainty, many points from within each of these four regions may be necessary. Areas addressed in this analysis but needing further investigation include:

1. explanation of changes in daily and seasonal geographic relationships among weather variables,
2. comparisons of the NBSLD and AISC models at non-sunbelt locations,
3. execution of the NBSLD model over a wider range of weather scenarios if observed data are unavailable,
4. development of energy related climatological products and forecast aids based on an increased understanding of weather factors which impact energy use,
5. further refinement of the mid-season forecast technique utilized in the climate/energy index, and
6. consideration of spatial characteristics of warm and cold season events and their implications for long- and short-term energy distribution planning.

Chapter V

ECONOMIC APPROACHES TO THE ASSESSMENT OF THE VALUE OF CLIMATOLOGICAL INFORMATION AND IMPACTS

The purpose of this chapter is to redirect attention towards traditional techniques presently employed by economists when considering events which involve direct climate impacts. Two issues will be considered, the application of economic modeling techniques which can utilize information or products developed in previous chapters and the valuation of climate/weather information using prevailing economic terminology. The former will be broken into econometric models with an agricultural example, and input/output analysis utilizing an energy example.

The Bayesian example in Chapter III briefly addresses a situation in which a critical decision must be made involving climate sensitive activities which take place over a large geographic area. Rather than the sector-constrained situation described earlier, decision makers may also be concerned with indirect sectoral impacts on the climate division, State, or National scales. The direct application of traditional, point-by-point unit production/consumption or direct impact models such as those discussed in Chapter II on a large geographic scale can be extremely laborious. Frequently, these detailed models are replaced by more traditional economic modeling techniques such as econometrics or input-output analysis. Traditionally these two modeling techniques would vastly underutilize climatological information.

Climate variables were relegated to a role of very minor importance, or represented only by long-term normal conditions. Fortunately these traditions are now being challenged. Examples of the use of climatological information in an economic framework may be found in W. Cooter (1984), R. Lansford, et. al. (1977), and Bowles, et. al. (1982). These studies all use an economic modeling technique known as input/output, or I/O analysis. Although a more thorough description of what I/O modeling entails may be found in Silbergerg (1978); Chiang(1974); or Archibald and Lipsey (1976), this type of model generally consists of transaction matrices which are tabular statements of the dollar value of production and states trading relations among the various sectors of the regional economy. "Multipliers" for each of these transactions are found which show the impacts upon the economy when changes in natural resource supplies affect the production of one or more sectors of the economy. The model can be used to relate systematically the producing sectors to the resources and the consumers of the economy (Grubb, 1980).

Once reasonably accurate input output multipliers have been determined, the primary control on the estimated magnitude of economic response to changes in climate sensitive sectoral activities is the validity of the estimate of climate induced changes in production and consumption. It is here that models which accurately represent the effects of climatological conditions on sectoral production or consumption are most valuable.

Consider a general example involving changes in demand for space conditioning energy. Sectoral responses to such variations may impact a

regional or national economy in a variety of ways. A simplified input-output table may be used to conceptualize and pin-point these impacts (Figure 106).

First, consider the effect of a temporary "episodic" increase in demand for space conditioning energy by commercial sectors and households due to an unusually cold winter or hot summer. If one considers a regional economy, utilities might need to purchase extra inputs from outside the region, electricity off a grid system, extra coal, natural gas, and so forth, to meet the increase in demand. This would appear as an increase in the element common to the import row and utility column (see Figure 107).

Alternatively, the utility might only need to purchase extra raw materials from within its own region. In either case, the energy production recipe could well change. Such a change should be reflected in technical coefficients associated with the utility sector (Figure 108). The climate-induced extra purchases by commercial sectors from utilities could also represent a change in their production recipes. Thus, changes in technical coefficients could extend to a number of economic sectors in addition to the utilities sector (Figure 109).

Also note that households must somehow pay for their extra energy purchases. If we assume that total household income and expenditures remain constant, the increased energy purchases by households would have to be accompanied by decreased spending for the output of other sectors. This shift in the pattern of household spending would change the total output levels of many sectors and thus would alter the pattern of income and employment for various sectors in the economy. Note that even

Figure 106: A Simplified Regional Input-Output Table.

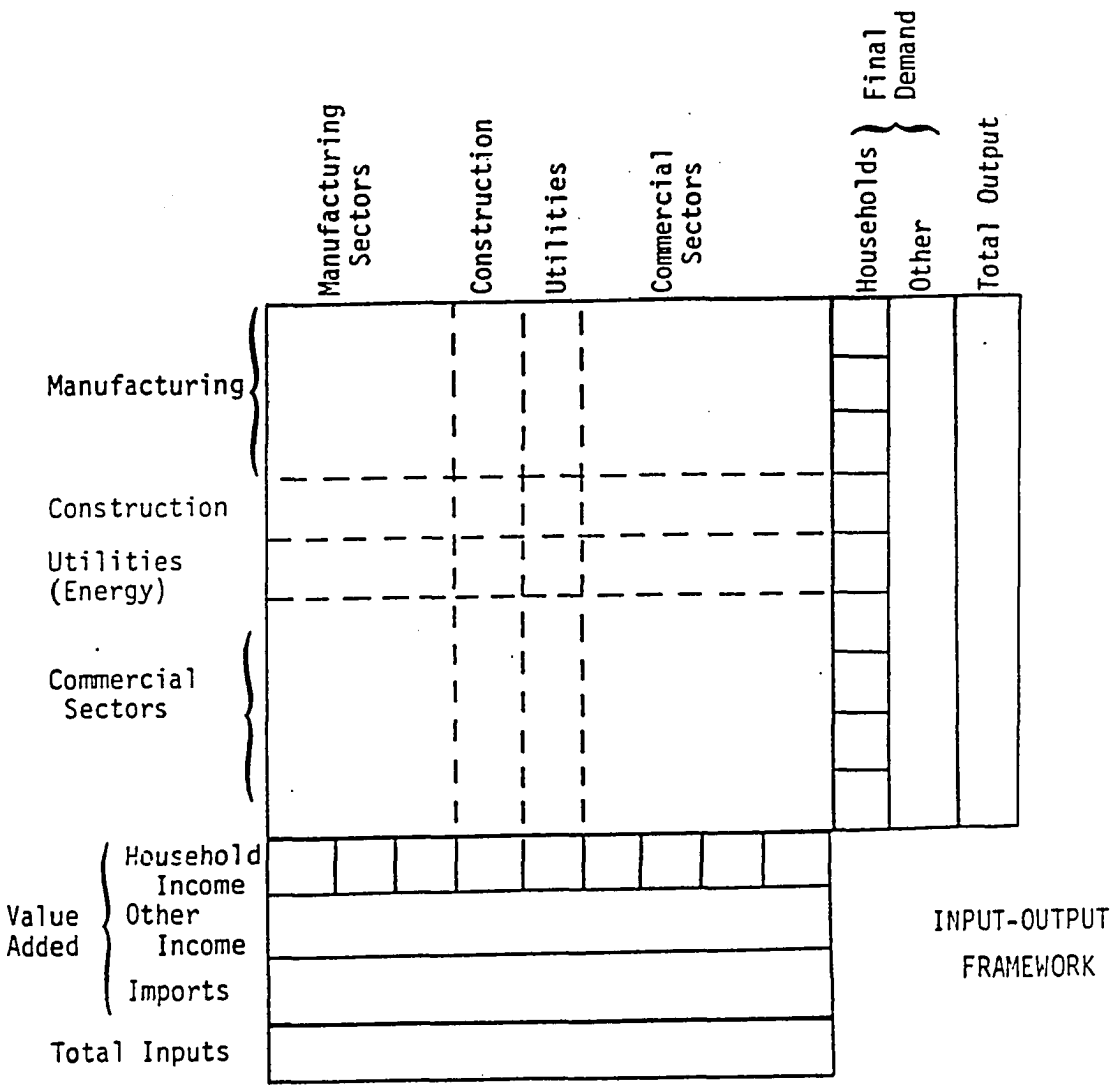


Figure 107: Possible Change in Utility Sector Technology Stemming From Increased Demand During Unusually Cold Winters or Hot Summers.

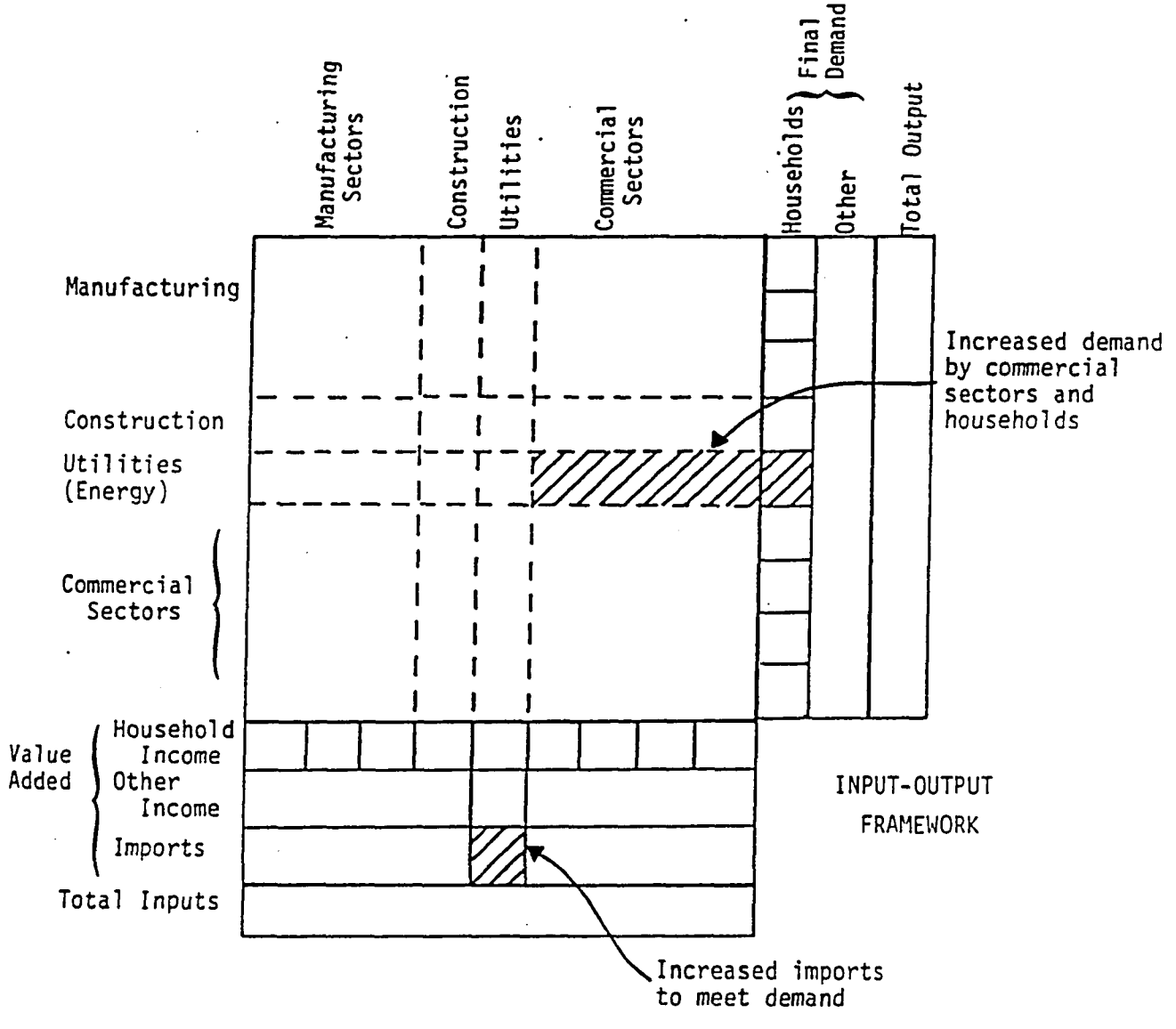


Figure 108: Alternative Pattern of Utility Sector Technology Change Stemming From Increased Demand During Unusually Cold Winters.

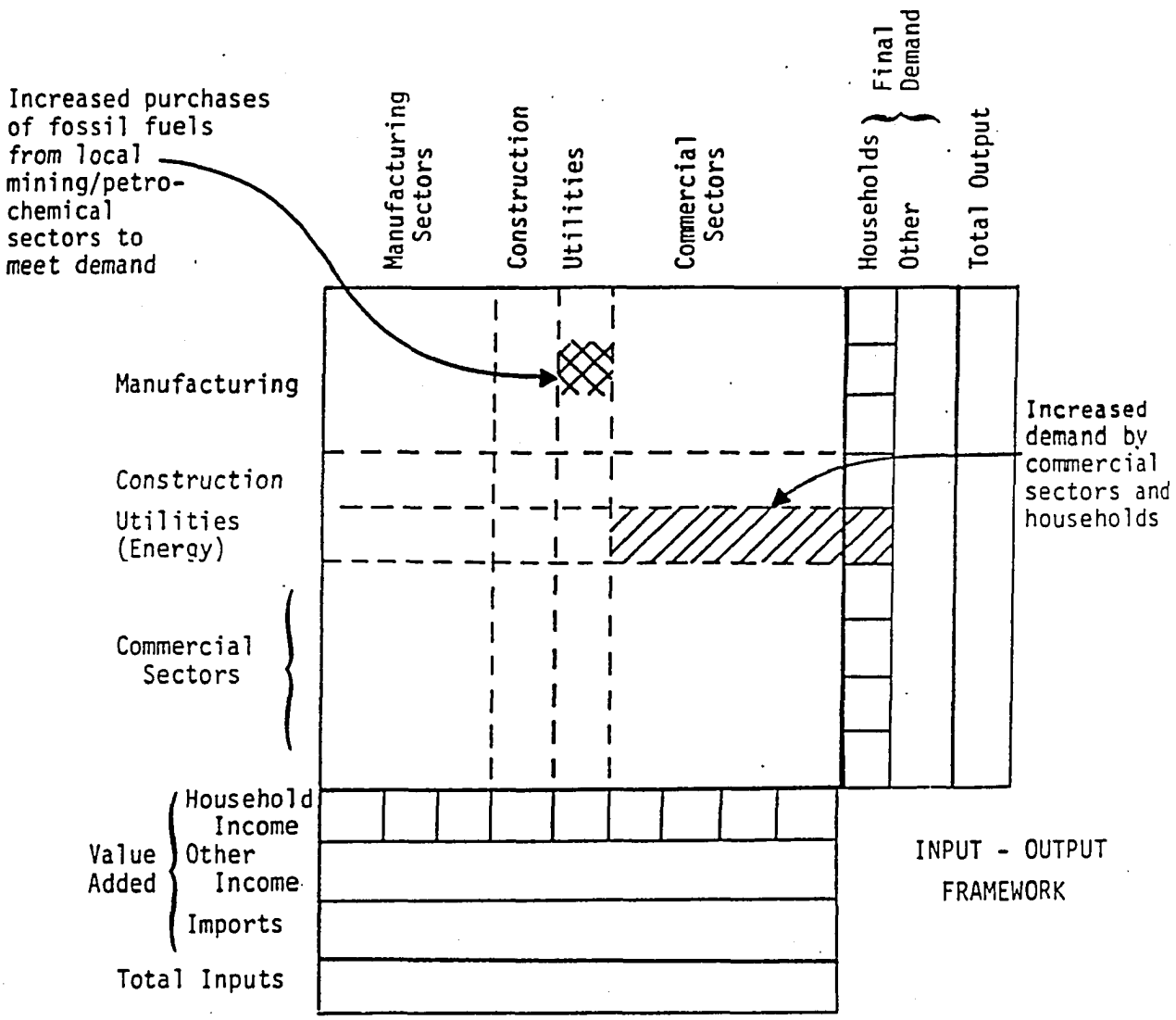
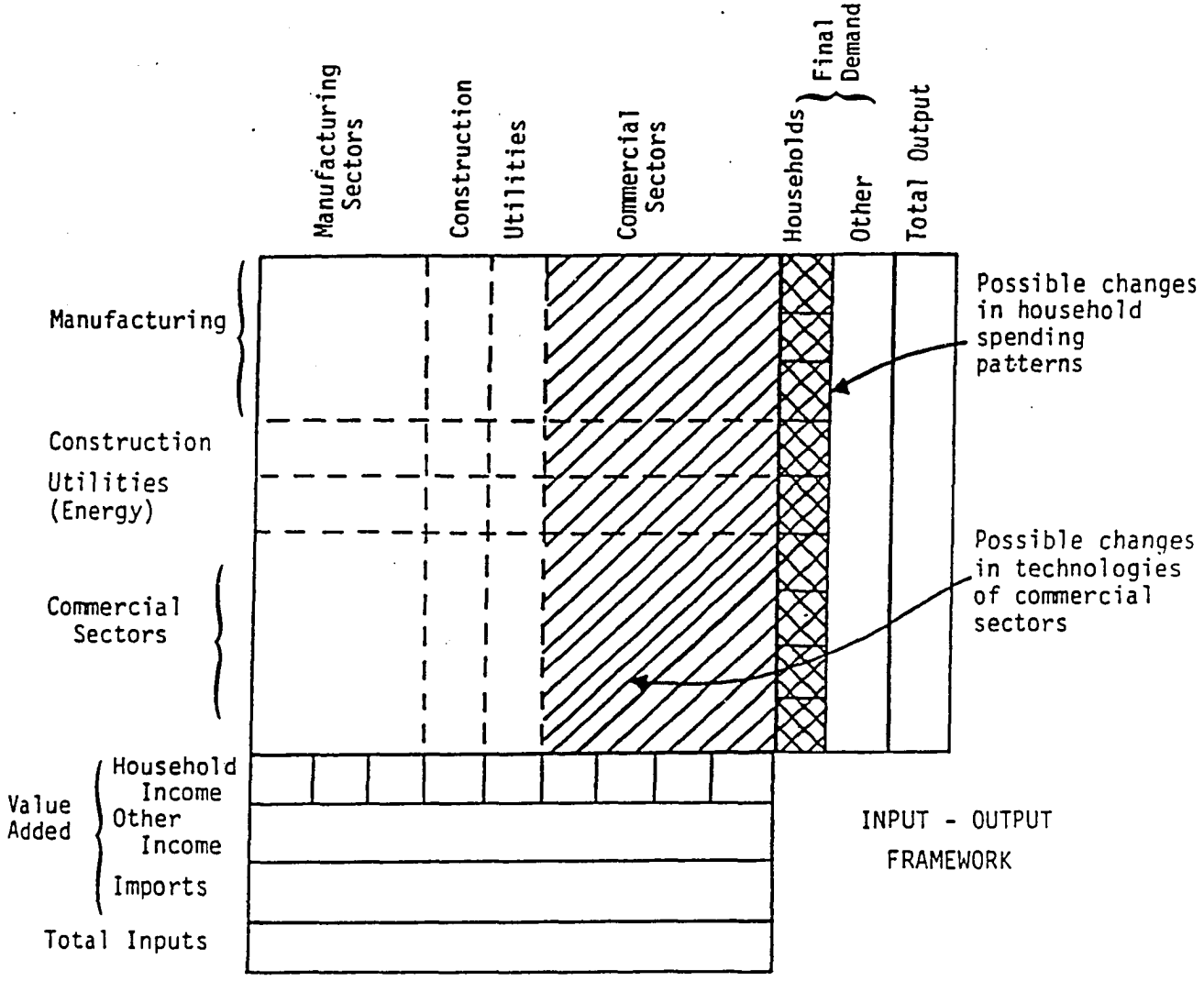


Figure 109: Possible Changes in Technologies of Commercial Sectors and Spending Patterns of Households Associated with Unusually Cold Winters or Hot Summers.



though the total income and expenditure might remain the same, sectoral distribution patterns could vary due to the changed pattern of final demand purchases. These shifts are of considerable economic interest (Figure 109).

Building models such as those discussed in Chapter IV can help to analyze these episodic events and their economic ramifications. Such models become even more valuable when one considers types of changes that are likely to take place in the future. For instance, the current energy crisis has sparked great interest in energy efficiency. A critical consideration is to develop building designs and urban planning patterns that will achieve greater efficiency in the use of traditional energy sources, especially fossil fuels, and also tap energy sources from the climate system (solar and wind energy). Clearly this would entail technical changes for utilities and commercial sectors. It would also affect construction practices and, hence, the technology of the construction sector. Production changes for manufacturing sectors which supply inputs for these other sectors are also probable. And, finally, one would expect changes in final demand patterns. In mapping out these alternative futures, it becomes increasingly essential to propose models that can accomodate a variety of energy scenarios. Building load determination models possess this desired flexibility. By themselves and in conjunction with other models, they provide a starting point for tackling other energy related issues, issues of ever increasing economic importance.

Another direct application of I/O methodology to assess the economic impacts of historic climatological conditions such as the

drought of 1934 can be found in Bowles, et al. (1982). A ten-region I/O model was specified for the U.S. with seven regions delineated within Utah to represent the agricultural activities of the climatological regions of the State. Various crop and livestock production systems, yield-water availability relationships, feed-to-livestock conversion systems, precipitation and water availability limits by region, and interregional trade routes and costs were included within the constraint system of the model. The objective was to maximize returns to fixed factors of production, subject to the constraint system. Running the model to an optimum solution for given prices and costs, as well as given resource constraints, determined the optimal levels of regional production, interregional feed and livestock trade flows, and resource (water, feeds, etc.) utilization. Thus, by combining the results of the system of climate impacted production/consumption equations just described, with a traditional I/O approach changes in levels of production due to the 1934 drought could be estimated. This enabled the following conclusions about the economic impacts of a significant drought period in Utah to be drawn:

> Simulated losses in net revenue to agriculture attributable to the 1934 drought conditions amounted to some $44.7 million in 1979 dollars. This was the loss derived from comparing net revenues generated by the model under the 1934 drought simulation with those generated from the base-year simulation. The losses under the drought conditions were caused mainly because of extensive reductions in non-grazing and grazing feed availability and the accompanying increases in non-grazing feed costs in all regions west of the Mississippi River in the U.S. Major Utah feed import changes were also derived from the 1934 drought simulation, as increased hay and barley imports and the costs of these imports were shown to occur in all Utah regions. Cow/calf and sheep grazing was reduced considerably and forced the liquidation of some 8,452 brood cows and 54,950 ewes and increased livestock liquidation costs by approximately $4.3 million. The competitive position of all livestock product activities in all regions in Utah was

> eroded by the increased cost imposed by the drought conditions. Feeding was primarily for maintaning herds to avoid liquidation. (Bowles, et.al.,pp.3-113, 114).

A similar example of I/O type analysis which estimates the impacts of changing patterns of water use in New Mexico can be found in Lansford, et. al. (1977). An example of the use of I/O analyses and climate impacted production estimates to assess the value of a proposed water transfer plan may be found in W. Cooter (1981).

In order to relate this I/O type of assessment more closely to the present study, the tables and methods described in W. Cooter (1984) will be used in conjunction with results generated by the AISC energy model to estimate the potential impact of winter-time temperature events in Oklahoma on selected aspects of the State economy. In his study W. Cooter utilizes input/output transactions and technical coefficient tables for Oklahoma taken from Little and Doeksen (1968). The sectoral breakdown is given in Table 72. For the present example, consider the sector which includes utilities. W. Cooter notes, "The sector that includes utilities also includes transportation and communications...While hardly ideal, it is felt that this feature does not unduly affect the usefulness of the analysis."

Later in his report W. Cooter derives a set of utility multipliers associated with a $1 decrease in consumer final demand for utility sector output. These multipliers are listed in Table 73.

The small size of the multipliers and the negative impact on total output show that this situation is a composite balance between negative impacts for some sectors and positive impacts for others. It will be assumed that the signs of the multiplers are reversed for a $1 increase

TABLE 72

Key to Sectors Used in Oklahoma Input-Output Model.

Sector Number	Sector Description
1	Crop Agriculture
2	Livestock
3	Agricultural Processing
4	Manufacturing
5	Transportation, Communication, and Utilities
6	Real Estate, Finance, and Insurance
7	Services
8	Wholesale and Retail Trade
9	Mining
10	Construction

TABLE 73

Multipliers for a $1 Decrease in Utility Final Demand.

Aggregate	Multiplier
Output	-0.07
Final Demand	0.38
Income	0.12
Taxation	0.05
GSP *	0.34

*Gross State Product (G.S.P.) ≅ Final Demand - Imports

in utility final demand. This information will now be utilized in two brief examples, a situation involving demand increases over normally expected use presented in W. Cooter (1984), and a situation in which demand is less than would be normally expected.

The first example utilizes weather events during December, 1983. This was an extremely cold wintertime event. W. Cooter reports that NOAA/AISC researchers estimated that each 1,000 HDD's induce 20.389 million BTU's of natural gas consumption per residential gas customer. The climatological population weighted HDD normal (1951 - 1980) for December in Oklahoma is 747 HDD's; the December, 1983 figure was 1144 HDD's. The difference between these two figures of 397 HDD's leads to an estimated extra natural gas consumption on Oklahoma of 8,094,433 BTU's per customer. A 1983 natural gas price of $6/million BTU's was assumed. The dollar impact was then estimated at about $48.54 per customer. Assuming a 1983 population figure of 746,100 residential natural gas customers in the State (Statistical Abstract of Oklahoma, 1984), the direct impact for the State as a whole was $36,215,694 for the month of December, 1983. If we apply this value to Table 73, a set of changes in various economic aggregate measures given in Table 74 are calculated. W. Cooter concludes that:

> "The overall implication is that an exceptionally cold winter has negative impacts on the Oklahoma economy; however, the initial size of the dirct impact (some $40 million) is significantly reduced (e.g., the income impact is under $5 million). This emphasizes the importance of trying to capture the total economic picture. When a climatic variation can lead to increases in demand for some sectors and decreases for others, a tool like input-output analysis is very helpful in estimating the net effects. The clear implication is that a very bad winter can have overall bad economic effects; but a moderately adverse winter might lead to overall impacts that are very minor."

Next the same technique will be applied to an unusually mild winter case. A consideration of population weighted state HDD's (NOAA, 1983) indicates December, 1965 to have been extremely mild. It's total, 557 HDD's is compared to the 88 year normal of 762 HDD. The difference is

TABLE 74

State-Level Economic Changes Induced by Weather Conditions During December, 1983 (W. Cooter, 1984).

1)	Output change:	$ 2,535,098.60
2)	Final demand change:	(-)$13,761,964.00
3)	Income change:	(-)$ 4,345,883.30
4)	Taxation change:	(-)$ 1,810,784.70
5)	GSP change:	(-)$12,313,336.00

205 HDD. If the same number of residential gas customers and price for 1965 as was used for 1983 are assumed, Table 75 can be computed. The question addressed by this calculation is, "What would be the economic impact of 1965 weather be if it occurred today?"

TABLE 75

State-Level Economic Changes Induced by Weather Conditions During December, 1965.

1)	Output Change	(-)	1,309,773
2)	Final Demand Change	(+)	7,110,197
3)	Income Change	(+)	2,245,325
4)	Taxation Change		935,552
5)	GSP Change		6,361,755

Direct impacts would amount to $18,711,046

In this case, the initial direct impact of $19 million has been reduced to a $2.2 million impact on household income, but the impact has

spread throughout the rest of the economy resulting in substantial increases in final demand for goods and services ($7 million). This increase in spending could effect a wide variety of economic sectors in Oklahoma. Exactly which sectors would benefit the most from these dollars could be determined by a Survey of the way in which consumers choose to spend unallocated portions of their income. On the State, economy-wide level, the resulting dollar impacts might disappear, but retail sales, for instance, could sustain substantial short-term demand pressures requiring alternative ordering, transport and distribution strategies for their goods. The direct impact reductions are most likely the result of a decrease in demand for gas utilities rippling through the entire economy of the state. Final net effect on the gross state product is a positive one on the order of $6 million dollars.

Next, consider this information in a time-series form to analyze the way in which weather of the past would impact household income and gross state product (GSP) given the number of residential gas customers and average price of 1983. Figure 110 is a plot of this information by winter heating month. The values plotted represent changes in these economic indicators resulting from HDD deviations from an 88 year normal value of HDD. The figures plotted have the statistical characterisitics provided in Table 76.

From these data one can say that in terms of long-term GSP, heating requirements in response to weather have had slightly negative impacts on the Oklahoma economy during the last 35 years as compared to the entire 88 year period of record, that is, on the average it has been a drain on state income on the order of $740,000 per calendar year. Over

Figure 110: Time-Series of GSP, Household Income and Direct Impacts of Heating Season Weather in Oklahoma.

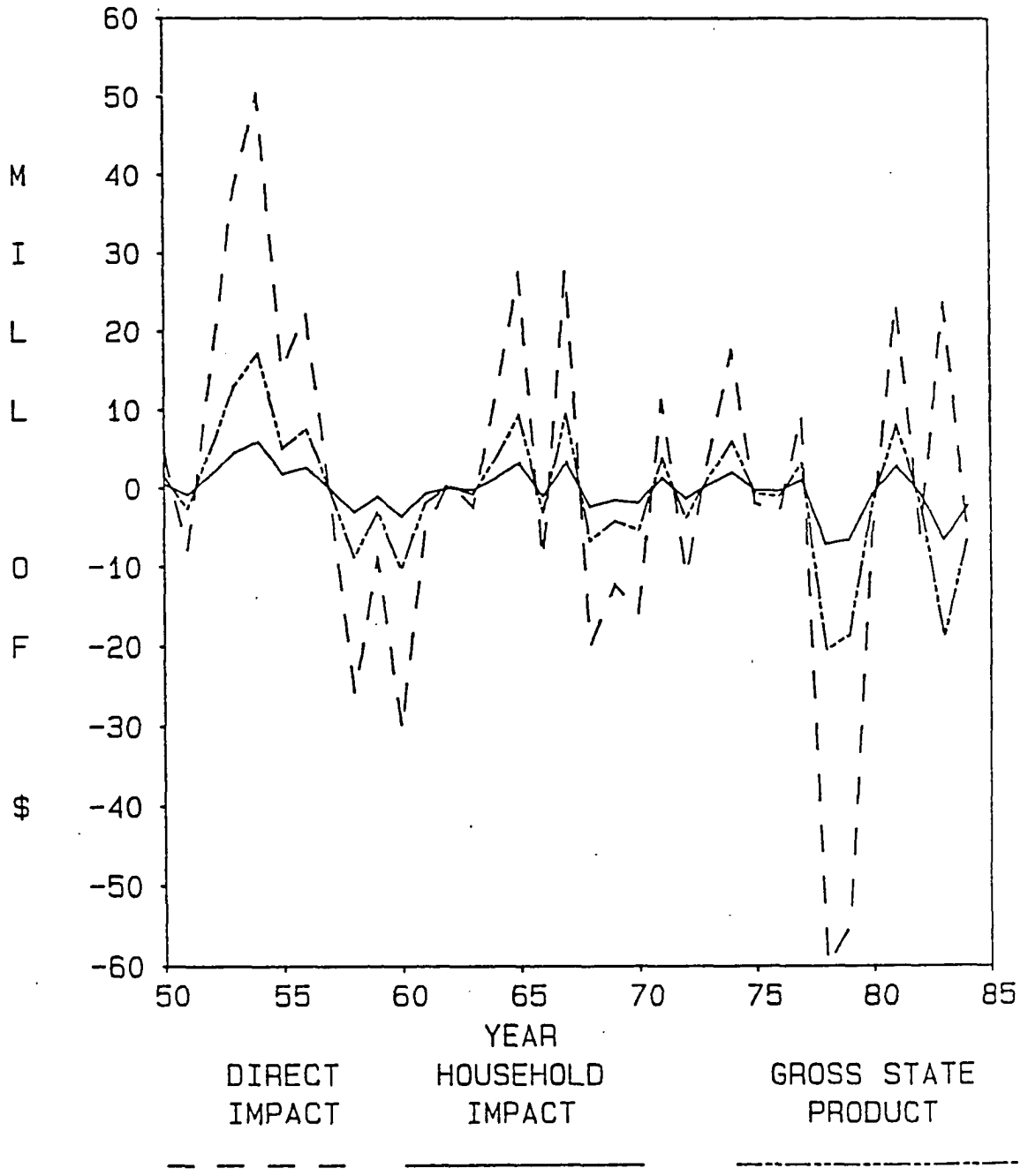


TABLE 76

State-Level Economic Impacts of Winter Heating Season Weather in Oklahoma.

($ Millions)

	*Mean	Standard Deviation
Direct Impact	- 2.17	24.48
Household Income	- .26	2.936
GSP	- .74	8.32

*If deviations from the 35-year mean rather than the 88 year mean were computed, we would expect the mean of the plotted changes to be 0.

the last 35 years, sixty-eight percent of the time impacts on GSP due to home heating weather ranged between decreasing the GSP $9.06 million from its long-term expected level and supplementing GSP by $7.58 million. Over the last 35 years, ninety-five percent of the time these impacts ranged between decreasing the GSP $16.64 million from its normal base level and supplementing the GSP with an additional $15.9 million. From these statistics one can say, for instance, that the losses to the state during December 1983 were almost as great as 96 percent of all HDD related negative GSP impacts during the last 35 years. A few extremely unusual years can be picked from Figure 110. Only one year was unexpectedly good for GSP (these or greater contributions could be expected only 5 years out of 100), 1954. During the last 35 years Oklahoma has experienced periods of significant negative impacts to GSP, that is, these or greater loses would normally be expected only 5 of 100 years. These years include 1978, 1979, and 1983.

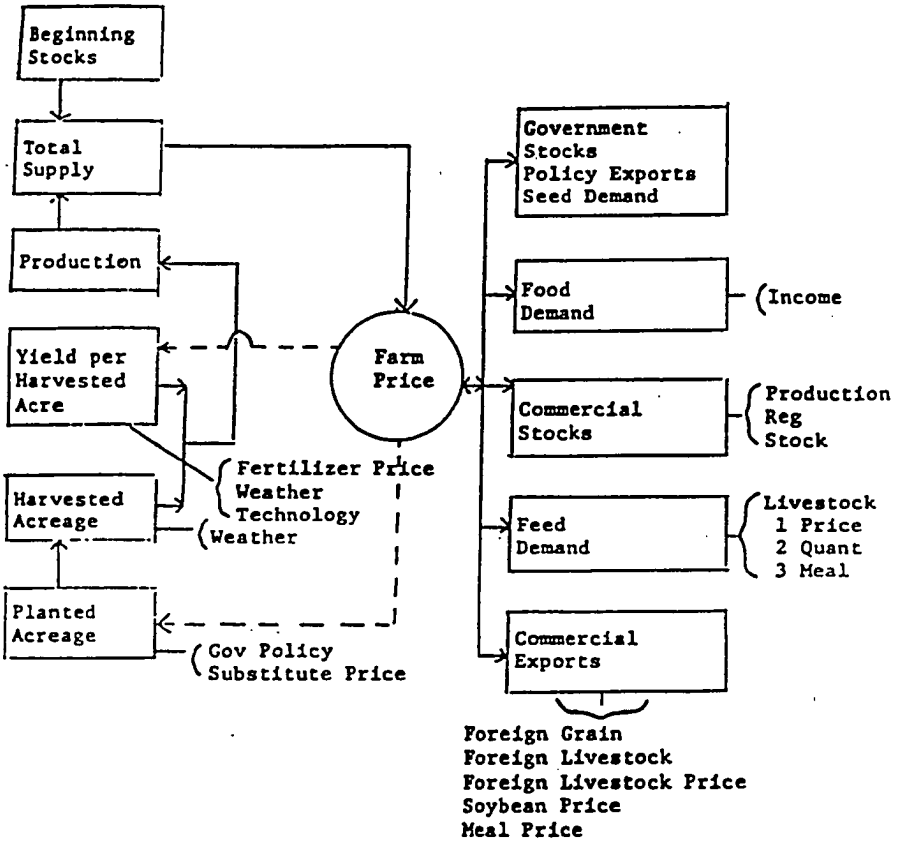
In summary, the information is very suggestive of several Baysian type problems that could be developed at a later date. As in the case

of other products developed in earlier Chapters, the role of meterological forecasts to make mid-season projections of changes in State revenues with confidence limits is clear. A study of the value of improved mid-season energy forecasts similar to that completed for corn production could also be developed but is beyond the present study. A similar study relating soil moisture to gross state product may be found in W. Cooter (1981).

The example just completed demonstrates the utilization of climate information within a traditional I/O framework. Econometricians as well as I/O economists are aware of the importance of including consumption/production estimates that realistically reflect climatological influences in their models. For instance, in a 1982 report entitled "The Economic Impact of Climate: Micro Component Model of the U.S. Crops Industry," econometricians Womack, Johnson, and Young state that "random exogenous events characterized by weather activity both in the domestic and foreign markets have a significant impact on the direction of price equilibrium." In general, an econometric model consists of a set of simultaneous, largely linear, equations. Quite commonly, the goal of the modeling system is to predict an equilibrium price for some commodity given predefined levels of activity in related economic sectors. Far more thorough treatments of econometrics can be found in Intriligator (1978), and Johnston (1960).

As an example of how estimates of weather impacts can be utilized in such an econometric modeling system, consider a small portion of the feed and livestock model described in Womack, et. al. (1982). Figure 111 illustrates the feed grains component only.

Figure 111: Feed Grains (Annual Model) Corn, Sorghum, Oats and Barley (After Womack, et.al., 1982).



ENDOGENOUS VARIABLES

1 Corn Price	7 Oats Fed	13 Oat Food
2 Sorghum Price	8 Barley Fed	14 Corn Food
3 Oat Price	9 Corn Stocks	15 Barley Food
4 Barley Price	10 Sorghum Stocks	16 Corn Exports
5 Corn Fed	11 Oat Stocks	17 Sorghum Exports
6 Sorghum Fed	12 Barley Stocks	

Planted Acres	Harvested Acres	Yield
18 Corn	21 Corn	25 Corn
19 Sorghum	22 Sorghum	26 Sorghum
20 Oats	23 Oats	27 Oats
21 Barley	24 Barley	28 Barley

Dr. Womack briefly described the system as follows:

> "The left column reflects the supply and production sector. The right column represents components in aggregate demand. The lower block in the supply column indicates major variables associated with estimation of total planted acreage. Planted acreage is a funciton of lagged market price, simulation prices, government policy variables, and input costs. Harvest acreage is conditioned on planted acreage and weather. Yield is dependent on fertilizer prices, weather conditions, and technology.
>
> On the demand side, commercial exports are linked to the livestock sector in importing regions, foreign or competitive grain production, competitive crop prices, exchange rates, and barriers to entry, including variable levies used by members of the European Economic Community. Feed demand is linked directly to the U.S. livestock industry and high protein meals from the soybean industry. Commercial stocks are functionally related to own price, current supply, expected future production, wholesale price index, and lagged commercial stocks. Farmer-owned and commodity credit reserves are treated as separate exogenous variables to the system. Food demand as a minor component of the feedgrain industry is dependent on own price, consumer expenditures as an income proxy, and the index price of nondurable goods and services as a deflator and proxy for the overall rate of inflation outside of the crop sector." (pp. 2-5)

Econometric models can be used to answer, from another perspective, some of the same questions we have already considered in earlier Chapters. For example, an econometric model presented in Womack (1980) can be used to readdress the value of decreased uncertainty in mid-season corn yield forecasts. In Womack (1980), relationships between corn, corn prices, and related corn activities are derived. These relationships are outlined in Table 77.

A second table in Womack (1980) provides the same information when domestic exports of corn increases by 100 million bushels (Table 78). We will assume these economic effects are the same as if the corn was not grown or is withheld from domestic use.

TABLE 77

Use Price Changes Associated with a Corn Supply Change of +100 million Bu.

Price	$- .10 per bushels
Feed Utilization	+ 40 million bushels
Food Use	+ 2 million bushels
Exports	+ 7 million bushels
Stocks	+ 50 million bushels

TABLE 78

Use Price Changes Associated with a Corn Supply Change of -100 million Bu.

Price	$+ .13 per bushel
Feed Utilization	- 50 million bushels
Food Use	- 3 million bushels
Stocks	- 40 million bushels.

The importance of narrowing mid-season forecasted yield confidence limits becomes apparent if the original independent pooled means sample at Rochester, MN is considered. If 20 sampling sites at flowering across the corn belt and an original of 15 bu/ac are assumed, variance of 11.25 bu^2/ac^2 or a standard deviation of 3.354 bu/ac can be determined (Figures 67 and 71). With a station density (effective degrees of freedom) of 40, the independent pooled variance becomes 5.625 bu^2 $/ac^2$ or =2.37 bu/ac. Next assume the 1981 corn-belt acreage of 67,093,000 acres. Using the information in Tables 77 and 78, Table 79 can be generated.

TABLE 79

Mean and Standard Deviation of Yield, Production and Production Value for a 1, 20 and 40 Station Network.

	(bu/ac) Yield	(bu) Production	Value	Production ($) Value
Mean	95.0	6.3738×10^9	$2.264/bu	1.443×10^{10}
+2 σ 1 station	125.0	8.3870×10^9	$ .251/bu	2.105×10^9
-2 σ 1 station	65.0	4.3610×10^9	$4.884/bu	2.129×10^{10}
+2 σ 20 stations	101.7	6.8234×10^9	$1.817/bu	1.240×10^{10}
-2 σ 20 stations	88.3	5.9243×10^9	$2.711/bu	1.606×10^{10}
+2 σ 40 stations	99.74	6.6919×10^9	$1.946/bu	1.302×10^{10}
-2 σ 40 stations	90.3	6.0585×10^9	$2.582/bu	1.564×10^{10}

If a Gausian distribution of outcomes about our forecasted yield using 20 station sites is assumed, 95 percent of the time production value will fall between $\$1.240 \times 10^{10}$ and $\$1.606 \times 10^{10}$, a range of $3.66 billion. This represents a decline in forecast uncertainty at a single point of 77% (from 15 bu/ac to 3.35 bu/ac). This also represents a decrease in the expected range of production value at the 95% confidence level of 82% or $15.53 billion. If 40 stations are used 95 percent of the time production value will fall between $\$1.302 \times 10^{10}$ and $\$1.564 \times 10^{10}$, a range of $2.62 billion. This represents a forecast uncertainty of 2.37 bu/ac, an additional 7% improvement over the original single point estimate. The $2.62 billion 95% confidence level range represents an additional narrowing by 28% of outcome possibilities. The difference between the 20 and 40 effective degrees of freedom estimated ranges is $1.04 billion. One would expect an

observed production value outside of this range only 5 out of 100 production seasons. In terms of the Bayes example, by increasing the EDF from 20 to 40 we would be able to cut our risk by 71 percent and over the long-term our decision maker would save $1.04 billion.

Two methods of assessing the independent impact of weather on two economic sectors have been presented. The input/output analysis, though, highlights the interactions between sectoral activities. A specific interaction between agricultural and utility sectors, irrigation pumping, was discussed briefly in Chapter II. If the combined impacts of weather on these two sectors were to be assessed simultaneously, input/output analysis again provides us with a flexible means. Because of the linear nature of the I/O transactions matrix, multipliers for each impact can be used independently and their results summed. Although this is a straightforward process, it reemphasizes the importance of understanding, and correctly applying, direct impact functions. By summing the results of a variety of impact estimates, any problems with model non-linearities and input data correlations will be highlighted. Many cross results could "wash-out". For instantce, unfavorable corn growing conditions could occur in the same year as very favorable energy demand weather. The positive and negative effects could balance with a net impact of zero. This in itself is an important conclusion, but in the process, sectoral detail of impacts has been lost. Thus, combined sectoral estimates are an important aspect of impact assessment, but should be used with caution.

We have now completed the case for the economic value of the climate impact products developed in this report. This aspect of

climate impact assessment is becoming increasingly critical due to the many pressures which presently exist for the creation or expansion of a system of user's fees and charges for climate information and services. The very nature of climatological information makes this a difficult task. Climate information may be made available at two levels: raw data and highly generalized forecasts; or products that have been refined and directed towards particular users or group of users. At present, the Federal government is largely responsible for the collection, production, and dissemination of both these types of information. The questions currently being asked in Washington include: "Can an economic value be assigned to any or all of the products; if so, could a system of charges be developed, applied and collected; and, finally, is it appropriate for the tax payers to be subsidizing the production of this information or should the process be turned over to private industry and the free market?"

A system of governmentally imposed user charges has been considered for a number of reasons (GAO, 1980). First, they are assumed equitable because they allow the costs of publicly produced goods and services to be borne by their recipients. Secondly, it is assumed that such a system would eliminate the production of services whose costs far outweighed their benefits. Finally, it is argued that pricing Government products would contribute to a more efficient allocation of products and resources. In 1952, Congress authorized Government agencies to impose such a system of fees for certain goods and services. This legislation, commonly known as the User Charge Statute, has sparked a controversy which has continued to the present. The publication of a

series of General Accounting Office (GAO) reports, including GAO(1980) and GAO(1981), illustrate some of the issues currently being debated. The discussion of these issues will begin with a brief summary of OMB Circular No. A-25, a document which instructs the heads of executive departments and establishments in the implementation of the User Charge Statute. A brief summary of implementation problems as currently perceived by the GAO will be presented to close this discussion.

The purpose of Circular A-25 (OMB, 1959) was to outline the scope of user charge activities, propose guidelines for carrying out the approved user fee policies, and provide instructions for filing periodic status reports. The statements contained in the circular cover all Federal activities which convey special benefits to recipients above and beyond those accruing to the public at large. The general policy stated in this circular is that a reasonable charge should be made to each identifiable recipient for a measureable unit or amount of Government service or property from which a user derives a special benefit. The circular goes on to say that when such special benefits occur, a charge should be imposed to recover the full cost to the Federal Government of rendering that service. Further, a charge should also be imposed if the government service provides business stability or assures public confidence in the business activity of the beneficiary or if the service is performed at the request of the recipient and is above and beyond the services regulary received by other members of the same industry group or the general public. No charge should be made for services when the identification of the ultimate beneficiary is obscure and the service can be primarily considered as benefiting broadly the general public.

These charges should be set so that all direct and indirect costs to the Goverment of carrying out the activity are covered. The maximum fee, however, for a special service will be governed by its total cost and not by the value of the service to the recipient. All collections of such fees should go into the general fund of the Treasury as miscellaneous receipts except when it is intended that the agency operate from these funds or the receipts are in payment of the cost of authorized special benefits for which the demand is irregular or unpredictable. Many problems have arisen from attempts to implement these guidelines.

The implimentation issues that are of concern today can be broken into two major categories (GAO, 1980): the set of arguments which refute the original justifications for the establishment of a user charge system; and legal decisions which limit the applicability of the User Charge Statute. GAO (1980) proposes that any system of fees or charges administered by the government could potentially be inequitable since individuals with lower incomes might be excluded from the product. Secondly, although individual beneficiaries of some products or services can be identified, charges may not be appropriate since the society as a whole may also benefit. For instance, assume a climatology dealing with the likelihood of urban flooding is produced. Although this information might suggest structural or production alternatives to a particular firm resulting in a decrease in flood related losses, such information would also benefit the general public by preventing the loss of life or personal property in adjoining residential areas. Another example can be found in generalized weather forecasts. Specific television or radio

stations may receive monetary benfits from the sale of advertising time during the weather segment. This individual benefit may be far outweighted by the benefits accrued from such information by society as a whole. Lastly, if there are prohibitive administrative costs in setting up a fee collection system, then a more efficient allocation of government products and resources could not result. If the administrative costs are high, the charges, even simply to recover costs of production, will be so high that some or all users may be excluded from the use of the product.

A second group of issues addressed in GAO (1980) are of a legal nature. A number of suits have been filed in Federal courts when attempts were made to assess and collect fees from some firms or individuals. Three major decisions resulted from these cases that, although pertaining explicitly to the User Charge Statute, appear to apply to any statute permitting an agency to assess fees. In the first of these decisions, the courts distinguished between fees, which Congress may authorize an agency to assess, and taxes, which only the Congress may assess. A fee is a charge an agency may exact in exchange for a benefit which is not shared by the public. The agency may charge no more than direct and indirect costs to the recipient. It may not charge the recipient for costs attributable to benefits to the public. A tax, on the other hand, need not be related to any specific benefit, and the Congress is not limited to the costs of providing any benefit in setting the tax rate. Secondly, a fee may be charged only to specific, identifiable recipients of a special Government benefit. An agency may not charge all the members of a group or an industry, regardless of

whether each member actually benefits. Lastly, an agency may include only direct and indirect costs it incurrs in conferring a special benefit. It may not calculate its fees on the basis of the return on investment of profit to be derived by the recipient as a result of the benefit. If such factors are included, the agency is unlawfully attempting to levy a tax rather than charging a fee. Therefore, when it is desirable to set a charge which exceeds the cost to the government of providing the benefit, the charge must be imposed directly by action of the Congress.

These court findings should be of particular interest to those presently supporting the reorganization of the National Weather Service (NWS) along corporate lines. At the least, these legal decisions dictate that such a corporation would be non-profit in nature since the government is prohibited from recovering any but direct and indirect costs from fee collections. Other problems would arise if both public and private types of goods are produced by the corporation. Public products would have to be discontinued because the costs of their production could not be recovered unless by specific acts of Congress. Such actions would be both time consuming and prohibitively expensive. Thus, a significant number of products and services would not be self-supporting, and the corporation would necessarily be heavily funded by tax dollars.

In summary, although a method for determining climatological impacts has been derived and potentially valuable products have been developed from these results, the final release of this information can be hopelessly delayed if it is caught-up in legal debates at the Federal

level. When considering problems associated with product communications, one is wise to include these issues since they can have rather drastic, and at times disastrous, effects on the transmission and use of research results.

Chapter VI

SUMMARY

The research presented in this report constitutes a synthesis of a variety of specific disciplinary approaches to address an intrinsically interdisciplinary problem. Meteorological data and statistical techniques have been used to deal with agronomic, architectural, and economic impact issues. The author's past experience as a public service employee dealing in user services and product development has also proven invaluable. The overall goal of the research has been to implement a methodology to produce climate impact assessments. It has been demonstrated that although such a product most likely can never be "cookbooked", as is often the case in environmental impact assessment, an organized super-structure can be imposed over a foundation of observable impacts that includes user identification, model selection, selection of analysis methodology, product development and communications.

In one case, the agricultural community was selected as a major user market. This selection was further constrained to corn growers in the United States. The next step was the selection of the CERES maize model as the impact analysis model. Existing statistical techniques were utilized and modified to determine how the model could reflect hypothesized impacts and to suggest product possibilities. The techniques utilized in this example included one- and two way ANOVA

layouts, K-S tests, F-tests, ^{2} -tests, Dunn's pairwise t-tests, means and standard deviations and Baysian decision theory techniques. The results suggest that although this is a statistically complex model, it can yield very useful impact information. It was determined that due to output distributional biases, traditional ANOVA techniques are not adequate analytical tools. If we assume the model truely does reflect reality, it was found that the yield distribution as a whole is probably non-gausian, particulary in the upper and lower tails. Further, there appears to be identifiable weekly patterns of forecasted yields throughout the growing season during the 36-year study period. These patterns may or may not match analog synoptic years currently in use by the Climate Analysis Center (CAC) in Washington, D.C.

The fourth step, product development is, perhaps, the most difficult aspect of a climate assessment to formalize. It requires some peripheral knowledge or understanding of the physical processes associated, in this case, with getting a crop into the ground, growing it, getting it out of the field and finally into the marketplace. This is not to say that one must become an "expert" in each impact activity. That would result in duplication of effort and would effectively narrow an interdisciplinary effort to an essentially disciplinary one. But, there must be adequate familiarity so that model results can be interpreted in practical terms. Banker(1985) quotes economist Mike Price of the USDA Economic Research Service as saying,

> "In modeling, interpretation is really important.... Researchers must know the model's limitations as well as their own."

Economist Shwu Eng Webb, also of the Economic Research Service adds,

> "If several different models or methods are used to evaluate a given policy, it is likely there will be several different results. Results can only be interpreted and used correctly if the researcher has some knowledge of the model and understands its assumptions, structural forms, characteristics, and objectives."

Returning to the fourth objective, types of products developed for the agricultural example included point yield impact estimates and distributional characteristics, geographic weather distributions, return period estimates, decision making criteria (confidence limits) and time series of indices.

The last phase of impact assessment is communication, that is, the manner in which the general product is presented to a specific user. This includes the language utilized. Again, familiarity with the market's interests is critical. For instance, a farmer might want his information in terms of the frequency of expected crop failure due to some specific set of weather conditions or, the likelihood (uncertainty) of a yield forecast. An insurance underwriter may want to know the "risk of an event." An investor may want to know the expected return on his investment given weather or climate forecasts. The economist might want to know about the expected distribution of market prices with respect to projected weather conditions. Information to meet each of these users requirements can be derived from the same basic probability or return period product mentioned in step four above, but the effectiveness of its communication is what ultimately determines the products' value. This usually involves further refinement or processing of the general product. Means of communicating climate products to specific users are explored in section 3.5 and Chapter V.

The same five step super-structure listed above and utilized for an agricultural assessment was followed in Chapter IV for residential utility demand. Under the impact example contained in Chapter IV the user is the utilities sector. This is further disaggregated into residential gas heating customers and those associated with meeting their demand. The models selected were the NBSLD and AISC gas use models. The methods of analysis included simple descriptive statisitcs such as mean, range, and standard deviation and simple correlations. This cursory analysis suggested the presence of interesting relationships among weather variables across the Oklahoma study sites. These relationships would appear to change slightly between daily and seasonal variable values. It was not determined if these changes were due to the statistical nature of the weather data analyzed or use of correlated input data by the energy process model. No time trends were detected in the weather data and none were detected in the technology-free energy model results. Upward linear trends in reported State-level energy use can be largely attributed to non-weather factors, since no such trends are present in the technology free process model results. Significant year-to-year variability on the order of 10^6 Btu's per household per heating season energy demand was found and related to variability in the Oklahoma economy(on the order of $\$10^{6)}$ The products developed included the definition of regional forecast areas, likelihood estimates of extreme seasonal conditions and an energy/climate index. An illustration of information translation is the inter-industry example contained in Chapter V. Here, changes in modeled gas heating demand are translated into changes in Gross State Product and household income.

Chapter I suggests that assessments of direct climate impacts have been performed by meteorologists and climatologists for some time but have failed to gain acceptance from economic or administrative decision makers. One possible reason that has been mentioned throughout this presentation is a general lack of effective communication of this potentially valuable information. Often administrators have been trained to think in traditional economic terms. If our information is to reach these users it must be in terms they understand and with which they are comfortable. For example, the present study has explored the use of more potentially weather sensitive models to assess direct climate impacts on the production or use of raw materials and economic goods. Items that can be directly impacted by weather are those raw materials such as plant biomass production, or end-user services such as household use of energy, which have no economic buffers or sectoral activities between them and environmental variability. In addition to the models studied being more sensitive to weather variability, methods of aggregating these small scale direct impacts to a larger regional or national scale were developed and utilized. This is a critical step since most formal economic models with which administrative decision makers are familiar operate on a fairly large space scale. Point or firm specific estimates are not immediately compatible with such models. Regional estimates are, then, essential for the development of economic products. The present study has also contributed to the communication of climate information to economists and administrators by expanding examples presented in W. Cooter(1984) which concluded with making dollar impact estimates for a particular event or scenario. The present work

carries this further by proposing the mechanism to produce mid-season economic forecasts throughout time with confidence limits similar to those proposed for mid-season corn yields in Chapter III, section 5.

Many of the methodological contributions to climate impact assessment made by this research are found in the use and analysis of the direct impact functions themselves. This report represents the first detailed weather sensitivitiy analysis of the CERES maize model. This includes the first CERES sensitivity analysis using broad space and time frames. This study also proposes and then utilizes mid-season forecasts with confidence limits. The use of a forecasting technique which favors the estimation of confidence limits is a distinct advantage in terms of providing additional statistical and applications information. The energy analysis makes significant contributions as well by utilizing a physical rather than statistical model over a fairly large space and time scale to assess energy demand; providing a comparison of statistical and physical model performance and translating energy demand changes into a time-series of climate impacts on household income and Gross State Product.

Future research suggested by this study includes further exploration of the general statistical nature of physical impact models. Such a study is essential if we are to use the output of such models to their highest potential without ignoring thier hidden liabilities. Other process type agricultural models should be considered in a manner similar to CERES. As a result of the quality, and potential monetary value of information available from these models, chances are great that they will be widely applied with or without such an anlysis. The

opportunity for stretching a model beyond its reasonable statistical limits looms large without the completion of such studies. The NBSLD and regression energy model comparison should be expanded to other geographic regions of the U.S. which possess greater winter weather variability and more complete hourly data sets. The changing relationships among weather variables across Oklahoma on a daily versus seasonal basis should be explored, and if verified, their implications for utility industry planners examined. A mid-season economic forecast with confidence limits similar to that computed for crop production should be more completely developed and carefully examined for use as an operational climate assessment product for regional or state government.

The tools for the systematic production of climate impact assessments are available. The data are in hand. All that remains is for meteorologists and climatologists to learn how to communicate this valuable information effectively to those who need it.

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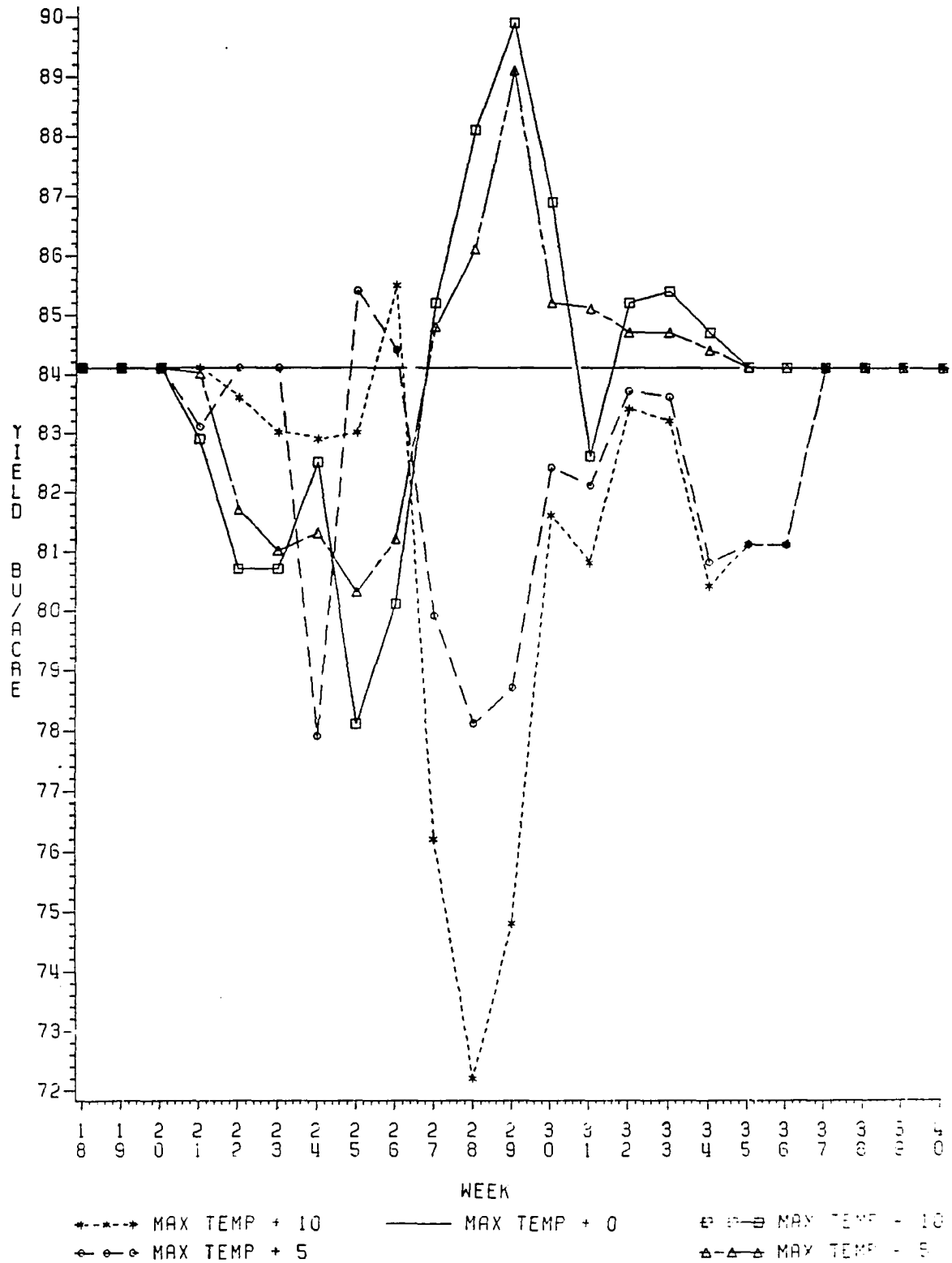
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Appendix A

CERES MODEL RESPONSES TO WEEKLY MAXIMUM TEMPERATURE, MINIMUM TEMPERATURE AND PRECIPITATION VARIABILITY AT SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT.

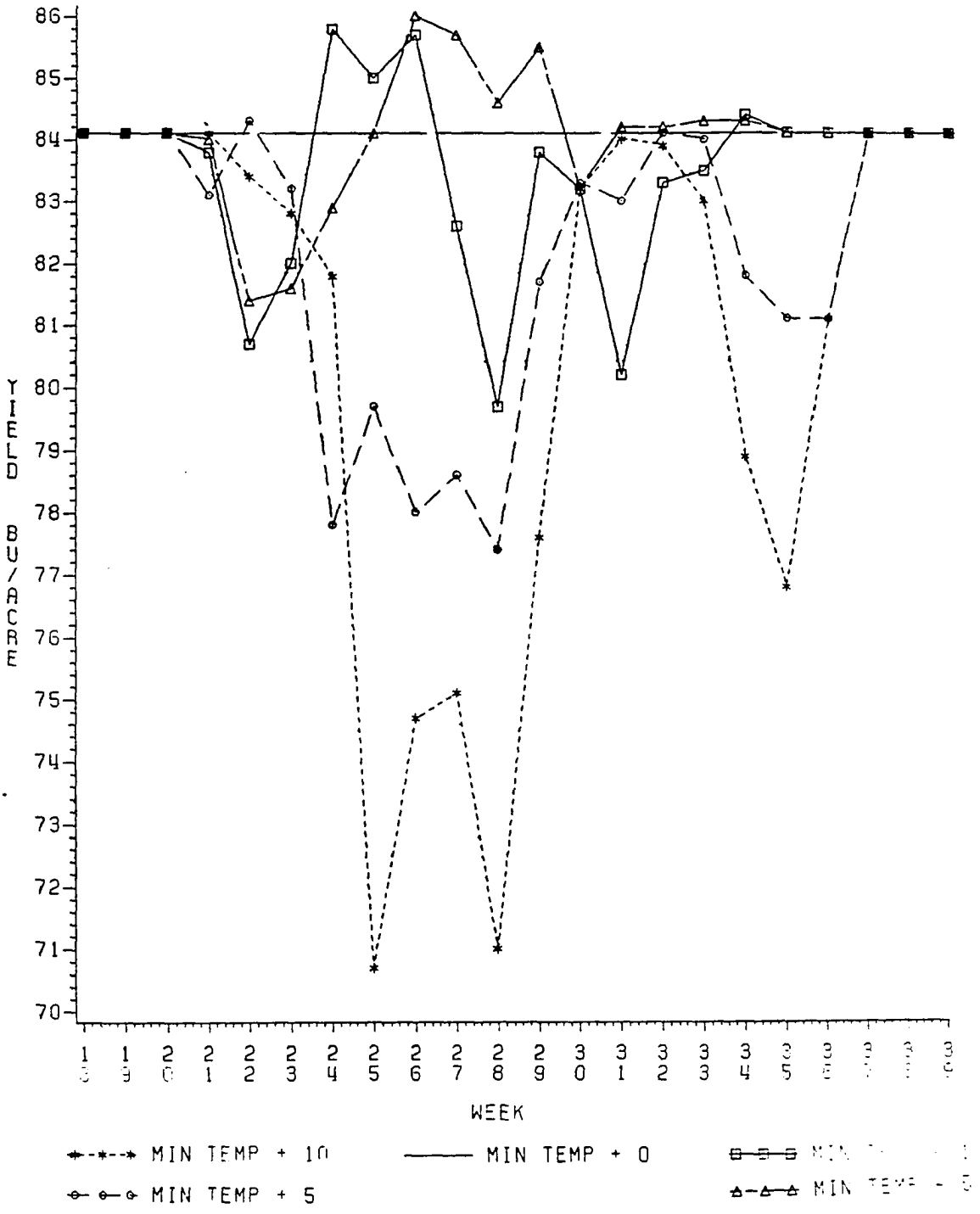
CERES Model Response to Weekly Maximum Temperature

at Springfield, MO



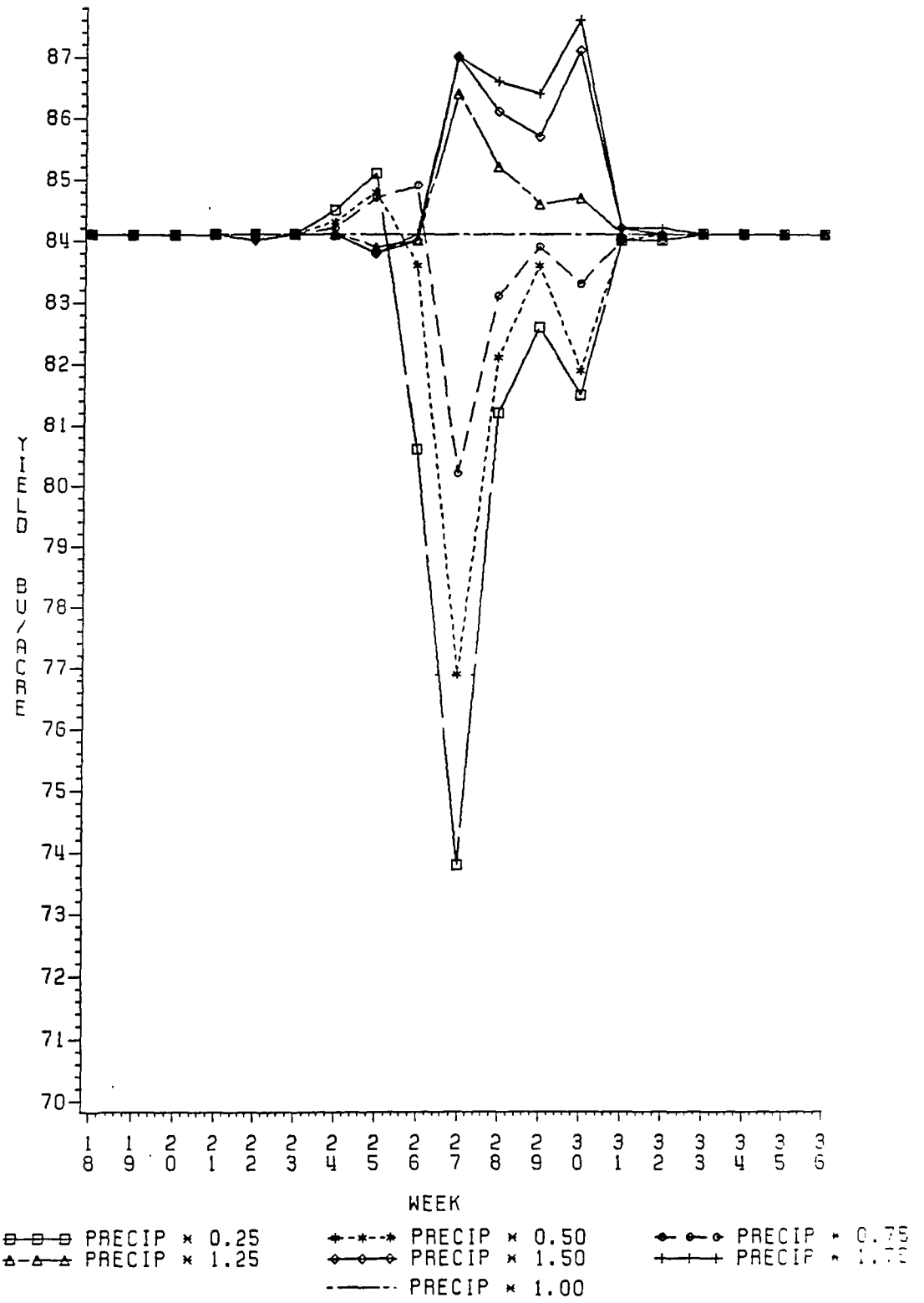
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at Springfield, MO



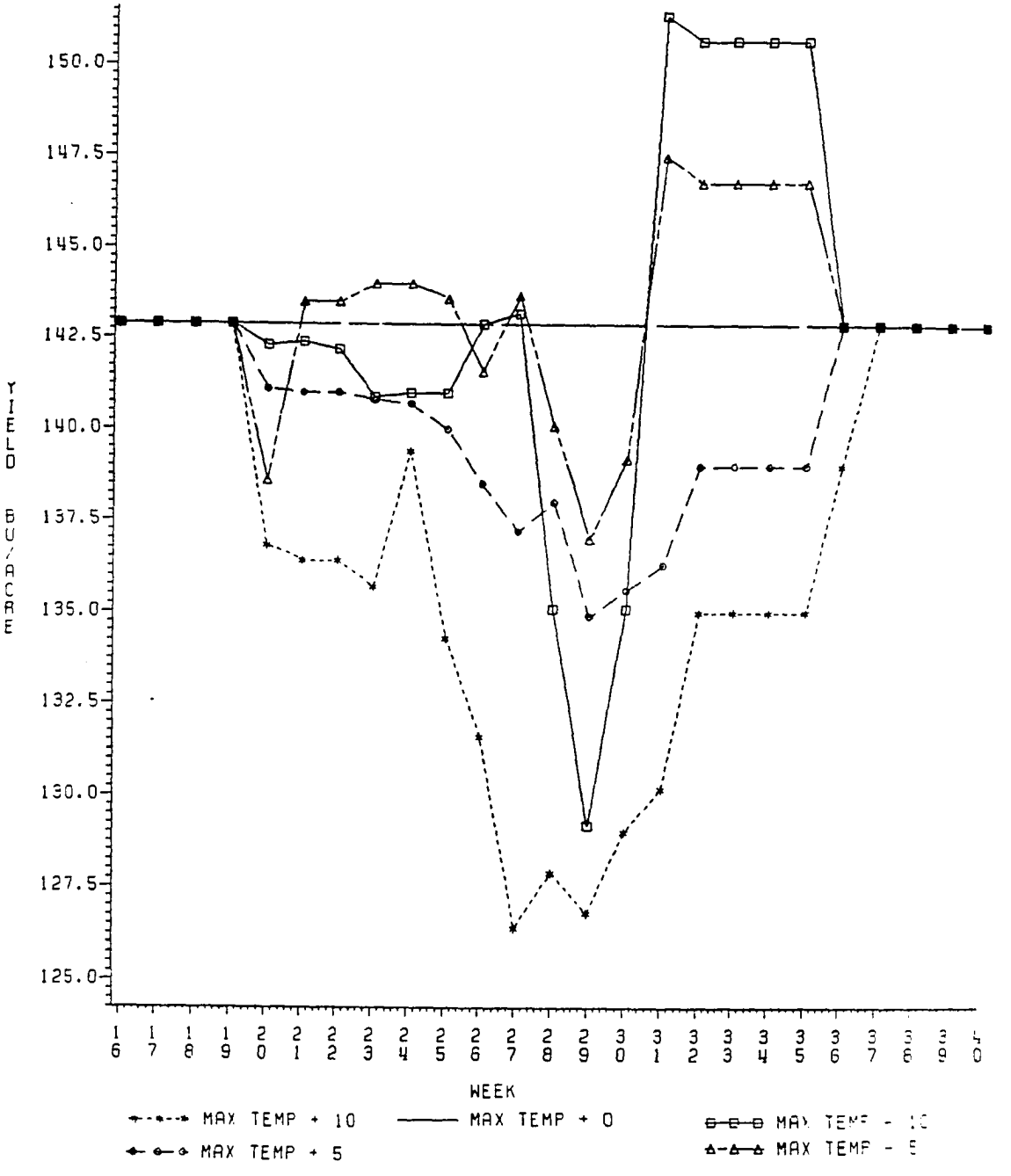
CERES Model Response to Weekly Precipitation

at Springfield, MO



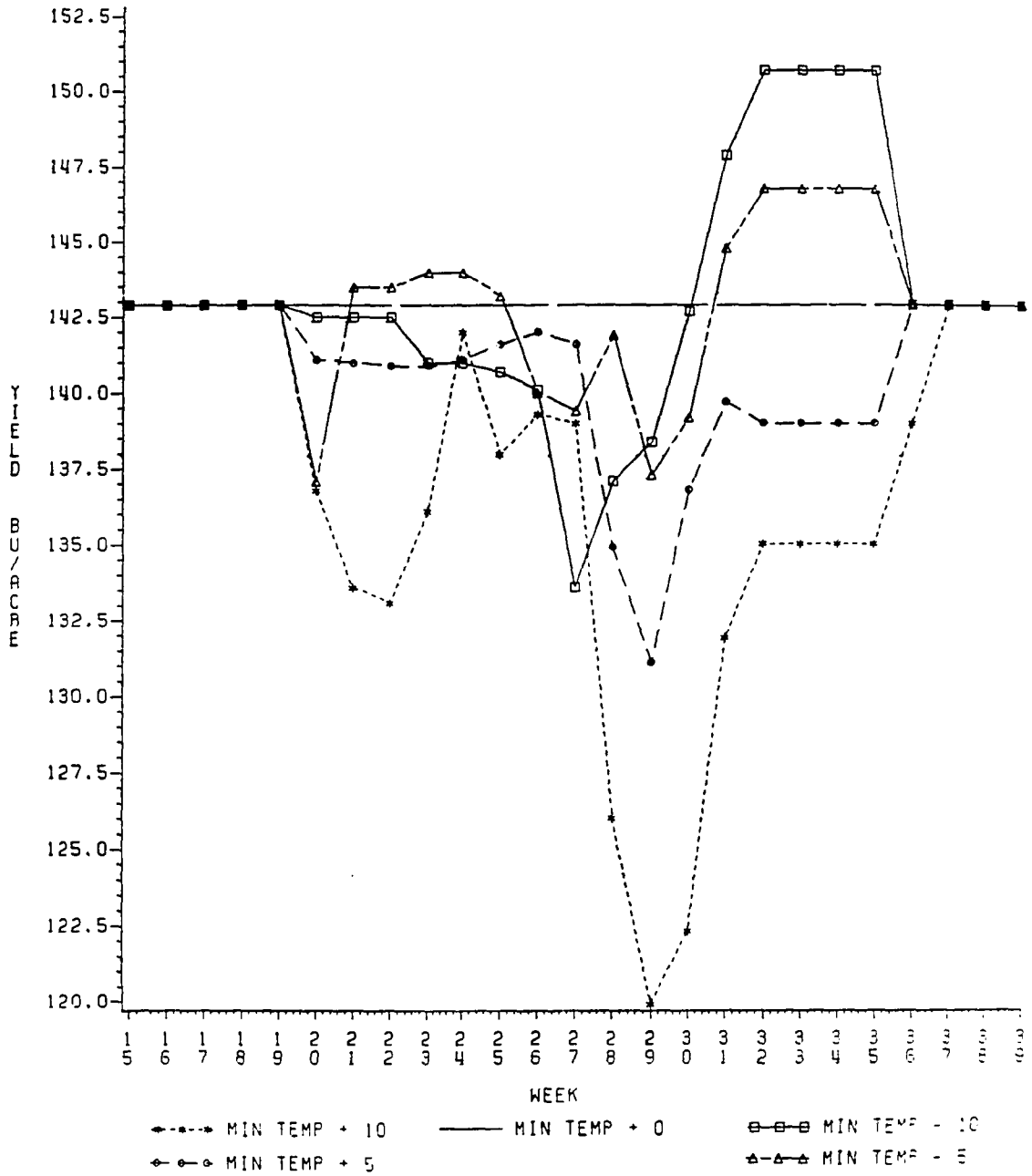
CERES Model Response to Weekly Maximum Temperature

at Des Moines, IO



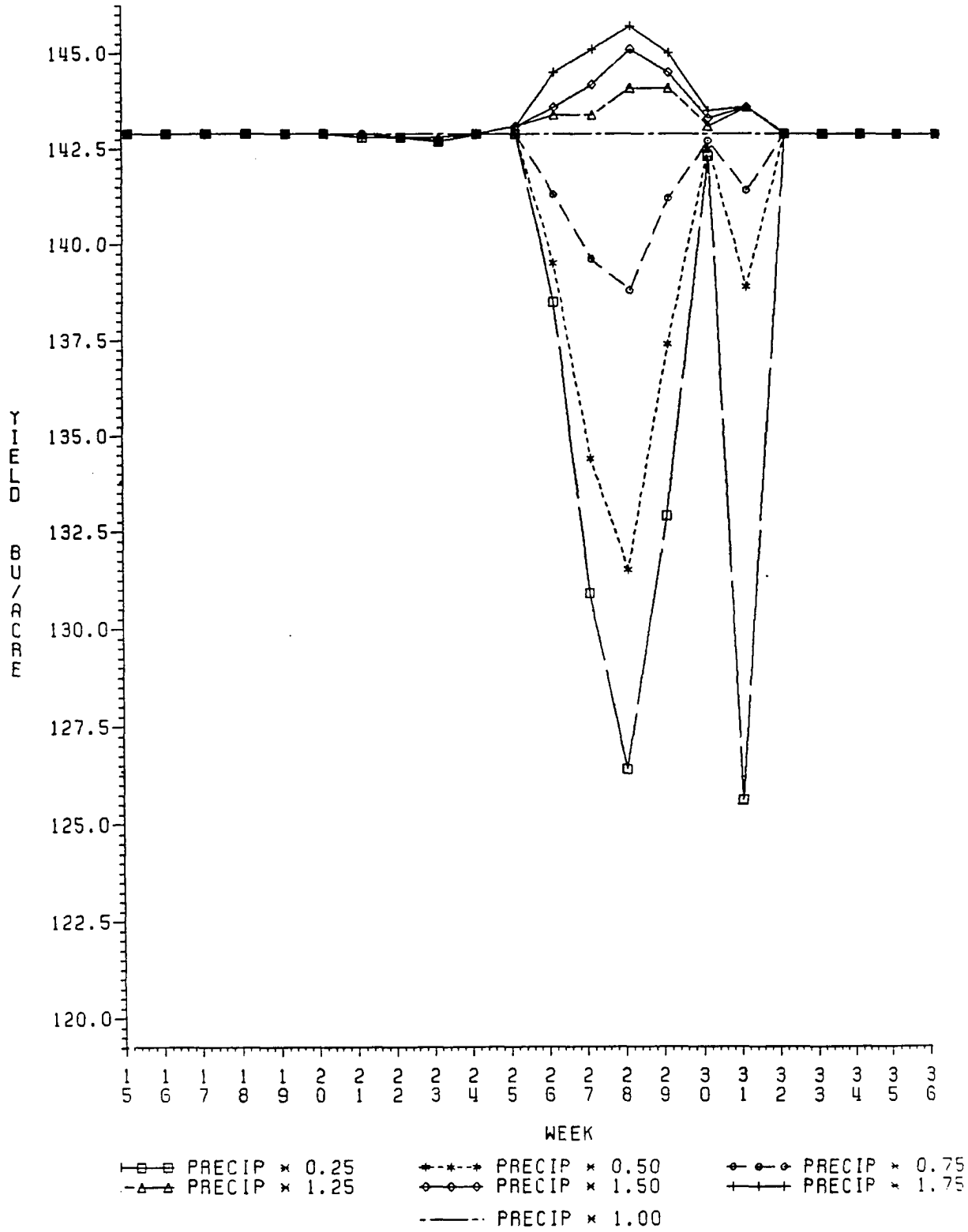
CERES Model Response to Weekly Minimum Temperature

at Des Moines, IO



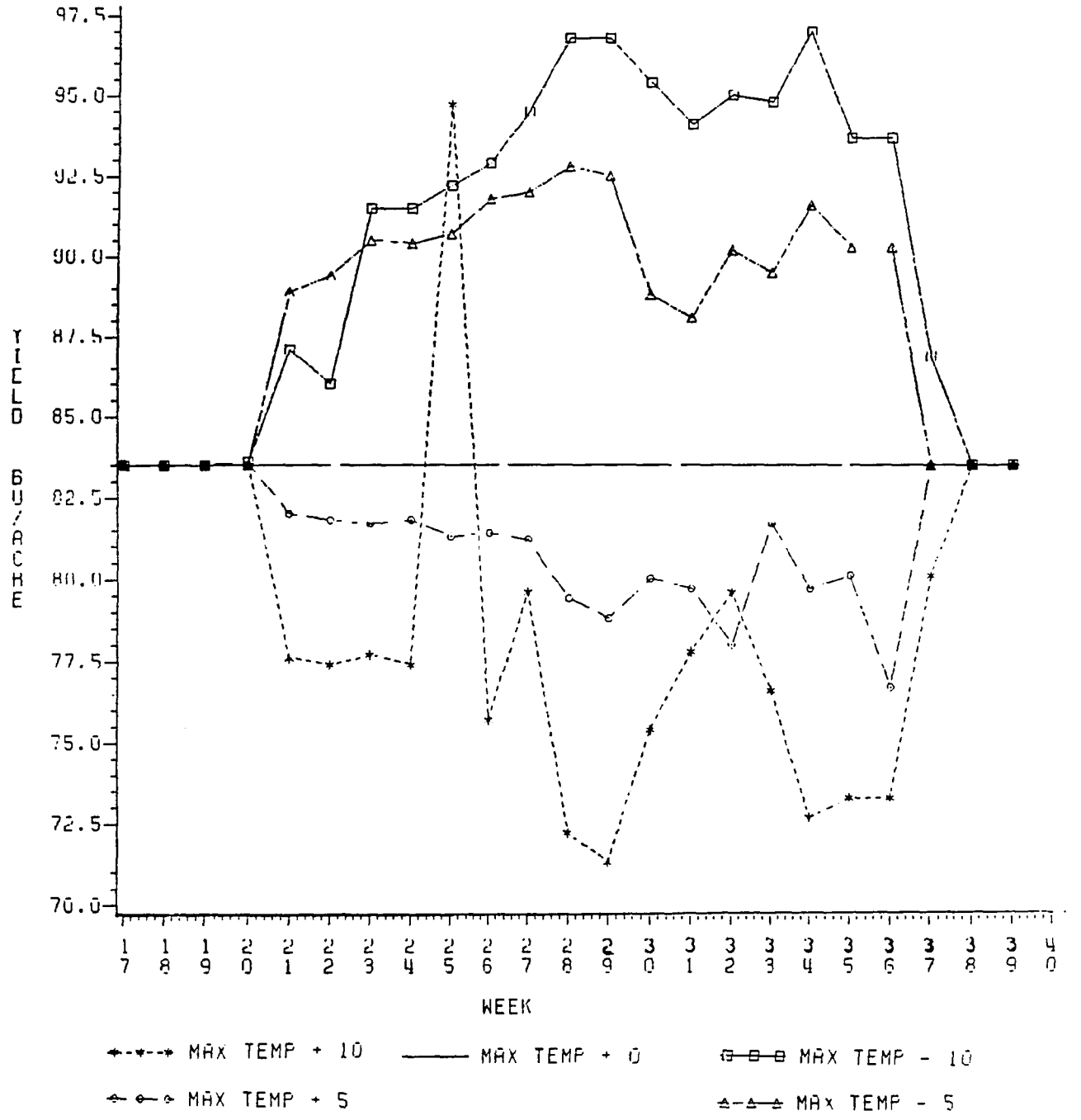
CERES Model Response to Weekly Precipitation

at Des Moines, IO



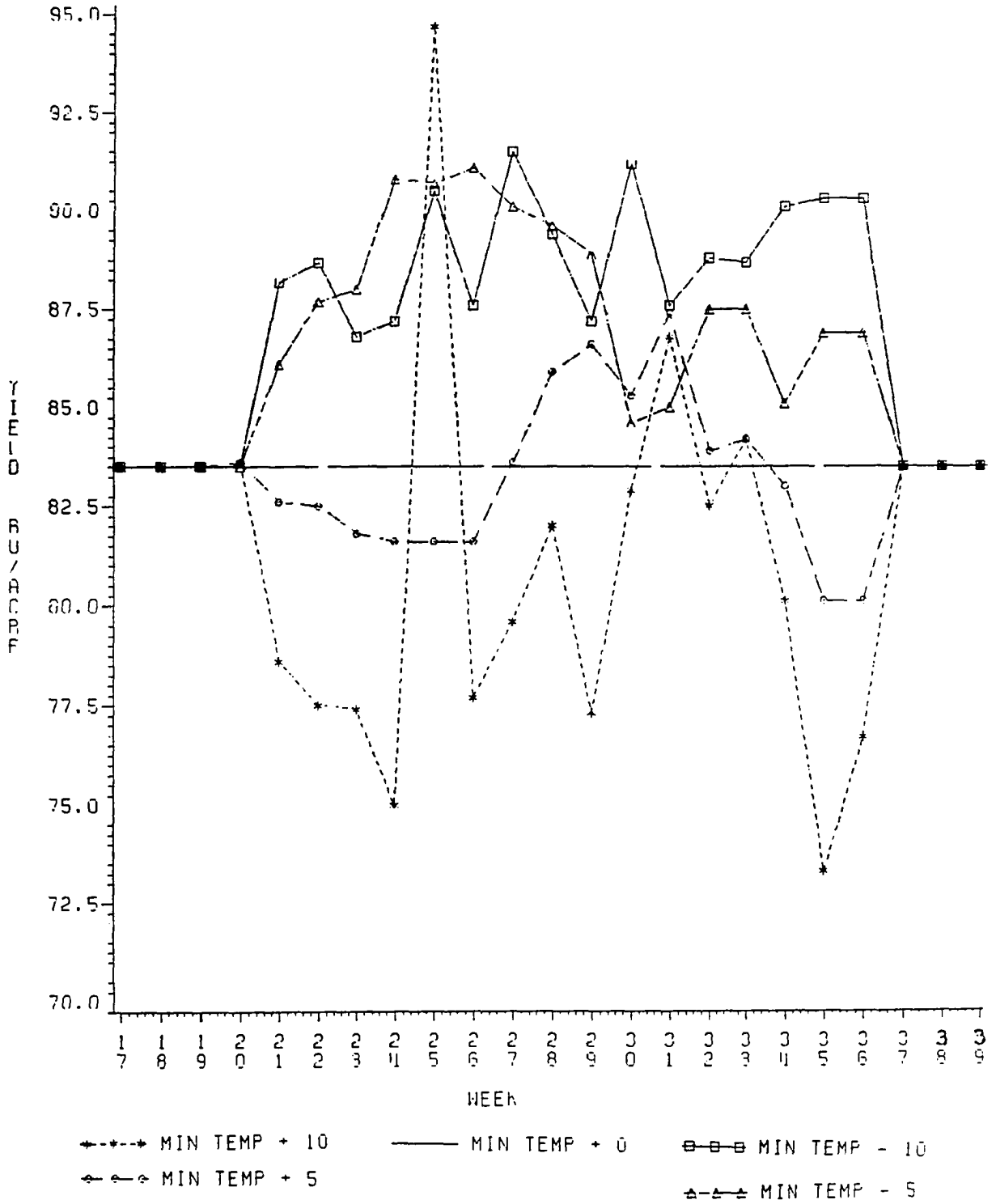
Ceres Model Response to Weekly Maximum Temperature

at Rapid City, SD



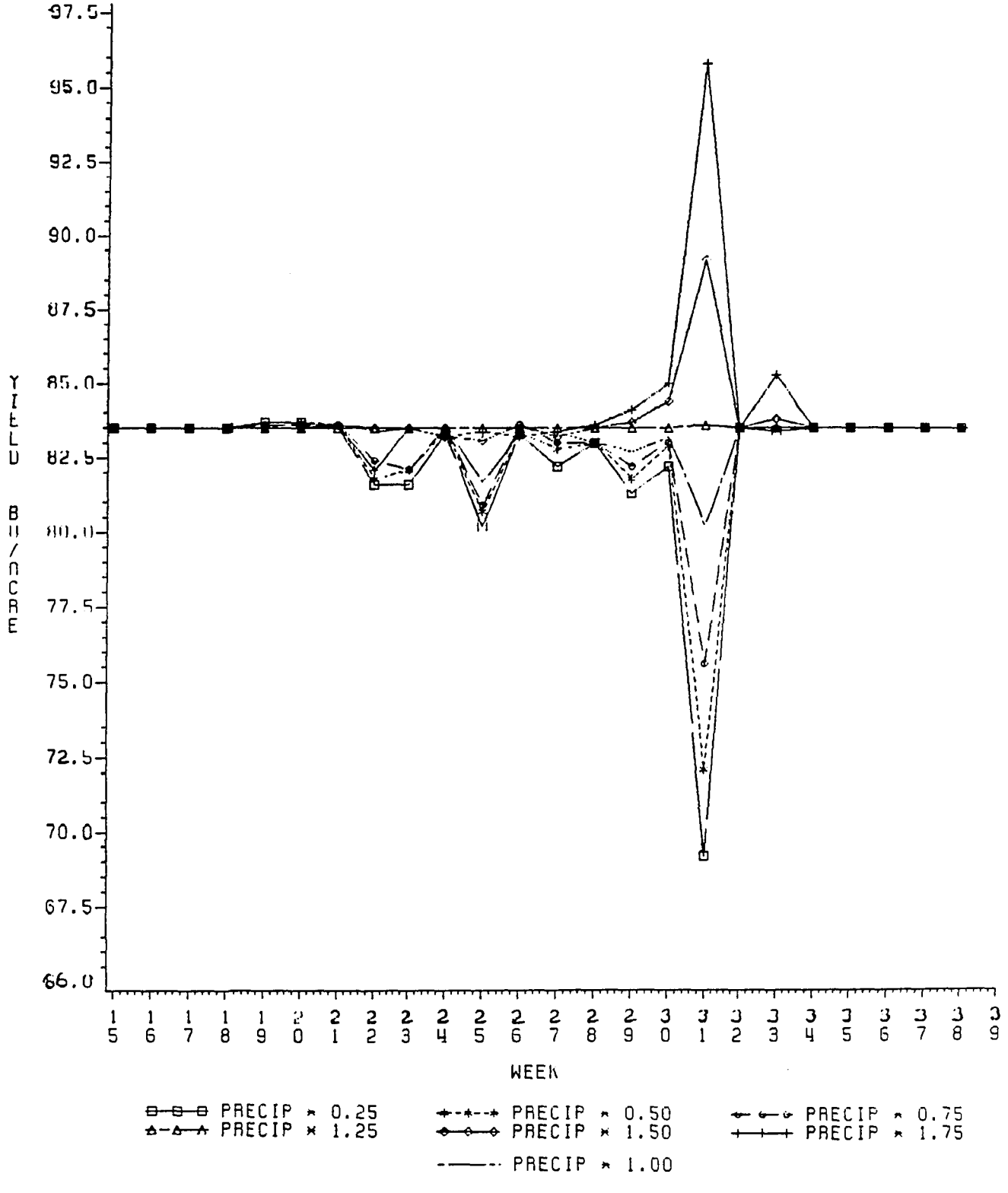
CERES Model Response to Weekly Minimum Temperature

at Rapid City, SD



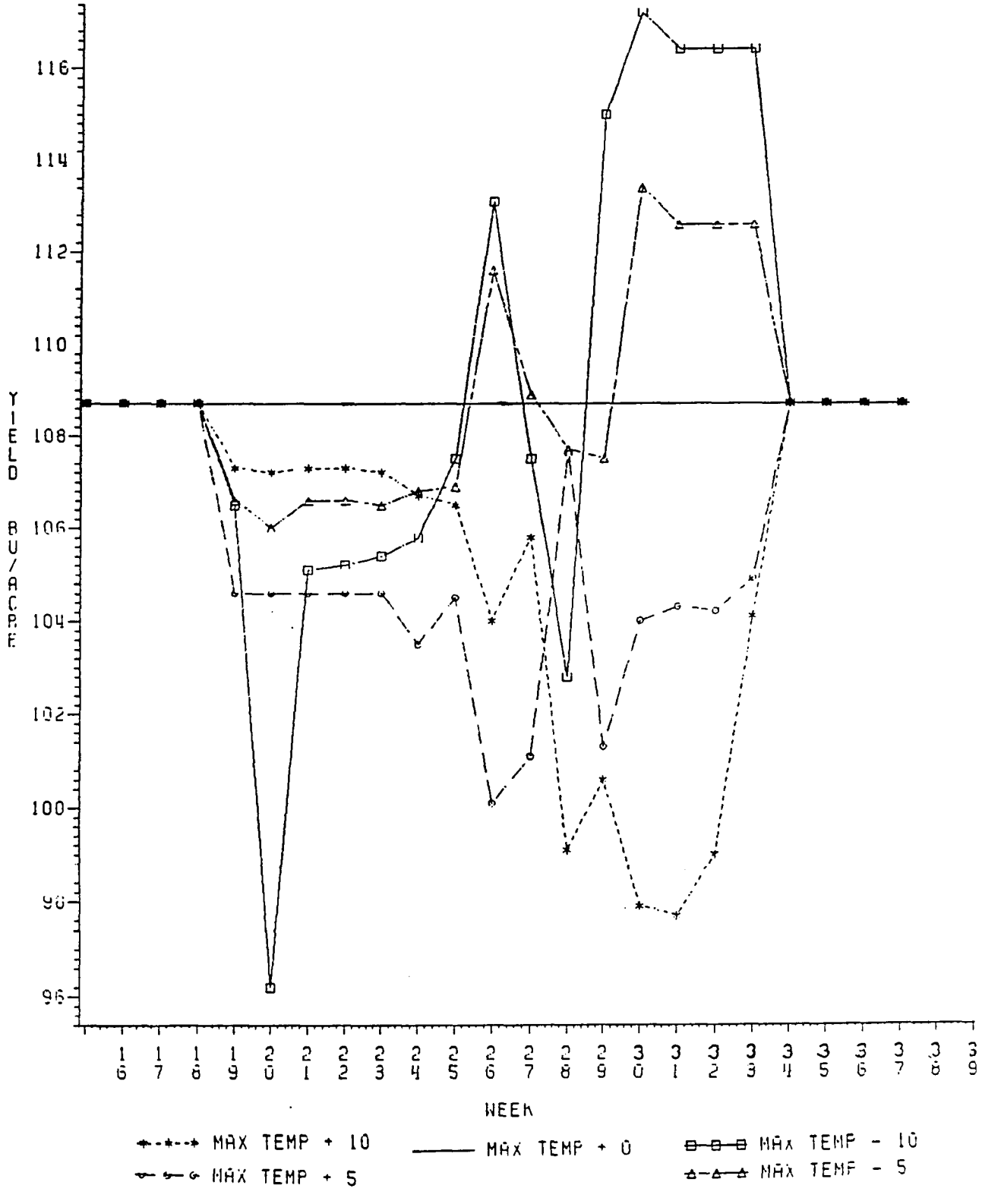
CERES Model Response to Weekly Precipitation

at Rapid City, SD



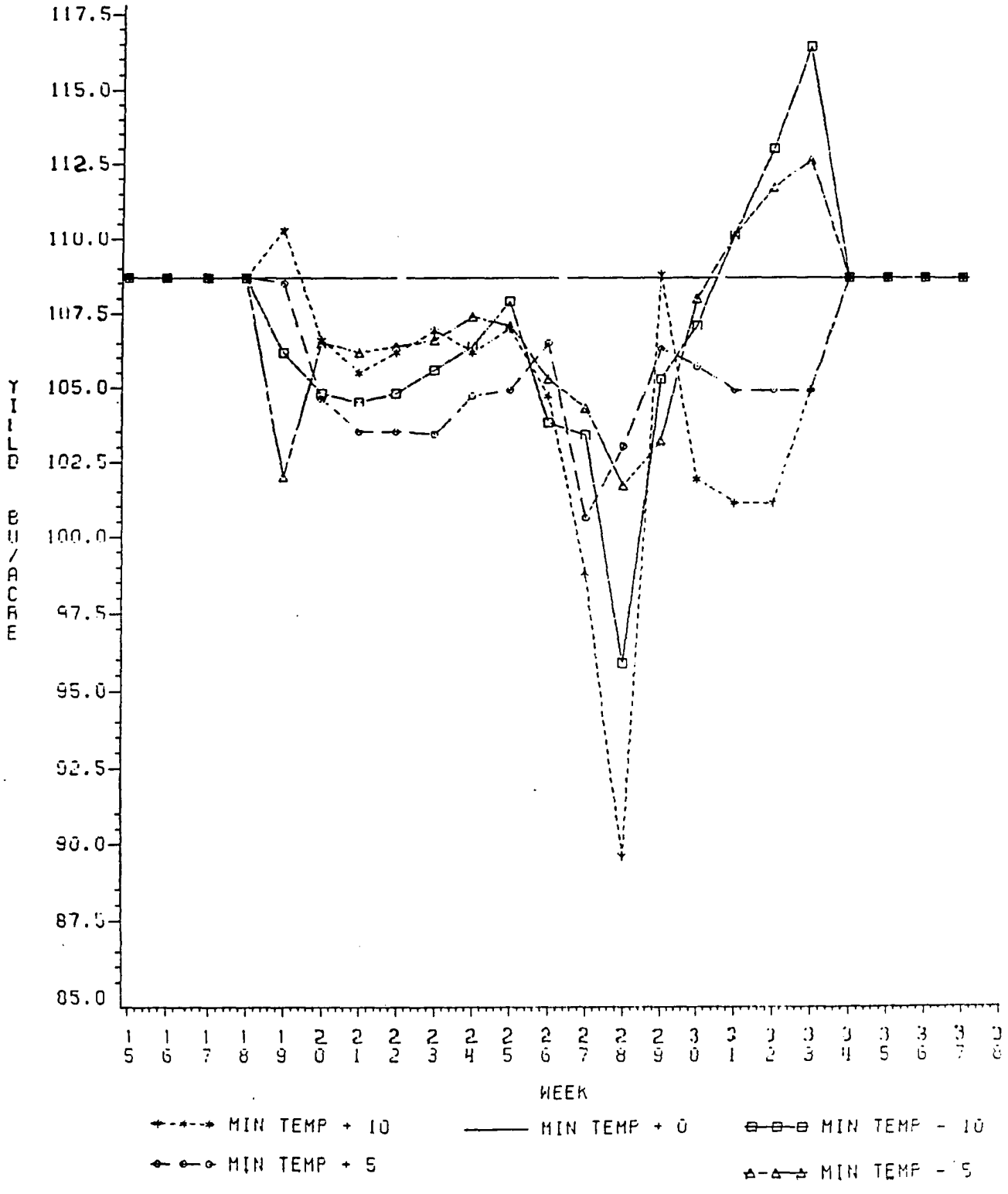
CERES Model Response to Weekly Maximum Temperature

at Columbus, OH



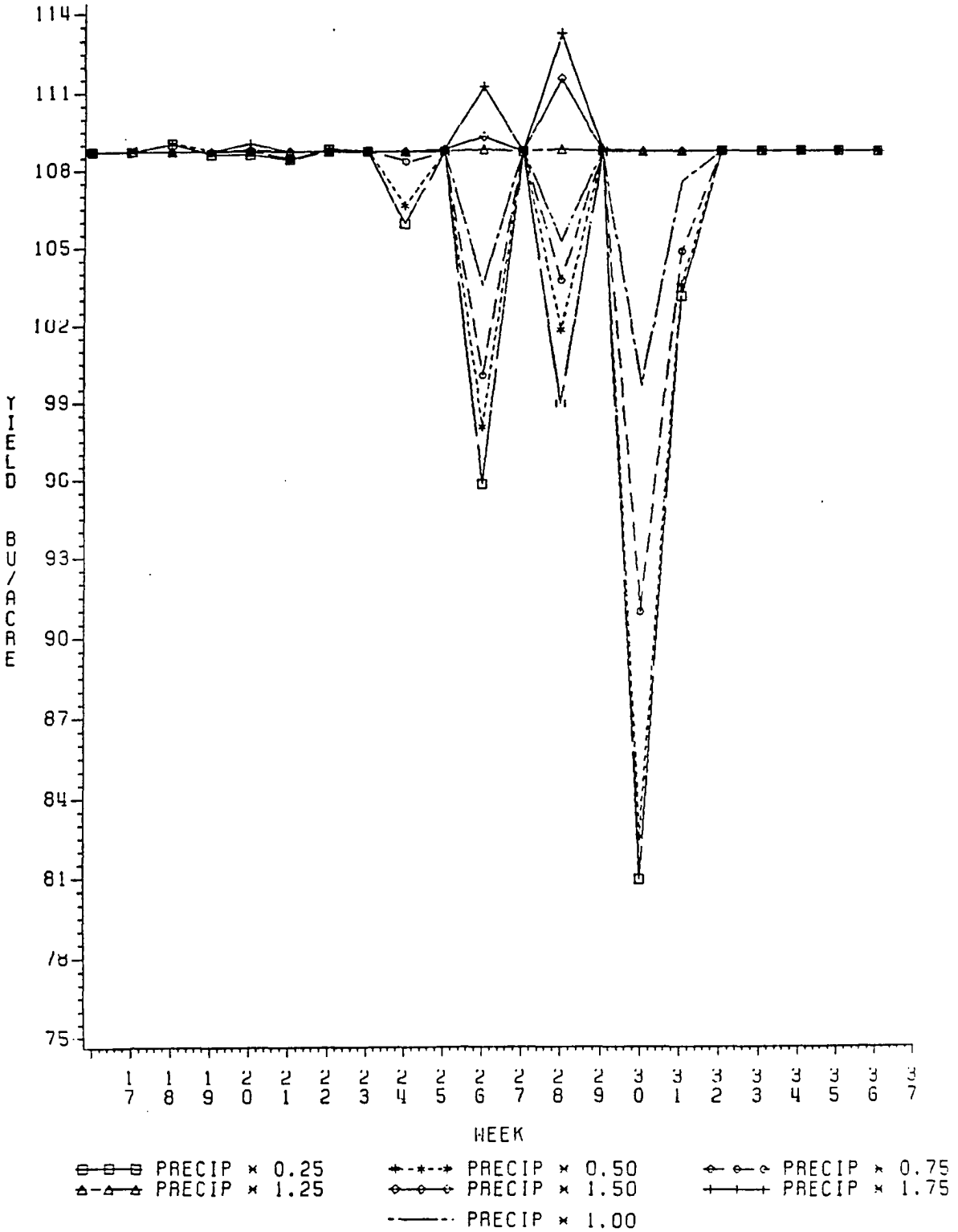
CERES Model Response to Weekly Minimum Temperature

