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A GENETIC CLIMATIC CLASSIFICATION SYSTEM OF THE COTERMINOUS UNITED STATES AS PORTRAYED BY MEAN MONTHLY TEMPERATURE-PRECIPITATION CLIMOGRAPHS

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CHAPTER I

BACKGROUND AND STATEMENT OF PROBLEM

Background

Numerous climatic classification systems have been devised in the past to reveal broadscale climatic patterns, the bulk of which were empirical and descriptive in nature. Problems encountered in these various climatic systems are intrinsic in any attempt to classify phenomena over the earth's surface. According to Trewartha, a classification system consists of recognizing individuals with certain important characteristics in common and grouping them into a few classes or types to introduce simplicity and order.[1] However, over the physical landscape, abrupt changes or steep gradients of climatic elements may not occur, and, consequently, the position of class boundary lines is many times questionable.

Phenomena that are near class boundaries in one class may have just as strong of an affinity to be assigned to an adjacent class. To

[1]Glenn T. Trewartha, An Introduction to Climate (4th ed.; New York: McGraw-Hill Book Company, 1968), p. 238.

alleviate this problem objective, numerical methods of classification can be employed. According to Steiner, a genuine and rational climatic classification system should not be influenced by external factors, e.g., changes in natural vegetation.[2] Although Köppen was first to quantify climatological facts to be used in a climatic classification system, much criticism ensued due to his subjective decisions. Köppen's primary purpose was to devise a climatic classification system that would be used primarily as a pedagogic tool and to fulfill this usefulness, it was necessary to formulate a relatively simple construct. Furthermore, Köppen maintained that the development of a climatic system cannot simulate the real world climates to a high degree since "...that classification must proceed with those climate elements for which observations are available..."[3] In his earliest publications, class boundaries were dictated almost entirely on plant-geographical origins with temperature representing the only climatic element.[4] In his 1918 publication entitled "Versuch einer Klassification der Klimate, vorzugweise nach ihren Beziehungen zur Pflanzenwelt," climatic classes and boundaries were based more on the climatic elements of temperature and precipitation and less on plant-geographical origins, but the organic world was still strongly reflected in his work as evident from

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[2]Dieter Steiner, "A Multivariate Statistical Approach to Climatic Regionalization and Classification," Tijdschrift van het Koninklijk Nederlandsch Aardrijkskundig Genootschap, LXXXII, No. 4 (October, 1965), 329.

[3]Arthur A. Wilcock, "Köppen After Fifty Years," Annals of the Association of American Geographers, LVIII (March, 1968), 21.

[4]*Ibid.*, p. 20.

the E2 Penguin climate.[5] This subjectiveness persisted throughout Köppen's lifelong work at classifying climates. One such example was his placement of the C/D boundary which he himself changed several times. Köppen, after much consideration, decided on a -3°C isotherm to represent the position of this boundary. It was to coincide with the equatorward limit of frozen ground and snow cover lasting for 30 days or more for the coldest month. However, subsequent research by Russell revealed that a 0°C isotherm was better suited for use in the United States.[6] On the other hand, Gorczynski strongly urged a -5°C isotherm as the best C/D boundary value in Europe.[7] Due to Köppen's subjectiveness and his use of external factors for the placement of class boundaries, numerous authors were dissatisfied with his system and attempts of clarification, modification, and amplification have been introduced.[8]

Another problem inherent within classification systems is with regard to the choice of elements and/or combination of elements to be used as criteria.[9] Due to Köppen's omission of certain climatic parameters in his climatic classification system, Thornthwaite was a principal advocate for discarding his entire system for a different one. Furthermore, he considered it a reproach to geographers that they should continue to use Köppen.[10] One of Thornthwaite's major efforts to improve

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[5]Ibid., p. 16.

[6]Ibid., p. 15.

[7]Ibid.

[8]Ibid., p. 13.

[9]Steiner, op. cit., p. 329.