at Columbus, OH



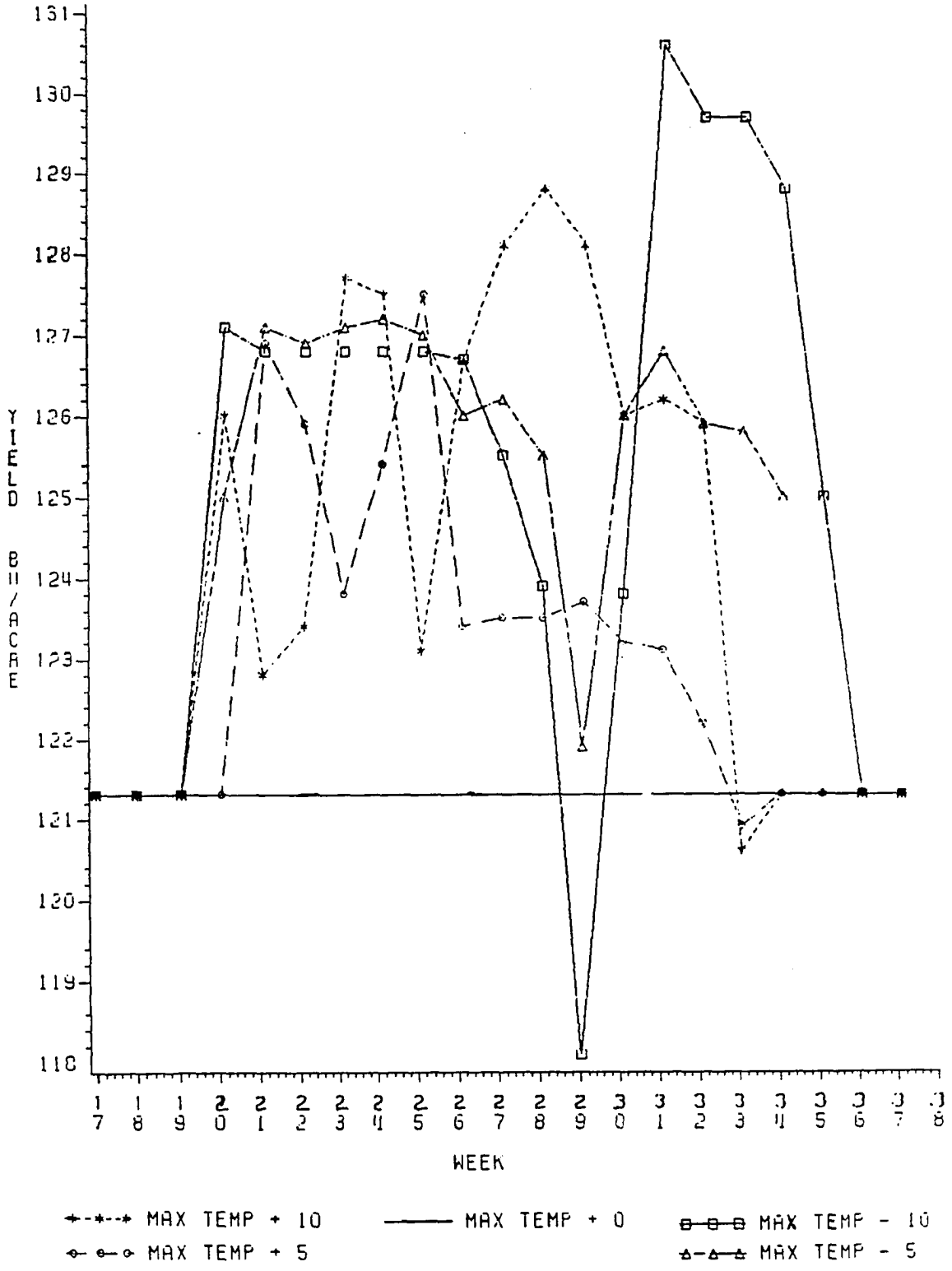
CERES Model Response to Weekly Precipitation

at Columbus, OH



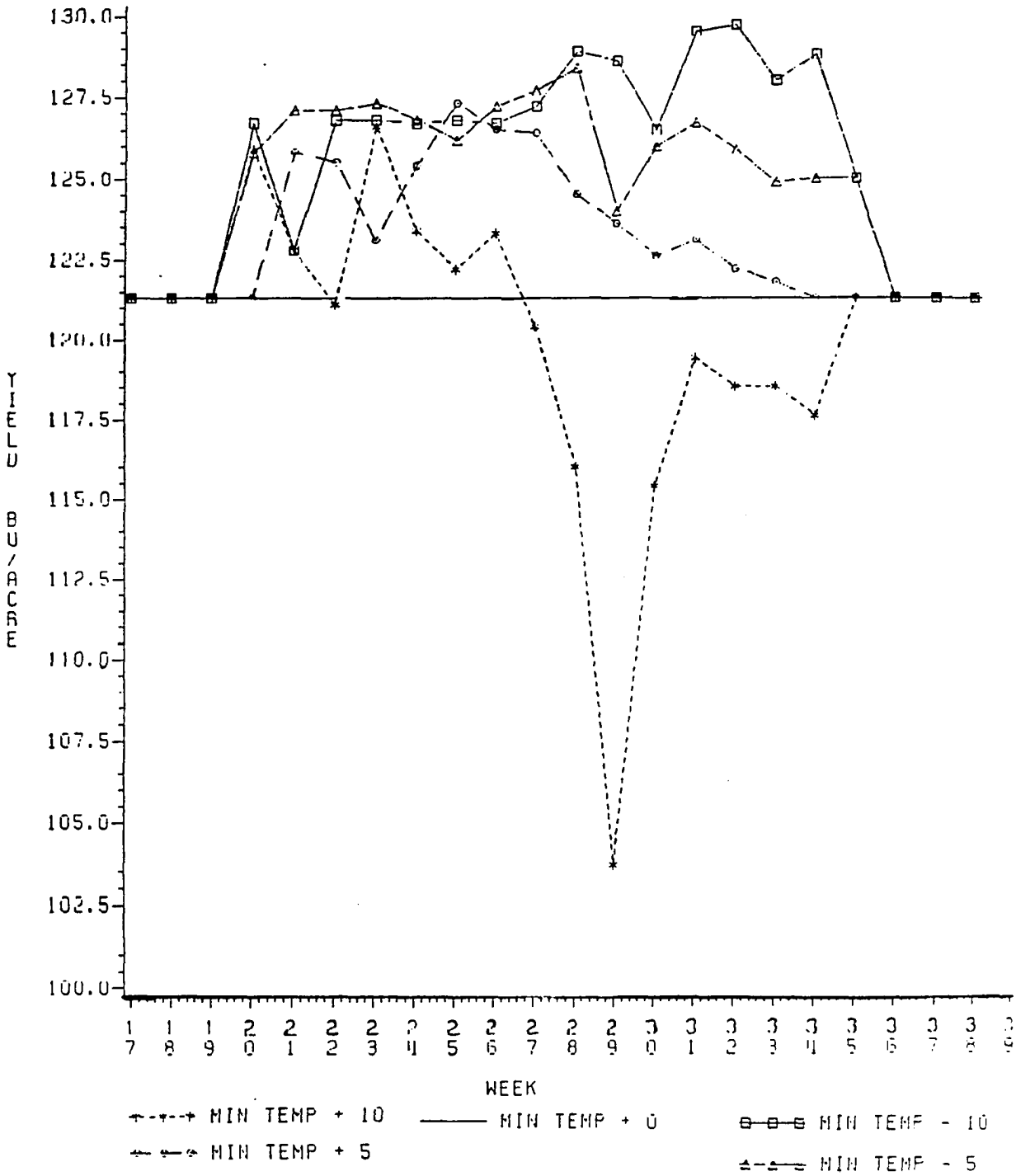
CERES Model Response to Weekly Maximum Temperature

at Dodge City, KS



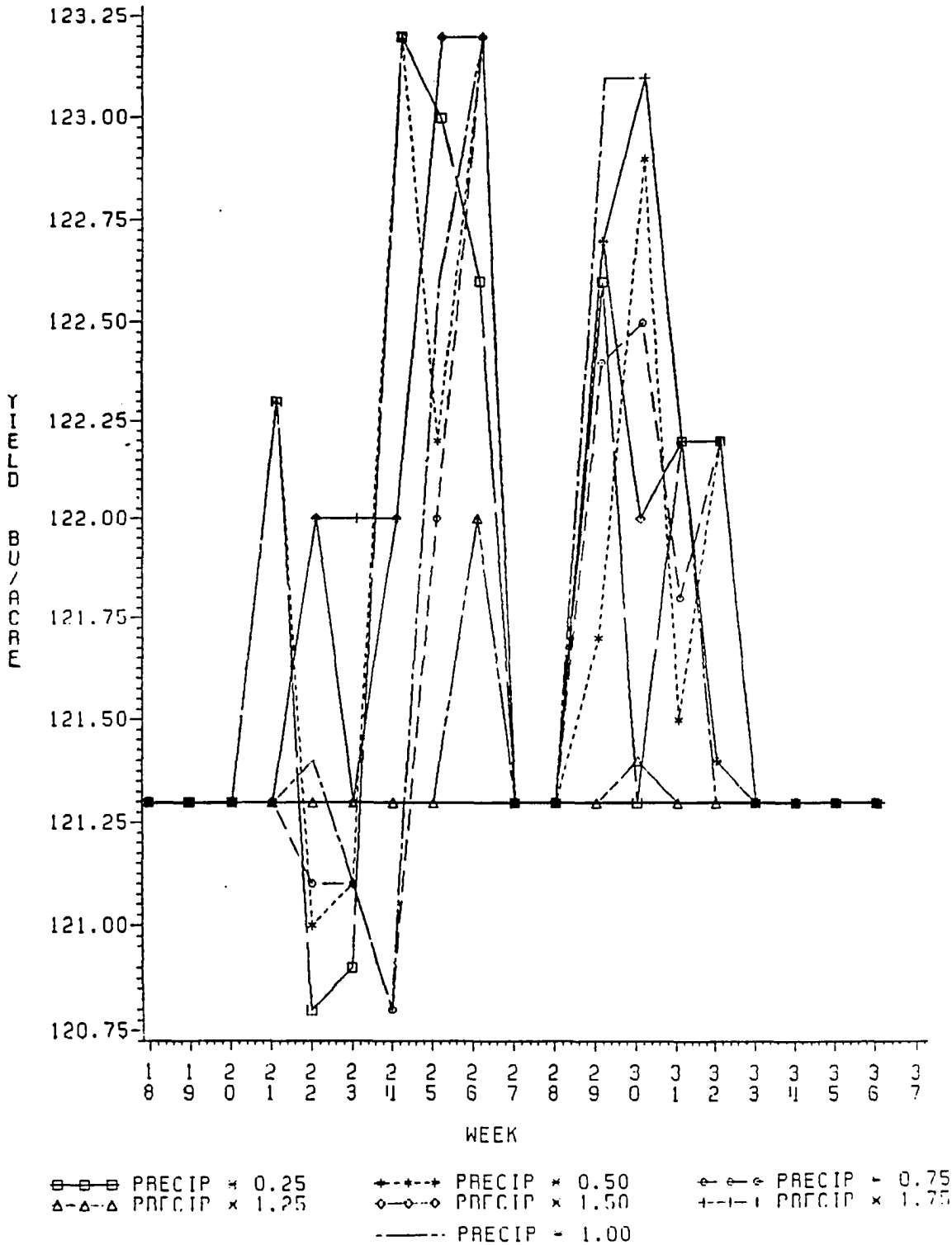
CERES Model Response to Weekly Minimum Temperature

at Dodge City, KS



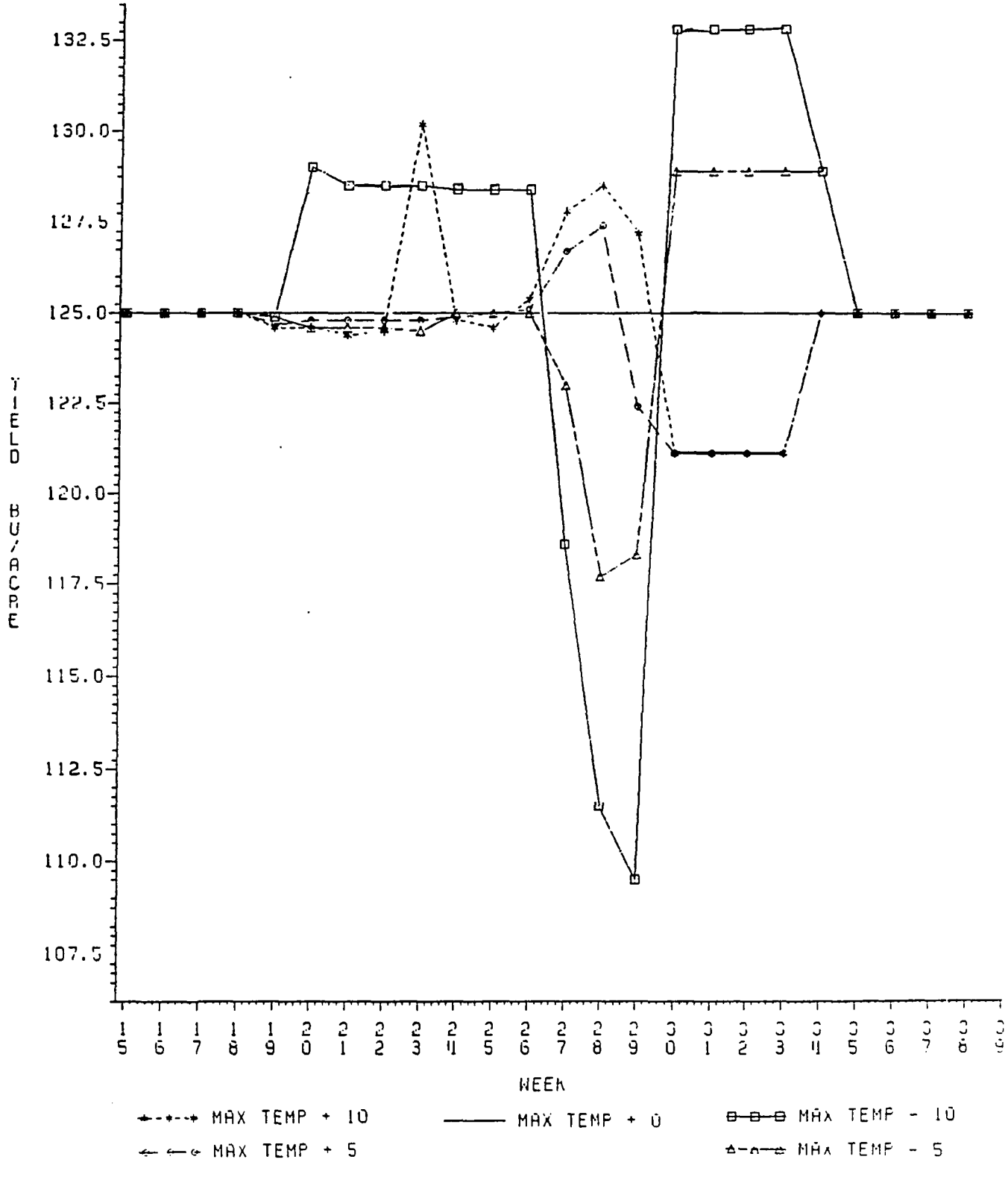
CERES Model Response to Weekly Precipitation

at Dodge City, KS



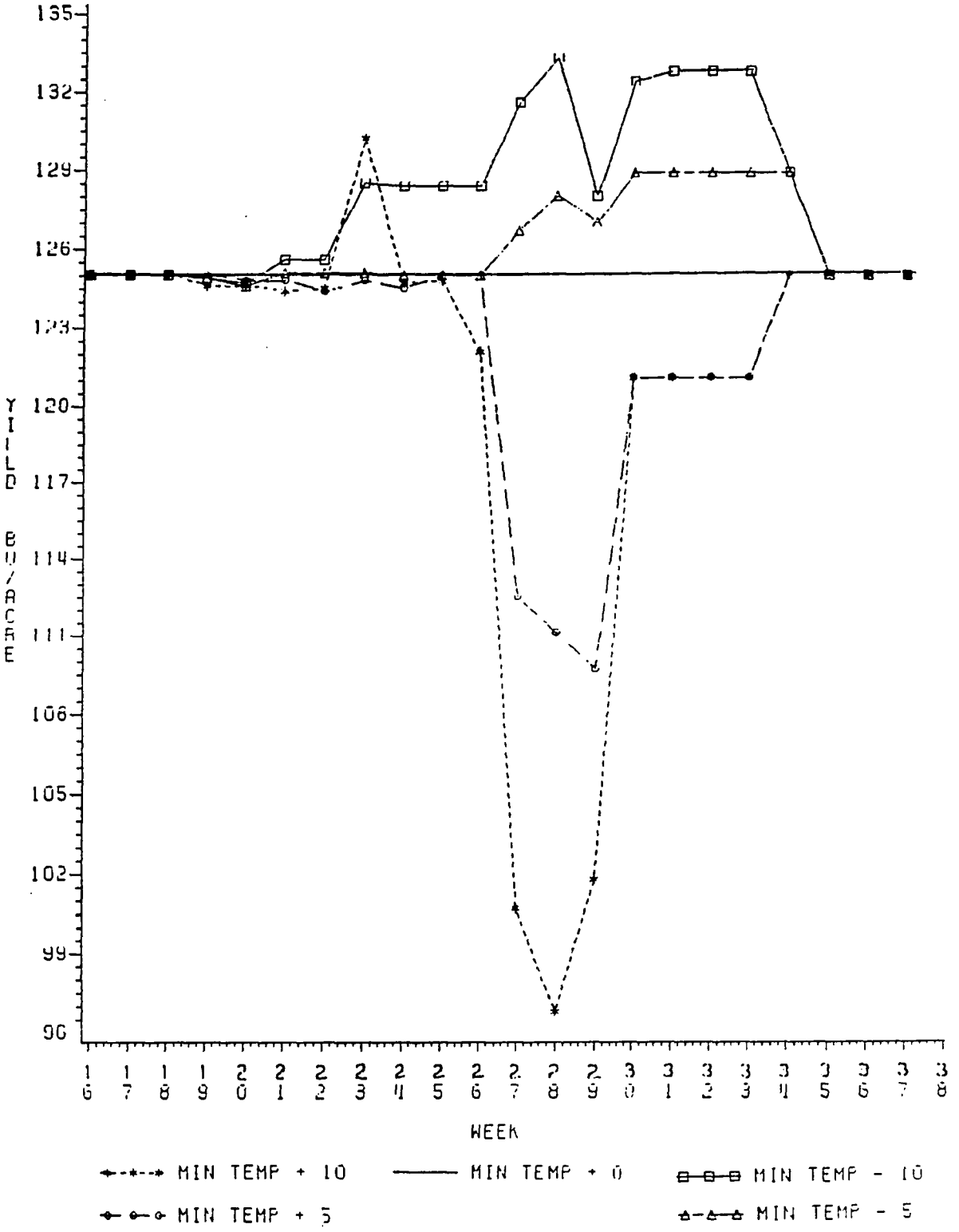
CERES Model Response to Weekly Maximum Temperature

at Omaha, NB



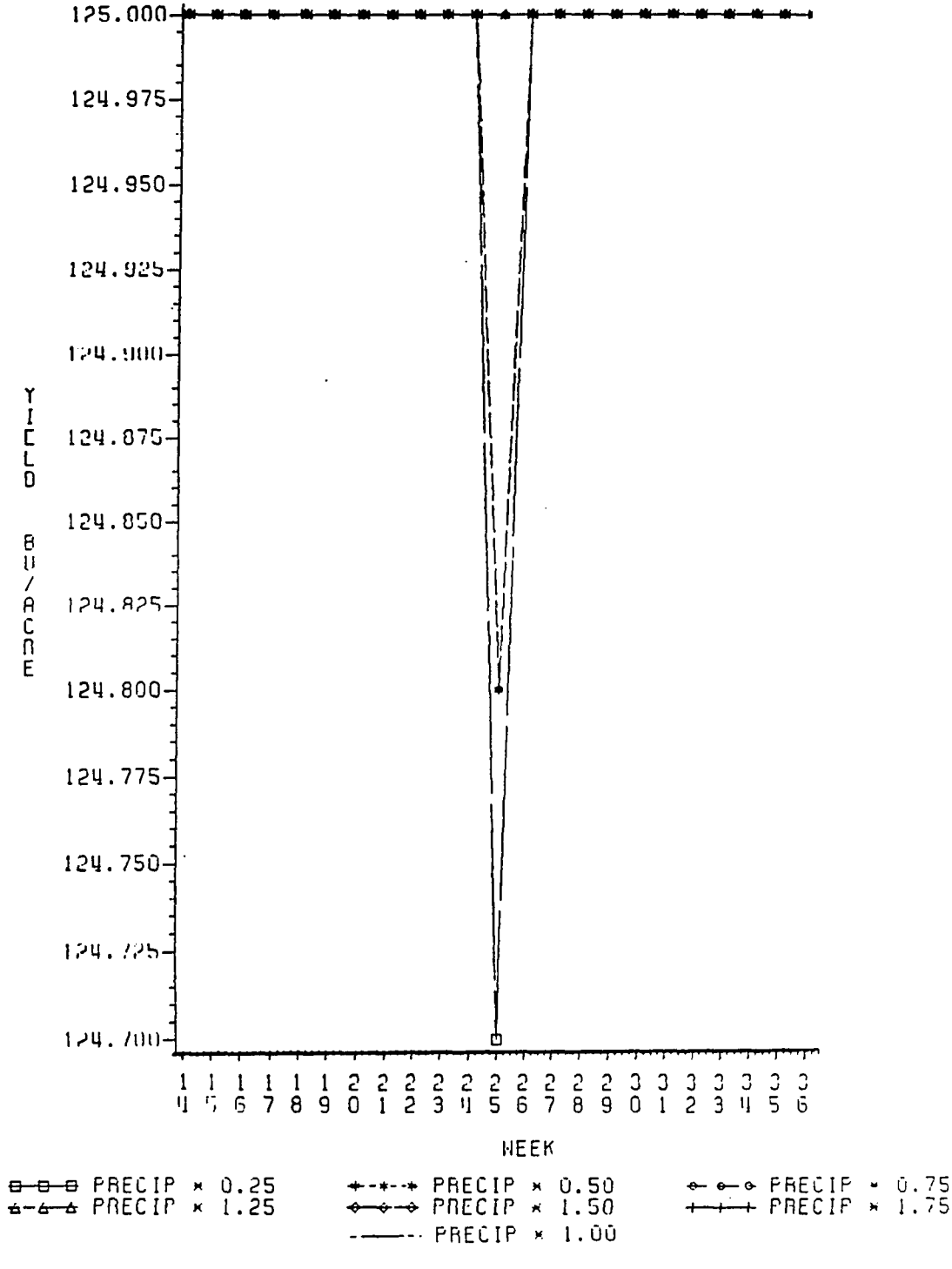
CERES Model Response to Weekly Minimum Temperature

at Omaha, NB



CERES Model Response to Weekly Precipitation

at Omaha, NB



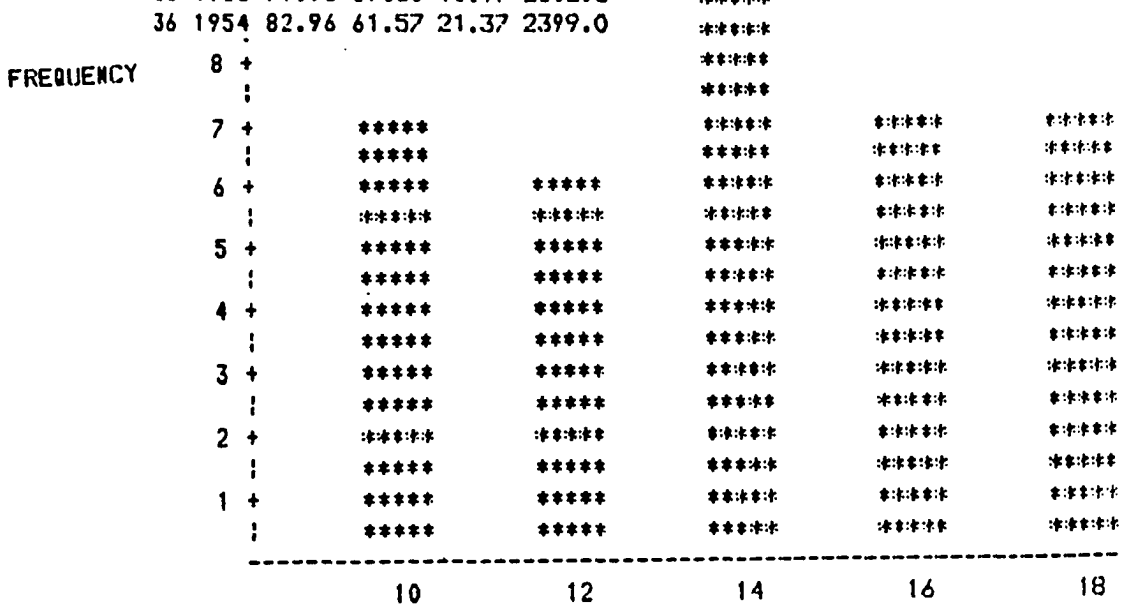
Appendix B

STATISTICAL RESULTS FOR MEAN SEASONAL MAXIMUM AND MINIMUM TEMPERATURES AND TOTAL PRECIPITATION AT SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT.

Statistical Results for Total Seasonal Precipitation
at Des Moines, IO

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1956	84.30	61.43	8.26	2524.0
2	1953	83.43	60.79	8.59	2413.5
3	1983	85.16	63.91	9.67	2202.0
4	1955	84.42	62.18	9.78	2334.5
5	1949	83.27	62.32	10.19	2553.0
6	1978	82.63	62.43	10.56	2524.5
7	1967	79.04	57.95	10.85	2071.5
8	1948	81.88	59.99	11.11	2308.0
9	1965	81.69	60.87	11.31	2384.5
10	1975	84.23	63.71	11.48	2610.0
11	1963	80.67	61.06	11.50	2309.5
12	1971	81.65	60.54	11.66	2326.5
13	1977	86.07	63.51	11.93	2430.0
14	1957	81.88	61.37	13.04	2275.5
15	1968	79.98	59.66	13.25	2225.0
16	1970	83.15	62.55	13.40	2448.0
17	1961	80.48	58.96	13.79	2210.0
18	1962	82.11	62.93	14.09	2522.0
19	1980	83.33	62.35	14.17	2297.5
20	1976	81.67	60.99	14.21	2352.5
21	1950	77.98	57.73	14.32	2000.0
22	1959	81.98	61.48	14.79	2443.0
23	1966	79.99	59.41	15.12	2054.0
24	1979	80.77	60.80	15.17	2293.0
25	1974	81.35	61.25	15.35	2158.5
26	1964	81.01	60.53	15.50	2287.5
27	1973	82.09	62.23	16.29	2482.0
28	1952	80.64	59.69	16.43	2236.0
29	1982	80.01	62.03	16.59	2317.0
30	1960	80.19	59.56	17.08	2158.5
31	1969	79.78	60.21	17.30	2242.5
32	1972	80.18	60.37	17.88	2272.5
33	1951	78.68	59.31	18.10	2129.5
34	1981	80.30	61.40	18.87	2261.5
35	1958	79.98	59.35	18.97	2202.5
36	1954	82.96	61.57	21.37	2399.0

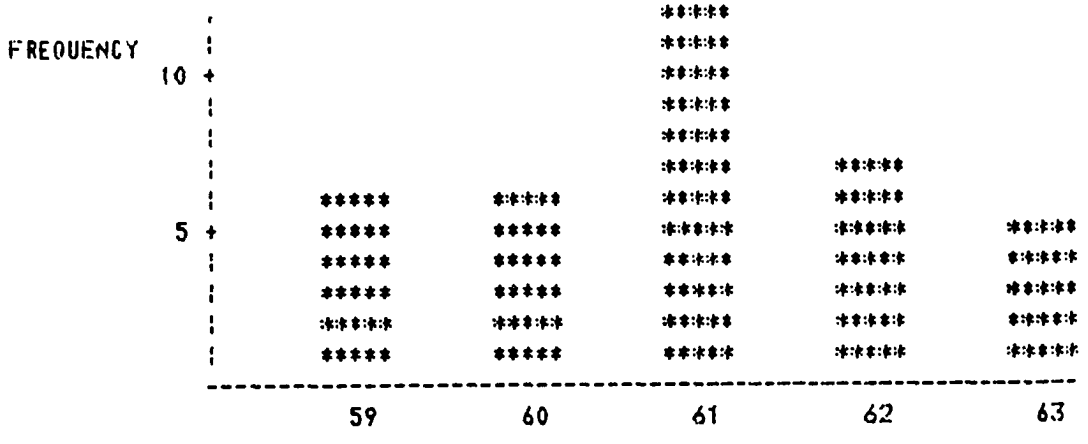
	MEAN	STANDARD DEVIATION
	13.94361111	3.18525187
	MINIMUM VALUE	MAXIMUM VALUE
	8.26000000	21.37000000
	STD ERROR OF MEAN	SUM
	0.53087531	501.97000000
	VARIANCE	C.V.
	10.14582944	22.844



Statistical Results for Mean Seasonal Minimum Temperature
at Des Moines, IO

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1950	77.98	57.73	14.32	2000.0
2	1967	79.04	57.95	10.85	2071.5
3	1961	80.48	58.96	13.79	2210.0
4	1951	78.68	59.31	18.10	2129.5
5	1958	79.98	59.35	18.97	2202.5
6	1966	79.99	59.41	15.12	2054.0
7	1960	80.19	59.56	17.08	2158.5
8	1968	79.98	59.66	13.25	2225.0
9	1952	80.64	59.69	16.43	2236.0
10	1948	81.88	59.99	11.11	2308.0
11	1969	79.78	60.21	17.30	2242.5
12	1972	80.18	60.37	17.88	2272.5
13	1964	81.01	60.53	15.50	2287.5
14	1971	81.65	60.54	11.66	2326.5
15	1953	83.43	60.79	8.59	2413.5
16	1979	80.77	60.80	15.17	2293.0
17	1965	81.69	60.87	11.31	2384.5
18	1976	81.67	60.99	14.21	2352.5
19	1963	80.67	61.06	11.50	2309.5
20	1974	81.35	61.25	15.35	2158.5
21	1957	81.88	61.37	13.04	2275.5
22	1981	80.30	61.40	18.87	2261.5
23	1956	84.30	61.43	8.26	2524.0
24	1959	81.98	61.48	14.79	2443.0
25	1954	82.96	61.57	21.37	2399.0
26	1982	80.01	62.03	16.59	2317.0
27	1955	84.42	62.18	9.78	2334.5
28	1973	82.09	62.23	16.29	2482.0
29	1949	83.27	62.32	10.19	2553.0
30	1980	83.33	62.35	14.17	2297.5
31	1978	82.63	62.43	10.56	2524.5
32	1970	83.15	62.55	13.40	2448.0
33	1962	82.11	62.93	14.09	2522.0
34	1977	86.07	63.51	11.93	2430.0
35	1975	84.23	63.71	11.48	2610.0
36	1983	85.16	63.91	9.67	2202.0

	MEAN	STANDARD DEVIATION
	61.01166667	1.50558674
	MINIMUM VALUE	MAXIMUM VALUE
	57.73000000	63.91000000
	STD ERROR OF MEAN	SUM
	0.25093112	2196.4200000
	VARIANCE	C.V.
	2.26679143	2.468



Statistical Results for Mean Seasonal Maximum Temperature
at Des Moines, IO

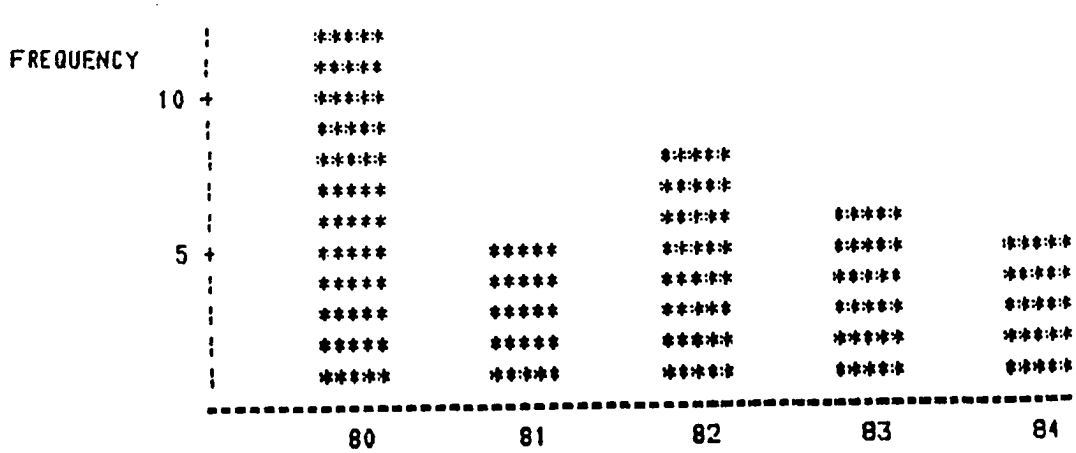
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1950	77.98	57.73	14.32	2000.0
2	1951	78.68	59.31	18.10	2129.5
3	1967	79.04	57.95	10.85	2071.5
4	1969	79.78	60.21	17.30	2242.5
5	1958	79.98	59.35	18.97	2202.5
6	1968	79.98	59.66	13.25	2225.0
7	1966	79.99	59.41	15.12	2054.0
8	1982	80.01	62.03	16.59	2317.0
9	1972	80.18	60.37	17.88	2272.5
10	1960	80.19	59.56	17.08	2158.5
11	1981	80.30	61.40	18.87	2261.5
12	1961	80.48	58.96	13.79	2210.0
13	1952	80.64	59.69	16.43	2236.0
14	1963	80.67	61.06	11.50	2309.5
15	1979	80.77	60.80	15.17	2293.0
16	1964	81.01	60.53	15.50	2287.5
17	1974	81.35	61.25	15.35	2158.5
18	1971	81.65	60.54	11.66	2326.5
19	1976	81.67	60.99	14.21	2352.5
20	1965	81.69	60.87	11.31	2384.5
21	1948	81.88	59.99	11.11	2308.0
22	1957	81.88	61.37	13.04	2275.5
23	1959	81.98	61.48	14.79	2443.0
24	1973	82.09	62.23	16.29	2482.0
25	1962	82.11	62.93	14.09	2522.0
26	1978	82.63	62.43	10.56	2524.5
27	1954	82.96	61.57	21.37	2399.0
28	1970	83.15	62.55	13.40	2448.0
29	1949	83.27	62.32	10.19	2553.0
30	1980	83.33	62.35	14.17	2297.5
31	1953	83.43	60.79	8.59	2413.5
32	1975	84.23	63.71	11.48	2610.0
33	1956	84.30	61.43	8.26	2524.0
34	1955	84.42	62.18	9.78	2334.5
35	1983	85.16	63.91	9.67	2202.0
36	1977	86.07	63.51	11.93	2430.0

MEAN	STANDARD DEVIATION
81.63694444	1.86490876

MINIMUM VALUE	MAXIMUM VALUE
77.98000000	86.07000000

STD ERROR OF MEAN	SUM
0.31081813	2938.9300000

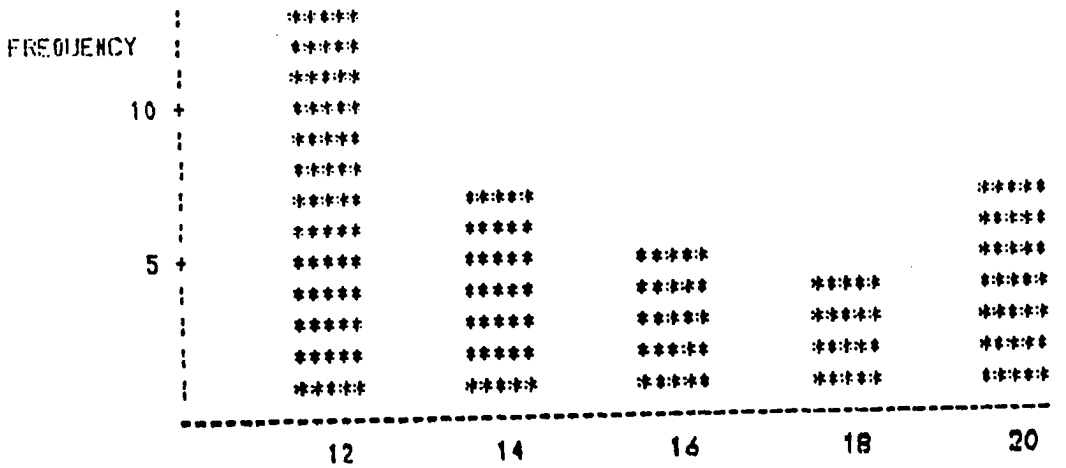
VARIANCE	C.V.
3.47788468	2.284



Statistical Results for Total Seasonal Precipitation
at Springfield, MO

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1953	89.37	66.38	5.54	2974.5
2	1980	90.16	66.35	7.03	2561.0
3	1972	88.06	61.24	7.63	2724.5
4	1962	87.32	63.49	8.46	2808.5
5	1961	84.19	60.54	9.60	2504.5
6	1954	91.04	66.28	10.64	2542.0
7	1969	86.38	63.16	10.67	2700.5
8	1960	85.10	62.71	10.74	2640.0
9	1983	87.18	64.26	11.07	2657.5
10	1952	87.63	65.38	11.71	2857.5
11	1955	83.94	63.25	11.93	2642.5
12	1967	83.68	59.31	11.97	2407.5
13	1971	87.83	61.54	12.09	2765.0
14	1959	84.09	64.04	13.13	2695.0
15	1977	87.97	66.90	13.22	2998.5
16	1970	86.27	61.99	13.79	2702.5
17	1978	86.99	64.26	14.00	2831.0
18	1966	85.94	61.36	14.17	2502.0
19	1956	86.12	64.52	14.59	2684.0
20	1968	83.79	62.21	14.86	2575.5
21	1976	83.38	60.30	15.03	2446.0
22	1965	85.27	62.29	15.55	2663.0
23	1950	80.24	61.45	15.65	2334.5
24	1963	86.29	65.70	15.69	2874.5
25	1973	85.66	61.46	16.04	2638.5
26	1975	87.14	62.78	17.36	2795.5
27	1964	85.29	63.34	17.57	2648.0
28	1948	83.03	63.06	18.57	2581.0
29	1981	85.10	64.58	18.79	2782.0
30	1949	84.11	64.53	19.09	2723.5
31	1974	84.99	61.34	19.17	2594.5
32	1982	85.96	64.75	19.67	2730.5
33	1951	83.38	64.00	20.71	2653.5
34	1957	85.12	64.63	20.77	2786.0
35	1979	82.91	61.42	23.46	2482.5
36	1958	83.96	63.30	30.03	2647.0

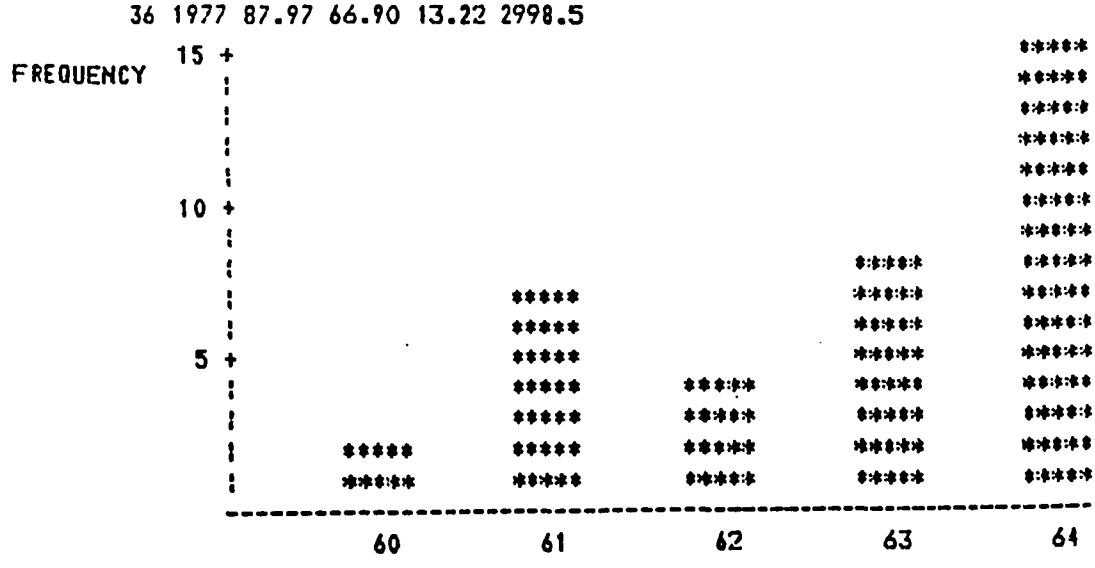
MEAN	STANDARD DEVIATION
14.72194444	4.94713529
MINIMUM VALUE	**MAXIMUM VALUE**
5.54000000	30.03000000
STD ERROR OF MEAN	**SUM**
0.82452255	529.99000000
VARIANCE	**C.V.**
24.47414754	33.604



Statistical Results for Mean Seasonal Minimum Temperature
at Springfield, MO

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1967	83.68	59.31	11.97	2407.5
2	1976	83.38	60.30	15.03	2446.0
3	1961	84.19	60.54	9.60	2504.5
4	1972	88.06	61.24	7.63	2724.5
5	1974	84.99	61.34	19.17	2594.5
6	1966	85.94	61.36	14.17	2502.0
7	1979	82.91	61.42	23.46	2482.5
8	1950	80.24	61.45	15.65	2334.5
9	1973	85.66	61.46	16.04	2638.5
10	1971	87.83	61.54	12.09	2765.0
11	1970	86.27	61.99	13.79	2702.5
12	1968	83.79	62.21	14.86	2575.5
13	1965	85.27	62.29	15.55	2663.0
14	1960	85.10	62.71	10.74	2640.0
15	1975	87.14	62.78	17.36	2795.5
16	1948	83.03	63.06	18.57	2581.0
17	1969	86.38	63.16	10.67	2700.5
18	1955	83.94	63.25	11.93	2642.5
19	1958	83.96	63.30	30.03	2647.0
20	1964	85.29	63.34	17.57	2648.0
21	1962	87.32	63.49	8.46	2808.5
22	1951	83.38	64.00	20.71	2653.5
23	1959	84.09	64.04	13.13	2695.0
24	1978	86.99	64.26	14.00	2831.0
25	1983	87.18	64.26	11.07	2657.5
26	1956	86.12	64.52	14.59	2684.0
27	1949	84.11	64.53	19.09	2723.5
28	1981	85.10	64.58	18.79	2782.0
29	1957	85.12	64.63	20.77	2786.0
30	1982	85.96	64.75	19.67	2730.5
31	1952	87.63	65.38	11.71	2857.5
32	1963	86.29	65.70	15.69	2874.5
33	1954	91.04	66.28	10.64	2542.0
34	1980	90.16	66.35	7.03	2561.0
35	1953	89.37	66.38	5.54	2974.5
36	1977	87.97	66.90	13.22	2998.5

MEAN	STANDARD DEVIATION
63.28055556	1.88665077
MINIMUM VALUE	**MAXIMUM VALUE**
59.31000000	66.90000000
STD ERROR OF MEAN	**SUM**
0.31444179	2278.1000000
VARIANCE	**C.V.**
3.55945111	2.981



Statistical Results for Mean Seasonal Maximum Temperature
at Springfield, MO

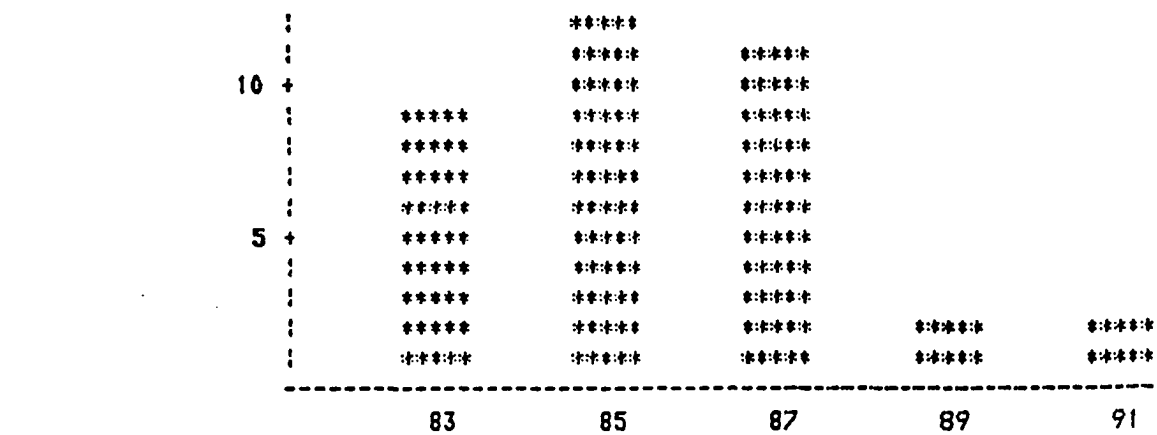
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1950	80.24	61.45	15.65	2334.5
2	1979	82.91	61.42	23.46	2482.5
3	1948	83.03	63.06	18.57	2581.0
4	1951	83.38	64.00	20.71	2653.5
5	1976	83.38	60.30	15.03	2446.0
6	1967	83.68	59.31	11.97	2407.5
7	1968	83.79	62.21	14.86	2575.5
8	1955	83.94	63.25	11.93	2642.5
9	1958	83.96	63.30	30.03	2647.0
10	1959	84.09	64.04	13.13	2695.0
11	1949	84.11	64.53	19.09	2723.5
12	1961	84.19	60.54	9.60	2504.5
13	1974	84.99	61.34	19.17	2594.5
14	1960	85.10	62.71	10.74	2640.0
15	1981	85.10	64.58	18.79	2782.0
16	1957	85.12	64.63	20.77	2786.0
17	1965	85.27	62.29	15.55	2663.0
18	1964	85.29	63.34	17.57	2648.0
19	1973	85.66	61.46	16.04	2638.5
20	1966	85.94	61.36	14.17	2502.0
21	1982	85.96	64.75	19.67	2730.5
22	1956	86.12	64.52	14.59	2684.0
23	1970	86.27	61.99	13.79	2702.5
24	1963	86.29	65.70	15.69	2874.5
25	1969	86.38	63.16	10.67	2700.5
26	1978	86.99	64.26	14.00	2831.0
27	1975	87.14	62.78	17.36	2795.5
28	1983	87.18	64.26	11.07	2657.5
29	1962	87.32	63.49	8.46	2808.5
30	1952	87.63	65.38	11.71	2857.5
31	1971	87.83	61.54	12.09	2765.0
32	1977	87.97	66.90	13.22	2998.5
33	1972	88.06	61.24	7.63	2724.5
34	1953	89.37	66.38	5.54	2974.5
35	1980	90.16	66.35	7.03	2561.0
36	1954	91.04	66.28	10.64	2542.0

MEAN	STANDARD DEVIATION
85.69111111	2.20068532

MINIMUM VALUE	MAXIMUM VALUE
80.24000000	91.04000000

STD ERROR OF MEAN	SUM
0.36678089	3084.8800000

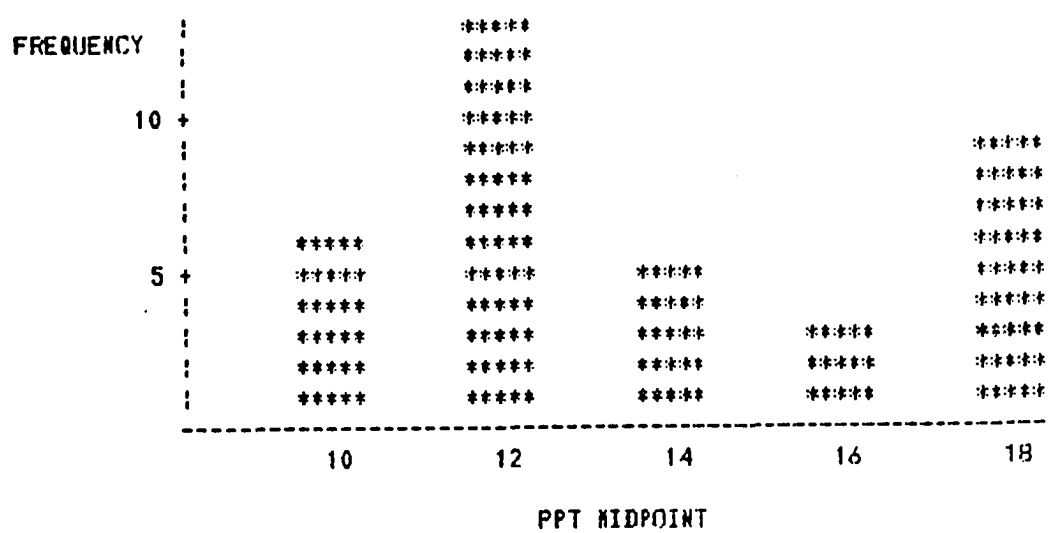
VARIANCE	C.V.
4.84301587	2.568



Statistical Results for Total Seasonal Precipitation
at Columbus, OH

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1963	81.43	56.74	8.08	2013.0
2	1951	82.07	58.52	8.14	2131.0
3	1959	83.36	60.52	9.10	2316.0
4	1962	82.00	59.53	9.92	2180.5
5	1977	82.36	59.52	10.68	2210.5
6	1967	78.21	57.03	10.71	1857.5
7	1952	83.19	60.14	11.03	2277.5
8	1975	83.68	62.27	11.28	2412.0
9	1978	79.99	60.16	11.50	2111.5
10	1983	80.67	58.42	11.53	2064.5
11	1971	79.99	57.01	11.63	1944.0
12	1974	80.13	58.97	11.71	2060.0
13	1954	81.42	57.67	11.76	2070.5
14	1950	79.73	57.14	11.81	1936.5
15	1955	83.64	59.98	11.96	2253.5
16	1953	83.91	59.90	12.01	2300.0
17	1982	80.78	58.90	12.54	2083.5
18	1961	79.26	56.68	12.70	1890.0
19	1956	81.90	59.29	12.92	2168.5
20	1964	81.29	58.07	13.31	2067.5
21	1965	81.91	58.88	13.58	2142.0
22	1976	78.23	56.83	13.82	1846.0
23	1957	83.73	59.88	13.99	2289.5
24	1960	79.17	58.14	14.18	1994.5
25	1966	80.61	57.78	15.20	2052.0
26	1981	78.50	58.68	15.52	1952.5
27	1948	81.12	57.91	15.53	2052.5
28	1949	83.90	61.42	17.01	2379.5
29	1970	81.11	60.50	17.17	2186.0
30	1972	76.82	56.05	17.39	1730.0
31	1979	78.75	58.95	17.49	1983.5
32	1968	79.48	59.51	17.50	2052.5
33	1973	80.06	61.02	18.29	2161.0
34	1980	80.38	60.24	19.05	2141.5
35	1958	80.78	58.44	21.87	2059.0
36	1969	79.41	58.70	22.14	2008.0

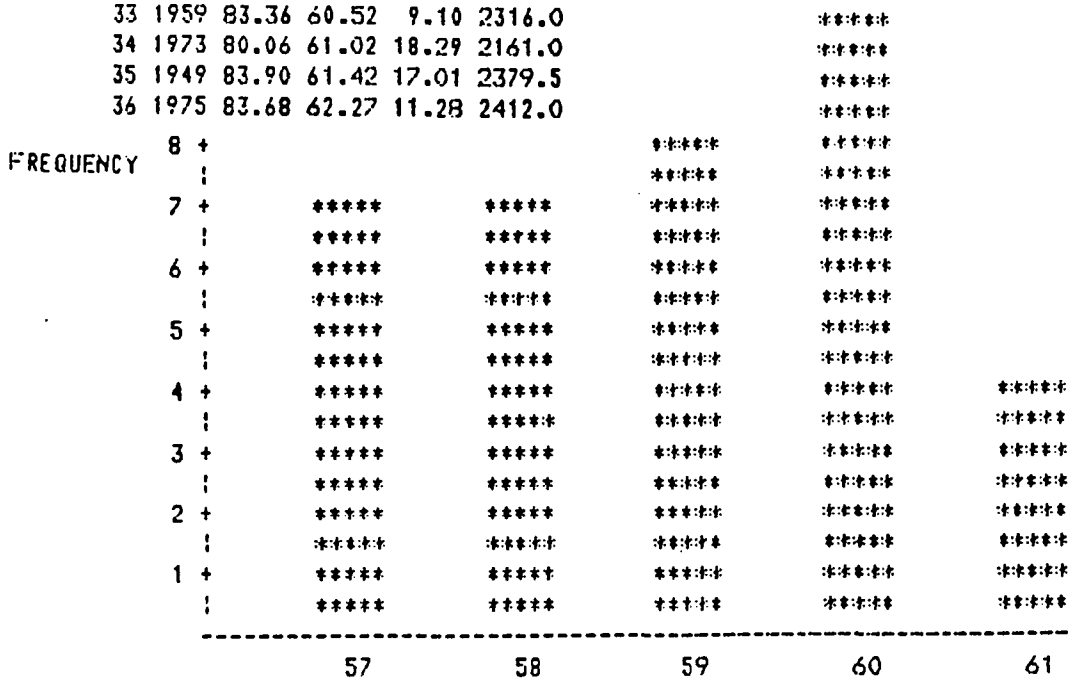
	MEAN	STANDARD DEVIATION
	13.72361111	3.48644899
	MINIMUM VALUE	**MAXIMUM VALUE**
	8.08000000	22.14000000
	STD ERROR OF MEAN	**SUM**
	0.58107483	494.05000000
	VARIANCE	**C.V.**
	12.15532659	25.405



Statistical Results for Mean Seasonal Minimum Temperature
at Columbus, OH

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1972	76.82	56.05	17.39	1730.0
2	1961	79.26	56.68	12.70	1890.0
3	1963	81.43	56.74	8.08	2013.0
4	1976	78.23	56.83	13.82	1846.0
5	1971	79.99	57.01	11.63	1944.0
6	1967	78.21	57.03	10.71	1857.5
7	1950	79.73	57.14	11.81	1936.5
8	1954	81.42	57.67	11.76	2070.5
9	1966	80.61	57.78	15.20	2052.0
10	1948	81.12	57.91	15.53	2052.5
11	1964	81.29	58.07	13.31	2067.5
12	1960	79.17	58.14	14.18	1994.5
13	1983	80.67	58.42	11.53	2064.5
14	1958	80.78	58.44	21.87	2059.0
15	1951	82.07	58.52	8.14	2131.0
16	1981	78.50	58.68	15.52	1952.5
17	1969	79.41	58.70	22.14	2008.0
18	1965	81.91	58.88	13.58	2142.0
19	1982	80.78	58.90	12.54	2083.5
20	1979	78.75	58.95	17.49	1983.5
21	1974	80.13	58.97	11.71	2060.0
22	1956	81.90	59.29	12.92	2168.5
23	1968	79.48	59.51	17.50	2052.5
24	1977	82.36	59.52	10.68	2210.5
25	1962	82.00	59.53	9.92	2180.5
26	1957	83.73	59.88	13.99	2289.5
27	1953	83.91	59.90	12.01	2300.0
28	1955	83.64	59.98	11.96	2253.5
29	1952	83.19	60.14	11.03	2277.5
30	1978	79.99	60.16	11.50	2111.5
31	1980	80.38	60.24	19.05	2141.5
32	1970	81.11	60.50	17.17	2186.0
33	1959	83.36	60.52	9.10	2316.0
34	1973	80.06	61.02	18.29	2161.0
35	1949	83.90	61.42	17.01	2379.5
36	1975	83.68	62.27	11.28	2412.0

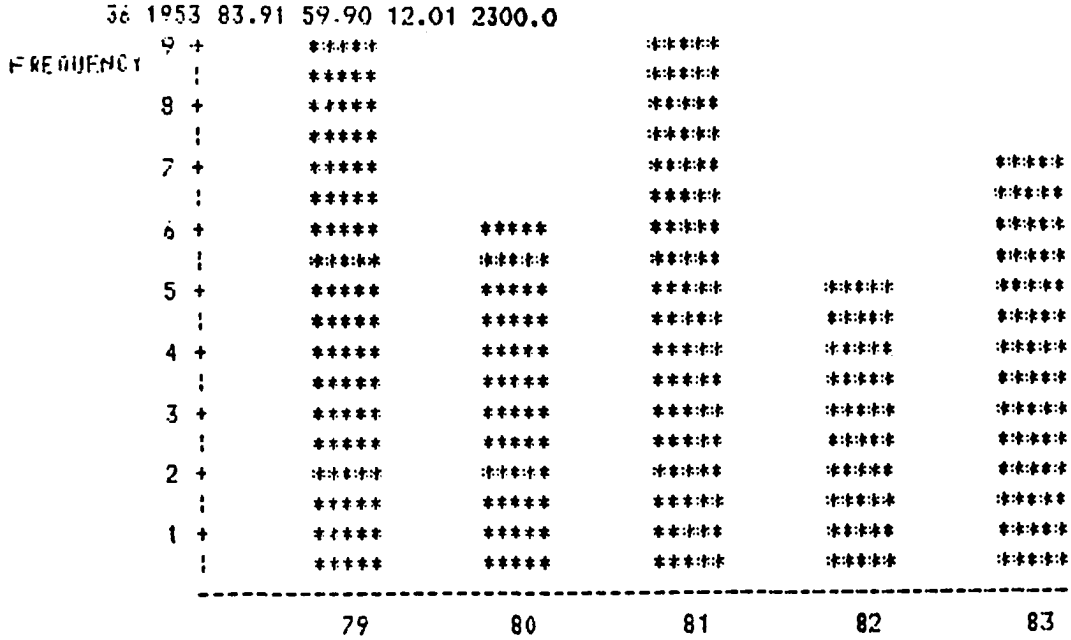
	MEAN	STANDARD DEVIATION
	58.87194444	1.45970020
	MINIMUM VALUE	**MAXIMUM VALUE**
	56.05000000	62.27000000
	STD ERROR OF MEAN	**SUM**
	0.24328337	2119.3900000
	VARIANCE	**C.V.**
	2.13072468	2.479



Statistical Results for Mean Seasonal Maximum Temperature
at Columbus, OH

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1972	76.82	56.05	17.39	1730.0
2	1967	78.21	57.03	10.71	1857.5
3	1976	78.23	56.83	13.82	1846.0
4	1981	78.50	58.68	15.52	1952.5
5	1979	78.75	58.95	17.49	1983.5
6	1960	79.17	58.14	14.18	1994.5
7	1961	79.26	56.68	12.70	1890.0
8	1969	79.41	58.70	22.14	2008.0
9	1968	79.48	59.51	17.50	2052.5
10	1950	79.73	57.14	11.81	1936.5
11	1971	79.99	57.01	11.63	1944.0
12	1978	79.99	60.16	11.50	2111.5
13	1973	80.06	61.02	18.29	2161.0
14	1974	80.13	58.97	11.71	2060.0
15	1980	80.38	60.24	19.05	2141.5
16	1966	80.61	57.78	15.20	2052.0
17	1983	80.67	58.42	11.53	2064.5
18	1958	80.78	58.44	21.87	2059.0
19	1982	80.78	58.90	12.54	2083.5
20	1970	81.11	60.50	17.17	2186.0
21	1948	81.12	57.91	15.53	2052.5
22	1964	81.29	58.07	13.31	2067.5
23	1954	81.42	57.67	11.76	2070.5
24	1963	81.43	56.74	8.08	2013.0
25	1956	81.90	59.29	12.92	2168.5
26	1965	81.91	58.88	13.58	2142.0
27	1962	82.00	59.53	9.92	2180.5
28	1951	82.07	58.52	8.14	2131.0
29	1977	82.36	59.52	10.68	2210.5
30	1952	83.19	60.14	11.03	2277.5
31	1959	83.36	60.52	9.10	2316.0
32	1955	83.64	59.98	11.96	2253.5
33	1975	83.68	62.27	11.28	2412.0
34	1957	83.73	59.88	13.99	2289.5
35	1949	83.90	61.42	17.01	2379.5
36	1953	83.91	59.90	12.01	2300.0

	MEAN	STANDARD DEVIATION
	80.91583333	1.82201517
	MINIMUM VALUE	**MAXIMUM VALUE**
	76.82000000	83.91000000
	STD ERROR OF MEAN	**SUM**
	0.30366920	2912.9700000
	VARIANCE	**C.V.**
	3.31973929	2.252



Statistical Results for Total Seasonal Precipitation
at Dodge City, KS

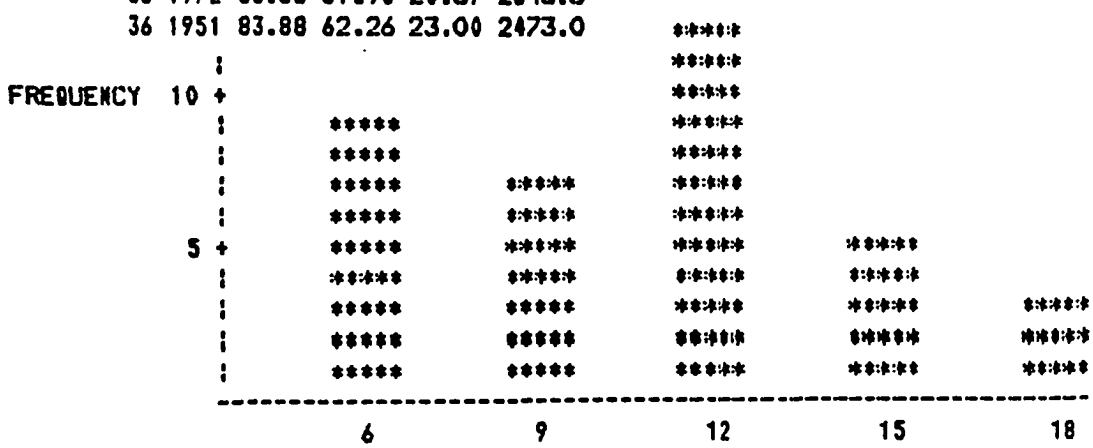
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1976	89.06	61.88	4.13	2741.0
2	1970	90.66	63.71	4.41	2624.5
3	1953	89.24	64.60	5.18	2667.0
4	1952	90.15	64.64	5.48	2386.0
5	1956	90.83	64.81	5.56	2734.5
6	1954	91.33	65.67	6.05	2468.0
7	1959	88.29	63.33	6.09	2700.5
8	1978	90.26	64.12	6.54	2422.5
9	1960	87.61	61.90	6.56	2547.5
10	1966	89.12	64.13	8.39	2598.0
11	1973	89.99	62.62	8.68	2531.5
12	1963	89.20	64.11	9.27	2652.5
13	1979	86.28	60.69	9.29	2630.0
14	1969	87.79	63.53	9.32	2375.5
15	1983	89.97	65.33	9.73	1993.0
16	1975	88.63	63.02	9.74	2817.0
17	1949	85.62	62.86	10.72	2639.5
18	1980	92.09	66.54	11.17	1980.5
19	1971	88.38	62.11	11.59	2562.0
20	1955	86.50	63.60	11.70	2657.0
21	1950	83.28	60.25	11.74	2405.0
22	1957	86.37	63.22	11.87	2591.5
23	1982	86.50	64.16	11.93	2534.0
24	1981	88.98	64.96	11.95	2522.5
25	1961	85.45	61.72	12.65	2641.5
26	1977	90.88	66.30	13.16	2446.0
27	1965	85.88	62.63	13.22	2606.5
28	1964	90.36	63.64	13.39	2527.0
29	1974	88.57	63.29	14.38	2525.0
30	1948	86.70	62.23	15.22	2740.0
31	1967	84.07	60.74	15.35	2511.0
32	1958	86.87	63.00	15.52	2792.5
33	1968	85.63	61.99	16.35	2485.0
34	1962	86.92	62.68	18.56	2703.5
35	1972	85.35	61.95	20.37	2648.5
36	1951	83.88	62.26	23.00	2473.0

MEAN	STANDARD DEVIATION
11.06277778	4.48799772

MINIMUM VALUE	MAXIMUM VALUE
4.13000000	23.00000000

STD ERROR OF MEAN	SUM
0.74799962	398.26000000

VARIANCE	C.V.
20.14212349	40.568



Statistical Results for Mean Seasonal Minimum Temperature
at Dodge City, KS

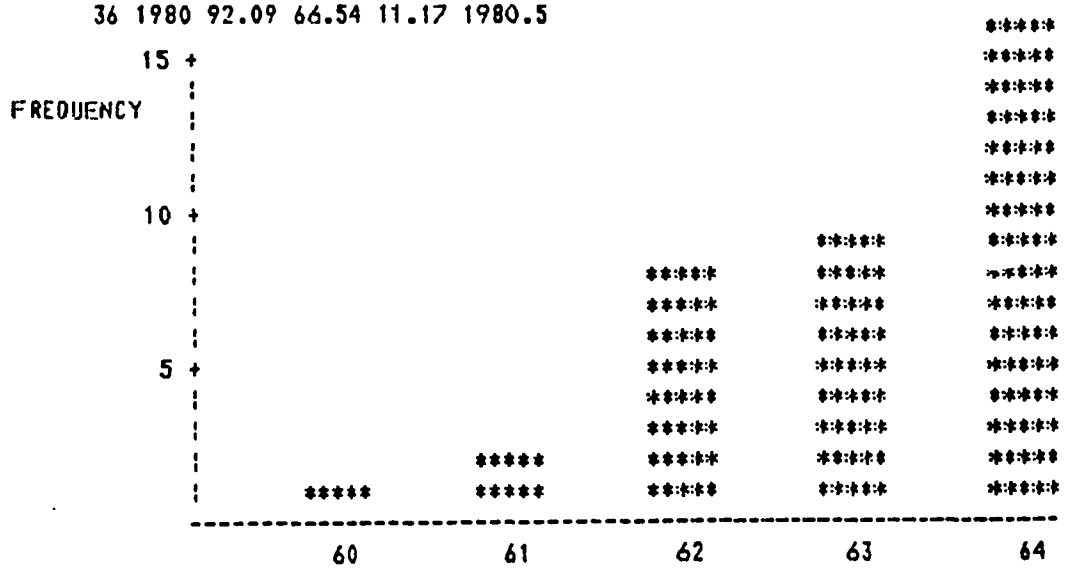
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1950	83.28	60.25	11.74	2405.0
2	1979	86.28	60.69	9.29	2630.0
3	1967	84.07	60.74	15.35	2511.0
4	1961	85.45	61.72	12.65	2641.5
5	1976	89.06	61.88	4.13	2741.0
6	1960	87.61	61.90	6.56	2547.5
7	1972	85.35	61.95	20.37	2648.5
8	1968	85.63	61.99	16.35	2485.0
9	1971	88.38	62.11	11.59	2562.0
10	1948	86.70	62.23	15.22	2740.0
11	1951	83.88	62.26	23.00	2473.0
12	1973	89.99	62.62	8.68	2531.5
13	1965	85.88	62.63	13.22	2606.5
14	1962	86.92	62.68	18.56	2703.5
15	1949	85.62	62.86	10.72	2639.5
16	1958	86.87	63.00	15.52	2792.5
17	1975	88.63	63.02	9.74	2817.0
18	1957	86.37	63.22	11.87	2591.5
19	1974	88.57	63.29	14.38	2525.0
20	1959	88.29	63.33	6.09	2700.5
21	1969	87.79	63.53	9.32	2375.5
22	1955	86.50	63.60	11.70	2657.0
23	1964	90.36	63.64	13.39	2527.0
24	1970	90.66	63.71	4.41	2624.5
25	1963	89.20	64.11	9.27	2652.5
26	1978	90.26	64.12	6.54	2422.5
27	1966	89.12	64.13	8.39	2598.0
28	1982	86.50	64.16	11.93	2534.0
29	1953	89.24	64.60	5.18	2667.0
30	1952	90.15	64.64	5.48	2386.0
31	1956	90.83	64.81	5.56	2734.5
32	1981	88.98	64.96	11.95	2522.5
33	1983	89.97	65.33	9.73	1993.0
34	1954	91.33	65.67	6.05	2468.0
35	1977	90.88	66.30	13.16	2446.0
36	1980	92.09	66.54	11.17	1980.5

MEAN	STANDARD DEVIATION
63.28388889	1.50160158

MINIMUM VALUE	MAXIMUM VALUE
60.25000000	66.54000000

STD ERROR OF MEAN	SUM
0.25026693	2278.2200000

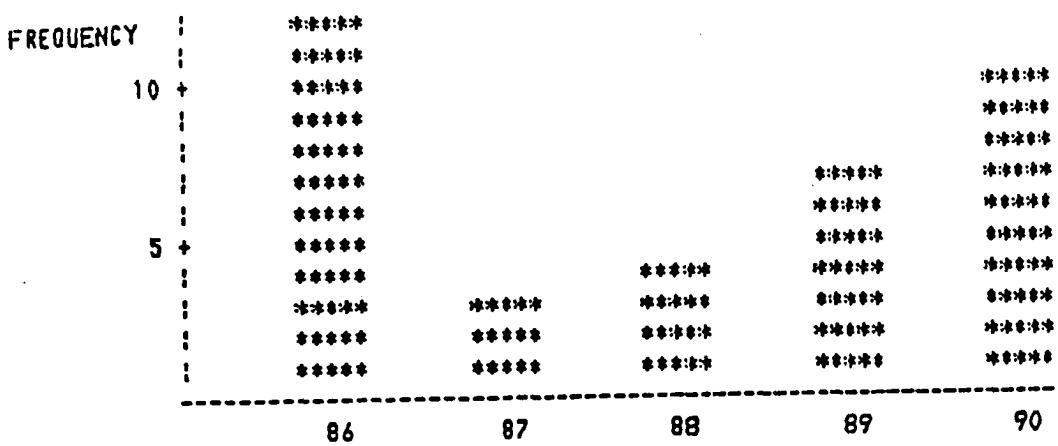
VARIANCE	C.V.
2.25480730	2.373



Statistical Results for Mean Seasonal Maximum Temperature
at Dodge City, KS

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1950	83.28	60.25	11.74	2405.0
2	1951	83.88	62.26	23.00	2473.0
3	1967	84.07	60.74	15.35	2511.0
4	1972	85.35	61.95	20.37	2648.5
5	1961	85.45	61.72	12.65	2641.5
6	1949	85.62	62.86	10.72	2639.5
7	1968	85.63	61.99	16.35	2485.0
8	1965	85.88	62.63	13.22	2606.5
9	1979	86.28	60.69	9.29	2630.0
10	1957	86.37	63.22	11.87	2591.5
11	1955	86.50	63.60	11.70	2657.0
12	1982	86.50	64.16	11.93	2534.0
13	1948	86.70	62.23	15.22	2740.0
14	1958	86.87	63.00	15.52	2792.5
15	1962	86.92	62.68	18.56	2703.5
16	1960	87.61	61.90	6.56	2547.5
17	1969	87.79	63.53	9.32	2375.5
18	1959	88.29	63.33	6.09	2700.5
19	1971	88.38	62.11	11.59	2562.0
20	1974	88.57	63.29	14.38	2525.0
21	1975	88.63	63.02	9.74	2817.0
22	1981	88.98	64.96	11.95	2522.5
23	1976	89.06	61.88	4.13	2741.0
24	1966	89.12	64.13	8.39	2598.0
25	1963	89.20	64.11	9.27	2652.5
26	1953	89.24	64.60	5.18	2667.0
27	1983	89.97	65.33	9.73	1993.0
28	1973	89.99	62.62	8.68	2531.5
29	1952	90.15	64.64	5.48	2386.0
30	1978	90.26	64.12	6.54	2422.5
31	1964	90.36	63.64	13.39	2527.0
32	1970	90.66	63.71	4.41	2624.5
33	1956	90.83	64.81	5.56	2734.5
34	1977	90.88	66.30	13.16	2446.0
35	1954	91.33	65.67	6.05	2468.0
36	1980	92.09	66.54	11.17	1980.5

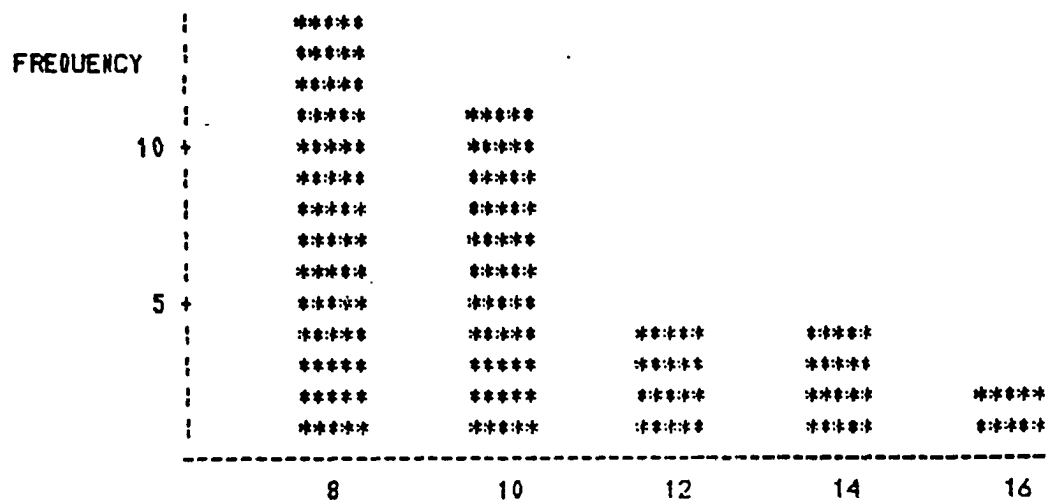
MEAN	STANDARD DEVIATION
87.96361111	2.26777695
MINIMUM VALUE	**MAXIMUM VALUE**
83.28000000	92.09000000
STD ERROR OF MEAN	**SUM**
0.37796283	3166.6900000
VARIANCE	**C.V.**
5.14281230	2.578



Statistical Results for Total Seasonal Precipitation
at Rapid City, SD

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1961	82.99	55.33	4.44	2546.0
2	1974	81.02	50.80	5.21	2149.0
3	1973	79.50	51.56	6.12	2116.0
4	1960	83.52	54.50	6.37	2498.0
5	1959	83.22	54.00	7.21	2509.0
6	1953	80.10	53.95	7.64	2327.5
7	1955	82.86	55.40	7.66	2529.5
8	1949	81.41	53.18	7.67	2334.5
9	1970	81.22	52.11	7.74	2270.0
10	1950	76.56	49.79	7.97	1814.0
11	1983	80.80	54.38	8.49	2393.0
12	1956	81.62	54.66	8.58	2430.0
13	1964	80.94	53.62	8.75	2230.0
14	1971	79.38	51.68	8.93	2102.5
15	1975	79.88	51.30	9.09	2092.0
16	1954	81.92	54.53	9.12	2359.5
17	1977	81.23	53.55	9.23	2313.5
18	1952	81.18	54.09	9.24	2319.0
19	1958	80.34	54.10	9.50	2290.0
20	1978	80.66	52.88	9.73	2251.0
21	1969	80.26	51.56	9.88	2153.5
22	1976	81.02	52.93	9.99	2281.0
23	1981	79.03	53.04	10.14	2146.5
24	1963	82.44	55.21	10.66	2522.0
25	1980	81.01	53.02	10.79	2288.0
26	1966	80.45	51.98	11.15	2171.0
27	1979	77.86	52.65	11.30	2085.0
28	1972	77.26	50.94	11.34	1913.0
29	1951	75.74	51.24	11.43	1844.5
30	1965	76.95	52.56	13.14	1982.5
31	1967	76.65	51.95	13.38	1965.0
32	1957	77.64	53.68	13.70	2117.0
33	1968	75.58	50.02	14.07	1766.5
34	1962	77.99	53.16	16.57	2094.0
35	1982	75.07	52.24	17.10	1848.5

	MEAN	STANDARD DEVIATION
	9.80942857	2.85670001
	MINIMUM VALUE	MAXIMUM VALUE
	4.44000000	17.10000000
	STD ERROR OF MEAN	SUM
	0.48287043	343.33000000
	VARIANCE	C.V.
	8.16073496	29.122



Statistical Results for Mean Seasonal Minimum Temperature
at Rapid City, SD

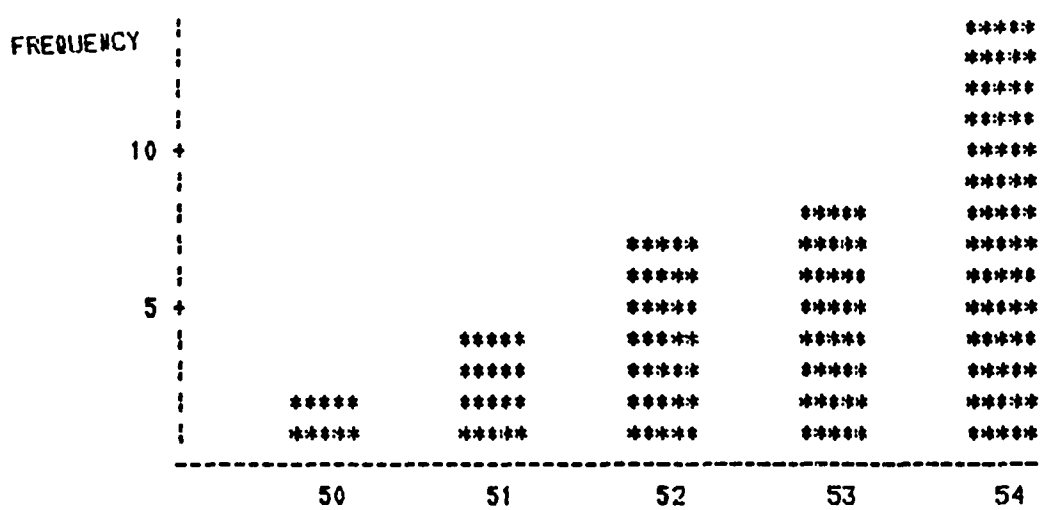
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1950	76.56	49.79	7.97	1814.0
2	1968	75.58	50.02	14.07	1766.5
3	1974	81.02	50.80	5.21	2149.0
4	1972	77.26	50.94	11.34	1913.0
5	1951	75.74	51.24	11.43	1844.5
6	1975	79.88	51.30	9.09	2092.0
7	1969	80.26	51.56	9.88	2153.5
8	1973	79.50	51.56	6.12	2116.0
9	1971	79.38	51.68	8.93	2102.5
10	1967	76.65	51.95	13.38	1965.0
11	1966	80.45	51.98	11.15	2171.0
12	1970	81.22	52.11	7.74	2270.0
13	1982	75.07	52.24	17.10	1848.5
14	1965	76.95	52.56	13.14	1982.5
15	1979	77.86	52.65	11.30	2085.0
16	1978	80.66	52.88	9.73	2251.0
17	1976	81.02	52.93	9.99	2281.0
18	1980	81.01	53.02	10.79	2288.0
19	1981	79.03	53.04	10.14	2146.5
20	1962	77.99	53.16	16.57	2094.0
21	1949	81.41	53.18	7.67	2334.5
22	1977	81.23	53.55	9.23	2313.5
23	1964	80.94	53.62	8.75	2230.0
24	1957	77.64	53.68	13.70	2117.0
25	1953	80.10	53.95	7.64	2327.5
26	1959	83.22	54.00	7.21	2509.0
27	1952	81.18	54.09	9.24	2319.0
28	1958	80.34	54.10	9.50	2290.0
29	1983	80.80	54.38	8.49	2393.0
30	1960	83.52	54.50	6.37	2498.0
31	1954	81.92	54.53	9.12	2359.5
32	1956	81.62	54.66	8.58	2430.0
33	1963	82.44	55.21	10.66	2522.0
34	1961	82.99	55.33	4.44	2546.0
35	1955	82.86	55.40	7.66	2529.5

MEAN	STANDARD DEVIATION
52.90257143	1.48021132

MINIMUM VALUE	MAXIMUM VALUE
49.79000000	55.40000000

STD ERROR OF MEAN	SUM
0.25020138	1851.5900000

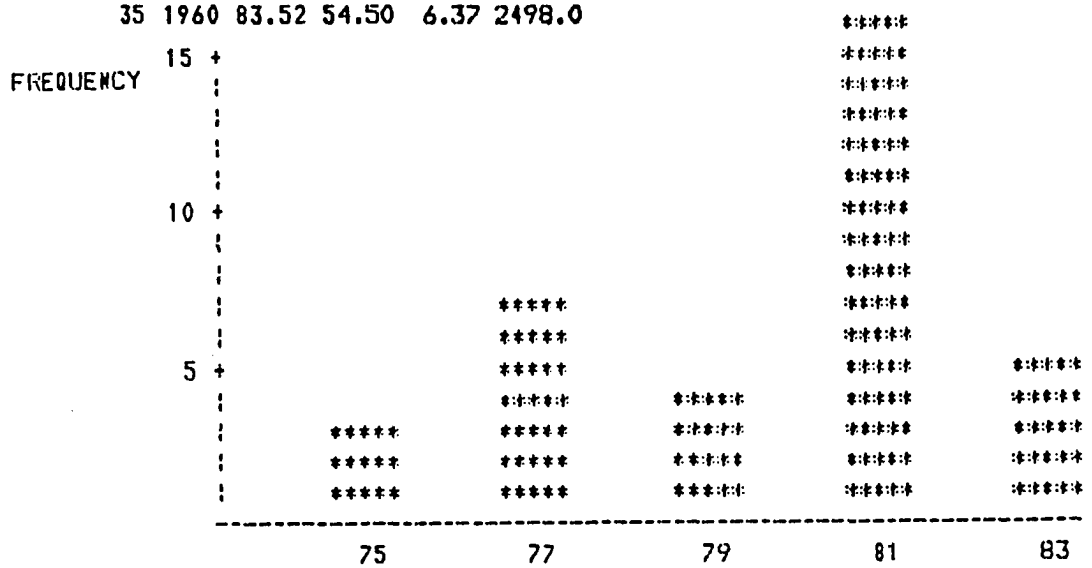
VARIANCE	C.V.
2.19102555	2.798



Statistical Results for Mean Seasonal Maximum Temperature
at Rapid City, SD

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1982	75.07	52.24	17.10	1848.5
2	1968	75.58	50.02	14.07	1766.5
3	1951	75.74	51.24	11.43	1844.5
4	1950	76.56	49.79	7.97	1814.0
5	1967	76.65	51.95	13.38	1965.0
6	1965	76.95	52.56	13.14	1982.5
7	1972	77.26	50.94	11.34	1913.0
8	1957	77.64	53.68	13.70	2117.0
9	1979	77.86	52.65	11.30	2085.0
10	1962	77.99	53.16	16.57	2094.0
11	1981	79.03	53.04	10.14	2146.5
12	1971	79.38	51.68	8.93	2102.5
13	1973	79.50	51.56	6.12	2116.0
14	1975	79.88	51.30	9.09	2092.0
15	1953	80.10	53.95	7.64	2327.5
16	1969	80.26	51.56	9.88	2153.5
17	1958	80.34	54.10	9.50	2290.0
18	1966	80.45	51.98	11.15	2171.0
19	1978	80.66	52.88	9.73	2251.0
20	1983	80.80	54.38	8.49	2393.0
21	1964	80.94	53.62	8.75	2230.0
22	1980	81.01	53.02	10.79	2288.0
23	1974	81.02	50.80	5.21	2149.0
24	1976	81.02	52.93	9.99	2281.0
25	1952	81.18	54.09	9.24	2319.0
26	1970	81.22	52.11	7.74	2270.0
27	1977	81.23	53.55	9.23	2313.5
28	1949	81.41	53.18	7.67	2334.5
29	1956	81.62	54.66	8.58	2430.0
30	1954	81.92	54.53	9.12	2359.5
31	1963	82.44	55.21	10.66	2522.0
32	1955	82.86	55.40	7.66	2529.5
33	1961	82.99	55.33	4.44	2546.0
34	1959	83.22	54.00	7.21	2509.0
35	1960	83.52	54.50	6.37	2498.0

	MEAN	STANDARD DEVIATION
	79.86571429	2.30717205
	MINIMUM VALUE	MAXIMUM VALUE
	75.07000000	83.52000000
	STD ERROR OF MEAN	SUM
	0.38998325	2795.3000000
	VARIANCE	C.V.
	5.32304286	2.889



Statistical Results for Total Seasonal Precipitation
at Rochester, MN

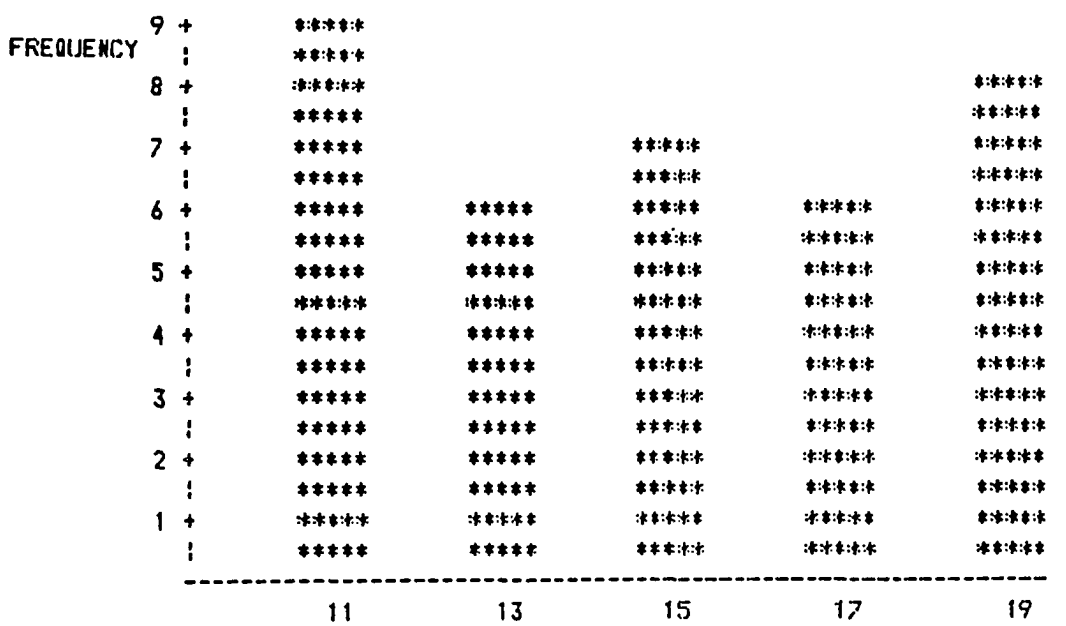
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1976	81.71	55.11	6.99	2152.5
2	1964	79.48	55.60	9.37	2087.0
3	1955	82.31	57.86	10.09	2353.0
4	1950	77.71	53.45	10.29	1855.0
5	1972	77.76	55.15	10.58	1959.0
6	1963	77.48	55.50	11.26	1988.0
7	1966	77.50	55.23	11.29	1949.5
8	1974	77.39	54.52	11.61	1906.0
9	1975	80.06	57.87	11.83	2257.0
10	1948	81.31	56.24	12.10	2157.5
11	1958	75.82	51.91	12.28	1651.0
12	1977	78.97	57.36	13.08	2161.5
13	1967	75.17	52.83	13.12	1675.0
14	1965	74.37	55.16	13.18	1782.5
15	1960	78.26	56.82	13.55	2087.5
16	1983	79.10	57.26	14.60	2178.0
17	1954	78.84	56.74	14.85	2118.0
18	1982	76.41	56.51	15.01	1959.0
19	1949	81.82	58.24	15.31	2383.5
20	1953	79.40	56.69	15.64	2111.5
21	1962	76.09	56.18	15.66	1920.5
22	1971	78.16	55.87	15.96	2037.5
23	1970	78.54	57.18	16.12	2135.5
24	1980	80.31	57.39	16.13	2248.5
25	1956	78.98	55.86	16.26	2084.0
26	1979	78.65	56.55	16.38	2096.5
27	1969	75.51	54.56	16.80	1805.0
28	1961	77.42	55.99	17.49	2004.5
29	1952	77.33	55.23	18.09	1945.5
30	1973	77.86	57.23	18.35	2097.5
31	1957	76.81	57.34	18.40	2049.0
32	1968	74.24	53.38	19.68	1669.0
33	1959	79.49	58.53	20.65	2275.5
34	1951	76.49	55.71	21.70	1915.5
35	1981	76.27	55.59	21.81	1895.5
36	1978	78.73	56.71	22.42	2109.0

MEAN	STANDARD DEVIATION
14.94250000	3.73894666

MINIMUM VALUE	MAXIMUM VALUE
6.99000000	22.42000000

STD ERROR OF MEAN	SUM
0.62315778	537.93000000

VARIANCE	C.V.
13.97972214	25.022



Statistical Results for Mean Seasonal Minimum Temperature
at Rochester, MN

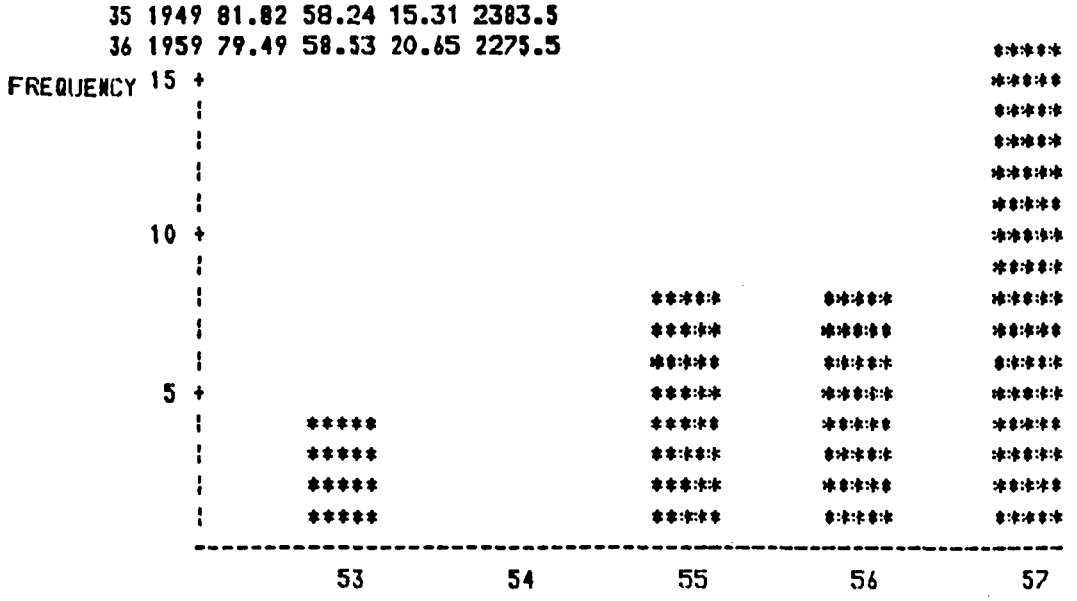
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1958	75.82	51.91	12.28	1651.0
2	1967	75.17	52.83	13.12	1675.0
3	1968	74.24	53.38	19.68	1669.0
4	1950	77.71	53.45	10.29	1855.0
5	1974	77.39	54.52	11.61	1906.0
6	1969	75.51	54.56	16.80	1805.0
7	1976	81.71	55.11	6.99	2152.5
8	1972	77.76	55.15	10.58	1959.0
9	1965	74.37	55.16	13.18	1782.5
10	1952	77.33	55.23	18.09	1945.5
11	1966	77.50	55.23	11.29	1949.5
12	1963	77.48	55.50	11.26	1988.0
13	1981	76.27	55.59	21.81	1895.5
14	1964	79.48	55.60	9.37	2087.0
15	1951	76.49	55.71	21.70	1915.5
16	1956	78.98	55.86	16.26	2084.0
17	1971	78.16	55.87	15.96	2037.5
18	1961	77.42	55.99	17.49	2004.5
19	1962	76.09	56.18	15.66	1920.5
20	1948	81.31	56.24	12.10	2157.5
21	1982	76.41	56.51	15.01	1959.0
22	1979	78.65	56.55	16.38	2096.5
23	1953	79.40	56.69	15.64	2111.5
24	1978	78.73	56.71	22.42	2109.0
25	1954	78.84	56.74	14.85	2118.0
26	1960	78.26	56.82	13.55	2087.5
27	1970	78.54	57.18	16.12	2135.5
28	1973	77.86	57.23	18.35	2097.5
29	1983	79.10	57.26	14.60	2178.0
30	1957	76.81	57.34	18.40	2049.0
31	1977	78.97	57.36	13.08	2161.5
32	1980	80.31	57.39	16.13	2248.5
33	1955	82.31	57.86	10.09	2353.0
34	1975	80.06	57.87	11.83	2257.0
35	1949	81.82	58.24	15.31	2383.5
36	1959	79.49	58.53	20.65	2275.5

MEAN	STANDARD DEVIATION
55.98194444	1.50995708

MINIMUM VALUE	MAXIMUM VALUE
51.91000000	58.53000000

STD ERROR OF MEAN	SUM
0.25165951	2015.3500000

VARIANCE	C.V.
2.27997040	2.697



Statistical Results for Mean Seasonal Maximum Temperature
at Rochester, MN

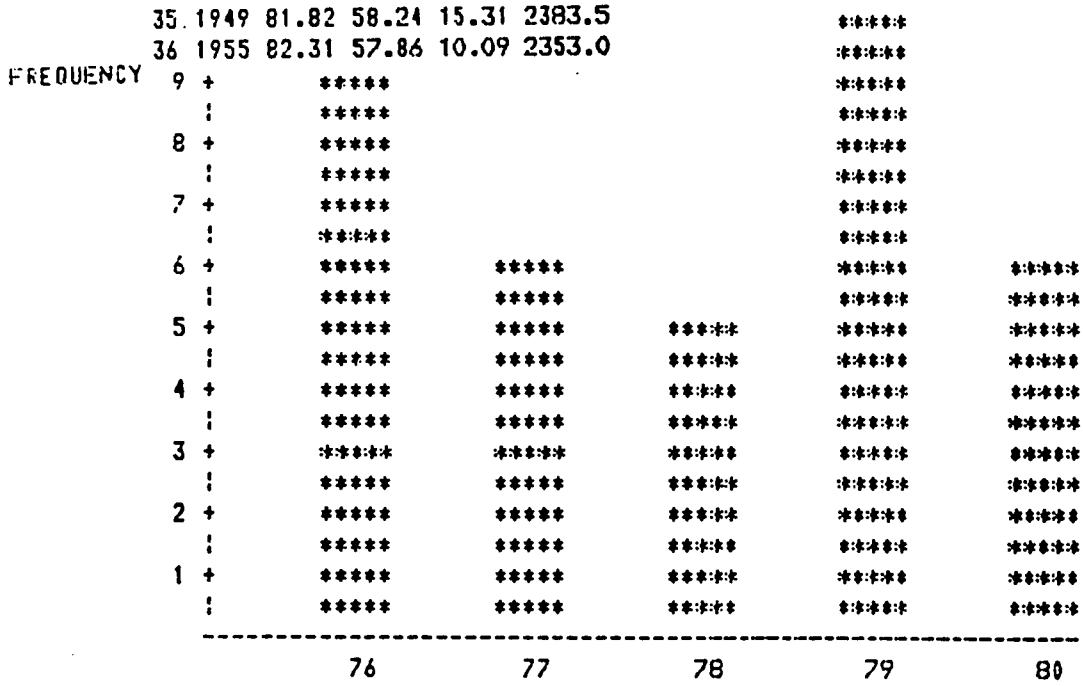
OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1968	74.24	53.38	19.68	1669.0
2	1965	74.37	55.16	13.18	1782.5
3	1967	75.17	52.83	13.12	1675.0
4	1969	75.51	54.56	16.80	1805.0
5	1958	75.82	51.91	12.28	1651.0
6	1962	76.09	56.18	15.66	1920.5
7	1981	76.27	55.59	21.81	1895.5
8	1982	76.41	56.51	15.01	1959.0
9	1951	76.49	55.71	21.70	1915.5
10	1957	76.81	57.34	18.40	2049.0
11	1952	77.33	55.23	18.09	1945.5
12	1974	77.39	54.52	11.61	1906.0
13	1961	77.42	55.99	17.49	2004.5
14	1963	77.48	55.50	11.26	1988.0
15	1966	77.50	55.23	11.29	1949.5
16	1950	77.71	53.45	10.29	1855.0
17	1972	77.76	55.15	10.58	1959.0
18	1973	77.86	57.23	18.35	2097.5
19	1971	78.16	55.87	15.96	2037.5
20	1960	78.26	56.82	13.55	2087.5
21	1970	78.54	57.18	16.12	2135.5
22	1979	78.65	56.55	16.38	2096.5
23	1978	78.73	56.71	22.42	2109.0
24	1954	78.84	56.74	14.85	2118.0
25	1977	78.97	57.36	13.08	2161.5
26	1956	78.98	55.86	16.26	2084.0
27	1983	79.10	57.26	14.60	2178.0
28	1953	79.40	56.69	15.64	2111.5
29	1964	79.48	55.60	9.37	2087.0
30	1959	79.49	58.53	20.65	2275.5
31	1975	80.06	57.87	11.83	2257.0
32	1980	80.31	57.39	16.13	2248.5
33	1948	81.31	56.24	12.10	2157.5
34	1976	81.71	55.11	6.99	2152.5
35	1949	81.82	58.24	15.31	2383.5
36	1955	82.31	57.86	10.09	2353.0

MEAN	STANDARD DEVIATION
78.10416667	1.99703834

MINIMUM VALUE	MAXIMUM VALUE
74.24000000	82.31000000

STD ERROR OF MEAN	SUM
0.33283972	2811.7500000

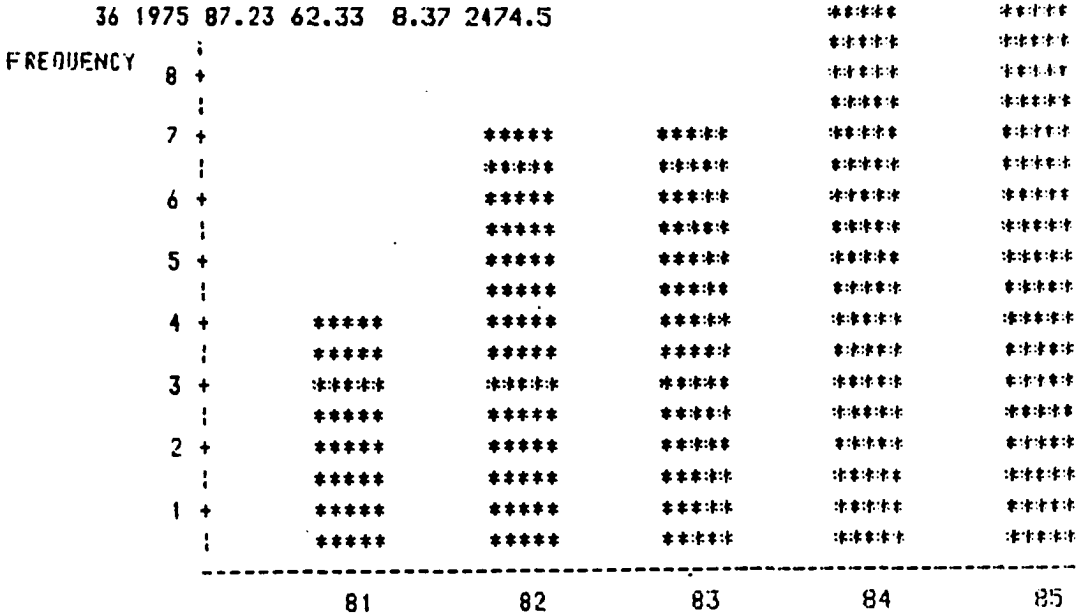
VARIANCE	C.V.
3.98816214	2.557



Statistical Results for Mean Seasonal Minimum Temperature
at Omaha, NB

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1950	79.93	59.16	18.13	2189.0
2	1951	80.07	60.13	21.67	2215.0
3	1982	80.12	60.04	18.66	2210.5
4	1960	81.44	60.51	17.80	2313.5
5	1969	81.62	60.76	12.90	2221.0
6	1981	81.71	58.70	10.39	2117.5
7	1967	81.81	58.82	17.66	2275.5
8	1958	82.04	60.95	15.80	2407.5
9	1961	82.17	60.90	17.16	2338.5
10	1972	82.20	60.77	14.01	2407.5
11	1966	82.21	60.17	16.16	2251.5
12	1968	82.63	60.12	13.47	2394.5
13	1959	82.69	62.38	20.36	2525.5
14	1979	82.79	61.38	8.76	2294.5
15	1983	82.84	63.04	9.57	2224.5
16	1957	83.02	62.79	15.84	2226.0
17	1965	83.21	61.96	16.53	2529.5
18	1952	83.33	62.06	16.96	2276.5
19	1949	83.71	63.57	15.74	2611.5
20	1962	83.77	63.28	16.23	2634.5
21	1973	83.79	60.14	11.20	2460.5
22	1971	84.04	60.99	12.62	2333.0
23	1948	84.05	61.03	11.65	2451.5
24	1963	84.16	63.38	9.90	2591.5
25	1980	84.21	62.21	20.86	2301.0
26	1978	84.33	62.18	15.71	2456.0
27	1964	84.35	61.72	20.59	2349.0
28	1974	85.09	59.25	8.81	2056.0
29	1976	85.63	59.75	8.54	2389.0
30	1954	85.67	63.89	12.26	2315.5
31	1953	85.78	62.63	8.04	2492.5
32	1955	86.05	63.27	10.47	2299.0
33	1956	86.10	63.52	14.25	2587.5
34	1970	86.22	62.98	11.67	2565.5
35	1977	86.42	63.46	18.19	2414.0
36	1975	87.23	62.33	8.37	2474.5

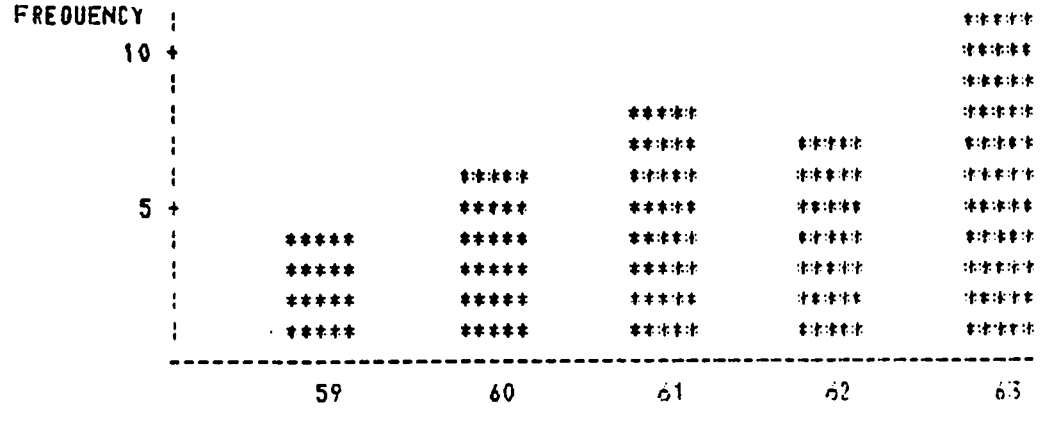
	MEAN	STANDARD DEVIATION
	83.51194444	1.87416087
	MINIMUM VALUE	MAXIMUM VALUE
	79.93000000	87.23000000
	STD ERROR OF MEAN	SUM
	0.31236015	3006.4300000
	VARIANCE	C.V.
	3.51247897	2.244



Statistical Results for Mean Seasonal Maximum Temperature
at Omaha, NB

OBS	YEAR	TMAX	TMIN	PPT	GDD
1	1981	81.71	58.70	10.39	2117.5
2	1967	81.81	58.82	17.66	2275.5
3	1950	79.93	59.16	18.13	2189.0
4	1974	85.09	59.25	8.81	2056.0
5	1976	85.63	59.75	8.54	2389.0
6	1982	80.12	60.04	18.66	2210.5
7	1968	82.63	60.12	13.47	2394.5
8	1951	80.07	60.13	21.67	2215.0
9	1973	83.79	60.14	11.20	2460.5
10	1966	82.21	60.17	16.16	2251.5
11	1960	81.44	60.51	17.80	2313.5
12	1969	81.62	60.76	12.90	2221.0
13	1972	82.20	60.77	14.01	2407.5
14	1961	82.17	60.90	17.16	2338.5
15	1958	82.04	60.95	15.80	2407.5
16	1971	84.04	60.99	12.62	2333.0
17	1948	84.05	61.03	11.65	2451.5
18	1979	82.79	61.38	8.76	2294.5
19	1964	84.35	61.72	20.59	2349.0
20	1965	83.21	61.96	16.53	2529.5
21	1952	83.33	62.06	16.96	2276.5
22	1978	84.33	62.18	15.71	2456.0
23	1980	84.21	62.21	20.86	2301.0
24	1975	87.23	62.33	8.37	2474.5
25	1959	82.69	62.38	20.36	2525.5
26	1953	85.78	62.63	8.04	2492.5
27	1957	83.02	62.79	15.84	2226.0
28	1970	86.22	62.98	11.67	2565.5
29	1983	82.84	63.04	9.57	2224.5
30	1955	86.05	63.27	10.47	2299.0
31	1962	83.77	63.28	16.23	2634.5
32	1963	84.16	63.38	9.90	2591.5
33	1977	86.42	63.46	18.19	2414.0
34	1956	86.10	63.52	14.25	2587.5
35	1949	83.71	63.57	15.74	2611.5
36	1954	85.67	63.89	12.26	2315.5

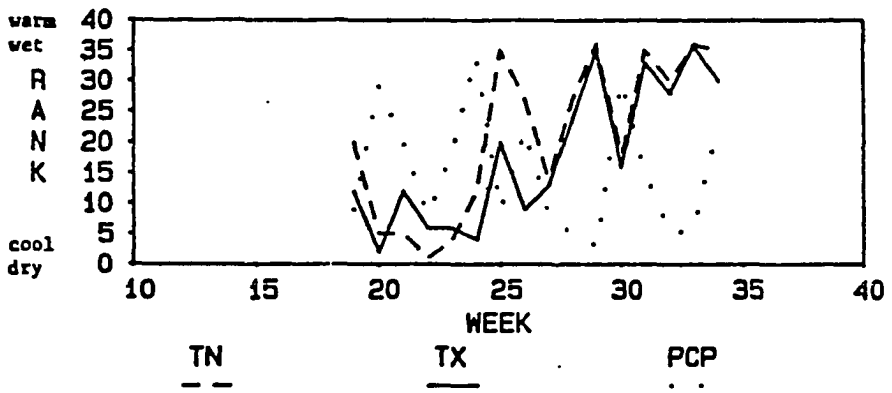
MEAN	STANDARD DEVIATION
61.50611111	1.50838282
MINIMUM VALUE	**MAXIMUM VALUE**
58.70000000	63.89000000
STD ERROR OF MEAN	**SUM**
0.25139714	2214.2200000
VARIANCE	**C.V.**
2.27521873	2.452



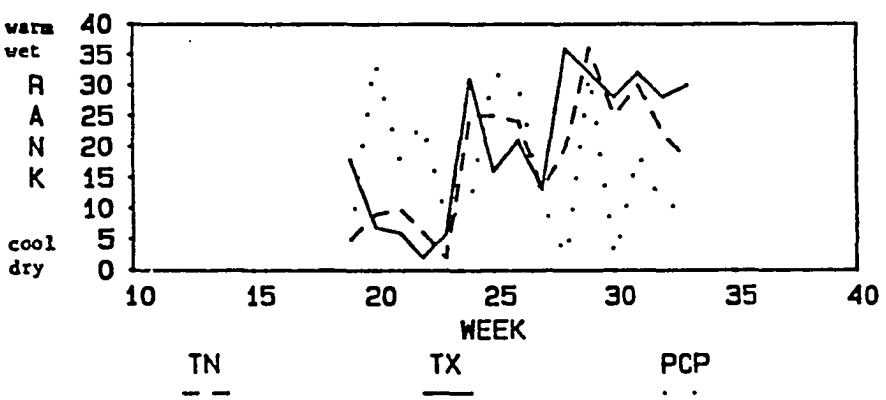
Appendix C

RAW WEEKLY 1983 RANKS OF MAXIMUM AND MINIMUM TEMPERATURE AND PRECIPITATION AT SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT.

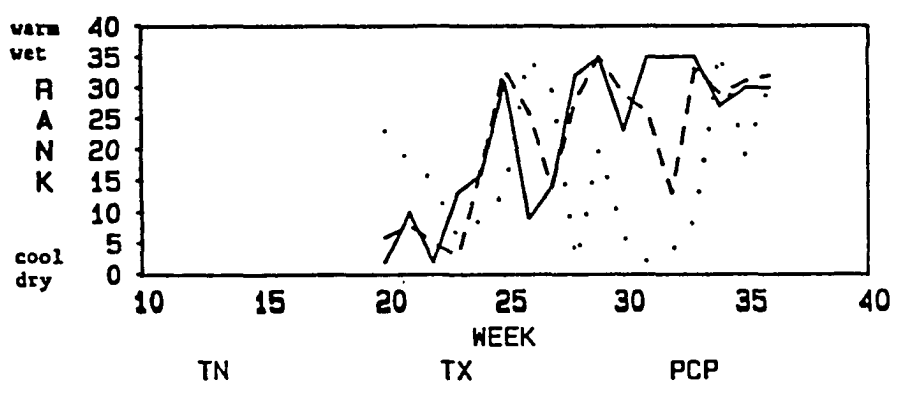
OMAHA WKLY WX



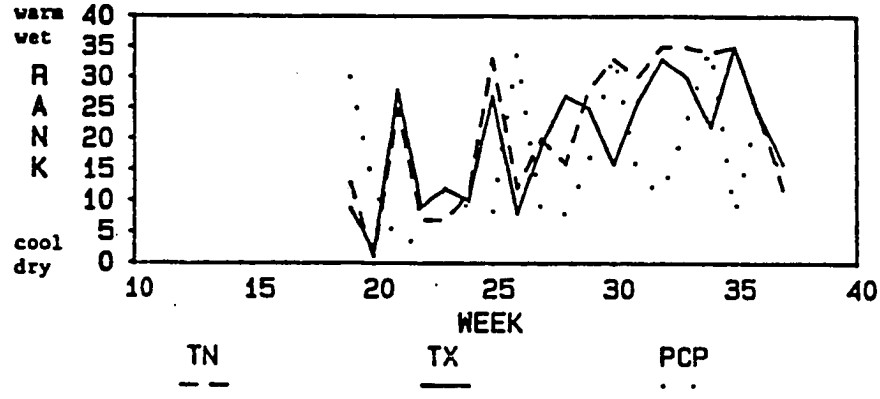
COLUMBUS WKLY WX



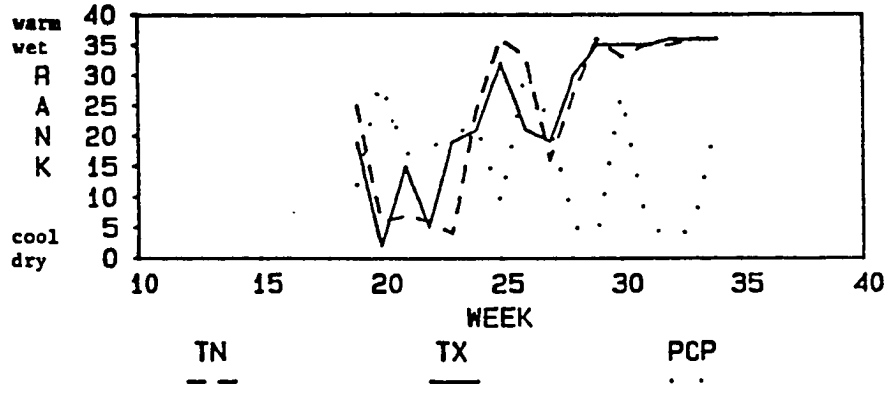
ROCHESTER WKLY WX



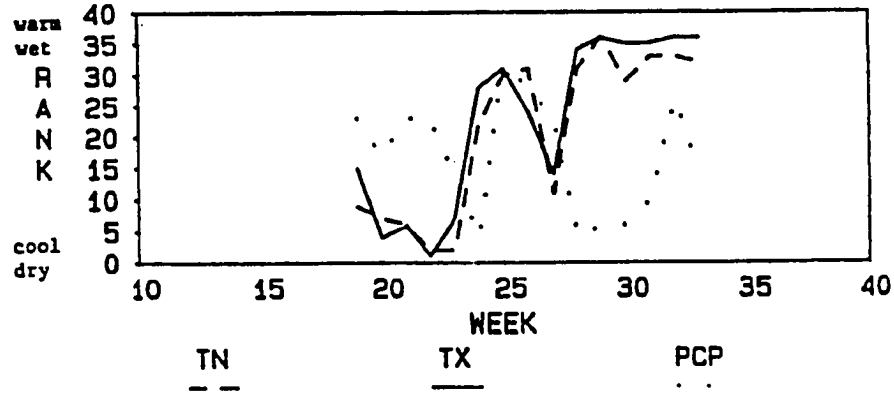
RAPID CITY WKLY WX



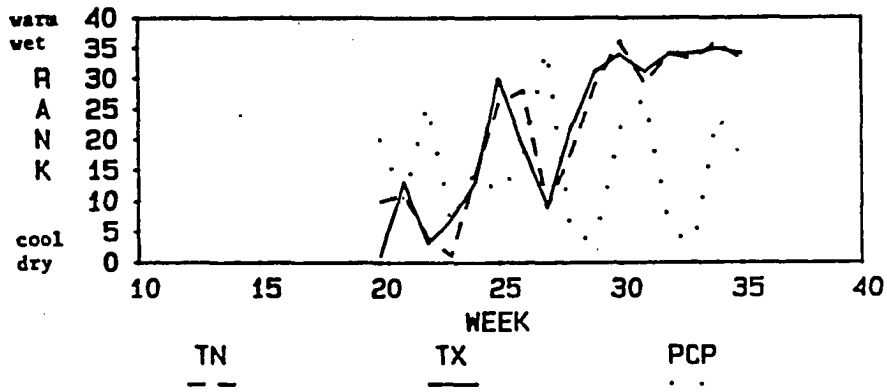
DES MOINES WKLY WX



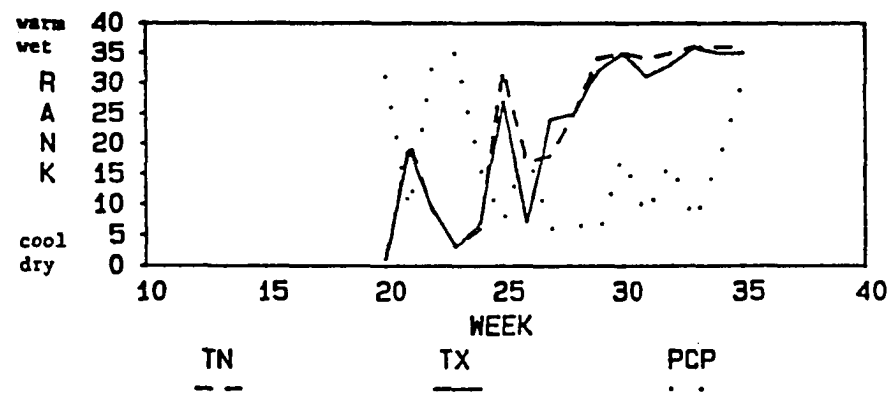
INDIANAPOLIS WKLY WX



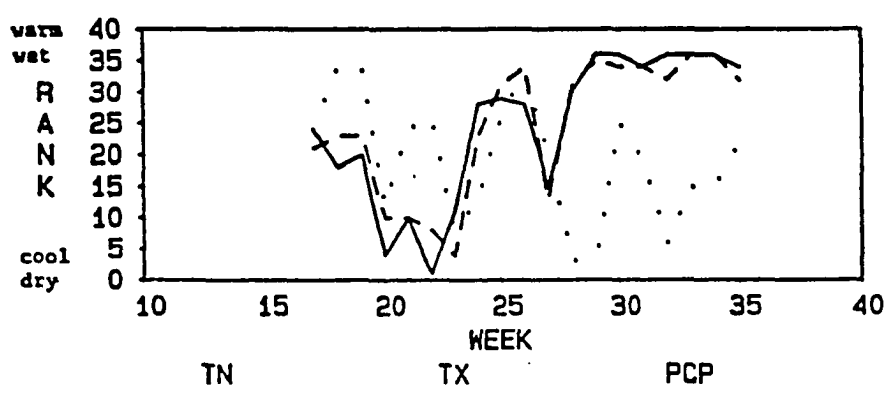
SPRINGFIELD WKLY WX



DODGE CITY WKLY WX



PEORIA WKLY WX



Appendix D

STATISTICAL RESULTS FOR INPUT SERIES 1 THROUGH 5 (TABLE 15) FOR SEVEN SENSITIVITY ANALYSIS SITES ACROSS THE U.S.A. CORN-BELT.

Statistical Results for Input Series 1 (see Table 15)
at Rapid City, SD

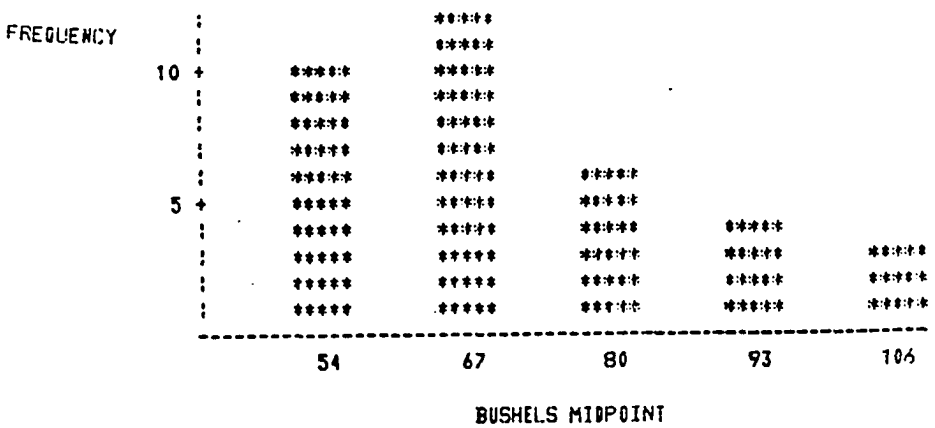
OBS	YEAR	BUSHELS
1	59	47.20
2	74	49.34
3	61	49.99
4	70	52.99
5	64	53.78
6	55	55.22
7	57	55.38
8	60	56.28
9	63	57.06
10	49	58.18
11	83	60.96
12	65	62.98
13	54	65.18
14	75	65.32
15	67	66.06
16	68	66.06
17	73	70.30
18	52	71.03
19	71	71.33
20	72	71.33
21	80	71.41
22	76	72.92
23	53	76.08
24	62	77.07
25	78	78.25
26	79	79.88
27	69	84.71
28	58	85.80
29	77	88.79
30	81	94.01
31	82	94.01
32	56	97.43
33	66	109.36
34	50	112.67
35	51	112.67

MEAN	STANDARD DEVIATION
72.60085714	17.97094998

MINIMUM VALUE	MAXIMUM VALUE
47.20000000	112.67000000

STD ERROR OF MEAN	SUM
3.03764497	2541.0300000

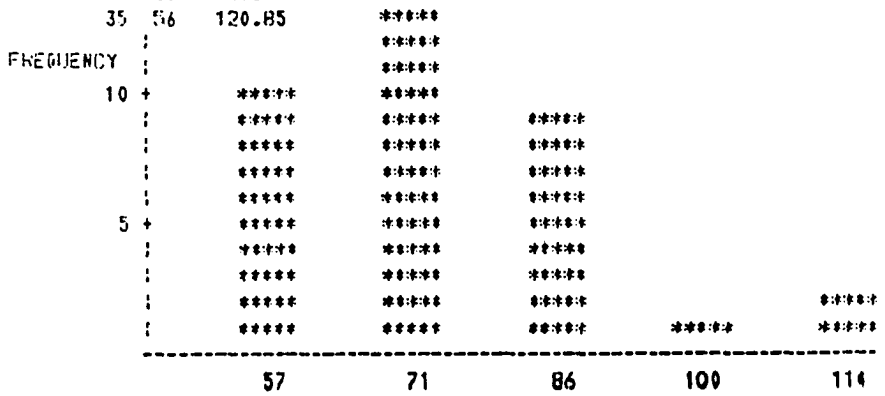
VARIANCE	C.V.
322.95504336	24.753



Statistical Results for Input Series 2 (see Table 15)
at Rapid City, SD

OBS	YEAR	BUSHELS
1	59	50.07
2	64	53.67
3	74	54.86
4	57	55.19
5	61	56.43
6	70	57.07
7	67	57.90
8	75	58.89
9	65	59.10
10	49	60.57
11	55	64.92
12	63	66.06
13	71	66.65
14	60	66.91
15	83	68.35
16	80	68.68
17	54	70.39
18	53	72.75
19	69	72.88
20	76	72.89
21	73	74.05
22	62	74.54
23	68	78.34
24	78	78.67
25	79	78.69
26	52	79.07
27	51	79.95
28	58	88.99
29	66	92.14
30	82	92.43
31	72	92.68
32	77	92.96
33	81	98.75
34	50	109.47
35	56	120.85

MEAN	STANDARD DEVIATION
73.88028571	16.54709669
MINIMUM VALUE	**MAXIMUM VALUE**
50.07000000	120.85000000
STD ERROR OF MEAN	**SUM**
2.79696983	2585.8100000
VARIANCE	**C.V.**
273.80640874	22.397



Statistical Results for Input Series 3 (see Table 15)
at Rapid City, SD

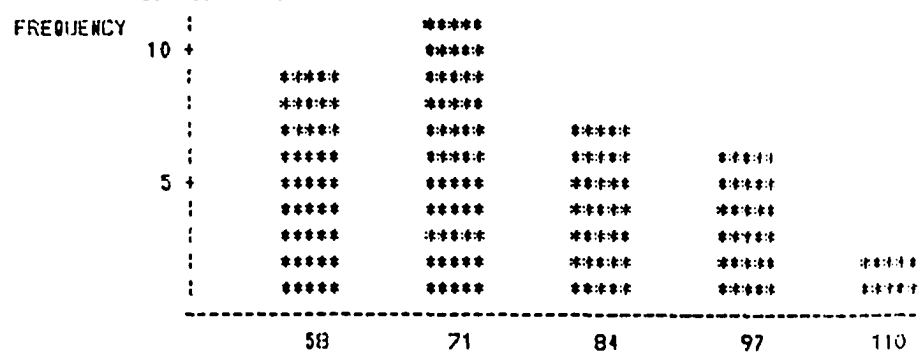
OBS	YEAR	BUSHELS
1	57	51.20
2	65	53.09
3	64	53.96
4	70	54.77
5	67	59.93
6	83	60.05
7	63	60.39
8	59	62.01
9	55	62.86
10	75	65.78
11	60	66.31
12	49	66.46
13	74	69.28
14	62	71.04
15	54	71.31
16	80	72.29
17	76	72.84
18	51	74.27
19	82	74.98
20	73	76.98
21	61	78.58
22	52	82.13
23	53	82.86
24	79	82.96
25	69	84.64
26	58	86.19
27	78	87.35
28	71	92.45
29	68	93.17
30	72	93.17
31	77	94.95
32	81	96.98
33	66	99.44
34	56	109.39
35	50	116.62

MEAN	STANDARD DEVIATION
76.59085714	16.28744958

MINIMUM VALUE	MAXIMUM VALUE
51.20000000	116.62000000

STD ERROR OF MEAN	SUM
2.75308146	2680.68000000

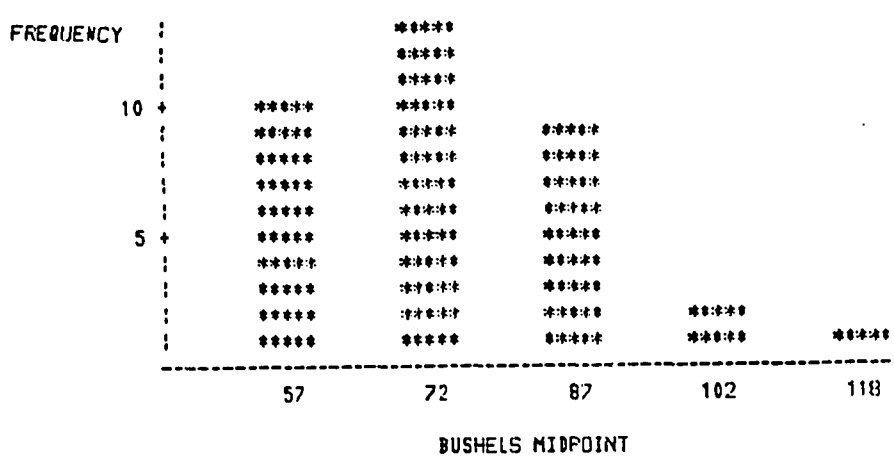
VARIANCE	C.V.
265.28101395	21.266



Statistical Results for Input Series 4 (see Table 15)
at Rapid City, SD

OBS	YEAR	BUSHELS
1	74	49.37
2	65	54.57
3	70	54.68
4	64	55.12
5	75	57.56
6	71	58.13
7	57	58.82
8	61	60.49
9	67	60.81
10	59	60.89
11	49	64.59
12	73	64.86
13	55	65.16
14	60	67.67
15	83	68.51
16	63	71.45
17	69	71.49
18	76	72.90
19	62	73.48
20	54	73.90
21	51	74.17
22	80	74.76
23	53	74.95
24	52	80.15
25	79	80.94
26	68	82.19
27	50	83.68
28	72	85.80
29	78	87.11
30	58	87.82
31	82	88.14
32	77	92.24
33	81	99.47
34	66	106.51
35	56	125.24

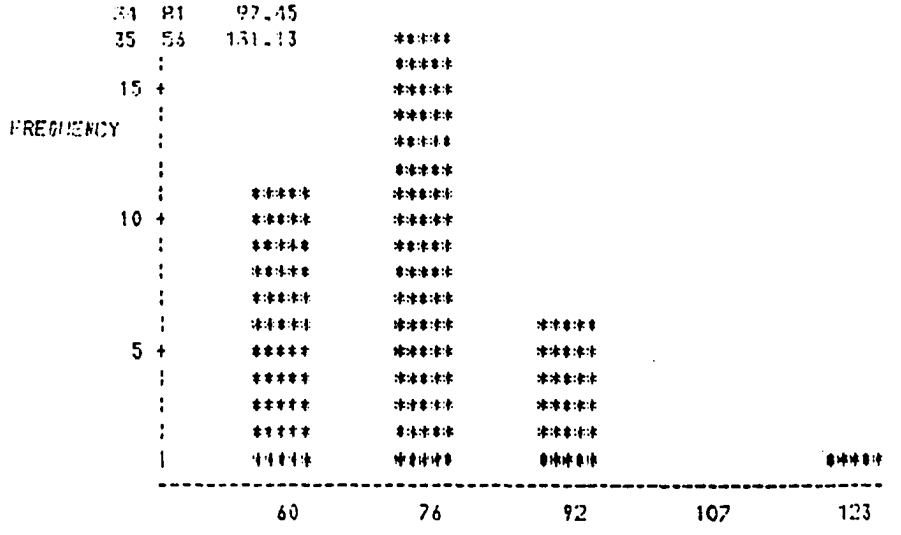
MEAN	STANDARD DEVIATION
73.93200000	16.21868672
MINIMUM VALUE	**MAXIMUM VALUE**
49.37000000	125.24000000
STD ERROR OF MEAN	**SUM**
2.74145842	2587.6200000
VARIANCE	**C.V.**
263.04579882	21.937



Statistical Results for Input Series 5 (see Table 15)
at Rapid City, SD

OBS	YEAR	BUSHELS
1	65	52.20
2	57	53.62
3	64	55.89
4	70	56.55
5	71	58.64
6	75	58.89
7	74	59.67
8	67	59.79
9	59	62.03
10	49	66.86
11	68	66.93
12	51	69.61
13	63	69.63
14	55	71.37
15	69	71.49
16	62	71.90
17	80	72.57
18	82	72.77
19	76	72.84
20	83	72.92
21	73	73.52
22	60	73.89
23	54	75.95
24	61	76.66
25	53	78.19
26	79	81.44
27	52	81.87
28	72	82.66
29	78	87.35
30	58	88.14
31	50	91.91
32	77	94.31
33	66	96.32
34	81	97.45
35	56	131.13

MEAN	STANDARD DEVIATION
74.48885714	15.66205508
MINIMUM VALUE	**MAXIMUM VALUE**
52.20000000	131.13000000
STD ERROR OF MEAN	**SUM**
2.64737050	2607.1100000
VARIANCE	**C.V.**
245.29996924	21.026



Statistical Results for Input Series 1 (see Table 15)
at Dodge City, KS

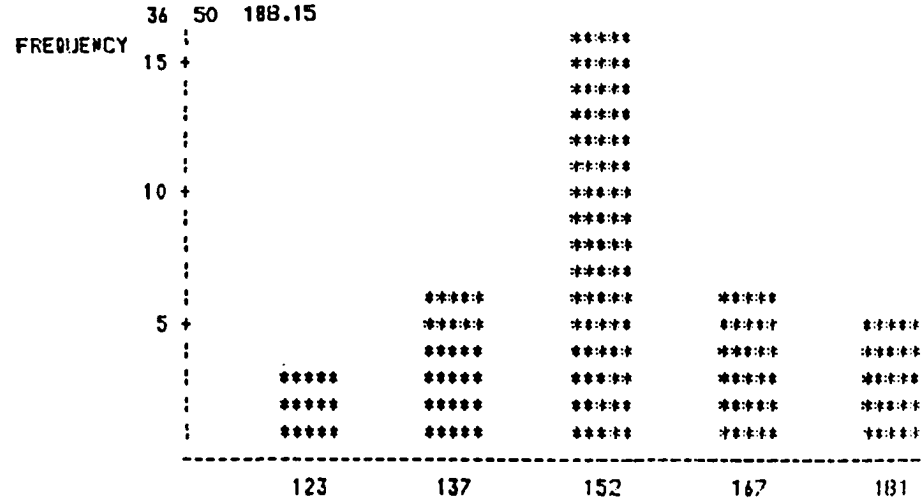
OBS	YEAR	BUSHELS
1	55	115.51
2	51	118.15
3	69	126.45
4	82	131.79
5	81	133.88
6	66	136.59
7	56	141.38
8	65	141.77
9	49	144.28
10	57	145.88
11	54	147.65
12	58	147.83
13	75	148.65
14	83	148.84
15	62	149.25
16	61	150.45
17	73	150.77
18	59	153.43
19	77	153.46
20	72	154.34
21	70	155.33
22	80	155.95
23	48	156.37
24	53	157.93
25	63	159.11
26	68	160.31
27	52	161.53
28	60	166.75
29	74	168.60
30	76	170.24
31	64	172.97
32	78	174.24
33	71	177.25
34	79	182.28
35	67	187.65
36	50	188.15

MEAN	STANDARD DEVIATION
153.75027778	17.37896355

MINIMUM VALUE	MAXIMUM VALUE
115.51000000	188.15000000

STD ERROR OF MEAN	SUM
2.89649393	5535.0100000

VARIANCE	C.V.
302.02837421	11.303



Statistical Results for Input Series 2 (see Table 15)
at Dodge City, KS

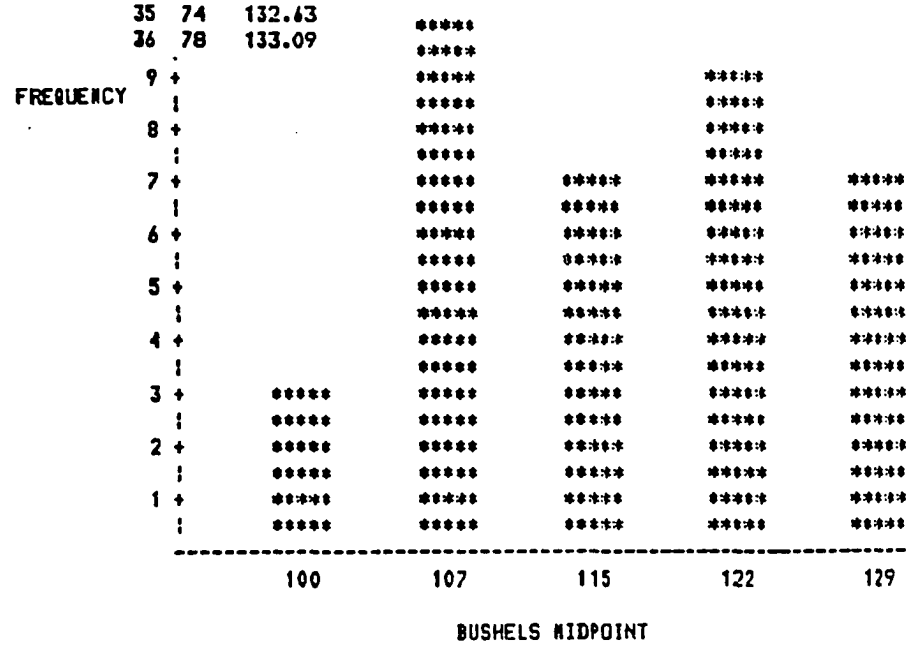
OBS	YEAR	BUSHELS
1	55	96.32
2	69	102.26
3	57	102.34
4	73	105.06
5	82	106.13
6	51	106.84
7	83	107.13
8	70	108.98
9	59	108.99
10	75	109.00
11	62	109.27
12	49	110.09
13	56	110.87
14	58	113.78
15	60	114.47
16	79	114.98
17	63	115.13
18	54	115.79
19	76	115.88
20	48	116.18
21	68	118.75
22	53	118.95
23	65	120.01
24	80	120.49
25	81	122.41
26	52	122.64
27	72	123.30
28	64	124.07
29	61	125.13
30	67	126.88
31	71	127.60
32	77	129.99
33	66	130.44
34	50	130.50
35	74	132.63
36	78	133.09

MEAN	STANDARD DEVIATION
116.56583333	9.51608604

MINIMUM VALUE	MAXIMUM VALUE
96.32000000	133.09000000

STD ERROR OF MEAN	SUM
1.58601434	4196.3700000

VARIANCE	C.V.
90.55589357	8.164



Statistical Results for Input Series 3 (see Table 15)
at Dodge City, KS

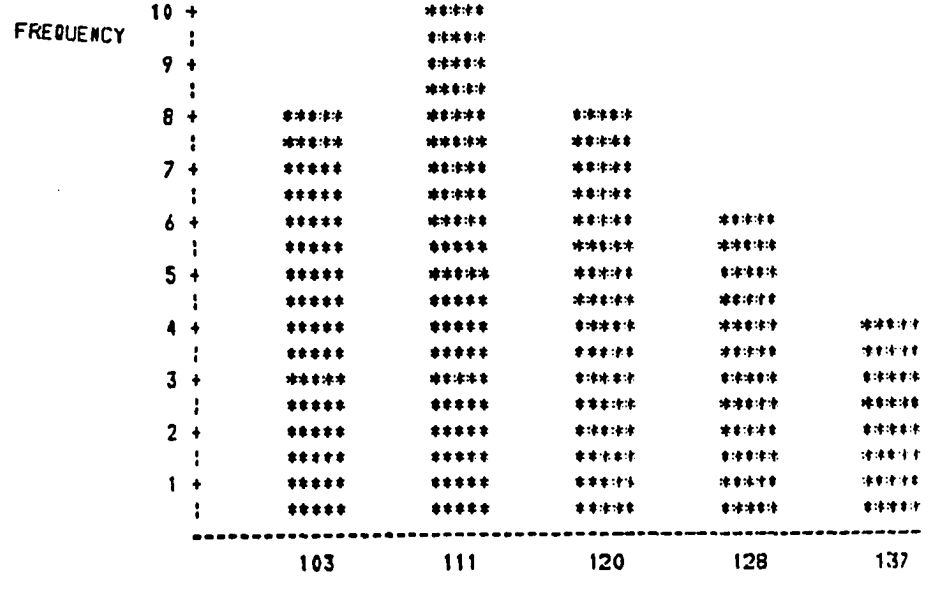
OBS	YEAR	BUSHELS
1	83	98.16
2	55	98.26
3	54	102.94
4	73	103.12
5	80	104.72
6	70	105.01
7	56	105.14
8	62	106.84
9	63	107.61
10	69	108.70
11	59	109.04
12	82	109.19
13	57	109.52
14	51	110.73
15	58	112.01
16	77	112.92
17	49	113.67
18	76	114.91
19	52	116.00
20	75	116.80
21	60	118.27
22	53	118.80
23	48	118.94
24	81	120.51
25	64	122.86
26	66	123.33
27	65	125.05
28	71	125.91
29	79	126.99
30	72	129.17
31	61	129.87
32	78	130.17
33	68	132.87
34	74	137.50
35	50	137.72
36	67	141.16

MEAN	STANDARD DEVIATION
116.78916667	11.43890938

MINIMUM VALUE	MAXIMUM VALUE
98.16000000	141.16000000

STD ERROR OF MEAN	SUM
1.90648490	4204.4100000

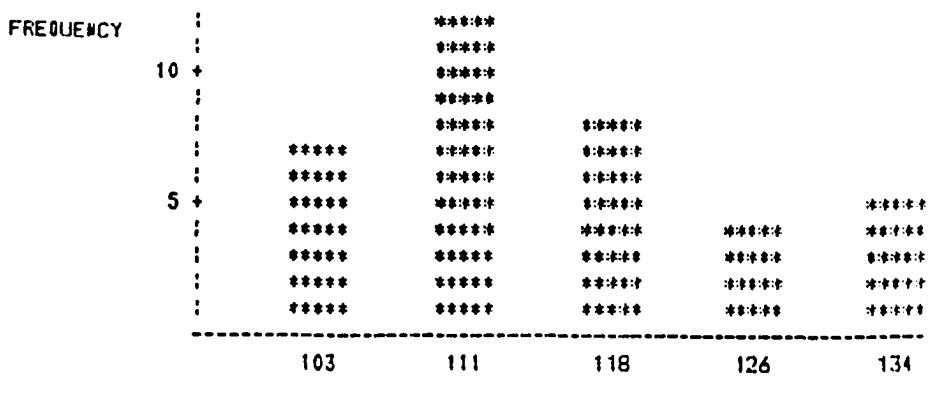
VARIANCE	C.V.
130.84864786	9.794



Statistical Results for Input Series 4 (see Table 15)
at Dodge City, KS

OBS	YEAR	BUSHELS
1	55	99.01
2	51	102.58
3	69	102.78
4	73	103.47
5	70	104.23
6	57	105.47
7	83	105.50
8	56	108.13
9	60	108.24
10	54	108.82
11	49	109.41
12	59	109.88
13	62	109.95
14	58	110.41
15	82	110.77
16	75	111.77
17	61	112.02
18	76	112.16
19	72	114.17
20	63	116.45
21	67	117.57
22	79	117.57
23	65	118.25
24	80	119.12
25	48	119.18
26	53	119.36
27	50	120.16
28	81	122.27
29	64	122.63
30	52	124.70
31	68	126.13
32	66	130.51
33	78	130.94
34	77	131.06
35	71	131.79
36	74	137.50

MEAN	STANDARD DEVIATION
115.38777778	9.62237248
MINIMUM VALUE	**MAXIMUM VALUE**
99.01000000	137.50000000
STD ERROR OF MEAN	**SUM**
1.60372875	4153.9600000
VARIANCE	**C.V.**
92.59005206	8.339



Statistical Results for Input Series 5 (see Table 15)
at Dodge City, KS

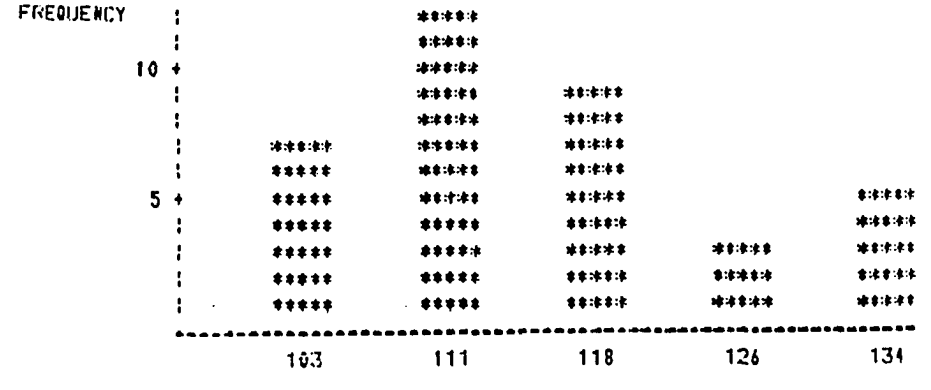
OBS	YEAR	BUSHELS
1	55	99.04
2	70	101.17
3	69	103.29
4	83	103.43
5	51	103.55
6	73	103.81
7	57	105.01
8	62	108.07
9	59	108.92
10	75	109.77
11	56	109.78
12	49	109.85
13	58	110.41
14	54	110.70
15	82	110.85
16	61	111.26
17	76	112.43
18	60	112.60
19	72	113.53
20	63	116.23
21	65	116.77
22	67	117.57
23	80	117.72
24	48	118.17
25	79	119.03
26	50	119.97
27	53	121.08
28	81	121.66
29	64	122.92
30	68	126.04
31	52	126.22
32	66	130.75
33	71	130.97
34	77	131.62
35	78	133.44
36	74	137.50

MEAN	STANDARD DEVIATION
115.42027778	9.86366796

MINIMUM VALUE	MAXIMUM VALUE
99.04000000	137.50000000

STD ERROR OF MEAN	SUM
1.64394466	4155.1300000

VARIANCE	C.V.
97.29194563	8.546



Statistical Results for Input Series 1 (see Table 15)
at Springfield, MO

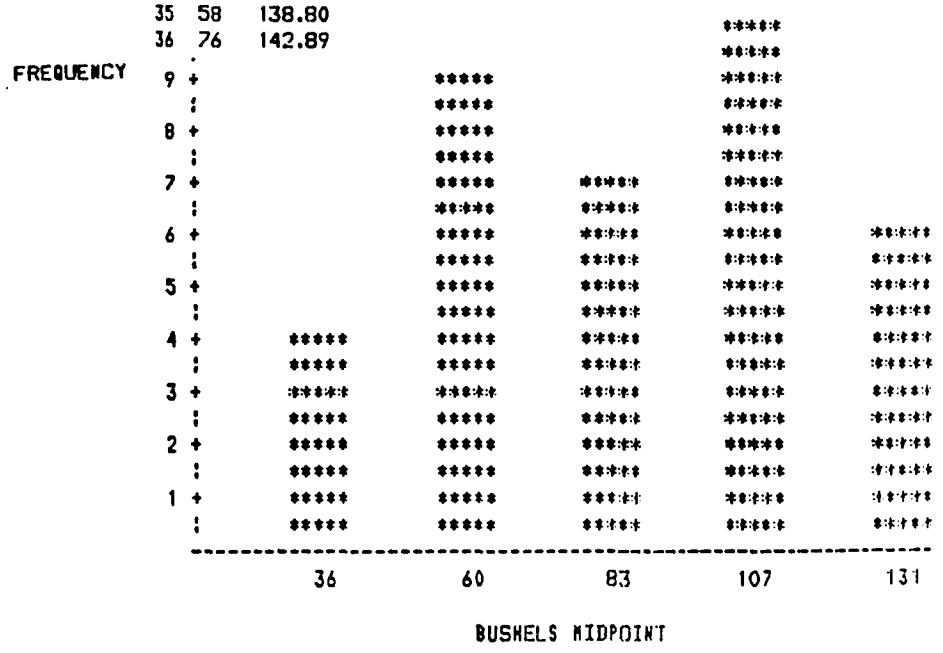
OBS	YEAR	BUSHELS
1	53	23.83
2	54	35.78
3	52	36.54
4	80	37.88
5	69	52.14
6	64	55.39
7	82	55.86
8	72	61.17
9	57	61.81
10	75	63.10
11	62	63.34
12	77	65.91
13	51	66.91
14	83	71.78
15	71	73.83
16	65	74.77
17	70	78.74
18	49	80.72
19	55	88.96
20	63	93.22
21	61	96.32
22	74	98.53
23	73	98.62
24	56	98.85
25	81	100.49
26	48	103.35
27	60	106.11
28	67	108.40
29	59	109.16
30	78	115.22
31	66	122.71
32	79	131.75
33	50	133.56
34	68	138.19
35	58	138.80
36	76	142.89

MEAN	STANDARD DEVIATION
85.68416667	31.89661150

MINIMUM VALUE	MAXIMUM VALUE
23.83000000	142.89000000

STD ERROR OF MEAN	SUM
5.31610192	3084.6300000

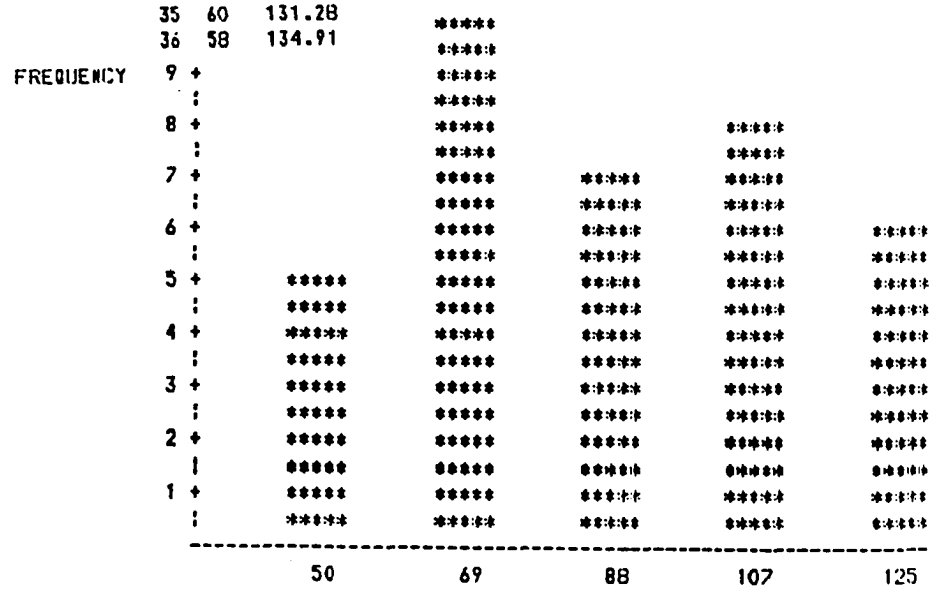
VARIANCE	C.V.
1017.3938250	37.226



Statistical Results for Input Series 2 (see Table 15)
at Springfield, MO

OBS	YEAR	BUSHELS
1	53	40.78
2	69	48.94
3	80	50.48
4	64	52.54
5	75	59.02
6	54	60.16
7	52	62.90
8	57	63.23
9	49	65.92
10	65	66.91
11	82	68.26
12	62	68.37
13	51	75.34
14	83	76.45
15	77	77.21
16	74	79.42
17	81	86.35
18	48	86.81
19	73	86.96
20	70	87.49
21	56	91.17
22	71	96.62
23	67	98.66
24	63	100.49
25	55	100.76
26	79	100.79
27	50	101.70
28	61	103.10
29	59	111.10
30	76	114.12
31	78	116.60
32	66	119.45
33	72	122.81
34	68	128.29
35	60	131.28
36	58	134.91

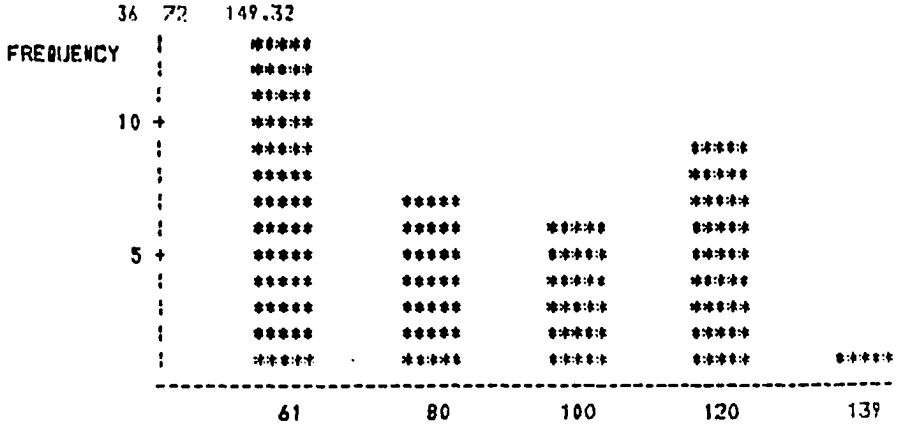
MEAN	STANDARD DEVIATION
87.09416667	25.33984208
MINIMUM VALUE	**MAXIMUM VALUE**
40.78000000	134.91000000
STD ERROR OF MEAN	**SUM**
4.22330701	3135.3900000
VARIANCE	**C.V.**
642.10759643	29.095



Statistical Results for Input Series 3 (see Table 15)
at Springfield, MO

OBS	YEAR	BUSHELS
1	69	50.67
2	53	51.48
3	64	52.04
4	57	53.71
5	80	56.87
6	52	59.50
7	49	62.68
8	77	62.69
9	51	62.93
10	75	63.87
11	54	67.94
12	62	68.28
13	82	69.28
14	81	72.14
15	65	73.12
16	83	76.17
17	74	78.99
18	48	87.77
19	63	88.06
20	70	88.57
21	50	94.41
22	73	95.44
23	55	95.68
24	79	95.73
25	56	100.74
26	59	101.48
27	67	110.86
28	61	111.16
29	71	112.55
30	76	113.81
31	78	117.61
32	66	126.28
33	58	126.66
34	60	127.73
35	68	128.52
36	72	149.32

MEAN	STANDARD DEVIATION
87.63166667	26.72904440
MINIMUM VALUE	**MAXIMUM VALUE**
50.67000000	149.32000000
STD ERROR OF MEAN	**SUM**
4.45484073	3154.7400000
VARIANCE	**C.V.**
714.44181429	30.502



Statistical Results for Input Series 4 (see Table 15)
at Springfield, MO

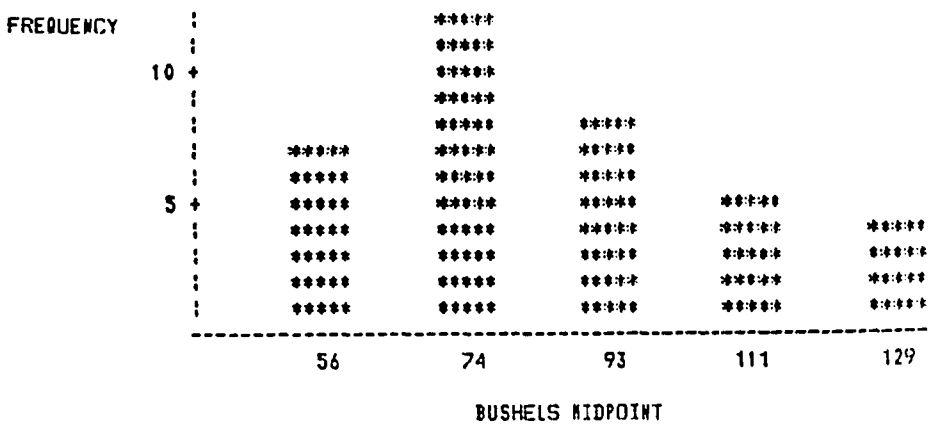
OBS	YEAR	BUSHELS
1	69	46.66
2	64	54.05
3	53	54.08
4	80	54.95
5	52	61.63
6	54	63.21
7	72	64.01
8	75	66.84
9	62	68.12
10	82	68.13
11	65	68.32
12	57	68.51
13	51	71.36
14	83	72.35
15	74	73.43
16	49	79.03
17	77	79.16
18	61	80.40
19	70	82.59
20	55	83.94
21	50	83.96
22	73	90.51
23	67	91.36
24	71	91.53
25	59	98.14
26	76	99.18
27	48	101.40
28	81	105.66
29	63	106.38
30	56	107.56
31	60	117.08
32	66	117.35
33	68	120.57
34	79	120.91
35	78	125.08
36	58	138.42

MEAN	STANDARD DEVIATION
85.44055556	23.30500743

MINIMUM VALUE	MAXIMUM VALUE
46.66000000	138.42000000

STD ERROR OF MEAN	SUM
3.88416790	3075.8600000

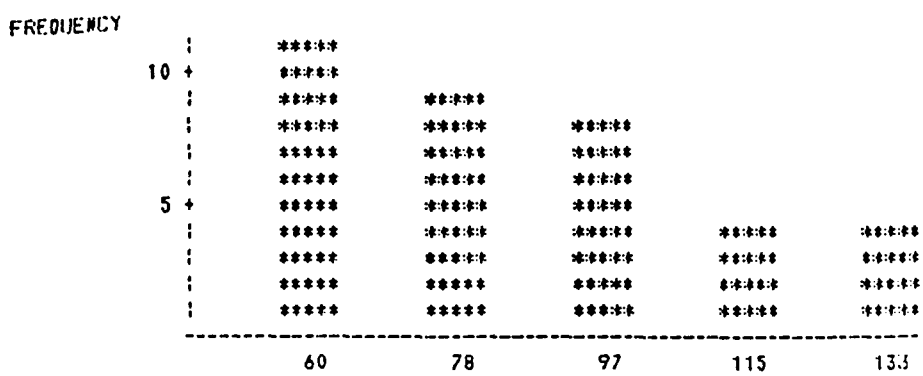
VARIANCE	C.V.
543.12337111	27.276



Statistical Results for Input Series 5 (see Table 15)
at Springfield, MO

OBS	YEAR	BUSHELS
1	69	50.64
2	64	51.81
3	74	56.46
4	57	62.90
5	75	63.52
6	80	64.68
7	53	65.69
8	51	65.84
9	49	66.57
10	82	67.34
11	65	67.46
12	62	69.77
13	83	76.32
14	52	76.83
15	50	80.88
16	77	81.06
17	54	82.95
18	70	83.58
19	81	84.86
20	73	86.96
21	48	88.16
22	55	95.68
23	79	96.91
24	76	98.25
25	67	99.26
26	61	100.50
27	59	101.44
28	63	103.68
29	71	107.15
30	56	107.98
31	68	120.10
32	66	120.47
33	58	126.66
34	78	131.07
35	60	141.47
36	72	142.58

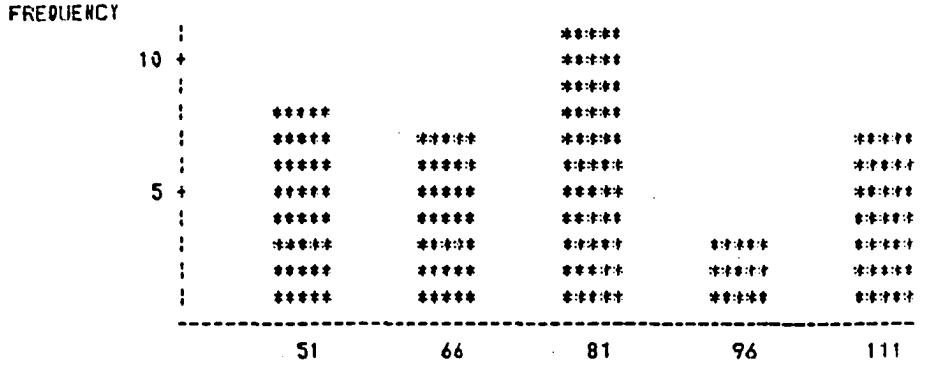
MEAN	STANDARD DEVIATION
88.54111111	24.78433789
MINIMUM VALUE	**MAXIMUM VALUE**
50.64000000	142.58000000
STD ERROR OF MEAN	**SUM**
4.13072298	3187.4800000
VARIANCE	**C.V.**
614.26340444	27.992



Statistical Results for Input Series 1 (see Table 15)
at Des Moines, IO

OBS	YEAR	BUSHELS
1	74	43.25
2	80	43.79
3	83	46.12
4	75	50.01
5	54	51.62
6	57	55.56
7	55	56.10
8	65	56.53
9	73	64.88
10	77	68.64
11	62	70.20
12	56	70.50
13	64	71.37
14	82	72.78
15	49	73.11
16	69	74.89
17	70	75.78
18	66	75.89
19	59	76.10
20	51	76.82
21	81	77.59
22	79	77.94
23	78	78.73
24	53	82.39
25	76	85.42
26	67	86.80
27	71	89.80
28	72	90.10
29	60	90.18
30	58	103.92
31	63	106.69
32	68	108.27
33	61	109.21
34	48	112.38
35	50	112.87
36	52	118.64

MEAN	STANDARD DEVIATION
77.91305556	20.58759000
MINIMUM VALUE	**MAXIMUM VALUE**
43.25000000	118.64000000
STD ERROR OF MEAN	**SUM**
3.43126500	2804.8700000
VARIANCE	**C.V.**
423.84886183	26.424



Statistical Results for Input Series 2 (see Table 15)
at Des Moines, IO

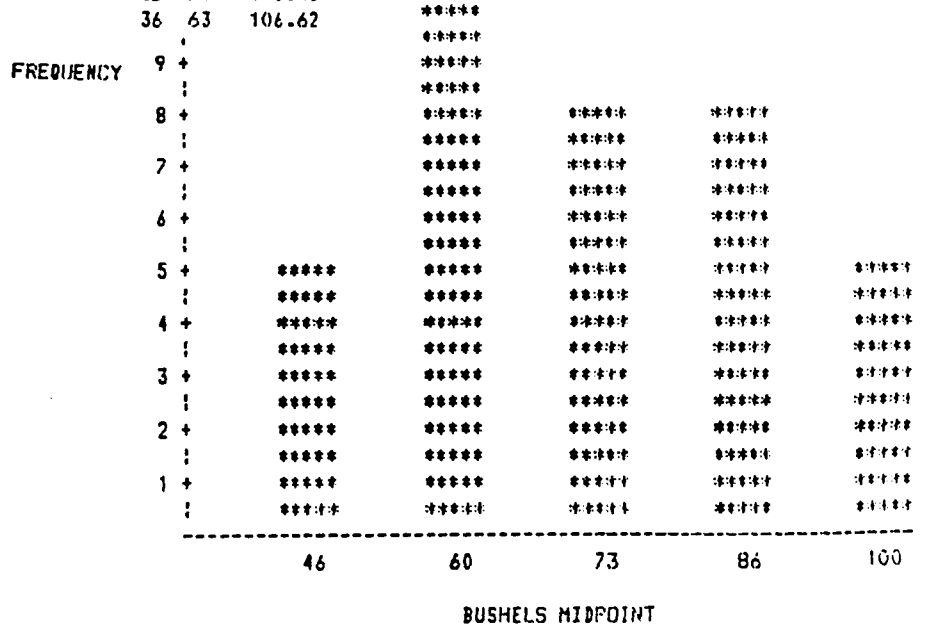
OBS	YEAR	BUSHELS
1	54	39.48
2	74	43.88
3	80	48.80
4	85	51.90
5	75	51.92
6	51	56.03
7	69	56.53
8	57	57.59
9	65	58.36
10	55	60.36
11	72	60.59
12	60	63.11
13	64	65.46
14	67	65.97
15	66	66.02
16	79	69.77
17	76	75.36
18	59	77.05
19	82	77.47
20	81	77.53
21	73	77.54
22	77	79.09
23	61	79.39
24	62	80.56
25	78	80.77
26	58	80.90
27	68	84.76
28	50	84.99
29	53	86.58
30	49	87.99
31	56	88.79
32	70	94.61
33	52	96.03
34	48	98.60
35	71	100.43
36	63	106.62

MEAN	STANDARD DEVIATION
73.07861111	16.77710739

MINIMUM VALUE	MAXIMUM VALUE
39.48000000	106.62000000

STD ERROR OF MEAN	SUM
2.79618456	2630.8300000

VARIANCE	C.V.
291.47143230	22.958



Statistical Results for Input Series 3 (see Table 15)
at Des Moines, IO

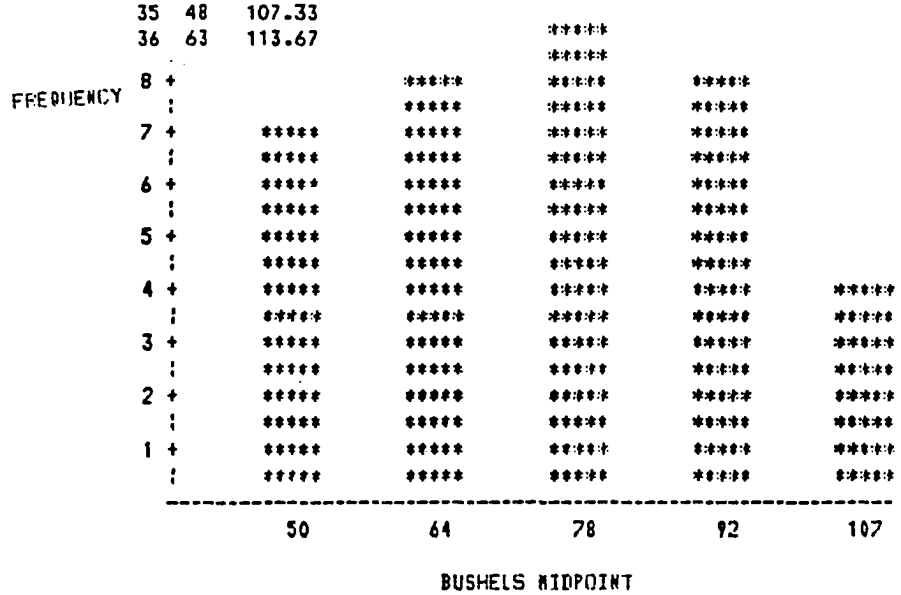
OBS	YEAR	BUSHELS
1	74	42.36
2	54	42.37
3	80	45.16
4	83	46.11
5	75	53.84
6	55	54.76
7	57	56.28
8	73	57.52
9	65	58.54
10	66	62.84
11	62	66.09
12	64	66.14
13	69	66.88
14	82	67.77
15	51	68.02
16	77	73.27
17	60	73.81
18	79	75.00
19	76	75.36
20	78	76.95
21	81	76.97
22	59	77.58
23	67	81.29
24	70	81.91
25	58	85.33
26	49	87.42
27	53	87.76
28	56	88.65
29	72	90.24
30	50	90.93
31	52	93.15
32	61	99.43
33	71	99.69
34	68	104.84
35	48	107.33
36	63	113.67

MEAN	STANDARD DEVIATION
74.86833333	18.73172260

MINIMUM VALUE	MAXIMUM VALUE
42.36000000	113.67000000

STD ERROR OF MEAN	SUM
3.12195377	2695.2600000

VARIANCE	C.V.
350.87743143	25.020



Statistical Results for Input Series 4 (see Table 15)
at Des Moines, IO

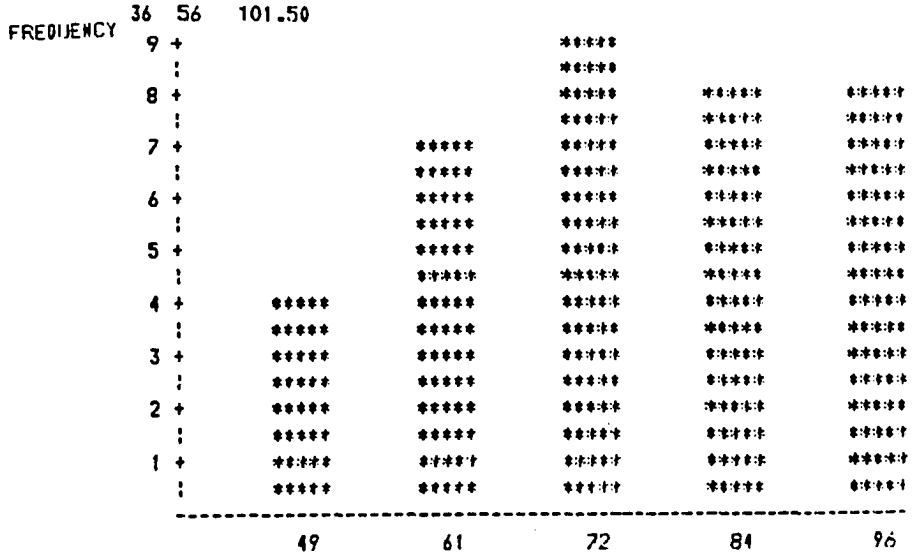
OBS	YEAR	BUSHELS
1	74	43.24
2	83	49.44
3	80	50.60
4	54	52.41
5	57	55.32
6	65	56.01
7	55	56.36
8	75	58.45
9	60	61.77
10	67	61.81
11	66	65.06
12	51	67.88
13	64	68.33
14	59	72.29
15	69	73.25
16	72	73.36
17	79	74.26
18	78	74.67
19	76	75.65
20	82	77.33
21	73	78.87
22	53	80.49
23	49	82.73
24	81	83.30
25	50	84.21
26	62	85.08
27	58	85.24
28	61	85.30
29	52	91.03
30	71	91.77
31	70	92.19
32	68	93.03
33	77	95.76
34	48	96.66
35	63	99.90
36	56	101.50

MEAN	STANDARD DEVIATION
74.84305556	15.72428255

MINIMUM VALUE	MAXIMUM VALUE
43.24000000	101.50000000

STD ERROR OF MEAN	SUM
2.62071376	2694.3500000

VARIANCE	C.V.
247.25306183	21.010



Statistical Results for Input Series 5 (see Table 15)
at Des Moines, IO

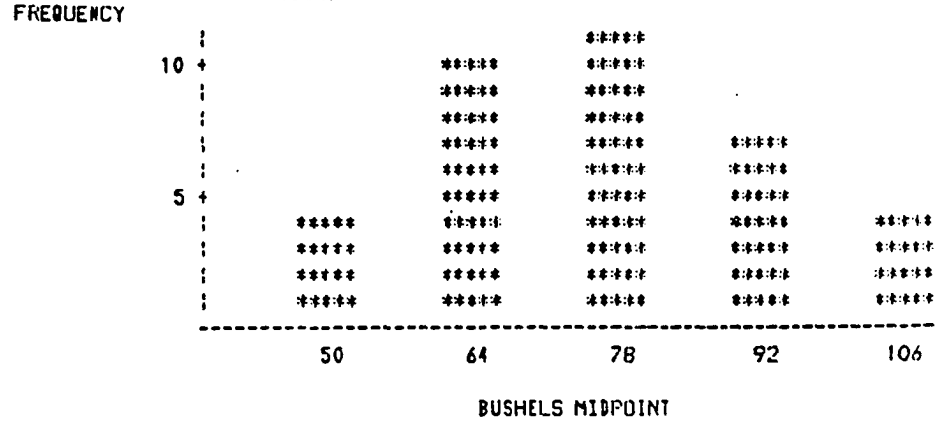
OBS	YEAR	BUSHELS
1	74	42.51
2	54	48.12
3	80	49.99
4	83	52.33
5	57	57.21
6	65	57.69
7	75	58.58
8	60	58.65
9	51	60.71
10	55	60.72
11	66	62.51
12	67	63.25
13	64	64.19
14	69	66.39
15	59	71.65
16	79	73.09
17	72	73.21
18	76	75.36
19	82	76.16
20	73	78.87
21	50	83.10
22	81	83.15
23	52	83.69
24	58	84.08
25	62	84.89
26	61	85.30
27	78	86.32
28	53	92.57
29	68	93.03
30	70	93.26
31	48	96.07
32	49	96.23
33	71	100.43
34	77	102.07
35	56	113.38
36	63	113.49

MEAN	STANDARD DEVIATION
76.17361111	18.33546340

MINIMUM VALUE	MAXIMUM VALUE
42.51000000	113.49000000

STD ERROR OF MEAN	SUM
3.05591057	2742.25000000

VARIANCE	C.V.
336.1292[illegible]1602	24.07[illegible]



Statistical Results for Input Series 1 (see Table 15)
at Columbus, OH

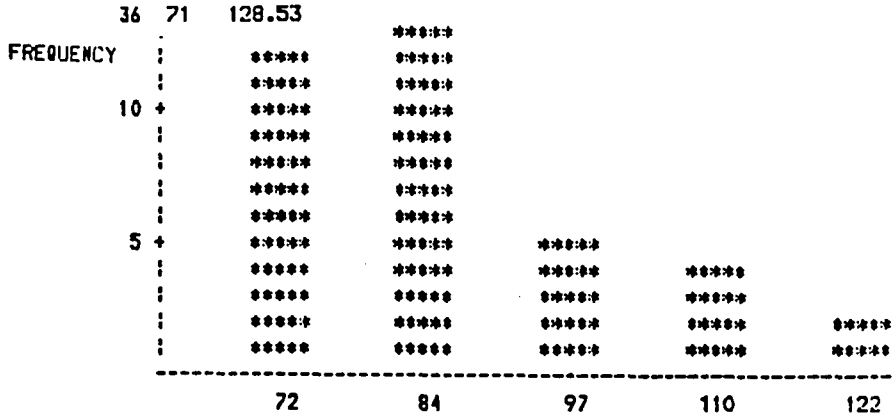
OBS	YEAR	BUSHELS
1	55	61.33
2	75	65.50
3	49	67.01
4	51	68.92
5	74	71.12
6	83	72.38
7	61	72.88
8	52	73.27
9	58	73.43
10	53	74.48
11	59	74.63
12	56	77.81
13	79	78.44
14	54	78.97
15	77	78.97
16	78	80.11
17	80	80.90
18	72	80.93
19	57	81.62
20	73	84.07
21	63	84.33
22	60	87.18
23	69	88.07
24	64	88.25
25	82	89.60
26	70	92.93
27	68	94.09
28	62	97.39
29	48	97.64
30	81	102.20
31	65	103.87
32	66	104.31
33	50	110.68
34	76	115.02
35	67	123.65
36	71	128.53

MEAN	STANDARD DEVIATION
86.23638889	16.18860484

MINIMUM VALUE	MAXIMUM VALUE
61.33000000	128.53000000

STD ERROR OF MEAN	SUM
2.69810081	3104.5100000

VARIANCE	C.V.
262.07072659	18.772



Statistical Results for Input Series 2 (see Table 15)
at Columbus, OH

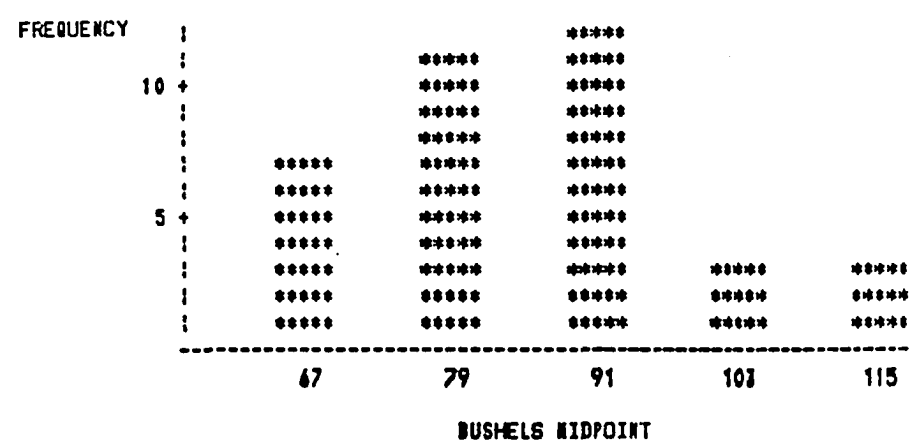
OBS	YEAR	BUSHELS
1	72	41.25
2	61	44.30
3	55	60.93
4	58	64.97
5	56	66.38
6	75	71.18
7	51	71.89
8	74	73.01
9	79	74.60
10	64	75.68
11	52	77.61
12	80	78.62
13	69	78.99
14	54	79.71
15	57	80.43
16	53	80.61
17	77	81.54
18	49	83.66
19	73	86.30
20	60	86.82
21	59	88.36
22	48	89.25
23	82	90.21
24	68	91.07
25	83	92.92
26	63	93.09
27	76	94.62
28	70	94.71
29	78	95.63
30	66	96.81
31	81	100.36
32	65	103.87
33	50	105.18
34	71	116.81
35	67	117.29
36	62	121.42

MEAN	STANDARD DEVIATION
84.72444444	17.61174615

MINIMUM VALUE	MAXIMUM VALUE
41.25000000	121.42000000

STD ERROR OF MEAN	SUM
2.93529103	3050.0800000

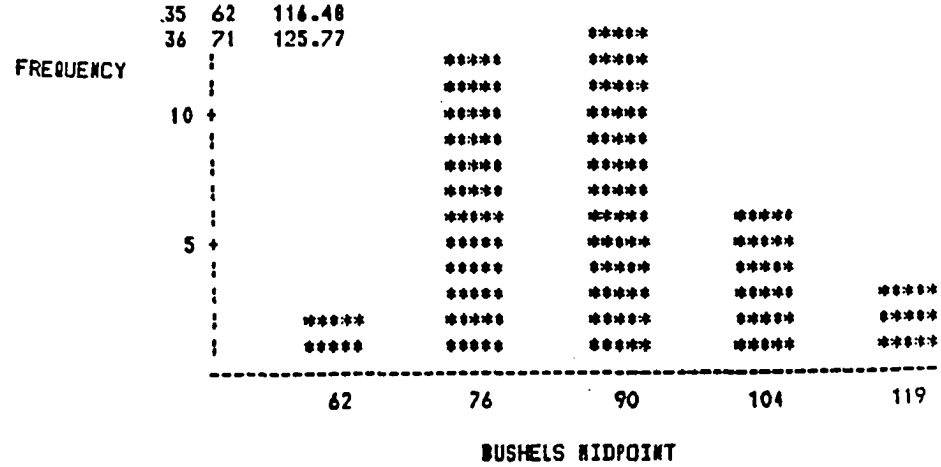
VARIANCE	C.V.
310.17360254	20.787



Statistical Results for Input Series 3 (see Table 15)
at Columbus, OH

OBS	YEAR	BUSHELS
1	49	54.54
2	55	60.86
3	80	69.23
4	75	71.15
5	58	72.06
6	73	72.14
7	74	72.46
8	56	76.68
9	72	77.12
10	83	78.65
11	78	78.69
12	61	80.37
13	77	80.48
14	60	80.82
15	51	84.17
16	68	84.55
17	52	85.26
18	59	85.63
19	70	87.10
20	54	87.71
21	82	90.16
22	57	90.30
23	69	90.69
24	64	90.96
25	53	92.19
26	79	95.51
27	81	96.90
28	48	99.16
29	66	102.90
30	65	103.56
31	63	108.22
32	67	110.22
33	50	110.41
34	76	116.30
35	62	116.48
36	71	125.77

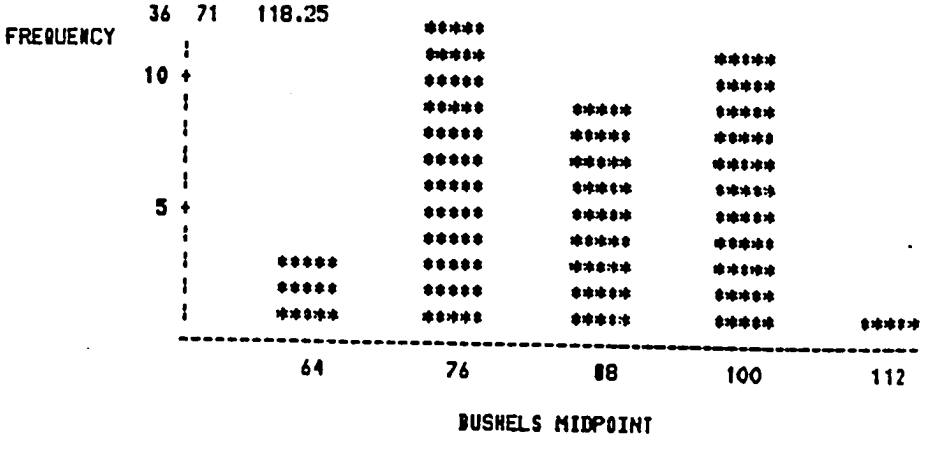
MEAN	STANDARD DEVIATION
88.31666667	16.10196386
MINIMUM VALUE	**MAXIMUM VALUE**
54.54000000	125.77000000
STD ERROR OF MEAN	**SUM**
2.68366064	3179.4000000
VARIANCE	**C.V.**
259.27324000	18.232



Statistical Results for Input Series 4 (see Table 15)
at Columbus, OH

OBS	YEAR	BUSHELS
1	61	58.16
2	55	66.86
3	72	68.72
4	74	70.21
5	58	72.35
6	75	72.80
7	69	75.54
8	51	77.25
9	52	77.96
10	54	78.07
11	77	79.90
12	64	80.20
13	56	80.21
14	78	81.27
15	60	81.61
16	63	82.09
17	80	84.15
18	49	85.22
19	59	86.57
20	48	88.17
21	82	89.48
22	73	92.20
23	67	92.37
24	83	93.72
25	76	94.20
26	68	95.30
27	79	96.04
28	62	96.07
29	66	96.23
30	50	96.31
31	53	96.53
32	57	97.79
33	81	98.38
34	70	100.14
35	65	103.56
36	71	118.25

MEAN	STANDARD DEVIATION
86.21888889	12.19034062
MINIMUM VALUE	**MAXIMUM VALUE**
58.16000000	118.25000000
STD ERROR OF MEAN	**SUM**
2.03172344	3103.8800000
VARIANCE	**C.V.**
148.60440444	14.139



Statistical Results for Input Series 5 (see Table 15)
at Columbus, OH

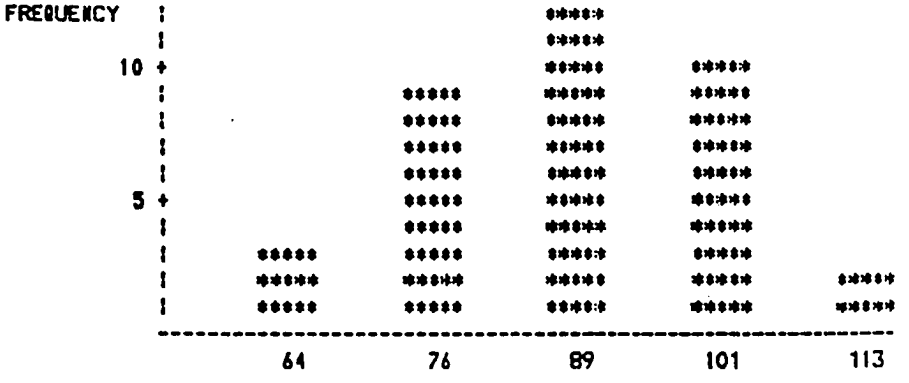
OBS	YEAR	BUSHELS
1	61	58.16
2	72	66.22
3	55	67.45
4	58	72.35
5	74	72.43
6	69	75.50
7	80	76.27
8	75	76.99
9	56	80.21
10	60	80.28
11	64	80.37
12	51	81.59
13	54	84.09
14	49	84.53
15	73	85.08
16	78	85.73
17	68	88.14
18	48	88.16
19	52	88.58
20	82	90.16
21	77	90.37
22	81	93.65
23	76	93.99
24	59	94.43
25	66	95.92
26	83	95.95
27	70	96.04
28	79	96.04
29	57	97.49
30	53	97.76
31	50	98.64
32	67	101.81
33	63	102.37
34	65	103.56
35	62	112.66
36	71	119.27

MEAN	STANDARD DEVIATION
88.11777778	12.92661642

MINIMUM VALUE	MAXIMUM VALUE
58.16000000	119.27000000

STD ERROR OF MEAN	SUM
2.15443607	3172.2400000

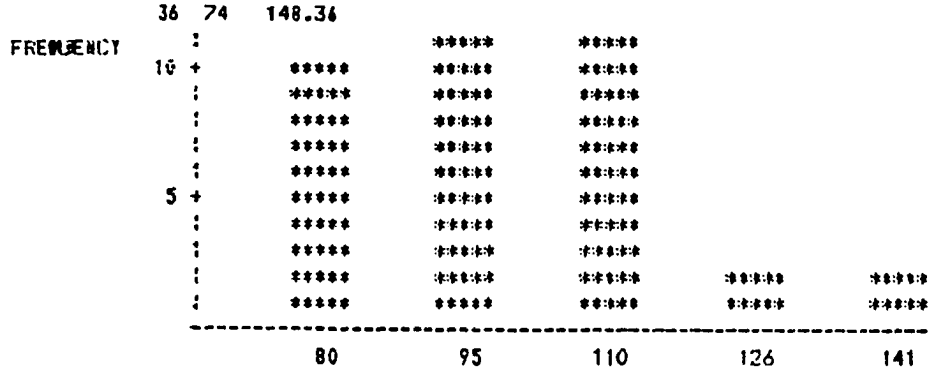
VARIANCE	C.V.
167.09741206	14.670



Statistical Results for Input Series 1 (see Table 15)
at Omaha, NB

OBS	YEAR	BUSHELS
1	83	72.36
2	80	79.28
3	57	79.63
4	66	81.08
5	64	82.47
6	54	82.94
7	56	84.66
8	69	84.85
9	65	86.87
10	55	87.38
11	62	87.90
12	51	91.61
13	49	94.88
14	73	95.62
15	82	95.92
16	79	97.16
17	53	99.05
18	75	99.98
19	52	101.31
20	70	101.53
21	63	101.61
22	68	103.03
23	48	103.41
24	72	105.86
25	78	106.45
26	59	106.51
27	58	107.60
28	61	108.72
29	71	108.94
30	60	113.73
31	77	115.54
32	76	117.68
33	81	124.77
34	50	128.14
35	67	134.03
36	74	148.36

	MEAN	STANDARD DEVIATION
	100.57944444	16.59689815
	MINIMUM VALUE	MAXIMUM VALUE
	72.36000000	148.36000000
	STD ERROR OF MEAN	SUM
	2.76614969	3620.8600000
	VARIANCE	C.V.
	275.45702825	16.501



Statistical Results for Input Series 2 (see Table 15)
at Omaha, NB

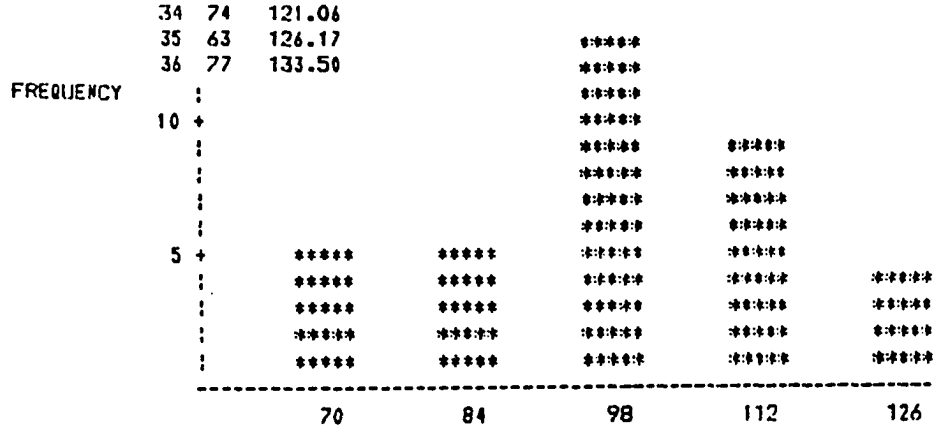
OBS	YEAR	BUSHELS
1	69	62.94
2	66	64.92
3	82	70.93
4	51	74.80
5	81	76.94
6	64	85.79
7	50	87.33
8	80	87.45
9	73	88.32
10	83	90.76
11	65	92.66
12	68	93.08
13	57	93.31
14	79	95.64
15	67	97.70
16	55	98.66
17	61	99.72
18	72	100.22
19	48	101.11
20	60	101.15
21	71	101.98
22	75	102.51
23	58	103.28
24	78	106.38
25	56	106.52
26	53	108.14
27	59	108.98
28	52	109.07
29	76	110.18
30	70	110.58
31	62	113.63
32	49	115.86
33	54	120.39
34	74	121.06
35	63	126.17
36	77	133.50

MEAN	STANDARD DEVIATION
98.93500000	16.16413587

MINIMUM VALUE	MAXIMUM VALUE
62.94000000	133.50000000

STD ERROR OF MEAN	SUM
2.69402265	3561.6600000

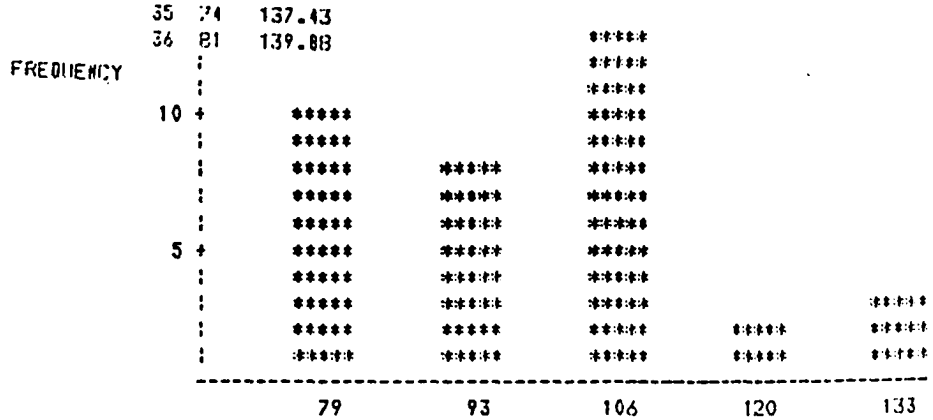
VARIANCE	C.V.
261.27928857	16.338



Statistical Results for Input Series 3 (see Table 15)
at Omaha, NB

OBS	YEAR	BUSHELS
1	55	68.42
2	80	72.57
3	64	78.87
4	54	79.38
5	57	81.76
6	83	82.02
7	56	83.18
8	66	83.28
9	69	84.25
10	53	85.84
11	62	86.35
12	65	88.96
13	51	91.58
14	63	92.50
15	75	93.55
16	78	93.70
17	49	93.85
18	73	96.04
19	79	101.78
20	77	102.36
21	52	102.65
22	58	103.05
23	68	103.95
24	70	104.93
25	61	105.03
26	72	105.69
27	48	105.79
28	59	107.24
29	82	108.16
30	71	108.70
31	60	110.56
32	76	115.02
33	50	119.58
34	67	131.58
35	74	137.43
36	81	139.88

MEAN	STANDARD DEVIATION
98.59666667	16.77387510
MINIMUM VALUE	**MAXIMUM VALUE**
68.42000000	139.88000000
STD ERROR OF MEAN	**SUM**
2.79564585	3549.4800000
VARIANCE	**C.V.**
281.36288571	17.013



Statistical Results for Input Series 4 (see Table 15)
at Omaha, NB

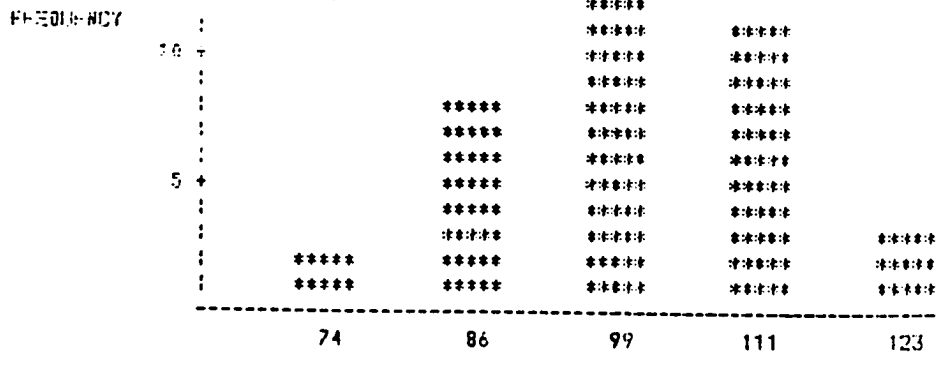
OBS	YEAR	BUSHELS
1	66	68.13
2	69	70.12
3	51	80.42
4	80	83.23
5	64	83.45
6	82	84.60
7	73	88.46
8	55	89.16
9	81	91.68
10	68	92.07
11	65	93.93
12	58	94.38
13	57	96.15
14	50	97.23
15	79	98.63
16	48	99.13
17	75	99.29
18	83	101.43
19	72	101.73
20	71	102.13
21	54	104.35
22	67	104.75
23	76	105.50
24	78	105.53
25	61	106.27
26	52	107.99
27	53	108.08
28	59	108.28
29	56	108.32
30	60	110.27
31	49	112.72
32	62	114.53
33	74	116.14
34	70	117.64
35	63	123.50
36	77	129.08

MEAN	STANDARD DEVIATION
99.95277778	13.55098154

MINIMUM VALUE	MAXIMUM VALUE
68.13000000	129.08000000

STD ERROR OF MEAN	SUM
2.25849692	3598.3000000

VARIANCE	C.V.
183.62910063	13.557



Statistical Results for Input Series 5 (see Table 15)
at Omaha, NB

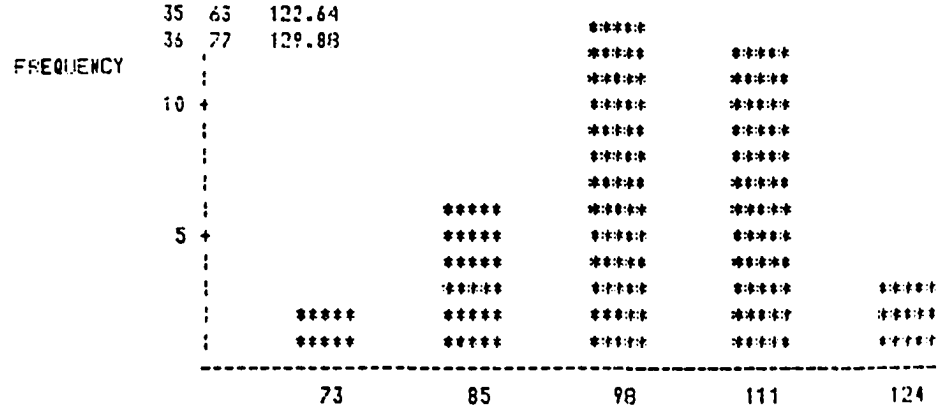
OBS	YEAR	BUSHELS
1	66	66.37
2	69	70.12
3	51	81.53
4	64	83.24
5	80	84.39
6	82	87.34
7	73	88.46
8	55	89.28
9	81	91.65
10	68	92.07
11	65	93.95
12	58	94.38
13	50	97.23
14	57	97.42
15	75	98.43
16	79	99.03
17	48	99.13
18	83	100.12
19	72	101.73
20	71	102.83
21	54	103.87
22	67	104.75
23	78	105.54
24	76	105.98
25	61	106.27
26	53	108.21
27	59	108.25
28	56	108.32
29	60	109.26
30	52	110.37
31	49	113.02
32	62	114.28
33	70	116.89
34	74	119.94
35	63	122.64
36	77	129.88

MEAN	STANDARD DEVIATION
100.17138889	13.65920812

MINIMUM VALUE	MAXIMUM VALUE
66.37000000	129.88000000

STD ERROR OF MEAN	SUM
2.27653469	3606.1700000

VARIANCE	C.V.
186.57396659	13.636



Statistical Results for Input Series 1 (see Table 15)
at Rochester, MN

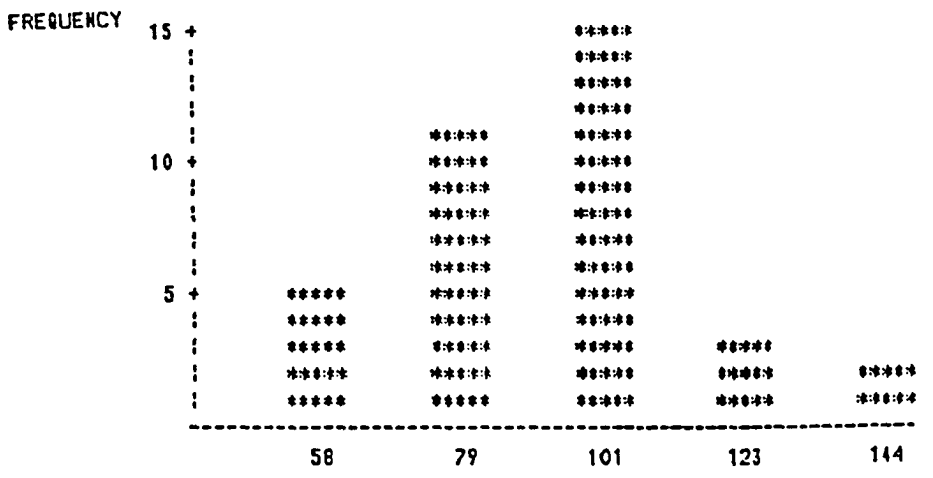
OBS	YEAR	BUSHELS
1	83	47.07
2	55	59.32
3	82	61.80
4	57	63.23
5	75	68.42
6	64	72.38
7	65	72.38
8	54	74.50
9	78	74.92
10	76	77.88
11	61	79.87
12	80	80.76
13	74	82.40
14	48	83.65
15	73	84.61
16	60	86.77
17	79	91.59
18	77	92.78
19	51	93.16
20	49	93.83
21	68	94.44
22	81	95.01
23	63	95.44
24	69	97.33
25	66	97.42
26	67	97.42
27	59	99.81
28	70	107.11
29	53	108.00
30	62	110.55
31	72	111.64
32	58	114.29
33	71	117.97
34	52	126.51
35	56	136.47
36	50	154.94

MEAN	STANDARD DEVIATION
91.82416667	22.14354151

MINIMUM VALUE	MAXIMUM VALUE
47.07000000	154.94000000

STD ERROR OF MEAN	SUM
3.69059025	3305.6700000

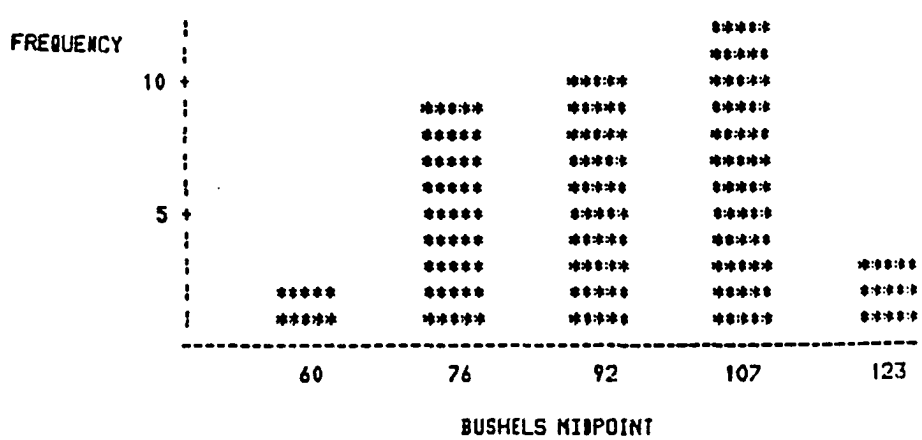
VARIANCE	C.V.
490.33643071	24.115



Statistical Results for Input Series 2 (see Table 15)
at Rochester, MN

OBS	YEAR	BUSHELS
1	83	51.79
2	68	62.98
3	82	68.90
4	63	73.20
5	58	76.65
6	57	76.80
7	64	77.55
8	65	77.55
9	54	78.29
10	61	80.23
11	78	80.81
12	74	85.13
13	75	85.90
14	48	86.45
15	80	87.12
16	55	89.00
17	81	91.40
18	51	91.72
19	60	94.37
20	77	96.44
21	69	96.72
22	79	99.56
23	62	100.55
24	72	103.11
25	49	103.86
26	59	105.75
27	67	107.63
28	73	108.75
29	76	108.92
30	66	109.45
31	53	111.45
32	71	113.46
33	52	114.10
34	50	128.75
35	56	130.67
36	70	131.27

MEAN	STANDARD DEVIATION
94.06333333	18.62349422
MINIMUM VALUE	**MAXIMUM VALUE**
51.79000000	131.27000000
STD ERROR OF MEAN	**SUM**
3.10391570	3386.2800000
VARIANCE	**C.V.**
346.83453714	19.799



Statistical Results for Input Series 3 (see Table 15)
at Rochester, MN

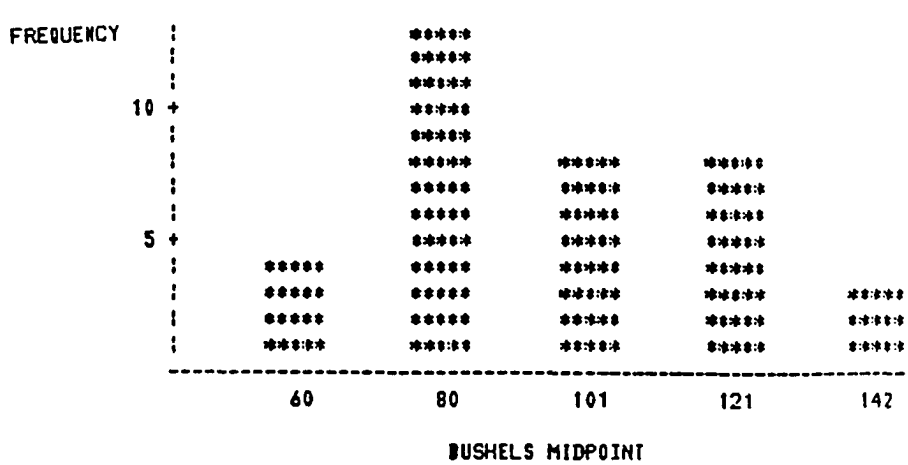
OBS	YEAR	BUSHELS
1	83	49.76
2	55	58.45
3	82	69.19
4	80	69.45
5	78	73.94
6	57	75.64
7	54	77.34
8	77	78.72
9	63	81.74
10	59	82.76
11	61	83.41
12	64	84.06
13	75	85.01
14	73	85.99
15	60	86.86
16	53	86.88
17	79	88.88
18	74	90.63
19	49	91.70
20	48	93.39
21	51	93.61
22	81	97.00
23	65	97.98
24	70	102.52
25	68	107.20
26	62	111.52
27	72	114.04
28	71	114.20
29	58	114.55
30	69	117.92
31	66	120.25
32	56	124.57
33	52	126.30
34	67	139.32
35	76	140.37
36	50	151.76

MEAN	STANDARD DEVIATION
96.30305556	23.21719939

MINIMUM VALUE	MAXIMUM VALUE
49.76000000	151.76000000

STD ERROR OF MEAN	SUM
3.86953323	3466.9100000

VARIANCE	C.V.
539.03834754	24.108



Statistical Results for Input Series 4 (see Table 15)
at Rochester, MN

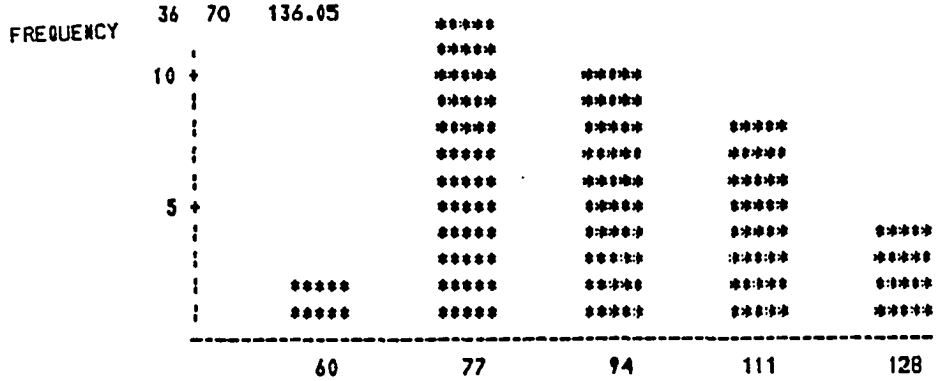
OBS	YEAR	BUSHELS
1	83	51.45
2	74	67.84
3	64	72.65
4	82	74.38
5	63	75.11
6	58	79.01
7	78	79.43
8	55	79.99
9	69	81.68
10	61	83.02
11	57	83.36
12	80	83.58
13	68	83.61
14	67	84.84
15	54	85.69
16	66	86.07
17	65	88.52
18	75	89.43
19	60	92.38
20	51	93.26
21	77	94.01
22	76	96.16
23	48	97.16
24	79	97.34
25	81	108.47
26	59	109.69
27	73	109.79
28	62	114.19
29	52	115.04
30	72	115.93
31	53	117.34
32	71	117.55
33	49	119.54
34	50	120.80
35	56	123.05
36	70	136.05

MEAN	STANDARD DEVIATION
94.45027778	18.76655787

MINIMUM VALUE	MAXIMUM VALUE
51.45000000	136.05000000

STD ERROR OF MEAN	SUM
3.12775964	3407.4100000

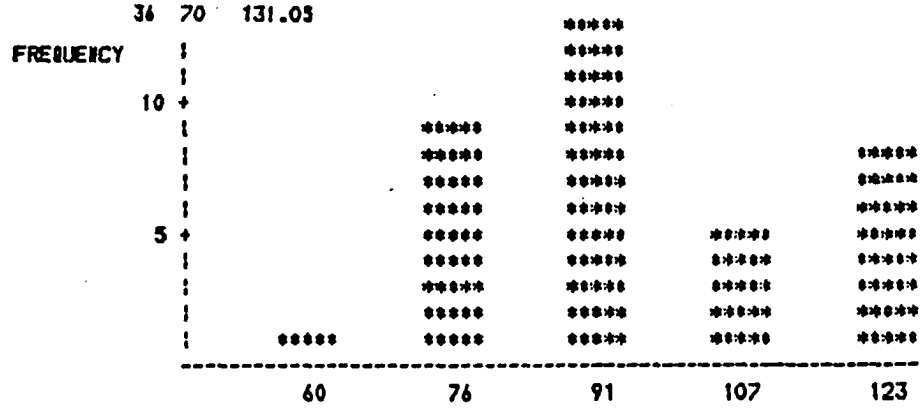
VARIANCE	C.V.
352.18369421	19.827



Statistical Results for Input Series 5 (see Table 15)
at Rochester, MN

OBS	YEAR	BUSHELS
1	83	51.77
2	82	74.40
3	63	75.11
4	74	77.06
5	78	78.86
6	58	81.02
7	69	81.68
8	64	82.16
9	57	83.34
10	61	83.41
11	68	83.61
12	80	83.62
13	55	84.72
14	54	85.69
15	67	85.77
16	66	86.16
17	65	88.52
18	75	90.49
19	60	92.71
20	51	93.13
21	77	94.55
22	48	96.59
23	79	98.09
24	81	108.47
25	59	108.90
26	73	110.24
27	62	112.94
28	71	114.03
29	52	115.40
30	72	115.93
31	53	117.34
32	49	119.41
33	50	120.79
34	56	122.88
35	76	124.80
36	70	131.05

MEAN	STANDARD DEVIATION
95.96222222	18.21632801
MINIMUM VALUE	**MAXIMUM VALUE**
51.77000000	131.05000000
STD ERROR OF MEAN	**SUM**
3.03605467	3454.6400000
VARIANCE	**C.V.**
331.83460635	18.983



Appendix E

WEEKLY IMPACTS OF OBSERVED MAXIMUM AND MINIMUM TEMPERATURES AND PRECIPITATION ON MODELED CORN YIELD AT SEVEN SENSITIVITY SITES ACROSS THE U.S.A. CORN-BELT.