[10]Wilcock, op. cit., p. 17.

on the Köppen classification was his empirical derivation of precipitation effectiveness (P-E) and temperature efficiency (T-E) indices. These were incorporated into his climatic classification system that was published in 1931.[11] Subsequently, a world map of climatic regions in 1933 was published utilizing these indices.[12] In his 1948 publication he included potential evapotranspiration as a climatic element.[13] This was looked upon as a step forward insofar as climatological research is concerned, but he drew considerable criticism. Since he was limited to observational data, air temperature was used as a surrogate for evapotranspiration. It has been revealed that radiation is more important than air temperature in promoting evapotranspiration and that the relationship between air temperature and evapotranspiration differs widely for varying climates.[14] Ironically, Thornthwaite has also been criticized for the omission of certain meteorological elements in his climatic classification system.[15]

Another problem encountered in a classification system is the difficulty in linking the static and dynamic aspects of climate.[16]

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[11] C. Warren Thornthwaite, "The Climates of North America According To A New Classification," Geographical Review, XXI (1931), 633-655.

[12] C. Warren Thornthwaite, "The Climates of the Earth," Geographical Review, XXIII (1933), 433-440.

[13] C. Warren Thornthwaite, "An Approach Toward a Rational Classification of Climates," Geographical Review, XXXVIII (1948), 55-94.

[14] Jen-hu Chang, "An Evaluation of the 1948 Thornthwaite Classification," Annals of the Association of American Geographers, XXXXIX (March, 1959), 25.

[15] Ibid., p. 25.

[16] Steiner, op. cit., p. 329.

Dynamic and synoptic climatologists use characteristic flow patterns, air masses, and frontal frequencies in an attempt to typify the behavior of the atmosphere.[17] This type of climatology can be useful to the geographer as well as the meteorologist. According to Borchert, mappable climatic boundary zones and regional differences in climate must be generated in the moving atmosphere. By means of this approach, significant climatic parameters may well be uncovered to strengthen both the static and dynamic approach.[18]

The above-mentioned problems and others exist in either a deductive, genetic approach to classifying climates or the inductive, empirical approach. In genetic climatic classifications, boundary lines are positioned to group climatic elements with respect to causative factors; the empirical approach relies on observations and experience.[19] These two approaches are valued differently among climatologists. Strahler views the genetic approach as one which underlies the fundamental principle of scientific classification which usually produces better results.[20] Conversely, Trewartha believes that the empirical method is basic to good climatic classification and that the genetic approach cannot adequately detail the complexity of climatic patterns over the earth.[21]

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[17]F. Kenneth Hare, "Dynamic and Synoptic Climatology," Annals of the Association of American Geographers, XXXV (June, 1955), 162.

[18]John R. Borchert, "Regional Differences in the World Atmospheric Circulation," Annals of the Association of American Geographers, XXXXIII, No. 1 (March, 1953), 14.

[19]Glenn T. Trewartha, op. cit., p. 242.

[20]Arthur N. Strahler, Physical Geography (3rd ed.; New York: John Wiley and Sons, Inc., 1969), p. 222.

[21]Trewartha, op. cit., p. 242.

Oliver, in his recent article on a genetic approach to climatic classification, advocates a dynamic, genetic approach which hopefully will conform more readily with related physical systems.[22] This classification system should be of special interest to the geographer since climate is an important control in the distribution of many physical and cultural phenomena, and, as Chang states, facilitation in recognition of spatial relationships of climatic patterns with other physical phenomena is a primary purpose for a climatic classification which is geared to the geographer.[23]

It is the contention of this author that an objective, numerical genetic climatic classification system with limited regional divisions which include both static and dynamic climatic controls can be developed. Since each of these regions include climatological stations with similar mean monthly temperature and precipitation values which should cluster together apart from other stations, characteristic temperature-precipitation climographs can portray these regions as climatic types. The different configurations of these mean climographs are attributed to different combinations and intensities of climatic controls operating over the earth's surface. If these climatic controls and their intensities are revealed through numerical multivariate techniques, understanding of causes which produce climatic regions over an area is advanced. Also, as was Köppen's purpose, this system will be of import pedagogically. The student could relate climatic regions to other

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[22]John E. Oliver, "A Genetic Approach to Climatic Classification," Annals of the Association of American Geographers, LX, No. 4 (December, 1970), 615.