Weekly Impact of All Observed Weather Variables on Modeled Corn Yields (Case 1 - Case 5, Table 15)
Columbus, OH

1948	999.0	0.0	-1.0	-1.3	-1.0	-1.0	-1.3	-1.0	-0.7	1.3	0.1	-3.6	-3.3	-1.1	0.0	0.6	-0.4	-0.4	999.0
1949	999.0	23.1	23.3	-0.3	-0.4	21.4	-0.6	-3.0	-1.7	-4.8	-4.9	-5.0	-4.7	-4.1	-3.1	-2.1	-1.2	-0.8	999.0
1950	999.0	0.7	2.5	0.5	0.5	-0.2	-0.1	0.4	1.4	3.3	4.0	5.8	4.1	4.2	2.8	1.5	1.5	0.4	999.0
1951	999.0	-2.3	-1.6	-2.0	-1.9	-2.2	-1.9	-1.3	-1.2	-1.3	-0.5	-0.6	-0.2	0.0	0.4	0.1	0.0	0.0	999.0
1952	999.0	0.0	0.4	0.2	0.1	0.3	-0.4	-0.9	-0.4	-0.1	0.7	0.9	1.3	0.9	0.7	0.5	0.5	0.1	999.0
1953	999.0	-2.6	-2.5	0.0	-2.6	0.0	0.0	0.3	0.1	0.1	-2.4	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	999.0
1954	999.0	0.0	0.6	0.7	-1.2	-1.3	-1.3	-2.4	-2.1	-2.3	-2.8	-2.3	-0.7	-1.0	-0.8	-0.6	-0.4	-0.2	999.0
1955	999.0	-0.8	-3.2	-1.0	-3.6	-1.9	13.2	-2.2	-2.0	-2.1	-1.7	-3.4	-3.7	-2.7	-1.9	-1.8	-1.5	-0.7	999.0
1956	999.0	-0.3	-0.3	0.0	-0.3	-0.1	0.3	0.3	0.5	0.2	0.4	-0.5	-0.1	0.0	-0.1	-0.3	-0.2	-0.3	999.0
1957	999.0	0.0	0.0	-0.1	-0.1	-0.4	-0.7	-0.9	-1.9	-2.9	-3.3	-2.7	-2.3	-1.6	-1.6	-0.8	-0.3	-0.1	999.0
1958	999.0	-0.2	-0.9	-2.1	0.7	-0.5	2.1	4.1	3.1	5.2	5.6	6.6	3.3	3.6	2.6	1.4	1.1	0.4	999.0
1959	999.0	0.6	0.5	1.0	-0.4	-1.0	-0.1	-2.4	-1.4	-3.0	-4.6	-2.2	-1.9	-1.4	-0.9	-1.6	-1.2	-0.3	999.0
1960	999.0	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.2	-0.6	-1.2	-1.0	-0.8	-0.8	-0.5	-0.6	-0.4	-0.1	999.0
1961	999.0	0.0	-0.9	-1.5	-1.5	-1.5	-1.4	-1.8	-0.4	-1.0	-1.2	-0.9	-0.4	-0.1	-0.2	-0.1	-0.1	0.0	999.0
1962	999.0	-11.1	-1.6	-0.8	-11.1	-1.1	-1.0	-0.9	-1.2	-1.7	-0.4	0.3	1.2	0.7	1.3	0.7	0.1	0.0	999.0
1963	999.0	0.7	0.6	0.8	1.0	0.8	1.1	0.9	1.3	1.7	0.6	0.8	0.8	0.7	0.4	0.4	0.3	0.0	999.0
1964	999.0	-0.2	-0.1	-0.4	-0.4	0.0	-0.9	-0.4	0.0	-0.3	-0.3	-7.8	-1.5	-2.5	-0.5	0.1	0.1	0.0	999.0
1965	999.0	-0.4	-1.2	-1.3	-0.7	-0.6	-0.1	-0.9	-0.3	0.0	-1.1	-0.9	0.0	0.2	0.0	0.2	0.0	0.0	999.0
1966	999.0	22.5	22.5	22.5	22.1	22.1	0.6	0.7	1.2	1.2	0.6	0.7	0.7	0.6	0.6	0.3	0.3	0.1	999.0
1967	999.0	0.6	22.0	22.6	8.2	9.5	4.1	4.8	9.4	9.4	10.1	7.6	5.7	3.6	3.1	2.3	0.8	0.1	999.0
1968	999.0	0.0	1.7	3.4	2.1	-12.1	2.7	2.8	3.5	4.4	4.5	3.6	4.0	3.4	2.8	2.7	1.5	0.9	999.0
1969	999.0	0.0	19.9	19.9	20.9	-1.7	-0.7	0.5	1.8	1.0	1.3	1.6	1.8	1.3	1.0	0.6	0.2	0.0	999.0
1970	999.0	0.3	-0.5	0.0	0.2	-0.8	-0.2	-0.7	-0.9	-0.6	-0.2	2.1	-0.8	0.3	-0.5	-0.6	-0.6	-0.6	999.0
1971	999.0	0.0	0.0	0.0	0.1	0.1	-0.1	0.4	0.5	1.0	0.1	0.6	0.0	0.2	0.3	1.1	0.0	0.0	999.0
1972	999.0	-11.1	-10.4	-10.4	-9.9	-0.9	-0.4	0.0	-0.1	1.5	1.6	1.5	0.9	0.7	1.8	1.1	1.1	0.2	999.0
1973	999.0	0.7	0.9	1.0	1.0	0.9	0.2	-0.5	-1.4	-1.7	-2.6	-2.2	-1.4	-1.9	-1.9	-1.5	-1.3	-0.4	999.0
1974	999.0	0.0	0.9	1.0	-0.3	1.2	0.0	0.5	0.9	0.5	-1.2	-1.5	-5.4	0.4	1.1	0.9	0.2	0.0	999.0
1975	999.0	12.0	-1.2	-1.3	-1.3	11.3	-3.9	-2.1	-3.3	-4.1	-4.4	-4.4	-2.3	-1.3	-0.9	-0.6	-0.2	0.0	999.0
1976	999.0	0.8	-0.1	0.3	-0.1	0.6	-0.6	1.5	1.0	5.1	3.2	3.1	-5.9	0.8	0.7	1.4	-0.4	-0.3	999.0
1977	999.0	-0.1	0.3	0.4	0.5	-0.2	-0.2	-0.8	-1.4	-1.5	-1.6	-1.8	-1.4	-1.2	-0.8	-0.6	-0.6	-0.5	999.0
1978	999.0	0.0	1.7	-0.6	1.8	0.3	2.5	2.1	1.1	2.7	-3.0	-0.6	3.5	0.0	0.3	0.1	0.1	0.0	999.0
1979	999.0	0.4	0.4	1.7	1.7	1.4	0.6	0.7	0.1	-0.4	-0.5	-0.5	-1.1	-0.7	-0.5	-0.5	-0.5	-0.2	999.0
1980	999.0	-0.2	2.4	0.5	0.6	1.0	0.4	0.8	0.7	-0.4	-1.7	-1.0	-1.6	-1.5	-0.9	-1.0	-0.9	-0.3	999.0
1981	999.0	-16.9	-17.5	-0.6	-0.6	-18.0	-1.4	-1.6	-1.3	-0.9	-1.2	-0.2	0.1	1.1	1.2	1.3	1.3	1.1	999.0
1982	999.0	0.2	0.1	-0.1	0.0	-0.1	0.1	-0.3	-1.0	-1.6	-1.8	-1.7	-1.1	-0.6	-0.8	-0.2	-0.2	-0.1	999.0
1983	999.0	0.0	0.1	0.4	0.3	0.4	1.0	0.8	0.4	-0.3	-1.7	-1.3	-0.6	-0.4	-0.3	-0.5	-0.1	0.0	999.0
		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	

WEEK

Weekly Impact of Observed Maximum Temperature on Modeled Corn Yields (Case 2 - Case 5, Table 15)
Columbus, OH

1948	999.0	-0.1	-1.0	-1.3	-1.0	-1.0	-1.3	-0.9	-0.4	1.5	0.0	-3.5	-1.9	-0.8	0.3	0.9	-0.3	-0.3	999.0
1949	999.0	-0.4	-0.4	0.7	0.6	21.5	0.5	0.4	2.2	-1.1	-2.5	-0.5	-0.3	0.0	0.2	-0.9	-0.2	-0.1	999.0
1950	999.0	0.0	-0.1	-0.1	-0.1	-0.2	0.5	-0.3	-0.4	-0.3	-0.2	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1951	999.0	-2.3	13.4	-1.9	-1.6	-2.1	-2.0	-1.3	-1.3	-1.5	-0.9	-1.0	-0.6	-0.4	0.2	-0.1	-0.2	0.0	999.0
1952	999.0	0.0	0.0	0.0	0.2	-17.6	-0.5	-0.6	-1.1	-0.6	-0.7	-0.1	0.2	0.3	0.0	0.0	-0.1	-0.1	999.0
1953	999.0	-2.6	-2.6	-2.6	-2.6	-2.5	-2.7	-2.5	-2.5	-2.5	-0.9	-1.0	-0.6	-2.7	-2.7	-2.7	-2.7	-2.7	999.0
1954	999.0	0.0	0.5	0.6	0.6	0.5	0.4	0.3	0.3	0.2	-0.1	-0.3	-0.5	-0.7	-0.4	0.0	0.0	0.0	999.0
1955	999.0	-0.1	0.2	-0.3	-0.2	0.2	13.0	1.1	1.7	2.5	3.0	2.4	1.8	-0.4	-0.5	-0.3	-0.8	-0.4	999.0
1956	999.0	-0.3	-0.2	0.0	-0.3	-0.1	0.3	0.1	0.4	0.1	0.2	-0.5	-0.2	-0.1	-0.2	-0.4	-0.3	-0.3	999.0
1957	999.0	0.0	10.4	10.2	10.2	10.0	-0.6	-0.6	-1.1	-0.9	-0.4	-0.3	0.1	0.3	0.3	0.4	0.5	0.0	999.0
1958	999.0	0.0	-0.3	-0.2	-0.2	-0.5	-0.6	-0.5	-0.1	-0.2	-0.1	0.1	1.5	-0.3	0.1	0.0	0.1	0.0	999.0
1959	999.0	0.7	0.2	0.7	0.8	-0.1	-0.2	-0.2	-0.6	-0.8	0.0	-0.8	-1.2	-0.8	-0.7	0.0	0.2	0.1	999.0
1960	999.0	0.0	0.0	0.7	0.7	0.7	0.7	0.8	0.1	-0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	999.0
1961	999.0	0.0	-0.9	-1.5	-1.5	-1.5	-1.6	-1.7	-0.3	-0.8	-1.0	-0.7	-0.4	-0.1	-0.2	-0.1	-0.1	0.0	999.0
1962	999.0	-11.2	-10.9	-10.9	-11.1	-1.1	-0.9	-0.8	-1.0	-1.4	-0.6	0.4	1.2	0.7	1.4	0.9	0.2	0.1	999.0
1963	999.0	0.0	0.6	0.7	0.2	0.8	0.7	0.0	0.4	0.7	-0.1	0.0	0.1	0.2	0.3	0.2	0.2	0.0	999.0
1964	999.0	-0.4	-0.7	-0.3	-0.9	-0.3	-1.2	-1.5	-1.0	-1.1	-0.5	-0.7	-1.0	-0.6	-0.6	0.0	0.0	0.0	999.0
1965	999.0	-0.2	-0.7	-1.6	-1.5	-1.0	-0.5	-1.2	-0.6	-2.3	-2.7	-2.0	-1.0	-0.9	-1.0	-0.3	-0.2	-0.1	999.0
1966	999.0	0.0	22.5	22.5	22.6	22.6	-0.2	-0.5	-0.3	0.2	-0.2	-0.2	0.2	0.0	-0.1	0.0	0.0	0.0	999.0
1967	999.0	0.6	22.9	22.6	20.2	-0.2	-2.0	-0.6	0.1	0.8	6.6	7.3	3.8	0.4	0.4	0.3	0.4	0.0	999.0
1968	999.0	0.0	1.4	1.8	2.8	1.2	2.1	0.8	2.1	1.0	-0.7	-0.1	0.2	-0.5	-0.3	0.1	0.4	0.4	999.0
1969	999.0	0.0	19.9	20.1	19.9	-1.3	-1.3	-1.4	-1.6	-2.3	-0.8	-0.3	0.3	-0.6	-0.5	-0.1	-0.2	0.0	999.0
1970	999.0	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.0	-0.2	-0.2	-0.4	-0.4	-0.3	-0.2	-0.3	-0.1	-0.1	999.0
1971	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1972	999.0	-0.4	-10.6	-10.4	-10.5	-0.5	-0.2	-0.2	-0.2	-0.3	-0.2	-0.1	-0.2	0.0	-0.1	0.0	0.0	0.0	999.0
1973	999.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.3	-0.3	-0.2	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	999.0
1974	999.0	0.0	0.0	0.0	-0.3	0.0	-0.1	0.4	0.8	0.8	2.0	1.0	0.4	0.5	0.8	0.3	0.1	0.0	999.0
1975	999.0	0.4	11.9	0.6	0.7	1.4	1.8	1.0	1.8	0.2	-0.3	-1.0	-0.9	-0.1	0.2	0.0	0.0	0.0	999.0
1976	999.0	1.4	0.3	0.3	-2.5	-1.7	-3.3	-1.9	-1.6	3.6	0.0	0.3	-1.3	-0.6	-0.7	-0.2	-1.1	-0.7	999.0
1977	999.0	0.8	-0.4	-0.5	-0.4	-0.2	-0.1	-0.7	0.9	0.3	0.1	0.0	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	999.0
1978	999.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.8	0.3	1.7	0.7	0.3	-0.2	-0.2	-0.2	0.0	-0.1	999.0
1979	999.0	0.1	0.1	0.9	0.9	0.9	0.1	0.8	0.5	0.8	0.7	0.4	0.3	0.0	0.0	0.0	0.1	0.1	999.0
1980	999.0	-0.2	1.7	1.2	0.8	1.2	0.7	1.3	1.7	1.4	0.6	0.1	0.1	0.2	0.0	-0.1	-0.2	-0.2	999.0
1981	999.0	-16.9	-17.5	-17.6	-17.6	-17.9	-1.4	-1.7	-1.5	-1.4	-2.4	-1.0	-0.7	0.3	0.8	0.8	1.1	0.9	999.0
1982	999.0	0.1	0.1	-0.8	-0.8	-0.8	-0.7	-1.0	-0.9	-1.2	-0.8	0.8	-0.2	0.0	-0.1	0.2	0.1	0.1	999.0
1983	999.0	0.0	0.1	0.2	0.3	0.2	0.3	0.2	-0.1	0.0	0.0	-0.4	-0.6	-0.3	-0.2	-0.1	0.0	0.0	999.0
		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	

WEEK

Weekly Impact of Observed Minimum Temperature on Modeled Corn Yields (Case 3 - Case 5, Table 15)
Columbus, OH

1948	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.5	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	999.0
1949	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1950	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1951	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1952	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.2	0.1	0.1	0.4	0.5	0.0	0.0	0.0	0.0	0.0	999.0
1953	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1954	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1955	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	-1.2	0.0	0.0	0.0	0.0	0.0	999.0
1956	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1957	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1958	999.0	0.0	0.0	0.1	-0.1	0.0	-0.2	-0.3	-0.3	-0.5	0.0	-0.1	-0.7	0.0	0.0	0.0	0.0	0.0	999.0
1959	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	1.0	1.6	0.8	1.0	0.0	0.0	0.0	999.0
1960	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	999.0
1961	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	-0.1	-0.3	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1962	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.1	0.2	0.0	0.2	0.0	0.0	999.0
1963	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1964	999.0	0.3	0.0	0.0	-0.1	0.0	-0.8	0.0	0.0	-0.8	-0.4	-7.2	-0.2	-1.9	0.0	0.0	0.0	0.0	999.0
1965	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1966	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	999.0
1967	999.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	-0.1	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	999.0
1968	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1969	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1970	999.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.3	0.8	3.0	0.0	1.9	0.1	0.0	0.0	0.0	999.0
1971	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.4	0.8	0.1	0.6	0.0	0.2	0.3	1.1	0.0	0.0	999.0
1972	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1973	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1974	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	-0.7	-1.6	-2.2	-6.0	-0.3	0.0	0.0	0.0	0.0	999.0
1975	999.0	0.0	0.0	0.2	0.1	0.4	0.1	0.0	-0.2	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1976	999.0	0.0	0.0	0.2	0.0	0.2	0.0	0.9	0.4	0.7	2.7	1.5	-3.8	0.0	0.0	0.0	0.0	0.0	999.0
1977	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1978	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.1	0.3	0.3	0.2	0.0	0.3	0.1	0.1	0.0	999.0
1979	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	-0.1	-0.5	0.0	0.0	0.0	0.0	0.0	999.0
1980	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1981	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1982	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1983	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	999.0
		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	

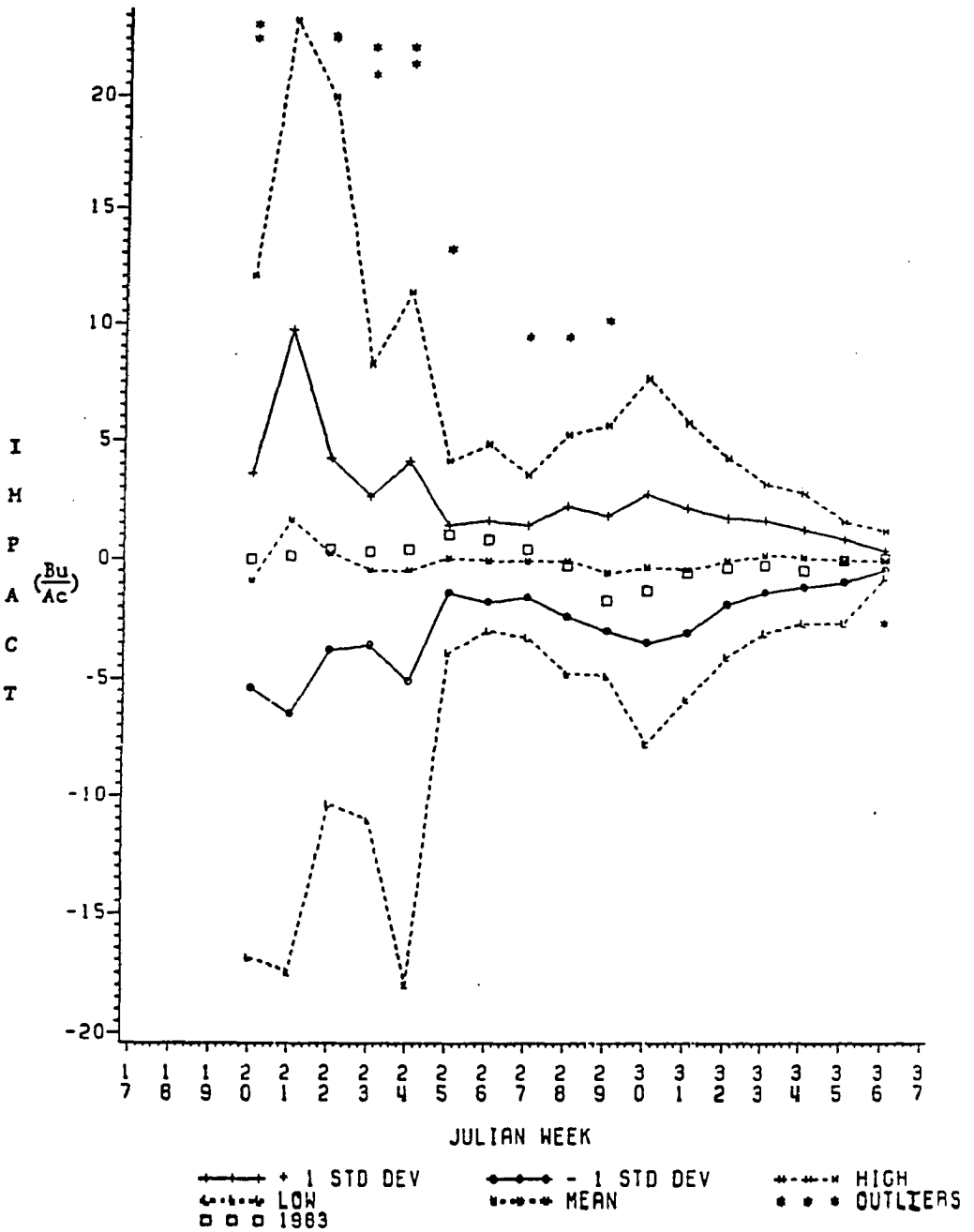
WEEK

Weekly Impact of Observed Precipitation on Modeled Corn Yields (Case 4 - Case 5, Table 15)
Columbus, OH

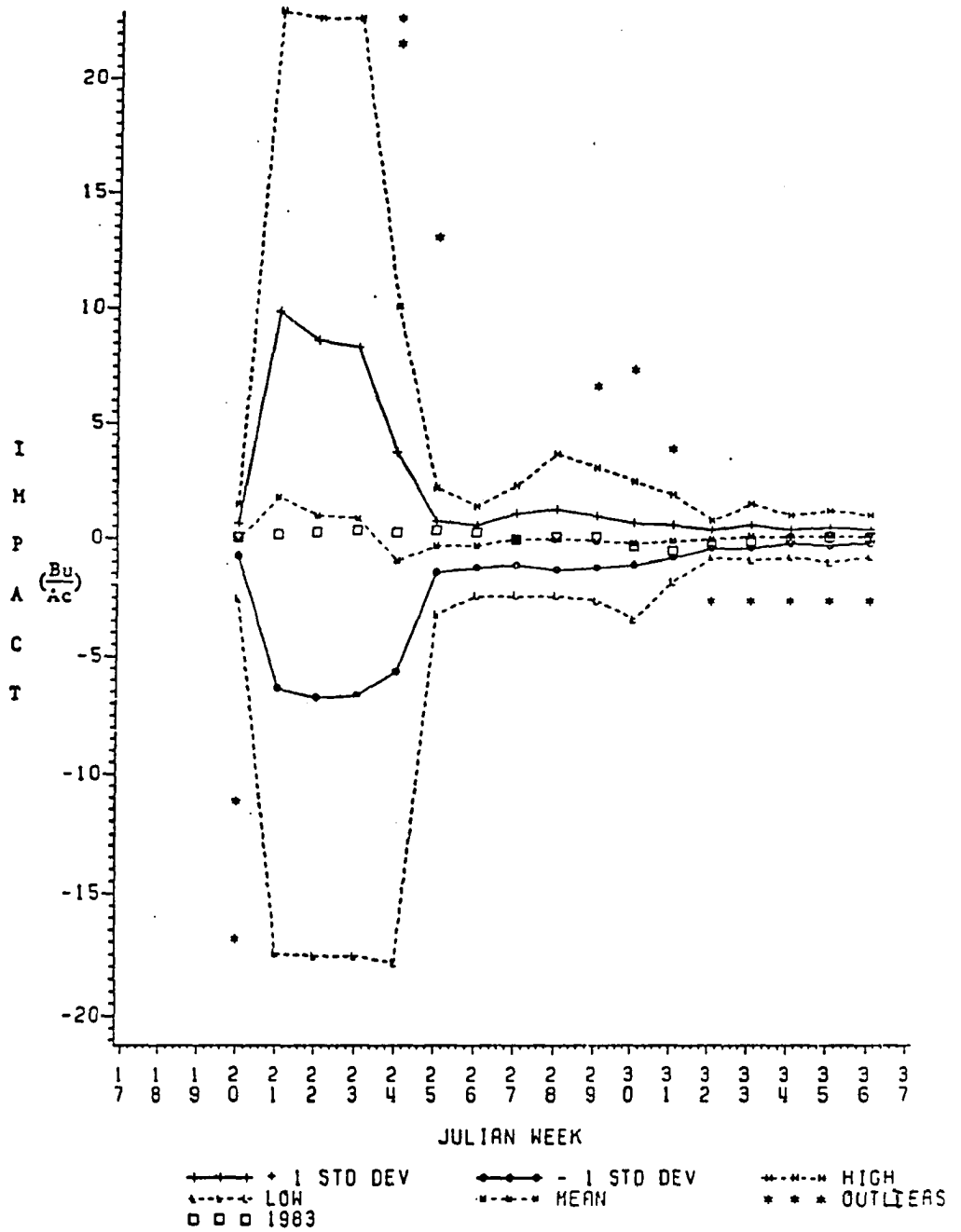
1948	999.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.1	-0.5	-0.5	-0.1	0.0	-0.2	-0.3	-0.3	-0.1	-0.1	999.0
1949	999.0	-0.2	-0.2	23.2	23.2	20.4	-4.2	-5.0	-4.9	-3.6	-3.9	-1.4	-3.3	-3.8	-2.9	-1.5	-0.5	-0.2	999.0
1950	999.0	0.7	-0.4	0.7	0.7	0.0	0.2	0.7	1.8	3.6	4.2	5.0	3.9	4.0	2.8	1.4	1.2	0.3	999.0
1951	999.0	-1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.4	0.4	0.3	0.1	0.2	0.2	0.0	999.0
1952	999.0	0.0	0.0	0.0	-0.1	-17.7	-0.3	-0.2	0.6	0.5	1.2	0.5	0.5	0.6	0.7	0.5	0.6	0.2	999.0
1953	999.0	0.0	0.0	-2.7	-2.7	-2.7	-2.7	-2.6	-2.6	-2.6	-4.6	-4.5	-5.0	-2.7	-2.7	-2.7	-2.7	0.0	999.0
1954	999.0	0.0	0.4	0.5	-0.6	0.3	0.5	-0.7	-0.2	-0.2	-1.0	-0.1	-0.1	-0.4	-0.4	-0.6	-0.4	-0.2	999.0
1955	999.0	0.0	-0.5	-0.7	-0.7	-1.4	0.0	-1.3	-1.7	-2.6	-4.7	-4.4	-3.2	-3.0	-2.4	-2.1	-1.2	-0.6	999.0
1956	999.0	0.0	0.6	0.6	0.5	0.5	0.5	0.6	0.7	0.7	0.7	0.0	0.1	0.2	0.1	0.1	0.1	0.0	999.0
1957	999.0	0.0	-0.4	0.0	-0.5	-0.7	-0.8	-1.0	-0.9	-1.6	-2.9	-2.0	-2.0	-1.5	-1.4	-0.7	-0.4	-0.1	999.0
1958	999.0	-0.4	-0.6	-0.7	0.4	0.0	0.7	2.3	0.7	2.4	2.6	2.8	2.0	3.6	2.3	1.4	0.9	0.4	999.0
1959	999.0	0.3	0.7	0.3	0.0	-0.4	-1.0	-2.3	-1.3	-1.9	-4.1	-2.8	-0.8	-1.9	-1.2	-1.8	-1.3	-0.4	999.0
1960	999.0	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	-0.8	-1.4	-1.1	-0.9	-0.9	-0.5	-0.6	-0.4	-0.1	999.0
1961	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1962	999.0	0.0	-0.8	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.3	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	999.0
1963	999.0	0.0	0.0	0.8	1.3	0.7	0.7	1.2	1.2	1.3	0.9	1.1	0.9	0.8	0.2	0.2	0.1	0.0	999.0
1964	999.0	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.6	0.3	0.1	0.0	0.0	0.1	0.1	0.2	0.1	0.0	999.0
1965	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.1	0.2	0.6	1.5	1.1	0.9	1.2	1.0	0.5	0.2	0.1	999.0
1966	999.0	0.0	22.5	22.6	22.6	22.6	0.9	0.8	1.9	1.3	0.7	0.9	0.7	0.5	0.6	0.3	0.3	0.1	999.0
1967	999.0	-0.1	24.0	24.8	32.4	14.2	6.5	7.0	5.1	10.4	9.9	6.2	1.5	3.1	2.6	1.8	0.4	0.1	999.0
1968	999.0	0.0	0.0	1.0	2.6	3.0	2.9	3.4	3.9	5.8	6.2	4.9	3.3	3.4	2.4	2.6	0.9	0.6	999.0
1969	999.0	0.0	0.9	0.8	0.8	0.9	1.0	0.7	1.5	2.2	2.9	2.7	2.2	1.8	1.4	0.6	0.4	0.0	999.0
1970	999.0	0.3	-0.4	0.0	0.1	-1.0	-0.3	-0.8	-0.7	-0.8	-0.7	-0.3	-0.3	-0.4	-0.5	-0.1	-0.4	-0.6	999.0
1971	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1972	999.0	-11.1	-10.3	-10.8	-9.7	-0.6	0.0	0.0	0.2	1.3	1.4	1.3	1.1	0.7	1.4	0.6	0.7	0.2	999.0
1973	999.0	0.7	1.0	-11.4	-10.9	1.5	0.8	-0.4	-3.0	-1.7	-3.7	-3.8	-1.3	-1.9	-1.8	-1.5	-1.3	-0.5	999.0
1974	999.0	-0.1	0.0	1.0	2.4	1.2	1.5	1.5	1.0	0.5	-0.3	-0.3	0.1	0.1	0.3	0.6	0.2	0.0	999.0
1975	999.0	0.4	0.9	0.3	0.2	0.5	-1.7	-0.8	-0.6	-1.2	-1.6	-0.5	-1.4	-1.4	-1.2	-0.6	-0.2	0.0	999.0
1976	999.0	-0.3	-0.6	-0.7	-0.6	-0.8	-0.6	0.2	0.3	1.6	2.2	1.7	1.7	1.8	1.7	1.8	1.1	0.9	999.0
1977	999.0	0.6	-0.3	-0.1	-0.5	-0.6	-0.9	-1.7	-2.4	-2.1	-1.9	-2.0	-1.4	-1.3	-0.8	-0.6	-0.7	-0.5	999.0
1978	999.0	0.0	0.0	0.3	0.0	-0.1	-0.3	3.2	2.3	-0.5	2.0	-1.5	3.3	0.2	0.3	0.3	0.1	0.0	999.0
1979	999.0	0.0	0.0	0.5	0.9	0.8	-0.1	0.3	-0.4	-0.9	-1.4	-0.8	-1.0	-0.8	-0.5	-0.4	-0.5	-0.3	999.0
1980	999.0	0.0	0.6	0.1	0.6	-0.2	-0.4	-0.6	-1.3	-2.6	-2.0	-1.4	-1.7	-1.6	-1.1	-0.9	-0.6	-0.3	999.0
1981	999.0	-0.3	-16.5	-16.5	-16.5	-16.9	-0.4	0.0	0.2	0.9	1.5	1.1	1.2	1.1	0.4	0.8	0.2	0.2	999.0
1982	999.0	-2.2	-2.2	0.0	0.1	0.1	-1.5	-1.6	-0.9	-1.1	-0.9	-0.8	-0.7	-0.5	-0.5	-0.2	-0.2	-0.1	999.0
1983	999.0	0.0	0.0	0.2	0.2	0.1	0.2	-0.2	-0.1	-0.6	-1.9	-1.2	0.0	-0.1	-0.1	-0.3	-0.1	0.0	999.0
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		

WEEK

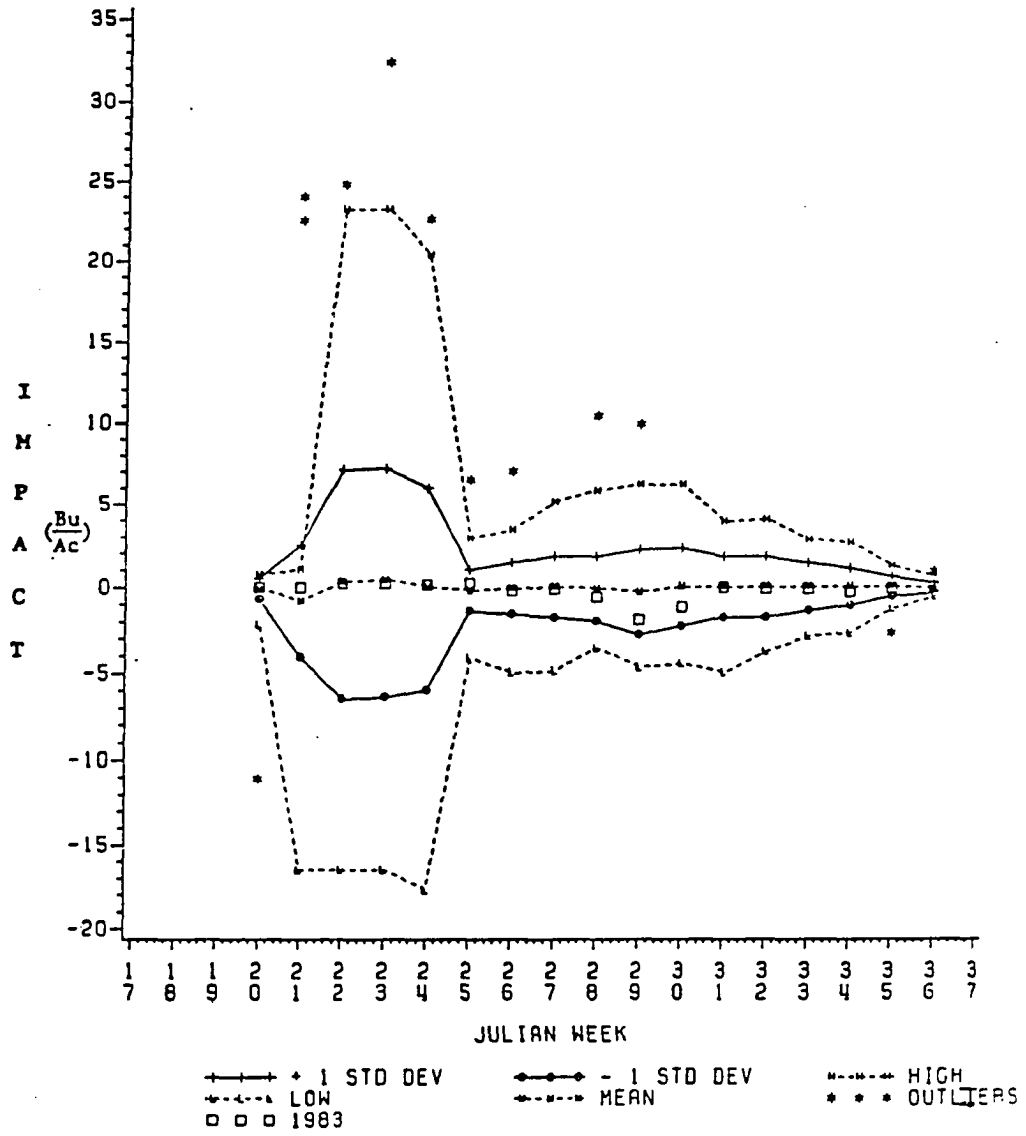
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 1 - Case 5, Table 15) Columbus, OH



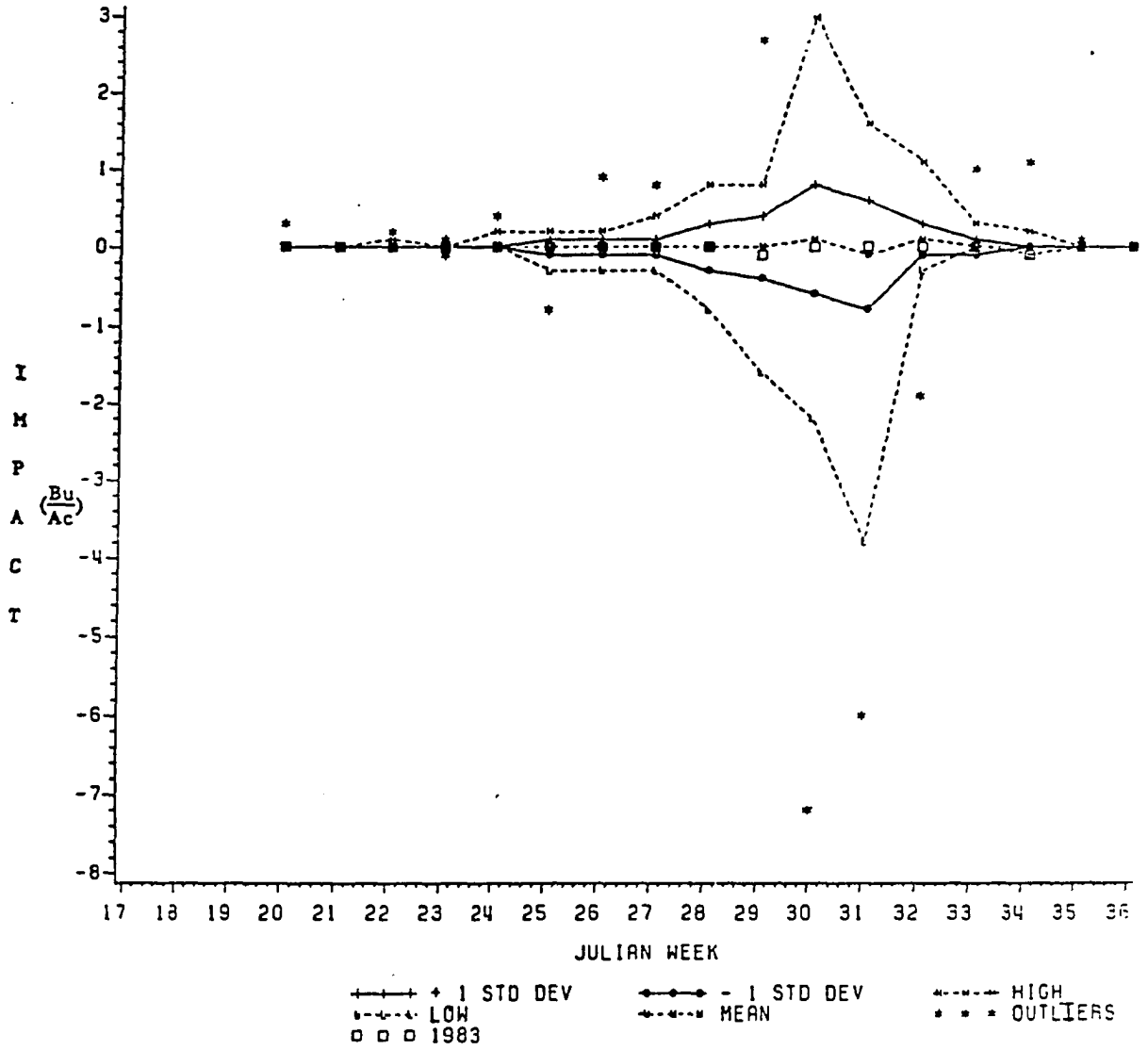
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 2 - Case 5, Table 15) Columbus, OH



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 3 - Case 5, Table 15) Columbus, OH



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 4 - Case 5, Table 15) Columbus, OH



Weekly Impact of All Observed Weather Variables on Modeled Corn Yields (Case 1 - Case 5, Table 15)
Des Moines, IO

1948	999.0	999.0	0.1	0.0	-0.1	2.2	0.0	0.2	0.2	0.9	2.6	3.2	2.1	1.2	1.6	1.5	1.3	0.5	999.0
1949	999.0	999.0	0.0	1.2	1.0	1.0	1.0	1.0	0.6	-1.5	-0.9	-2.1	-9.9	-3.7	-1.6	-1.9	-1.0	-0.2	999.0
1950	999.0	999.0	0.0	-2.0	-0.3	-1.8	-1.4	-1.7	0.6	1.3	2.6	4.8	4.7	3.7	2.8	2.3	1.7	0.2	999.0
1951	999.0	999.0	0.0	-2.0	-1.5	-1.9	-2.2	-1.1	-0.3	0.0	4.7	3.3	2.5	2.7	2.2	1.2	0.1	0.0	999.0
1952	999.0	999.0	0.0	-0.4	-1.0	-1.1	-1.2	1.1	-1.0	-1.0	4.3	3.3	0.7	1.5	5.0	2.1	1.1	0.5	999.0
1953	999.0	999.0	0.0	0.9	0.9	0.9	0.9	1.1	0.8	0.7	-0.8	-4.0	-1.0	-1.8	-3.9	-2.2	-0.9	-0.3	999.0
1954	999.0	999.0	0.0	-5.6	-5.1	-5.1	-5.1	-5.1	2.0	-0.4	-0.1	-0.8	0.0	-0.7	-0.1	0.1	-0.2	0.0	999.0
1955	999.0	999.0	0.0	-1.2	-1.5	-0.9	-1.1	0.7	-1.4	-2.6	-4.7	-3.6	-1.7	-1.2	-1.6	-1.0	-0.5	0.0	999.0
1956	999.0	999.0	0.2	-19.6	-20.3	-21.0	-19.8	-3.9	-3.3	-3.9	-2.9	-5.1	-7.3	-8.5	0.8	0.2	0.2	0.2	999.0
1957	999.0	999.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	-0.2	-0.3	-0.7	-0.7	-1.2	-0.1	-0.1	-0.1	0.0	999.0
1958	999.0	999.0	0.0	-4.9	-4.7	2.6	0.2	-0.1	0.2	0.3	0.6	2.0	1.7	1.3	-0.1	-0.4	0.0	0.0	999.0
1959	999.0	999.0	0.0	-0.5	-0.5	-0.5	-0.6	-0.7	0.2	0.2	0.3	-0.1	0.1	0.1	0.4	0.3	0.4	0.0	999.0
1960	999.0	999.0	0.0	0.2	0.2	0.2	0.2	0.2	1.3	1.7	2.0	4.2	1.5	1.3	1.0	1.0	0.2	0.0	999.0
1961	999.0	999.0	0.0	0.2	0.1	-0.2	-0.1	0.2	1.2	2.2	3.7	3.8	4.0	3.7	3.9	3.7	2.9	1.8	999.0
1962	999.0	999.0	0.0	-0.1	-0.1	-1.1	-2.3	-0.1	-3.2	-2.5	-5.1	-3.7	-4.3	0.8	-1.5	-1.5	0.6	0.0	999.0
1963	999.0	999.0	0.0	0.3	0.3	0.3	-6.4	0.5	0.6	1.0	-1.8	-2.0	-3.3	0.6	0.7	0.0	0.0	0.0	999.0
1964	999.0	999.0	0.0	-0.3	-0.4	-0.4	-0.4	-0.4	-0.2	0.5	2.7	2.8	0.6	0.3	0.3	0.3	0.1	0.0	999.0
1965	999.0	999.0	0.0	-0.1	-0.1	-0.2	-0.1	-0.1	-0.2	-0.2	-0.2	0.2	-1.1	-0.1	-0.1	0.0	0.0	0.0	999.0
1966	999.0	999.0	0.0	-0.4	-0.5	-0.5	-0.5	-0.6	0.0	-0.3	0.8	0.8	2.5	0.9	1.2	1.0	0.5	0.0	999.0
1967	999.0	999.0	-0.1	-0.8	0.3	6.5	4.2	6.0	1.8	3.7	2.8	3.9	4.4	1.0	1.0	0.8	3.2	3.2	999.0
1968	999.0	999.0	0.0	0.0	0.1	-3.7	-0.8	-1.5	-4.2	-1.6	-1.5	-2.3	0.8	0.9	3.2	3.2	3.2	0.0	999.0
1969	999.0	999.0	0.0	-0.4	-0.3	-0.3	-4.7	-0.3	-0.2	-0.2	0.4	1.1	4.0	5.2	1.4	2.2	0.9	0.2	999.0
1970	999.0	999.0	0.0	-5.2	8.9	8.1	8.9	-5.6	-5.5	-6.1	-6.6	-8.0	-7.4	-7.5	-2.0	-1.7	-1.3	-0.4	999.0
1971	999.0	999.0	0.0	0.0	0.0	-2.1	-2.0	-0.2	0.1	-0.6	0.3	0.0	-0.2	-0.2	-2.9	-0.5	-0.4	-0.3	999.0
1972	999.0	999.0	-0.1	2.9	3.3	3.3	3.2	3.1	3.1	3.0	3.3	2.1	2.7	1.4	2.2	2.2	2.2	2.2	999.0
1973	999.0	999.0	0.0	-0.8	-2.4	-2.4	-2.4	-2.2	-2.3	-2.3	-2.4	-6.5	-5.3	-6.7	-2.5	-2.5	-2.5	-2.5	999.0
1974	999.0	999.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	1.2	0.9	0.1	0.2	0.0	0.0	0.0	0.0	999.0
1975	999.0	999.0	0.0	-2.3	-0.1	2.4	5.5	0.1	1.7	1.7	-3.0	-3.1	1.4	1.8	1.7	0.1	0.0	0.0	999.0
1976	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.1	0.2	0.0	0.0	0.0	0.0	999.0
1977	999.0	999.0	0.0	0.1	1.2	0.9	2.0	0.4	-2.7	-2.4	-0.5	-6.1	-5.7	-7.3	-5.5	-2.8	-1.8	-0.9	999.0
1978	999.0	999.0	0.0	-2.7	-2.9	-2.9	-2.9	-2.9	-3.1	-4.1	-4.7	-4.5	-8.8	-2.7	-2.5	-2.8	-2.9	-3.0	999.0
1979	999.0	999.0	0.0	0.1	0.0	0.0	-0.1	0.1	0.2	0.4	0.8	0.3	0.3	1.0	0.3	0.3	0.1	0.0	999.0
1980	999.0	999.0	0.0	0.1	-2.2	-2.4	-2.2	-0.3	-0.5	-0.6	-0.1	-1.2	-0.8	-1.3	-1.0	-1.2	-0.6	-0.1	999.0
1981	999.0	999.0	0.0	-0.3	-0.5	-0.6	-0.7	-0.7	-0.7	-1.0	-2.0	-2.7	-1.7	-0.8	-0.9	-0.9	-0.5	-0.1	999.0
1982	999.0	999.0	0.0	1.4	0.5	1.5	1.4	1.4	1.3	0.6	0.4	1.0	1.7	0.9	-0.1	-1.5	-1.2	-0.7	999.0
1983	999.0	999.0	0.0	0.0	-3.4	3.9	3.9	3.5	3.9	2.5	3.2	3.5	-1.4	-5.5	-1.2	-0.9	0.4	0.0	999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	

WEEK

Weekly Impact of Observed Maximum Temperature on Modeled Corn Yields (Case 2 - Case 5, Table 15)
Des Moines, IO

1948	999.0	999.0	0.1	2.2	2.2	2.2	-0.3	-0.2	0.1	0.5	2.2	2.7	1.9	1.2	1.5	1.4	1.2	0.4	999.0
1949	999.0	999.0	0.0	0.3	0.3	0.4	0.2	-0.5	-0.1	0.7	0.3	-1.8	-0.3	-0.2	-0.2	-0.7	-0.3	-0.2	999.0
1950	999.0	999.0	0.0	-2.7	-1.2	-3.1	-1.9	-1.7	1.9	-1.5	-2.2	2.4	1.3	-0.2	-0.7	-0.5	-0.1	0.2	999.0
1951	999.0	999.0	0.0	0.6	0.5	-0.2	0.0	0.3	0.8	2.2	2.4	2.2	0.3	0.0	0.2	0.5	0.1	0.0	999.0
1952	999.0	999.0	0.0	0.0	-0.4	-0.4	-0.5	1.2	-0.4	-2.2	-0.4	1.2	-0.6	-0.1	0.0	0.0	1.1	0.5	999.0
1953	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.1	0.3	0.3	0.2	0.0	0.0	0.1	0.0	0.0	999.0
1954	999.0	999.0	0.0	0.0	-4.9	-0.4	-4.9	0.2	0.5	0.3	-0.6	0.0	0.1	0.0	0.0	-0.3	-0.1	0.0	999.0
1955	999.0	999.0	0.0	0.2	0.2	0.2	0.1	0.1	0.2	-0.5	-2.4	-2.7	-0.8	-0.1	-0.2	-0.3	-0.1	0.0	999.0
1956	999.0	999.0	0.0	0.0	-19.7	-19.7	-20.1	-5.7	-5.6	-5.4	-5.9	-6.2	-5.9	-5.7	-0.8	-0.6	-0.5	-0.2	999.0
1957	999.0	999.0	0.0	0.0	0.1	0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.5	0.0	-0.1	0.0	0.0	-0.1	0.0	999.0
1958	999.0	999.0	0.0	2.2	-0.5	-0.5	-0.5	-0.6	-0.2	-0.2	0.2	3.2	2.2	1.1	-1.2	-1.2	-0.9	0.0	999.0
1959	999.0	999.0	0.0	-0.5	-0.5	-0.5	-0.5	0.0	0.2	0.0	0.1	-0.1	0.1	0.2	0.4	0.3	0.3	0.0	999.0
1960	999.0	999.0	0.0	0.6	0.7	0.7	0.7	0.9	1.4	1.8	2.2	2.4	0.6	0.2	0.5	1.3	0.2	0.0	999.0
1961	999.0	999.0	0.0	-0.4	0.0	0.4	0.8	1.0	0.5	2.9	4.5	4.4	5.0	4.6	4.5	4.3	3.1	1.9	999.0
1962	999.0	999.0	0.0	0.0	-0.1	-1.0	-2.3	-0.2	0.0	-0.7	-2.5	-0.8	-1.6	1.1	1.4	1.5	0.7	0.0	999.0
1963	999.0	999.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.2	-0.1	-0.1	0.0	0.1	0.0	0.0	0.0	999.0
1964	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.7	0.3	0.0	0.0	0.1	0.0	0.0	999.0
1965	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	999.0
1966	999.0	999.0	0.0	0.0	-0.4	-0.4	-0.4	-0.5	-0.6	-1.8	0.5	1.1	0.1	0.0	-0.1	0.1	0.3	0.0	999.0
1967	999.0	999.0	0.0	2.1	2.1	5.3	4.9	6.3	2.4	3.0	2.7	2.9	3.4	1.9	1.6	1.3	2.8	3.2	999.0
1968	999.0	999.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	1.6	1.6	1.0	0.0	0.0	0.0	0.0	999.0
1969	999.0	999.0	0.0	0.0	0.0	-0.1	0.0	-0.1	-0.2	-0.2	-0.1	0.0	0.2	0.4	0.1	0.1	0.2	0.1	999.0
1970	999.0	999.0	0.0	-5.6	-5.1	-6.6	-7.3	-8.6	-6.3	-6.2	-8.7	-6.8	-6.1	-8.0	-0.6	-1.7	-1.5	-0.4	999.0
1971	999.0	999.0	0.0	0.0	0.0	-2.1	-2.0	-0.2	0.0	-0.1	0.4	0.8	0.2	-0.1	-0.3	-0.5	-0.3	-0.2	999.0
1972	999.0	999.0	0.0	2.1	2.1	2.1	2.1	2.0	2.1	2.1	1.5	6.6	6.5	4.3	2.2	2.2	2.2	2.2	999.0
1973	999.0	999.0	0.0	0.0	-0.8	-0.8	-0.7	-2.3	-0.7	-0.7	-2.5	-7.8	-6.1	-7.9	-2.5	-2.5	-2.5	-2.5	999.0
1974	999.0	999.0	0.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.7	0.8	0.0	0.0	0.0	-0.1	0.0	0.0	999.0
1975	999.0	999.0	0.0	0.2	-3.6	-2.2	-3.0	-2.0	-2.5	-0.6	-2.6	-3.4	2.4	1.1	1.5	0.8	0.0	0.0	999.0
1976	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1977	999.0	999.0	0.0	-7.2	-7.2	-7.5	0.3	-1.1	-1.6	-1.9	-3.2	-1.9	-0.3	-1.0	-1.7	-3.2	-2.4	-1.3	999.0
1978	999.0	999.0	-0.1	-3.1	-3.1	-3.0	-3.0	-3.1	-3.1	-2.9	-4.7	-4.6	-4.6	-2.3	-2.2	-2.3	-2.4	-3.0	999.0
1979	999.0	999.0	0.0	0.0	0.0	1.1	1.1	0.0	0.1	0.1	0.2	0.3	0.2	0.1	0.0	0.0	0.1	0.1	999.0
1980	999.0	999.0	0.0	0.0	-2.7	-3.0	-3.0	-0.4	-0.1	0.2	1.1	0.1	-0.1	0.0	0.0	-0.7	-0.7	-0.1	999.0
1981	999.0	999.0	0.0	0.0	0.1	0.1	0.0	0.0	-0.1	-0.3	-0.8	-0.9	-0.7	-0.6	-0.6	-0.5	-0.3	-0.1	999.0
1982	999.0	999.0	0.0	0.3	0.3	0.3	0.4	0.4	0.4	-0.1	-0.3	-0.1	0.4	-0.9	-0.5	-1.3	-1.1	-0.6	999.0
1983	999.0	999.0	0.0	0.1	0.4	8.9	8.8	0.1	-0.6	-2.0	1.0	0.5	-0.1	-0.8	1.9	2.1	1.3	0.0	999.0

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
WEEK																

Weekly Impact of Observed Minimum Temperature on Modeled Corn Yields (Case 3 - Case 5, Table 15)
Des Moines, IO

1948	999.0	999.0	0.1	0.4	0.4	0.4	0.4	-0.3	0.5	0.3	0.6	0.4	0.2	0.1	0.1	0.1	0.1	999.0
1949	999.0	999.0	0.0	0.4	0.4	0.5	0.5	0.5	0.3	-0.6	-0.4	-0.1	-1.5	-1.3	-1.2	-1.0	-0.9	0.0 999.0
1950	999.0	999.0	0.0	-3.2	-3.5	-3.2	-3.9	-3.9	-1.8	-0.7	-1.4	-0.6	2.1	3.6	2.2	1.7	0.4	0.0 999.0
1951	999.0	999.0	0.0	-1.7	-1.7	-1.9	-1.9	-0.6	-1.0	-1.0	-0.6	-0.2	0.5	2.6	1.7	0.4	-0.1	0.0 999.0
1952	999.0	999.0	0.0	0.0	0.0	-0.1	-0.5	0.1	-2.4	0.6	0.3	0.5	1.0	1.5	1.6	0.9	0.0	0.0 999.0
1953	999.0	999.0	0.0	0.9	1.0	1.0	1.0	1.2	0.9	1.5	1.0	0.5	-0.7	-1.6	-0.6	-0.5	-0.9	-2.1 999.0
1954	999.0	999.0	0.0	-5.6	-5.6	-5.6	-5.6	-5.3	-0.3	-0.7	-0.3	-0.7	-0.5	-0.6	-0.4	-0.1	0.0	0.0 999.0
1955	999.0	999.0	0.0	-1.6	-1.3	-1.1	-1.3	0.1	-1.1	-1.3	-0.9	-1.8	-1.3	-1.2	-0.5	-0.7	-0.4	0.0 999.0
1956	999.0	999.0	0.0	-19.4	-19.0	-18.5	-18.3	-3.6	-2.8	-3.3	-3.2	-4.5	-4.8	-6.4	0.9	0.9	0.8	0.4 999.0
1957	999.0	999.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0 999.0
1958	999.0	999.0	0.0	2.3	-0.5	-0.6	-0.6	-0.6	-0.2	-0.2	-0.3	-2.1	-1.3	-0.4	0.2	0.4	0.6	0.0 999.0
1959	999.0	999.0	0.0	-0.5	-0.5	-0.5	-0.5	0.0	0.0	0.1	0.1	0.2	0.0	-0.2	-0.1	-0.1	-0.1	0.0 999.0
1960	999.0	999.0	0.0	0.6	0.5	0.5	0.5	0.4	0.6	0.6	1.0	0.0	0.7	1.0	0.6	-1.4	-0.1	0.0 999.0
1961	999.0	999.0	0.0	-0.2	0.1	0.0	-0.1	-0.3	-0.2	-0.5	-0.6	-1.3	-0.9	-0.8	-0.5	-0.5	-0.5	-0.2 999.0
1962	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.3	0.1	0.1	-0.1	0.1	0.1	-0.1	0.0 999.0
1963	999.0	999.0	0.0	0.3	0.3	0.3	-6.4	0.5	0.6	1.1	1.1	0.4	-0.2	0.5	0.8	0.0	0.0	0.0 999.0
1964	999.0	999.0	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	0.3	0.3	0.5	0.4	0.1	0.1	0.1	0.0 999.0
1965	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0 999.0
1966	999.0	999.0	0.0	-0.4	-0.4	-0.5	-0.8	-0.5	-0.4	-0.3	-0.2	-0.3	1.1	0.5	1.0	0.1	0.2	0.0 999.0
1967	999.0	999.0	0.0	2.1	1.2	3.2	-1.2	-1.2	3.6	4.4	4.2	4.7	4.4	3.7	1.9	2.9	3.5	3.2 999.0
1968	999.0	999.0	0.0	0.0	0.0	0.1	0.1	0.0	-1.5	0.0	-1.5	-1.5	-2.7	-0.1	0.0	0.0	0.0	0.0 999.0
1969	999.0	999.0	0.0	-0.5	-0.3	-0.3	-0.3	-0.3	-0.3	-1.6	-0.6	1.7	0.7	1.2	1.3	1.1	0.7	0.1 999.0
1970	999.0	999.0	0.0	-5.4	-5.3	-3.6	-5.1	-5.0	-5.4	-5.5	-5.6	-6.8	-6.6	-7.0	-1.5	0.1	0.2	-0.1 999.0
1971	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 999.0
1972	999.0	999.0	0.0	3.0	1.9	1.9	1.8	1.8	1.8	1.7	1.9	-5.6	-1.2	-0.7	2.2	2.2	2.2	2.2 999.0
1973	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.1	-0.1	1.2	0.8	1.2	0.0	0.0	0.0	0.0 999.0
1974	999.0	999.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	1.0	0.1	0.1	0.0	0.0	0.0	0.0 999.0
1975	999.0	999.0	0.0	-2.5	-2.4	-2.3	-2.3	-2.3	-2.1	-3.2	-2.2	-2.0	-0.5	0.6	0.3	-0.6	0.0	0.0 999.0
1976	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 999.0
1977	999.0	999.0	0.0	-7.4	-7.4	-7.5	1.6	2.7	2.1	1.3	2.7	-2.2	-2.3	-5.1	-3.4	0.4	0.1	0.0 999.0
1978	999.0	999.0	0.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-2.8	-2.7	-2.4	-3.5	-3.4	-3.3	-3.4	-3.0 999.0
1979	999.0	999.0	0.0	0.3	0.0	0.0	-0.1	-0.7	-0.7	-0.5	-0.4	-0.1	0.0	0.2	0.2	0.2	0.0	0.0 999.0
1980	999.0	999.0	0.0	0.0	-2.5	-2.4	-2.4	-0.6	-0.5	-0.3	-0.3	1.0	-0.7	-1.6	-1.4	-1.2	0.1	0.0 999.0
1981	999.0	999.0	0.0	-0.4	-0.5	-0.5	-1.0	-0.6	-0.5	-0.7	-1.4	-1.8	-1.0	-0.3	-0.3	-0.3	-0.2	-0.1 999.0
1982	999.0	999.0	0.0	1.4	1.3	1.3	1.2	1.3	1.2	1.2	0.6	1.2	2.3	1.9	1.1	-0.2	-0.2	-0.1 999.0
1983	999.0	999.0	0.0	0.0	8.7	8.9	8.9	-0.3	-0.2	2.0	-1.2	-0.7	-0.3	-0.2	0.1	0.5	-0.6	0.0 999.0

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

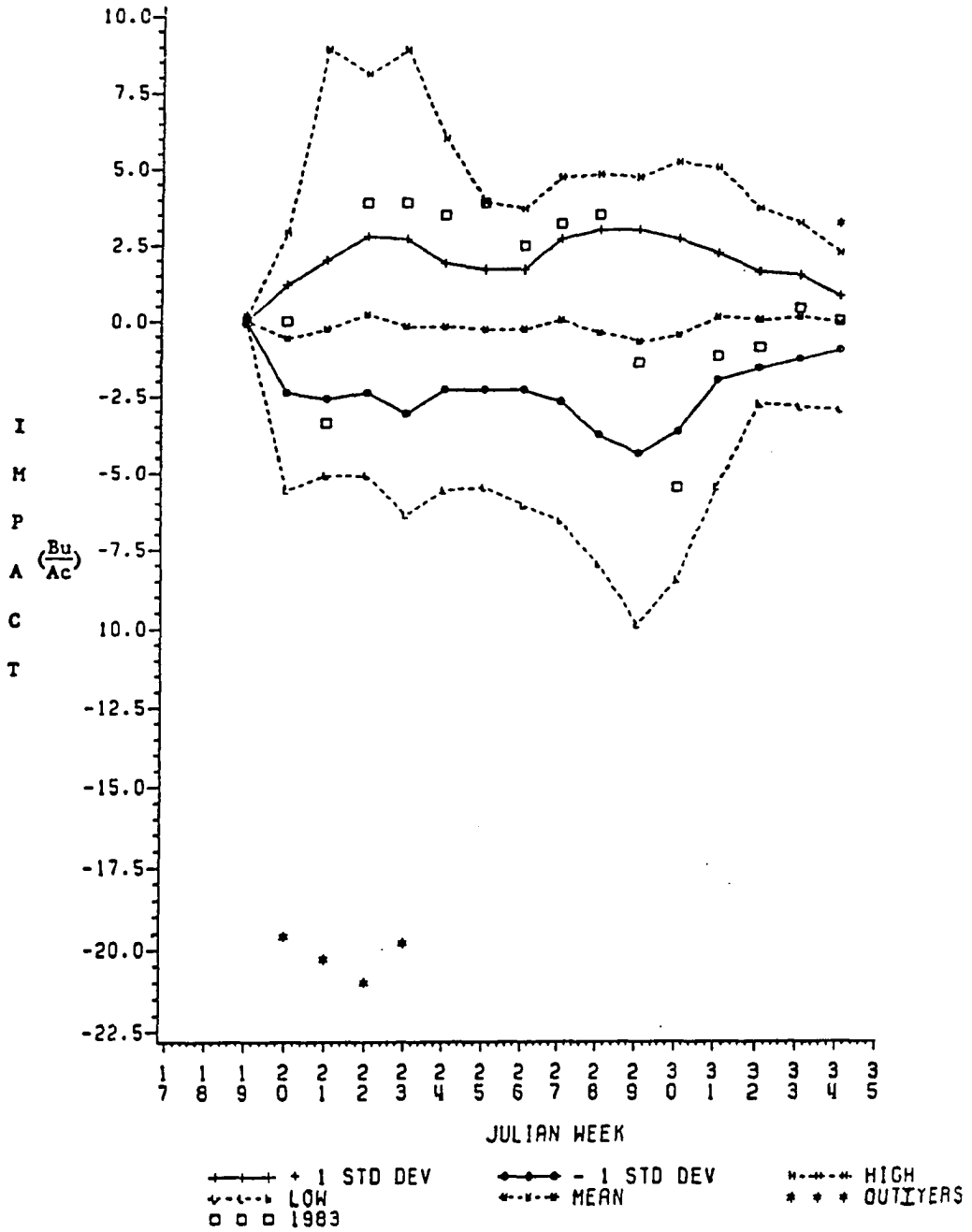
WEEK

Weekly Impact of Observed Precipitation on Modeled Corn Yields (Case 4 - Case 5, Table 15)
Des Moines, IO

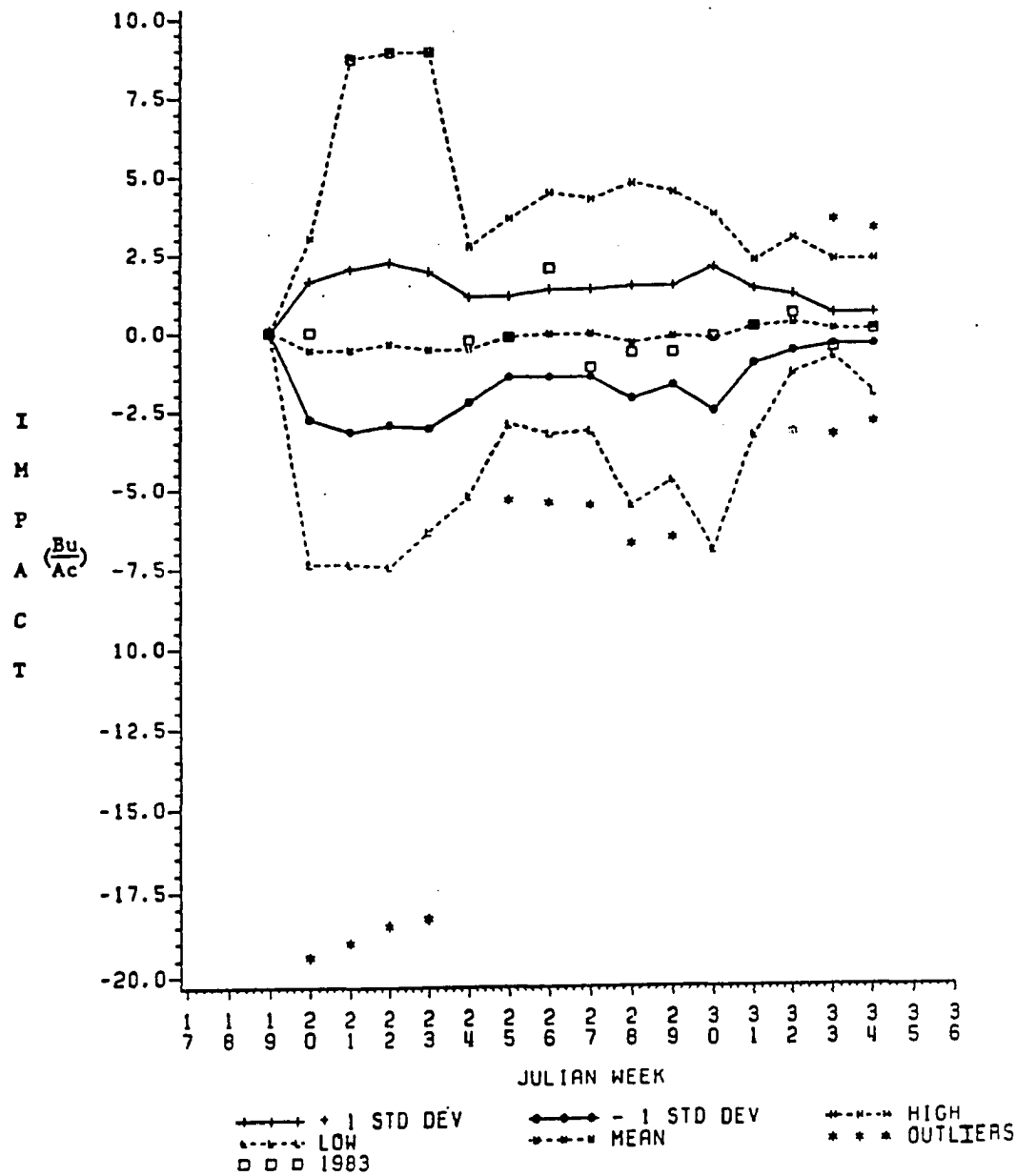
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
1948	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1949	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-1.6	-1.5	0.0	-8.3	-2.4	-0.1	-1.0	0.0	0.0	999.0
1950	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.1	0.0	0.5	0.3	0.0	0.0	999.0
1951	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.3	1.9	0.7	3.9	1.8	1.5	0.0	0.1	0.0	0.0	0.0	999.0
1952	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.2	4.0	1.7	0.0	0.3	3.3	0.5	0.0	0.0	999.0
1953	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-1.7	-4.9	-0.3	-0.2	-3.2	-1.8	0.0	0.0	999.0
1954	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3	0.0	0.0	0.0	0.4	-0.2	0.3	0.3	-0.1	0.0	999.0
1955	999.0	999.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.1	-0.1	-1.6	0.1	0.0	0.0	-0.6	-0.1	0.0	0.0	999.0
1956	999.0	999.0	0.2	-0.1	0.0	-0.2	0.0	0.0	-0.3	-0.8	-0.2	0.0	-1.9	-1.8	0.0	0.0	0.0	0.0	999.0
1957	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.1	-0.4	-1.1	0.0	0.0	0.0	0.0	999.0
1958	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.4	0.4	0.0	0.0	0.0	999.0
1959	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.2	0.0	999.0
1960	999.0	999.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.3	0.3	0.1	2.0	0.0	0.2	0.0	0.0	0.0	0.0	999.0
1961	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1962	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	999.0
1963	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-2.8	-2.9	-4.2	0.0	-0.3	0.0	0.0	0.0	999.0
1964	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	2.0	2.1	0.1	0.0	0.2	0.1	0.0	0.0	999.0
1965	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	-1.1	0.0	-0.1	0.0	0.0	0.0	999.0
1966	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.1	1.2	0.3	0.0	0.3	0.0	0.0	999.0
1967	999.0	999.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	-0.3	0.0	-0.2	0.0	-0.1	-0.7	0.0	0.0	0.0	0.0	999.0
1968	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1969	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	2.8	3.4	0.0	1.3	0.0	0.0	999.0
1970	999.0	999.0	0.0	0.0	0.0	0.1	0.0	-0.1	-0.2	0.0	-0.1	-0.2	-0.3	-0.4	0.0	0.0	0.0	0.0	999.0
1971	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	-0.4	-0.1	-0.6	-0.3	-0.1	-2.6	0.0	-0.1	-0.1	999.0
1972	999.0	999.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1973	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1974	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1975	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1976	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.1	0.2	0.0	0.0	0.0	0.0	999.0
1977	999.0	999.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.7	-0.1	-0.2	-2.2	-1.1	-1.1	-0.2	0.0	0.0	0.0	999.0
1978	999.0	999.0	0.0	0.0	-0.1	0.0	0.0	0.1	-0.2	-2.1	-1.5	-0.3	-5.1	0.0	0.0	-0.4	-0.1	0.0	999.0
1979	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.1	0.8	0.0	0.0	0.0	0.0	999.0
1980	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	999.0
1981	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1982	999.0	999.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.9	0.0	0.0	0.0	0.0	999.0
1983	999.0	999.0	0.0	0.0	-0.4	-0.4	-0.5	-0.4	0.0	-0.1	-0.1	0.0	0.0	-1.9	0.0	0.0	0.0	0.0	999.0

WEEK

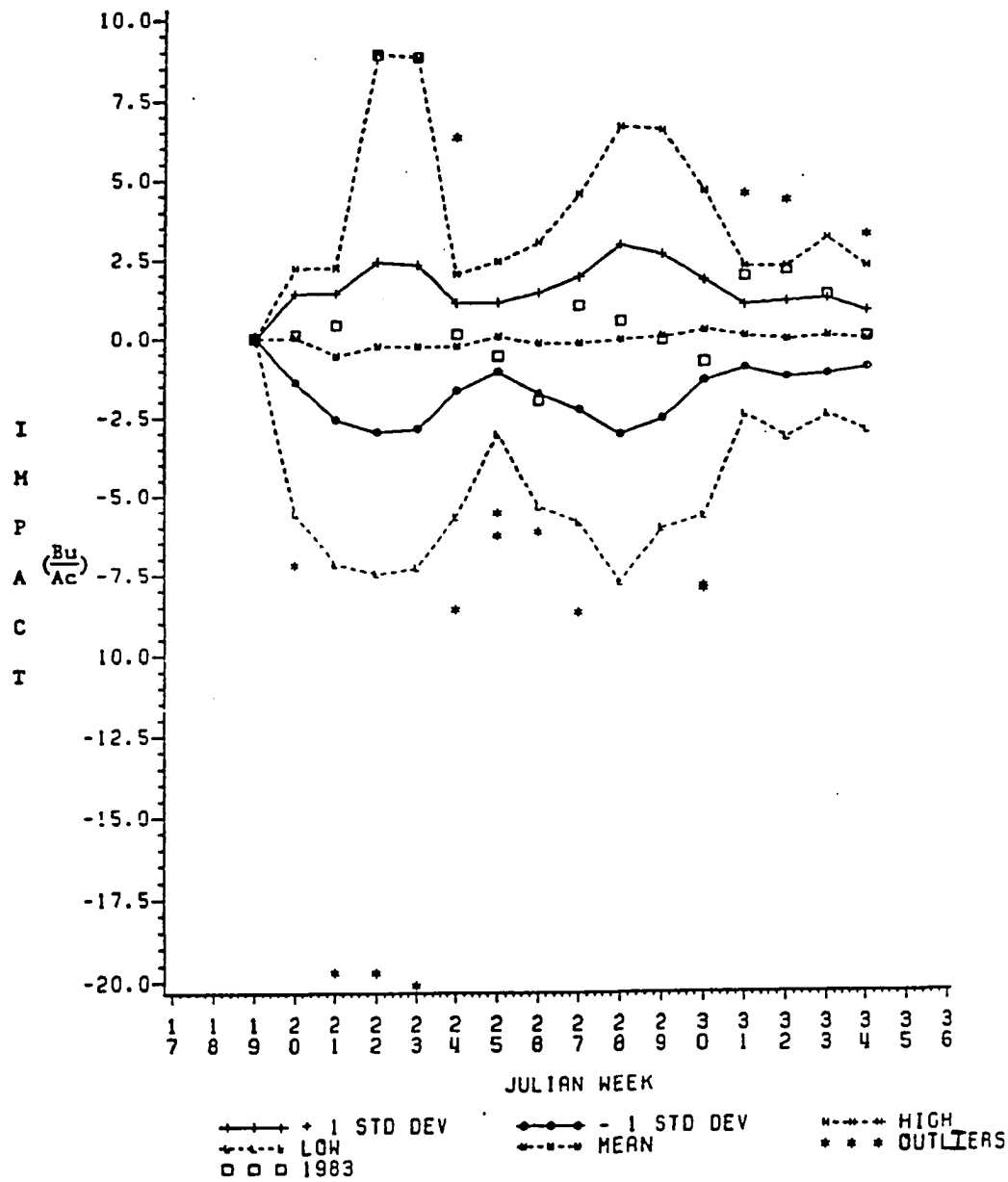
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 1 - Case 5, Table 15) Des Moines, IO



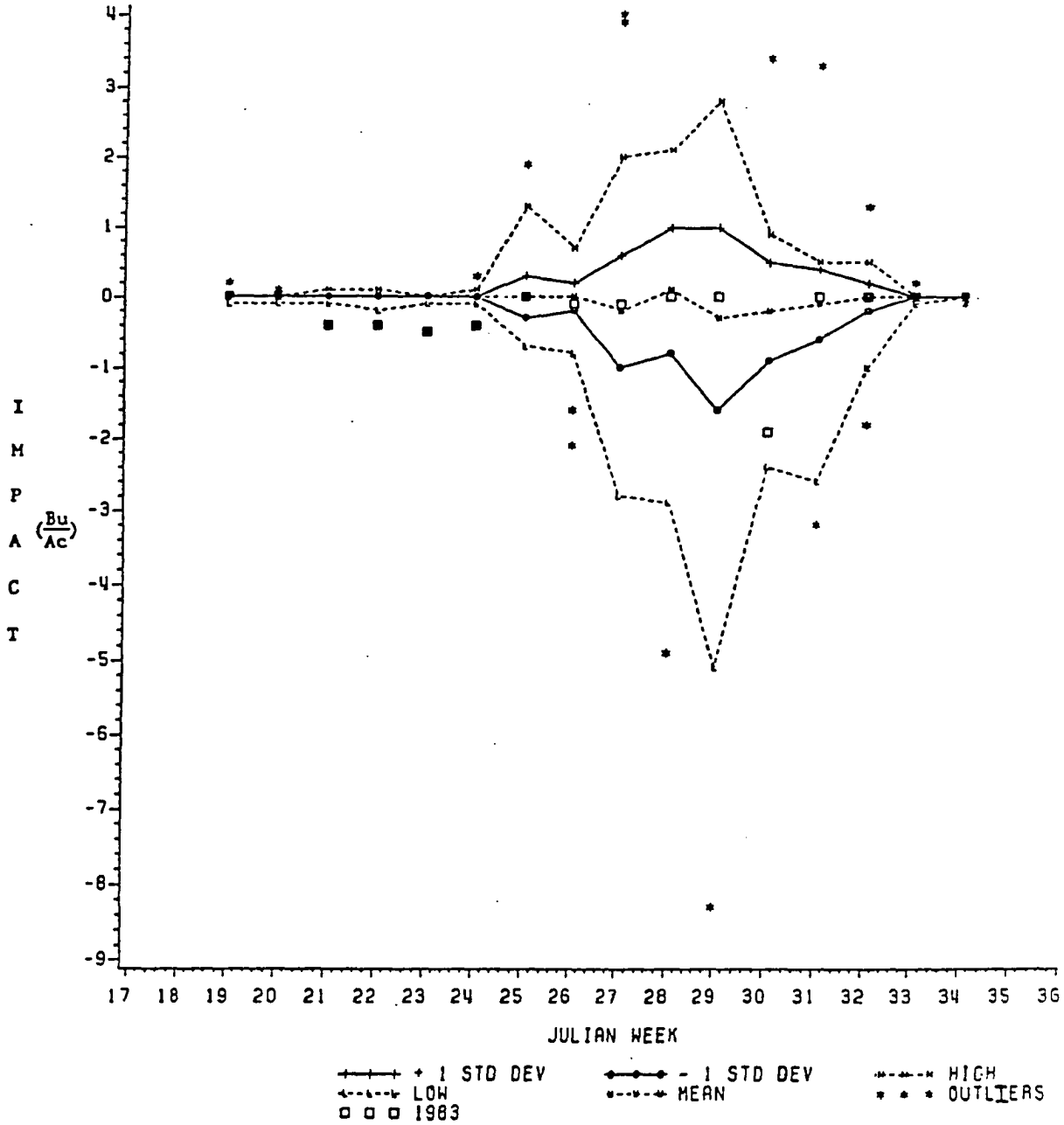
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 2 - Case 5, Table 15) Des Moines, IO



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 3 - Case 5, Table 15) Des Moines, IO



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 4 - Case 5, Table 15) Des Moines, IO



Weekly Impact of All Observed Weather Variables on Modeled Corn Yields (Case 1 - Case 5, Table 15)
Dodge City, KS

1948	999.0	999.0	999.0	0.0	0.1	0.0	0.1	0.9	0.9	0.9	1.0	1.1	0.7	1.1	1.0	0.6	1.0	0.2	0.0
1949	999.0	999.0	999.0	0.5	-6.1	-6.1	-6.1	1.9	1.9	1.4	0.2	0.0	0.0	-0.8	1.3	-1.8	-1.4	0.0	0.0
1950	999.0	999.0	999.0	3.8	3.0	-0.6	2.5	0.0	0.1	2.3	3.2	3.7	3.9	3.6	6.3	6.3	6.3	6.3	6.3
1951	999.0	999.0	999.0	1.4	4.7	4.7	4.7	4.6	4.6	1.5	-0.8	0.8	-0.8	2.5	-0.3	3.2	0.0	3.2	0.0
1952	999.0	999.0	999.0	0.0	-6.8	-4.4	-4.1	0.0	2.2	1.8	-1.8	1.3	1.6	-1.6	0.0	-0.5	2.0	0.0	0.0
1953	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-2.2	-1.0	0.0	-0.9	-3.5	-1.1	-3.3	-4.8	-3.9	-3.3	-3.3	0.0
1954	999.0	999.0	999.0	-3.3	1.3	1.2	1.1	-0.9	-0.2	-0.2	-0.4	-0.6	-0.7	-1.4	-1.9	-5.2	-0.6	-3.3	0.0
1955	999.0	999.0	999.0	0.2	1.0	1.0	1.0	-1.3	-1.1	-1.1	-0.3	-3.5	-1.2	-1.5	-0.4	-0.1	-0.1	0.0	0.0
1956	999.0	999.0	999.0	9.8	10.2	-0.1	9.7	-0.1	-0.8	1.6	-0.6	-0.6	-0.3	0.4	0.5	0.4	3.1	0.0	0.0
1957	999.0	999.0	999.0	0.0	3.2	1.2	0.9	1.3	1.4	0.1	1.1	-0.6	-0.9	-0.2	0.2	0.3	0.6	0.1	0.0
1958	999.0	999.0	999.0	0.0	3.2	3.2	3.2	0.9	1.0	1.1	2.8	-0.9	2.0	2.3	3.2	0.0	0.0	3.2	0.0
1959	999.0	999.0	999.0	0.0	0.0	0.0	-0.1	0.0	0.0	1.3	2.6	-1.0	-0.1	-0.2	-0.2	-0.1	0.0	0.0	0.0
1960	999.0	999.0	999.0	0.0	0.0	2.1	-1.2	-1.3	-0.2	0.6	-2.2	1.6	0.3	2.1	-0.3	0.0	0.0	0.0	0.0
1961	999.0	999.0	999.0	-6.3	4.5	4.6	-4.9	-6.6	4.7	0.4	4.6	4.7	4.2	4.2	3.5	3.3	6.6	6.6	3.3
1962	999.0	999.0	999.0	-1.0	-0.9	-0.9	1.6	0.6	0.7	0.5	1.8	1.8	0.7	1.6	1.6	0.2	-0.9	0.0	0.0
1963	999.0	999.0	999.0	0.0	-3.3	-2.7	-2.7	1.1	-2.5	1.1	0.5	0.1	-0.8	0.6	-0.4	-0.3	1.6	-0.3	0.0
1964	999.0	999.0	999.0	0.8	-5.5	0.1	0.9	0.9	0.8	0.9	-2.6	1.0	0.5	0.7	-1.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	7.3	4.5	4.5	2.8	2.9	0.9	1.5	3.3	3.0	2.1	-1.6	0.2	2.9	0.1	0.0	0.0
1966	999.0	999.0	999.0	2.2	2.3	-1.2	2.3	-0.1	-2.3	2.6	-2.0	0.3	3.0	3.1	-0.1	-3.1	0.0	-3.1	0.0
1967	999.0	999.0	999.0	3.2	0.4	4.0	-4.7	0.8	4.1	3.8	4.9	4.2	3.2	3.3	6.2	6.4	6.1	6.3	6.4
1968	999.0	999.0	999.0	-1.1	-1.2	2.6	-0.8	-0.8	-1.7	-0.2	1.9	-6.2	2.1	0.2	-1.6	-1.5	-0.2	0.0	0.0
1969	999.0	999.0	999.0	0.0	0.0	0.0	4.9	5.1	4.9	5.6	4.8	5.5	4.3	4.8	0.2	-0.4	0.0	0.0	0.0
1970	999.0	999.0	999.0	6.4	4.1	3.0	3.5	3.4	5.3	2.2	2.5	2.2	-1.1	3.3	1.1	1.3	1.3	0.0	0.0
1971	999.0	999.0	999.0	0.0	-0.1	0.7	0.7	-0.3	-0.1	-0.1	0.3	1.4	0.3	0.0	-0.8	-0.7	-1.2	-0.5	0.0
1972	999.0	999.0	999.0	-0.9	2.5	2.4	-1.2	2.6	4.3	4.3	4.3	-0.2	3.8	2.5	3.2	2.9	3.3	3.3	3.3
1973	999.0	999.0	999.0	0.8	0.6	0.1	0.2	0.1	0.1	0.5	-0.1	0.9	0.7	0.7	0.2	0.1	0.1	2.7	0.0
1974	999.0	999.0	999.0	0.0	-0.1	-4.0	-4.0	-4.0	0.0	-4.0	-4.7	0.2	0.1	0.0	-0.9	0.0	0.0	0.0	0.0
1975	999.0	999.0	999.0	0.0	2.2	0.0	3.2	0.0	3.2	2.8	3.9	2.0	3.2	-0.4	1.6	-0.1	0.0	0.0	0.0
1976	999.0	999.0	999.0	0.0	-0.2	0.0	0.0	3.5	-0.7	3.7	3.3	4.4	5.7	4.1	2.3	3.5	2.3	3.5	3.5
1977	999.0	999.0	999.0	-1.2	4.7	4.7	-1.8	-0.5	-3.8	-1.2	-1.2	-4.2	2.0	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4
1978	999.0	999.0	999.0	-2.5	-2.2	-2.1	-2.2	-1.5	-2.8	-1.1	-7.0	-0.9	-0.8	-1.4	-1.0	0.0	0.0	0.0	0.0
1979	999.0	999.0	999.0	-3.3	-3.3	-3.3	-3.3	-3.3	-0.5	-1.4	-0.7	0.6	-2.4	-3.4	0.0	0.0	0.0	0.0	0.0
1980	999.0	999.0	999.0	-0.1	-2.9	-3.2	2.5	-0.7	-1.0	-0.2	-2.5	-0.7	-1.3	-5.2	-0.9	-1.5	-3.5	0.0	0.0
1981	999.0	999.0	999.0	0.0	2.6	2.6	1.8	3.2	2.8	2.5	3.3	-0.6	1.4	-3.7	-3.3	-3.3	-3.3	-3.3	-3.3
1982	999.0	999.0	999.0	0.0	3.4	0.0	3.4	3.4	3.5	1.6	1.6	-1.3	-1.0	0.7	1.0	0.6	0.3	0.0	0.0
1983	999.0	999.0	999.0	0.0	7.1	7.1	7.1	3.3	7.0	7.0	7.1	3.3	-2.5	1.6	-0.1	0.0	0.0	0.0	0.0

	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
								WEEK								

Weekly Impact of Observed Maximum Temperature on Modeled Corn Yields (Case 2 - Case 5, Table 15)
Dodge City, KS

1948	999.0	999.0	999.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.9	0.8	0.6	0.2	0.8	0.4	0.1	1.0	0.4	0.0
1949	999.0	999.0	999.0	0.5	-6.1	-6.1	-6.1	1.9	3.0	0.7	1.3	-0.1	0.0	-0.6	-1.8	-1.5	-0.8	0.0	0.0
1950	999.0	999.0	999.0	3.1	2.9	3.0	2.2	1.7	-0.2	-0.2	2.6	1.1	1.0	1.3	3.2	3.2	3.2	3.2	3.2
1951	999.0	999.0	999.0	1.2	4.6	4.4	4.7	4.6	4.7	3.1	0.5	-3.6	0.5	-1.4	-0.1	0.0	0.0	3.2	0.0
1952	999.0	999.0	999.0	0.0	-6.9	-2.4	-2.4	3.5	5.0	4.4	1.9	2.1	-1.3	0.6	0.0	-0.2	5.6	0.0	0.0
1953	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-1.7	0.6	-0.6	0.0	0.2	0.3	-0.2	0.0	0.0	0.0	0.0	0.0
1954	999.0	999.0	999.0	0.0	-1.7	-1.8	-1.7	-1.9	-0.3	-5.0	0.0	0.3	-0.4	-4.4	-2.0	-3.3	0.0	-3.3	0.0
1955	999.0	999.0	999.0	0.2	1.0	1.0	1.0	-1.2	-1.0	-1.1	-0.5	-2.2	-0.6	-1.6	-0.6	-0.2	-0.2	0.0	0.0
1956	999.0	999.0	999.0	0.3	10.1	9.9	10.0	0.5	3.5	0.6	0.7	1.2	0.5	0.1	0.6	3.8	3.1	0.0	0.0
1957	999.0	999.0	999.0	0.0	0.0	1.3	0.9	1.3	1.3	0.1	0.9	-0.6	0.3	0.6	1.3	0.3	0.7	0.1	0.0
1958	999.0	999.0	999.0	0.0	3.2	0.0	0.0	0.0	1.8	0.0	3.2	-0.3	-0.4	1.7	-1.1	-1.7	0.0	3.2	0.0
1959	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.2	-0.3	-0.3	-0.2	0.0	0.0	0.0
1960	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-1.0	-0.9	-1.0	-1.0	-2.3	-0.5	0.2	0.0	0.0	0.0	0.0
1961	999.0	999.0	999.0	-3.8	5.1	-4.9	-6.3	-2.4	1.8	2.6	1.3	0.7	0.3	0.5	0.4	0.0	3.3	3.3	3.3
1962	999.0	999.0	999.0	-1.0	-1.0	-1.0	1.6	-0.9	1.6	1.6	-1.2	1.4	1.6	0.0	0.2	-0.5	-0.8	0.0	0.0
1963	999.0	999.0	999.0	0.0	-2.1	-3.3	-2.0	1.3	-0.1	0.9	1.2	0.0	-0.1	-0.3	-0.5	-0.8	-0.3	-0.4	0.0
1964	999.0	999.0	999.0	0.8	-5.5	1.3	1.3	0.9	1.4	0.7	-2.7	1.9	0.8	0.5	0.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	7.9	7.3	7.3	2.7	2.5	2.9	3.5	2.7	3.6	2.2	2.6	3.4	2.8	0.1	0.0	0.0
1966	999.0	999.0	999.0	2.3	2.3	2.3	2.3	0.7	0.7	2.6	0.4	0.6	1.0	0.5	-0.2	0.0	0.0	0.0	0.0
1967	999.0	999.0	999.0	3.2	-0.3	0.6	2.3	-0.3	-0.1	-0.2	-0.1	-2.9	-1.7	1.9	3.2	3.0	6.4	6.4	3.2
1968	999.0	999.0	999.0	-1.2	-1.2	-1.1	-1.1	-1.1	-1.9	-0.2	-1.8	-1.5	-0.5	-3.1	1.7	-3.5	0.5	-3.6	0.0
1969	999.0	999.0	999.0	0.0	-0.1	-0.1	0.0	0.0	-0.1	-0.1	0.2	5.5	-0.1	0.1	0.1	0.2	0.0	0.0	0.0
1970	999.0	999.0	999.0	6.4	3.0	3.1	3.0	3.5	5.4	2.6	3.0	1.5	0.6	0.5	4.3	0.4	1.3	0.0	0.0
1971	999.0	999.0	999.0	0.0	-0.3	-0.4	-0.4	0.0	-0.2	0.8	0.4	0.9	-0.1	-3.6	-3.6	-3.6	-3.9	-0.2	0.0
1972	999.0	999.0	999.0	-1.5	0.7	-0.8	-0.8	-0.7	-0.7	1.1	-1.3	-0.5	1.2	-1.4	3.0	4.0	0.0	0.0	3.3
1973	999.0	999.0	999.0	-1.1	0.1	0.1	0.2	0.2	0.2	0.1	0.4	0.6	0.6	0.6	0.2	0.1	0.1	3.2	0.0
1974	999.0	999.0	999.0	0.0	-0.1	-0.1	-4.0	-4.0	0.0	-4.0	-4.7	0.2	0.1	-1.6	-0.9	0.0	0.0	0.0	0.0
1975	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	1.9	3.3	2.0	3.2	-0.3	1.6	-0.1	0.0	0.0	0.0
1976	999.0	999.0	999.0	2.1	-1.4	-1.4	0.2	0.2	0.3	0.2	0.0	0.2	0.5	4.0	0.0	3.5	0.0	0.0	0.0
1977	999.0	999.0	999.0	2.2	2.0	2.1	-0.4	0.1	-0.6	2.8	-0.2	-1.0	0.7	0.0	-3.4	0.0	-3.4	-3.4	-3.4
1978	999.0	999.0	999.0	0.0	-2.5	-2.5	-2.5	-2.4	-3.0	-2.9	-3.1	-0.5	0.5	-0.5	-1.2	0.0	0.0	0.0	0.0
1979	999.0	999.0	999.0	0.0	-3.4	-3.4	-3.3	-1.0	0.0	-1.1	-1.1	-4.6	-2.3	-0.3	0.0	-0.7	0.0	0.0	0.0
1980	999.0	999.0	999.0	-0.1	-0.7	-0.7	-0.6	-0.1	-0.7	-0.4	-0.2	0.1	-1.0	1.3	2.0	3.5	0.0	0.0	0.0
1981	999.0	999.0	999.0	0.0	-3.3	-3.3	0.0	-3.4	-0.1	-0.2	-3.4	0.4	0.5	0.1	0.0	-3.3	-3.3	-3.3	0.0
1982	999.0	999.0	999.0	3.4	3.4	3.4	3.4	3.4	3.4	5.0	0.1	3.4	-1.3	0.1	0.4	3.6	0.2	0.0	0.0
1983	999.0	999.0	999.0	0.0	3.8	0.3	5.3	3.5	3.4	-4.2	0.3	-4.7	2.6	-0.5	2.1	0.0	0.0	0.0	0.0
				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

WEEK

Weekly Impact of Observed Minimum Temperature on Modeled Corn Yields (Case 3 - Case 5, Table 15)
Dodge City, KS

1948	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.5	1.3	1.0	1.0	1.0	1.0	0.0
1949	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.2	2.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1950	999.0	999.0	999.0	0.0	3.2	0.6	0.6	-0.1	-0.1	-0.2	3.1	2.5	5.0	4.3	3.2	3.2	3.2	3.2	3.2
1951	999.0	999.0	999.0	-1.1	0.0	0.0	0.0	-1.1	1.4	-0.1	-1.3	-1.1	-1.5	0.6	-1.7	-0.1	0.0	0.0	0.0
1952	999.0	999.0	999.0	0.0	0.0	-6.5	2.1	2.1	0.0	0.0	0.0	1.7	-0.5	-0.3	0.3	0.3	0.0	0.0	0.0
1953	999.0	999.0	999.0	0.0	0.0	-2.3	0.0	0.0	-0.7	0.0	-1.4	-0.5	-0.6	-0.2	0.0	0.0	0.0	0.0	0.0
1954	999.0	999.0	999.0	0.0	-3.3	0.0	-1.6	-1.7	2.1	-0.1	1.2	-5.0	-0.7	-5.0	-5.0	-4.4	-3.9	-3.3	0.0
1955	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.4	-0.1	-0.4	-0.3	-0.3	0.0	0.0	0.0
1956	999.0	999.0	999.0	0.3	10.3	9.9	9.9	0.4	0.3	1.5	-1.1	0.6	0.7	0.5	0.7	0.3	0.1	0.0	0.0
1957	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1958	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.4	0.2	0.1	0.0	0.0	0.0	0.0
1959	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
1960	999.0	999.0	999.0	0.0	0.0	-1.2	-0.2	-1.2	1.7	-1.2	1.0	-1.9	0.3	2.1	-0.4	0.0	0.0	0.0	0.0
1961	999.0	999.0	999.0	-3.2	-3.2	-3.2	-3.2	-3.2	0.9	1.0	0.7	2.7	3.8	3.3	3.2	3.3	3.3	3.3	3.3
1962	999.0	999.0	999.0	-1.0	-1.0	-1.0	-1.0	0.6	-1.0	-1.1	0.2	0.4	0.1	0.7	0.5	-0.2	-0.3	0.0	0.0
1963	999.0	999.0	999.0	0.0	0.0	-1.0	-2.1	1.2	1.2	1.4	-1.0	-1.4	-1.0	-1.4	-1.8	1.5	0.4	0.2	0.0
1964	999.0	999.0	999.0	0.0	-5.5	-5.5	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	0.4	0.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	0.0	5.0	5.0	0.1	0.2	0.1	1.2	1.3	1.3	0.9	-1.5	2.0	-0.3	0.0	0.0	0.0
1966	999.0	999.0	999.0	2.3	2.3	2.3	2.3	3.2	3.2	1.7	2.4	2.3	2.2	0.4	-1.5	0.0	0.0	0.0	0.0
1967	999.0	999.0	999.0	3.2	-1.4	-0.4	-4.6	-0.4	-0.4	-0.6	-1.2	3.4	2.2	1.5	2.8	1.4	2.7	2.9	3.2
1968	999.0	999.0	999.0	-1.1	0.0	-1.1	-1.1	-1.4	-1.4	-1.3	-0.1	0.5	-0.6	0.1	0.7	0.6	-0.3	0.0	0.0
1969	999.0	999.0	999.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.5	5.4	5.5	5.0	0.1	0.1	0.0	0.0	0.0
1970	999.0	999.0	999.0	0.0	4.8	4.8	4.8	0.1	1.9	1.5	1.2	-0.3	-0.1	0.1	0.2	0.1	0.1	0.0	0.0
1971	999.0	999.0	999.0	0.0	-0.1	0.7	0.7	-0.1	-0.1	-0.1	0.7	1.3	-0.3	-0.4	-0.4	-0.8	-1.0	-0.4	0.0
1972	999.0	999.0	999.0	0.3	0.2	-1.5	0.5	0.5	0.1	0.5	0.1	0.8	4.0	3.2	1.3	1.1	0.0	0.0	0.0
1973	999.0	999.0	999.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.2	0.0	-0.1	-0.2	0.0	0.0
1974	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	999.0	999.0	999.0	0.1	0.1	2.3	2.3	2.3	2.3	3.2	3.3	0.0	3.3	-0.1	1.6	0.0	0.0	0.0	0.0
1976	999.0	999.0	999.0	0.0	3.3	3.3	3.3	3.7	3.7	3.7	3.5	4.2	4.3	4.3	3.5	3.5	3.4	3.5	3.5
1977	999.0	999.0	999.0	2.2	2.0	2.0	2.0	-1.2	-4.0	-3.5	-4.9	-3.6	-3.0	-3.6	-3.4	-3.4	-3.4	-3.4	-3.4
1978	999.0	999.0	999.0	0.0	-1.4	-2.3	-2.3	-0.6	-2.3	-0.7	-2.3	-2.6	-1.6	-0.1	-1.7	0.0	0.0	0.0	0.0
1979	999.0	999.0	999.0	-6.5	-3.2	-3.2	-3.2	-3.6	-1.4	-0.2	-0.5	0.9	1.3	-0.4	-0.5	-0.7	0.0	0.0	0.0
1980	999.0	999.0	999.0	0.0	-0.7	1.0	1.0	1.0	1.0	0.2	0.0	-3.7	-0.1	0.4	-0.8	0.0	0.0	0.0	0.0
1981	999.0	999.0	999.0	0.0	1.8	1.8	1.8	1.8	2.9	3.4	3.2	0.9	1.0	-3.9	-3.3	-3.3	-3.3	-3.3	-3.3
1982	999.0	999.0	999.0	0.0	1.7	1.7	1.7	1.7	1.7	0.0	0.0	-0.2	-2.1	0.0	0.2	0.1	0.1	0.0	0.0
1983	999.0	999.0	999.0	0.0	-3.4	-3.4	3.5	3.4	5.7	3.7	4.9	3.0	1.3	-1.7	-0.3	-1.1	0.0	0.0	0.0
				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

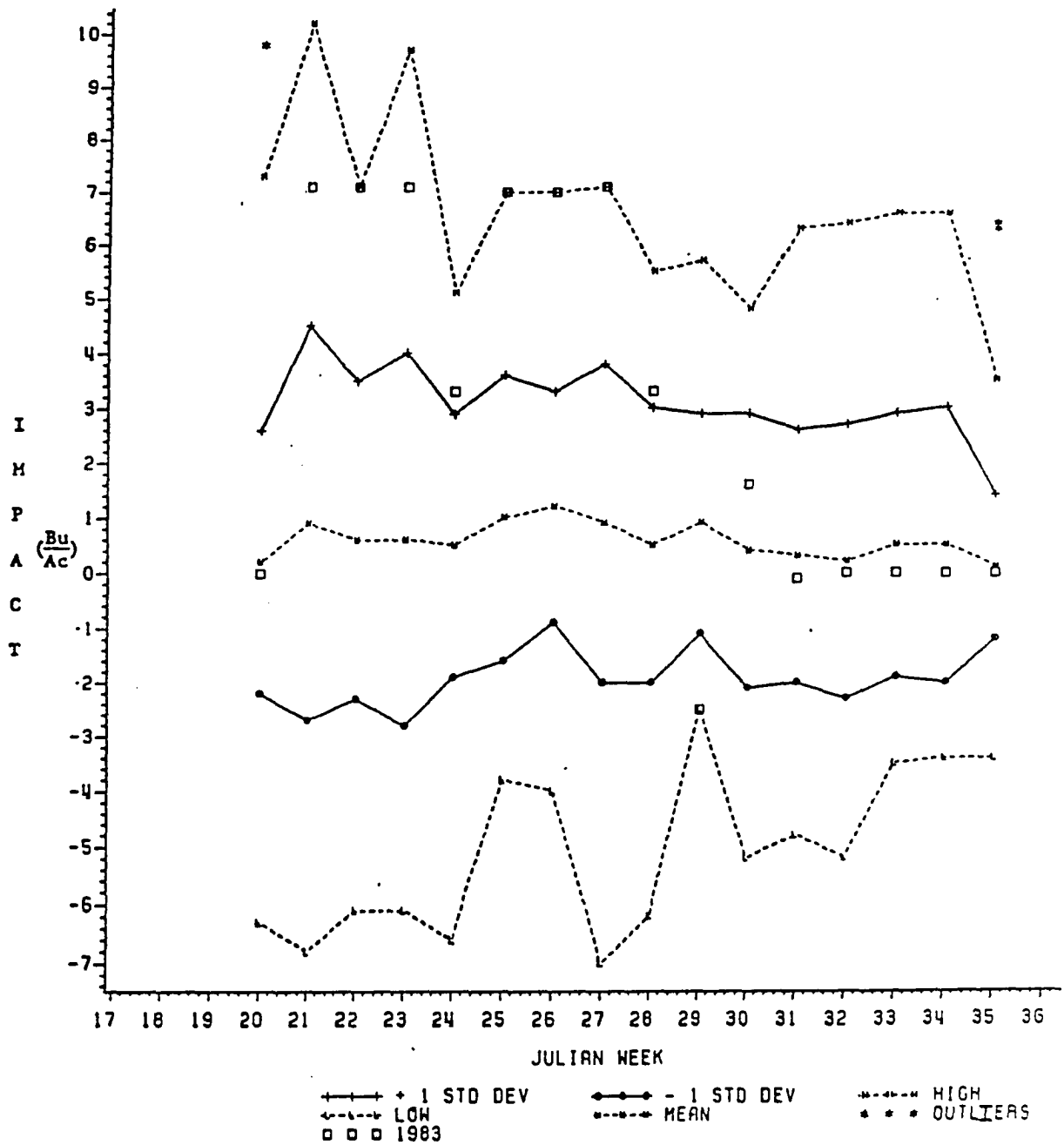
WEEK

Weekly Impact of Observed Precipitation on Modeled Corn Yields (Case 4 - Case 5, Table 15)
Dodge City, KS