[23]Chang, *op. cit.*, p. 30.

physical systems with a knowledge of causative factors, i.e., climatic controls which produce a climatic region.

Difficulty in devising a genetic climatic classification arises not only through coping with the above-mentioned problems but also due to the complex interaction of climatic controls which produce a climate. Therefore, the monumental task of selecting independent climatic controls which operate together and produce a climate based on principal climatic elements which are objectively classified into climatic regions is necessary. Some of these climatic controls are obvious and are mutually recognized by climatologists (see Table 1). Others are more difficult to discern and may be masked by their complex interrelationship with other climatic controls and elements. Furthermore, maps, tables, and graphs of these climatic controls should accompany the climatic regions to aid the student to conceptualize the causative factors responsible for the derived classification system.

Statement of Problem

The problem of this investigation is twofold: firstly, to isolate, identify and analyze salient climatic controls for objectively classified climatic stations which group into discreet regions in the coterminous United States based on mean monthly temperature and precipitation data; secondly, to depict climatic controls most significantly operating within each class to afford a better understanding of the genesis of climatic types from a pedagogic standpoint. Graphically displayed characteristic climographs for each climatic region will aid in visualizing the various kinds of genetic differences which actually exist between these regions since a change in the configuration

TABLE 1

CLIMATIC CONTROLS AND ELEMENTS[a]

Climatic Controls		Climatic Elements
(1) Sun or Latitude		(1) Temperature
(2) Land and Water		(2) Precipitation and Humidity
(3) Semipermanent Low-and High-Pressure Cells	ACTING →	(3) Air Pressure
(4) Wind and Air Masses	UPON	(4) Winds
(5) Altitude		PRODUCE
(6) Mountain Barriers		↓
(7) Ocean Currents		Types and Varieties of
(8) Storms		Weather and Climate

[a]Glenn T. Trewartha, An Introduction to Climate (3rd ed.; New York: McGraw-Hill Book Company, Inc., 1954), p. 5.

of this bivariate climograph will reflect a change in one or more climatic controls which spatially influence mean monthly temperature and precipitation at a weather station. This type of climograph is superior to the conventional bar and line graph or other univariate type graphs which depict temperature and precipitation separately.

If the genesis of climatic types can be readily conveyed to students in geography and climatology, the question of why a certain climate exists in a particular locale will be answered satisfactorily, and the impression of broad climatic patterns will be more easily grasped.

It is therefore hypothesized that the interplay of a distinct combination and intensity of climatic controls will determine a peculiar climatic type as characterized by a representative mean monthly temperature-precipitation climograph. The validity of the above hypothesis can be verified if the following procedures are carried out successfully.

1. Mean monthly temperature and precipitation for various climatic stations in the coterminous United States have been objectively clustered which will yield a distinctive climatic type for those stations which enter into a cluster and are represented by a characteristic mean monthly temperature-precipitation climograph.

2. Independent principal climatic controls which prevail at all selected climatic stations have been discerned from the total mix of variables that may conceivably be of genetic import in producing the various characteristic climographs.

3. Climatic controls have been depicted for each climatic

type so that deeper insight into the physical basis of climatic regions is afforded.

4. Discriminant functions from mean monthly temperature and precipitation have been computed to facilitate further classification of additional climatic stations to the a priori climatic classes.

CHAPTER II

STATEMENT CONCERNING DATA CHARACTER AND METHODOLOGY USED IN ANALYSIS

If a useful genetic climatic classification system is to be developed both as a device to further climatological analysis and as a pedagogic tool, meaningful measurement characteristics of primary climatic elements must be used to establish a priori classes. Temperature and precipitation are two such elements that are widely observed and are the basis of many climatic classification systems. Since the climate of an area is frequently depicted by not only mean annual temperature and total annual precipitation but also the annual variation of these two elements, mean monthly temperature and precipitation are used in this investigation.