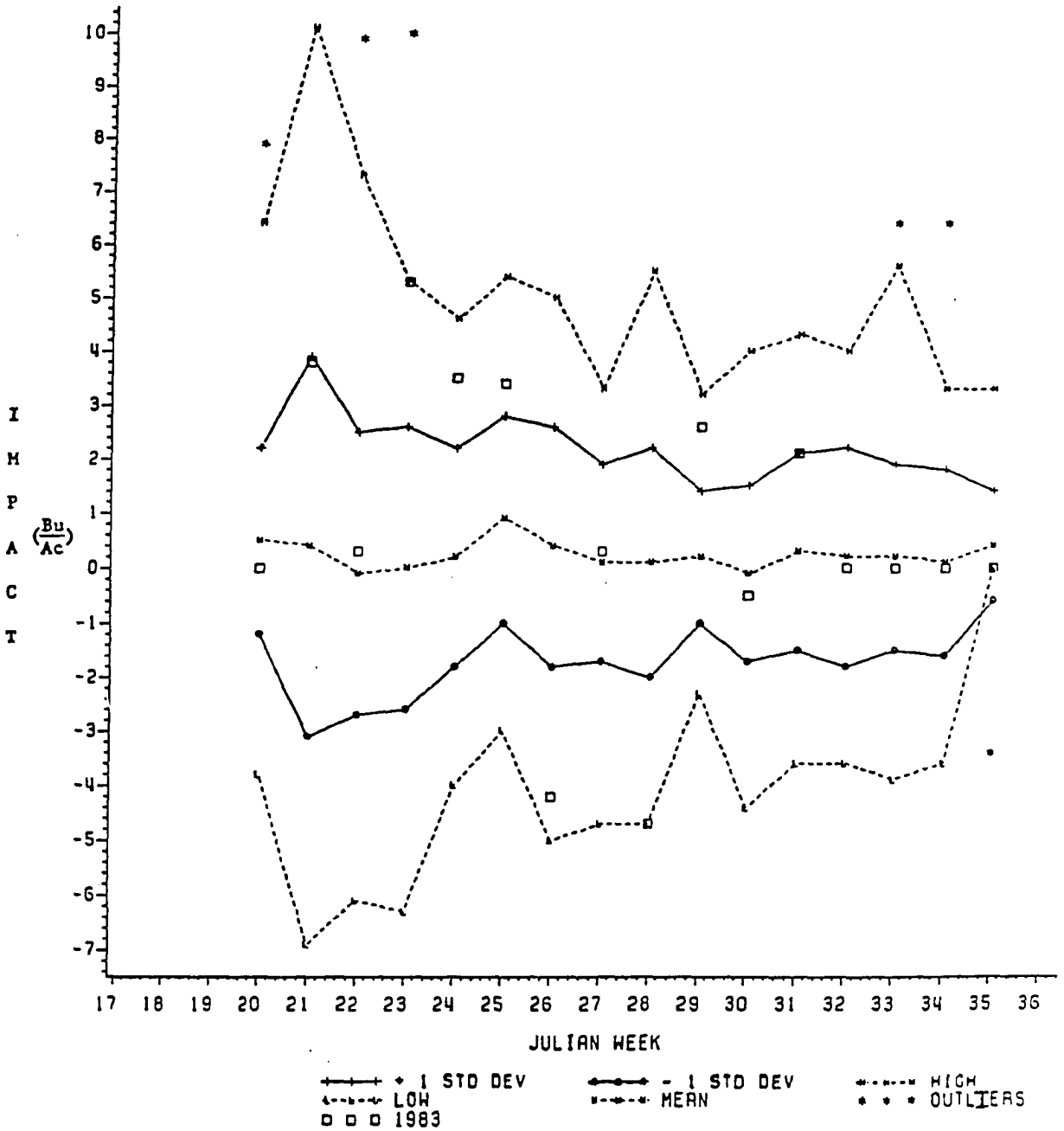
1948	999.0	999.0	999.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	1.0	0.1	0.5	0.3	1.0	0.8	1.0	0.0	0.0
1949	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1950	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1951	999.0	999.0	999.0	0.0	-1.1	1.3	0.0	-0.1	-1.1	0.9	1.4	-2.3	1.0	-1.0	-1.1	0.0	0.0	0.0	0.0
1952	999.0	999.0	999.0	0.0	0.0	2.2	0.0	0.0	2.2	0.0	2.2	2.0	-2.1	1.2	0.0	0.0	0.0	0.0	0.0
1953	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.7	-0.5	0.0	-0.7	-0.9	0.0	-1.5	-0.4	0.0	0.0	0.0
1954	999.0	999.0	999.0	0.0	0.1	0.0	0.0	-1.7	0.0	0.0	0.0	0.0	-2.2	-3.0	0.0	-1.1	-0.1	0.0	0.0
1955	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	0.0	-0.3	0.0	0.0
1956	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.3	-1.0	-0.4	0.0	0.4	1.3	0.8	0.7	0.0	0.0	0.0
1957	999.0	999.0	999.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	-0.5	0.0	0.0	0.0
1958	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-2.4	-2.3	0.0	-0.4	-1.1	-1.2	-1.2	0.0	0.0	0.0	0.0	0.0
1959	999.0	999.0	999.0	0.0	-0.1	0.0	-0.1	0.0	0.0	1.4	2.6	-1.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1960	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-1.4	0.0	-1.9	1.6	-0.6	0.0	1.9	0.0	0.0	0.0	0.0	0.0
1961	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.9	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0
1962	999.0	999.0	999.0	0.0	0.0	0.1	0.1	0.0	0.8	0.8	0.7	1.9	0.4	1.6	1.6	0.0	0.0	0.0	0.0
1963	999.0	999.0	999.0	0.0	0.0	0.0	-1.0	1.2	0.0	0.0	0.0	0.7	-0.5	-2.8	0.0	0.0	1.6	0.0	0.0
1964	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	0.2	0.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	0.0	0.0	0.0	2.1	0.2	0.0	3.8	2.6	2.1	0.0	1.5	1.7	0.2	0.0	0.0	0.0
1966	999.0	999.0	999.0	-1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0
1967	999.0	999.0	999.0	0.0	0.0	0.0	-0.1	-0.9	-0.9	-0.6	-0.1	-0.6	-0.1	-0.9	0.0	0.0	0.0	0.0	0.0
1968	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.9	-0.1	0.0	2.8	1.3	0.2	0.0	0.0	0.0
1969	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.1	-0.1	0.0	-0.4	2.4	1.5	-0.2	0.0	0.0	0.0	0.0	0.0
1970	999.0	999.0	999.0	0.0	0.7	1.8	0.0	1.4	-0.1	0.7	0.9	0.8	-0.2	0.7	0.5	1.3	1.3	0.0	0.0
1971	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.3	0.0	0.1	0.0	0.0	0.0
1972	999.0	999.0	999.0	0.0	-1.5	-1.4	0.0	0.0	0.3	-0.7	-0.2	0.2	0.7	0.3	-1.0	0.0	0.0	0.0	0.0
1973	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.1	0.1	-0.6	-0.2	0.0
1974	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	999.0	999.0	999.0	0.0	2.5	0.0	0.0	0.0	0.0	4.7	2.7	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0
1976	999.0	999.0	999.0	0.0	-0.2	0.0	0.0	0.0	-0.6	0.0	0.0	0.0	0.2	-0.8	-1.6	0.0	-0.6	0.0	0.0
1977	999.0	999.0	999.0	0.0	-0.4	0.0	0.0	0.0	0.0	0.0	-2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-3.1	-0.4	0.0	0.0	-1.0	0.0	-1.2	0.0	0.0	0.0	0.0
1979	999.0	999.0	999.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.6	0.0	-0.4	-0.9	0.0	0.0	0.0	0.0	0.0
1980	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
1981	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.6	0.0	0.2	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
1982	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.7	0.0	1.3	0.1	0.0	0.0	0.0
1983	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-2.1	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0
				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

WEEK

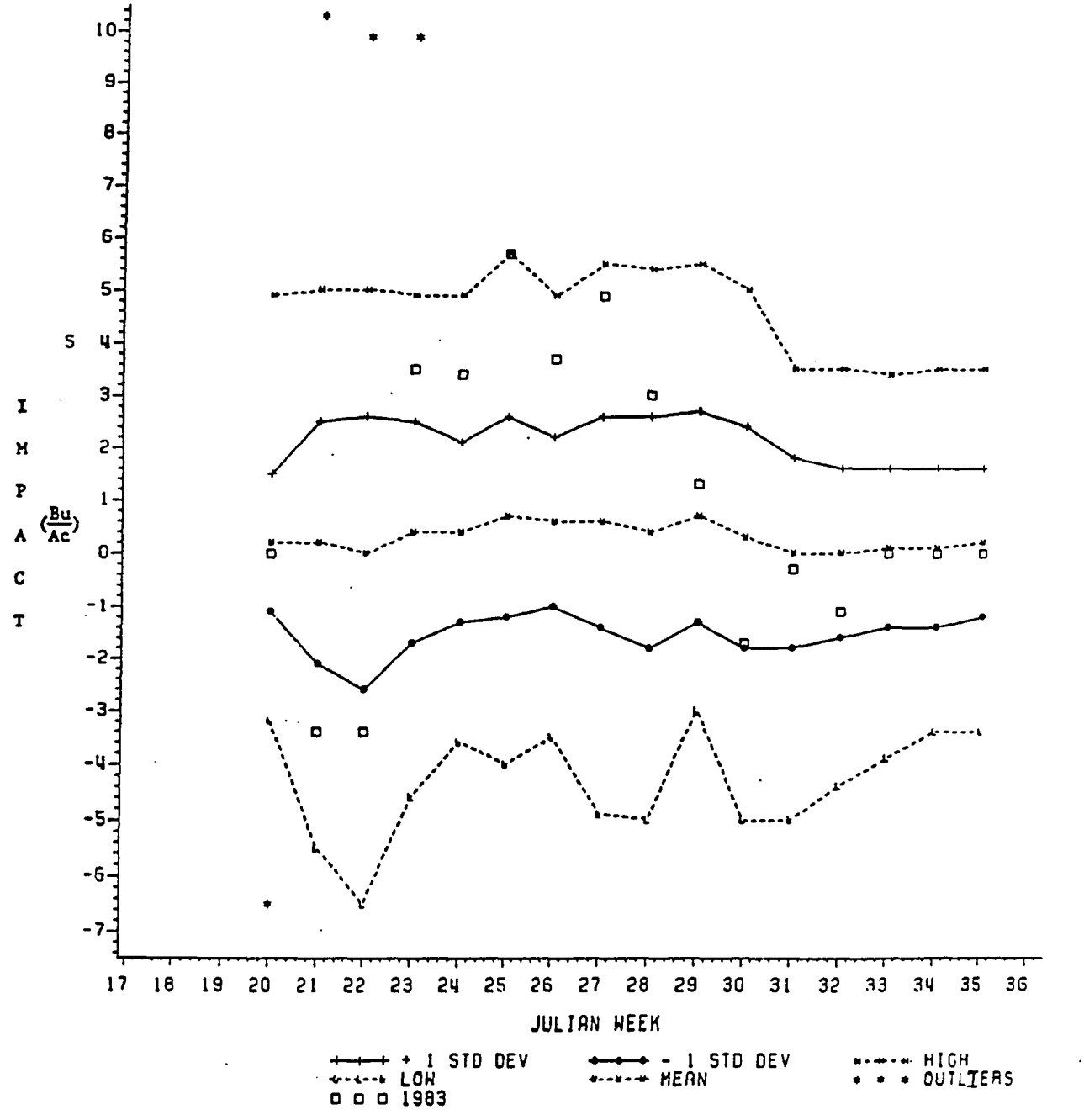
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 1 - Case 5, Table 15) Dodge City, KS



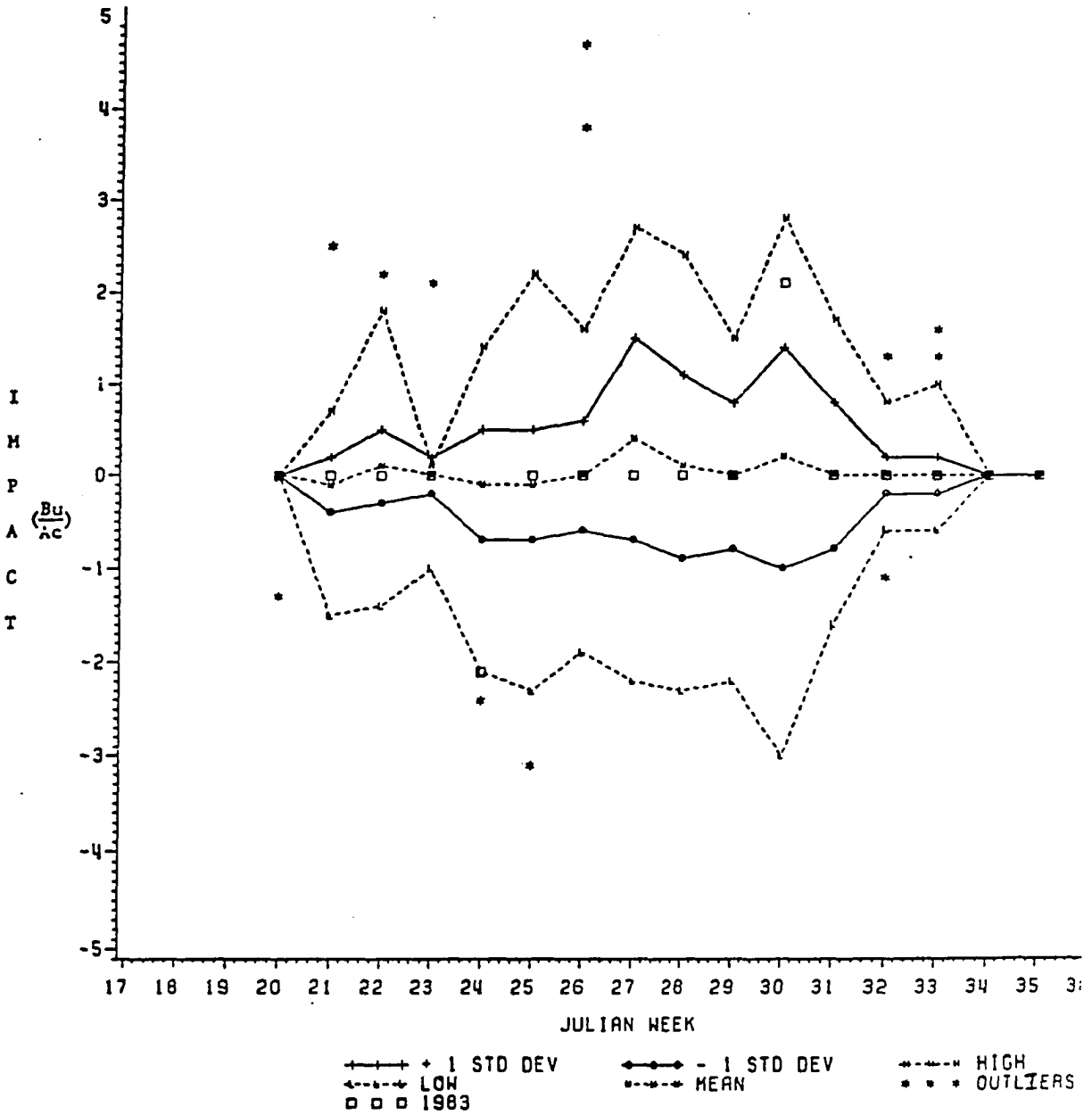
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 2 - Case 5, Table 15) Dodge City, KS



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 3 - Case 5, Table 15) Dodge City, KS



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 4 - Case 5, Table 15) Dodge City, KS



Weekly Impact of All Observed Weather Variables on Modeled Corn Yields (Case 1 - Case 5, Table 15)
Omaha, NB

1948	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0	1.7	0.0	0.0	0.0	0.0	0.0 999.0
1949	999.0	999.0	0.0	1.5	2.2	1.9	2.4	2.5	2.8	0.6	2.0	-0.4	-1.0	-1.4	0.2	0.0	0.0	0.0 999.0
1950	999.0	999.0	-1.3	-1.4	-1.4	4.3	-1.5	-1.4	-1.4	-1.5	0.1	0.5	1.3	2.9	2.9	2.9	2.9	0.0 999.0
1951	999.0	999.0	-0.4	0.7	0.7	0.5	0.0	-0.2	0.2	-0.1	0.3	0.1	-0.5	0.9	0.5	0.5	0.4	0.0 999.0
1952	999.0	999.0	0.0	-0.3	0.3	0.2	0.3	0.0	-0.1	-0.6	-3.3	-3.8	-1.9	-1.1	-0.7	-0.7	-0.4	-0.3 999.0
1953	999.0	999.0	0.0	-8.7	-8.2	-8.2	-0.4	-0.4	-0.1	1.0	0.8	-0.3	-3.0	0.9	0.0	-3.3	-3.3	0.0 999.0
1954	999.0	999.0	-0.3	2.7	0.4	0.1	0.5	0.7	-0.2	0.3	-0.8	-2.6	-2.4	-1.4	-2.1	-1.8	-1.4	-0.6 999.0
1955	999.0	999.0	0.3	1.3	1.4	1.4	0.9	1.1	0.4	-1.4	-2.6	-3.4	-2.6	-0.5	-0.7	-1.1	-0.4	0.0 999.0
1956	999.0	999.0	-0.9	-1.0	-0.6	-0.6	-0.5	-1.6	-3.1	-1.7	-3.1	-3.1	-3.3	-1.6	-2.7	-2.4	-1.9	-0.1 999.0
1957	999.0	999.0	0.6	0.6	0.7	0.7	0.7	-3.4	-1.4	-2.0	-3.7	-3.7	-2.0	-4.2	-0.9	-1.7	-1.0	-0.3 999.0
1958	999.0	999.0	3.3	3.9	3.9	3.9	3.9	3.9	3.8	0.4	3.6	3.0	3.1	3.3	3.4	3.4	3.4	3.4 999.0
1959	999.0	999.0	0.0	0.0	-0.1	0.0	-0.1	-0.2	-0.1	-0.2	-0.3	-0.5	-1.0	-0.3	0.0	0.0	0.0	0.0 999.0
1960	999.0	999.0	-0.2	1.0	1.0	1.0	1.0	0.8	0.9	2.2	2.2	0.9	1.4	4.3	0.8	3.6	3.6	3.6 999.0
1961	999.0	999.0	-3.7	-4.0	-5.1	-5.1	-5.1	-0.8	-0.4	0.3	-0.4	0.2	-0.2	-0.2	0.0	0.0	0.0	0.0 999.0
1962	999.0	999.0	0.3	-0.7	-0.7	0.5	-0.7	-0.8	-2.1	-4.5	-5.8	-3.3	-2.8	-2.7	-3.0	-2.3	-1.4	-0.1 999.0
1963	999.0	999.0	-0.7	-0.5	-1.4	-1.2	-0.5	-0.9	-2.0	-3.8	-4.5	-3.9	-2.8	-3.8	-2.9	-2.5	-1.5	-1.0 999.0
1964	999.0	999.0	-2.4	-1.9	-1.8	-1.8	-1.8	-2.1	-1.8	-1.9	-2.0	-2.3	-2.0	0.2	0.3	-0.1	0.0	0.0 999.0
1965	999.0	999.0	0.0	0.0	-0.2	-0.1	-0.2	-0.4	-0.4	-0.4	-1.2	-1.0	-0.8	-0.8	-0.6	-0.4	-0.3	-0.1 999.0
1966	999.0	999.0	0.0	13.8	13.9	13.9	13.9	2.1	2.5	2.7	4.5	1.0	1.9	1.7	1.9	1.3	0.1	0.0 999.0
1967	999.0	999.0	0.0	-1.4	2.4	1.1	2.5	0.5	0.3	0.1	0.8	1.6	2.1	4.3	3.4	3.4	3.4	3.4 999.0
1968	999.0	999.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1	1.0	1.9	0.9	0.0	0.0	0.0	0.0 999.0
1969	999.0	999.0	2.7	2.5	2.4	3.0	2.4	2.4	3.0	2.8	2.7	-2.0	1.3	2.3	0.0	0.0	0.0	0.0 999.0
1970	999.0	999.0	0.6	1.1	2.6	-0.9	-0.7	-1.0	-0.9	0.9	-1.4	-3.3	-0.9	-3.5	-3.5	-6.9	-6.9	-3.5 999.0
1971	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.2	-0.1	2.8	0.6	1.0	-0.2	0.0	-0.3	0.0	0.0 999.0
1972	999.0	999.0	0.0	-0.1	3.0	3.0	-0.1	-0.1	3.0	3.0	-0.1	3.1	3.1	3.1	3.1	3.1	0.0	0.0 999.0
1973	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	1.0	2.9	1.3	1.1	0.0	0.0	0.0 999.0
1974	999.0	999.0	0.0	0.5	0.0	-1.7	-1.4	-1.4	-0.2	0.0	0.5	3.7	0.9	0.3	0.8	0.0	0.0	0.0 999.0
1975	999.0	999.0	-0.4	2.7	4.9	2.9	4.9	3.4	2.9	4.1	4.5	-0.4	1.0	0.3	0.0	0.7	0.2	0.0 999.0
1976	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	6.6	3.1	1.8	0.0	0.0	0.0	0.0 999.0
1977	999.0	999.0	-0.3	-0.4	-0.6	0.0	-0.4	0.4	-0.9	-1.3	-0.4	-1.3	-1.1	-2.4	-1.7	-1.7	-1.0	-0.3 999.0
1978	999.0	999.0	0.0	-0.1	-0.7	-0.1	-0.1	0.0	0.0	-0.1	-0.4	-0.2	-0.4	0.0	0.0	0.0	0.0	0.0 999.0
1979	999.0	999.0	-0.1	-0.1	-0.1	1.1	1.0	-0.1	0.8	0.7	-0.6	-0.5	1.0	1.1	0.0	0.0	1.2	0.0 999.0
1980	999.0	999.0	0.0	-0.3	-0.5	-0.5	0.3	0.2	0.0	-0.3	-0.3	-1.6	-0.4	0.3	-1.3	-0.5	-0.3	-0.1 999.0
1981	999.0	999.0	0.0	-0.5	-1.2	-1.3	-1.2	-0.4	-0.5	2.7	3.8	4.0	3.8	4.0	4.6	2.9	2.2	0.6 999.0
1982	999.0	999.0	10.0	0.5	0.7	0.5	0.5	1.6	2.2	1.9	0.2	0.6	2.1	0.7	-1.6	0.6	0.5	0.1 999.0
1983	999.0	999.0	0.0	0.0	0.3	0.3	0.3	0.4	-1.2	-1.7	-0.4	-2.5	-2.7	-2.8	-3.2	-1.8	-2.1	-0.5 999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

WEEK

Weekly Impact of Observed Maximum Temperature on Modeled Corn Yields (Case 2 - Case 5, Table 15)
Omaha, NB

1948	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1949	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.6	-0.6	-0.6	-0.6	0.0	0.0	0.0	999.0
1950	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1951	999.0	999.0	0.0	0.0	0.0	-0.1	-0.3	-0.2	-0.8	-0.5	-0.9	-0.4	0.0	0.0	0.0	0.0	0.0	999.0
1952	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-3.2	-0.6	-0.1	0.0	0.0	0.0	0.0	999.0
1953	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.2	0.1	-0.9	0.0	0.0	0.0	0.0	999.0
1954	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	-0.2	0.0	0.0	0.0	-0.1	-0.2	0.0	0.0	999.0
1955	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1956	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1957	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.8	-0.2	0.0	0.0	0.3	0.0	0.1	0.0	0.0	999.0
1958	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1959	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1960	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	1.7	0.7	0.0	0.1	0.0	0.0	999.0
1961	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1962	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1963	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.1	0.3	0.0	0.0	0.0	0.0	0.0	999.0
1964	999.0	999.0	0.0	-0.5	-0.5	0.0	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	999.0
1965	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1966	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1967	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1968	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1969	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1970	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.7	0.5	0.0	0.0	0.0	0.0	999.0
1971	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1972	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1973	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1974	999.0	999.0	0.0	-0.1	0.0	-1.5	-1.5	-1.5	0.0	0.0	-0.1	-2.1	0.0	0.0	-0.1	0.0	0.0	999.0
1975	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-3.3	-0.3	-0.3	0.0	0.0	0.0	999.0
1976	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1977	999.0	999.0	0.0	0.0	-0.1	0.0	0.0	-0.4	0.5	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1978	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1979	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1980	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1981	999.0	999.0	0.0	0.0	0.1	0.0	0.1	0.1	-0.5	0.2	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1982	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.9	1.0	-0.1	0.0	0.0	0.0	0.0	999.0
1983	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	0.0	-0.5	0.0	0.0	0.0	999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

WEEK

Weekly Impact of Observed Minimum Temperature on Modeled Corn Yields (Case 3 - Case 5, Table 15)
Omaha, NB

1948	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.5	1.2	1.1	0.0	0.0	0.0	0.0	0.0 999.0
1949	999.0	999.0	0.0	2.1	2.2	-4.6	2.3	2.3	2.7	0.4	1.9	-0.6	-1.1	-1.7	-0.2	0.0	0.0	0.0 999.0
1950	999.0	999.0	-1.3	5.8	5.8	5.8	-1.4	-1.3	-1.2	-1.1	2.0	2.7	2.8	0.0	0.0	0.0	0.0	0.0 999.0
1951	999.0	999.0	-0.1	-0.5	-0.4	-0.5	0.6	0.0	0.7	0.4	1.4	0.9	2.1	2.0	1.2	0.5	0.2	0.0 999.0
1952	999.0	999.0	0.0	-0.2	0.3	0.3	0.3	0.0	0.0	-0.5	-0.7	-0.8	-1.3	-1.0	-0.6	-0.6	-0.4	-0.3 999.0
1953	999.0	999.0	0.0	0.0	0.0	-0.1	-0.1	1.0	0.0	-0.1	-1.5	-1.0	-0.8	0.6	0.0	0.0	0.0	0.0 999.0
1954	999.0	999.0	-1.7	-0.2	0.2	0.1	0.0	0.2	-1.7	-2.6	-6.0	-8.6	-1.8	-1.5	-3.0	-2.6	-1.9	-0.9 999.0
1955	999.0	999.0	0.3	0.6	0.6	0.3	0.2	0.2	-0.3	-0.9	-0.9	-3.7	-3.2	-3.5	-3.0	-1.8	-0.8	-0.1 999.0
1956	999.0	999.0	0.0	0.2	-1.1	-1.2	-1.4	-1.8	-4.3	-2.6	-3.8	-3.6	-3.9	-3.2	-3.0	-2.5	-1.5	-0.2 999.0
1957	999.0	999.0	0.7	0.7	0.2	0.2	0.7	-3.1	0.2	-1.9	-3.2	-4.0	-4.6	-1.8	-1.3	-1.6	-0.9	-0.2 999.0
1958	999.0	999.0	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.7	4.0	3.8	3.5	3.4	3.4	3.4	3.4 999.0
1959	999.0	999.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3	-0.1	-0.3	-0.4	-0.1	0.0	0.0	0.0	0.0 999.0
1960	999.0	999.0	0.0	-0.2	-0.3	-0.3	-0.2	0.2	-0.3	-0.3	-0.1	1.0	0.2	0.6	-0.4	0.0	0.0	0.0 999.0
1961	999.0	999.0	0.1	-3.7	0.1	-3.7	-3.6	0.0	0.0	0.0	0.2	1.0	0.6	0.1	0.0	0.0	0.0	0.0 999.0
1962	999.0	999.0	0.3	0.4	-0.1	0.3	0.0	-0.7	-1.7	-4.8	-5.9	-3.5	-2.2	-2.1	-2.5	-2.4	-0.8	-0.1 999.0
1963	999.0	999.0	-0.7	-0.5	1.4	-1.4	-0.7	-1.3	-2.6	-4.5	-5.9	-4.0	-3.6	-4.2	-3.2	-2.7	-1.6	-1.1 999.0
1964	999.0	999.0	0.0	-2.4	-2.4	-2.4	-2.4	-2.4	-2.6	-2.6	-2.8	-2.7	-0.6	-0.7	-0.7	-0.1	-0.1	0.0 999.0
1965	999.0	999.0	0.0	-0.4	-0.4	-0.4	0.0	-0.2	-0.3	-0.2	-1.0	-0.8	-0.7	-0.7	-0.5	-0.4	-0.2	-0.1 999.0
1966	999.0	999.0	0.0	12.2	14.4	14.5	-0.3	-0.2	1.4	1.0	1.8	2.3	2.7	2.3	1.6	0.8	0.1	0.0 999.0
1967	999.0	999.0	0.0	-2.2	-1.0	-0.8	-1.0	0.5	0.3	0.1	1.0	2.5	2.7	4.2	3.4	3.4	3.4	3.4 999.0
1968	999.0	999.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	1.5	2.9	1.3	0.0	0.0	0.0	0.0 999.0
1969	999.0	999.0	0.0	2.7	2.7	2.6	2.6	2.6	2.6	2.7	3.1	7.0	6.0	0.0	0.0	0.0	0.0	0.0 999.0
1970	999.0	999.0	-1.1	-1.1	-0.6	0.1	-1.3	-1.6	-2.3	-3.5	-4.2	-3.0	-2.4	-3.5	-3.5	-3.5	-3.5	-3.5 999.0
1971	999.0	999.0	0.0	0.7	-2.2	0.7	0.7	0.7	0.8	0.9	2.7	0.9	0.6	0.0	0.0	-0.1	0.0	0.0 999.0
1972	999.0	999.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.2	2.4	-0.1	0.1	0.0	0.0	0.0	0.0 999.0
1973	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.6	1.1	1.0	0.0	0.0	0.0	0.0 999.0
1974	999.0	999.0	0.0	0.5	0.1	0.1	-0.4	-0.1	-1.7	-1.5	-1.5	4.3	0.5	-0.1	-0.2	0.0	0.0	0.0 999.0
1975	999.0	999.0	0.0	-0.5	0.2	-0.5	0.2	0.1	-0.6	0.1	-6.6	-0.5	-0.8	-0.6	-1.0	-0.7	-0.4	0.0 999.0
1976	999.0	999.0	0.0	0.0	2.4	2.5	2.7	2.7	3.3	3.5	3.5	5.3	5.4	4.4	3.5	3.5	3.5	3.5 999.0
1977	999.0	999.0	0.1	-1.2	-1.1	-1.1	-1.3	-2.7	-3.5	-2.6	-5.2	-2.7	-4.0	-3.3	-2.0	-2.2	-1.3	-0.5 999.0
1978	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-1.6	-0.9	-1.3	0.0	0.0	0.0	0.0	0.0 999.0
1979	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0 999.0
1980	999.0	999.0	0.0	0.5	0.1	0.1	0.0	-0.1	-0.4	-0.8	-1.1	-1.4	-0.7	-0.5	-1.7	-1.5	-0.4	-0.1 999.0
1981	999.0	999.0	0.0	-0.1	-0.7	-0.8	-1.0	0.1	0.8	4.0	5.3	5.7	5.0	4.5	5.5	3.4	2.6	0.8 999.0
1982	999.0	999.0	-0.1	10.1	10.1	10.1	0.0	0.9	1.1	3.0	4.3	2.5	1.7	4.0	1.8	1.3	0.8	0.1 999.0
1983	999.0	999.0	0.0	0.0	0.4	0.4	0.4	0.5	-0.6	-1.0	-2.0	-1.7	-1.1	-1.8	-3.5	-1.6	-1.6	-0.4 999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

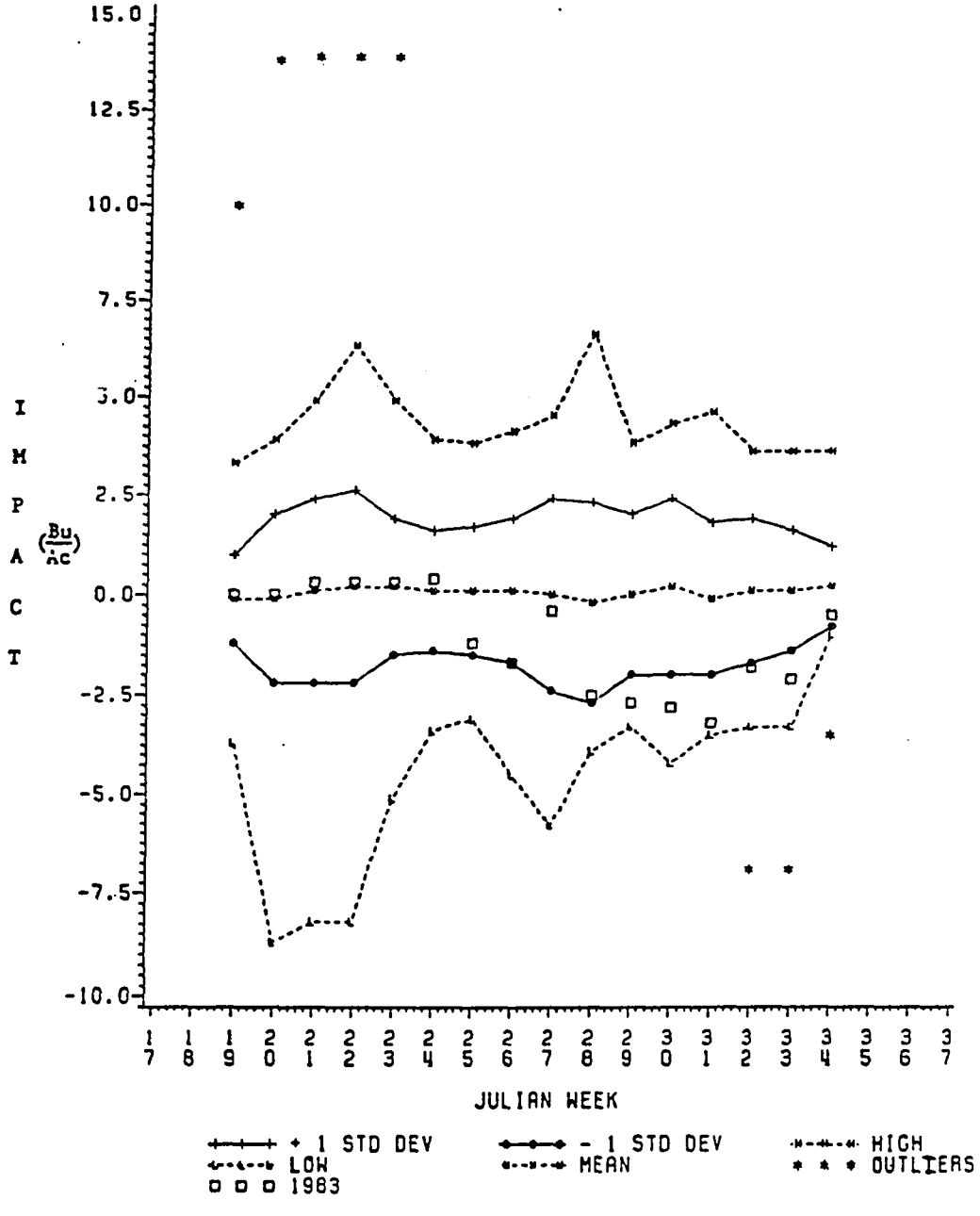
WEEK

Weekly Impact of Observed Precipitation on Modeled Corn Yields (Case 4 - Case 5, Table 15)
Omaha, NB

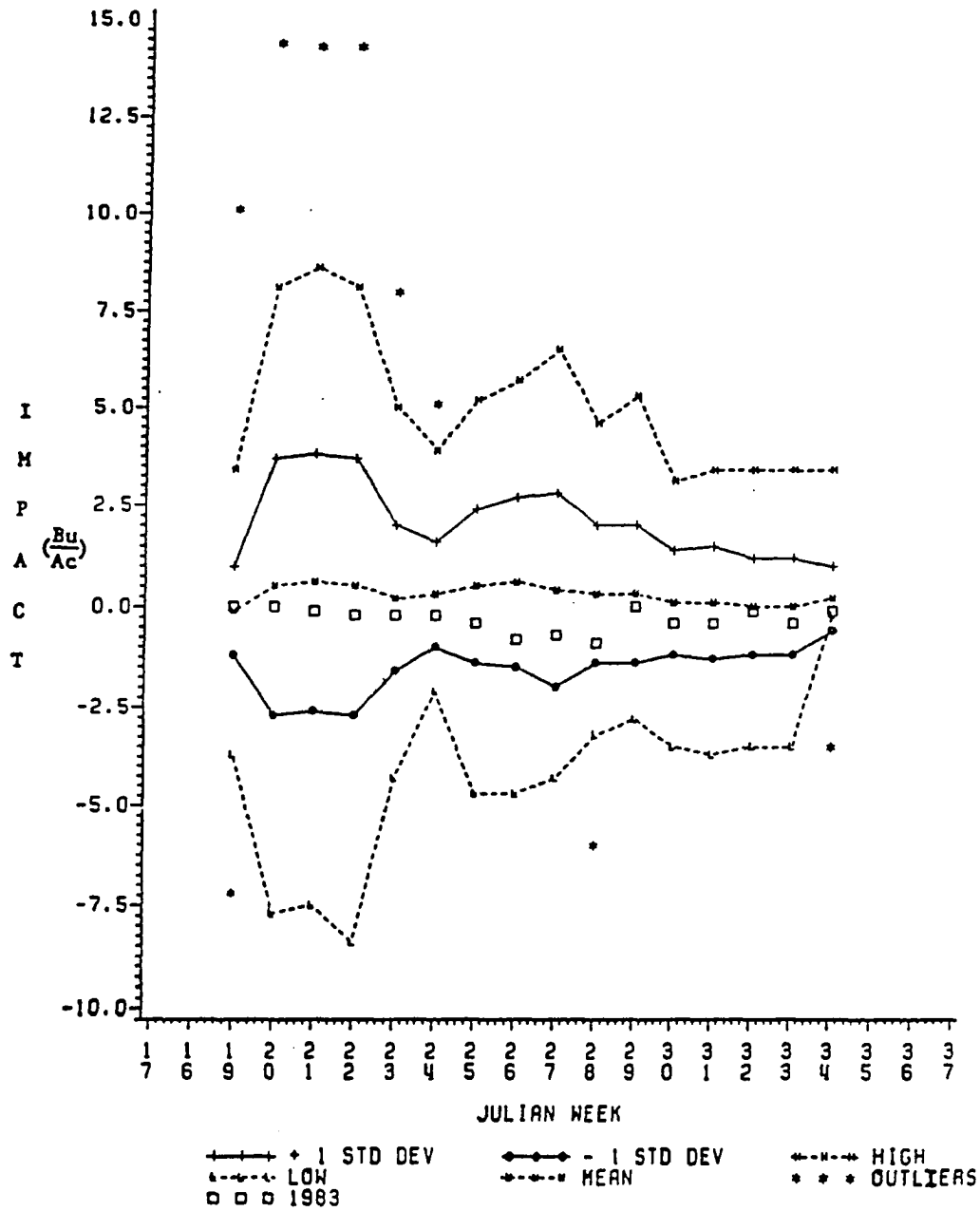
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
1948	999.0	999.0	0.0	4.1	4.2	4.9	5.0	5.1	5.2	5.4	0.3	4.6	4.4	0.0	0.0	0.0	0.0	0.0	999.0
1949	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1950	999.0	999.0	-1.2	6.3	6.3	6.3	-1.4	-1.5	-1.7	-1.6	-4.3	-1.4	-1.9	0.0	0.0	0.0	0.0	0.0	999.0
1951	999.0	999.0	-0.9	7.8	7.3	7.3	0.0	0.0	-2.9	-2.1	-2.9	-1.8	-2.8	-1.3	-1.5	-0.7	0.1	0.0	999.0
1952	999.0	999.0	0.0	0.0	-0.3	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.1	-0.2	-0.1	0.0	-0.1	0.0	0.0	999.0
1953	999.0	999.0	0.0	-7.7	-7.5	-8.4	0.1	0.0	0.2	1.4	2.5	1.6	1.4	-0.5	0.0	0.0	0.0	0.0	999.0
1954	999.0	999.0	-1.7	0.3	0.3	-0.2	0.4	1.2	2.7	3.8	5.0	-0.5	2.4	0.9	1.2	0.9	0.5	0.3	999.0
1955	999.0	999.0	0.3	1.7	1.3	1.3	1.1	1.3	1.6	1.9	2.9	2.3	1.9	2.2	2.5	0.3	0.3	0.1	999.0
1956	999.0	999.0	0.1	-0.9	-0.9	-0.8	-0.7	-0.6	0.9	-0.1	1.0	0.1	0.0	1.7	1.1	0.8	0.4	0.1	999.0
1957	999.0	999.0	0.0	0.0	1.0	1.0	1.0	-0.5	-4.7	-4.7	-4.2	0.5	0.4	-0.2	-0.1	-0.1	-0.1	0.0	999.0
1958	999.0	999.0	3.4	3.3	3.3	3.3	3.4	3.4	3.3	3.2	2.8	2.2	2.7	3.1	3.4	3.4	3.4	3.4	999.0
1959	999.0	999.0	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.1	-0.2	-0.1	-0.1	-0.2	-0.1	0.0	0.0	0.0	0.0	999.0
1960	999.0	999.0	-0.2	1.6	1.6	1.0	1.5	0.3	1.0	1.0	2.1	0.5	0.9	1.6	0.8	0.0	0.0	0.0	999.0
1961	999.0	999.0	-3.7	-3.8	-4.0	-4.1	-4.3	0.2	1.1	-0.4	-0.5	-1.2	-0.8	-0.3	0.0	0.0	0.0	0.0	999.0
1962	999.0	999.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.4	0.1	0.0	0.0	0.1	0.0	0.0	0.0	999.0
1963	999.0	999.0	0.0	-0.7	0.1	0.7	0.2	0.3	0.5	0.8	1.9	0.7	0.7	0.4	0.2	0.1	0.1	0.1	999.0
1964	999.0	999.0	0.0	-1.8	-1.8	-1.8	-1.9	-2.1	-1.7	-1.8	-1.7	-2.0	-1.6	0.5	0.6	0.0	0.0	0.0	999.0
1965	999.0	999.0	-0.1	-0.6	-0.6	-0.6	-0.6	-0.2	-0.2	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	0.0	-0.1	0.0	999.0
1966	999.0	999.0	0.0	14.4	14.3	14.3	-0.5	-0.6	-0.5	0.8	1.1	1.1	-0.7	-0.6	-0.4	-0.2	0.0	0.0	999.0
1967	999.0	999.0	0.0	1.2	-0.1	-0.7	-1.1	3.1	3.2	3.2	3.2	1.7	2.7	2.9	3.4	3.4	3.4	3.4	999.0
1968	999.0	999.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.6	-1.5	-0.5	0.0	0.0	0.0	0.0	999.0
1969	999.0	999.0	2.7	2.5	2.5	2.5	2.5	2.5	2.5	2.4	1.7	-6.0	-1.1	0.0	0.0	0.0	0.0	0.0	999.0
1970	999.0	999.0	-1.0	0.9	2.1	2.7	1.7	3.9	2.1	-0.7	-1.5	1.5	0.5	-3.5	-3.5	-3.5	-3.5	-3.5	999.0
1971	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.1	1.1	0.5	0.4	0.0	0.0	-0.1	0.0	0.0	999.0
1972	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	-0.2	-2.6	-1.5	-0.1	0.0	0.0	0.0	0.0	999.0
1973	999.0	999.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	-0.1	0.1	0.4	0.1	0.1	0.0	0.0	0.0	0.0	999.0
1974	999.0	999.0	-7.2	-6.8	-6.6	-6.8	-2.6	0.0	-1.4	4.2	-2.5	1.7	0.6	-0.2	-3.7	-3.5	-3.5	-3.5	999.0
1975	999.0	999.0	-0.4	4.9	5.0	2.8	4.5	-0.5	3.2	5.7	5.0	1.9	0.4	0.8	1.5	1.4	0.5	0.1	999.0
1976	999.0	999.0	0.0	-0.5	-0.5	-0.5	-0.5	-0.4	-0.5	-0.5	-0.5	4.5	1.1	0.3	0.0	0.0	0.0	0.0	999.0
1977	999.0	999.0	0.3	-0.6	-0.6	-0.4	1.3	2.2	2.0	1.0	6.5	1.2	5.3	0.6	0.0	0.4	0.3	0.1	999.0
1978	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	0.5	0.8	0.0	0.0	0.0	0.0	0.0	999.0
1979	999.0	999.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.8	-0.6	-0.3	0.0	0.0	0.0	0.0	0.0	999.0
1980	999.0	999.0	0.0	-0.3	0.0	0.1	0.3	0.4	0.4	0.6	0.7	-0.2	1.5	-2.3	0.2	0.4	0.1	0.1	999.0
1981	999.0	999.0	0.0	-0.1	-0.6	-0.6	-0.7	-0.9	-0.7	-1.9	-2.8	-3.2	-1.2	-0.3	-0.8	-0.6	-0.4	-0.2	999.0
1982	999.0	999.0	10.1	8.1	8.6	8.1	8.0	1.3	1.6	0.8	-2.3	-2.0	-1.9	-2.3	-2.4	-0.7	-0.3	-0.1	999.0
1983	999.0	999.0	0.0	0.0	-0.1	-0.2	-0.2	-0.2	-0.4	-0.8	-0.7	-0.9	0.0	-0.4	-0.4	-0.1	-0.4	-0.1	999.0

WEEK

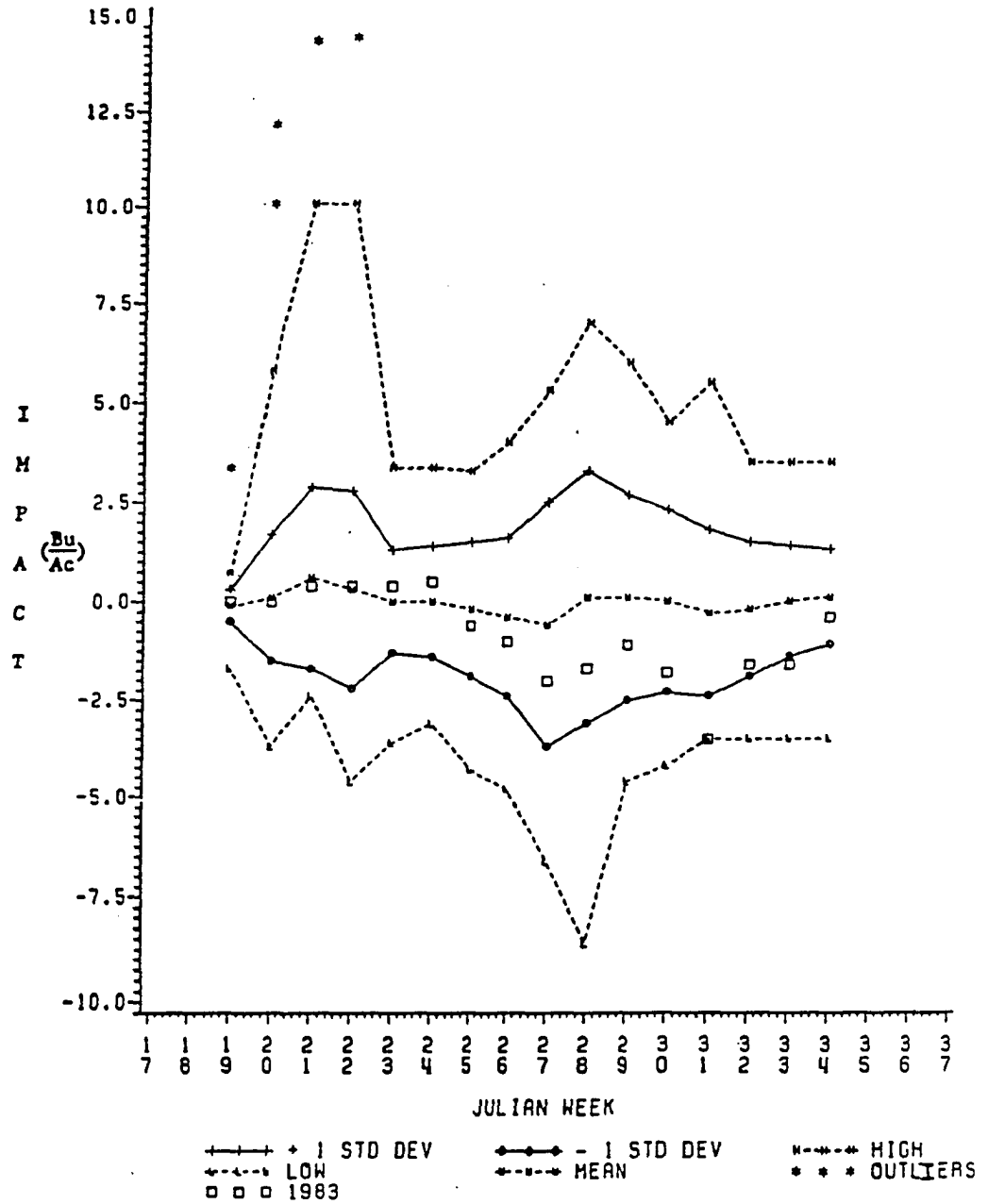
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 1 - Case 5, Table 15) Omaha, NB



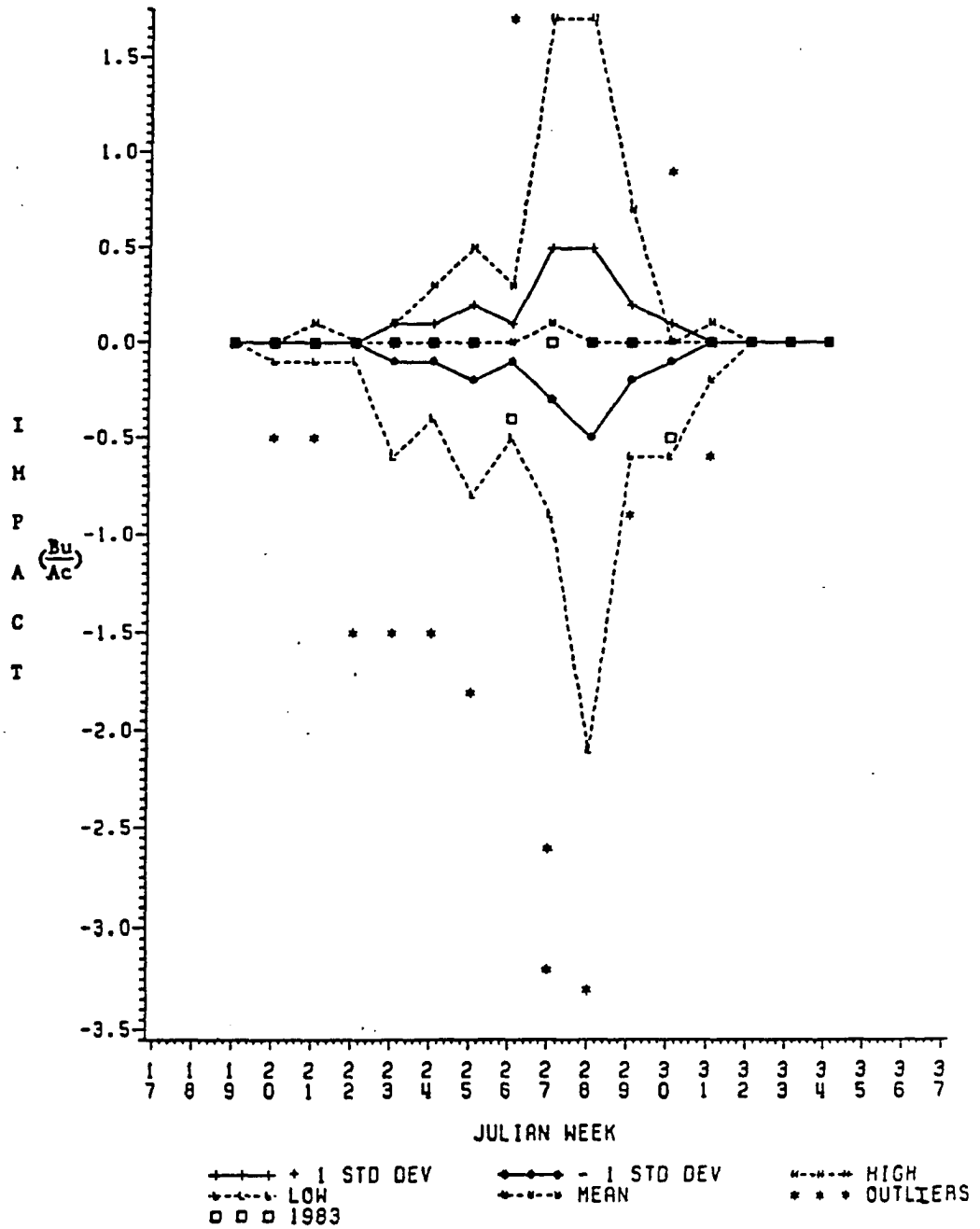
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 2 - Case 5, Table 15) Omaha, NB



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 3 - Case 5, Table 15) Omaha, NB



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 4 - Case 5, Table 15) Omaha, NB



Weekly Impact of All Observed Weather Variables on Modeled Corn Yields (Case 1 - Case 5, Table 15)
Rapid City, SD

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1950	0.1	0.0	-5.5	0.5	0.6	4.7	-3.3	4.6	4.8	1.5	0.7	4.6	1.1	-6.8	-2.1	-1.0	-0.1	0.0	0.0
1951	0.0	0.0	0.7	-0.6	0.6	0.4	0.7	0.7	0.6	2.9	1.8	2.2	1.7	2.3	3.0	0.9	0.2	0.0	0.0
1952	0.0	0.0	0.3	0.2	0.5	0.5	-5.0	0.1	0.0	-0.6	-0.1	-0.7	-0.5	0.3	0.5	0.5	-0.1	0.0	0.0
1953	0.0	0.1	-4.3	0.3	-1.7	-1.9	-1.3	-1.6	-1.1	-1.0	-2.5	-2.2	-4.8	0.3	0.4	0.4	0.0	0.0	0.0
1954	0.0	0.0	-0.2	-0.6	0.3	-1.8	-2.0	-2.0	-1.5	-1.1	-1.9	-2.0	-0.6	-2.6	-1.1	-0.6	-0.5	0.0	0.0
1955	0.0	0.0	-0.2	2.0	2.0	1.9	2.0	0.7	1.4	-1.2	-2.4	-5.1	-1.9	-3.6	-1.4	-1.5	-0.7	0.0	0.0
1956	0.0	0.0	0.2	-1.3	-0.3	-0.3	0.0	-1.1	-1.5	-3.5	-4.0	-1.3	-1.3	-4.7	-2.2	-1.5	-1.4	-0.2	-0.4
1957	0.0	-0.1	0.0	3.4	3.7	3.3	3.1	-0.3	-0.4	3.3	0.0	1.0	1.2	1.2	0.2	0.1	0.0	0.0	0.0
1958	0.0	0.0	0.9	1.1	1.2	1.8	0.9	0.2	0.6	0.3	-0.2	-1.2	-0.9	-0.5	-0.4	-0.3	-0.4	-0.1	0.0
1959	0.0	-0.1	0.1	-0.4	5.1	4.1	5.3	5.2	4.9	4.0	4.1	-1.1	4.4	0.6	0.5	-0.4	0.0	0.0	0.0
1960	0.0	0.0	-0.8	-0.2	-0.8	-0.9	-0.9	-2.2	-2.3	-4.9	-3.4	-2.0	-1.3	-3.9	-3.6	-0.7	-0.5	0.0	0.0
1961	0.0	0.2	1.4	-13.0	-13.2	-10.0	0.0	-6.4	-5.0	1.3	-2.0	0.2	1.0	-2.3	-2.5	-3.6	-3.4	0.0	0.0
1962	0.0	0.0	0.0	-0.3	0.4	0.3	-0.6	-0.7	-0.9	-2.2	1.7	-0.1	0.9	0.6	0.5	1.1	0.1	0.0	0.0
1963	0.0	0.0	0.4	0.5	0.7	0.4	0.5	-0.5	-0.6	-1.4	-1.5	-0.5	-1.7	-0.8	-0.8	-0.6	-0.1	0.0	0.0
1964	-0.1	0.0	-0.1	0.1	-0.2	-0.1	0.1	-1.6	-1.3	-1.4	-1.0	-0.6	-0.3	-0.4	-0.3	-0.2	0.0	0.0	0.0
1965	0.1	0.1	-1.0	0.3	0.2	0.0	0.7	0.9	1.0	0.9	1.0	2.3	1.7	0.8	0.9	0.1	0.0	0.0	0.0
1966	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.3	0.6	2.0	0.9	2.2	-0.4	2.6	2.7	0.5	0.0	-0.1	0.0
1967	0.0	0.0	-1.7	-1.6	-1.8	-1.6	-1.6	-1.3	-0.7	-0.1	0.5	0.9	1.7	1.1	0.9	0.5	0.0	0.0	0.0
1968	0.0	0.0	0.3	0.0	4.3	1.6	-2.2	2.3	2.7	4.9	7.4	6.1	1.6	6.4	3.0	1.0	0.3	0.0	0.0
1969	0.0	0.0	-0.3	-0.3	-0.3	0.0	-0.2	0.0	0.1	0.8	2.8	1.1	0.3	0.0	0.0	-0.1	0.1	0.0	0.0
1970	0.0	0.0	0.6	0.5	0.4	0.3	0.4	-0.2	-0.4	-0.8	-1.1	-1.2	-0.8	-0.4	-0.3	-0.2	0.0	0.0	0.0
1971	0.0	0.0	0.0	1.2	7.7	7.6	-2.1	-2.0	-1.9	-1.7	-2.1	-2.1	-0.5	-0.9	2.4	3.0	3.1	0.0	0.0
1972	0.0	0.0	2.1	0.8	2.3	2.8	3.1	4.0	2.9	4.3	0.5	4.0	6.3	3.4	2.6	2.5	3.1	3.0	3.0
1973	0.0	0.0	0.1	-0.5	-4.2	-4.6	-4.2	-3.8	-5.7	-4.8	-9.9	-3.9	-3.9	-0.6	-0.5	0.0	0.0	0.0	0.0
1974	-0.1	-0.2	-0.4	-0.7	-0.3	0.1	0.2	0.8	0.4	0.7	0.2	-0.2	-1.4	-1.4	-5.2	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	1.5	1.0	1.1	1.1	1.5	1.3	1.1	2.4	1.7	-1.0	0.0	0.1	0.0	0.1	0.0	0.0
1976	0.0	0.0	-0.1	0.1	0.2	0.1	0.0	-0.1	0.0	-0.4	-0.4	-0.7	-0.4	-0.4	-0.2	-0.3	0.0	0.0	0.0
1977	0.0	-0.1	1.1	1.6	1.7	1.5	0.5	1.1	0.3	-0.1	-0.9	-1.4	-1.6	-1.2	-0.2	-0.2	-0.1	-0.1	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.2	-0.1	0.1	-0.3	-0.2	-0.3	-0.1	0.0	0.0
1979	0.0	0.0	-0.5	-1.1	-1.5	-0.7	-0.7	-1.3	-1.1	-0.7	-0.2	-0.4	0.1	0.5	0.6	0.6	0.4	0.3	0.0
1980	0.0	0.0	0.7	0.9	0.8	0.7	0.9	0.4	-0.4	0.3	-0.8	-0.3	-0.3	0.6	0.1	-0.2	0.0	0.0	0.0
1981	0.1	-0.1	0.0	-2.1	-2.1	-2.1	0.0	0.1	0.1	0.1	0.1	1.2	0.7	0.5	1.3	0.4	0.4	0.0	0.0
1982	0.0	0.0	0.9	0.8	-0.6	-0.6	-0.8	0.4	0.1	1.8	4.9	2.5	18.2	11.5	2.5	0.7	1.0	0.0	0.0
1983	0.1	0.1	-4.1	-0.5	-4.8	-4.9	-3.6	-3.7	-4.4	-1.1	-1.6	-7.3	-4.3	-0.7	-1.8	-1.3	-0.4	0.0	0.0

WEEK

Weekly Impact of Observed Maximum Temperature on Modeled Corn Yields (Case 2 - Case 5, Table 15)
Rapid City, SD

1950	0.0	0.0	-0.1	-5.7	-5.7	-6.1	1.3	1.5	3.0	3.3	2.0	1.7	1.2	0.4	1.0	1.1	1.7	0.0	0.0
1951	0.0	0.0	0.3	-0.5	0.3	0.1	-0.1	0.5	0.5	-0.1	0.7	1.3	1.5	0.6	1.1	0.5	0.1	0.0	0.0
1952	0.0	0.0	0.3	-1.1	-0.4	-1.2	-0.6	-0.8	0.1	-1.0	-1.3	-1.2	-0.5	-0.1	-0.1	-0.1	-0.2	0.0	0.0
1953	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1954	0.0	0.0	0.0	-0.3	-0.2	-0.2	-0.4	-0.2	0.1	-0.1	-0.6	-2.2	-0.8	-1.0	-1.2	-0.4	-0.4	0.0	0.0
1955	0.0	0.0	-0.4	0.8	0.3	1.0	2.0	0.5	1.2	0.8	-0.3	-0.3	-1.6	-2.0	-0.5	-1.3	-0.5	0.0	0.0
1956	0.0	0.0	0.7	1.0	1.1	1.4	1.8	1.9	1.2	0.6	0.0	-0.8	-0.7	-0.9	-0.7	-0.7	-1.0	0.0	-0.1
1957	0.0	0.0	4.1	-0.6	-0.6	-0.5	2.8	-1.4	-0.2	0.2	0.7	0.9	0.8	0.4	0.3	0.2	0.0	0.0	0.0
1958	0.0	0.0	0.8	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	0.7	-0.2	-0.3	-0.2	-0.2	-0.1	0.0	0.0
1959	0.0	-0.3	-0.3	-0.4	4.3	4.5	5.2	4.5	3.7	3.7	1.9	-2.0	-1.1	0.2	0.0	-0.7	0.0	0.0	0.0
1960	0.0	0.0	0.8	-0.6	-0.9	-1.0	-0.9	-1.4	-1.9	-1.7	-2.1	-1.2	-1.2	-0.6	-0.5	-0.5	-0.4	0.0	0.0
1961	0.0	0.1	1.0	1.4	1.5	1.7	1.8	-1.2	-0.5	0.7	0.1	0.0	4.8	-3.9	-4.2	-3.8	-3.4	0.0	0.0
1962	0.0	0.0	0.0	-0.3	0.3	0.0	-0.8	-1.1	-0.9	-0.6	0.6	0.1	0.9	0.6	0.5	0.2	0.1	0.0	0.0
1963	0.0	0.0	0.2	0.6	1.4	0.8	1.8	1.1	-0.1	0.6	-1.1	-1.0	-1.3	-0.6	-0.7	-0.3	-0.1	0.0	0.0
1964	0.0	0.0	-0.2	0.0	0.0	-0.1	-0.2	-0.3	-0.5	-0.5	-0.6	-0.5	-0.3	-0.3	-0.2	-0.1	0.0	0.0	0.0
1965	0.1	0.0	-0.9	0.2	-0.1	0.1	0.4	0.7	0.7	0.8	0.5	1.9	0.8	0.3	0.7	0.0	0.0	0.0	0.0
1966	0.0	0.0	0.5	0.5	0.5	0.5	0.6	0.4	0.5	0.7	0.0	-0.2	-0.4	-0.1	-0.2	-0.1	-0.1	-0.1	0.0
1967	0.0	0.0	-1.6	-0.7	-1.5	-1.4	-1.7	-1.1	-0.9	-0.8	-0.5	0.7	1.1	1.0	0.8	0.5	0.0	0.0	0.0
1968	0.0	0.0	0.3	1.6	0.1	2.0	0.9	1.4	1.8	2.5	3.7	2.2	1.4	0.9	1.2	0.6	0.2	0.0	0.0
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	-0.1	0.2	0.0	-0.2	-0.2	-0.1	-0.1	0.0	0.0	0.0
1970	0.0	0.0	0.5	0.3	0.0	0.2	0.0	-0.2	-0.2	-0.6	-0.5	-0.4	-0.3	0.5	0.3	0.0	0.0	0.0	0.0
1971	0.0	0.0	-0.2	-3.8	-3.8	-3.8	-3.7	-3.7	-3.5	-3.1	-3.1	-3.4	-3.5	0.0	0.0	0.1	0.0	0.0	0.0
1972	0.0	0.0	2.1	0.2	0.5	0.2	0.1	0.5	-0.4	0.4	-0.6	-0.1	-0.2	1.1	0.5	0.1	0.6	0.0	0.0
1973	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	-0.2	0.3	0.4	0.1	0.2	0.1	0.1	0.2	0.0	0.0	0.0	0.0
1974	0.0	-0.1	0.2	0.0	0.1	0.2	0.1	-0.1	-0.4	-1.1	-0.2	-0.3	-0.5	-0.6	-0.3	-0.1	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	-0.1	0.1	0.2	0.1	0.0	-0.1	0.0	-0.5	-0.4	-0.7	-0.4	-0.4	-0.3	-0.3	0.0	0.0	0.0
1977	0.0	0.0	1.0	1.2	1.3	1.3	1.3	1.0	0.6	0.1	-0.5	-0.8	-0.8	-0.8	-0.2	-0.2	0.0	-0.1	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.4	-0.1	0.1	-0.3	-0.1	-0.3	-0.1	0.0	0.0
1979	0.0	0.0	-0.5	-0.7	-1.1	-0.1	-0.6	-1.9	-1.2	-0.9	-0.5	-0.7	-0.3	0.2	0.4	0.5	0.3	0.3	0.0
1980	0.0	0.0	0.7	0.7	0.7	0.7	0.7	-0.1	-0.3	-0.6	-0.9	-0.3	-0.3	-0.4	-0.1	-0.2	0.0	0.0	0.0
1981	0.0	0.0	0.1	-2.1	-2.1	-2.1	-0.1	-0.1	0.2	-0.1	0.3	0.4	0.6	0.5	0.7	0.5	0.4	0.0	0.0
1982	-0.1	0.0	0.7	0.6	-0.6	-0.6	-0.5	-0.9	0.3	1.5	3.1	0.7	1.7	1.5	1.4	0.6	0.7	0.0	0.0
1983	0.2	0.0	0.2	-0.6	-0.6	-0.6	-0.5	-0.5	-0.9	-0.2	-0.2	-0.4	-0.8	-0.7	-0.7	-0.1	0.0	0.0	0.0
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	

WEEK

Weekly Impact of Observed Minimum Temperature on Modeled Corn Yields (Case 3 - Case 5, Table 15)
Rapid City, SD

1950	0.0	0.0	-0.1	-4.6	-5.6	-5.3	1.4	1.1	0.8	0.4	0.8	0.6	0.1	-3.1	-2.4	-1.4	-1.1	0.0	0.0
1951	0.0	0.0	-0.1	-0.2	-0.2	-0.2	-0.3	0.5	0.5	0.3	0.6	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1952	0.0	0.0	0.4	0.1	-0.5	-0.5	-1.0	-3.7	-0.3	0.1	0.1	0.5	0.0	0.7	0.7	0.6	0.1	0.0	0.0
1953	-0.1	0.0	0.0	-1.8	-1.7	-1.8	-1.4	-1.3	-1.1	-0.9	-1.2	-0.9	-0.4	0.3	0.4	0.5	0.0	0.0	0.0
1954	0.0	0.0	0.0	0.0	-0.5	-0.3	-1.3	-0.9	-0.9	-1.3	-1.5	-0.2	-0.1	-0.3	0.0	-0.2	-0.2	0.0	0.0
1955	0.0	0.0	0.1	-0.1	-0.3	0.0	0.5	0.1	1.0	-0.8	-1.6	-1.9	0.3	0.9	0.0	0.2	-0.2	0.0	0.0
1956	0.2	0.0	-0.3	-0.1	0.9	0.8	1.0	-0.4	-0.4	-1.8	-2.3	-0.7	-0.3	-0.8	-1.3	-1.0	-0.5	-0.2	-0.3
1957	0.0	0.0	-0.1	0.0	-0.1	-0.1	-0.1	-0.2	-0.5	-0.9	-0.7	-0.3	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
1958	0.0	0.0	1.0	1.0	1.0	1.3	1.1	-0.1	0.5	0.2	-0.4	-1.4	-0.7	-0.3	-0.3	-0.1	-0.3	-0.1	0.0
1959	0.0	0.0	-0.6	-0.7	-0.6	-0.5	-0.5	-0.1	-0.1	0.0	0.4	0.0	0.0	0.6	0.5	0.4	0.0	0.0	0.0
1960	0.0	0.0	0.6	0.7	0.7	0.5	0.3	-0.8	-0.6	-1.8	-1.6	-1.4	-0.1	-0.4	-0.2	-0.1	-0.1	0.0	0.0
1961	0.0	0.2	1.3	1.5	1.5	1.1	1.4	1.1	2.8	2.2	2.5	1.4	3.5	-1.4	-1.5	-3.1	-3.4	0.0	0.0
1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1963	0.0	0.0	0.2	0.6	0.5	-0.7	0.3	-0.4	-0.3	-1.6	-1.7	-0.8	-0.2	-0.3	-0.2	-0.3	-0.1	0.0	0.0
1964	0.0	0.1	0.1	0.2	-0.1	-0.2	-0.2	-0.3	-0.8	-0.6	-0.4	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
1965	0.0	0.0	0.1	-1.1	-1.1	-0.9	-0.9	-0.8	-0.9	-0.8	-0.8	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
1966	0.0	0.0	-0.6	-0.3	-0.2	-0.1	-0.2	0.0	0.4	1.2	0.8	0.4	0.0	0.1	0.1	0.0	0.1	0.0	0.0
1967	0.0	0.0	-0.2	0.0	-0.5	-0.4	-0.1	-0.1	0.1	0.4	0.9	0.5	-0.1	0.1	0.1	0.1	0.0	0.0	0.0
1968	0.0	0.0	-0.2	0.0	2.1	1.0	1.1	1.5	1.3	4.7	4.8	1.0	-0.1	-0.3	0.1	0.3	0.1	0.0	0.0
1969	0.0	0.0	-0.3	-0.5	-0.8	-0.1	-0.7	-0.5	0.0	0.8	2.6	1.2	0.6	0.1	0.2	0.0	0.1	0.0	0.0
1970	0.0	0.0	0.2	0.2	3.1	3.0	3.0	3.1	3.2	3.0	2.3	3.3	3.3	2.6	2.7	3.0	3.3	0.0	0.0
1971	0.0	0.0	0.0	-3.6	7.6	7.6	-2.3	-2.0	-1.9	-2.1	-2.5	-3.5	-3.5	-3.9	-0.4	-0.1	0.0	0.0	0.0
1972	0.0	0.0	-0.2	-0.3	-0.1	0.1	0.1	-0.2	-0.5	-0.5	-0.1	1.1	1.0	-0.4	-1.0	-0.6	-0.3	0.0	0.0
1973	0.0	0.0	0.0	-0.3	-4.1	-4.1	-4.0	-4.0	-3.9	-4.4	-3.4	-4.0	-4.0	-0.6	-0.6	0.0	0.0	0.0	0.0
1974	0.0	0.0	-0.2	-0.2	-0.5	0.1	0.1	0.9	1.6	1.6	1.2	0.2	0.3	0.2	0.3	0.1	0.0	0.0	0.0
1975	0.0	0.0	0.0	1.5	1.0	1.1	1.1	1.5	1.2	1.1	2.4	1.7	0.0	0.0	0.2	0.0	0.1	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.9	0.9	0.9	0.9	0.8	0.7	0.7	0.5	0.3	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.6	0.9	0.4	0.4	0.3	0.3	0.2	0.1	0.1	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.5	0.0	0.5	0.5	0.5	0.1	0.2	0.3	0.9	0.7	0.1	0.1	0.0	0.1	0.0	0.0	0.0
1983	0.0	0.2	-0.7	0.3	-0.5	-0.6	-0.7	-1.0	-1.5	-0.9	-1.1	-1.5	-0.5	0.1	-0.3	-1.3	-0.5	0.0	0.0
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	

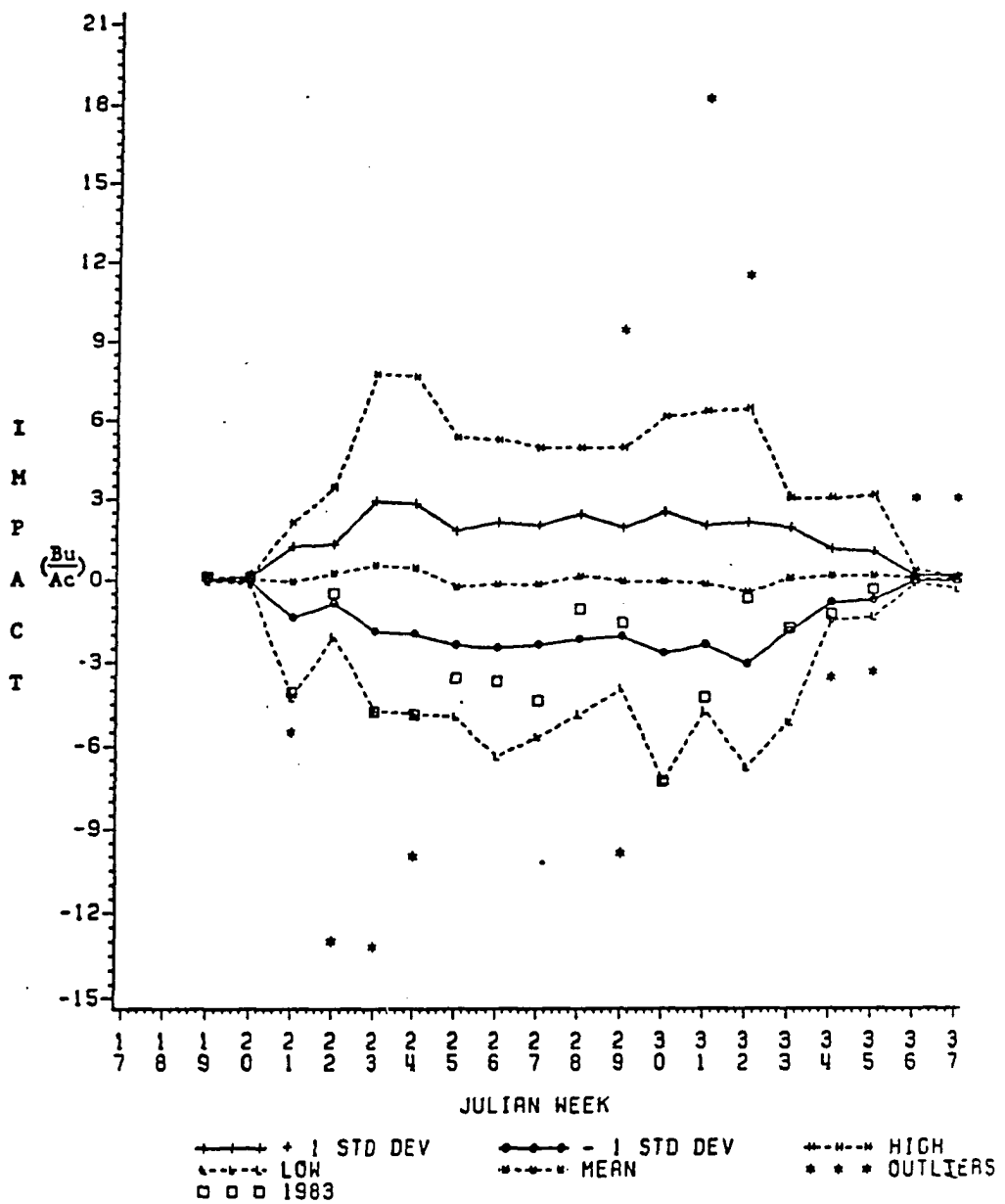
WEEK

Weekly Impact of Observed Precipitation on Modeled Corn Yields (Case 4 - Case 5, Table 15)
Rapid City, SD

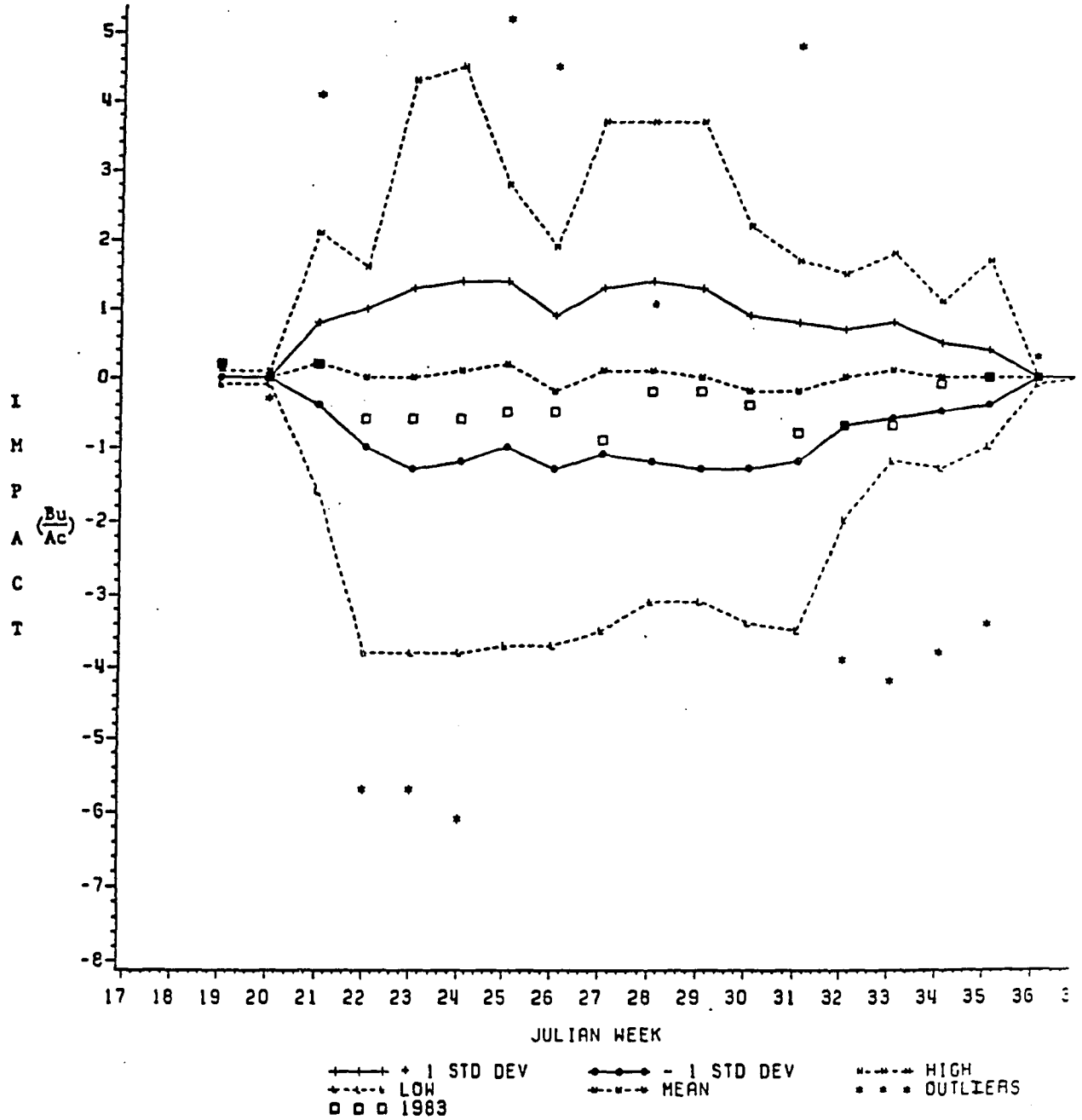
1950	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.3	-0.4	-0.7	-0.2	-0.1	-7.4	-0.3	0.0	0.0	0.0	0.0
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	0.1	0.1	0.1	1.4	1.6	0.2	0.0	0.0	0.0
1952	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-1.5	0.0	0.0	0.0	-0.3	-0.1	0.0	0.0	0.0	0.0
1953	0.1	0.1	0.5	0.0	0.0	-0.2	0.0	-0.1	-0.1	0.0	-1.3	-1.2	-1.0	-0.1	-0.1	0.0	0.0	0.0	0.0
1954	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	-0.6	0.0	-0.1	0.0	0.0	-1.6	0.0	0.0	0.0	0.0	0.0
1955	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.3	-2.3	-0.2	-2.0	-0.5	0.0	0.0	0.0	0.0
1956	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.4	0.0	0.1	0.0	-0.1	-5.5	-0.6	0.0	0.0	0.0	0.0
1957	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	0.0	3.3	0.1	0.4	0.4	1.5	0.0	0.0	0.0	0.0	0.0
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1959	0.0	-0.1	0.0	0.0	-0.2	-0.1	0.0	0.1	-0.1	-0.4	-0.3	0.0	0.1	-0.3	0.0	0.0	0.0	0.0	0.0
1960	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	-1.0	-0.7	0.0	0.0	-3.1	-2.5	-0.1	0.0	0.0	0.0
1961	0.0	0.2	0.0	0.0	0.1	0.4	0.0	-5.2	-3.8	0.0	-2.1	-0.5	-1.9	0.0	0.0	0.0	0.0	0.0	0.0
1962	0.0	0.0	0.0	0.0	0.1	0.0	-0.1	0.0	0.0	-0.8	1.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1963	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1964	-0.1	0.0	0.0	0.2	0.1	0.0	0.6	-0.8	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1965	0.0	0.0	0.0	0.2	0.1	0.1	0.2	0.3	0.1	0.1	0.2	0.3	0.8	0.4	0.1	0.0	0.0	0.0	0.0
1966	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.3	0.1	0.9	0.2	2.2	0.1	2.6	2.5	0.5	0.0	0.0	0.0
1967	0.0	0.0	0.0	0.0	0.1	0.0	0.1	-0.1	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.7	3.8	2.6	0.1	4.8	2.1	0.0	0.0	0.0	0.0
1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1970	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	-0.1	-0.1	0.0	-0.4	-0.5	-0.2	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.3	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	-0.1	0.0	0.2	0.1	2.3	0.0	0.3	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.1	-0.1	0.0	-0.4	0.0	0.0	-1.5	0.0	-7.1	-0.2	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
1974	-0.1	0.0	0.0	-0.3	0.1	0.0	-0.2	0.0	-0.7	0.0	-0.5	0.0	-1.3	-4.0	-5.3	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	-1.2	0.0	-0.1	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	-0.1	0.0	0.0	0.0	-0.2	0.0	-0.1	-0.6	0.0	0.0	-0.7	-0.9	-0.4	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.3	0.0	0.0	0.0	1.3	0.1	0.0	0.0	0.0	0.0
1981	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.1	0.1	0.0	1.0	0.0	0.0	0.0	0.0
1982	-0.1	-0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.4	2.3	14.7	9.6	0.4	0.0	0.2	0.0	0.0
1983	0.1	0.1	0.0	0.0	0.2	0.2	0.0	0.1	-0.2	0.0	-0.2	-2.5	-0.1	-0.1	-1.2	0.0	0.0	0.0	0.0
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	

WEEK

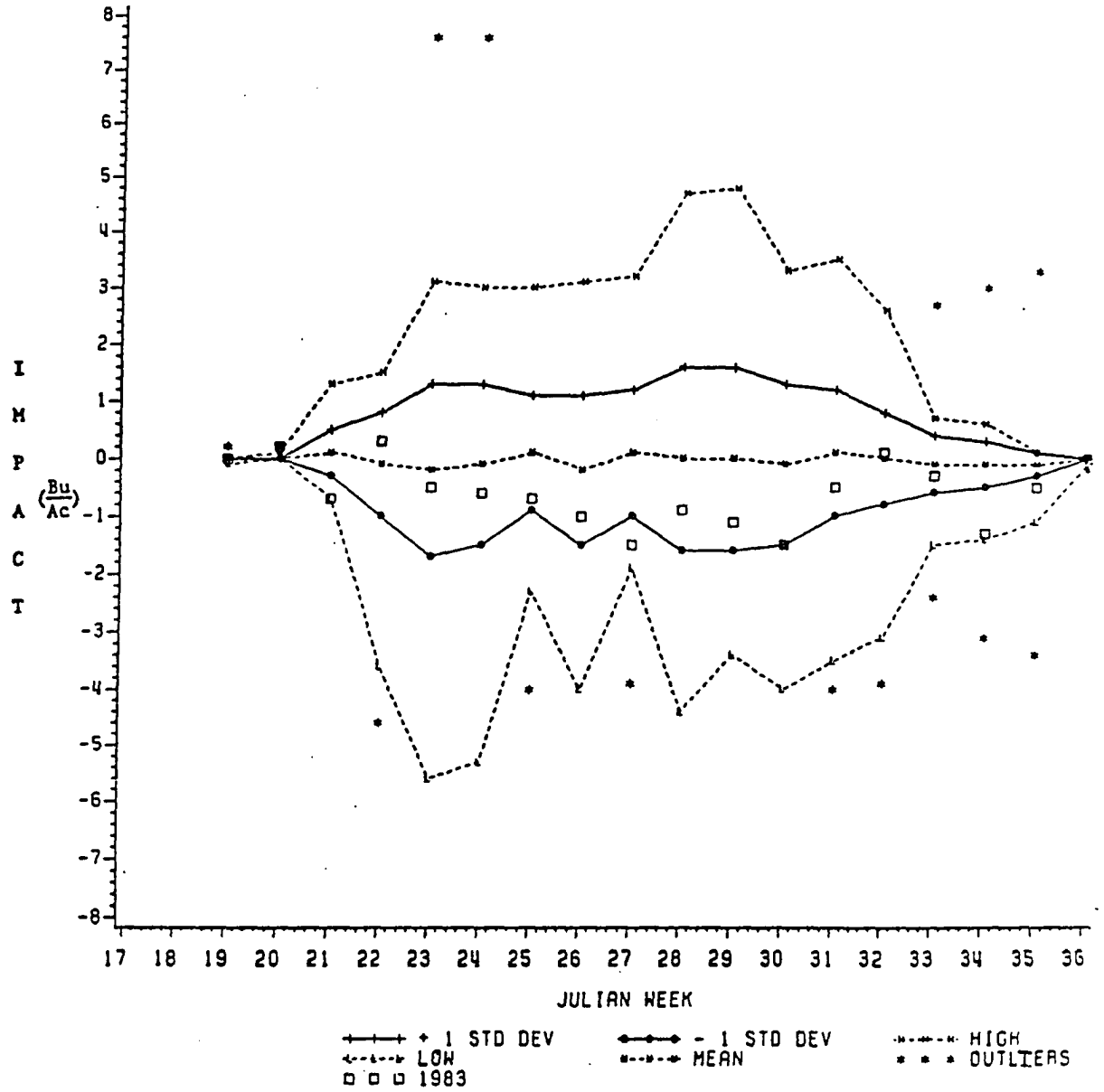
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 1 - Case 5, Table 15) Rapid City, SD



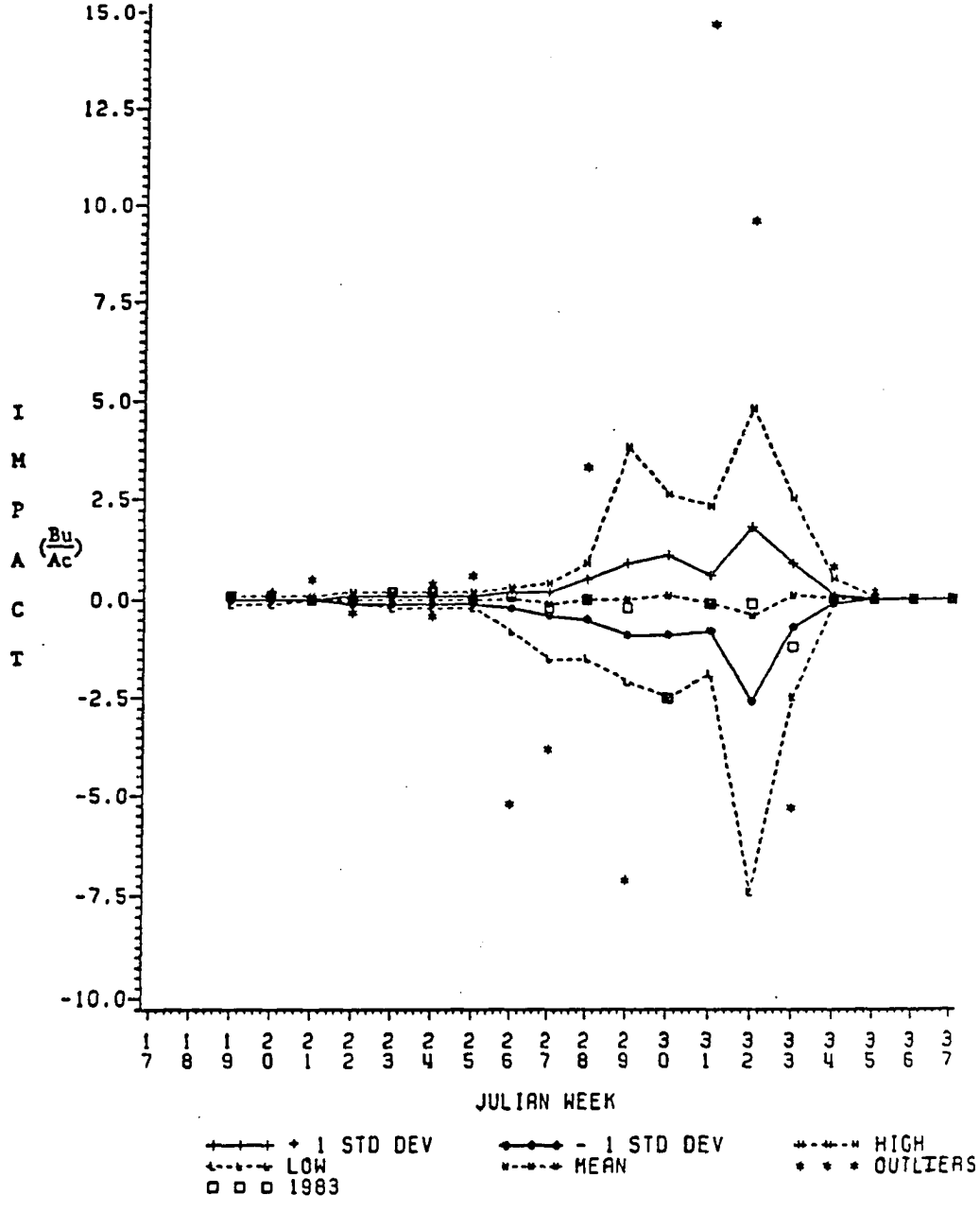
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 2 - Case 5, Table 15) Rapid City, SD



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 3 - Case 5, Table 15) Rapid City, SD



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 4 - Case 5, Table 15) Rapid City, SD



Weekly Impact of All Observed Weather Variables on Modeled Corn Yields (Case 1 - Case 5, Table 15)
Rochester, MN

1948	999.0	999.0	-0.5	-1.0	-0.5	-0.5	-0.5	-0.4	0.1	1.0	1.3	1.1	1.8	1.2	0.8	0.3	0.1	999.0
1949	999.0	999.0	1.2	0.4	0.9	0.7	0.7	0.0	-0.8	-2.1	-2.2	-2.3	-3.6	-2.3	-1.4	-1.3	-0.7	999.0
1950	999.0	999.0	3.1	2.9	2.7	2.7	2.6	2.7	2.7	3.0	4.7	3.6	3.7	3.3	3.3	3.3	3.3	999.0
1951	999.0	999.0	0.5	1.0	1.0	0.5	0.9	0.9	1.6	-0.3	-0.7	-0.9	2.3	-2.6	-0.2	-0.7	0.0	999.0
1952	999.0	999.0	0.4	0.5	0.5	0.5	0.3	-0.2	0.3	-3.3	0.2	-5.0	-2.5	-0.9	0.7	-0.1	0.0	999.0
1953	999.0	999.0	1.6	1.4	0.2	0.1	1.0	0.9	0.6	0.3	-0.5	0.3	-3.6	-3.3	-3.3	-3.3	-3.3	999.0
1954	999.0	999.0	0.0	0.3	0.0	0.2	0.2	0.1	-0.6	-0.4	-1.1	-1.1	-4.6	-0.4	-1.8	0.0	0.0	999.0
1955	999.0	999.0	0.0	-3.0	-3.1	-3.0	-3.0	-3.0	-3.0	-3.1	-3.3	-3.6	-3.8	-3.8	-0.5	-3.2	0.0	999.0
1956	999.0	999.0	0.2	0.6	0.6	0.8	0.8	-0.1	-0.2	0.0	-0.1	-0.1	-0.3	-0.2	-0.2	-0.1	0.0	999.0
1957	999.0	999.0	-2.8	-3.1	-3.0	-2.8	-2.7	-2.8	-2.8	-2.9	-3.5	-4.0	-3.8	-3.3	-3.2	-4.1	-3.5	999.0
1958	999.0	999.0	-9.3	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0	-9.1	-8.0	-7.8	-8.2	0.0	0.0	0.0	0.0	999.0
1959	999.0	999.0	0.2	-3.3	1.3	1.2	1.4	1.5	0.0	1.2	0.4	-0.5	-4.2	-3.5	-3.4	-3.4	-3.4	999.0
1960	999.0	999.0	0.0	3.6	0.4	0.4	0.4	0.4	0.5	0.5	1.0	1.2	4.3	4.2	4.0	3.9	3.6	999.0
1961	999.0	999.0	7.7	7.7	-0.2	7.7	7.2	0.9	1.0	0.9	0.7	7.3	9.6	4.2	2.1	2.1	0.0	999.0
1962	999.0	999.0	9.4	12.2	12.4	3.3	3.2	3.2	0.9	2.9	-1.9	-2.0	-0.2	0.1	-0.2	0.0	0.0	999.0
1963	999.0	999.0	0.5	-3.9	0.5	-1.0	-4.3	-4.7	-4.9	-13.6	-6.1	-7.6	-14.6	-3.9	-1.0	-1.3	0.0	999.0
1964	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	1.3	0.7	0.0	-0.2	-0.1	0.0	0.0	999.0
1965	999.0	999.0	-0.4	-0.1	-0.1	-0.3	-0.2	-0.1	-0.4	-0.1	-0.2	0.4	0.0	0.0	0.0	0.0	0.0	999.0
1966	999.0	999.0	-1.6	-1.6	-1.4	-1.7	1.4	-1.6	1.3	1.2	2.8	3.4	0.3	0.0	0.0	0.0	0.0	999.0
1967	999.0	999.0	0.0	-0.4	-0.3	-0.3	-0.1	-0.4	-0.1	-0.9	-0.1	1.4	-2.0	0.6	2.8	3.5	3.5	999.0
1968	999.0	999.0	-5.2	-5.4	-4.8	-4.9	-4.7	-4.1	-4.2	-1.9	-4.5	-4.2	-1.2	3.0	0.6	0.4	0.3	999.0
1969	999.0	999.0	0.0	-1.4	14.8	14.7	-1.0	-1.1	-0.2	-0.9	-0.1	-0.1	1.1	0.2	0.3	0.1	0.0	999.0
1970	999.0	999.0	-0.9	-1.0	-10.6	-1.2	-1.1	-1.5	-0.4	1.0	-0.5	0.9	0.7	1.0	0.9	0.1	0.0	999.0
1971	999.0	999.0	-2.2	-9.3	-2.3	-9.3	-2.4	-2.4	-2.4	-2.5	-1.1	-0.7	-1.9	0.0	0.0	0.0	0.0	999.0
1972	999.0	999.0	-3.7	1.6	1.8	1.9	1.8	1.8	1.5	2.9	4.4	4.3	2.7	2.2	2.3	1.0	2.5	999.0
1973	999.0	999.0	0.2	-4.2	-3.9	-4.2	-4.1	-0.8	-0.7	-1.6	-1.9	0.7	3.0	0.6	-0.4	-0.6	-0.4	999.0
1974	999.0	999.0	-0.5	-0.7	-0.7	-0.7	-0.8	-0.6	-0.2	0.1	-1.7	0.5	0.1	-0.1	-0.3	0.1	0.0	999.0
1975	999.0	999.0	2.3	2.7	2.3	2.6	2.4	2.3	2.8	1.4	-1.7	-0.6	1.0	-3.0	-3.4	-3.3	-3.3	999.0
1976	999.0	999.0	0.1	0.6	0.5	0.4	-0.1	-0.8	1.3	2.5	2.7	3.4	3.4	3.0	2.2	1.6	0.9	999.0
1977	999.0	999.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-3.7	-3.8	-5.3	-0.9	-1.1	-0.6	-0.5	999.0
1978	999.0	999.0	-1.8	-1.8	-1.8	-1.7	-1.7	-1.7	-1.6	-2.2	-3.2	-1.7	0.6	0.6	0.8	0.0	0.0	999.0
1979	999.0	999.0	-1.3	-0.8	-1.3	-0.8	-1.2	-1.2	-0.7	-0.8	-0.6	-1.4	-0.7	-0.2	-0.6	-0.3	0.0	999.0
1980	999.0	999.0	0.0	-0.3	-0.4	-0.3	-0.3	0.1	-0.2	-0.3	-0.8	1.6	3.0	2.4	0.8	0.0	0.0	999.0
1981	999.0	999.0	2.8	1.2	4.0	3.9	4.1	5.4	5.5	5.6	4.4	3.5	5.7	5.8	4.6	3.7	3.4	999.0
1982	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.3	0.0	-0.4	0.0	-0.1	0.0	0.0	999.0
1983	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.6	-0.7	0.1	0.5	0.3	-1.2	0.6	0.5	0.3	0.0	999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	

WEEK

Weekly Impact of Observed Maximum Temperature on Modeled Corn Yields (Case 2 - Case 5, Table 15)
Rochester, MN

1948	999.0	999.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.3	-0.4	-0.5	-0.5	-0.6	-0.6	-0.6	-0.6	999.0
1949	999.0	999.0	0.3	1.0	0.6	1.1	1.3	1.2	1.0	2.3	0.2	0.0	0.1	-0.5	-0.3	-0.8	0.2	999.0
1950	999.0	999.0	-0.2	3.1	3.1	3.1	3.0	3.0	2.9	3.0	2.1	3.0	3.0	3.3	3.3	3.3	3.3	999.0
1951	999.0	999.0	0.5	-12.2	-12.2	-12.3	0.9	0.7	1.0	-0.1	-0.4	0.3	4.1	-0.1	0.1	-0.4	0.0	999.0
1952	999.0	999.0	-0.1	0.5	0.4	0.4	0.4	0.3	0.3	-0.5	-0.4	-1.3	-2.6	-1.4	0.1	-0.6	0.0	999.0
1953	999.0	999.0	-3.1	0.1	1.6	1.5	1.4	1.0	0.6	-0.3	1.2	0.3	-3.6	-3.3	-3.3	-3.3	0.6	999.0
1954	999.0	999.0	0.0	2.6	2.6	2.6	1.0	1.1	0.9	-0.2	0.2	0.1	-0.4	-0.2	-1.2	0.0	0.0	999.0
1955	999.0	999.0	0.1	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.6	0.5	-0.4	-1.1	-0.8	-0.2	0.0	999.0
1956	999.0	999.0	0.1	0.5	0.5	0.7	1.2	0.9	0.9	0.8	0.5	0.2	0.1	0.1	0.1	0.1	0.0	999.0
1957	999.0	999.0	-3.6	-3.1	-2.8	-2.7	-2.8	-3.2	-2.9	-2.8	-2.6	-3.9	-4.0	-3.6	-3.4	-4.2	-3.5	999.0
1958	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.3	-9.5	-9.5	-0.1	0.0	0.0	0.0	0.0	999.0
1959	999.0	999.0	0.0	0.4	-3.4	-3.6	-3.3	-3.3	-3.3	-3.5	-3.7	-4.4	-4.1	-3.4	-3.4	-3.4	0.0	999.0
1960	999.0	999.0	0.0	0.0	3.6	3.5	0.2	0.5	0.4	0.5	0.9	3.7	4.3	4.3	4.3	4.2	3.6	999.0
1961	999.0	999.0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	0.0	-0.2	-0.3	-3.5	-5.8	-1.5	0.0	0.0	0.0	999.0
1962	999.0	999.0	9.3	9.6	9.6	0.2	0.2	0.2	0.1	0.2	0.7	0.3	0.0	0.0	-0.3	0.0	0.0	999.0
1963	999.0	999.0	-0.2	-0.1	-0.2	-0.2	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	-0.3	-0.5	-0.3	0.0	0.0	999.0
1964	999.0	999.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	999.0
1965	999.0	999.0	-0.4	-0.1	-0.1	-0.3	-0.2	-0.1	-0.4	-0.1	-0.2	0.4	0.0	0.0	0.0	0.0	0.0	999.0
1966	999.0	999.0	0.0	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.6	-1.8	-0.4	-0.1	0.0	0.0	0.0	0.0	999.0
1967	999.0	999.0	0.0	-1.0	-0.4	-0.4	-0.4	-0.3	-0.2	0.0	-0.5	-3.7	-3.6	4.3	0.0	0.0	0.0	999.0
1968	999.0	999.0	-5.4	-5.8	-4.9	-4.8	-4.7	-4.4	-4.1	-4.3	-4.5	-4.3	-4.6	0.3	0.0	0.0	0.2	999.0
1969	999.0	999.0	0.0	-1.2	14.8	14.8	-1.0	-1.1	-0.3	-1.1	-0.3	-0.3	1.0	0.0	0.2	0.1	0.0	999.0
1970	999.0	999.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.5	-0.1	-0.1	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	999.0
1971	999.0	999.0	-2.2	-2.3	-2.2	-2.3	-2.3	-2.3	-2.3	-2.3	-2.8	-3.1	-2.6	0.0	0.0	0.0	0.0	999.0
1972	999.0	999.0	-4.1	3.5	3.2	-4.8	3.1	3.3	3.4	3.3	0.5	-7.0	3.1	4.1	3.4	3.1	2.5	999.0
1973	999.0	999.0	-0.1	-0.1	1.4	1.3	1.3	1.2	1.2	1.3	1.6	0.6	0.2	0.0	0.3	0.4	0.0	999.0
1974	999.0	999.0	-0.5	-0.9	-0.7	-0.7	-0.6	-0.5	-0.2	0.1	-0.2	0.4	0.1	-0.1	0.1	0.1	0.0	999.0
1975	999.0	999.0	4.4	4.7	4.6	4.5	4.3	4.9	4.7	4.4	2.1	2.0	-0.6	-0.9	-0.3	0.0	0.0	999.0
1976	999.0	999.0	-1.0	0.6	0.5	0.0	0.3	0.7	0.1	-0.6	-1.0	0.2	1.3	0.3	0.6	0.5	0.3	999.0
1977	999.0	999.0	0.1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.4	-1.3	-1.2	-1.3	-0.9	-1.2	-0.7	-0.3	999.0
1978	999.0	999.0	0.4	0.4	0.4	0.4	0.6	0.7	0.4	0.8	0.3	0.3	0.3	0.8	0.3	0.0	0.0	999.0
1979	999.0	999.0	-1.3	-0.8	-1.4	-0.8	-1.2	-1.2	-0.7	-0.8	-0.5	-1.3	-0.6	-0.1	-0.5	-0.2	0.0	999.0
1980	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.3	0.2	0.1	0.3	0.0	0.0	999.0
1981	999.0	999.0	2.8	1.2	3.9	3.8	4.0	4.2	5.5	5.6	3.7	3.0	3.3	4.2	4.3	3.8	3.4	999.0
1982	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.1	0.0	0.0	0.0	999.0
1983	999.0	999.0	0.0	0.0	-0.1	0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.1	-0.2	-0.1	0.0	0.0	0.0	999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	

WEEK

Weekly Impact of Observed Minimum Temperature on Modeled Corn Yields (Case 3 - Case 5, Table 15)
Rochester, MN

1948	999.0	999.0	-1.0	-1.1	-0.9	-0.9	-0.9	-0.5	0.0	0.8	1.1	1.1	1.8	1.2	0.9	0.4	0.1	999.0
1949	999.0	999.0	0.4	0.5	0.3	0.3	0.4	-0.5	-0.9	-3.3	-3.3	-3.7	-3.0	-2.9	-1.2	-0.5	-0.4	999.0
1950	999.0	999.0	-0.2	3.1	3.1	3.1	3.0	2.9	2.8	3.2	5.8	3.8	4.0	3.3	3.3	3.3	3.3	999.0
1951	999.0	999.0	0.1	0.2	0.1	0.1	0.1	0.1	0.5	0.0	0.0	0.1	-0.2	-0.3	-0.2	-0.2	0.0	999.0
1952	999.0	999.0	0.0	-0.1	0.1	0.3	0.3	0.2	0.1	0.9	0.7	0.2	1.1	0.9	0.6	0.6	0.0	999.0
1953	999.0	999.0	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.1	-0.6	-0.1	0.0	0.0	0.0	0.0	0.0	999.0
1954	999.0	999.0	0.0	0.1	0.2	0.2	0.3	0.2	-0.2	-0.2	0.8	0.1	-0.7	-0.3	-1.6	0.0	0.0	999.0
1955	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-1.5	-1.3	-0.5	0.6	0.5	0.1	0.0	999.0
1956	999.0	999.0	0.6	0.7	0.7	0.6	0.6	-0.5	-1.1	-0.2	-0.5	-0.4	-0.4	-0.4	-0.3	-0.2	0.0	999.0
1957	999.0	999.0	-0.1	-3.8	-3.4	-3.3	-3.3	-3.1	-3.1	-3.8	-4.6	-3.7	-3.2	-3.0	-3.2	-3.3	-3.5	999.0
1958	999.0	999.0	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3	-9.4	-7.7	-7.5	-8.0	0.0	0.0	0.0	0.0	999.0
1959	999.0	999.0	0.1	0.1	-0.3	0.5	0.5	0.5	0.6	-2.9	-1.2	-0.2	0.4	0.0	0.0	0.0	0.0	999.0
1960	999.0	999.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	-0.1	0.0	0.2	0.0	-0.3	-0.4	-0.5	0.0	999.0
1961	999.0	999.0	-0.2	-0.2	-0.4	-0.2	-0.2	-0.1	0.0	-0.3	-0.3	10.1	10.7	3.5	0.0	0.0	0.0	999.0
1962	999.0	999.0	0.1	9.4	9.4	0.1	0.2	0.1	0.1	-0.3	-1.0	-0.5	0.1	0.1	0.1	0.0	0.0	999.0
1963	999.0	999.0	-3.9	-4.1	0.4	-3.8	0.7	-4.5	-4.6	-1.3	-4.7	-4.0	-1.3	1.2	2.9	3.6	0.0	999.0
1964	999.0	999.0	2.9	0.0	0.0	0.0	0.1	0.1	0.1	0.1	1.1	0.6	0.2	-0.1	-0.1	0.0	0.0	999.0
1965	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1966	999.0	999.0	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.8	-2.0	-0.2	0.7	0.3	0.0	0.0	0.0	0.0	999.0
1967	999.0	999.0	0.0	0.0	-1.0	-1.6	-0.4	-0.4	-0.3	-0.6	1.9	0.4	0.2	-0.7	0.0	0.0	0.0	999.0
1968	999.0	999.0	-6.8	-5.6	-5.7	-5.6	-5.7	-5.7	-5.5	-5.2	-5.3	-4.9	0.1	0.2	0.1	0.1	0.1	999.0
1969	999.0	999.0	0.0	15.1	15.1	15.1	0.0	0.0	0.6	0.7	0.8	0.2	0.2	0.2	0.1	0.1	0.0	999.0
1970	999.0	999.0	-0.8	-0.7	-1.1	-1.2	-1.1	-1.4	-0.3	-0.3	-1.4	-1.0	0.4	1.0	0.7	0.2	0.0	999.0
1971	999.0	999.0	-2.2	-2.3	-2.3	-2.3	-2.4	-2.4	-2.4	-2.4	-0.6	0.0	-1.7	0.0	0.0	0.0	0.0	999.0
1972	999.0	999.0	2.5	-3.9	3.3	-2.8	3.3	4.9	2.8	2.8	5.0	5.5	4.0	1.1	1.8	2.4	2.5	999.0
1973	999.0	999.0	-4.0	-4.2	-4.3	-4.3	-4.4	-0.2	-0.2	-1.5	-2.9	-1.0	-0.5	-1.2	-0.7	-0.7	-0.4	999.0
1974	999.0	999.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1975	999.0	999.0	4.5	4.3	3.9	3.8	3.6	3.2	4.4	1.1	0.9	2.4	3.1	1.2	0.3	0.0	0.0	999.0
1976	999.0	999.0	0.0	17.6	-0.5	17.5	0.7	0.3	2.4	3.6	2.4	1.6	1.9	3.2	2.1	1.6	1.0	999.0
1977	999.0	999.0	0.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.7	-1.3	-1.5	-0.4	-0.3	-0.2	-0.5	-0.5	999.0
1978	999.0	999.0	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.8	-2.5	-2.0	0.3	1.4	0.4	0.0	0.0	999.0
1979	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	999.0
1980	999.0	999.0	0.0	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.5	-1.6	-1.8	0.3	0.6	0.6	0.0	0.0	999.0
1981	999.0	999.0	0.0	0.0	3.2	3.2	3.2	3.1	3.2	3.1	3.3	3.2	3.1	3.0	3.0	3.1	3.2	999.0
1982	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1983	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.1	0.4	0.4	0.8	0.7	0.5	0.2	0.0	999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	

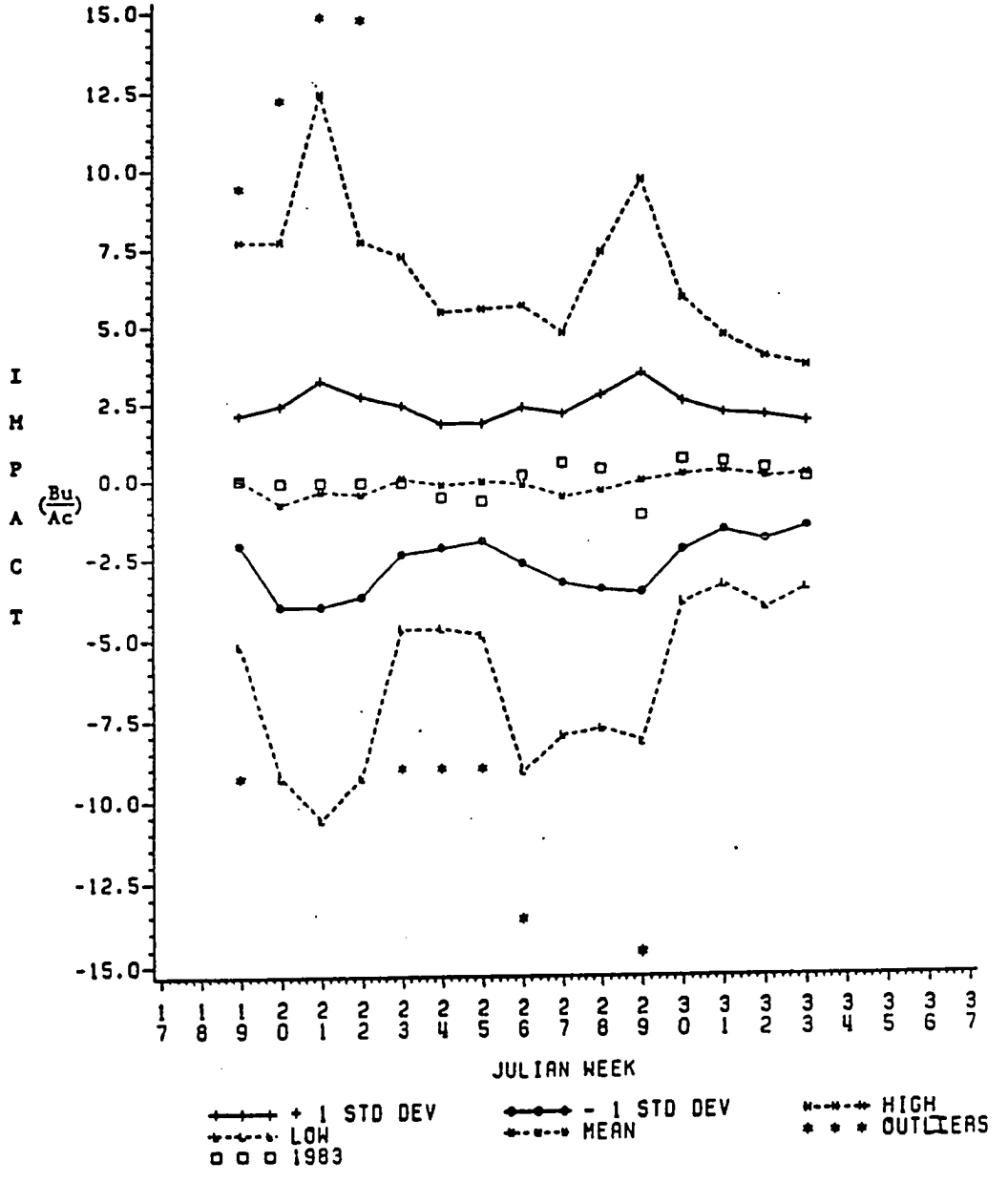
WEEK

Weekly Impact of Observed Precipitation on Modeled Corn Yields (Case 4 - Case 5, Table 15)
Rochester, MN

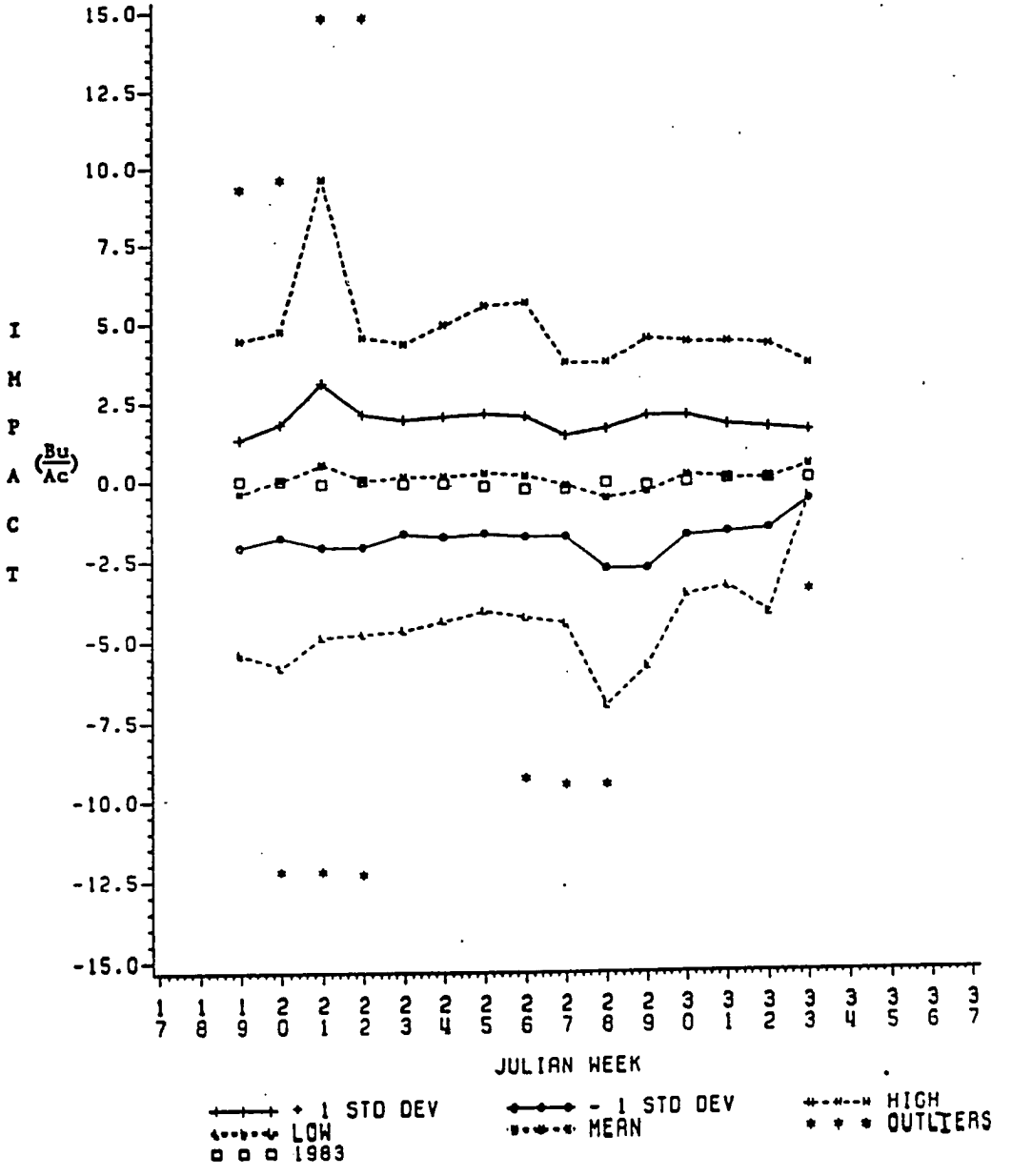
1948	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1949	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.8	0.7	0.8	0.0	0.1	0.3	0.0	999.0
1950	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1951	999.0	999.0	0.0	0.1	0.1	0.0	0.0	0.0	0.4	0.5	-0.2	-0.8	-1.9	-2.8	-0.1	-0.1	0.0	999.0
1952	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	-3.0	0.1	-3.7	-1.2	-0.2	0.0	0.0	0.0	999.0
1953	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1954	999.0	999.0	0.0	0.3	0.0	0.0	0.0	0.0	0.2	0.0	-0.8	-1.6	-3.6	0.0	-1.2	0.0	0.0	999.0
1955	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	-0.2	0.0	-0.3	0.0	0.0	0.0	999.0
1956	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1957	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	999.0
1958	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1959	999.0	999.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	-2.1	-0.9	-0.2	-1.4	-0.4	-0.3	0.0	0.0	0.0	999.0
1960	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.4	0.1	0.3	0.1	0.0	0.0	999.0
1961	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1962	999.0	999.0	0.2	0.0	0.0	0.0	0.0	0.0	-1.6	0.0	-4.6	-4.9	-0.2	0.0	0.0	0.0	0.0	999.0
1963	999.0	999.0	0.1	0.0	0.1	0.1	-0.1	0.0	-0.1	-6.6	-1.1	-3.4	-8.9	-1.3	0.0	-0.5	0.0	999.0
1964	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1965	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1966	999.0	999.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1967	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.1	-2.1	-1.1	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1968	999.0	999.0	0.0	0.0	0.1	0.0	0.0	0.8	0.0	1.8	0.0	0.2	2.2	2.3	0.4	0.2	0.0	999.0
1969	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	999.0
1970	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.4	1.0	1.9	0.4	0.9	0.4	0.0	0.0	999.0
1971	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1972	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.5	1.0	1.4	0.6	0.0	0.0	0.0	0.0	999.0
1973	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.1	0.9	3.3	1.9	0.1	0.0	0.0	999.0
1974	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	-0.1	-1.4	-0.1	0.0	-0.1	-0.5	0.0	0.0	999.0
1975	999.0	999.0	-0.1	0.0	0.0	0.0	0.0	-0.3	0.0	-0.7	-1.5	-1.4	-0.2	0.0	0.0	0.0	0.0	999.0
1976	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	999.0
1977	999.0	999.0	-0.4	0.0	0.0	0.0	0.0	0.1	0.0	-0.6	-2.4	-2.6	-4.0	-0.1	0.0	0.0	0.0	999.0
1978	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.8	-1.0	-0.1	0.0	-0.9	-0.1	0.0	0.0	999.0
1979	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.0
1980	999.0	999.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.8	3.2	2.6	1.9	0.0	0.0	999.0
1981	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	-0.3	2.3	1.5	0.8	0.0	0.0	999.0
1982	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.2	0.0	-0.5	-0.1	-0.2	0.0	0.0	999.0
1983	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.0	-1.6	0.0	0.0	0.0	0.0	999.0
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	

WEEK

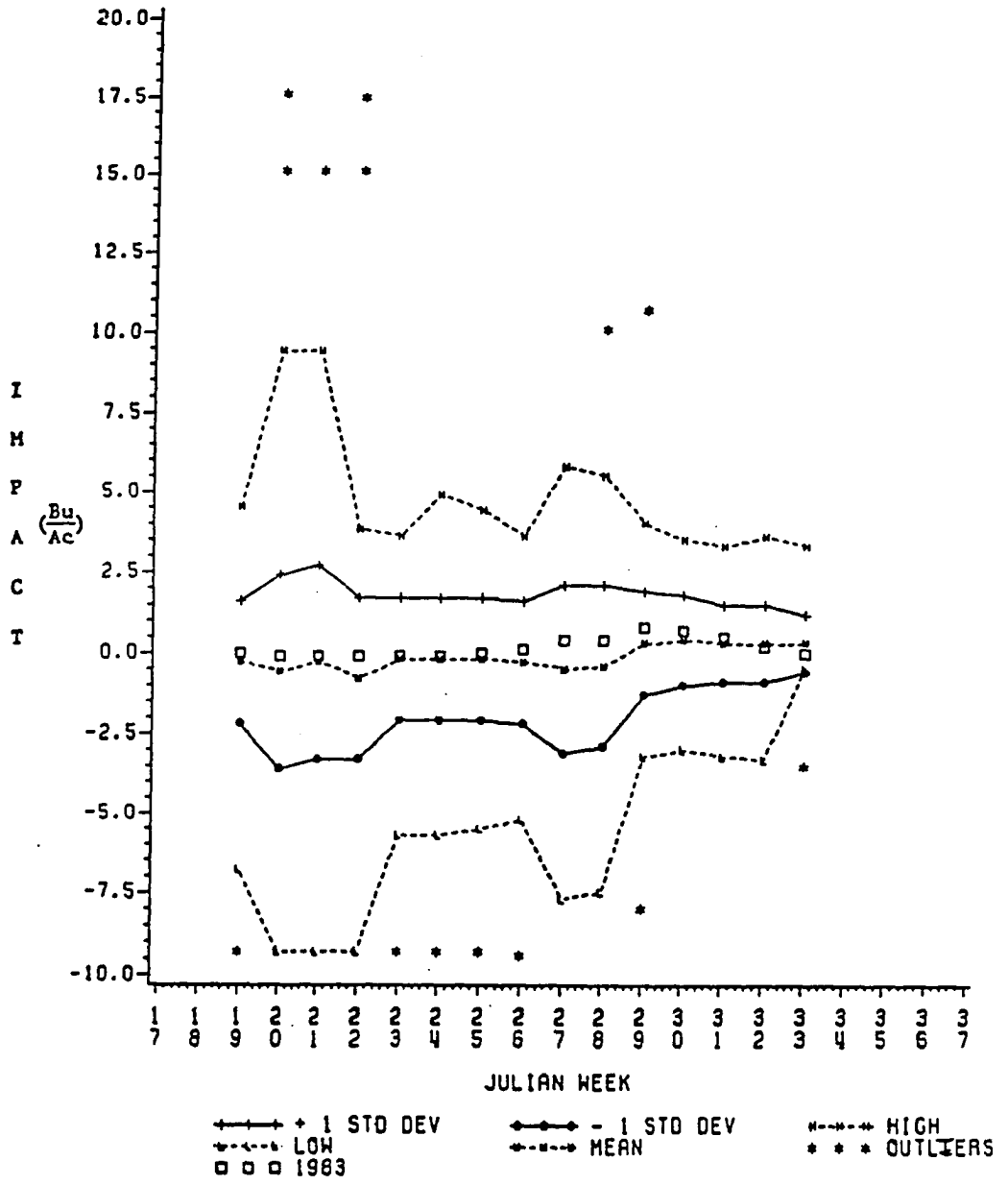
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 1 - Case 5, Table 15) Rochester, MN



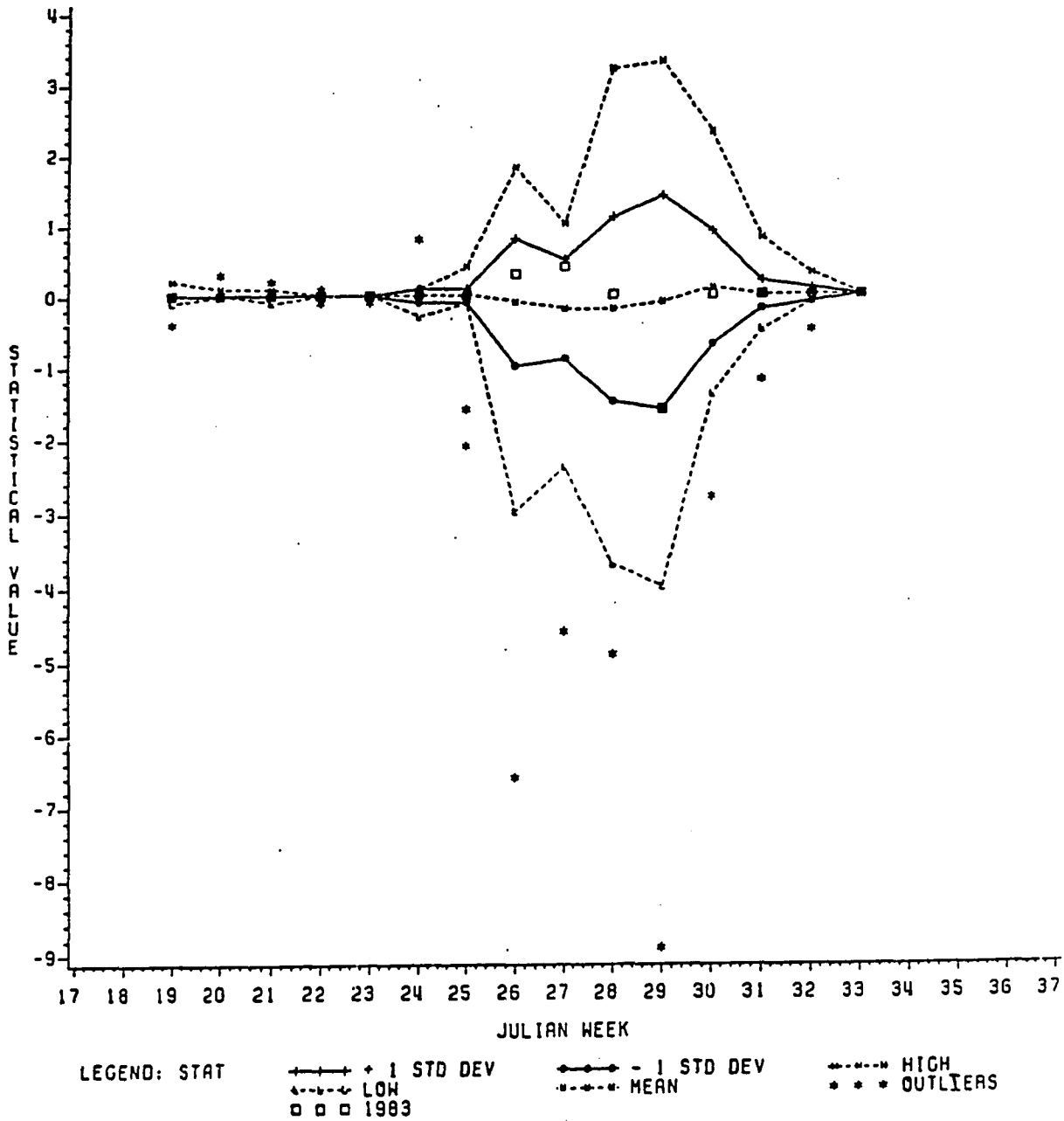
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 2 - Case 5, Table 15) Rochester, MN



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 3 - Case 5, Table 15) Rochester, MN



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 4 - Case 5, Table 15) Rochester, MN



Weekly Impact of All Observed Weather Variables on Modeled Corn Yields (Case 1 - Case 5, Table 15)
Springfield, MO

1948	999.0	999.0	999.0	2.3	3.4	3.1	3.2	-1.8	-1.7	-1.0	1.9	1.9	6.8	8.0	4.3	0.8	0.2	0.2	0.0
1949	999.0	999.0	999.0	-0.1	-0.2	-0.3	-0.6	-0.6	-0.7	0.3	2.9	1.5	1.1	1.4	0.4	0.2	0.6	0.0	0.0
1950	999.0	999.0	999.0	1.2	5.0	5.0	1.7	1.0	2.7	4.6	5.3	5.7	4.7	5.9	2.7	2.1	1.0	0.0	0.0
1951	999.0	999.0	999.0	-0.4	1.3	1.1	-0.7	-0.7	-1.2	-1.7	0.2	3.4	1.8	1.0	0.8	1.0	0.2	0.0	0.0
1952	999.0	999.0	999.0	0.1	-1.3	-1.6	-1.2	8.8	-2.1	-1.4	-5.1	-6.9	-2.4	-0.7	-2.5	-1.1	-1.7	-0.5	0.0
1953	999.0	999.0	999.0	-0.8	-2.0	-2.0	-1.6	-2.1	-4.1	-9.1	-5.4	-4.4	-4.9	-0.9	-1.4	-2.1	-0.1	0.0	0.0
1954	999.0	999.0	999.0	0.0	0.4	1.6	1.4	-1.0	-3.4	-5.7	-14.9	-4.9	-7.0	-4.9	-7.4	-6.3	-0.7	-1.5	0.0
1955	999.0	999.0	999.0	0.1	0.1	-0.1	-0.1	0.0	0.2	-0.4	0.6	1.5	-3.7	-5.0	0.8	0.4	0.4	0.0	0.0
1956	999.0	999.0	999.0	-0.1	-3.7	-3.7	-3.7	-0.2	-0.5	-0.1	0.6	0.0	-0.3	0.3	1.1	0.7	0.4	0.0	0.0
1957	999.0	999.0	999.0	0.0	-0.1	-0.2	-0.2	-1.1	-1.9	0.3	-0.8	-0.1	4.0	-0.5	0.1	0.0	0.0	0.0	0.0
1958	999.0	999.0	999.0	0.3	0.5	0.2	0.6	1.5	2.2	1.3	3.2	0.1	5.6	0.7	4.2	6.6	1.0	0.1	0.6
1959	999.0	999.0	999.0	0.1	0.0	0.0	0.0	-0.1	0.2	0.5	-0.7	-1.2	-1.6	1.4	0.8	0.4	0.7	0.0	0.0
1960	999.0	999.0	999.0	-11.7	-11.6	-11.5	0.8	-0.5	1.0	-0.2	-1.6	-0.3	-5.7	-4.6	-8.2	-3.1	-0.9	-0.2	0.0
1961	999.0	999.0	999.0	0.6	0.0	0.8	-1.3	0.0	0.8	0.6	-0.4	-8.9	-5.0	1.5	-2.2	0.6	0.7	0.0	0.0
1962	999.0	999.0	999.0	0.3	-0.1	-0.1	0.1	0.1	-0.4	-0.7	1.2	0.5	-1.0	-0.4	-0.7	-0.3	-0.3	0.0	0.0
1963	999.0	999.0	999.0	-0.8	-1.0	-0.8	-0.6	-0.9	-1.0	-0.7	-2.8	-3.1	-1.0	-0.1	-0.3	0.2	-0.6	-0.5	-1.0
1964	999.0	999.0	999.0	0.0	0.0	0.0	-0.2	0.0	0.5	1.3	1.0	0.4	0.1	0.3	0.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	-1.2	0.2	0.1	0.1	0.4	0.8	1.3	1.7	1.7	0.5	0.2	0.1	0.2	0.1	0.0	0.0
1966	999.0	999.0	999.0	-2.1	-2.1	-2.5	-1.0	-0.7	2.6	2.9	2.7	2.0	2.4	-0.7	0.6	1.8	2.6	1.3	0.6
1967	999.0	999.0	999.0	1.1	-4.1	-4.2	-0.2	1.6	1.6	2.4	1.7	5.1	2.4	-1.4	0.7	0.8	0.8	0.3	0.0
1968	999.0	999.0	999.0	0.0	0.4	0.7	0.7	0.7	1.3	2.2	3.3	4.2	3.3	2.5	3.4	3.3	3.0	2.6	1.8
1969	999.0	999.0	999.0	0.0	4.8	4.8	-0.1	-0.1	-0.9	-0.2	-2.3	-0.6	-1.4	-1.6	-1.1	-0.1	0.0	0.0	0.0
1970	999.0	999.0	999.0	1.5	1.5	1.6	1.6	2.4	2.3	2.0	1.6	1.2	1.2	1.2	-0.7	0.7	1.4	1.3	1.4
1971	999.0	999.0	999.0	0.0	0.0	-0.2	0.6	1.1	-1.9	-1.1	-2.6	-2.4	-3.2	-2.5	-5.0	-2.4	-0.7	-0.1	0.0
1972	999.0	999.0	999.0	0.0	-0.7	-0.1	0.0	-1.9	-0.8	-22.3	-5.6	-4.9	-1.5	-17.3	-3.5	-8.6	2.4	4.0	0.0
1973	999.0	999.0	999.0	0.9	0.5	0.6	0.7	1.0	1.2	1.8	2.1	3.7	0.7	1.5	0.1	0.2	0.2	0.1	0.0
1974	999.0	999.0	999.0	12.1	24.5	10.8	10.1	10.9	8.8	7.7	20.5	9.0	0.6	0.5	-0.3	2.7	-0.1	2.2	0.0
1975	999.0	999.0	999.0	-0.1	0.0	0.0	0.2	0.1	-0.1	-1.0	-1.4	-0.8	-1.4	0.2	-0.2	-0.1	0.2	0.0	0.0
1976	999.0	999.0	999.0	9.3	6.4	6.4	6.5	6.5	7.0	8.8	9.8	11.0	8.3	0.1	3.1	3.3	2.2	0.6	0.0
1977	999.0	999.0	999.0	-0.2	0.0	0.1	1.5	-0.3	-0.3	-3.1	-7.6	-8.2	-2.6	-2.4	-1.9	-2.1	-1.7	-0.1	0.0
1978	999.0	999.0	999.0	-0.1	-9.1	-9.1	0.4	0.2	-0.6	-2.2	-2.2	-2.0	-1.9	-1.5	-2.1	-1.3	-0.5	-0.4	0.0
1979	999.0	999.0	999.0	-1.0	-0.4	-2.6	-2.2	-0.8	1.3	2.4	7.2	4.1	2.7	8.9	8.1	0.9	5.8	0.2	0.0
1980	999.0	999.0	999.0	-0.7	0.8	0.6	-4.1	-0.5	-1.6	-3.4	-5.6	-4.0	-9.3	-3.4	-1.6	-0.7	-0.8	0.0	0.0
1981	999.0	999.0	999.0	0.0	0.1	0.8	0.6	0.6	1.7	2.7	1.4	0.4	2.2	3.5	5.5	0.6	2.4	0.0	0.0
1982	999.0	999.0	999.0	0.5	0.5	0.7	0.6	0.6	0.5	-0.3	-2.4	-0.5	-0.1	-0.5	-0.6	-0.9	-0.8	0.0	0.0
1983	999.0	999.0	999.0	0.0	-0.3	-0.1	-0.3	-0.4	0.9	0.9	0.8	-0.6	-0.6	-2.2	-1.6	0.3	-0.1	0.0	0.0
				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

WEEK

Weekly Impact of Observed Maximum Temperature on Modeled Corn Yields (Case 2 - Case 5, Table 15)
Springfield, MO

				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1948	999.0	999.0	999.0	2.3	3.3	3.2	3.2	-1.7	-1.7	-1.1	0.1	0.4	1.4	2.3	2.1	0.8	0.3	0.2	0.0
1949	999.0	999.0	999.0	-3.0	-1.3	-0.4	-0.7	-0.3	-0.5	0.3	-0.5	0.0	1.3	1.3	0.6	0.4	0.2	0.0	0.0
1950	999.0	999.0	999.0	2.9	5.8	1.5	0.4	0.5	1.8	2.5	0.8	2.8	2.5	3.4	2.0	1.4	0.7	0.0	0.0
1951	999.0	999.0	999.0	1.4	1.1	0.9	-0.9	-1.0	-1.1	-1.2	0.6	1.0	1.6	0.6	0.5	0.3	0.3	0.0	0.0
1952	999.0	999.0	999.0	0.0	0.6	0.6	0.7	0.3	-0.4	-0.8	-1.6	-0.9	-0.8	-0.5	-1.7	-1.9	-1.8	0.0	0.0
1953	999.0	999.0	999.0	-0.9	-1.4	-1.4	1.1	0.1	-3.9	-4.6	-3.9	-1.6	-1.6	-0.4	-0.7	-1.2	0.0	0.0	0.0
1954	999.0	999.0	999.0	0.0	0.4	0.3	-0.3	-2.5	-4.5	-1.8	-4.4	-5.9	-2.8	-4.9	-2.6	-0.4	0.0	-0.1	0.0
1955	999.0	999.0	999.0	0.1	0.2	-0.1	-0.1	0.0	0.3	0.4	0.9	1.6	0.8	1.3	0.8	0.4	0.4	0.0	0.0
1956	999.0	999.0	999.0	-0.1	0.0	0.0	0.0	-0.1	-0.2	-0.6	-0.8	-0.3	-0.2	-0.1	0.1	-0.2	-0.1	0.0	0.0
1957	999.0	999.0	999.0	-0.4	-0.4	-0.8	0.3	0.2	0.3	0.3	1.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
1958	999.0	999.0	999.0	0.2	0.2	0.1	0.3	0.5	0.6	0.5	0.5	-1.0	-1.1	-0.6	0.8	1.2	0.1	0.0	0.6
1959	999.0	999.0	999.0	0.1	2.1	2.3	0.0	0.0	0.2	0.4	-0.2	0.2	0.1	0.9	0.3	0.0	0.5	0.0	0.0
1960	999.0	999.0	999.0	0.1	-11.6	-11.6	0.2	0.4	0.5	0.7	0.8	0.2	0.0	-0.1	0.2	0.6	0.2	0.2	0.0
1961	999.0	999.0	999.0	-1.2	-0.6	-1.6	-0.6	-0.5	-0.1	0.0	0.1	0.2	0.7	0.9	0.9	0.2	0.3	0.0	0.0
1962	999.0	999.0	999.0	0.3	-0.2	-0.1	0.1	0.1	-0.3	-0.5	1.5	-0.5	-0.6	-0.4	-0.1	-0.2	-0.3	0.0	0.0
1963	999.0	999.0	999.0	-0.2	-0.1	0.1	0.0	0.0	-0.1	-0.3	-0.7	-0.6	-0.5	-0.4	-0.4	-0.2	-0.1	-0.1	0.0
1964	999.0	999.0	999.0	0.0	0.0	0.0	-0.1	0.0	0.1	0.3	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	0.1	0.0	0.0	0.0	0.0	0.2	0.1	-0.1	-0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.0
1966	999.0	999.0	999.0	0.2	0.0	0.1	0.0	0.1	0.0	-0.1	-0.4	2.0	-0.2	-0.7	-0.2	-0.2	0.1	0.0	0.0
1967	999.0	999.0	999.0	-0.1	1.1	0.7	0.7	0.2	-0.2	0.6	2.0	1.7	0.9	0.3	0.5	0.3	0.4	0.2	0.0
1968	999.0	999.0	999.0	0.0	0.0	0.4	0.9	1.0	1.3	1.4	1.9	3.6	1.1	0.3	0.3	0.3	1.4	1.6	0.0
1969	999.0	999.0	999.0	0.0	4.8	4.8	0.0	-0.9	-0.8	-0.2	-0.5	-0.6	-0.4	-0.4	-0.1	-0.1	0.0	0.0	0.0
1970	999.0	999.0	999.0	5.3	5.6	5.6	5.6	-0.1	-0.2	-0.7	-0.5	0.6	-0.2	-0.0	0.9	-0.2	0.1	-0.1	0.0
1971	999.0	999.0	999.0	-3.6	-4.1	-4.0	-0.6	-1.7	-0.8	-1.4	-3.1	-1.3	-0.9	-1.0	-0.8	-1.1	-0.8	-0.2	0.0
1972	999.0	999.0	999.0	-0.2	0.0	-0.1	-0.4	-0.7	-1.1	-1.6	-1.4	-1.1	-1.7	-1.3	-1.9	-1.5	-1.2	-0.3	0.0
1973	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	999.0	999.0	999.0	7.4	0.0	-0.3	-0.3	0.1	0.3	0.3	1.7	1.5	0.5	0.1	-0.1	0.1	0.1	0.0	0.0
1975	999.0	999.0	999.0	-0.2	0.1	0.1	0.4	0.1	0.0	-0.7	-2.0	-1.0	-0.6	-0.1	-0.2	-0.1	0.0	0.0	0.0
1976	999.0	999.0	999.0	-0.7	9.0	8.9	-1.5	-1.5	-1.0	0.0	0.1	-1.4	2.2	1.6	2.0	1.7	0.2	0.1	0.0
1977	999.0	999.0	999.0	-1.2	-1.9	-1.8	-1.5	-1.4	-1.4	-0.9	-3.7	-2.6	-2.3	-1.9	-1.4	-0.4	-0.9	0.0	0.0
1978	999.0	999.0	999.0	-0.2	-9.4	-9.2	0.2	0.1	-0.2	-1.4	-3.8	-0.7	-1.3	-1.1	0.0	-0.7	-0.3	-0.3	0.0
1979	999.0	999.0	999.0	-2.0	-0.8	-1.2	-1.1	0.1	-0.2	0.4	0.9	1.8	2.2	3.0	0.8	0.5	0.1	0.2	0.0
1980	999.0	999.0	999.0	-0.6	0.0	0.2	0.3	-0.8	-1.3	-2.1	-4.8	-4.1	-0.5	-2.3	-0.1	-0.3	0.1	0.0	0.0
1981	999.0	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.4	-0.1	0.1	0.2	0.7	0.1	0.3	0.5	0.2	0.2	0.0	0.0
1982	999.0	999.0	999.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.3	-0.1	-0.1	-0.1	0.0	-0.1	0.0	0.0	0.0
1983	999.0	999.0	999.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	-0.6	-0.8	-0.6	-1.0	-0.8	-0.2	-0.3	4.2	4.2

WEEK

Weekly Impact of Observed Minimum Temperature on Modeled Corn Yields (Case 3 - Case 5, Table 15)
Springfield, MO

1948	999.0	999.0	999.0	0.0	-0.2	-0.2	-0.2	-0.1	0.0	0.1	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0
1949	999.0	999.0	999.0	0.1	0.2	-0.1	-0.1	-0.3	-0.9	-0.9	-2.3	-1.4	-0.3	0.0	-0.2	-0.3	-0.2	0.0	0.0
1950	999.0	999.0	999.0	3.8	4.9	5.0	1.6	1.8	2.7	2.4	3.2	0.6	0.2	0.1	0.2	0.3	0.3	0.0	0.0
1951	999.0	999.0	999.0	0.8	0.9	0.9	0.7	0.7	0.3	0.0	0.0	-0.6	-0.2	0.0	0.0	0.0	0.0	0.0	0.0
1952	999.0	999.0	999.0	0.1	0.7	0.7	0.4	-0.1	-0.9	-0.7	-0.6	-0.9	-1.3	0.1	0.7	-0.8	-1.2	-0.6	0.0
1953	999.0	999.0	999.0	-0.9	-1.4	-1.5	0.1	-2.7	-2.0	-0.8	-2.0	-0.5	-0.5	-0.5	-0.3	-0.6	-0.2	0.0	0.0
1954	999.0	999.0	999.0	0.0	0.0	0.0	0.3	-2.7	-4.5	-5.1	-5.6	-2.3	-2.3	-3.1	-1.4	-2.4	-0.9	-0.8	0.0
1955	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1956	999.0	999.0	999.0	-0.1	-0.1	-0.1	-0.3	-0.2	-0.3	0.4	0.6	0.4	0.0	0.6	1.1	0.9	0.5	0.0	0.0
1957	999.0	999.0	999.0	-0.1	0.2	0.2	0.1	-0.3	-0.2	-1.3	-1.0	-0.7	-0.4	-0.5	0.0	0.0	0.0	0.0	0.0
1958	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1959	999.0	999.0	999.0	5.4	5.5	5.5	5.5	5.5	5.5	5.9	5.4	5.3	5.3	6.1	0.4	0.4	0.2	0.0	0.0
1960	999.0	999.0	999.0	0.0	-11.6	-11.6	0.1	0.2	0.0	-0.2	-0.3	0.1	0.3	0.4	-0.3	-1.0	-0.4	-0.3	-0.1
1961	999.0	999.0	999.0	0.6	0.4	1.5	-0.4	0.5	0.3	1.2	1.8	3.0	1.1	0.1	-0.9	0.3	0.3	0.0	0.0
1962	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1963	999.0	999.0	999.0	-0.8	-1.1	-1.0	-0.8	-1.0	-1.2	-1.7	-2.9	-2.9	-1.3	-0.5	-0.3	-0.3	-0.5	-0.4	-1.0
1964	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	-1.2	0.2	0.0	0.2	0.3	0.5	1.1	1.6	1.7	0.2	0.0	0.1	0.1	0.1	0.0	0.0
1966	999.0	999.0	999.0	-2.1	-1.3	-1.4	-1.2	-0.9	3.5	3.7	3.1	2.1	2.5	1.8	1.1	1.9	2.6	1.3	0.6
1967	999.0	999.0	999.0	-0.2	-0.8	-0.7	0.2	1.1	1.5	1.6	4.0	4.6	1.3	0.8	0.1	0.4	0.3	0.1	0.0
1968	999.0	999.0	999.0	0.0	0.1	0.0	0.1	0.1	0.1	-0.2	-0.3	-0.1	0.1	0.4	-0.2	-0.1	0.0	0.0	0.0
1969	999.0	999.0	999.0	0.0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1970	999.0	999.0	999.0	1.5	1.4	1.5	1.7	0.2	2.3	0.2	2.3	1.7	1.4	1.4	1.2	1.1	1.5	1.4	1.4
1971	999.0	999.0	999.0	-0.1	0.2	0.3	0.6	1.2	1.2	1.0	0.7	1.1	0.9	0.5	0.5	0.3	0.1	0.1	0.0
1972	999.0	999.0	999.0	2.5	-1.1	-1.2	-0.8	3.2	3.6	3.7	3.6	5.0	4.0	3.8	3.2	3.4	3.5	4.2	4.0
1973	999.0	999.0	999.0	0.9	0.5	0.6	0.7	1.0	1.2	1.8	1.9	1.9	0.6	0.0	0.1	0.1	0.2	0.1	0.0
1974	999.0	999.0	999.0	11.6	18.9	6.9	8.0	7.5	7.0	6.2	6.0	6.9	0.1	-0.4	-0.4	-0.6	-0.3	0.0	0.0
1975	999.0	999.0	999.0	0.3	0.3	0.3	0.4	0.4	0.6	0.5	0.3	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0
1976	999.0	999.0	999.0	-0.1	8.9	8.9	-1.3	0.8	1.0	1.7	2.0	7.4	1.3	-1.0	-0.8	1.5	1.1	0.5	0.0
1977	999.0	999.0	999.0	-0.9	-1.3	-1.3	2.1	-1.4	-3.0	-3.7	-5.0	-5.9	-1.2	-0.9	-0.8	-1.9	-0.1	-0.1	0.0
1978	999.0	999.0	999.0	-0.2	-0.1	0.0	-0.1	-0.3	-0.3	0.3	0.6	-0.1	-0.1	0.0	0.0	-0.1	-0.4	-0.1	0.0
1979	999.0	999.0	999.0	-0.9	-1.1	-0.4	-0.3	1.2	2.5	1.7	2.0	2.4	0.3	0.2	0.4	0.1	0.2	0.0	0.0
1980	999.0	999.0	999.0	-0.8	-0.5	-0.3	-0.8	-1.1	-2.1	-3.6	-4.3	-1.5	-1.0	-1.4	-0.5	-0.4	-0.7	0.0	0.0
1981	999.0	999.0	999.0	0.0	0.1	0.9	0.7	0.7	0.4	-0.2	-1.0	-0.6	-0.8	0.2	0.1	0.0	0.0	0.0	0.0
1982	999.0	999.0	999.0	0.5	0.4	0.6	0.4	0.4	0.3	-0.6	-2.7	-1.2	-0.1	-0.4	-0.6	-1.0	-0.8	0.0	0.0
1983	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	0.2	0.7	0.2	0.7	0.6	0.5	0.2	0.0	0.0
				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

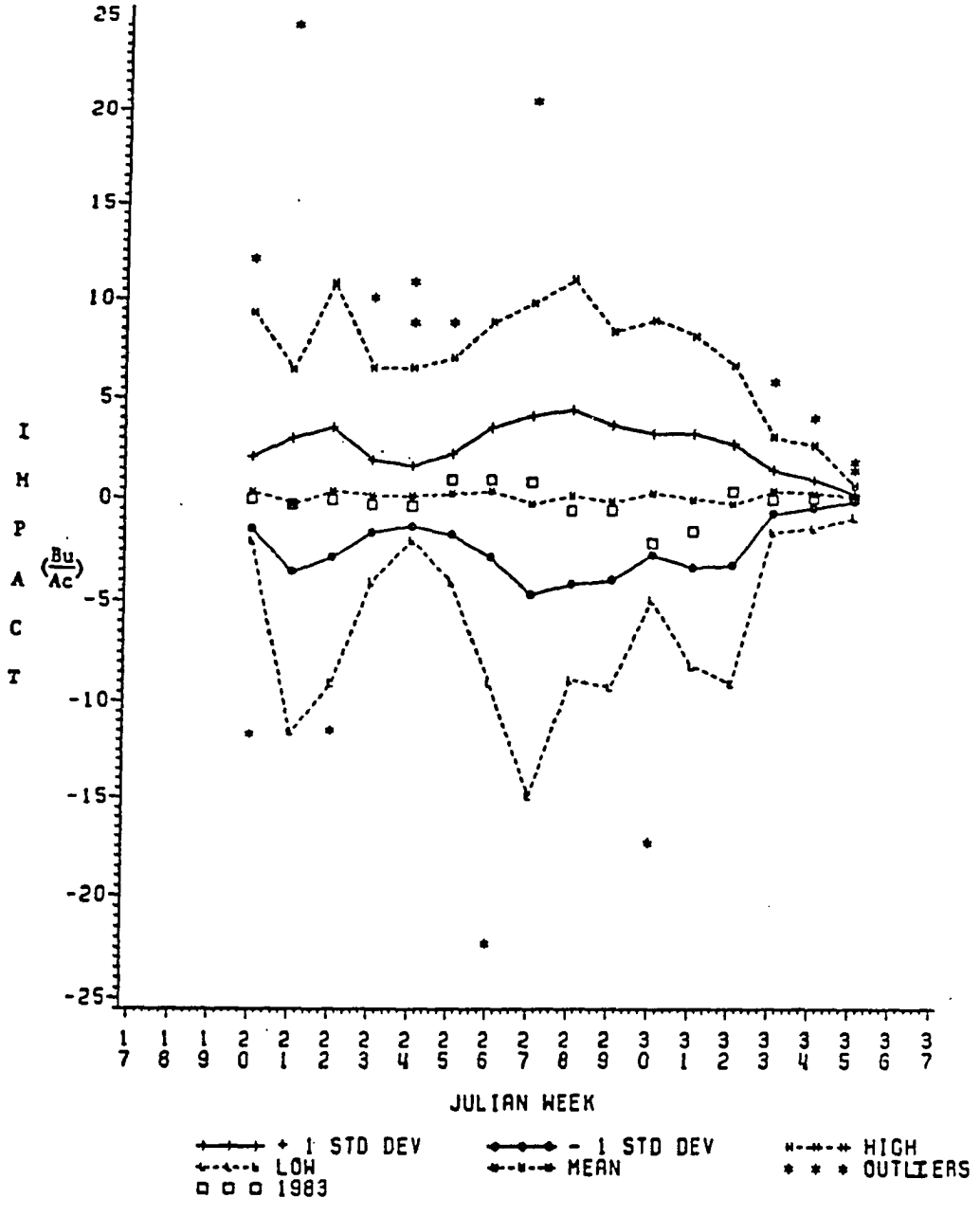
WEEK

Weekly Impact of Observed Precipitation on Modeled Corn Yields (Case 4 - Case 5, Table 15)
Springfield, MO

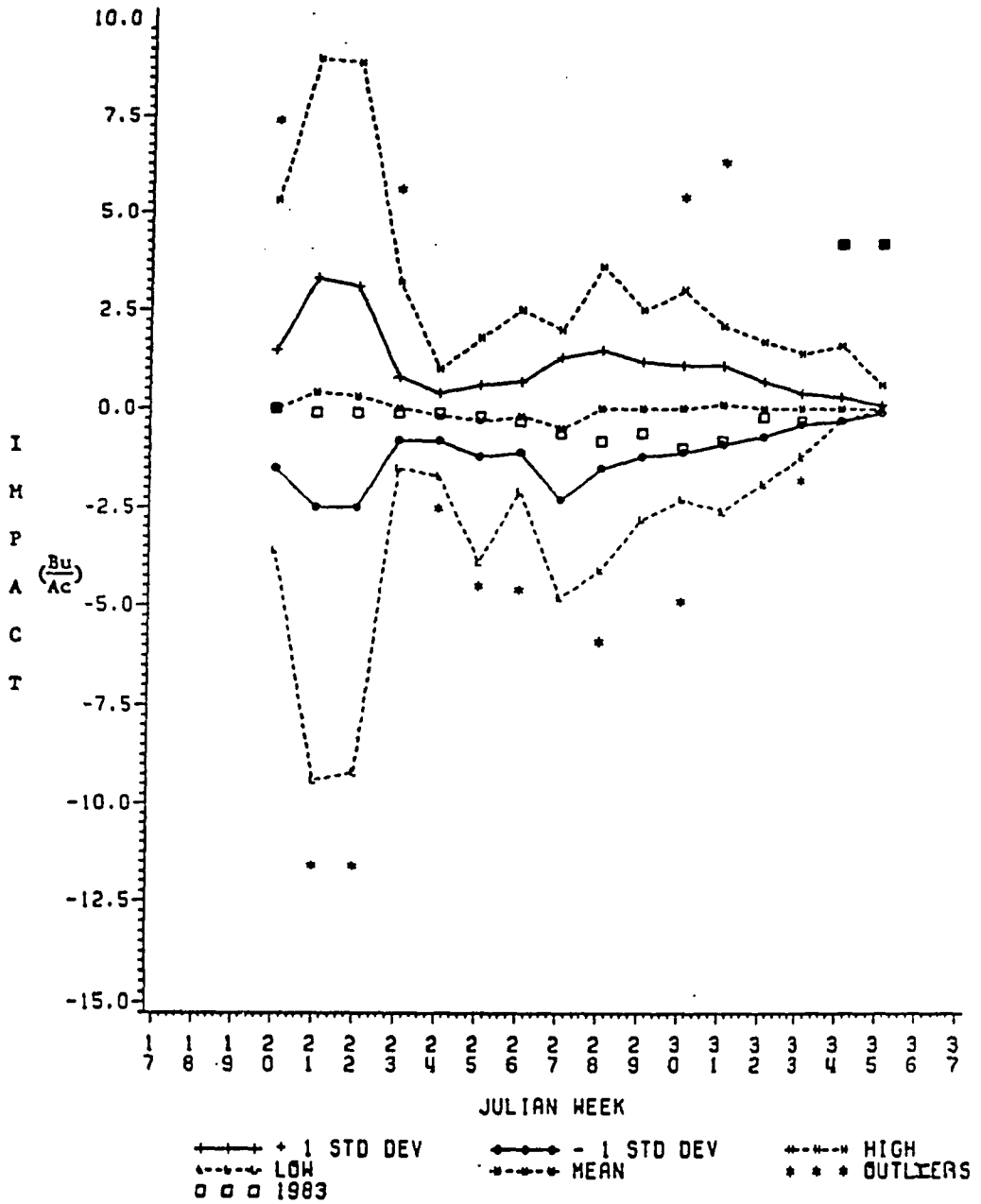
1948	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.7	3.8	6.7	3.6	0.0	-0.1	0.0	0.0
1949	999.0	999.0	999.0	0.0	0.0	0.1	0.0	0.0	0.8	0.9	4.7	3.0	0.5	0.0	0.0	0.1	1.0	0.0	0.0
1950	999.0	999.0	999.0	-0.1	0.0	0.0	0.0	0.0	0.1	1.3	0.2	0.2	0.2	0.4	0.1	0.1	0.0	0.0	0.0
1951	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	4.0	0.3	0.4	0.4	0.6	0.0	0.0	0.0
1952	999.0	999.0	999.0	0.0	0.2	-0.1	0.1	0.0	0.0	0.0	-1.5	-4.8	-0.6	0.0	-0.7	-7.7	0.0	0.0	0.0
1953	999.0	999.0	999.0	0.0	0.0	-0.1	-0.2	0.0	0.0	-3.6	-1.6	-2.4	-2.1	0.0	-0.3	-11.7	0.0	0.0	0.0
1954	999.0	999.0	999.0	0.0	0.0	0.0	-0.2	0.0	0.0	-1.0	-6.3	-0.1	-4.1	0.0	-4.8	-3.9	0.0	-0.2	0.0
1955	999.0	999.0	999.0	0.0	-0.1	0.0	0.0	0.0	-0.1	-0.2	0.1	-0.1	-4.7	-6.5	0.0	0.0	0.0	0.0	0.0
1956	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
1957	999.0	999.0	999.0	0.0	-0.1	-0.1	-0.2	-0.2	-1.2	1.1	0.0	0.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0
1958	999.0	999.0	999.0	0.2	0.3	0.1	0.3	1.4	2.0	1.2	2.1	2.1	7.4	1.6	3.3	4.7	0.0	0.0	0.0
1959	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.8	-1.1	-1.6	-0.1	0.0	0.0	0.0	0.0	0.0
1960	999.0	999.0	999.0	-0.3	0.0	0.1	-0.5	-2.1	0.0	-1.0	-2.1	-0.7	-6.0	-4.6	-7.9	-2.7	-0.7	0.0	0.0
1961	999.0	999.0	999.0	0.0	0.0	0.0	0.1	-0.6	0.0	-0.4	-2.8	-12.8	-7.2	-0.3	-3.1	0.0	0.0	0.0	0.0
1962	999.0	999.0	999.0	0.0	0.0	0.0	-0.1	0.0	-0.2	-0.1	-0.1	0.8	-0.4	0.0	-0.6	0.0	0.0	0.0	0.0
1963	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	0.8	0.3	1.0	0.9	0.0	0.6	0.1	0.0	0.0
1964	999.0	999.0	999.0	0.0	0.0	0.0	-0.1	0.1	0.4	1.0	0.6	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.0
1965	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.1	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1966	999.0	999.0	999.0	0.0	-0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	-0.6	0.0	-2.2	-0.4	0.0	0.0	0.0
1967	999.0	999.0	999.0	0.0	0.0	-0.2	0.0	0.0	-0.1	-0.5	-2.8	-0.9	-0.3	-1.8	-0.1	0.0	0.0	0.0	0.0
1968	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
1969	999.0	999.0	999.0	0.0	0.0	0.1	0.0	0.0	0.1	-0.1	-2.2	0.0	-1.2	-1.4	-0.9	0.0	0.0	0.0	0.0
1970	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.5	-1.0	-0.2	0.0	0.0
1971	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-0.1	-1.9	-1.0	-1.0	-1.6	-2.5	-1.6	-4.4	-2.0	0.0	0.0	0.0
1972	999.0	999.0	999.0	0.0	-0.6	0.0	0.0	-1.4	0.0	-15.9	-3.6	-3.2	-0.1	-18.7	-0.3	-6.8	-0.2	0.0	0.0
1973	999.0	999.0	999.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	1.6	0.1	1.0	0.0	0.1	0.0	0.0	0.0
1974	999.0	999.0	999.0	0.0	7.9	0.0	-0.1	0.6	0.0	0.0	11.1	0.4	0.0	1.0	0.2	2.7	0.0	0.0	0.0
1975	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	-1.1	0.3	0.0	0.0	0.3	0.0	0.0
1976	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.0
1977	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.3	-0.6	0.0	-0.2	0.0	-1.0	-0.4	0.0	0.0
1978	999.0	999.0	999.0	-1.4	-1.4	-1.4	-1.4	0.0	-1.3	0.0	0.0	-1.3	-1.7	-0.3	-1.3	-0.4	0.0	0.0	0.0
1979	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.8	0.0	0.0	7.6	6.7	0.2	4.2	0.0	0.0
1980	999.0	999.0	999.0	0.0	0.0	0.0	0.2	-0.1	0.0	0.0	0.0	0.0	0.0	-7.6	-0.6	-1.1	0.0	-0.3	0.0
1981	999.0	999.0	999.0	0.0	0.0	0.7	0.1	0.2	1.1	3.0	2.4	0.0	1.7	3.2	4.8	0.2	1.9	0.0	0.0
1982	999.0	999.0	999.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1983	999.0	999.0	999.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.7	-2.0	0.0	0.0	0.0	0.0
				20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

WEEK

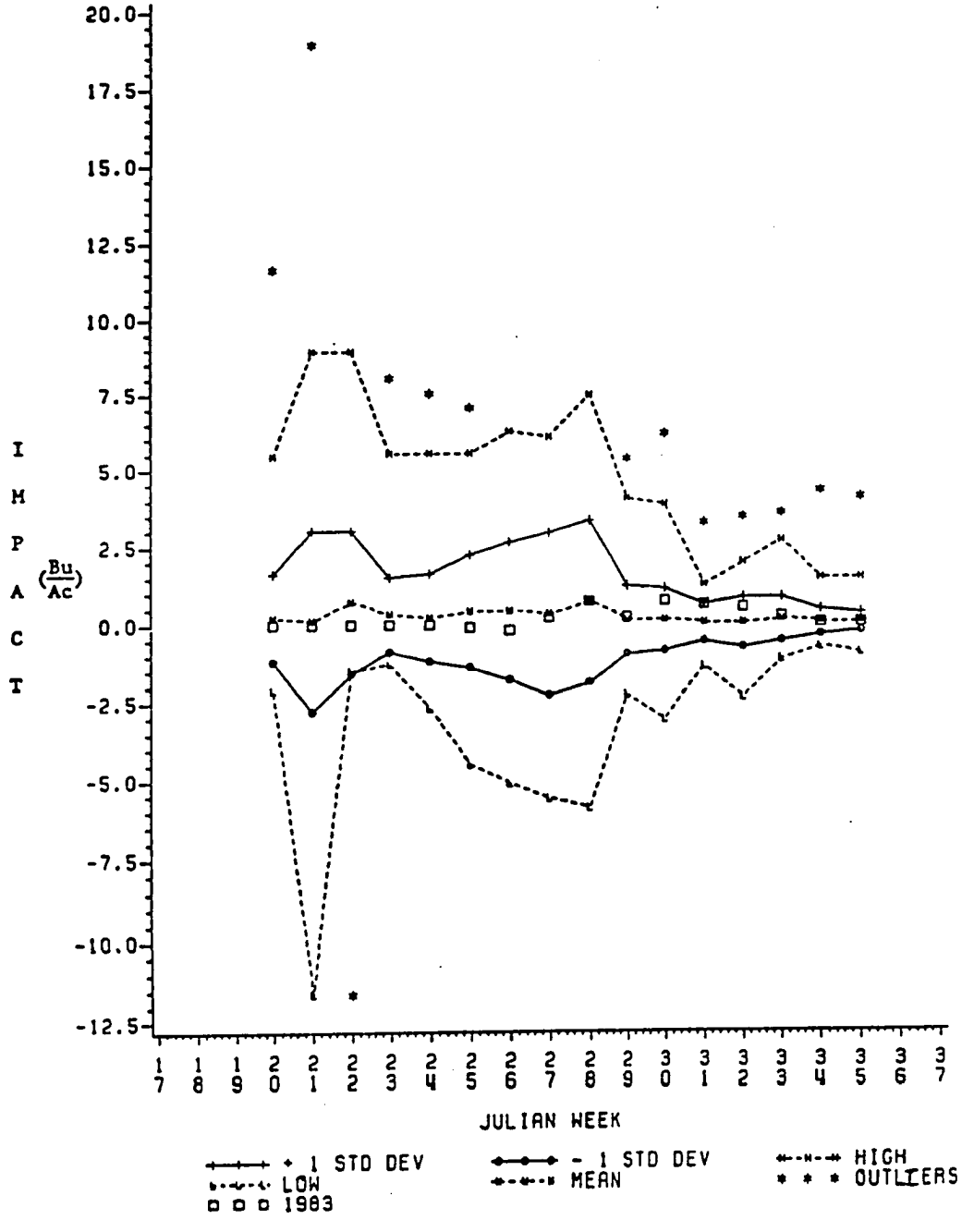
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 1 - Case 5, Table 15) Springfield, MO



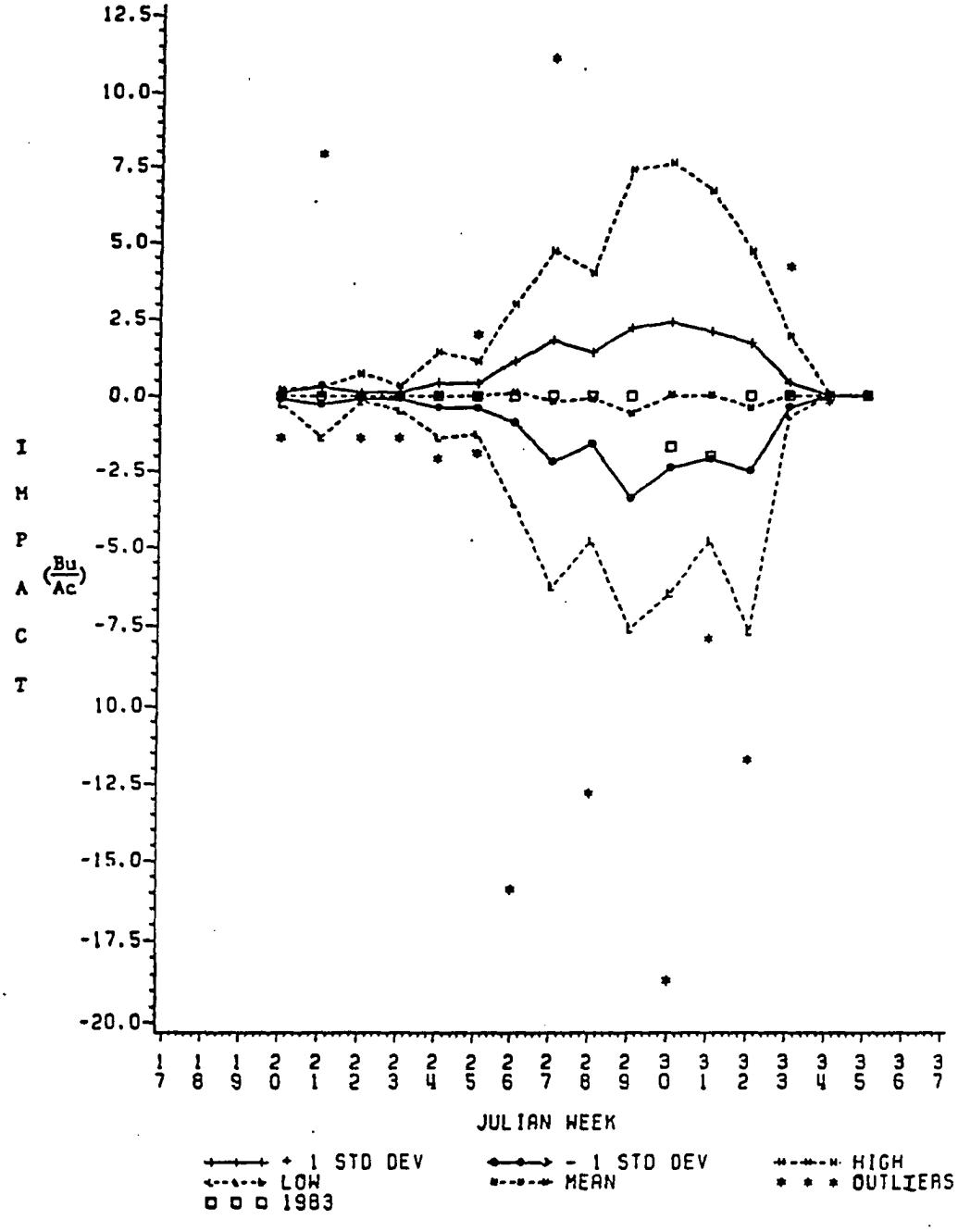
Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 2 - Case 5, Table 15) Springfield, MO



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 3 - Case 5, Table 15) Springfield, MO



Weekly Yield Difference Means, Standard Deviation and Ranges
(Case 4 - Case 5, Table 15) Springfield, MO

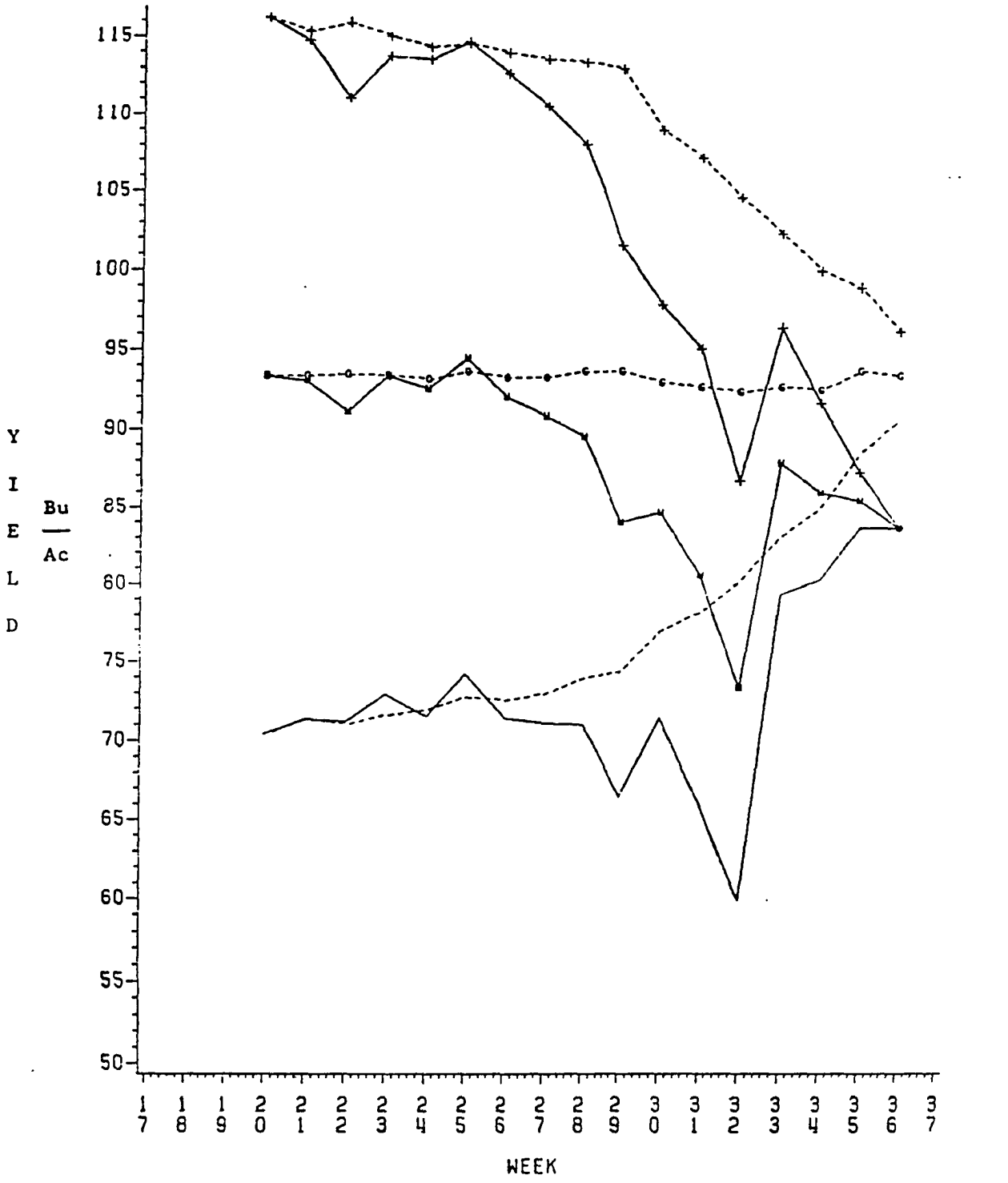


Appendix F

LONG-TERM AND ANNUAL WEEKLY MEAN MODELED YIELD AND FOLLOWING WEATHER YIELD VARIABILITY (1948-1983) AT ROCHESTER, MN.

Long-Term and 1948 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G-. Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

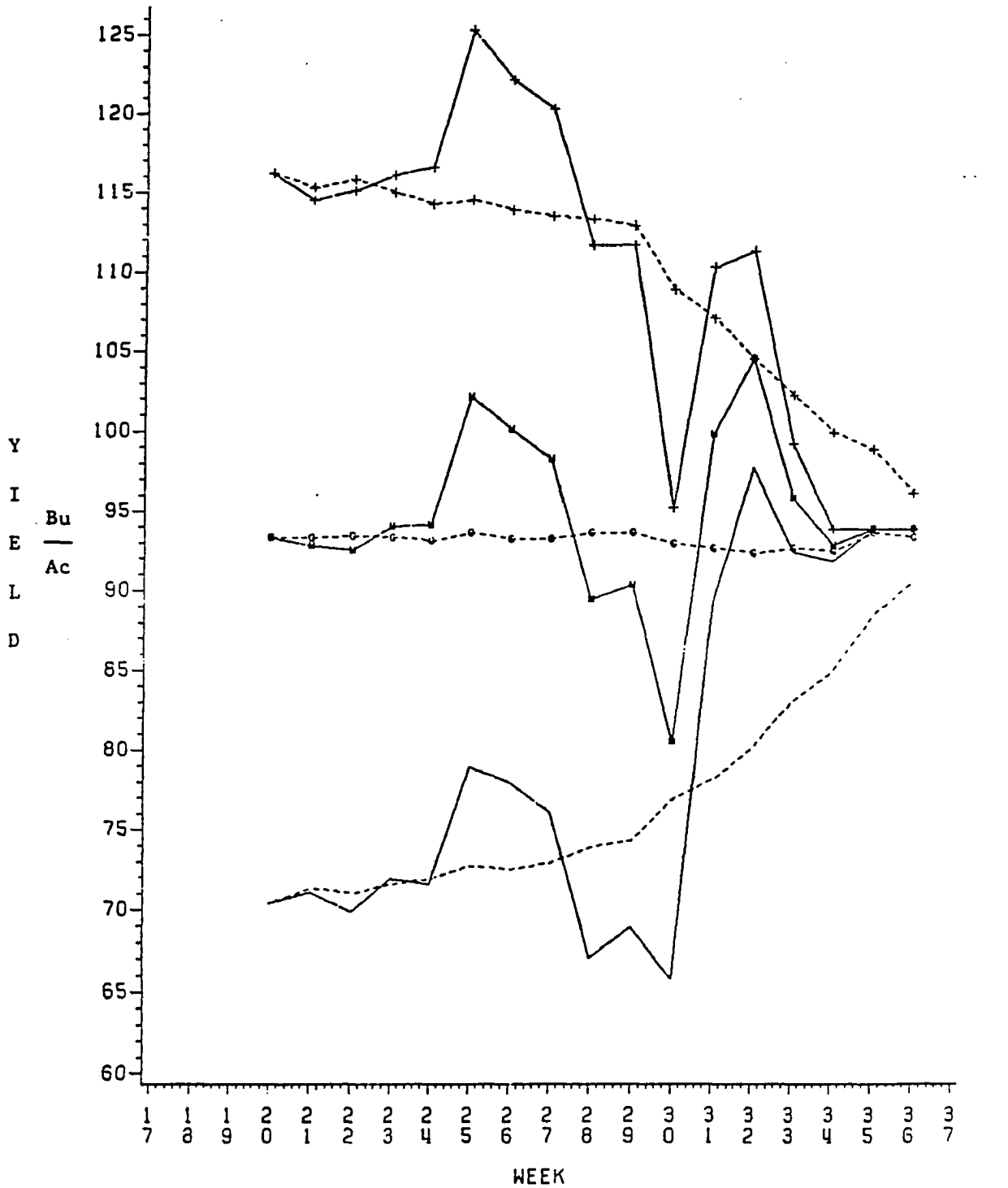
+-+- +1 Std. Dev. about the 1948 Mean

-M-M-M- 1948 Weekly Mean

_____ -1 Std. Dev. about the 1948 Mean

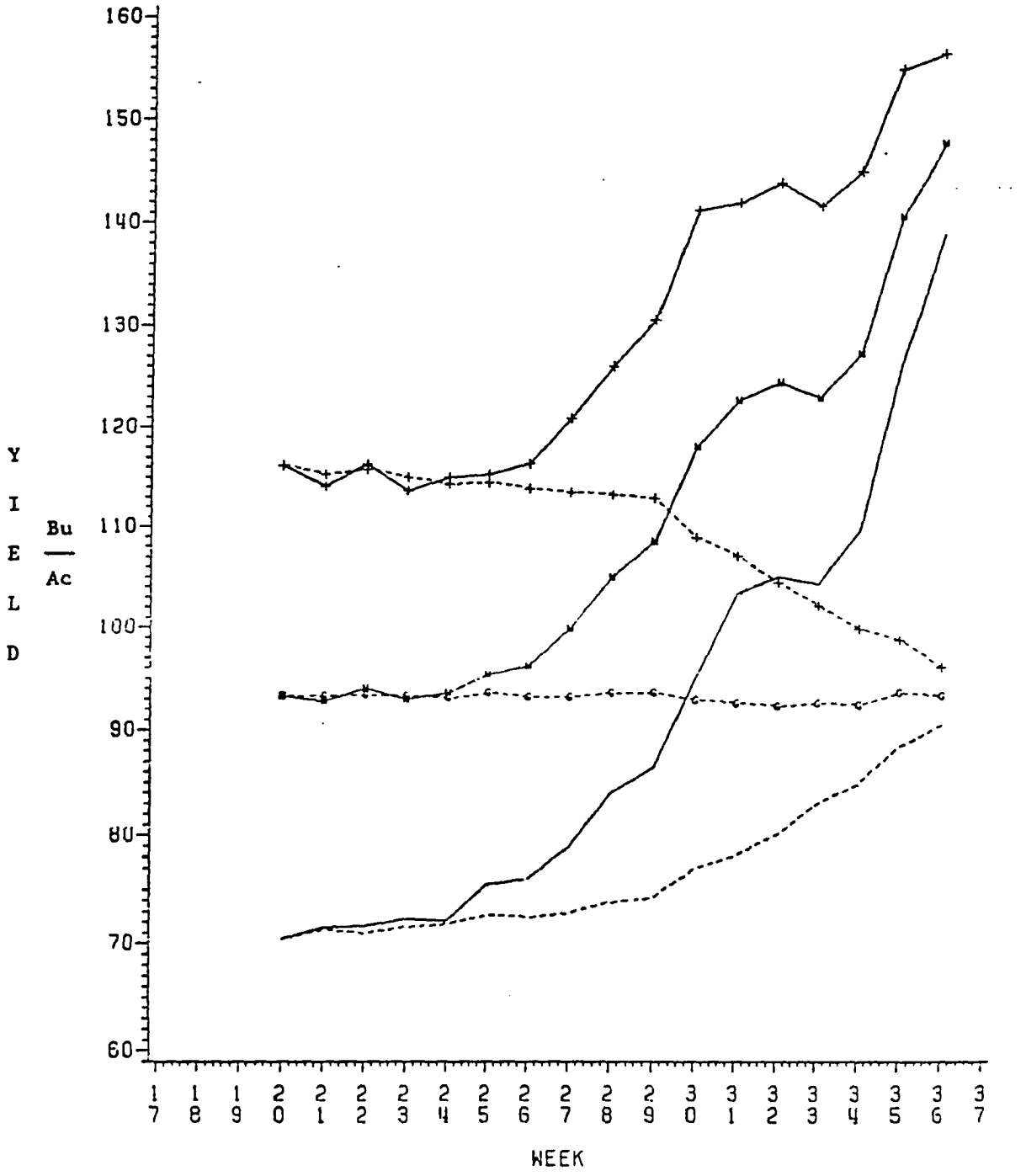
Long-Term and 1949 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1950 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

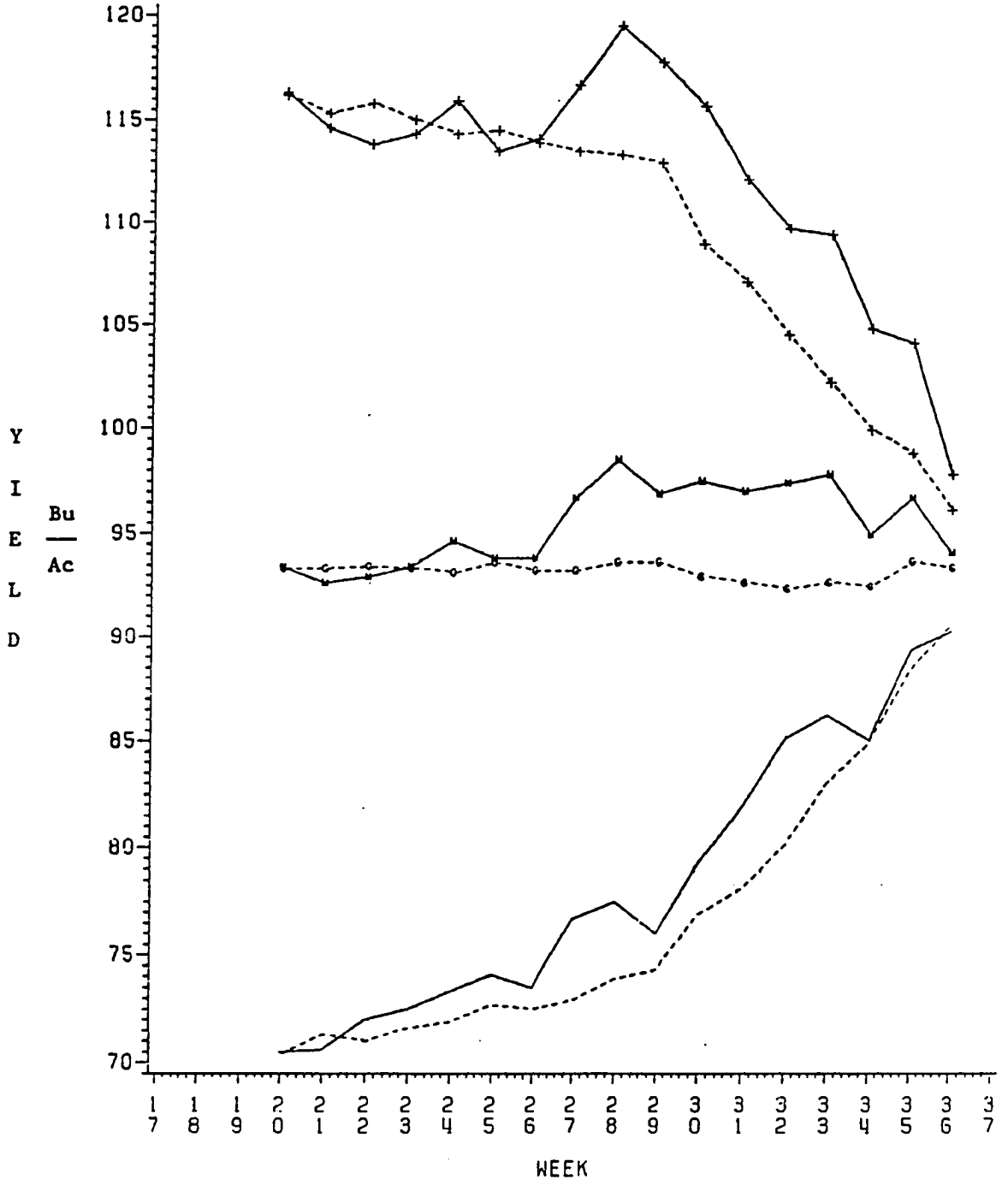
+-+- +1 Std. Dev. about the 1950 Mean

-M-M-M- 1950 Weekly Mean

_____ -1 Std. Dev. about the 1950 Mean

Long-Term and 1951 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

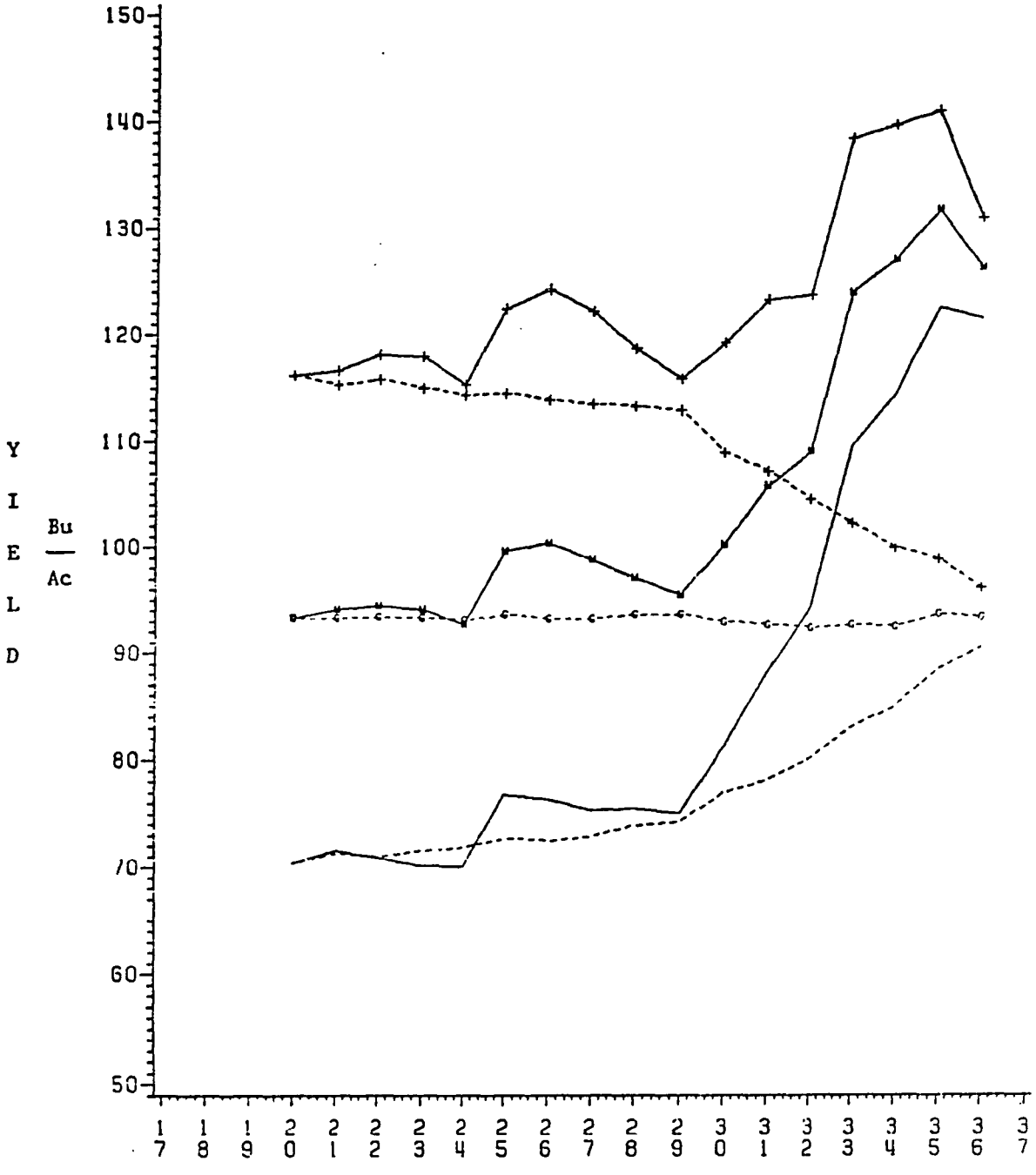
+-+- +1 Std. Dev. about the 1951 Mean

-M-M-M- 1951 Weekly Mean

_____ -1 Std. Dev. about the 1951 Mean

Long-Term and 1952 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

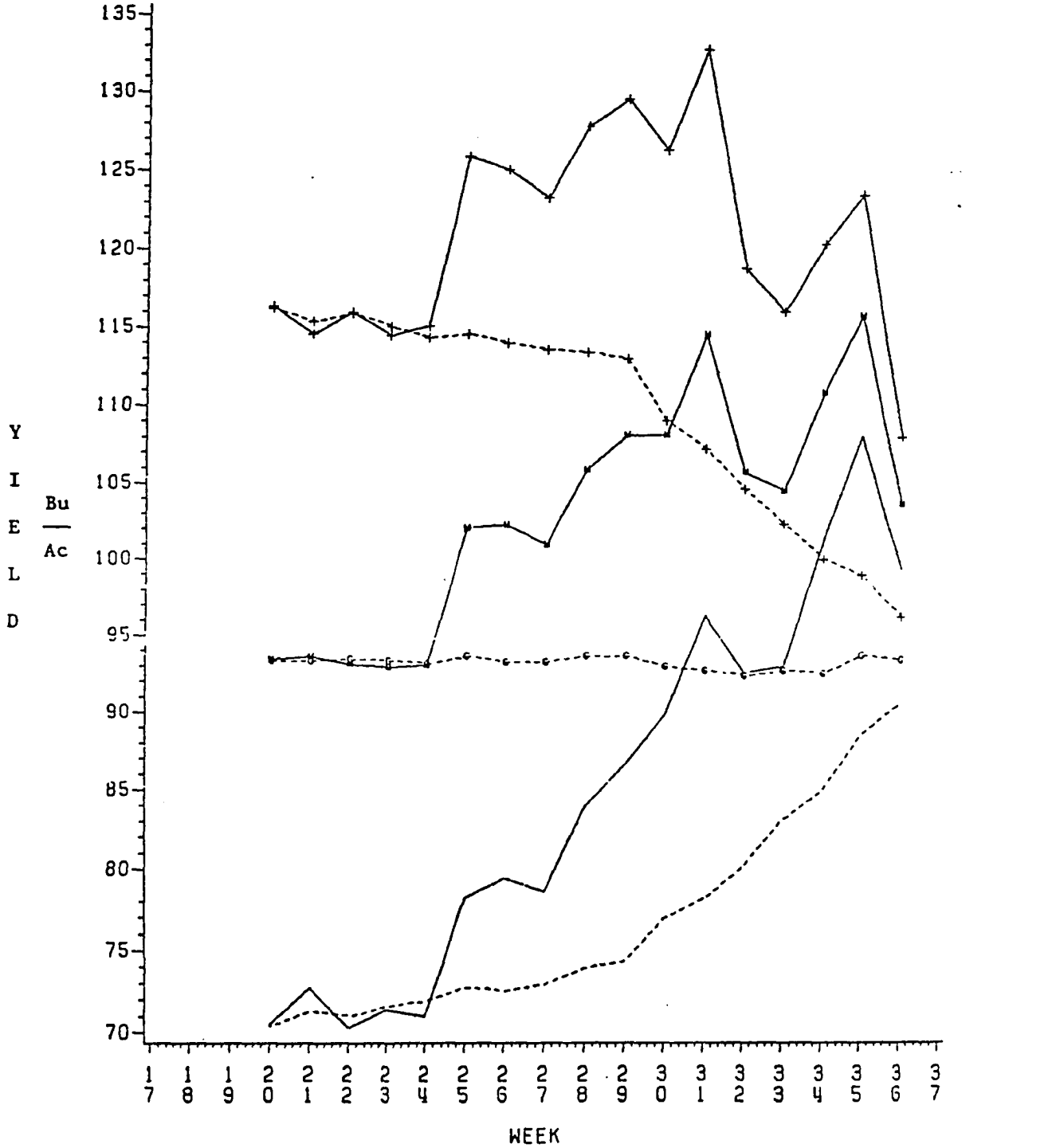
+-+- +1 Std. Dev. about the 1952 Mean

-M-M-M- 1952 Weekly Mean

_____ -1 Std. Dev. about the 1952 Mean

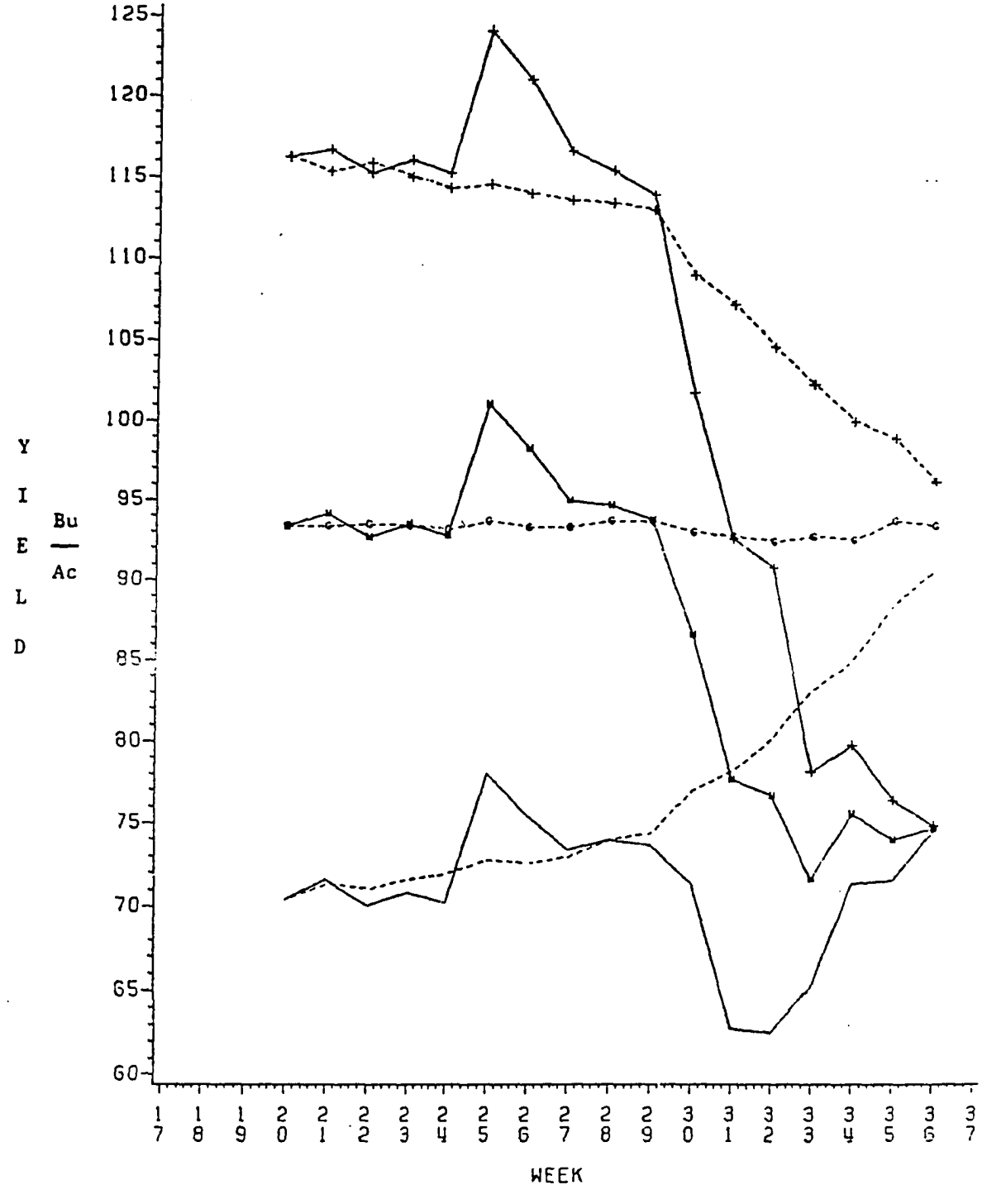
Long-Term and 1953 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1954 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

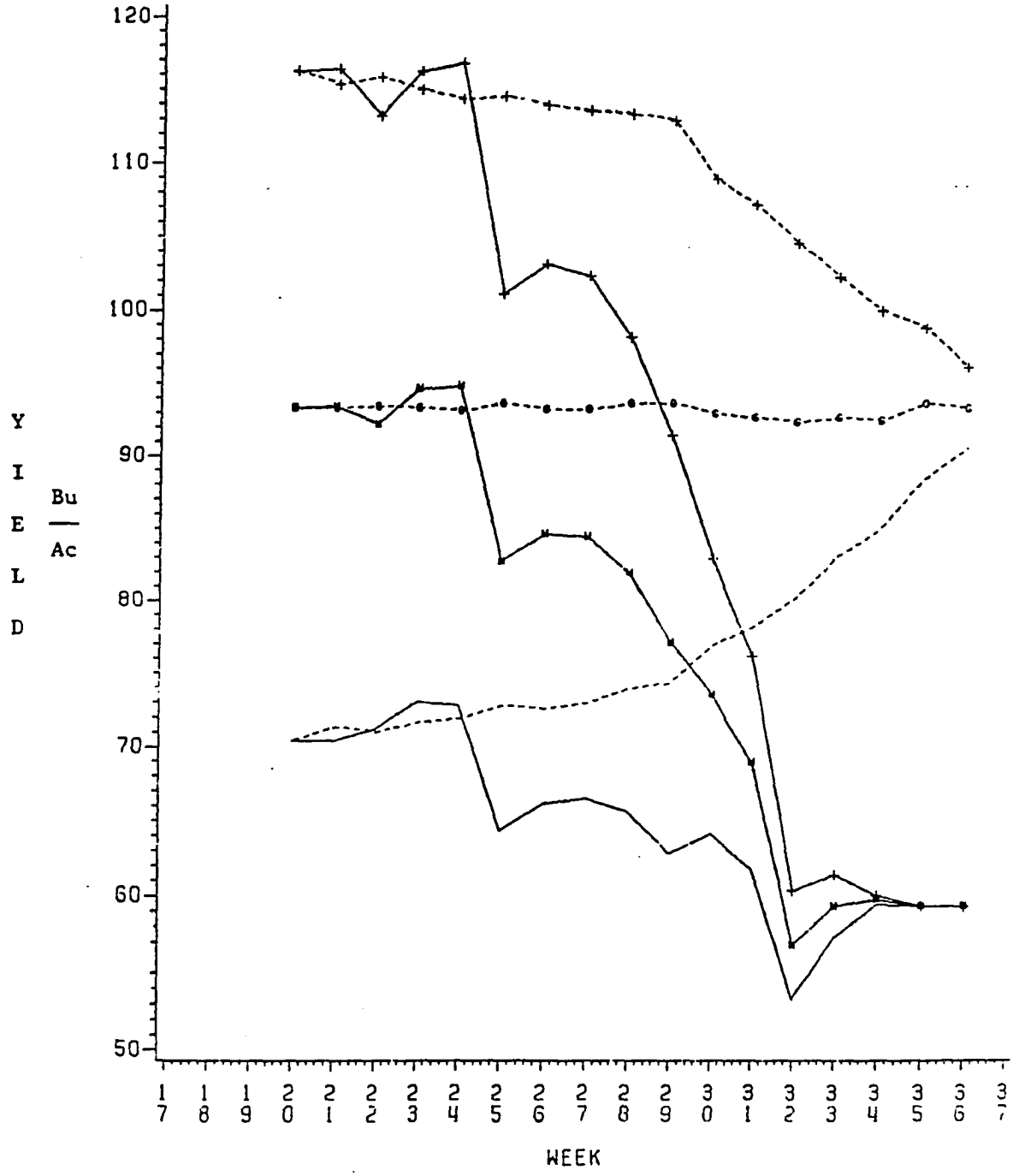
+-+- +1 Std. Dev. about the 1954 Mean

-M-M-M- 1954 Weekly Mean

_____ -1 Std. Dev. about the 1954 Mean

Long-Term and 1955 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

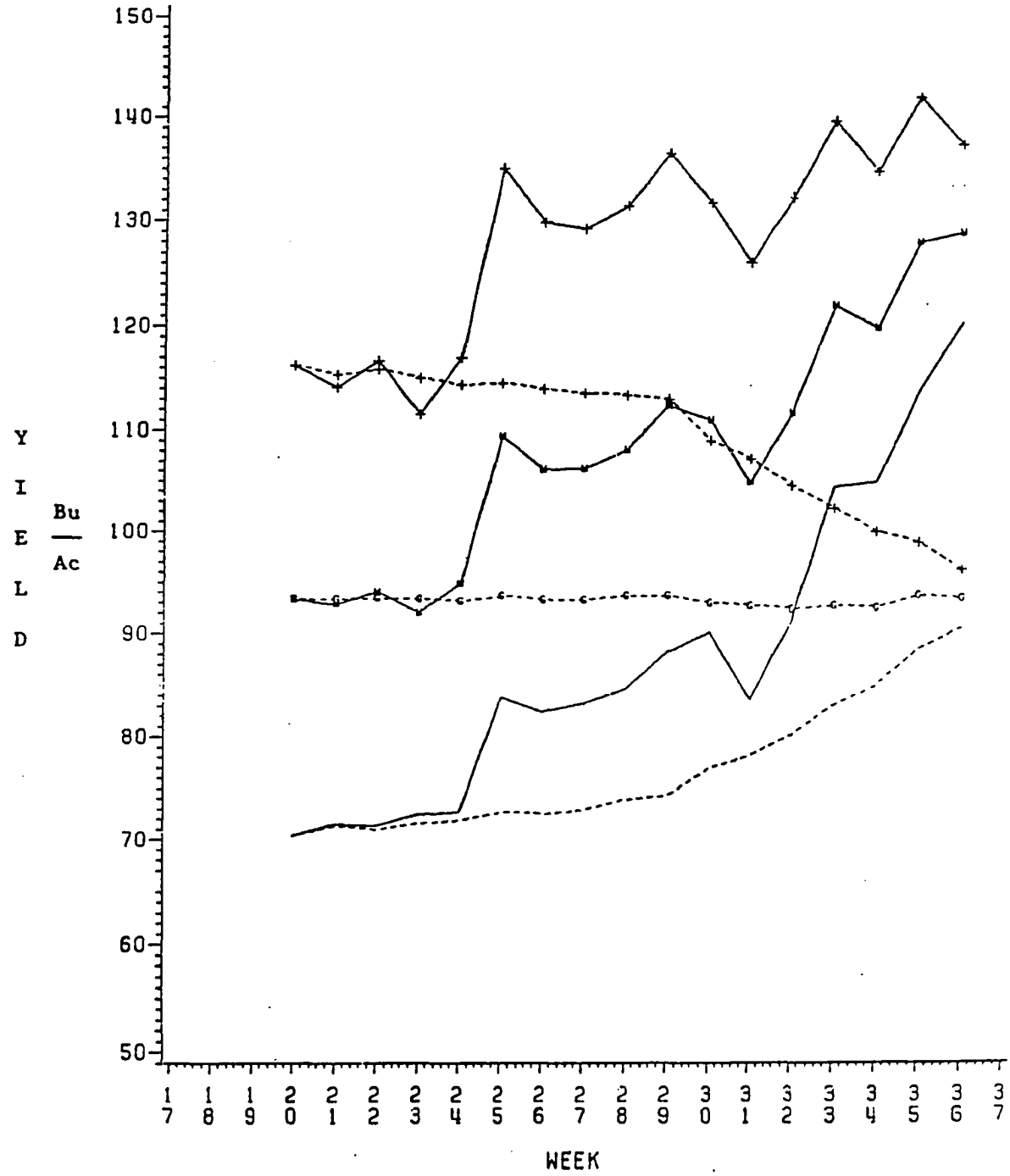
+-+- +1 Std. Dev. about the 1955 Mean

-M-M-M- 1955 Weekly Mean

_____ -1 Std. Dev. about the 1956 Mean

Long-Term and 1956 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G-. Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

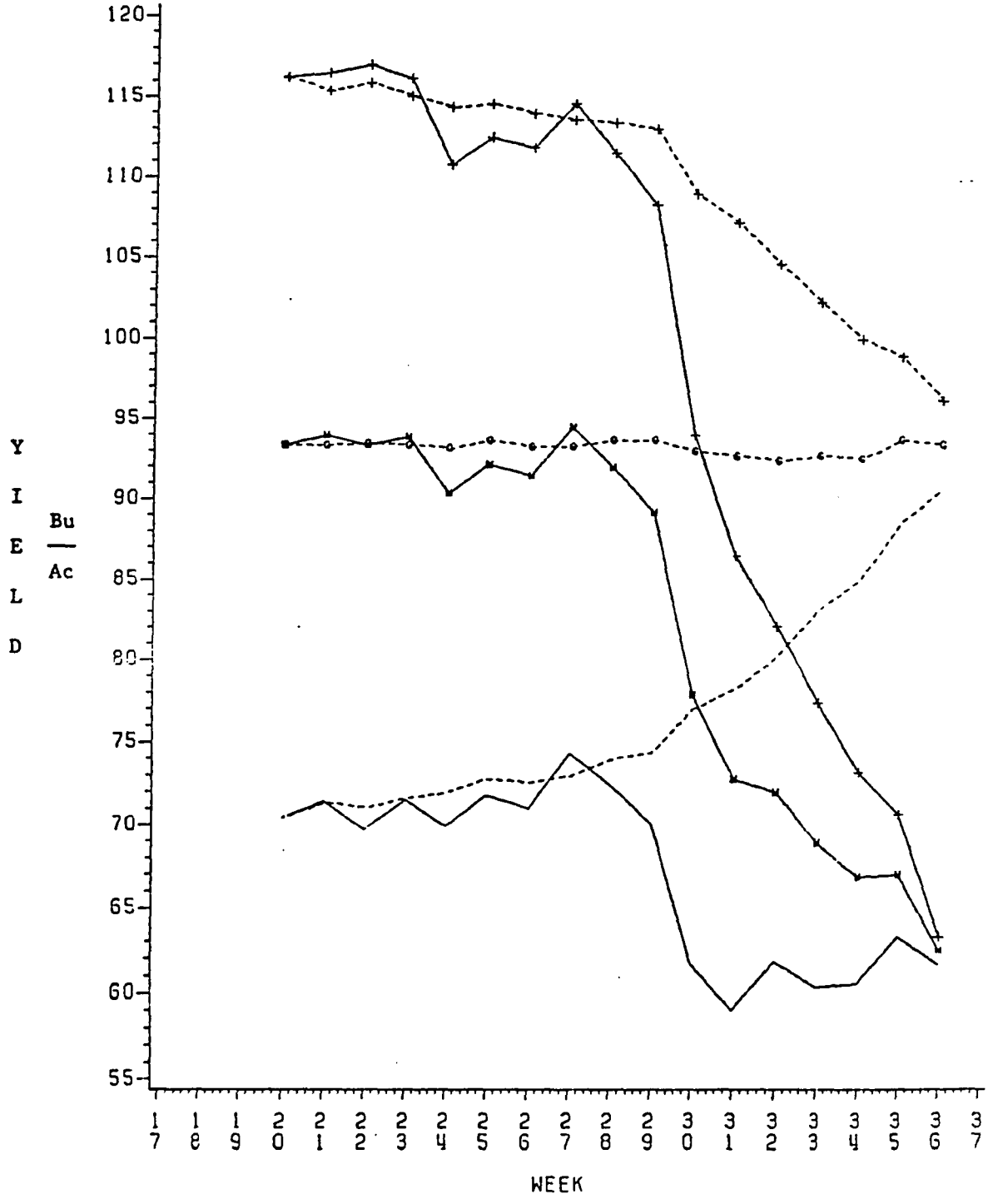
+-+- +1 Std. Dev. about the 1956 Mean

-M-M-M- 1956 Weekly Mean

_____ -1 Std. Dev. about the 1956 Mean

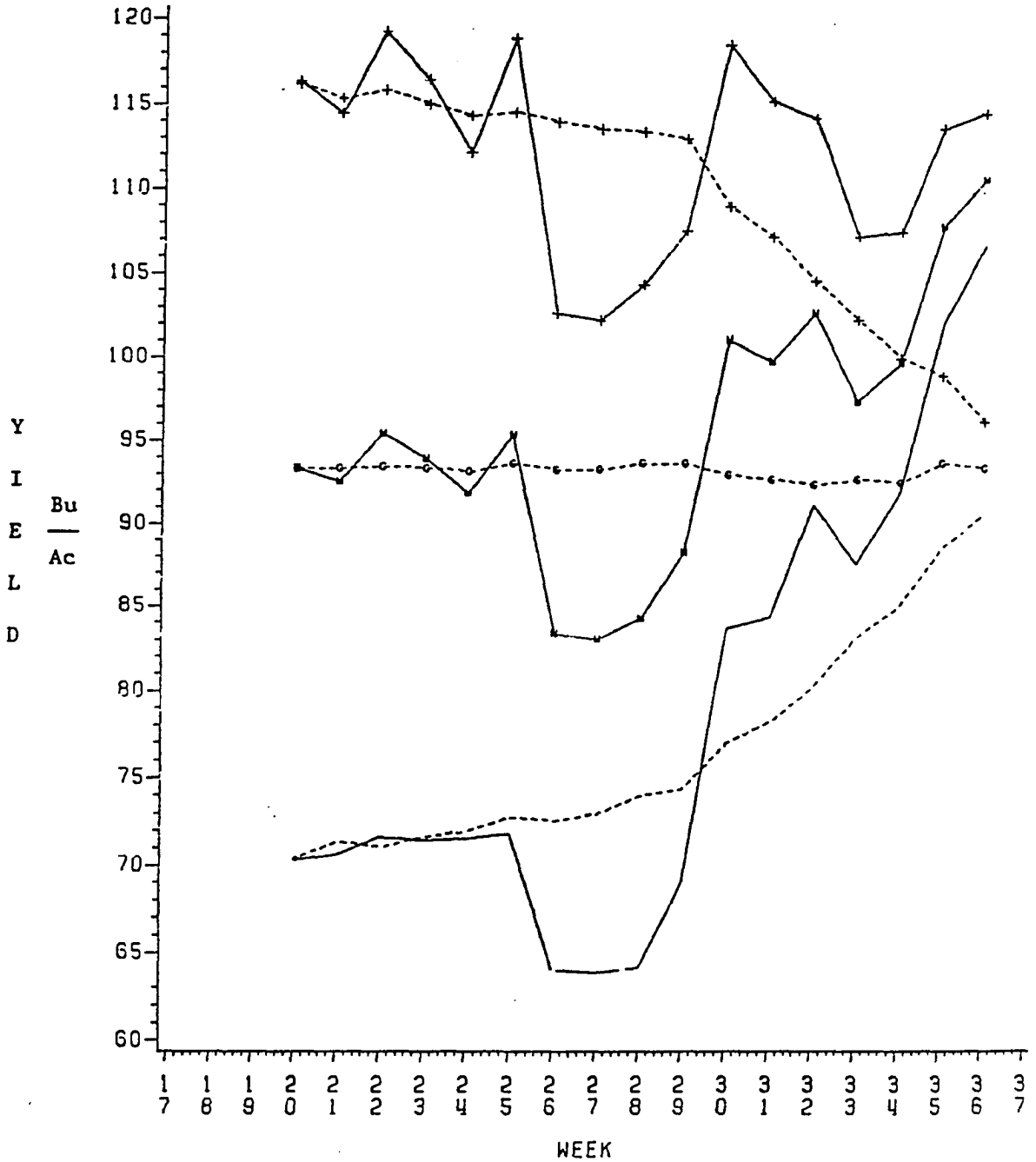
Long-Term and 1957 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1958 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.

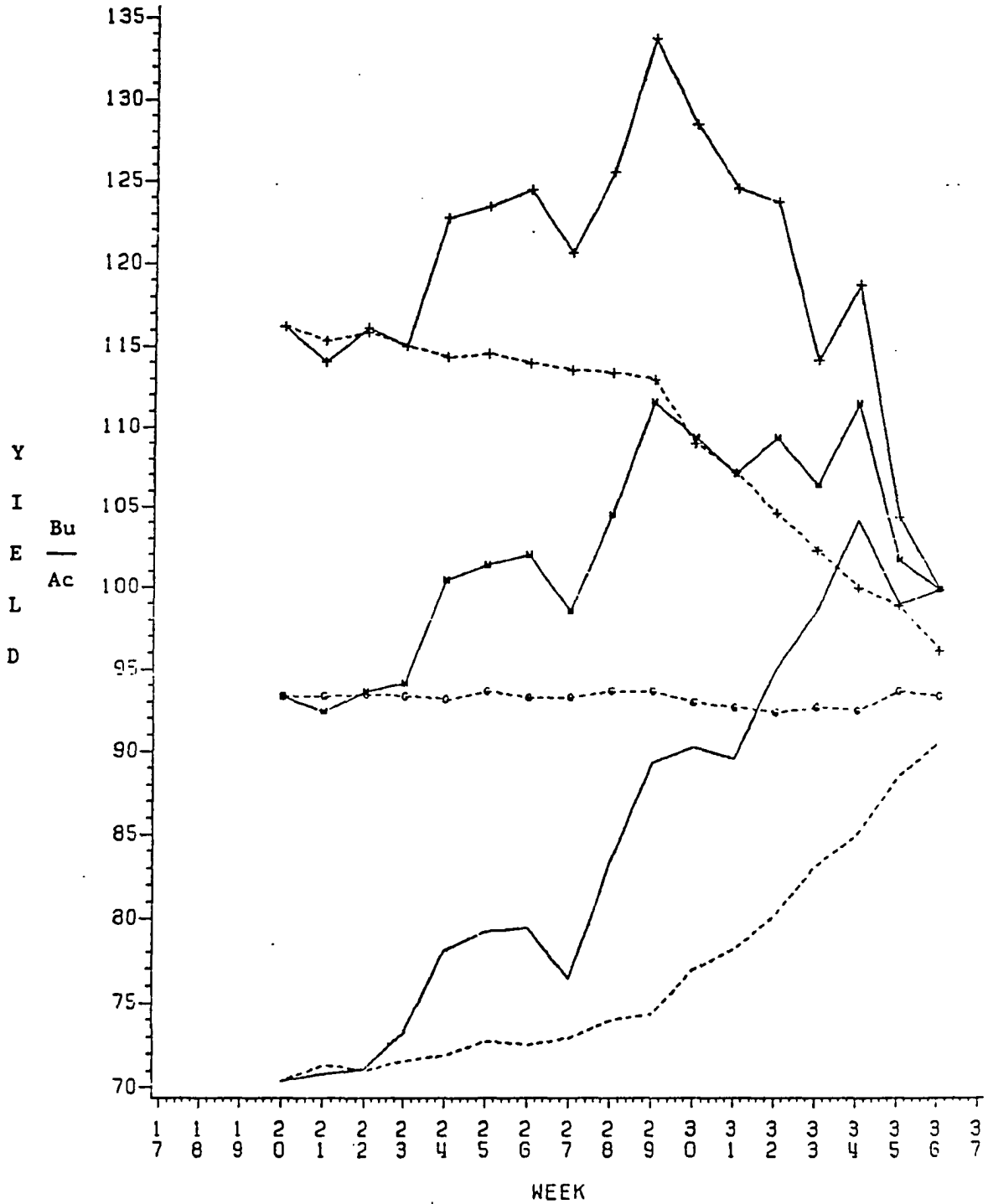


---- +1 Std. Dev. about the Grand Mean -G-G- Grand Weekly Mean -+-+- -1 Std. Dev. about the Grand Mean

+--+- +1 Std. Dev. about the 1958 Mean -M-M-M- 1958 Weekly Mean _____ -1 Std. Dev. about the 1958 Mean

Long-Term and 1959 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

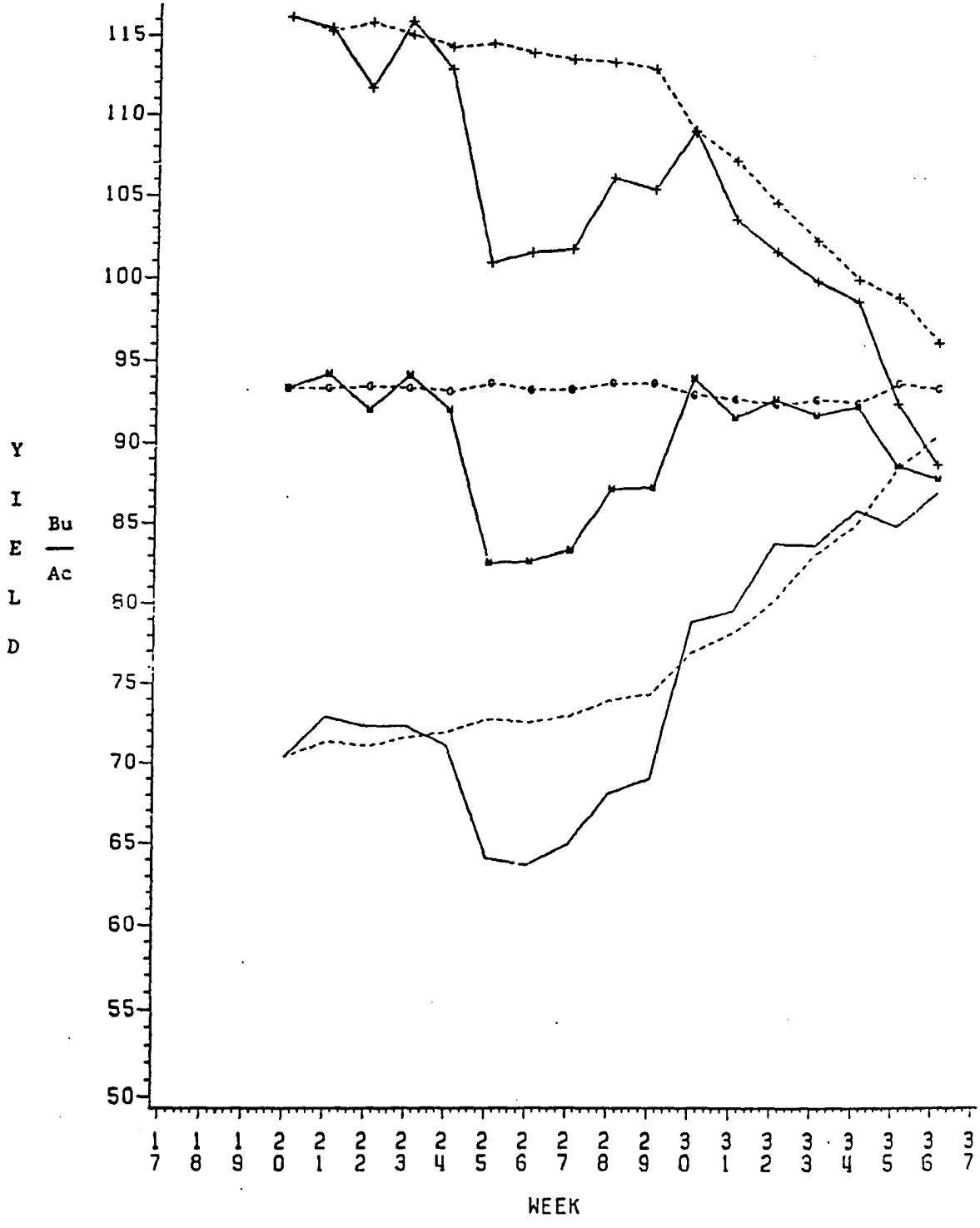
+-+- +1 Std. Dev. about the 1959 Mean

-M-M-M- 1959 Weekly Mean

_____ -1 Std. Dev. about the 1959 Mean

Long-Term and 1960 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

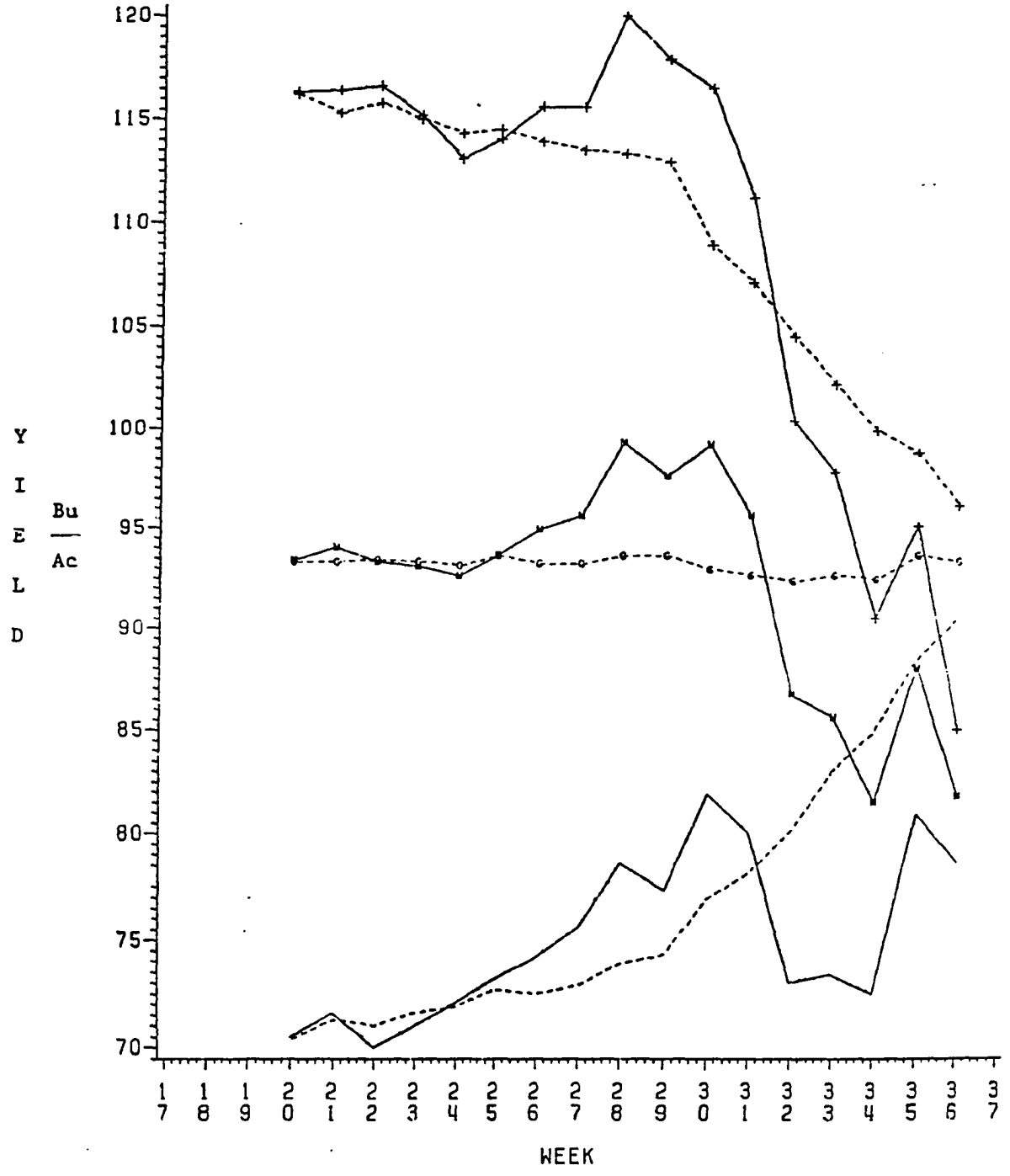
+-+- +1 Std. Dev. about the 1960 Mean

-M-M-M- 1960 Weekly Mean

_____ -1 Std. Dev. about the 1960 Mean

Long-Term and 1961 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

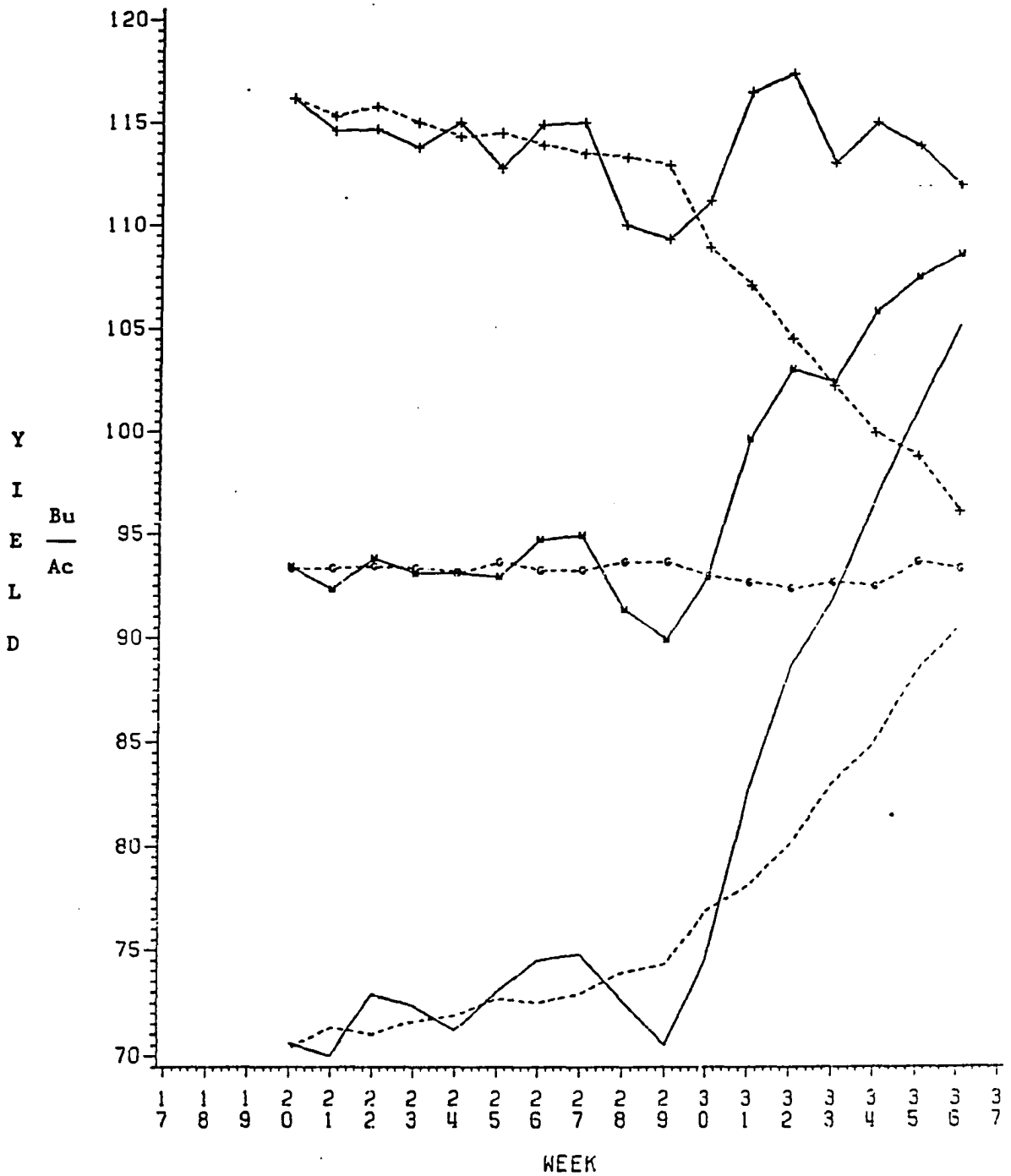
+-+- +1 Std. Dev. about the 1961 Mean

-M-M-M- 1961 Weekly Mean

_____ -1 Std. Dev. about the 1961 Mean

Long-Term and 1962 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

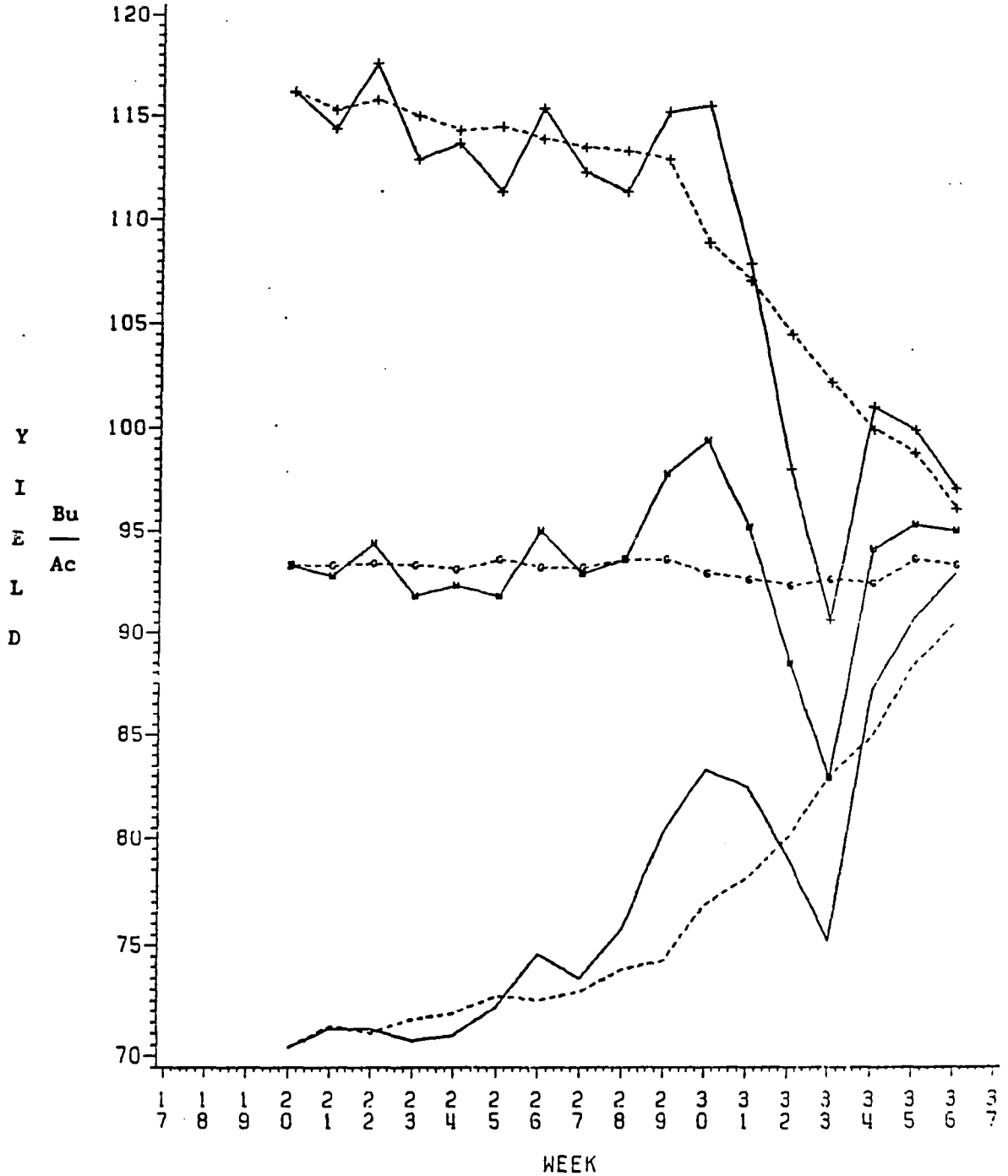
+-+- +1 Std. Dev. about the 1962 Mean

-M-M-M- 1962 Weekly Mean

_____ -1 Std. Dev. about the 1962 Mean

Long-Term and 1963 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.

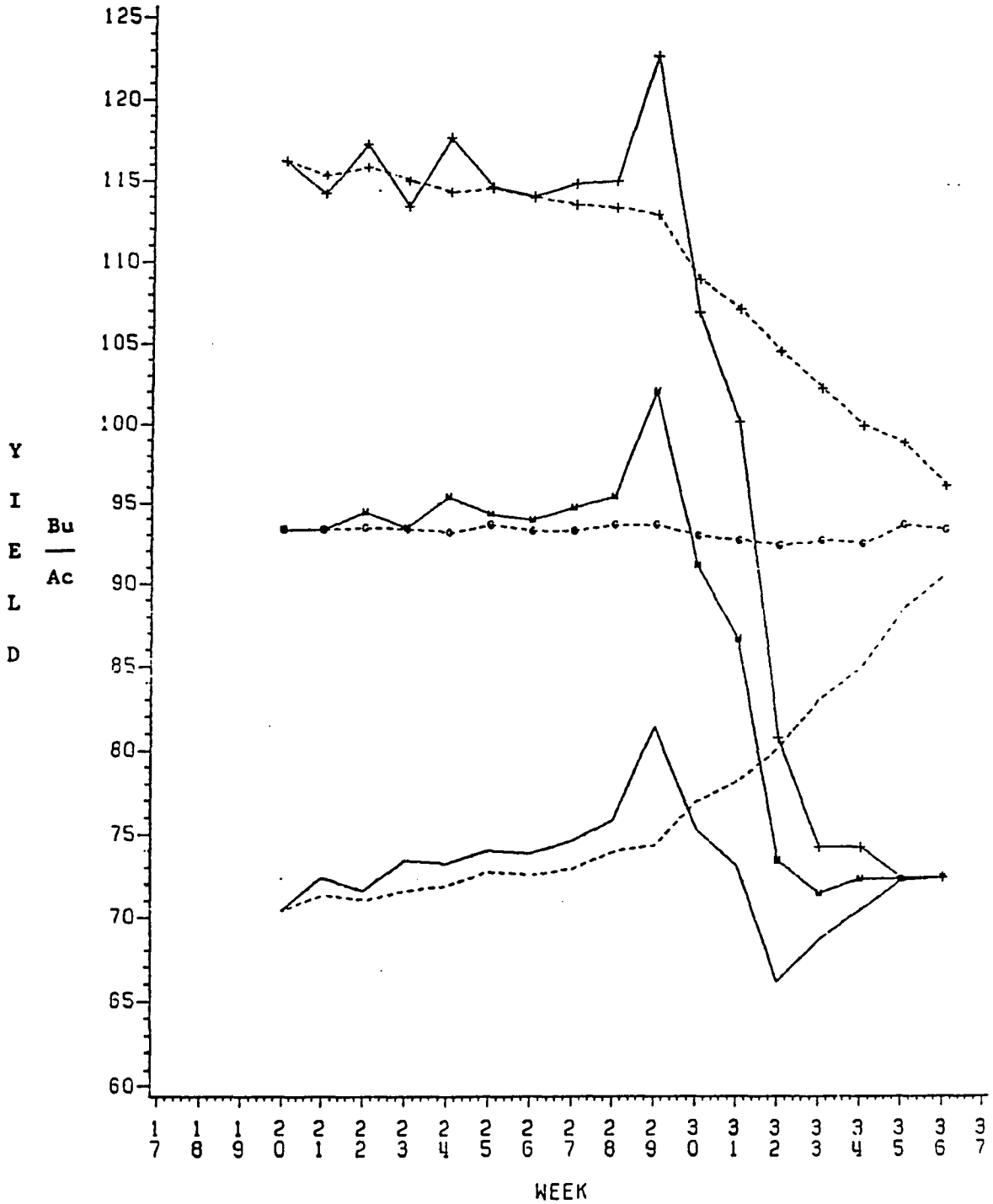


---- +1 Std. Dev. about the Grand Mean -G-G- Grand Weekly Mean -+-+- -1 Std. Dev. about the Grand Mean

+-+- +1 Std. Dev. about the 1963 Mean -M-M-M- 1963 Weekly Mean _____ -1 Std. Dev. about the 1963 Mean

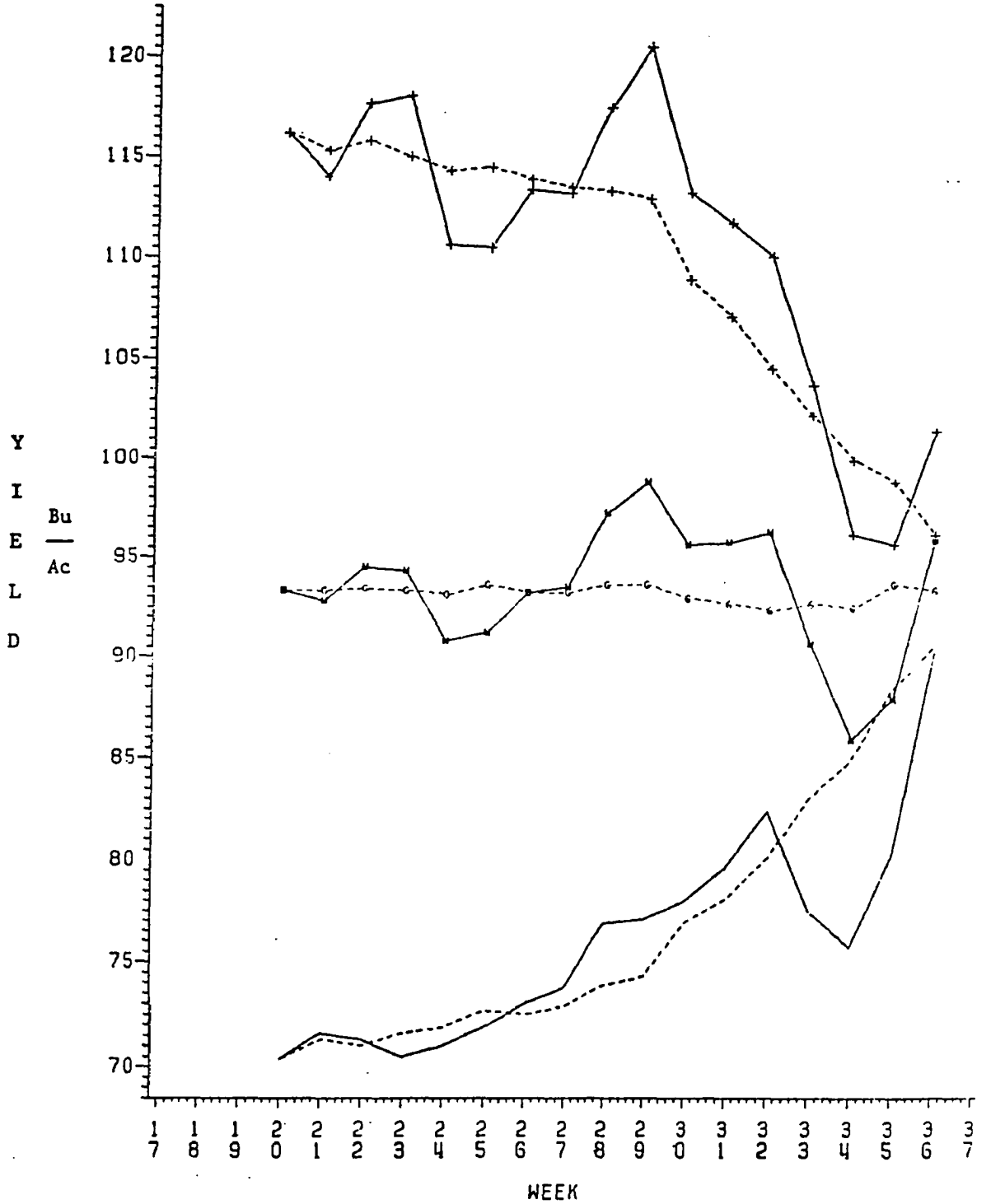
Long-Term and 1964 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1965 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

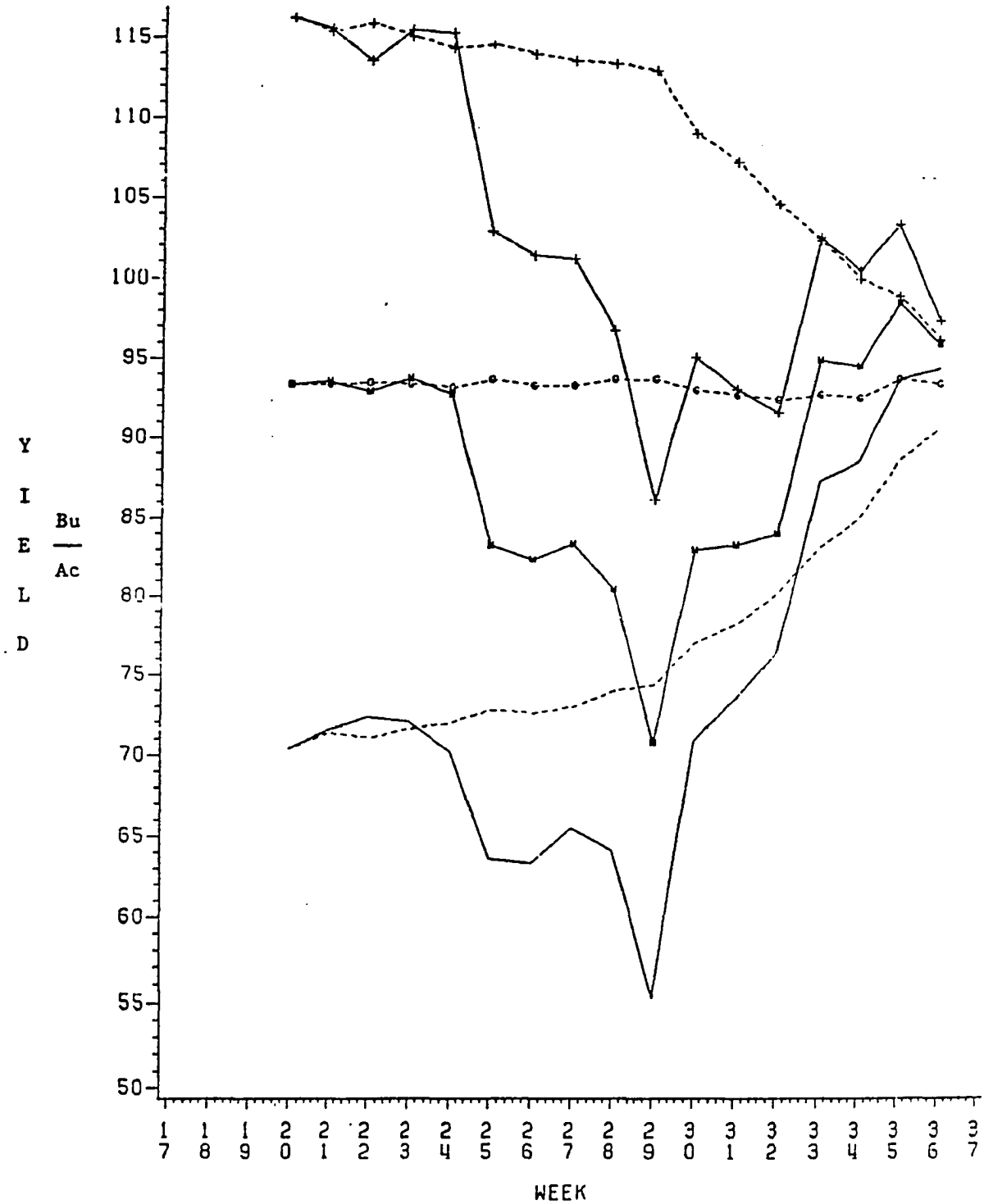
+-+- +1 Std. Dev. about the 1965 Mean

-M-M-M- 1965 Weekly Mean

_____ -1 Std. Dev. about the 1965 Mean

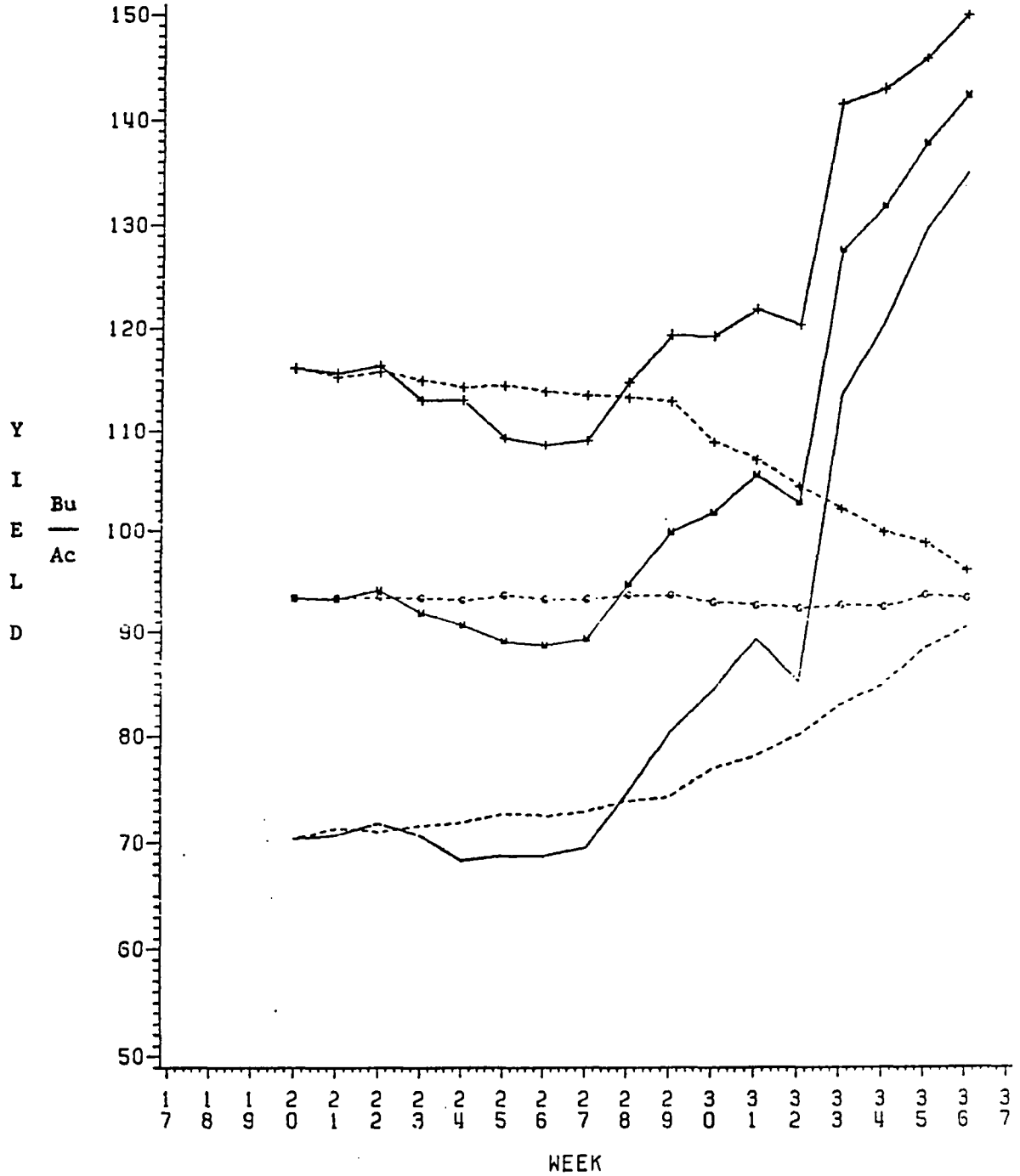
Long-Term and 1966 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1967 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

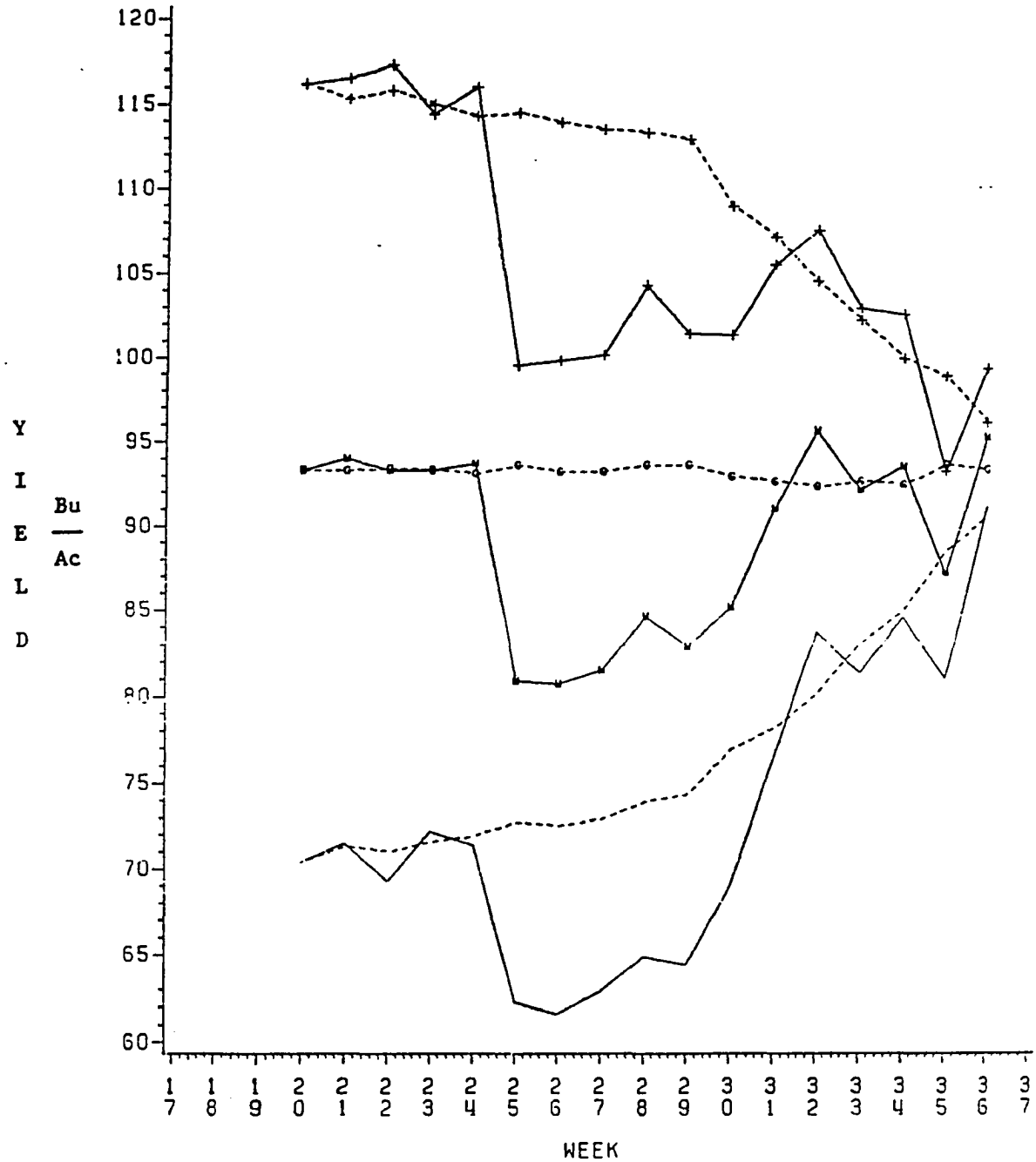
+-+- +1 Std. Dev. about the 1967 Mean

-M-M-M- 1967 Weekly Mean

_____ -1 Std. Dev. about the 1967 Mean

Long-Term and 1968 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

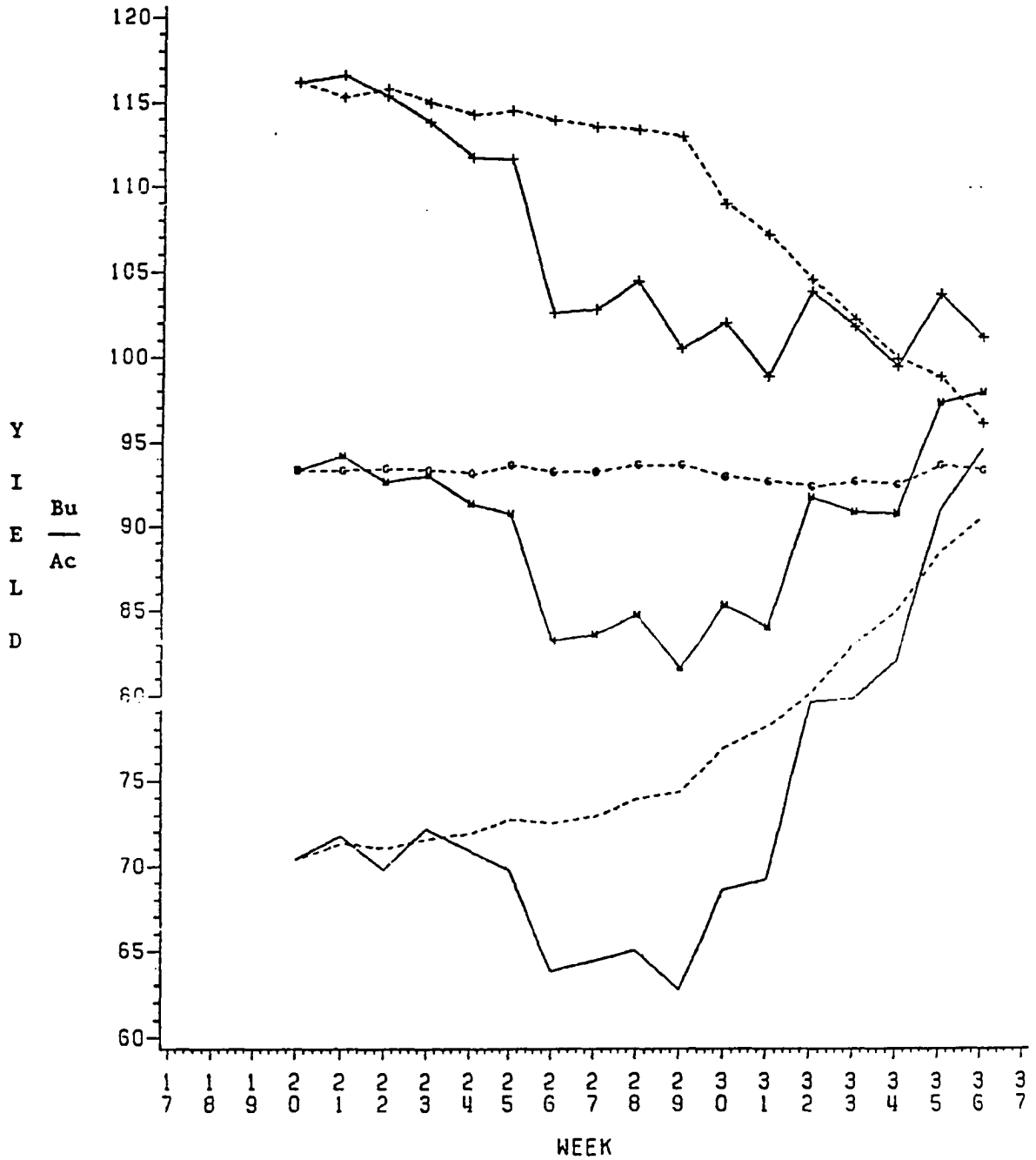
+-+- +1 Std. Dev. about the 1968 Mean

-M-M-M- 1968 Weekly Mean

_____ -1 Std. Dev. about the 1968 Mean

Long-Term and 1969 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

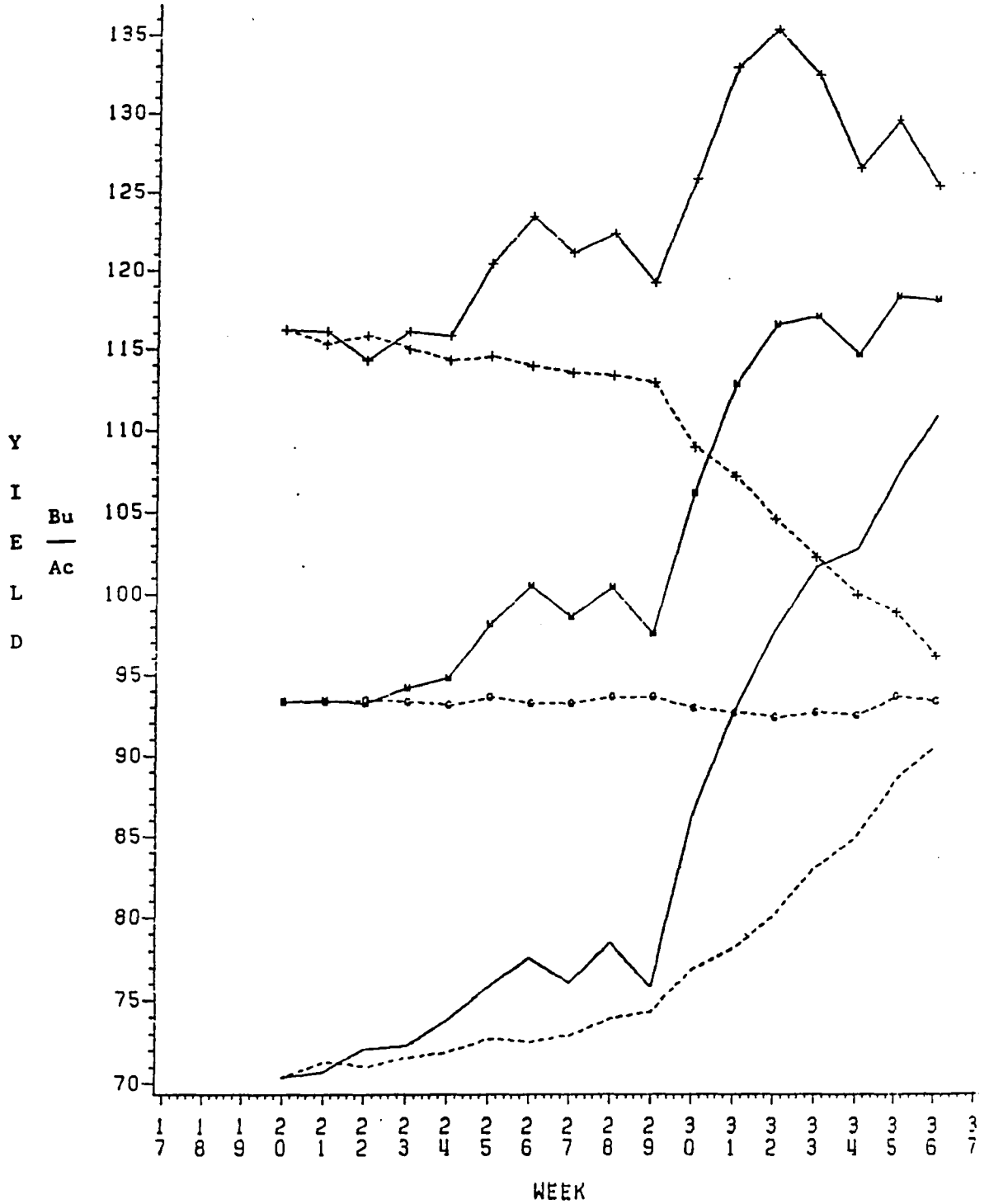
+-+- +1 Std. Dev. about the 1969 Mean

-M-M-M- 1969 Weekly Mean

_____ -1 Std. Dev. about the 1969 Mean

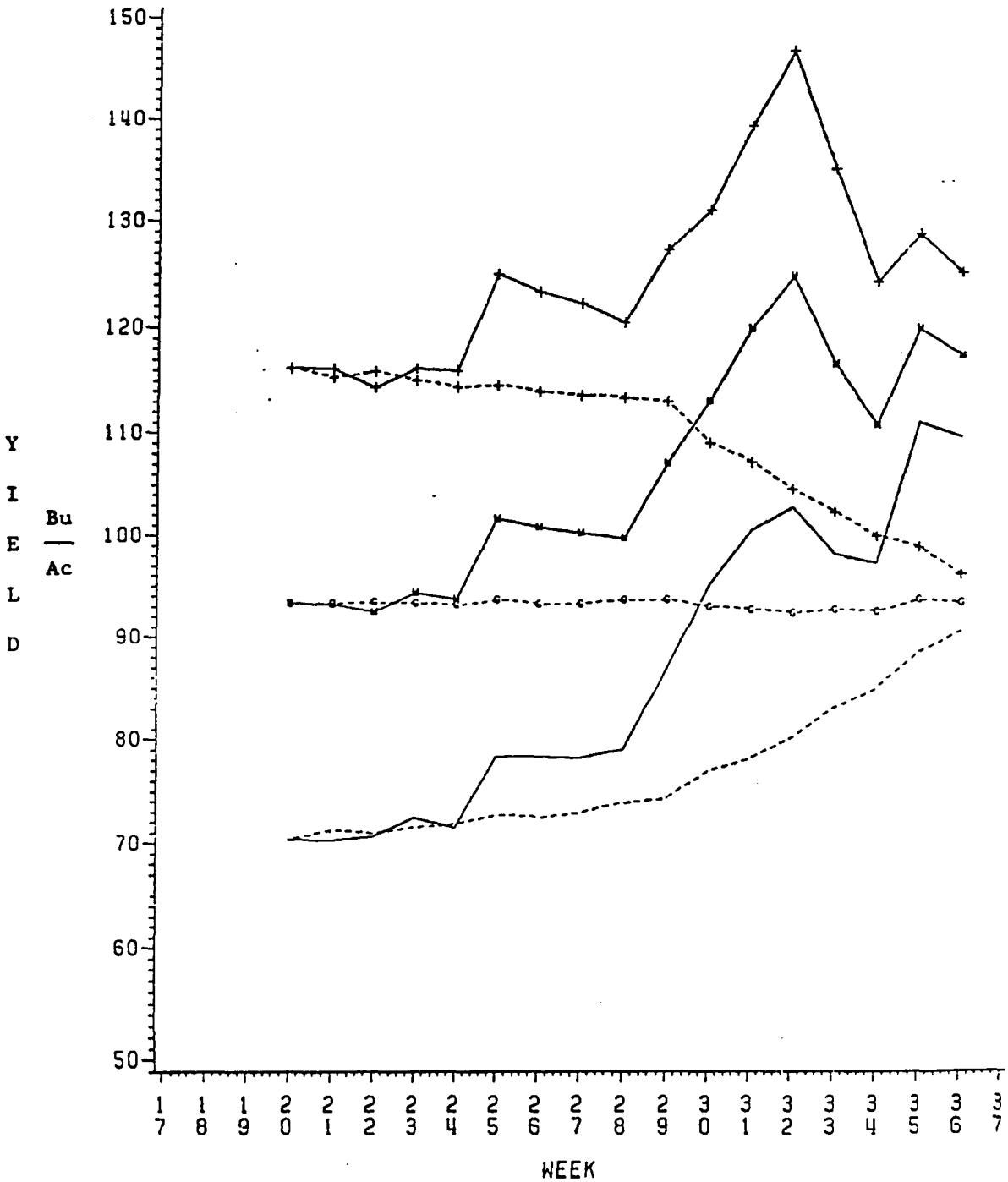
Long-Term and 1970 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1971 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

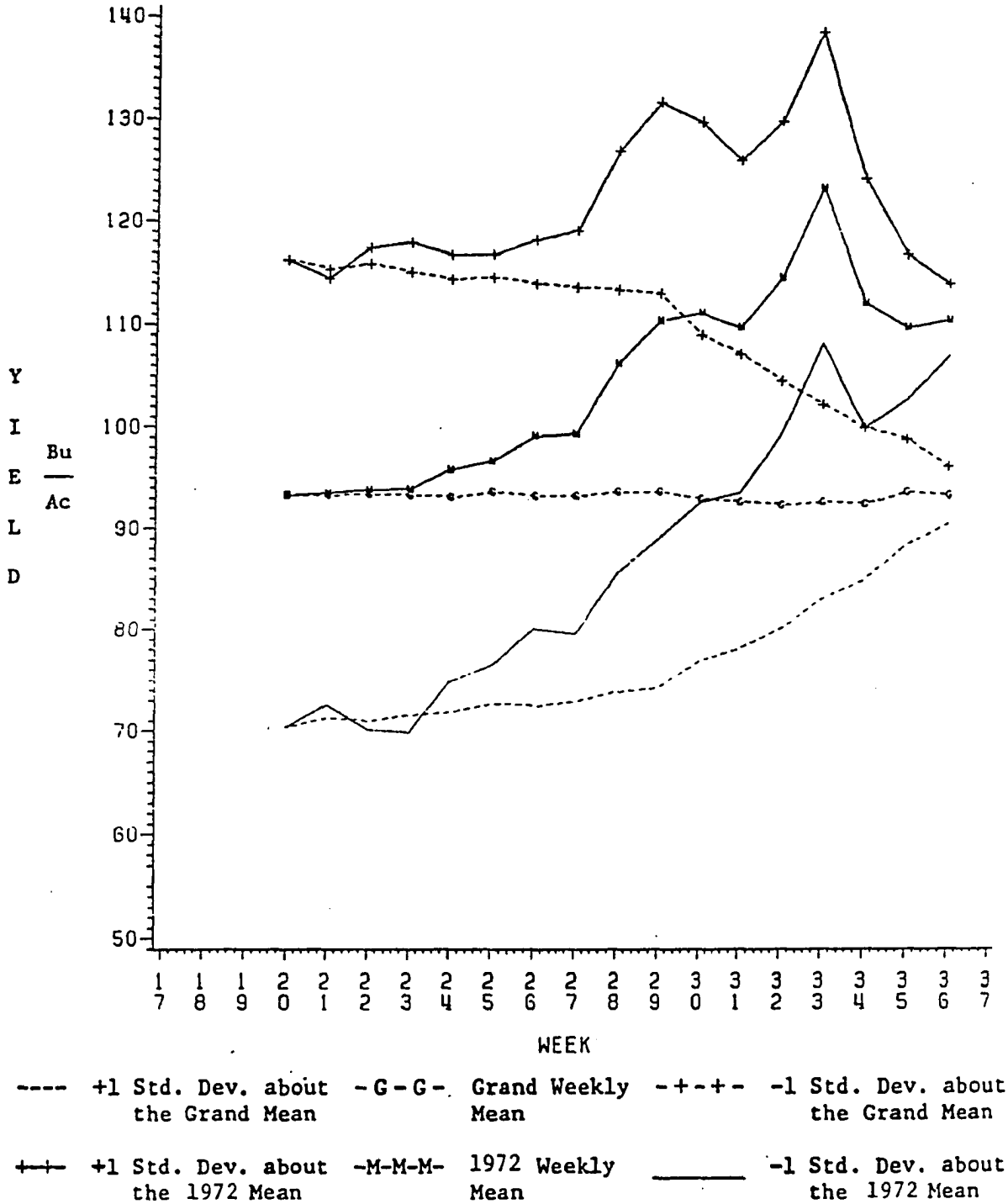
+-+- +1 Std. Dev. about the 1971 Mean

-M-M-M- 1971 Weekly Mean

_____ -1 Std. Dev. about the 1971 Mean

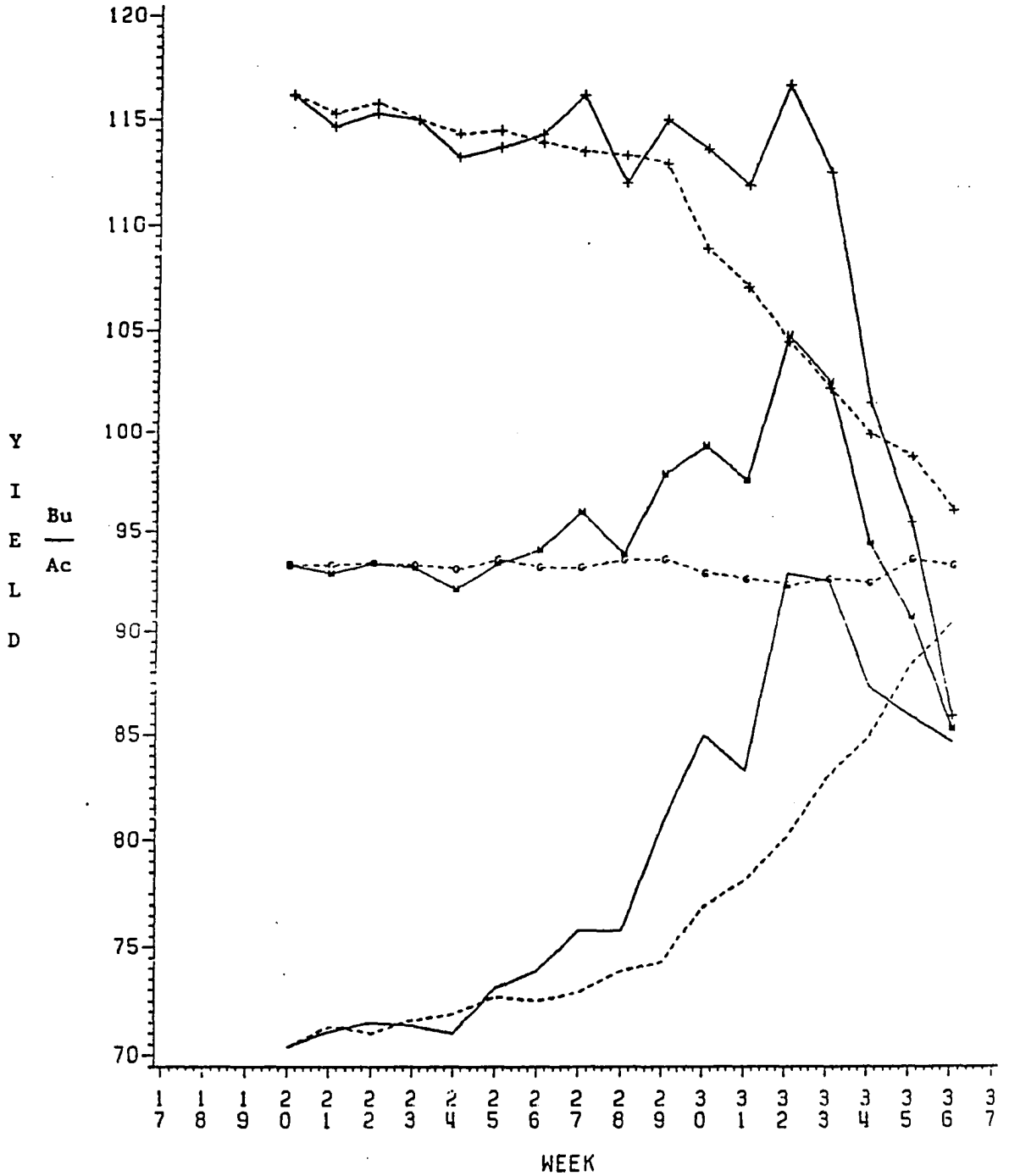
Long-Term and 1972 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1973 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

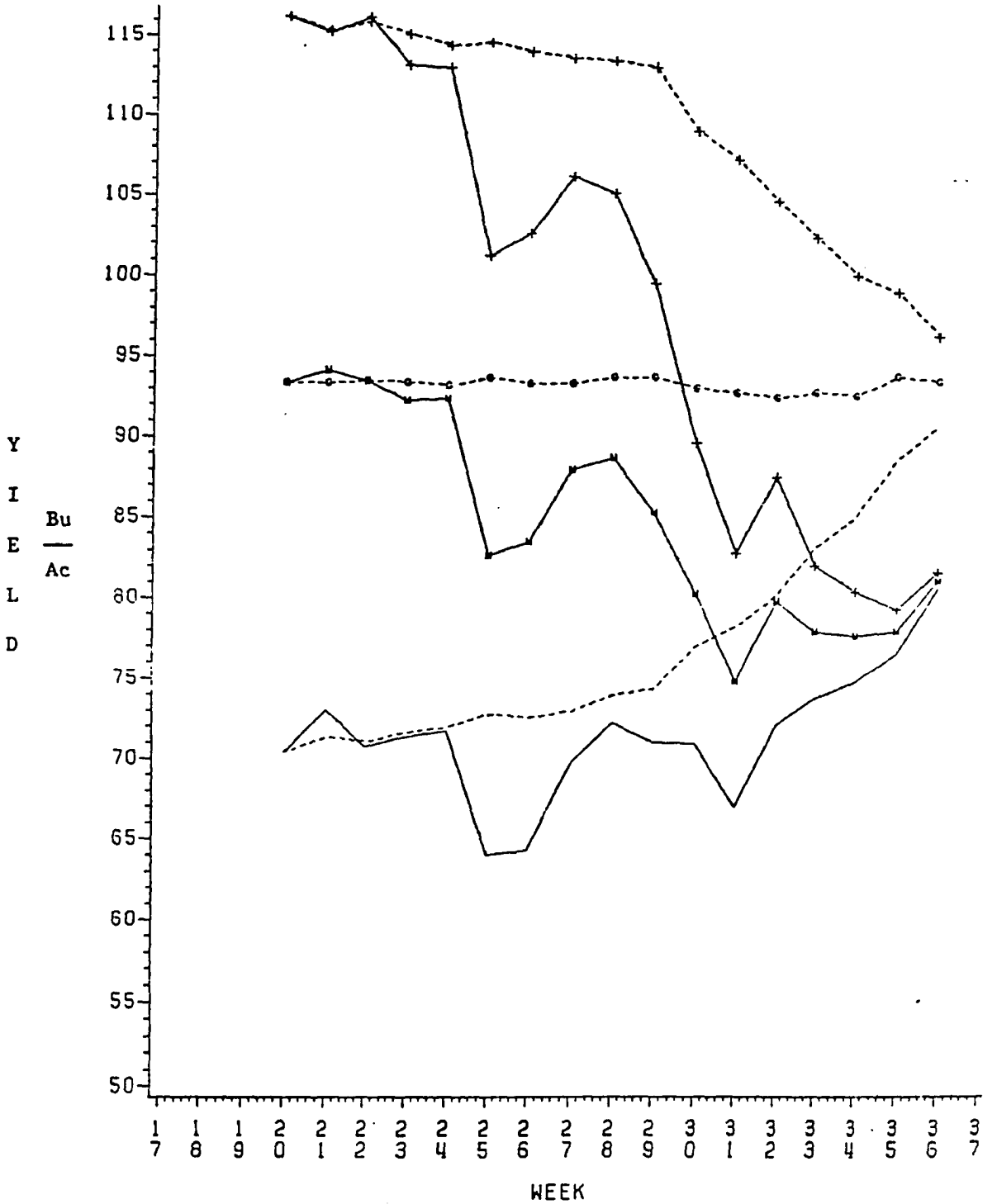
+-+- +1 Std. Dev. about the 1973 Mean

-M-M-M- 1973 Weekly Mean

_____ -1 Std. Dev. about the 1973 Mean

Long-Term and 1974 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

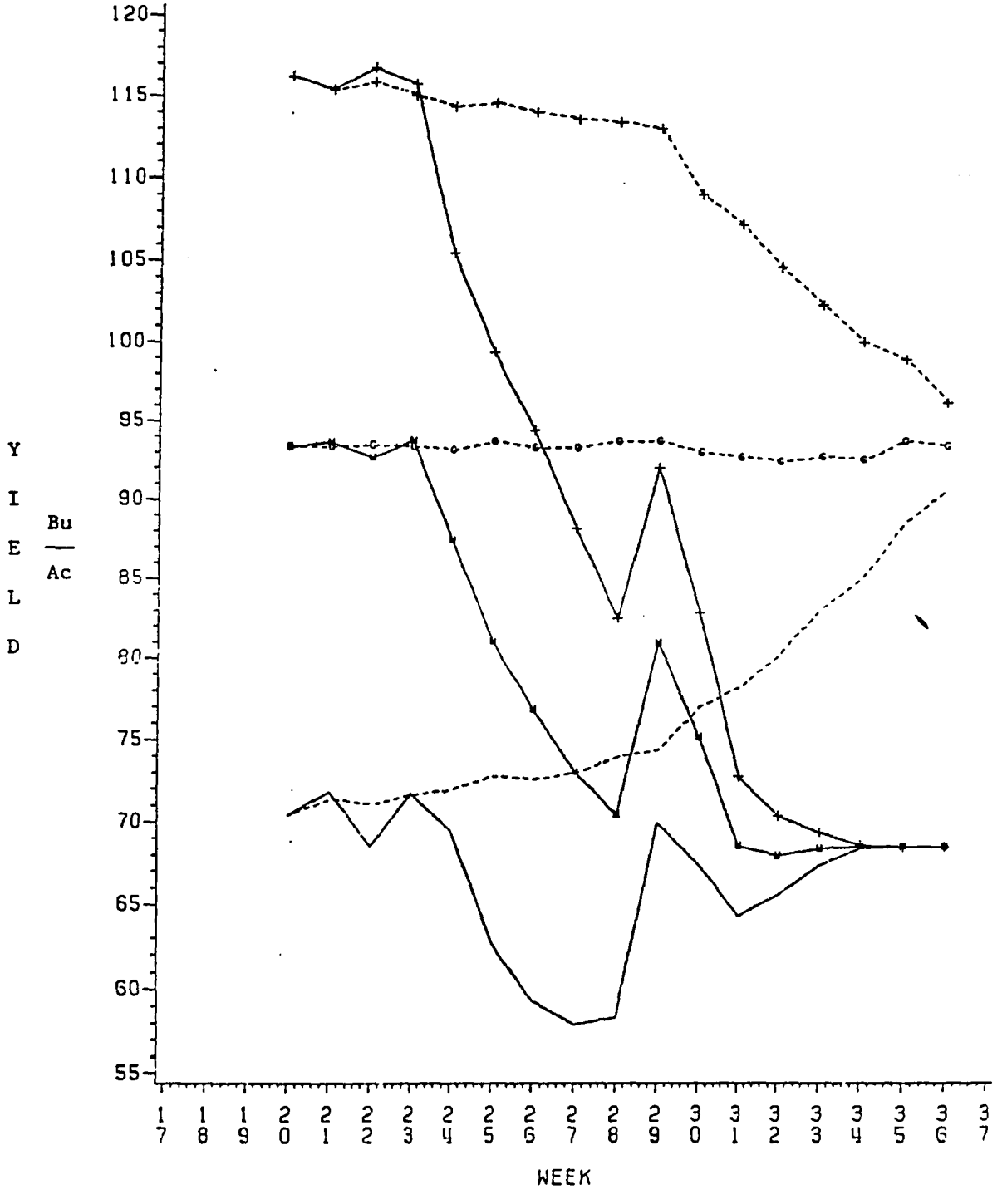
+-+- +1 Std. Dev. about the 1974 Mean

-M-M-M- 1974 Weekly Mean

_____ -1 Std. Dev. about the 1974 Mean

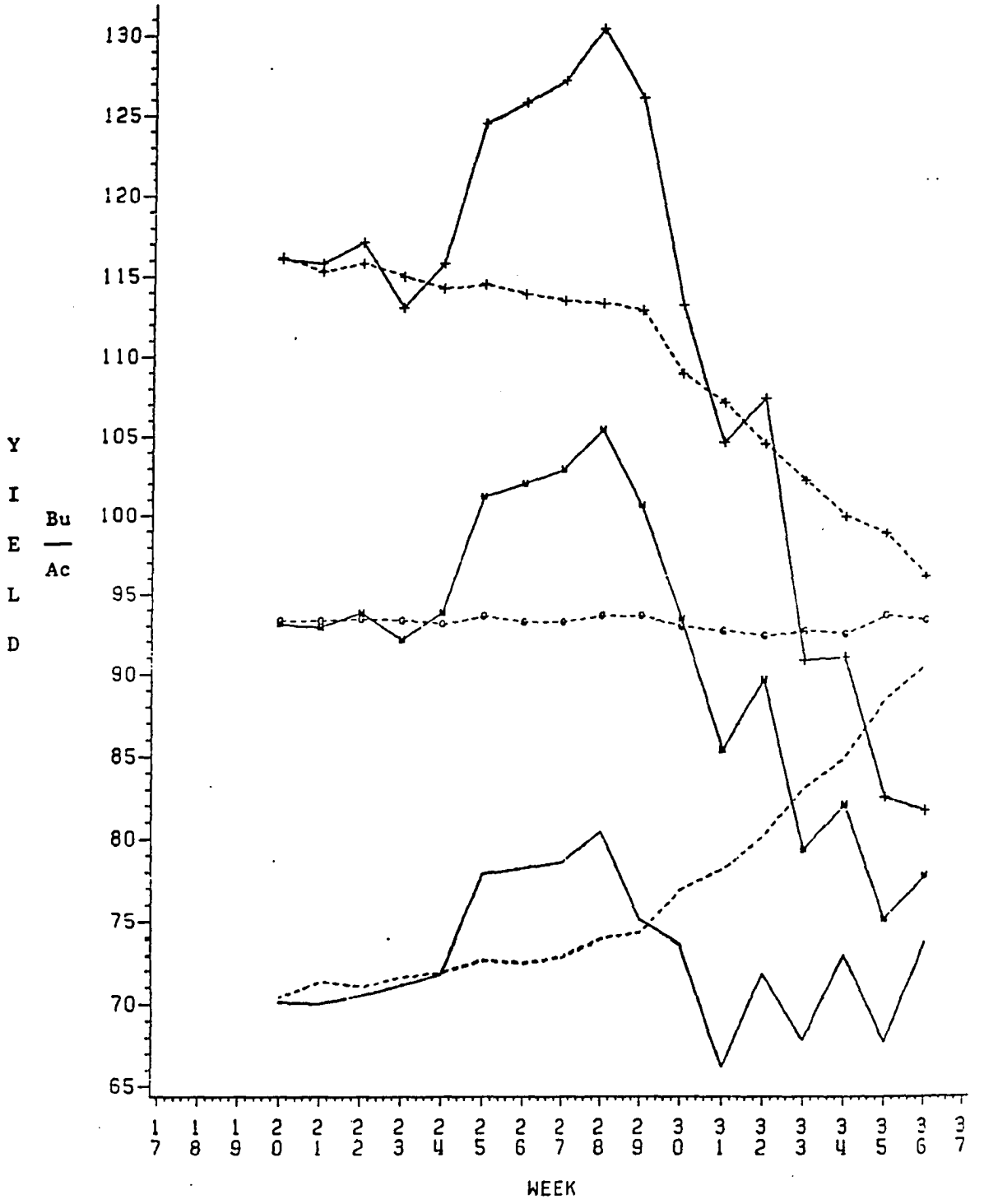
Long-Term and 1975 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



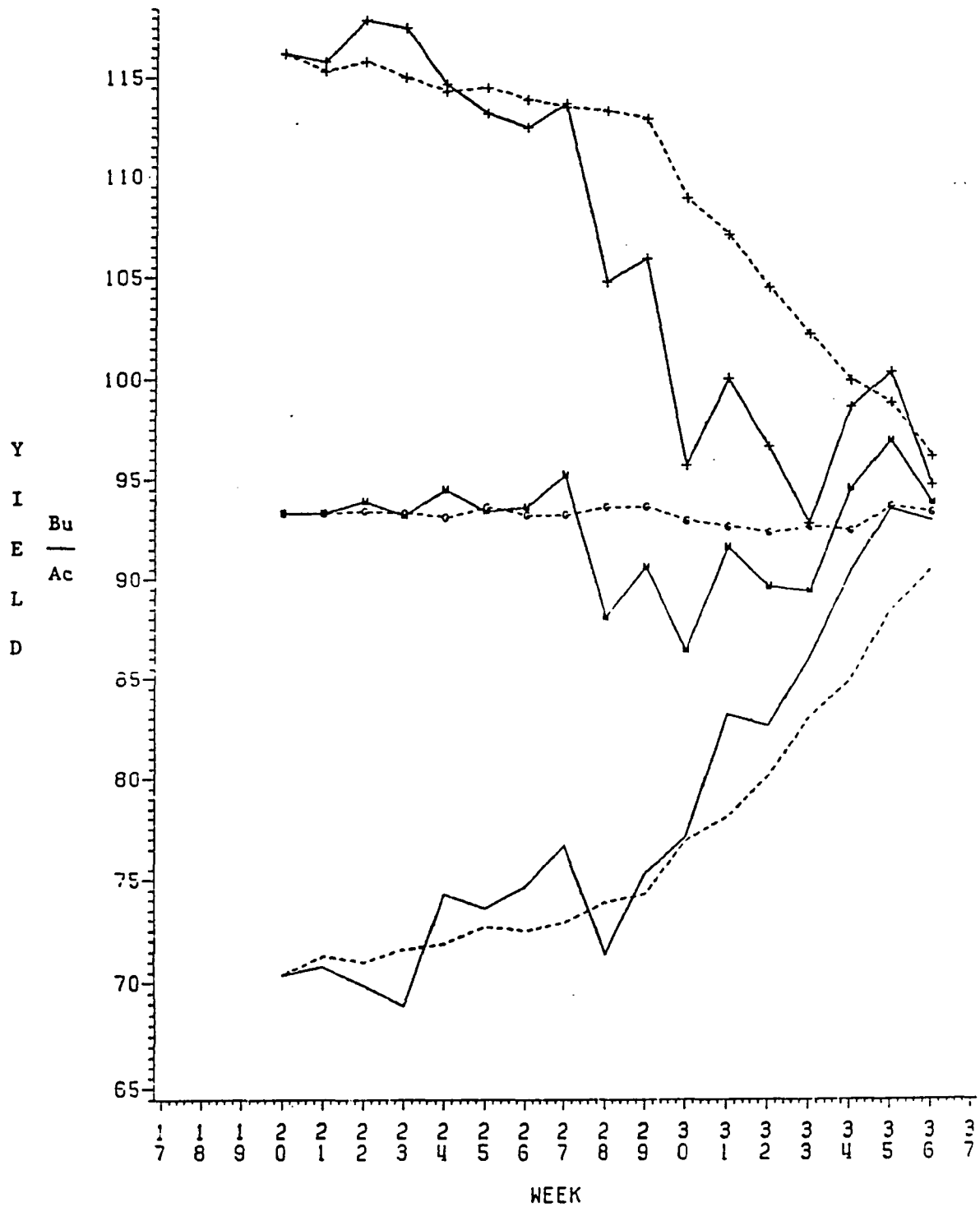
Long-Term and 1976 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1977 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

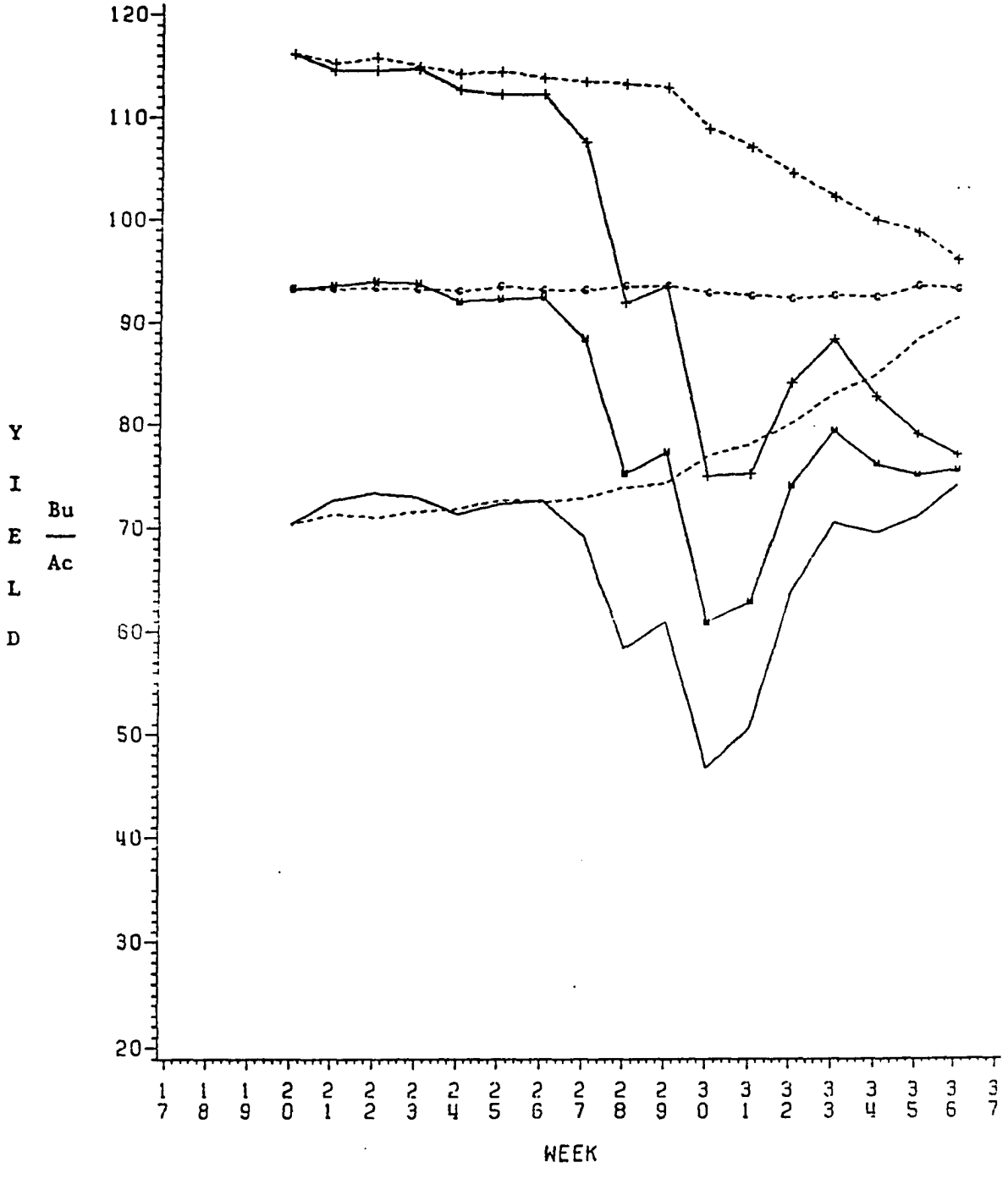
+-+- +1 Std. Dev. about the 1977 Mean

-M-M-M- 1977 Weekly Mean

_____ -1 Std. Dev. about the 1977 Mean

Long-Term and 1978 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

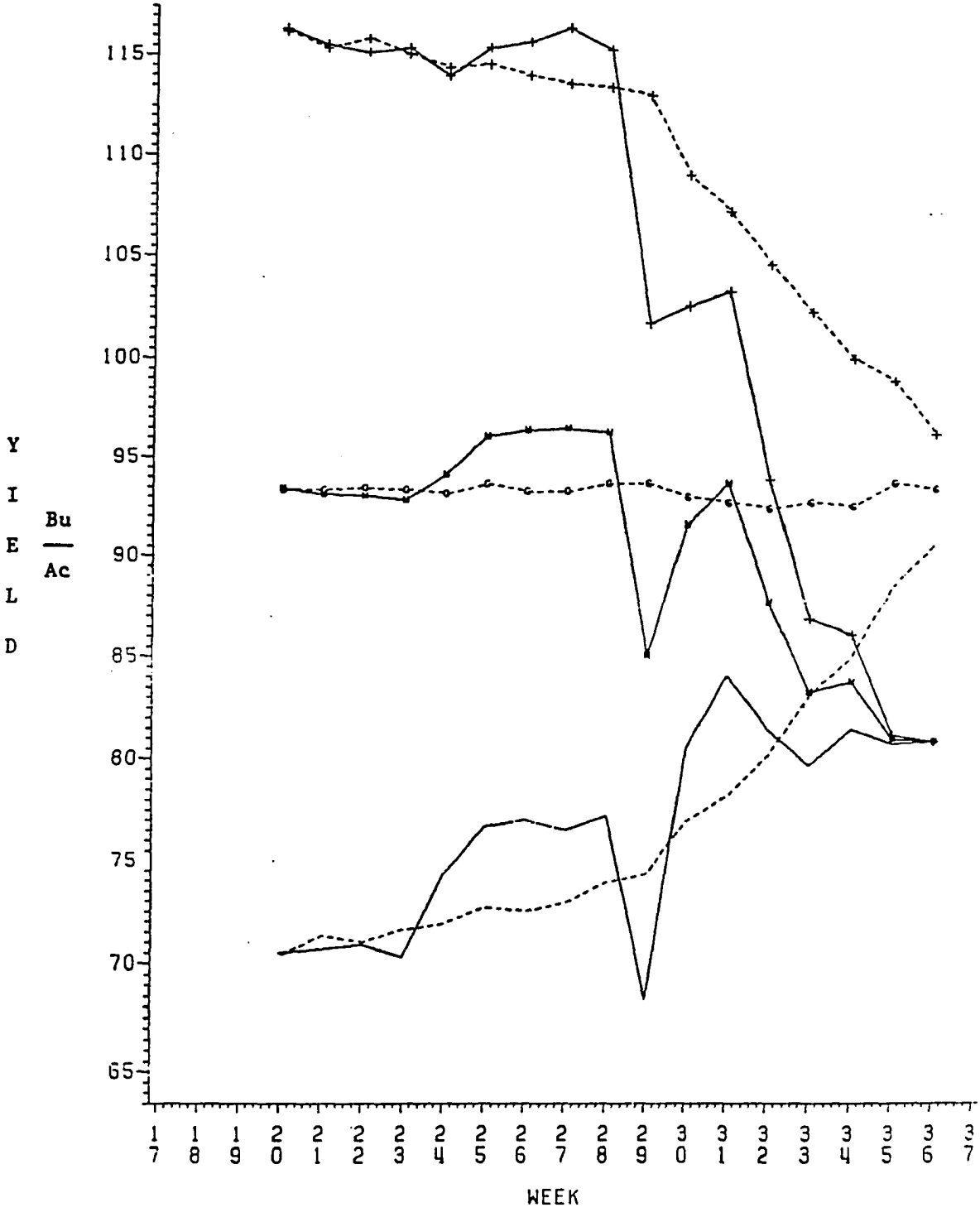
+-+- +1 Std. Dev. about the 1978 Mean

-M-M-M- 1978 Weekly Mean

_____ -1 Std. Dev. about the 1978 Mean

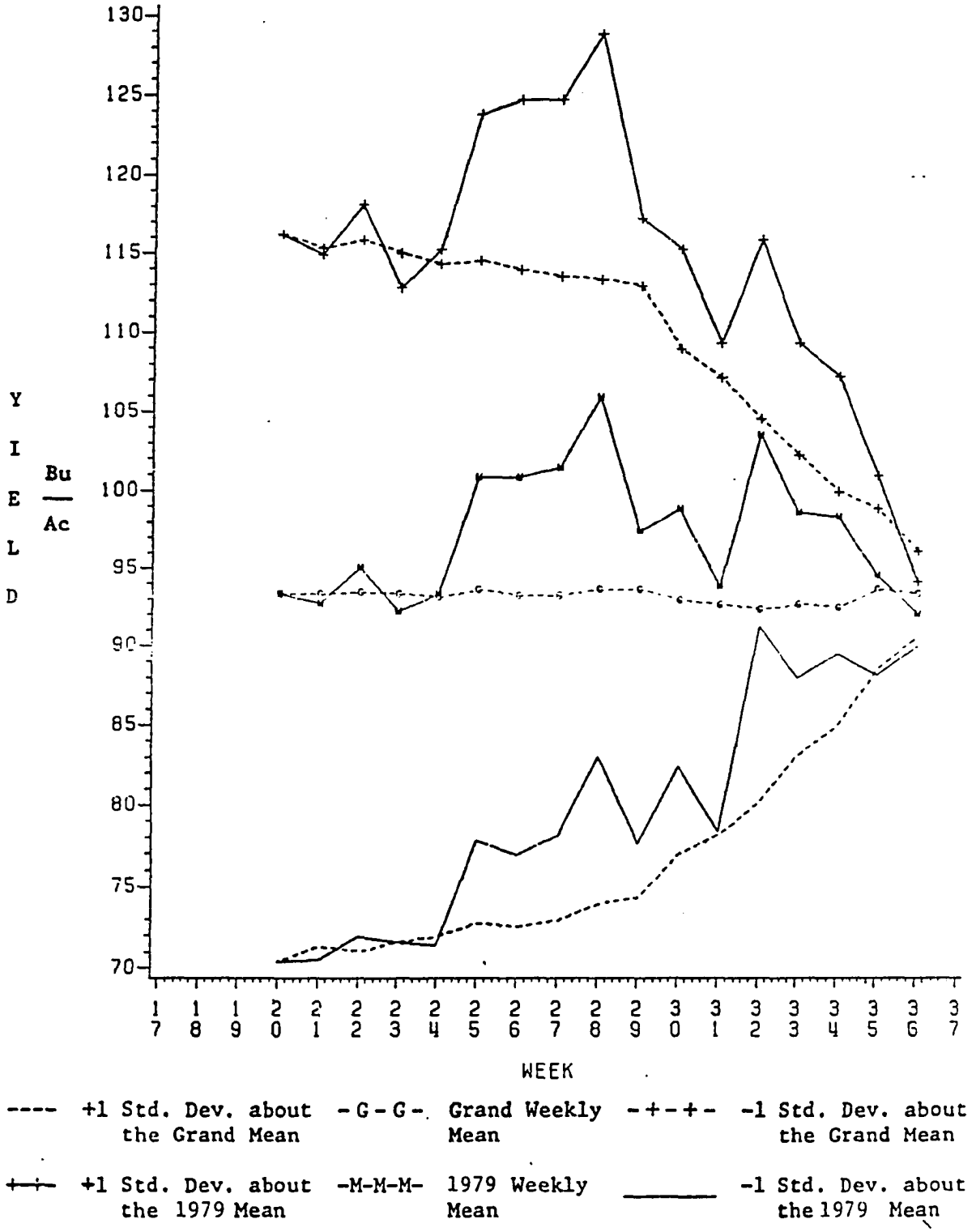
Long-Term and 1980 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



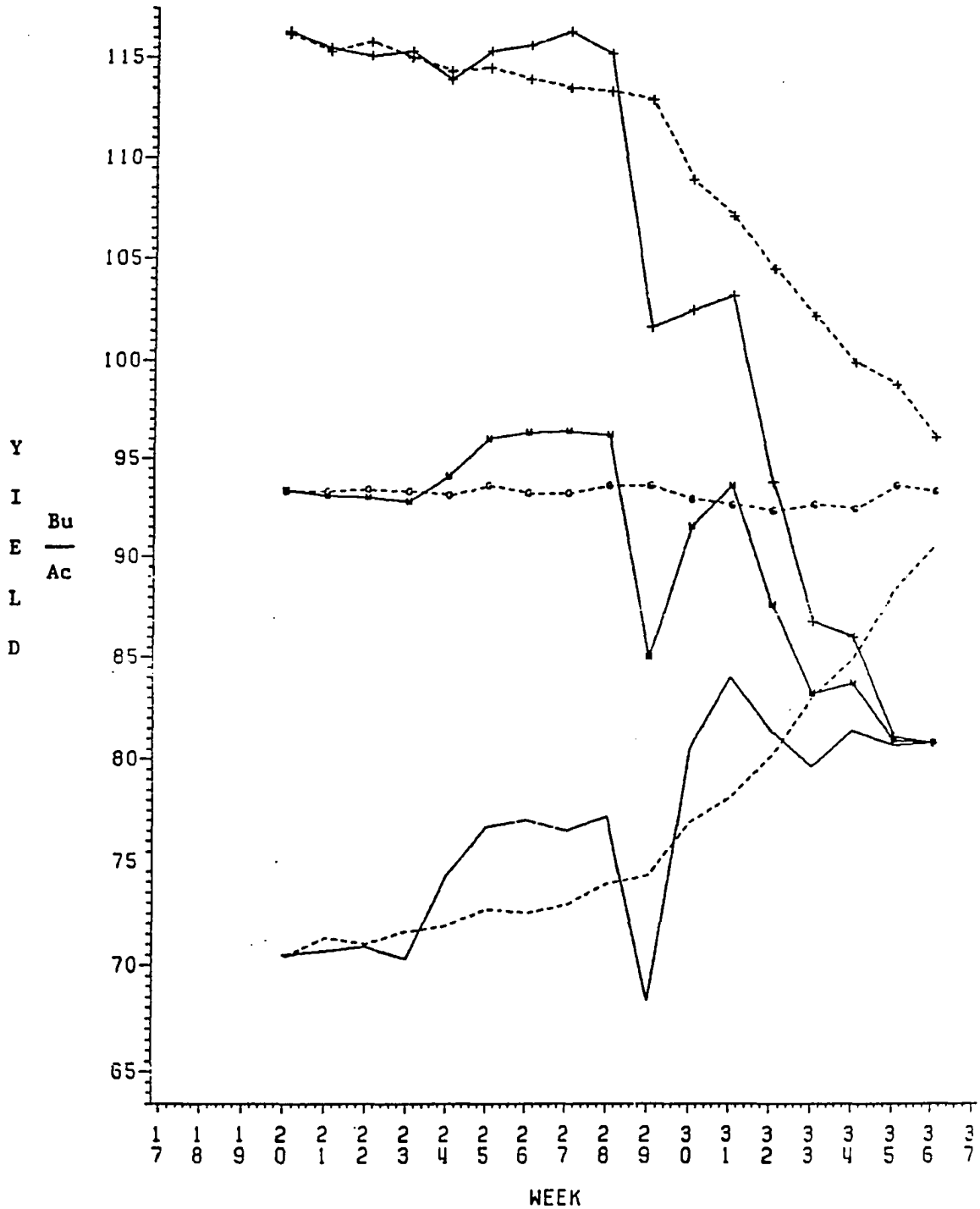
Long-Term and 1979 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



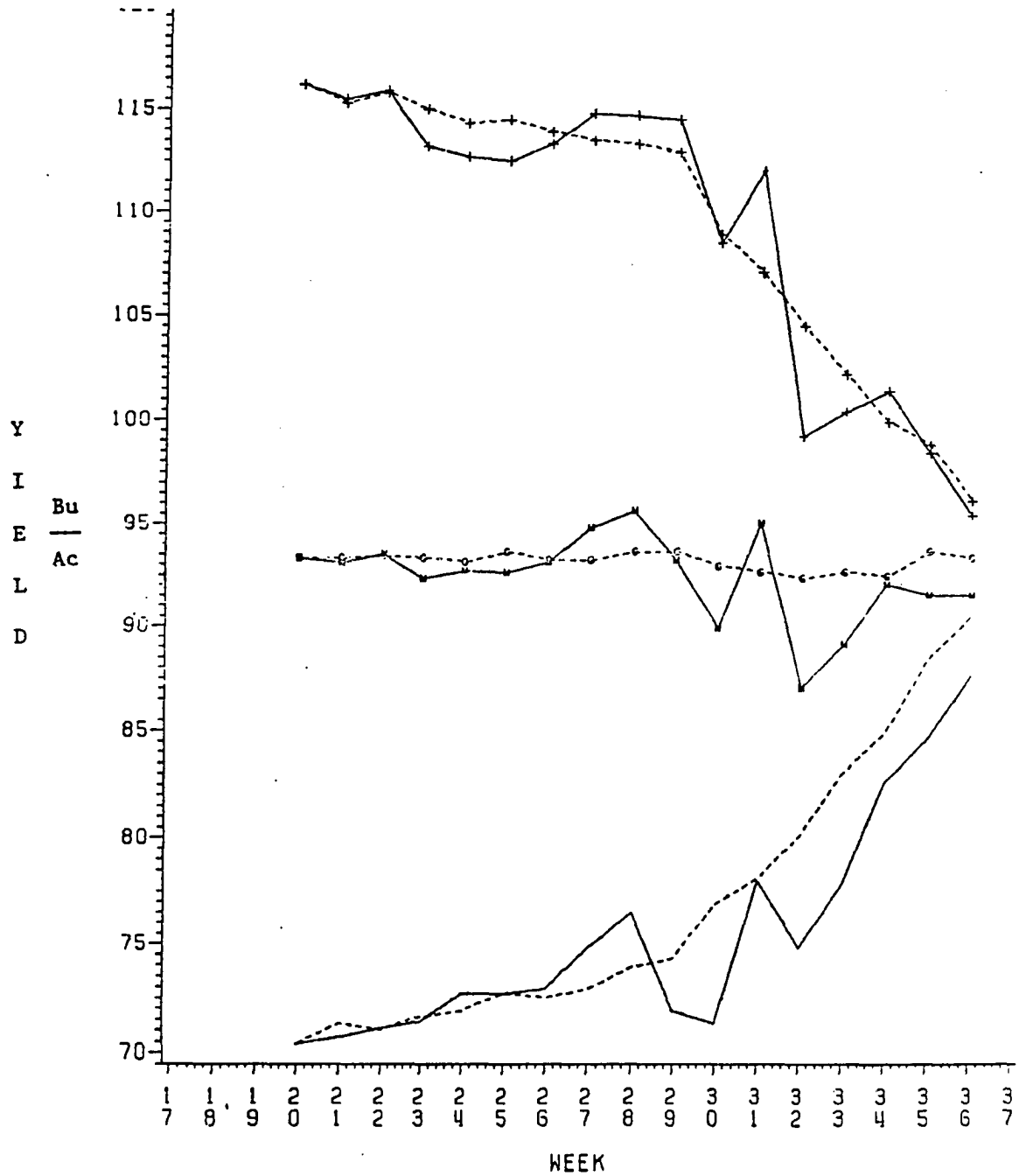
Long-Term and 1980 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



Long-Term and 1981 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

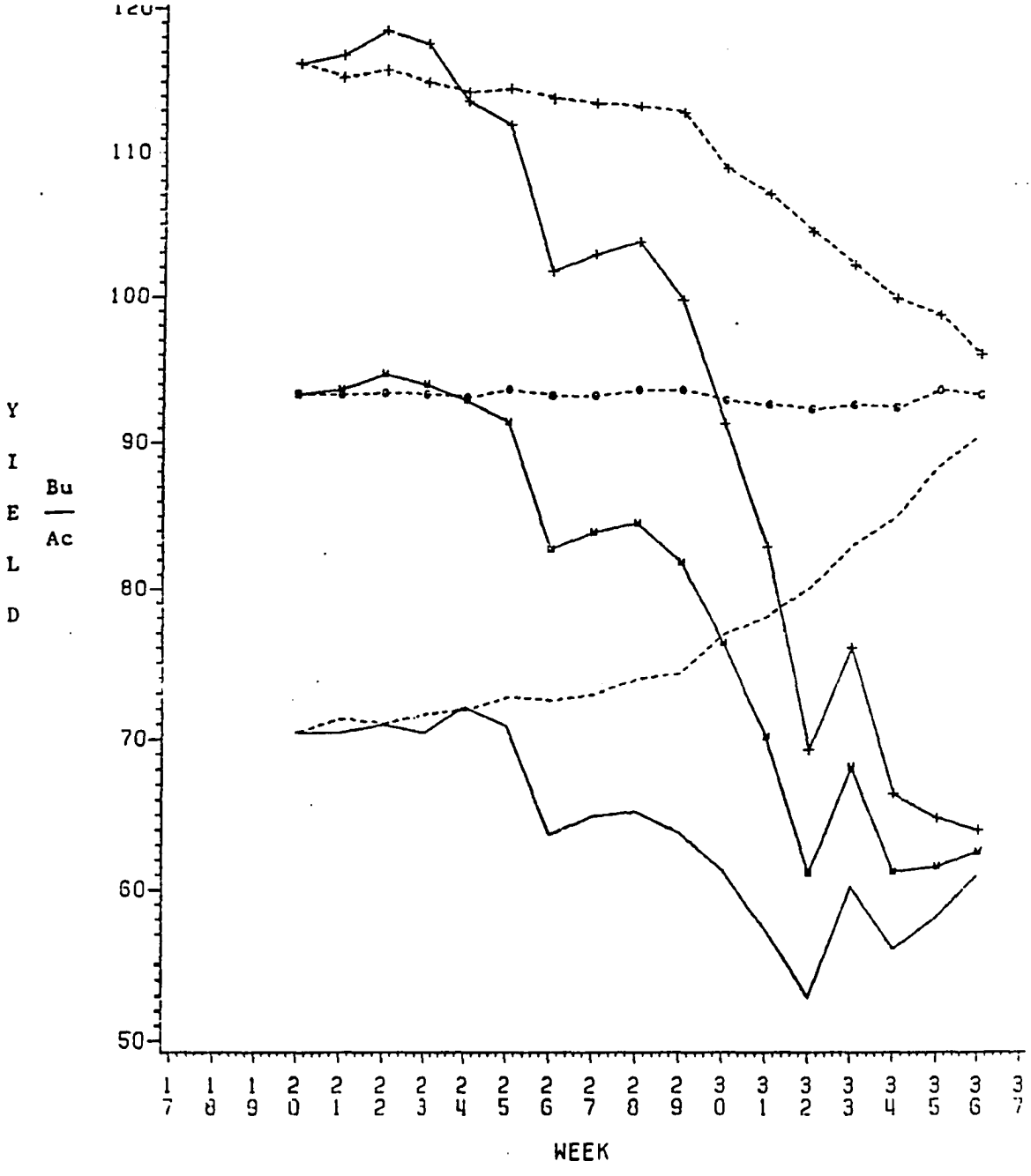
+-+- +1 Std. Dev. about the 1981 Mean

-M-M-M- 1981 Weekly Mean

_____ -1 Std. Dev. about the 1981 Mean

Long-Term and 1982 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

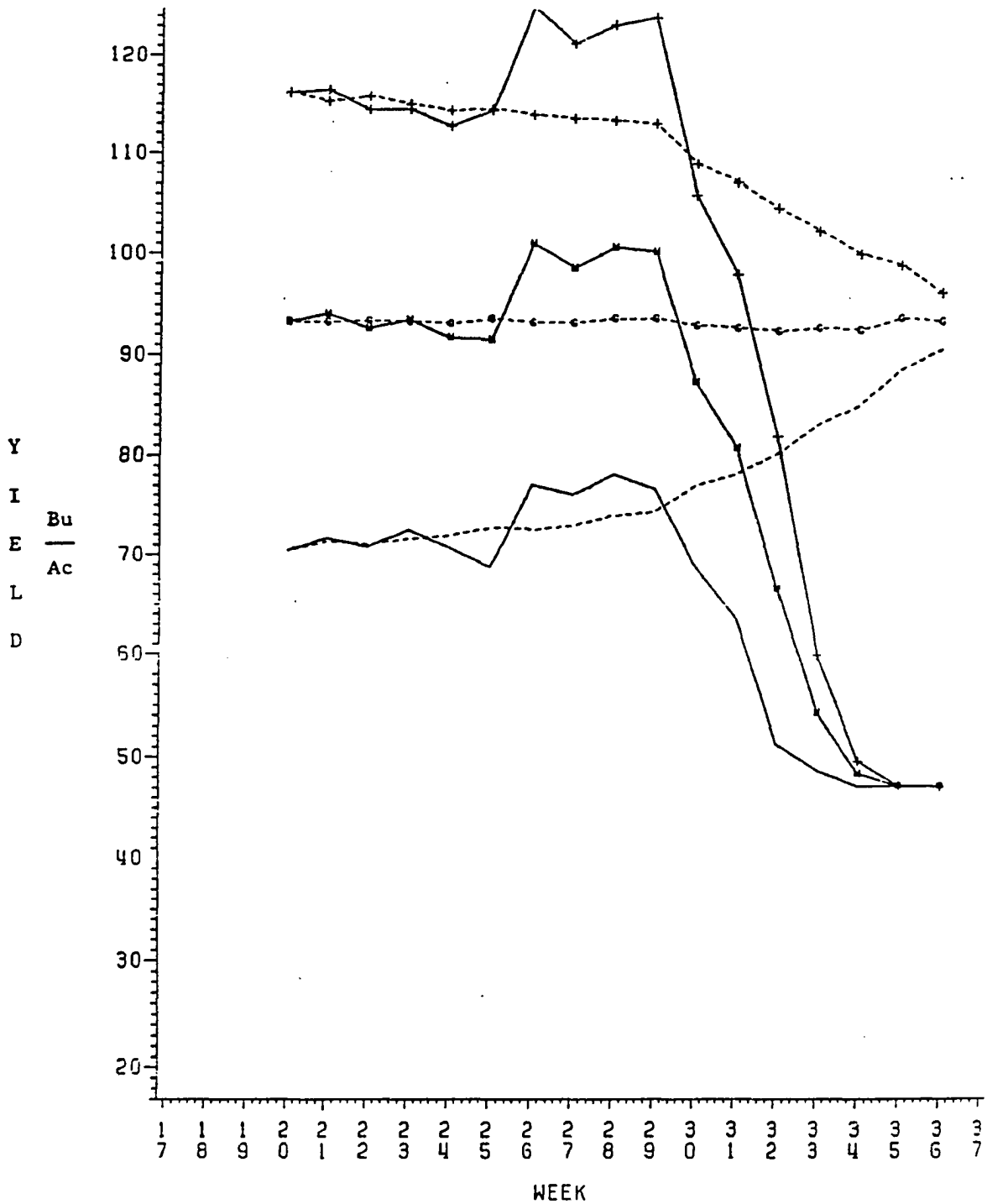
+-+- +1 Std. Dev. about the 1982 Mean

-M-M-M- 1982 Weekly Mean

_____ -1 Std. Dev. about the 1982 Mean

Long-Term and 1983 Weekly Mean and Following Weather

Modeled Yield Variability at Rochester, MN.



---- +1 Std. Dev. about the Grand Mean

-G-G- Grand Weekly Mean

-+-+- -1 Std. Dev. about the Grand Mean

+-+- +1 Std. Dev. about the 1983 Mean

-M-M-M- 1983 Weekly Mean

_____ -1 Std. Dev. about the 1983 Mean

Appendix G

PHYSICAL DESCRIPTION OF NBSLD STRUCTURE.

DEFINITIONS

L: Thickness of the layer, ft.

K: Thermal Conductivity of the layer, Btuh per (hr) (ft^2) (^oF).

P: Density of the layer material, lb per cu. ft.

C: Specific heat of the layer material Btu per (lb) (^oF).

R: Thermal resistance value of the layer in (hr) (sq. ft.) (^oF) per Btu.

The value of R is to be given only when the layer has no apparent thermal mass. If the value of L, K, P and C are given, R should be zero. If R is given, L, K, P and C should all be zero.

ITYPE : Exposure surface type index:

= 1 if roof.

= 2 if exterior wall.

= 3 if window or glass door.

= 4 if door.

= 5 if floor on ground or basement wall.

= 6 if partition walls, party walls, floor/ceiling, furnishings and other internal mass.

= 7 if completely open.

= 8 if the adjacent space is not air conditioned and will be considered as having a temperature the same as the outdoors.

IRF: Roof/wall/floor construction identifier index shown in the upper right corner of the roof/wall/floor data sheet 6. If not applicable (such as the cases for lightweight walls, doors and windows), which are not specified in data sheets 6 and 7. IRF = 10.

A: Area of the surface, sq. ft.

AZW: Surface orientation angle, degrees clockwise from south:

0 for south facing surface, roof/ceiling or floor.

45 for southwest facing surface.

90 for west facing surface.

135 for northwest facing surface.

180 for north facing surface.

-135 for northeast facing surface.

-90 for east facing surface.

U: Overall heat transfer coefficient of a surface (Btuh) for which the data for roof/wall/floor are not provided (IRF = 10). For the surface for which roof/wall/floor data are provided (IRF $\neq$ 10), U should be zero because it will be computed in the program.

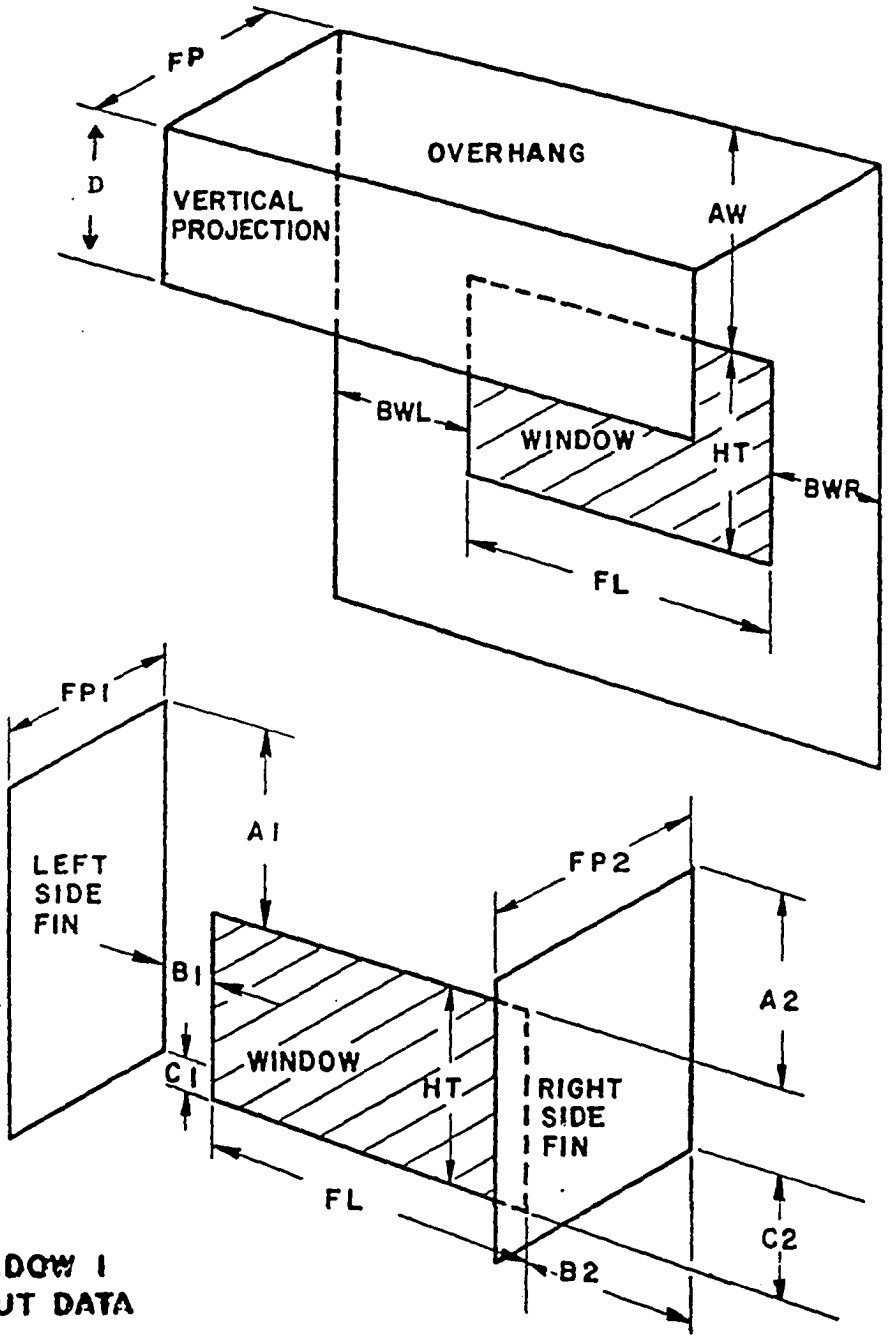
SHADE: Shading coefficient for the ITYPE = 3 surface (window or glass door) (see Table C5 which has been taken from the 1972 ASHRAE Handbook of Fundamentals). For all other types of surfaces, this parameter should be zero.

ABSP: Solar absorption coefficient for the exterior surface (see Table C6 which has been taken from Thermal Radiation Properties Survey, G. G. Gubareff, J. E. Jansen, and R. H. Torborg, Honeywell Research Center, 1960). This value should be zero for the surfaces of ITYPE = 3, 5, 6 and 7, and 8.

SHDW: Shadow parameter = 1 if completely shaded by an adjacent building or an external shading device; = 0 if otherwise.

(Exterior Shading Device Data)

Data are given in ft. and as dictated by the figure below.



SHADOW I
INPUT DATA

ROOM NAME	ELEMENT	ELEMENT DESCRIPTION	L	K	P	C	R
Living room	wall	3/8 sheet rock	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		building paper	0.0	0.0	0.0	0.0	.08
		4" brick facing	.33	.77	125.	.22	0.0
	wall	3/8" gypsum board	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		3/8" gypsum board	.031	.120	50.	.26	0.0
	ceiling/ roof	3/8" sheet rock	.031	.120	50.	.26	0.0
		4" blown insulation	.333	.021	1.5	.17	0.0
		ceiling air space	0.0	0.0	0.0	0.0	.91
		1/4" plywood	.021	.067	34.	.29	0.0
		asphalt shingles	.010	.024	70.	.30	0.0
	floor	carpet(1.5"+1/2"pad)	.125	.067	2.	.33	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0
	floor	linoleum tile 1/8"	.01	.122	.69	.30	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
1	3	675	0	0	0	.89	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	220	0	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
3	10	12	0	.87	1	0	0		

FL	HT	FP	AW	BWL	BWR	D			
3	4	2	3	8	8	.333			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	180	90	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
3	10	24	90	.87	1	0	0		

FL	HT	FP	AW	BWL	BWR	D			
6	4	2	3	10.5	10.5	.333			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	180	180	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	210	-90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	60	-90	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
5	4	837	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ROOM NAME	ELEMENT	ELEMENT DESCRIPTION	L	K	P	C	R
Master Bdrm	wall	3/8 sheet rock	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		building paper	0.0	0.0	0.0	0.0	.08
		4" brick facing	.33	.77	125.	.22	0.0
	wall	3/8" gypsum board	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		3/8" gypsum board	.031	.120	50.	.26	0.0
	ceiling/	3/8" sheet rock	.031	.120	50.	.26	0.0
	roof	4" blown insulation	.333	.021	1.5	.17	0.0
		ceiling air space	0.0	0.0	0.0	0.0	.91
		1/4" plywood	.021	.067	34.	.29	0.0
		asphalt shingles	.010	.024	70.	.30	0.0
	floor	carpet(1.5"+1/2"pad)	.125	.067	2.	.33	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0
	floor	linoleum tile 1/8"	.01	.122	.69	.30	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
1	3	182	0	0	0	.89	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	130	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	130	90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	100	180	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
3	10	12	180	.87	1	0	0		

FL	HT	FP	AW	BWL	BWR	D			
3	4	2	3	5	5	.333			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	130	-90	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
5	4	182	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FP1	A1	B1	C1	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ROOM NAME	ELEMENT	ELEMENT DESCRIPTION	L	K	P	C	R
Bedroom 1	wall	3/8 sheet rock	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		building paper	0.0	0.0	0.0	0.0	.08
		4" brick facing	.33	.77	125.	.22	0.0
	wall	3/8" gypsum board	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		3/8" gypsum board	.031	.120	50.	.26	0.0
	ceiling/	3/8" sheet rock	.031	.120	50.	.26	0.0
	roof	4" blown insulation	.333	.021	1.5	.17	0.0
		ceiling air space	0.0	0.0	0.0	0.0	.91
		1/4" plywood	.021	.067	34.	.29	0.0
		asphalt shingles	.010	.024	70.	.30	0.0
	floor	carpet(1.5"+1/2"pad)	.125	.067	2.	.33	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0
	floor	linoleum tile 1/8"	.01	.122	.69	.30	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
1	3	140	0	0	0	.89	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	140	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	70	90	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
3	10	12	90	.87	1	0	0		

FL	HT	FP	AW	BWL	BWR	D			
3	4	2	3	3.5	3.5	.333			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	140	180	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	100	-90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
5	4	140	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ROOM NAME	ELEMENT	ELEMENT DESCRIPTION	L	K	P	C	R
Bedroom 2	wall	3/8 sheet rock	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		building paper	0.0	0.0	0.0	0.0	.08
		4" brick facing	.33	.77	125.	.22	0.0
	wall	3/8" gypsum board	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		3/8" gypsum board	.031	.120	50.	.26	0.0
	ceiling/ roof	3/8" sheet rock	.031	.120	50.	.26	0.0
		4" blown insulation	.333	.021	1.5	.17	0.0
		ceiling air space	0.0	0.0	0.0	0.0	.91
		1/4" plywood	.021	.067	34.	.29	0.0
		asphalt shingles	.010	.024	70.	.30	0.0
	floor	carpet(1.5"+1/2"pad)	.125	.067	2.	.33	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0
	floor	linoleum tile 1/8"	.01	.122	.69	.30	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
1	3	168	0	0	0	.89	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	140	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	120	90	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	110	180	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
3	10	12	180	.87	1	0	0		

FL	HT	FP	AW	BWL	BWR	D			
3	4	2	3	5.5	5.5	.333			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	120	-90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
5	4	168	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ROOM NAME	ELEMENT	ELEMENT DESCRIPTION	L	K	P	C	R
Full Bath	wall	3/8 sheet rock	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		building paper	0.0	0.0	0.0	0.0	.08
		4" brick facing	.33	.77	125.	.22	0.0
	wall	3/8" gypsum board	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		3/8" gypsum board	.031	.120	50.	.26	0.0
	ceiling/ roof	3/8" sheet rock	.031	.120	50.	.26	0.0
		4" blown insulation	.333	.021	1.5	.17	0.0
		ceiling air space	0.0	0.0	0.0	0.0	.91
		1/4" plywood	.021	.067	34.	.29	0.0
		asphalt shingles	.010	.024	70.	.30	0.0
	floor	carpet(1.5"+1/2"pad)	.125	.067	2.	.33	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0
	floor	linoleum tile 1/8"	.01	.122	.69	.30	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
1	3	65	0	0	0	.89	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FP1	A1	B1	C1	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	130	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FP1	A1	B1	C1	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	50	90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FP1	A1	B1	C1	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	130	180	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FP1	A1	B1	C1	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	50	-90	0	0	0	.699		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
5	4	65	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ROOM NAME	ELEMENT	ELEMENT DESCRIPTION	L	K	P	C	R
Master Bath	wall	3/8 sheet rock	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		building paper	0.0	0.0	0.0	0.0	.08
		4" brick facing	.33	.77	125.	.22	0.0
	wall	3/8" gypsum board	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		3/8" gypsum board	.031	.120	50.	.26	0.0
	ceiling/ roof	3/8" sheet rock	.031	.120	50.	.26	0.0
		4" blown insulation	.333	.021	1.5	.17	0.0
		ceiling air space	0.0	0.0	0.0	0.0	.91
		1/4" plywood	.021	.067	34.	.29	0.0
		asphalt shingles	.010	.024	70.	.30	0.0
	floor	carpet(1.5"+1/2"pad)	.125	.067	2.	.33	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0
	floor	linoleum tile 1/8"	.01	.122	.69	.30	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
1	3	52	0	0	0	.89	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	130	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	40	90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	130	180	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	40	-90	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
5	4	52	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ROOM NAME	ELEMENT	ELEMENT DESCRIPTION	L	K	P	C	R
Kitchen	wall	3/8 sheet rock	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		building paper	0.0	0.0	0.0	0.0	.08
		4" brick facing	.33	.77	125.	.22	0.0
	wall	3/8" gypsum board	.031	.120	50.	.26	0.0
		air space	0.0	0.0	0.0	0.0	.91
		3/8" gypsum board	.031	.120	50.	.26	0.0
	ceiling/ roof	3/8" sheet rock	.031	.120	50.	.26	0.0
		4" blown insulation	.333	.021	1.5	.17	0.0
		ceiling air space	0.0	0.0	0.0	0.0	.91
		1/4" plywood	.021	.067	34.	.29	0.0
		asphalt shingles	.010	.024	70.	.30	0.0
	floor	carpet(1.5"+1/2"pad)	.125	.067	2.	.33	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0
	floor	linoleum tile 1/8"	.01	.122	.69	.30	0.0
		4" HW concrete slab	.333	1.0	140.	.20	0.0
		2" rigid insulation	.167	.015	2.2	.20	0.0

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
1	3	210	0	0	0	.89	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
3	10	12	0	.87	1	0	0		

FL	HT	FP	AW	BWL	BWR	D			
4	3	6	4.5	3	3	.333			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	88	0	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	100	90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
6	2	60	180	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
2	1	20	180	0	0	.699	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
4	10	20	180	.33	0	.78	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
8	2	270	-90	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

ITYPE	IRF	A	AZW	U	SHADE	ABSP	SHDW		
5	4	210	0	0	0	0	0		

FL	HT	FP	AW	BWL	BWR	D			
0	0	0	0	0	0	0			

FPI	AI	BI	CI	FP2	A2	B2	C2		
0	0	0	0	0	0	0	0		

Appendix H

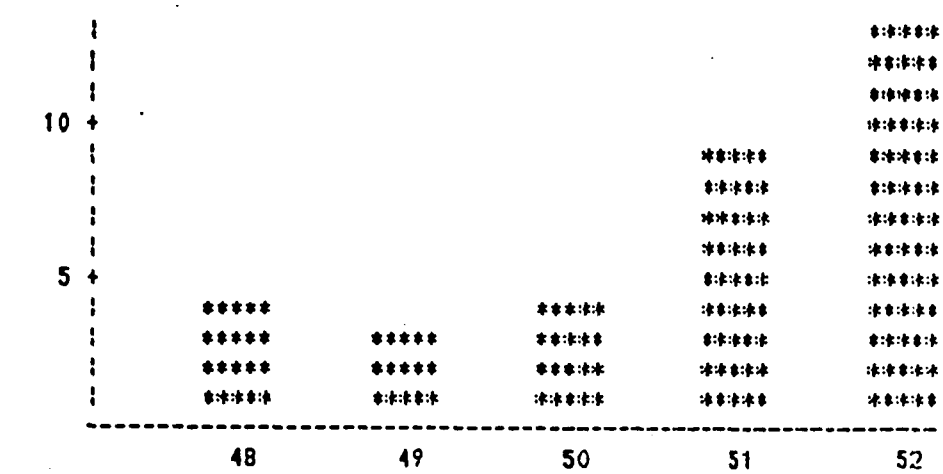
STATISTICAL SUMMARY OF AVERAGE HEATING SEASON MEAN, MAXIMUM AND MINIMUM TEMPERATURES AND TOTAL HEATING DEGREE DAYS AT FOUR OKLAHOMA SITES.

Statistical Summary of Average Heating Season Mean Temperature
at Altus, OK (1948 - 81)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	59	60	58.9	34.6	46.8	3583.0
2	48	49	60.5	35.2	47.7	3695.5
3	72	73	59.2	36.8	48.0	3752.0
4	78	79	61.0	35.7	48.4	3622.5
5	76	77	63.7	34.2	48.8	3465.0
6	57	58	60.1	38.3	49.2	3432.5
7	69	70	62.1	36.5	49.3	3437.0
8	74	75	62.7	37.3	50.0	3301.5
9	77	78	63.8	35.9	50.0	3301.5
10	67	68	63.8	36.5	50.1	3288.0
11	61	62	64.1	36.7	50.4	3239.0
12	79	80	65.5	36.0	50.7	3201.5
13	64	65	64.3	37.3	50.8	3154.0
14	68	69	64.1	37.2	50.8	3099.5
15	50	51	66.4	36.2	51.3	3119.5
16	70	71	67.8	34.8	51.3	3086.0
17	49	50	65.6	37.2	51.5	3068.0
18	55	56	65.9	37.0	51.5	3075.5
19	65	66	64.1	39.0	51.5	2995.0
20	81	82	65.3	37.8	51.5	3008.0
21	60	61	64.9	38.3	51.6	3057.0
22	51	52	65.0	38.4	51.7	2983.5
23	52	53	66.3	37.9	52.1	2892.0
24	56	57	64.2	40.2	52.2	2936.5
25	63	64	68.1	38.8	52.5	3033.0
26	71	72	66.7	38.2	52.5	2898.0
27	62	63	67.4	38.0	52.7	2947.0
28	75	76	68.7	37.4	53.0	2651.0
29	66	67	69.1	37.2	53.2	2792.0
30	73	74	68.8	37.7	53.2	2715.5
31	53	54	67.1	39.6	53.3	2727.0
32	80	81	67.7	38.9	53.6	2616.0
33	54	55	68.3	39.6	54.0	2708.5

MEAN	STANDARD DEVIATION
51.06666667	1.81360598
MINIMUM VALUE	**MAXIMUM VALUE**
46.80000000	54.00000000
STD ERROR OF MEAN	**SUM**
0.31570828	1685.2000000
VARIANCE	**C.V.**
3.28916667	3.551

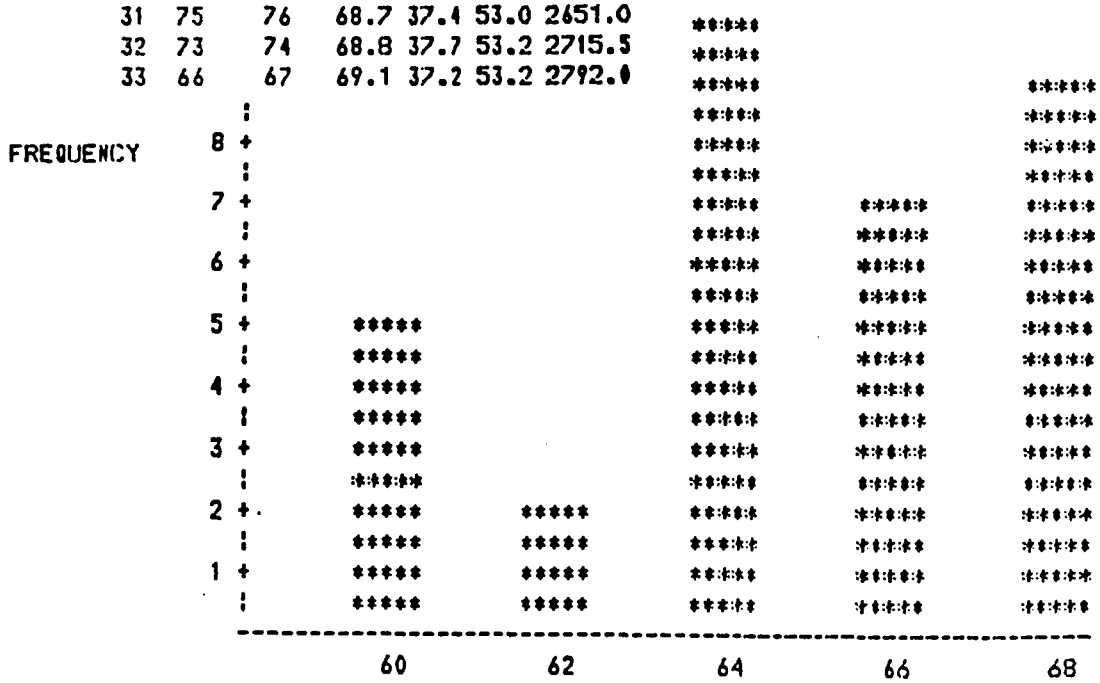
FREQUENCY



Statistical Summary of Average Heating Season Maximum Temperature
at Altus, OK (1948 - 81)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	59	60	58.9	34.6	46.8	3583.0
2	72	73	59.2	36.8	48.0	3752.0
3	57	58	60.1	38.3	49.2	3432.5
4	48	49	60.5	35.2	47.7	3695.5
5	78	79	61.0	35.7	48.4	3622.5
6	69	70	62.1	36.5	49.3	3437.0
7	74	75	62.7	37.3	50.0	3301.5
8	76	77	63.7	34.2	48.8	3465.0
9	67	68	63.8	36.5	50.1	3288.0
10	77	78	63.8	35.9	50.0	3301.5
11	61	62	64.1	36.7	50.4	3239.0
12	65	66	64.1	39.0	51.5	2995.0
13	68	69	64.1	37.2	50.8	3099.5
14	56	57	64.2	40.2	52.2	2936.5
15	64	65	64.3	37.3	50.8	3154.0
16	60	61	64.9	38.3	51.6	3057.0
17	51	52	65.0	38.4	51.7	2983.5
18	81	82	65.3	37.8	51.5	3008.0
19	79	80	65.5	36.0	50.7	3201.5
20	49	50	65.6	37.2	51.5	3008.0
21	55	56	65.9	37.0	51.5	3075.5
22	52	53	66.3	37.9	52.1	2892.0
23	50	51	66.4	36.2	51.3	3119.5
24	71	72	66.7	38.2	52.5	2898.0
25	53	54	67.1	39.6	53.3	2727.0
26	62	63	67.4	38.0	52.7	2947.0
27	80	81	67.7	38.9	53.6	2616.0
28	70	71	67.8	34.8	51.3	3086.0
29	63	64	68.1	36.8	52.5	3033.0
30	54	55	68.3	39.6	54.0	2708.5
31	75	76	68.7	37.4	53.0	2651.0
32	73	74	68.8	37.7	53.2	2715.5
33	66	67	69.1	37.2	53.2	2792.0

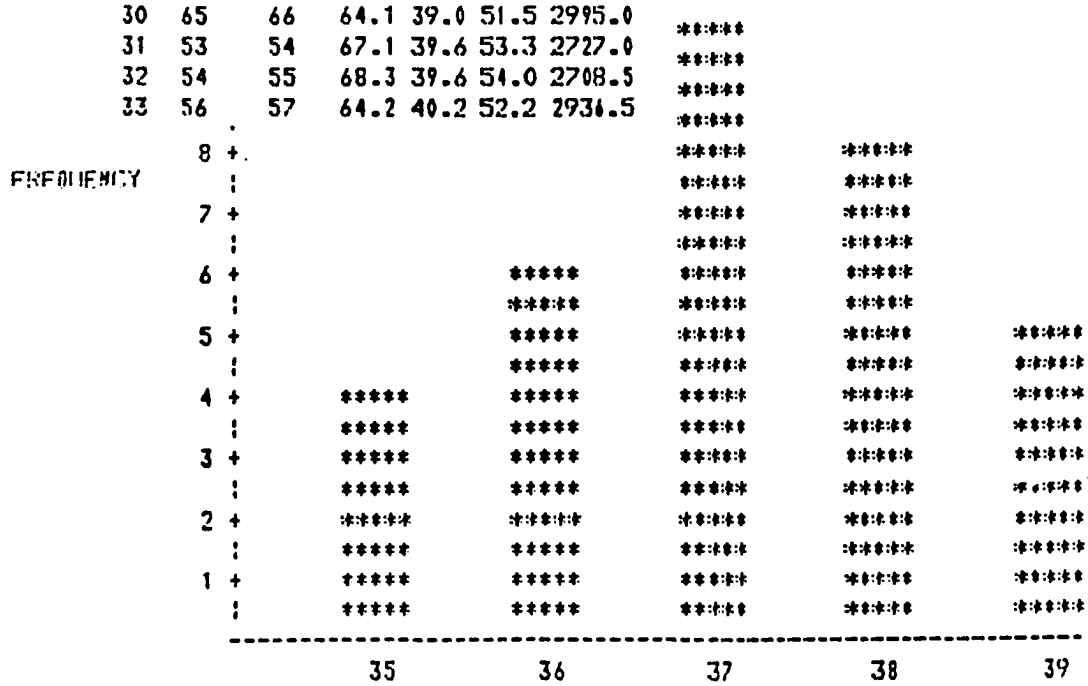
MEAN	STANDARD DEVIATION
64.88484848	2.80235629
MINIMUM VALUE	**MAXIMUM VALUE**
58.90000000	69.10000000
STD ERROR OF MEAN	**SUM**
0.48782761	2141.2000000
VARIANCE	**C.V.**
7.85320076	4.319



Statistical Summary of Average Heating Season Minimum Temperature
at Altus, OK (1948 - 81)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	76	77	63.7	34.2	48.8	3465.0
2	59	60	58.9	34.6	46.8	3583.0
3	70	71	67.8	34.8	51.3	3086.0
4	48	49	60.5	35.2	47.7	3695.5
5	78	79	61.0	35.7	48.4	3622.5
6	77	78	63.8	35.9	50.0	3301.5
7	79	80	65.5	36.0	50.7	3201.5
8	50	51	66.4	36.2	51.3	3119.5
9	67	68	63.8	36.5	50.1	3288.0
10	69	70	62.1	36.5	49.3	3437.0
11	61	62	64.1	36.7	50.4	3239.0
12	63	64	68.1	36.8	52.5	3033.0
13	72	73	59.2	36.8	48.0	3752.0
14	55	56	65.9	37.0	51.5	3075.5
15	49	50	65.6	37.2	51.5	3008.0
16	66	67	69.1	37.2	53.2	2792.0
17	68	69	64.1	37.2	50.8	3099.5
18	64	65	64.3	37.3	50.8	3154.0
19	74	75	62.7	37.3	50.0	3301.5
20	75	76	68.7	37.4	53.0	2651.0
21	73	74	68.8	37.7	53.2	2715.5
22	81	82	65.3	37.8	51.5	3008.0
23	52	53	66.3	37.9	52.1	2892.0
24	62	63	67.4	38.0	52.7	2947.0
25	71	72	66.7	38.2	52.5	2898.0
26	57	58	60.1	38.3	49.2	3432.5
27	60	61	64.9	38.3	51.6	3057.0
28	51	52	65.0	38.4	51.7	2983.5
29	80	81	67.7	38.9	53.6	2616.0
30	65	66	64.1	39.0	51.5	2995.0
31	53	54	67.1	39.6	53.3	2727.0
32	54	55	68.3	39.6	54.0	2708.5
33	56	57	64.2	40.2	52.2	2936.5

	MEAN	STANDARD DEVIATION
	37.22424242	1.44460858
	MINIMUM VALUE	MAXIMUM VALUE
	34.20000000	40.20000000
	STD ERROR OF MEAN	SUM
	0.25147407	1228.4000000
	VARIANCE	C.V.
	2.08689394	3.881



Statistical Summary of Average Heating Season Total Heating Degree Days at Altus, OK (1948 - 81)

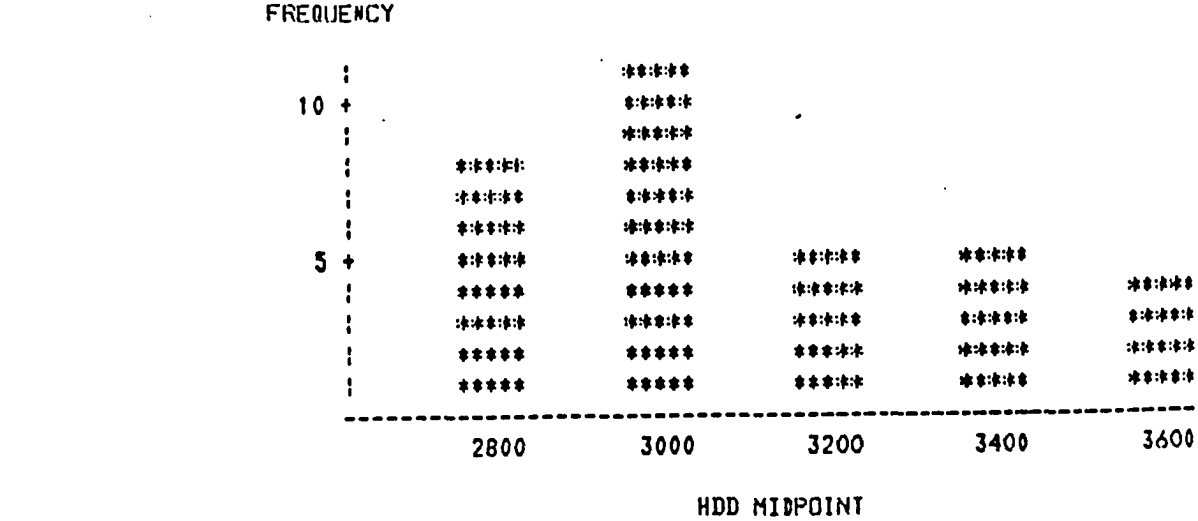
OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	80	81	67.7	38.9	53.6	2616.0
2	75	76	68.7	37.4	53.0	2651.0
3	54	55	68.3	39.6	54.0	2708.5
4	73	74	68.8	37.7	53.2	2715.5
5	53	54	67.1	39.6	53.3	2727.0
6	66	67	69.1	37.2	53.2	2792.0
7	52	53	66.3	37.9	52.1	2892.0
8	71	72	66.7	38.2	52.5	2898.0
9	56	57	64.2	40.2	52.2	2936.5
10	62	63	67.4	38.0	52.7	2947.0
11	51	52	65.0	38.4	51.7	2983.5
12	65	66	64.1	39.0	51.5	2995.0
13	49	50	65.6	37.2	51.5	3008.0
14	81	82	65.3	37.8	51.5	3008.0
15	63	64	68.1	36.8	52.5	3033.0
16	60	61	64.9	38.3	51.6	3057.0
17	55	56	65.9	37.0	51.5	3075.5
18	70	71	67.8	34.8	51.3	3086.0
19	68	69	64.1	37.2	50.8	3099.5
20	50	51	66.4	36.2	51.3	3119.5
21	64	65	64.3	37.3	50.8	3154.0
22	79	80	65.5	36.0	50.7	3201.5
23	61	62	64.1	36.7	50.4	3239.0
24	67	68	63.8	36.5	50.1	3288.0
25	74	75	62.7	37.3	50.0	3301.5
26	77	78	63.8	35.9	50.0	3301.5
27	57	58	60.1	38.3	49.2	3432.5
28	69	70	62.1	36.5	49.3	3437.0
29	76	77	63.7	34.2	48.8	3465.0
30	59	60	58.9	34.6	46.8	3583.0
31	78	79	61.0	35.7	48.4	3622.5
32	48	49	60.5	35.2	47.7	3695.5
33	72	73	59.2	36.8	48.0	3752.0

MEAN	STANDARD DEVIATION
3115.80303030	303.02784369

MINIMUM VALUE	MAXIMUM VALUE
2616.0000000	3752.0000000

STD ERROR OF MEAN	SUM
52.75037672	102821.50000

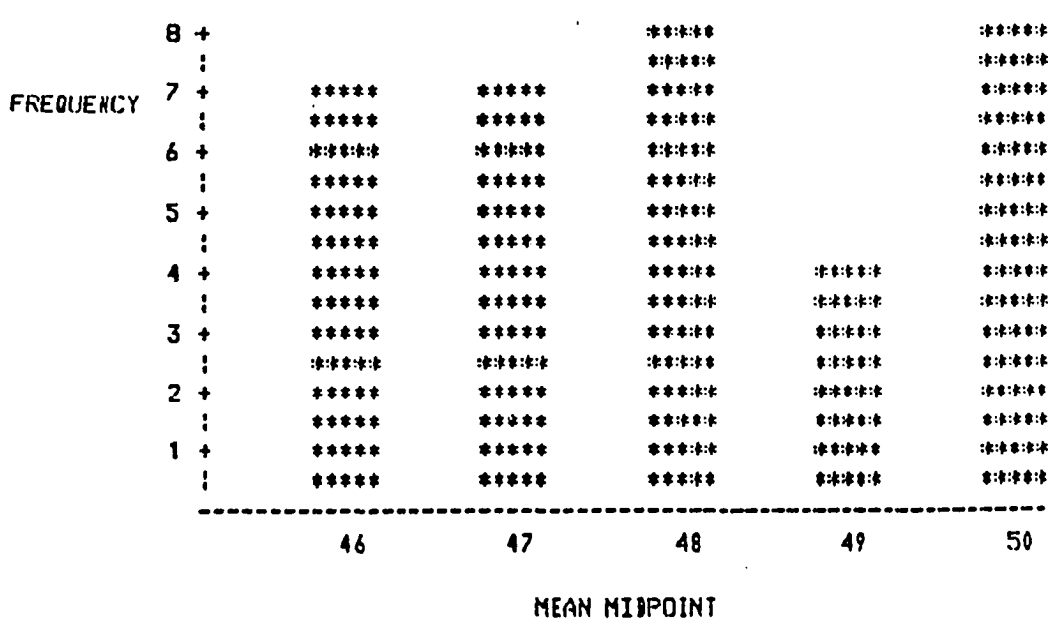
VARIANCE	C.V.
91825.874053	9.726



Statistical Summary of Average Heating Season Mean Temperature
at Enid, OK (1948 - 82)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	78	79	55.4	33.8	44.6	4335.0
2	72	73	54.7	36.2	45.4	4264.5
3	77	78	56.1	34.6	45.4	4280.0
4	48	49	56.0	35.2	45.6	4154.5
5	59	60	56.2	34.9	45.6	4190.0
6	57	58	56.1	35.9	46.0	4081.0
7	68	69	56.7	36.3	46.5	4052.5
8	61	62	57.6	35.6	46.6	4005.5
9	81	82	57.2	36.0	46.6	3998.5
10	74	75	56.7	37.3	47.0	3900.0
11	79	80	58.1	36.2	47.1	3933.0
12	69	70	58.4	36.1	47.3	3795.5
13	76	77	59.8	34.9	47.3	3874.0
14	55	56	60.3	34.3	47.4	3836.5
15	67	68	58.6	36.7	47.6	3763.0
16	64	65	58.9	36.5	47.7	3807.5
17	70	71	59.5	35.9	47.7	3766.5
18	49	50	60.4	36.1	48.2	3693.0
19	51	52	59.4	37.1	48.2	3634.5
20	56	57	59.1	37.4	48.3	3676.0
21	58	59	60.4	36.3	48.4	3708.5
22	50	51	61.4	35.6	48.5	3664.5
23	65	66	59.9	37.2	48.6	3568.5
24	62	63	60.9	36.5	48.7	3685.5
25	60	61	60.8	36.9	48.9	3597.0
26	63	64	61.2	37.1	49.2	3638.5
27	71	72	61.7	38.0	49.8	3379.0
28	52	53	61.8	38.0	49.9	3324.5
29	73	74	61.3	38.8	50.0	3334.0
30	66	67	63.2	38.0	50.6	3250.5
31	53	54	63.3	38.3	50.8	3241.0
32	54	55	63.8	37.8	50.8	3306.5
33	80	81	62.9	39.4	51.1	3169.5
34	75	76	63.9	39.3	51.6	2988.5

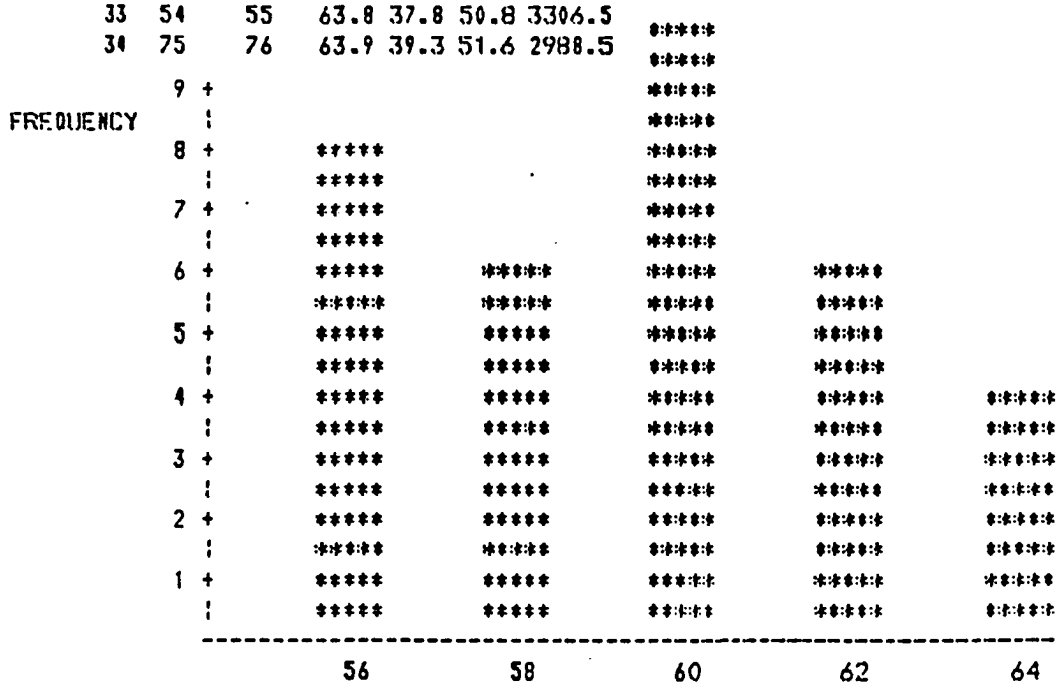
MEAN	STANDARD DEVIATION
48.02941176	1.82383702
MINIMUM VALUE	**MAXIMUM VALUE**
44.60000000	51.60000000
STD ERROR OF MEAN	**SUM**
0.31278547	1633.0000000
VARIANCE	**C.V.**
3.32638146	3.797



Statistical Summary of Average Heating Season Maximum Temperature at Enid, OK (1948 - 82)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	72	73	54.7	36.2	45.4	4264.5
2	78	79	55.4	33.8	44.6	4335.0
3	48	49	56.0	35.2	45.6	4154.5
4	57	58	56.1	35.9	46.0	4081.0
5	77	78	56.1	34.6	45.4	4280.0
6	59	60	56.2	34.9	45.6	4190.0
7	68	69	56.7	36.3	46.5	4052.5
8	74	75	56.7	37.3	47.0	3900.0
9	81	82	57.2	36.0	46.6	3998.5
10	61	62	57.6	35.6	46.6	4005.5
11	79	80	58.1	36.2	47.1	3933.0
12	69	70	58.4	36.1	47.3	3795.0
13	67	68	58.6	36.7	47.6	3763.0
14	64	65	58.9	36.5	47.7	3807.5
15	56	57	59.1	37.4	48.3	3676.0
16	51	52	59.4	37.1	48.2	3634.5
17	70	71	59.5	35.9	47.7	3766.5
18	76	77	59.8	34.9	47.3	3874.0
19	65	66	59.9	37.2	48.6	3568.5
20	55	56	60.3	34.3	47.4	3836.5
21	49	50	60.4	36.1	48.2	3693.0
22	58	59	60.4	36.3	48.4	3708.5
23	60	61	60.8	36.9	48.9	3597.0
24	62	63	60.9	36.5	48.7	3685.5
25	63	64	61.2	37.1	49.2	3638.5
26	73	74	61.3	38.8	50.0	3334.0
27	50	51	61.4	35.6	48.5	3664.5
28	71	72	61.7	38.0	49.8	3379.0
29	52	53	61.8	38.0	49.9	3324.5
30	80	81	62.9	39.4	51.1	3169.5
31	66	67	63.2	38.0	50.6	3250.5
32	53	54	63.3	38.3	50.8	3241.0
33	54	55	63.8	37.8	50.8	3306.5
34	75	76	63.9	39.3	51.6	2988.5

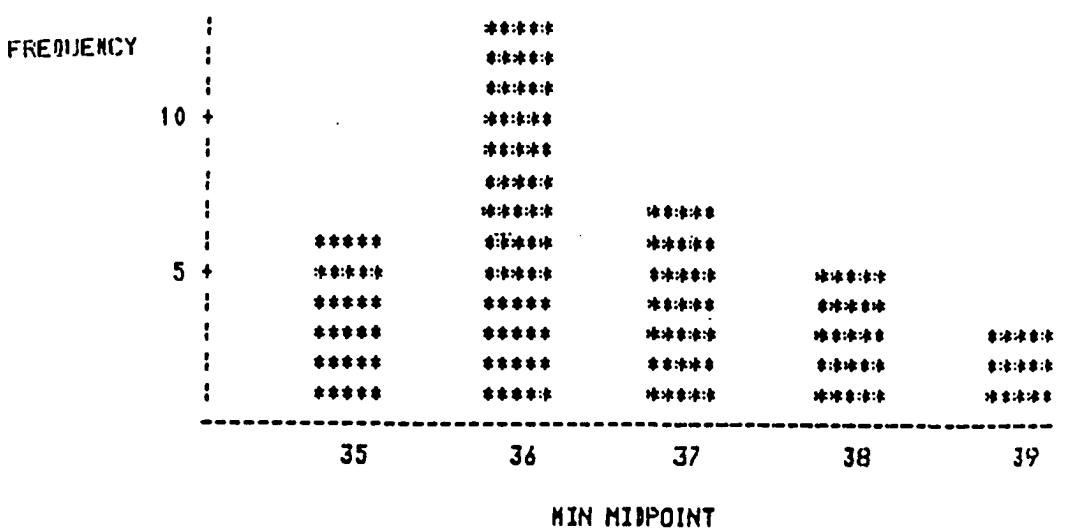
MEAN	STANDARD DEVIATION
59.46176471	2.57446843
MINIMUM VALUE	**MAXIMUM VALUE**
54.70000000	63.90000000
STD ERROR OF MEAN	**SUM**
0.44151769	2021.7000000
VARIANCE	**C.V.**
6.62788770	4.330



Statistical Summary of Average Heating Season Minimum Temperature
at Enid, OK (1948 - 82)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	78	79	55.4	33.8	44.6	4335.0
2	55	56	60.3	34.3	47.4	3836.5
3	77	78	56.1	34.6	45.4	4280.0
4	59	60	56.2	34.9	45.6	4190.0
5	76	77	59.8	34.9	47.3	3874.0
6	48	49	56.0	35.2	45.6	4154.5
7	50	51	61.4	35.6	48.5	3664.5
8	61	62	57.6	35.6	46.6	4005.5
9	57	58	56.1	35.9	46.0	4081.0
10	70	71	59.5	35.9	47.7	3766.5
11	81	82	57.2	36.0	46.6	3998.5
12	49	50	60.4	36.1	48.2	3693.0
13	69	70	58.4	36.1	47.3	3795.0
14	72	73	54.7	36.2	45.4	4264.5
15	79	80	58.1	36.2	47.1	3933.0
16	58	59	60.4	36.3	48.4	3708.5
17	68	69	56.7	36.3	46.5	4052.5
18	62	63	60.9	36.5	48.7	3685.5
19	64	65	58.9	36.5	47.7	3807.5
20	67	68	58.6	36.7	47.6	3763.0
21	60	61	60.8	36.9	48.9	3597.0
22	51	52	59.4	37.1	48.2	3634.5
23	63	64	61.2	37.1	49.2	3638.5
24	65	66	59.9	37.2	48.6	3568.5
25	74	75	56.7	37.3	47.0	3900.0
26	56	57	59.1	37.4	48.3	3676.0
27	54	55	63.8	37.8	50.8	3306.5
28	52	53	61.8	38.0	49.9	3324.5
29	66	67	63.2	38.0	50.6	3250.5
30	71	72	61.7	38.0	49.8	3379.0
31	53	54	63.3	38.3	50.8	3241.0
32	73	74	61.3	38.8	50.0	3334.0
33	75	76	63.9	39.3	51.6	2988.5
34	80	81	62.9	39.4	51.1	3169.5

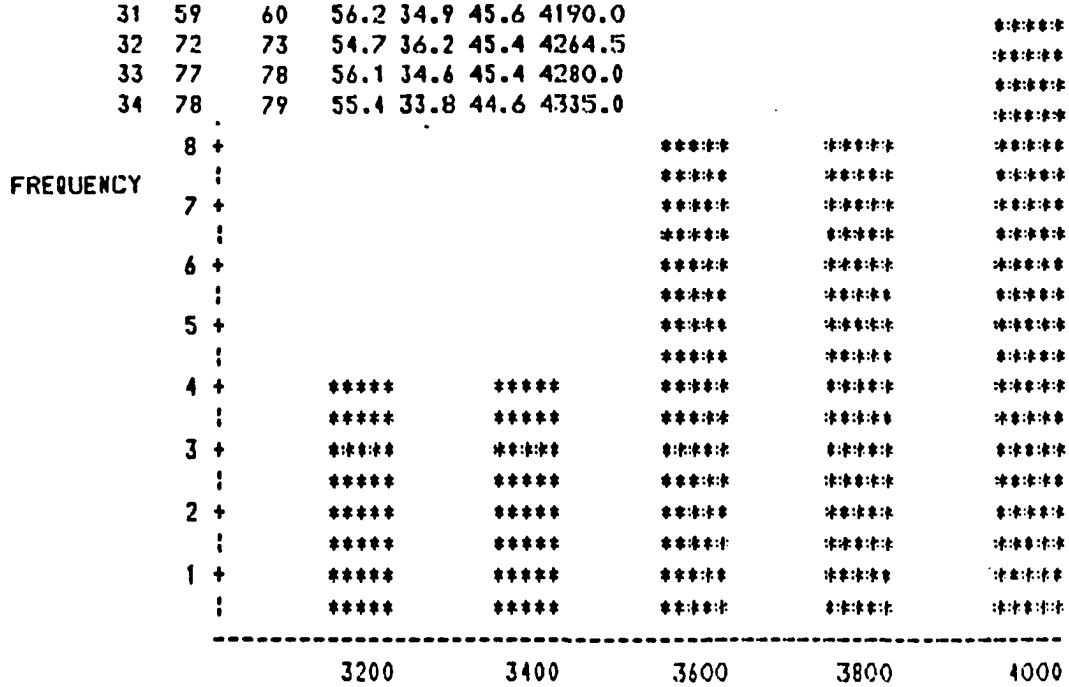
MEAN	STANDARD DEVIATION
36.59411765	1.36513762
MINIMUM VALUE	**MAXIMUM VALUE**
33.80000000	39.40000000
STD ERROR OF MEAN	**SUM**
0.23411917	1244.2000000
VARIANCE	**C.V.**
1.86360071	3.730



Statistical Summary of Average Heating Season Total Heating Degree Days
at Enid, OK (1948 - 82)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	75	76	63.9	39.3	51.6	2988.5
2	80	81	62.9	39.4	51.1	3169.5
3	53	54	63.3	38.3	50.8	3241.0
4	66	67	63.2	38.0	50.6	3250.5
5	54	55	63.8	37.8	50.8	3306.5
6	52	53	61.8	38.0	49.9	3324.5
7	73	74	61.3	38.8	50.0	3334.0
8	71	72	61.7	38.0	49.8	3379.0
9	65	66	59.9	37.2	48.6	3568.5
10	60	61	60.8	36.9	48.9	3597.0
11	51	52	59.4	37.1	48.2	3634.5
12	63	64	61.2	37.1	49.2	3638.5
13	50	51	61.4	35.6	48.5	3664.5
14	56	57	59.1	37.4	48.3	3676.0
15	62	63	60.9	36.5	48.7	3685.5
16	49	50	60.4	36.1	48.2	3693.0
17	58	59	60.4	36.3	48.4	3708.5
18	67	68	58.6	36.7	47.6	3763.0
19	70	71	59.5	35.9	47.7	3766.5
20	69	70	58.4	36.1	47.3	3795.0
21	64	65	58.9	36.5	47.7	3807.5
22	55	56	60.3	34.3	47.4	3836.5
23	76	77	59.8	34.9	47.3	3874.0
24	74	75	56.7	37.3	47.0	3900.0
25	79	80	58.1	36.2	47.1	3933.0
26	81	82	57.2	36.0	46.6	3998.5
27	61	62	57.6	35.6	46.6	4005.5
28	68	69	56.7	36.3	46.5	4052.5
29	57	58	56.1	35.9	46.0	4081.0
30	48	49	56.0	35.2	45.6	4154.5
31	59	60	56.2	34.9	45.6	4190.0
32	72	73	54.7	36.2	45.4	4264.5
33	77	78	56.1	34.6	45.4	4280.0
34	78	79	55.4	33.8	44.6	4335.0

MEAN	STANDARD DEVIATION
3732.25000000	342.22921722
MINIMUM VALUE	**MAXIMUM VALUE**
2988.5000000	4335.0000000
STD ERROR OF MEAN	**SUM**
58.69182655	126896.50000
VARIANCE	**C.V.**
117120.83712	9.170

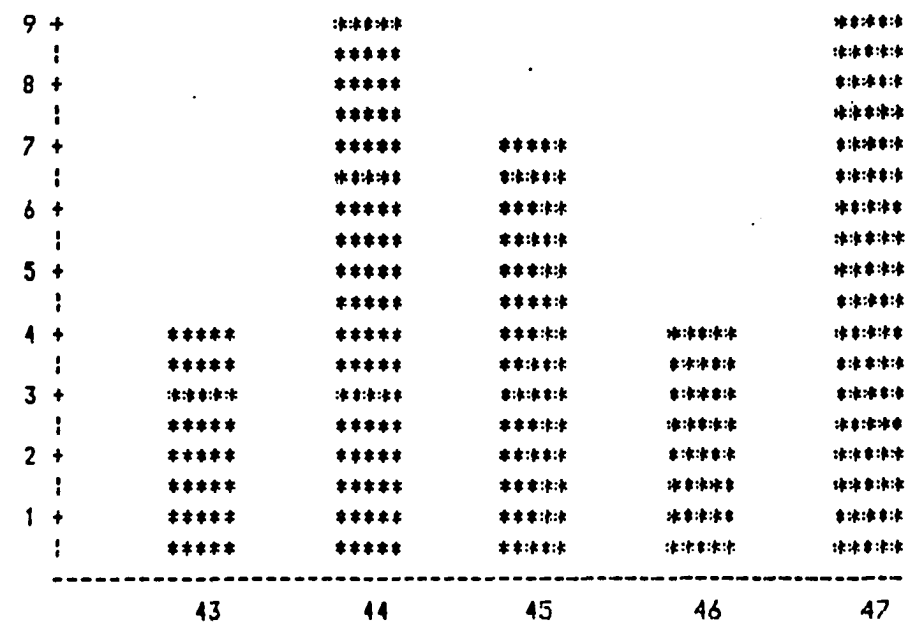


Statistical Summary of Average Heating Season Mean Temperature
at Gage, OK (1948 - 81)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	78	79	54.4	29.3	41.8	4973.5
2	72	73	53.6	31.3	42.4	4877.5
3	59	60	56.9	29.4	43.1	4682.0
4	77	78	57.1	29.3	43.2	4703.0
5	57	58	55.9	31.6	43.8	4551.5
6	69	70	57.8	29.8	43.8	4557.0
7	48	49	56.5	31.5	44.0	4522.0
8	74	75	57.1	31.2	44.2	4487.0
9	76	77	59.2	29.2	44.2	4480.0
10	51	52	58.3	30.4	44.3	4423.5
11	61	62	58.9	29.8	44.3	4439.0
12	70	71	59.1	29.5	44.3	4454.5
13	68	69	57.1	31.9	44.5	4451.0
14	79	80	58.1	31.2	44.6	4393.5
15	58	59	59.8	29.8	44.8	4369.5
16	55	56	60.5	29.4	45.0	4357.5
17	64	65	58.9	31.0	45.0	4330.5
18	67	68	59.0	31.7	45.3	4252.5
19	50	51	61.0	29.7	45.4	4286.5
20	60	61	60.0	30.8	45.4	4283.5
21	56	57	58.8	33.2	46.0	4153.5
22	65	66	59.9	32.4	46.1	4036.5
23	63	64	60.9	31.8	46.3	4184.0
24	52	53	61.3	31.5	46.4	4023.0
25	73	74	61.0	32.5	46.7	3992.5
26	49	50	62.6	31.7	47.1	3925.5
27	71	72	61.9	32.9	47.4	3835.5
28	62	63	62.4	32.6	47.7	3605.0
29	66	67	63.3	32.1	47.7	3786.5
30	75	76	62.9	32.7	47.8	3747.0
31	53	54	62.2	33.7	48.0	3720.5
32	54	55	63.6	32.4	48.0	3810.5
33	80	81	62.6	33.4	48.0	3751.0

MEAN	STANDARD DEVIATION
45.35151515	1.72846052
MINIMUM VALUE	**MAXIMUM VALUE**
41.80000000	48.00000000
STD ERROR OF MEAN	**SUM**
0.30088636	1496.6000000
VARIANCE	**C.V.**
2.98757576	3.811

FREQUENCY



MEAN MIDPOINT

Statistical Summary of Average Heating Season Maximum Temperature
at Cage, OK (1948 - 81)

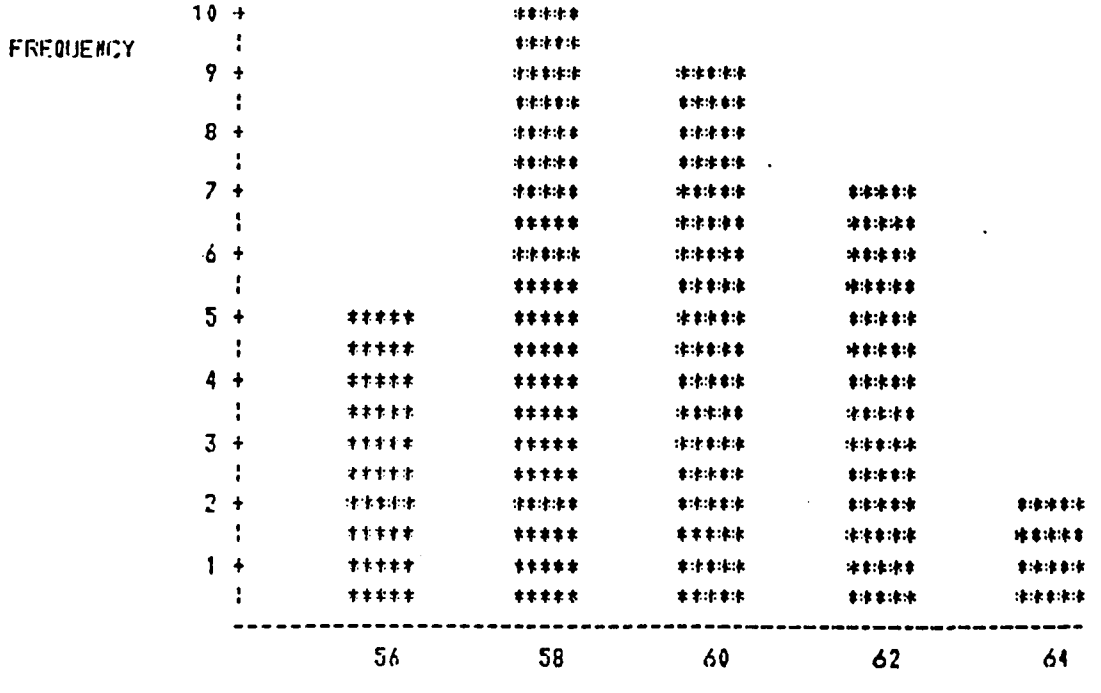
OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	72	73	53.6	31.3	42.4	4877.5
2	78	79	54.4	29.3	41.8	4973.5
3	57	58	55.9	31.6	43.8	4551.5
4	48	49	56.5	31.5	44.0	4522.0
5	59	60	56.9	29.4	43.1	4682.0
6	68	69	57.1	31.9	44.5	4451.0
7	74	75	57.1	31.2	44.2	4487.0
8	77	78	57.1	29.3	43.2	4703.0
9	69	70	57.8	29.8	43.8	4557.0
10	79	80	58.1	31.2	44.6	4393.5
11	51	52	58.3	30.4	44.3	4423.5
12	56	57	58.8	33.2	46.0	4153.5
13	61	62	58.9	29.8	44.3	4439.0
14	64	65	58.9	31.0	45.0	4330.5
15	67	68	59.0	31.7	45.3	4252.5
16	70	71	59.1	29.5	44.3	4454.5
17	76	77	59.2	29.2	44.2	4480.0
18	58	59	59.8	29.8	44.8	4369.5
19	65	66	59.9	32.4	46.1	4036.5
20	60	61	60.0	30.8	45.4	4283.5
21	55	56	60.5	29.4	45.0	4357.5
22	63	64	60.9	31.8	46.3	4184.0
23	50	51	61.0	29.7	45.4	4286.5
24	73	74	61.0	32.5	46.7	3992.5
25	52	53	61.3	31.5	46.4	4023.0
26	71	72	61.9	32.9	47.4	3835.5
27	53	54	62.2	33.7	48.0	3720.5
28	62	63	62.4	32.6	47.7	3805.0
29	49	50	62.6	31.7	47.1	3925.5
30	80	81	62.6	33.4	48.0	3751.0
31	75	76	62.9	32.7	47.8	3747.0
32	66	67	63.3	32.1	47.7	3786.5
33	54	55	63.6	32.4	48.0	3810.5

MEAN	STANDARD DEVIATION
59.47272727	2.55859736

MINIMUM VALUE	MAXIMUM VALUE
53.60000000	63.60000000

STD ERROR OF MEAN	SUM
0.44539463	1962.6000000

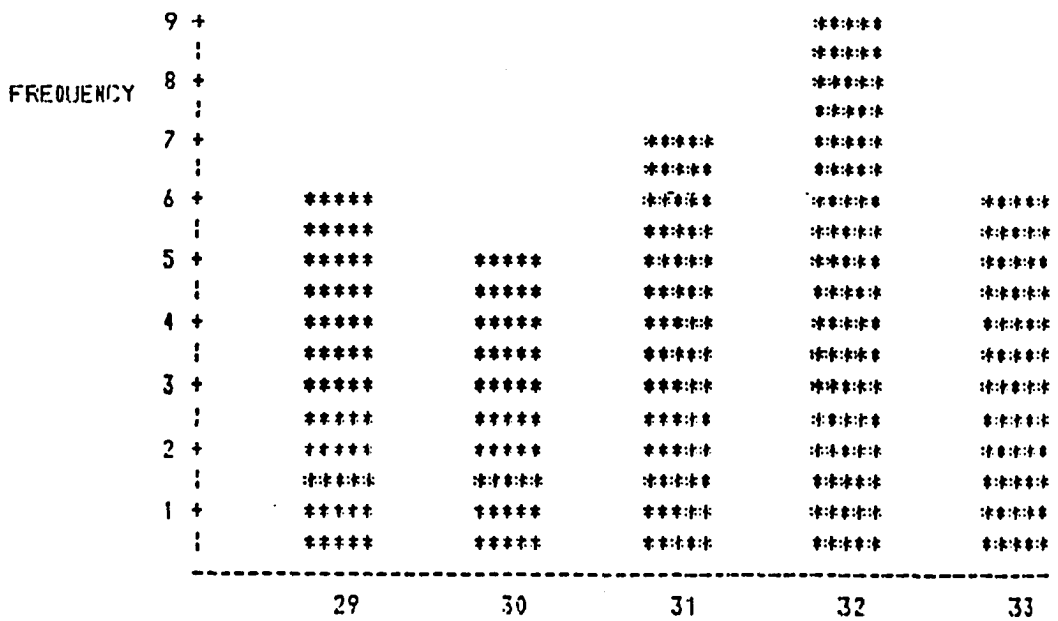
VARIANCE	C.V.
6.54642045	4.302



Statistical Summary of Average Heating Season Minimum Temperature
at Gage, OK (1948 - 81)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	76	77	59.2	29.2	44.2	4480.0
2	77	78	57.1	29.3	43.2	4703.0
3	78	79	54.4	29.3	41.8	4973.5
4	55	56	60.5	29.4	45.0	4357.5
5	59	60	56.9	29.4	43.1	4682.0
6	70	71	59.1	29.5	44.3	4454.5
7	50	51	61.0	29.7	45.4	4286.5
8	58	59	59.8	29.8	44.8	4369.5
9	61	62	58.9	29.8	44.3	4439.0
10	69	70	57.8	29.8	43.8	4557.0
11	51	52	58.3	30.4	44.3	4423.5
12	60	61	60.0	30.8	45.4	4283.5
13	64	65	58.9	31.0	45.0	4330.5
14	74	75	57.1	31.2	44.2	4487.0
15	79	80	58.1	31.2	44.6	4393.5
16	72	73	53.6	31.3	42.4	4877.5
17	48	49	56.5	31.5	44.0	4522.0
18	52	53	61.3	31.5	46.4	4023.0
19	57	58	55.9	31.6	43.8	4551.5
20	49	50	62.6	31.7	47.1	3925.5
21	67	68	59.0	31.7	45.3	4252.5
22	63	64	60.9	31.8	46.3	4184.0
23	68	69	57.1	31.9	44.5	4451.0
24	66	67	63.3	32.1	47.7	3786.5
25	54	55	63.6	32.4	48.0	3810.5
26	65	66	59.9	32.4	46.1	4036.5
27	73	74	61.0	32.5	46.7	3992.5
28	62	63	62.4	32.6	47.7	3605.0
29	75	76	62.9	32.7	47.8	3747.0
30	71	72	61.9	32.9	47.4	3835.5
31	56	57	58.8	33.2	46.0	4153.5
32	80	81	62.6	33.4	48.0	3751.0
33	53	54	62.2	33.7	48.0	3720.5

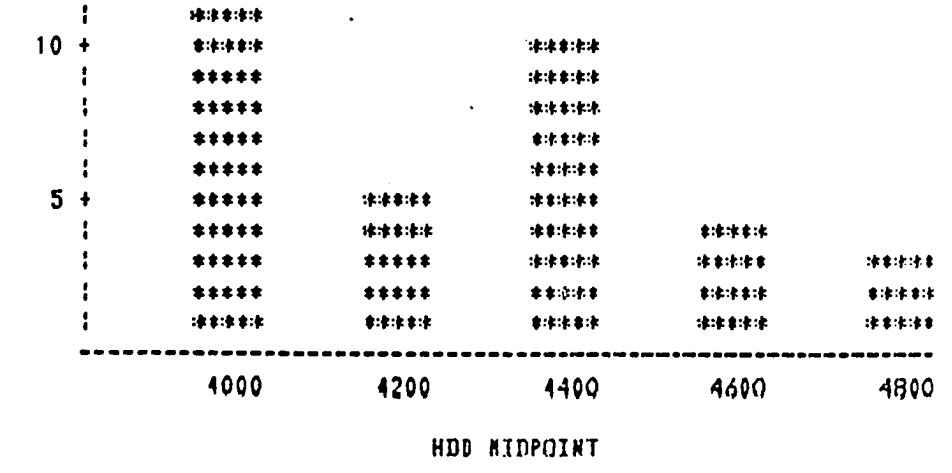
MEAN	STANDARD DEVIATION
31.23333333	1.35546732
MINIMUM VALUE	**MAXIMUM VALUE**
29.20000000	33.70000000
STD ERROR OF MEAN	**SUM**
0.23595657	1030.7000000
VARIANCE	**C.V.**
1.83729167	4.340



Statistical Summary of Average Heating Season Total Heating Degree Days at Gage, OK (1948 - 81)

OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	62	63	62.4	32.6	47.7	3605.0
2	53	54	62.2	33.7	48.0	3720.5
3	75	76	62.9	32.7	47.8	3747.0
4	80	81	62.6	33.4	48.0	3751.0
5	66	67	63.3	32.1	47.7	3786.5
6	54	55	63.6	32.4	48.0	3810.5
7	71	72	61.9	32.9	47.4	3835.5
8	49	50	62.6	31.7	47.1	3925.5
9	73	74	61.0	32.5	46.7	3992.5
10	52	53	61.3	31.5	46.4	4023.0
11	65	66	59.9	32.4	46.1	4036.5
12	56	57	58.8	33.2	46.0	4153.5
13	63	64	60.9	31.8	46.3	4184.0
14	67	68	59.0	31.7	45.3	4252.5
15	60	61	60.0	30.8	45.4	4283.5
16	50	51	61.0	29.7	45.4	4286.5
17	64	65	58.9	31.0	45.0	4330.5
18	55	56	60.5	29.4	45.0	4357.5
19	58	59	59.8	29.8	44.8	4369.5
20	79	80	58.1	31.2	44.6	4393.5
21	51	52	58.3	30.4	44.3	4423.5
22	61	62	58.9	29.8	44.3	4439.0
23	68	69	57.1	31.9	44.5	4451.0
24	70	71	59.1	29.5	44.3	4454.5
25	76	77	59.2	29.2	44.2	4480.0
26	74	75	57.1	31.2	44.2	4487.0
27	48	49	56.5	31.5	44.0	4522.0
28	57	58	55.9	31.6	43.8	4551.5
29	69	70	57.8	29.8	43.8	4557.0
30	59	60	56.9	29.4	43.1	4682.0
31	77	78	57.1	29.3	43.2	4703.0
32	72	73	53.6	31.3	42.4	4877.5
33	78	79	54.4	29.3	41.8	4973.5

MEAN	STANDARD DEVIATION
4255.93939394	350.89572342
MINIMUM VALUE	**MAXIMUM VALUE**
3605.0000000	4973.5000000
STD ERROR OF MEAN	**SUM**
61.08310502	140446.00000
VARIANCE	**C.V.**
123127.80871	8.245



Statistical Summary of Average Heating Season Mean Temperature
at Tulsa, OK (1948 - 82)

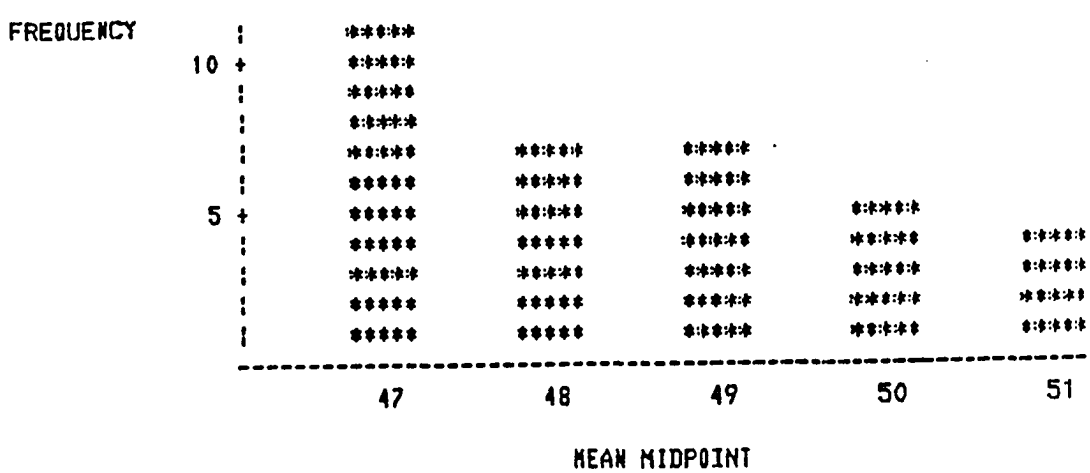
OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	77	78	55.8	35.0	45.4	4263.5
2	59	60	56.2	35.1	45.7	4146.5
3	78	79	56.8	34.7	45.7	4225.5
4	61	62	56.6	34.9	45.8	4177.0
5	69	70	57.1	35.1	46.1	4115.5
6	72	73	55.4	37.6	46.5	4034.5
7	57	58	56.1	37.5	46.8	3909.5
8	68	69	58.1	35.9	47.0	3948.0
9	76	77	59.0	35.1	47.0	3960.5
10	67	68	58.6	35.8	47.2	3865.5
11	70	71	58.6	36.5	47.5	3774.0
12	48	49	58.7	36.5	47.6	3789.0
13	55	56	59.3	36.0	47.6	3792.5
14	74	75	58.0	37.6	47.8	3765.0
15	51	52	58.5	37.3	47.9	3720.5
16	50	51	60.1	35.7	48.0	3626.0
17	81	82	58.6	37.8	48.2	3683.0
18	64	65	60.8	35.8	48.3	3618.0
19	58	59	59.8	37.6	48.7	3609.5
20	62	63	60.7	37.1	48.9	3674.0
21	79	80	60.4	37.5	48.9	3572.5
22	52	53	60.6	37.4	49.0	3485.5
23	60	61	60.2	37.7	49.0	3595.5
24	49	50	61.2	37.4	49.3	3440.0
25	56	57	59.1	39.7	49.4	3495.5
26	63	64	62.7	36.8	49.7	3594.0
27	65	66	62.2	37.3	49.8	3349.5
28	66	67	62.4	37.1	49.8	3444.5
29	71	72	61.1	39.0	50.0	3338.0
30	73	74	61.2	39.1	50.2	3334.0
31	75	76	62.8	38.6	50.7	3170.5
32	80	81	62.9	39.2	51.0	3200.5
33	53	54	62.5	39.7	51.1	3163.5
34	54	55	62.5	39.7	51.1	3224.0

MEAN	STANDARD DEVIATION
48.31470588	1.66043666

MINIMUM VALUE	MAXIMUM VALUE
45.40000000	51.10000000

STD ERROR OF MEAN	SUM
0.28476254	1642.7000000

VARIANCE	C.V.
2.75704991	3.437



Statistical Summary of Average Heating Season Maximum Temperature
at Tulsa, OK (1948 - 82)

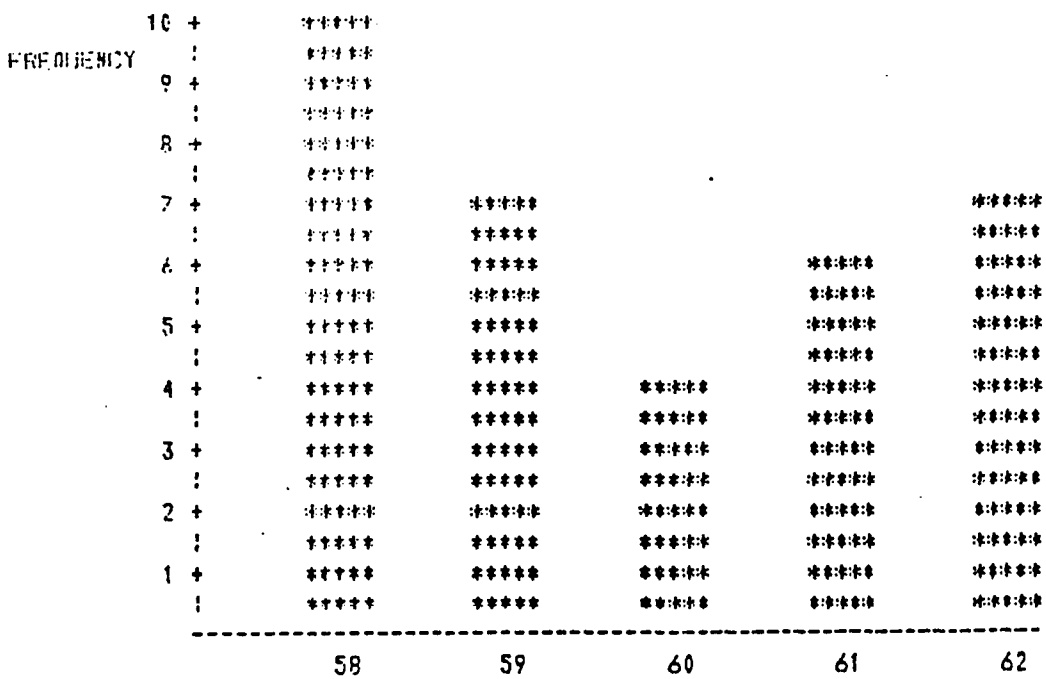
OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	72	73	55.4	37.6	46.5	4034.5
2	77	78	55.8	35.0	45.4	4263.5
3	57	58	56.1	37.5	46.8	3909.5
4	59	60	56.2	35.1	45.7	4146.5
5	61	62	56.6	34.9	45.8	4177.0
6	78	79	56.8	34.7	45.7	4225.5
7	69	70	57.1	35.1	46.1	4115.5
8	74	75	58.0	37.6	47.8	3765.0
9	68	69	58.1	35.9	47.0	3948.0
10	51	52	58.5	37.3	47.9	3720.5
11	67	68	58.6	35.8	47.2	3865.5
12	70	71	58.6	36.5	47.5	3774.0
13	81	82	58.6	37.8	48.2	3683.0
14	48	49	58.7	36.5	47.6	3789.0
15	76	77	59.0	35.1	47.0	3960.5
16	56	57	59.1	39.7	49.4	3495.5
17	55	56	59.3	36.0	47.6	3792.5
18	58	59	59.8	37.6	48.7	3609.5
19	50	51	60.1	35.7	48.0	3626.0
20	60	61	60.2	37.7	49.0	3595.5
21	79	80	60.4	37.5	48.9	3572.5
22	52	53	60.6	37.4	49.0	3485.5
23	62	63	60.7	37.1	48.9	3674.0
24	64	65	60.8	35.8	48.3	3698.0
25	71	72	61.1	39.0	50.0	3338.0
26	49	50	61.2	37.4	49.3	3440.0
27	73	74	61.2	39.1	50.2	3334.0
28	65	66	62.2	37.3	49.8	3349.5
29	66	67	62.4	37.1	49.8	3444.5
30	53	54	62.5	39.7	51.1	3163.5
31	54	55	62.5	39.7	51.1	3224.0
32	63	64	62.7	36.8	49.7	3594.0
33	75	76	62.8	38.6	50.7	3170.5
34	80	81	62.9	39.2	51.0	3200.5

MEAN	STANDARD DEVIATION
59.54705882	2.22849797

MINIMUM VALUE	MAXIMUM VALUE
55.40000000	62.90000000

STD ERROR OF MEAN	SUM
0.38218425	2024.6000000

VARIANCE	C.V.
4.96620321	3.742



Statistical Summary of Average Heating Season Minimum Temperature
at Tulsa, OK (1948 - 82)

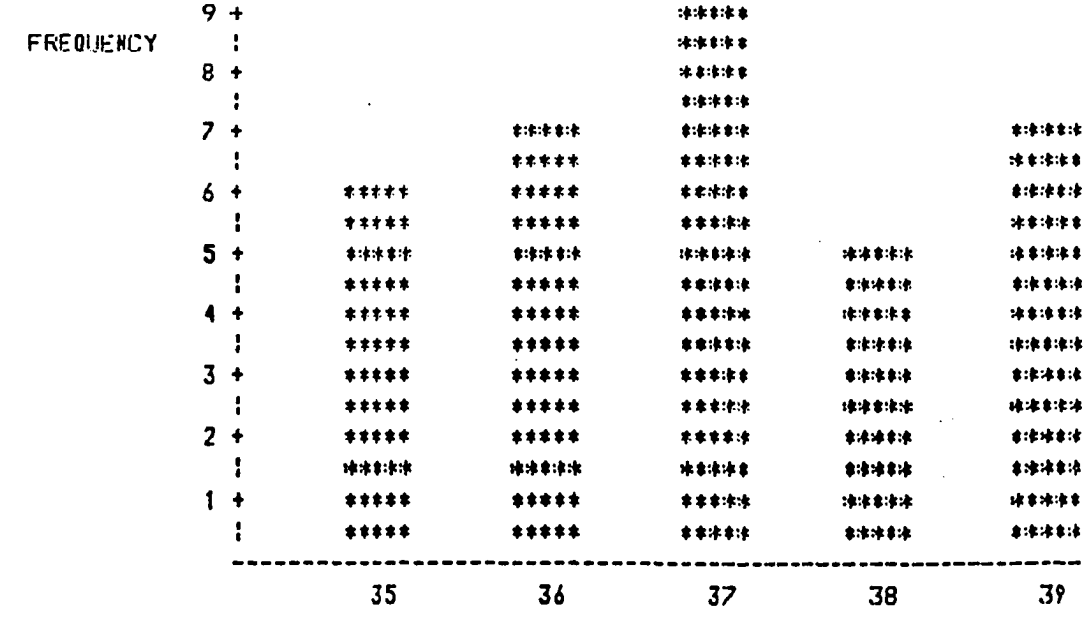
OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	78	79	56.8	34.7	45.7	4225.5
2	61	62	56.6	34.9	45.8	4177.0
3	77	78	55.8	35.0	45.4	4263.5
4	59	60	56.2	35.1	45.7	4146.5
5	69	70	57.1	35.1	46.1	4115.5
6	76	77	59.0	35.1	47.0	3960.5
7	50	51	60.1	35.7	48.0	3626.0
8	64	65	60.8	35.8	48.3	3698.0
9	67	68	58.6	35.8	47.2	3865.5
10	68	69	58.1	35.9	47.0	3948.0
11	55	56	59.3	36.0	47.6	3792.5
12	48	49	58.7	36.5	47.6	3789.0
13	70	71	58.6	36.5	47.5	3774.0
14	63	64	62.7	36.8	49.7	3594.0
15	62	63	60.7	37.1	48.9	3674.0
16	66	67	62.4	37.1	49.8	3444.5
17	51	52	58.5	37.3	47.9	3720.5
18	65	66	62.2	37.3	49.8	3349.5
19	49	50	61.2	37.4	49.3	3440.0
20	52	53	60.6	37.4	49.0	3485.5
21	57	58	56.1	37.5	46.8	3909.5
22	79	80	60.4	37.5	48.9	3572.5
23	58	59	59.8	37.6	48.7	3609.5
24	72	73	55.4	37.6	46.5	4034.5
25	74	75	58.0	37.6	47.8	3765.0
26	60	61	60.2	37.7	49.0	3595.5
27	81	82	58.6	37.8	48.2	3683.0
28	75	76	62.8	38.6	50.7	3170.5
29	71	72	61.1	39.0	50.0	3338.0
30	73	74	61.2	39.1	50.2	3334.0
31	80	81	62.9	39.2	51.0	3200.5
32	53	54	62.5	39.7	51.1	3163.5
33	54	55	62.5	39.7	51.1	3224.0
34	56	57	59.1	39.7	49.4	3495.5

MEAN	STANDARD DEVIATION
37.08235294	1.48251845

MINIMUM VALUE	MAXIMUM VALUE
34.70000000	39.70000000

STD ERROR OF MEAN	SUM
0.25424982	1260.8000000

VARIANCE	C.V.
2.19786096	3.998



Statistical Summary of Average Heating Season Total Heating Degree Days at Tulsa, OK (1948 - 82)

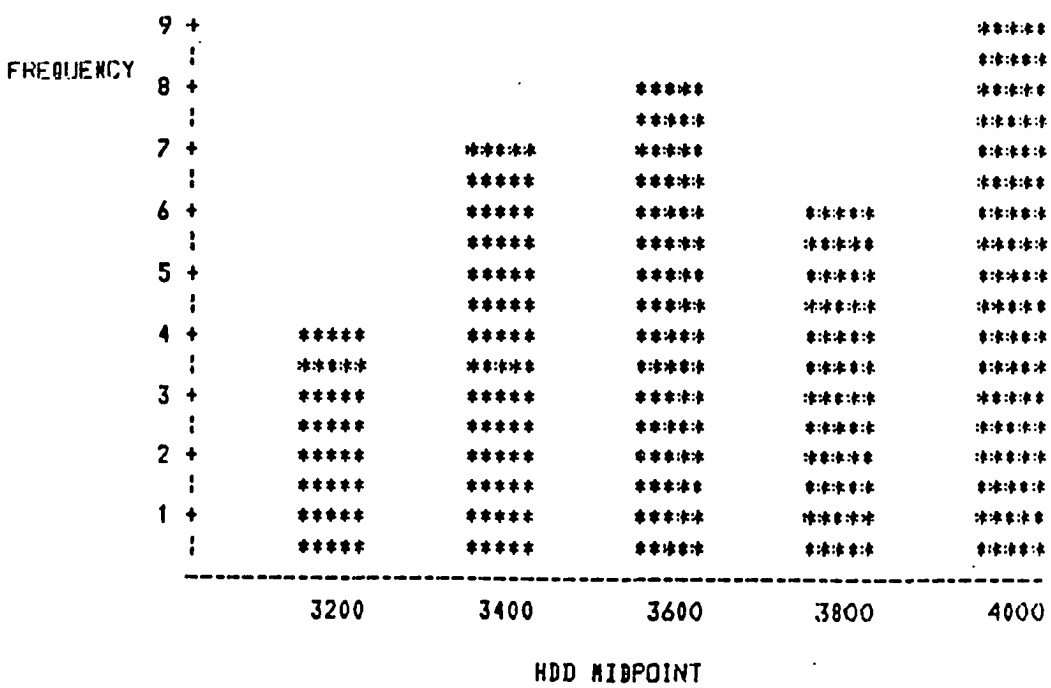
OBS	YEAR1	YEAR2	MAX	MIN	MEAN	HDD
1	53	54	62.5	39.7	51.1	3163.5
2	75	76	62.8	38.6	50.7	3170.5
3	80	81	62.9	39.2	51.0	3200.5
4	54	55	62.5	39.7	51.1	3224.0
5	73	74	61.2	39.1	50.2	3334.0
6	71	72	61.1	39.0	50.0	3338.0
7	65	66	62.2	37.3	49.8	3349.5
8	49	50	61.2	37.4	49.3	3440.0
9	66	67	62.4	37.1	49.8	3444.5
10	52	53	60.6	37.4	49.0	3485.5
11	56	57	59.1	39.7	49.4	3495.5
12	79	80	60.4	37.5	48.9	3572.5
13	63	64	62.7	36.8	49.7	3594.0
14	60	61	60.2	37.7	49.0	3595.5
15	58	59	59.8	37.6	48.7	3609.5
16	50	51	60.1	35.7	48.0	3626.0
17	62	63	60.7	37.1	48.9	3674.0
18	81	82	58.6	37.8	48.2	3683.0
19	64	65	60.8	35.8	48.3	3698.0
20	51	52	58.5	37.3	47.9	3720.5
21	74	75	58.0	37.6	47.8	3765.0
22	70	71	58.6	36.5	47.5	3774.0
23	48	49	58.7	36.5	47.6	3789.0
24	55	56	59.3	36.0	47.6	3792.5
25	67	68	58.6	35.8	47.2	3865.5
26	57	58	56.1	37.5	46.8	3909.5
27	68	69	58.1	35.9	47.0	3948.0
28	76	77	59.0	35.1	47.0	3960.5
29	72	73	55.4	37.6	46.5	4034.5
30	69	70	57.1	35.1	46.1	4115.5
31	59	60	56.2	35.1	45.7	4146.5
32	61	62	56.6	34.9	45.8	4177.0
33	78	79	56.8	34.7	45.7	4225.5
34	77	78	55.8	35.0	45.4	4263.5

MEAN	STANDARD DEVIATION
3681.91176471	312.71590046

MINIMUM VALUE	MAXIMUM VALUE
3163.5000000	4263.5000000

STD ERROR OF MEAN	SUM
53.63033448	125185.00000

VARIANCE	C.V.
97791.234403	8.493



Appendix I

SAMPLE OUTPUT FOR ROOM 1, JANUARY 1-2, 1955 AT ALTUS, OKLAHOMA.

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CONGRATULATIONS## NOW YOU ARE ON NBSLD

WE ASSUME YOU HAVE ALREADY PREPARED THE DATA
ON NBS DATA FORMS..IF YOU HAD NOT ,PLEASE TURN OFF
THE TERMINAL AND HAVE YOUR DATA READY ON THE DATA FORMS

RUNID,RUNTYP,ASHRAE,IDETAL,METHOD
RUNID.........IDENTIFICATION OF THE RUN
              1 NEED RESPONSE FACTOR DATA
              2 SKIP RESPONSE FACTOR DATA
RUNTYP........TYPE OF RUN
              1 ENERGY CALCULATION ..NEEDS WEATHER TAPE
              2 DESIGN LOAD CALCULATION
              3 DESIGN AND ENERGY LOAD CALCULATIONS
ASHRAE........0   USE RMTMP
              1   USE ASHRAE WEIGHTING FACTORS
IDETAL........0   NO DETAILED OUTPUT
              1   DETAILED OUTPUT
METHOD........0   REGULAR TREATMENT FOR THE RCOM
..............1   SPECIAL TREATMENT OF THE ROOM
  TYPICAL OKLAHOMA CITY HOME
LIGHTING SCHEDULE FOR WEEKDAYS
EQUIPMENT USAGE SCHEDULE FOR WEEKDAYS
OCCUPANCY SCHEDULE FOR WEEKDAYS
LIGHTING SCHEDULE FOR WEEKEND
EQUIPMENT SCHEDULE FOR WEEKENDS
OCCUPANCY SCHEDULE FOR WEEKEND
LIGHTING SCHEDULE FOR THE VACATION PERIOD
EQUIPMENT USAGE SCHEDULE FOR THE VACATION PERIOD
OCCUPANCY SCHEDULE FOR THE VACATION PERIOD
THERMOSTAT SETTING FOR THE COOLING SEASON
THERMOSTAT SETTING FOR THE HEATING SEASON
RMDBWO,RMDBSO,RHW,RHS
DATA SHEET NO 1:NDAY,NSKIP,TAPE2
DATA SHEET NO 2 +3 :MONTH,DAY,ELAPS,DBMAX,RANGE,WBMAX,
DATA SHEET NO 4: NAME OF THE ROOM
DATA SHEET NO 5:IBOT,ISKIP,INCLUDE
DATA SHEET NO 6:N/L,K,P,C,R
DATA SHEET NO 7: DESCRIPTION OF EACH LAYER
```

WALL COMPOSITION

LAYER NO	L(I)	K(I)	(I)	C(I)	RES(I)	DESCRIPTION OF LAYERS
1	0.031	0.120	50.00	0.260	0.0	3/8" SHEET ROCK
2	0.0	0.0	0.0	0.0	0.91	AIR SPACE
3	0.0	0.0	0.0	0.0	0.08	BUILDING PAPER
4	0.330	0.770	125.00	0.220	0.0	4" BRICK FACING

TIME INCREMENT DT= 1.

THERMAL CONDUCTANCE U= 0.596

RESPONSE FACTORS

J	X	Y	Z
0	1.0445	0.0774	-5.1746
1	-0.3968	1.2599	-3.2694
2	-0.0283	0.1423	-0.7207
3	-0.0127	0.0641	-0.3234
4	-0.0057	0.0289	-0.1456

COMMON RATIO CR=0.44975

DATA SHEET NO 7: DESCRIPTION OF EACH LAYER

IRF= 2

WALL COMPOSITION

LAYER NC	L(I)	K(I)	(I)	C(I)	RES(I)	DESCRIPTION OF LAYERS
1	0.031	0.120	50.00	0.260	0.0	3/8" GYPSUM BOARD
2	0.0	0.0	0.0	0.0	0.91	AIR SPACE
3	0.031	0.120	50.00	0.260	0.0	3/8" GYPSUM BOARD

TIME INCREMENT DT= 1.

THERMAL CONDUCTANCE U= 0.701

RESPONSE FACTORS

J	X	Y	Z
0	1.0398	0.6368	1.0398
1	-0.3388	-0.0642	-0.3388
2	0.0	0.0	0.0
3	0.0	0.0	0.0

COMMON RATIO CR=0.0

DATA SHEET NO 7: DESCRIPTION OF EACH LAYER

IRF= 3

WALL COMPOSITION

LAYER NC	L(I)	K(I)	(I)	C(I)	RES(I)	DESCRIPTION OF LAYERS
1	0.031	0.120	50.00	0.260	0.0	3/8" SHEET ROCK
2	0.333	0.021	1.50	0.170	0.0	4" BLOWN INSULATION
3	0.0	0.0	0.0	0.0	0.91	CEILING AIR-SPACE
4	0.021	0.067	34.00	0.290	0.0	1/4" PLYWOOD
5	0.010	0.024	70.00	0.300	0.0	ASPHALT SHINGLES

TIME INCREMENT DT= 1.

THERMAL CONDUCTANCE U= 0.050

RESPONSE FACTORS

J	X	Y	Z
0	0.4939	0.0295	0.4793
1	-0.4274	0.0265	-0.4207
2	-0.0002	0.0004	-0.0013
3	-0.0000	0.0000	-0.0000
4	-0.0000	0.0000	-0.0000

COMMON RATIO CR=0.00581

DATA SHEET NO 7: DESCRIPTION OF EACH LAYER

IRF= 4

WALL COMPOSITION

LAYER NO	L(I)	K(I)	(I)	C(I)	RES(I)	DESCRIPTION OF LAYERS
1	0.125	0.067	2.00	0.330	0.0	CARPET(1.5" + 1/2" PAD)
2	0.333	1.000	140.00	0.200	0.0	4" HW CONCRETE SLAB
3	0.167	0.015	2.20	0.200	0.0	2" RIGID INSULTATION

TIME INCREMENT DT= 1.

THERMAL CONDUCTANCE U= 0.075

RESPONSE FACTORS

J	X	Y	Z
0	0.5283	0.0005	0.1136
1	-0.0605	0.0035	-0.0257
2	-0.0246	0.0044	-0.0033
3	-0.0228	0.0041	-0.0008
4	-0.0214	0.0039	-0.0007
5	-0.0201	0.0036	-0.0007

COMMON RATIO CR=0.93769

DATA SHEET NO 8: ROOMNO,QLITY,QEQPY,QCH,FLCG,ERAS,TS,CFMV,ARCHGS

~~DATA SHEET NO 9: IW,IL,TUL,TLL,QCMAX,QHMAX,ITHSI,ITK~~

DATA SHEET NO 10: NS,NW,NN,NE,L,W,H

DATA SHEET 11 AND 12: ROOM SURFACE DATA AND EXTERIOR SURFACE SHADOW

ROOMNO	HT	AG	NOFLR	QCH	ARCHGS	ARCHGW
1.0	10.0	837.0	1.0	3.0	0.6	1.0

LAT	LONG	TZN	ZNORM
35.4	97.6	6.0	1.0

QLITY	QEQPY	CFMV	DBIN	TS	TV	WBIN
1.7	1.2	10.0	72.0	52.0	65.0	63.0

NEXP	ITK	ITHST
9	0	0

DATA SHEET NO 13: UENDW,UCEILNG,AENDW,ATCHT,AIRCHG,AIRWT

DATA SHEET NO 14: IEXTSD,IEXMS,ISXME,NTVNT,NVENT

UENDW	UCEILNG	AENDW	ATCHT
2.1	0.2	186.0	6.0

SURFACE NO	ITYPE	INT	IRF	ABSP	U	H	A	WAZ	SHADE
1	1	1	3	0.89	0.05	6.00	675.00	0.0	0.1
2	2	1	1	0.70	0.40	6.00	220.00	0.0	0.1
3	3	-1	10	0.0	0.87	6.00	12.00	0.0	1.0
4	2	1	1	0.70	0.40	6.00	180.00	90.00	0.1
5	3	-1	10	0.0	0.87	6.00	24.00	90.00	1.0
6	6	1	2	0.0	0.47	0.0	180.00	180.00	0.1
7	6	1	2	0.0	0.47	0.0	210.00	-90.00	0.1
8	2	1	1	0.70	0.40	6.00	60.00	-90.00	0.1
9	5	1	4	0.0	0.07	0.0	837.00	0.0	0.1

SHADOW CASTING DATA

HT	FL	FP	AW	BWL	BWR	D	FP1	A1	B1	C1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	4.0	2.0	3.0	8.0	8.0	0.3	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	4.0	2.0	3.0	10.5	10.5	0.3	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RADIATION INTERCHANGE FACTORS

SURFACE	1	2	3	4	5	6	7	8
1	0.0	0.089	0.005	0.072	0.010	0.073	0.084	0.024
2	0.337	0.0	0.0	0.076	0.010	0.056	0.089	0.025
3	0.337	0.0	0.0	0.076	0.010	0.056	0.089	0.025
4	0.333	0.093	0.005	0.0	0.0	0.076	0.055	0.016
5	0.333	0.093	0.005	0.0	0.0	0.076	0.055	0.016
6	0.337	0.069	0.004	0.076	0.010	0.0	0.089	0.025
7	0.333	0.093	0.005	0.048	0.006	0.076	0.0	0.0
8	0.333	0.093	0.005	0.048	0.006	0.076	0.0	0.0
9	0.535	0.089	0.005	0.072	0.010	0.073	0.084	0.024

CLIMATIC DATA FOR DAY= 1
DAYS ELAPSED SINCE JAN 1= 1 YEAR= 55 MONTH= 1 DAY= 1
LIV IRG IOCR

SOLAR DATA (QSUN/QGLASS)

1	0.	0.	0.	0.	0.	0.	0.	0.	48.	96.	136.	157.	160.	145.	112.	66.	14.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	-0.	-0.	-0.	-0.	-0.	-0.	-0.	8.	101.	152.	183.	200.	202.	190.	163.	120.	44.	-0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	13.	117.	180.	219.	240.	243.	228.	194.	140.	50.	0.
4	0.	0.	0.	0.	0.	0.	0.	1.	8.	13.	16.	18.	37.	86.	122.	132.	70.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	1.	10.	16.	19.	22.	22.	76.	139.	157.	84.	0.
6	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
8	0.	0.	0.	0.	0.	0.	0.	16.	125.	130.	100.	54.	19.	17.	14.	10.	3.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROOM NAME= LIVING ROOM				MONTH= 1
DAY	MHR QLMAX	CLDAY	HLDAY	DBA
1	5 8887.	-4682.	109654.	44.5

DBA = 44.54
QLDSUM = 104972.

TOTAL COOLING CONSUMPTION PER DAY = -4682. BTU
TOTAL HEATING CONSUMPTION PER DAY = 109654. BTU
TOTAL COOLING CONSUMPTION FOR THE ROOM OVER THE 1 DAY PERIOD =-.46821E+04 BTU
TOTAL HEATING CONSUMPTION FOR THE ROOM OVER THE 1 DAY PERIOD =0.10965E+06 BTU

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TOTAL COOLING CONSUMPTION PER DAY =          0. BTU
TOTAL HEATING CONSUMPTION PER DAY =     100383. BTU
TOTAL COOLING CONSUMPTION FOR THE ROOM OVER THE   2 DAY PERIOD =-.46821E+04 BTU
TOTAL HEATING CONSUMPTION FOR THE ROOM OVER THE   2 DAY PERIOD =0.21004E+06 BTU
MAX COOLING LOAD =          0. MONTH =  0 DAY =  0 HOUR =  0
MAX HEATING LOAD =       8887. MONTH =  1 DAY =  1 HOUR =  5
TOTAL COOLING CONSUMPTION FOR   1 ROOMS =-.46821E+04 BTU
TOTAL HEATING CONSUMPTION FOR   1 ROOMS =0.21004E+06 BTU
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