Data Character

All first-order weather stations were selected within the coterminous United States for this study except where two or more weather stations exist in the same city (see Figure 1) (for listing of stations, see Appendix I). These duplications are where one or more airport sites with weather stations occur in addition to a downtown site. In these instances, an airport site was selected in order to minimize local climatological influences from urban structures. Local Climatological

DISTRIBUTION OF SELECTED FIRST-ORDER WEATHER STATIONS

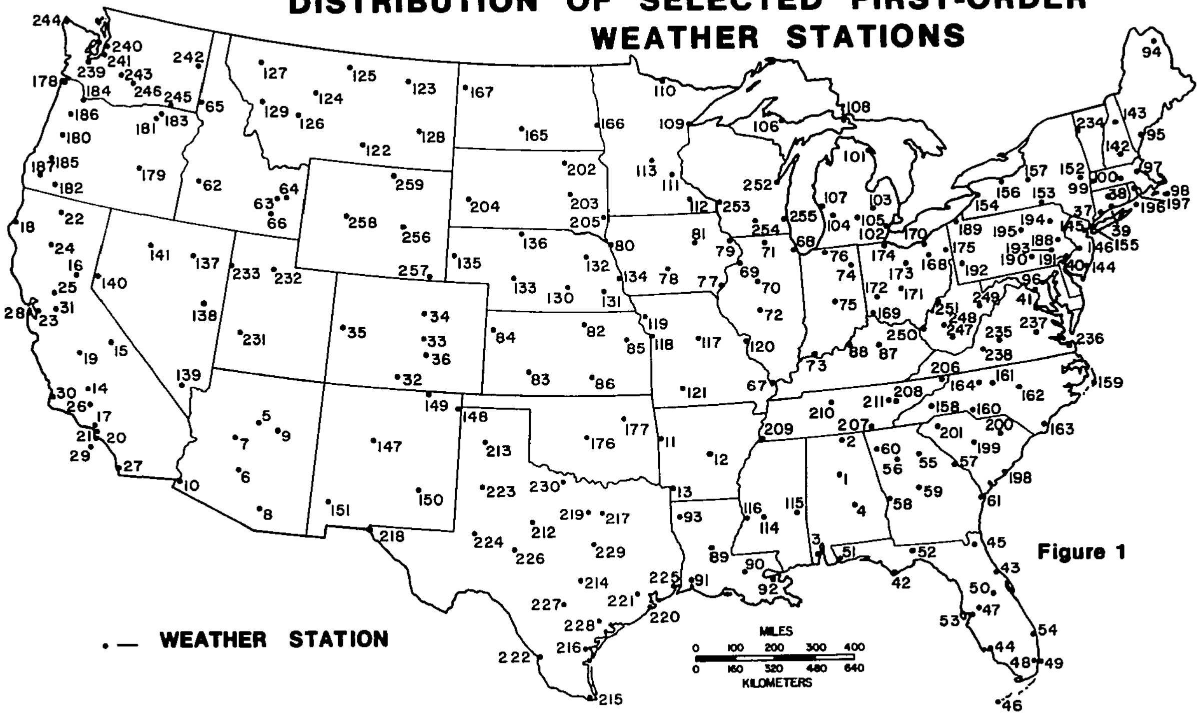

Figure 1

Data, 1964, published by the U. S. Department of Commerce, Weather Bureau, was used for the collection of mean monthly temperatures and precipitation values for the above-mentioned weather stations.[1] Climatological standard normals (1931-1960) were collected. There were no missing data for any of the stations selected. However, a paucity of weather stations is evident in the western part of the United States, particularly the mountain regions (see Figure 1). The twelve mean monthly temperature and precipitation values were punched on IBM cards.

Methodology

Taxonomic Clustering

From all temperature and precipitation data, a preliminary check is necessary to verify an intuitive notion that these data are amenable to a classification technique. According to Ahmand, if "within-group distance or variance is minimized and, by definition, between-group variance maximized", meaningful classes may be developed.[2] Therefore, variation in measured characteristics must exist between station data that are distant from one another and similarity must be present between station data that are near each other. An intercorrelation matrix from sampled groups of stations from various parts of the United States provides insight to this question.

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[1] Local Climatological Data with Comparative Data, U. S. Department of Commerce, Weather Bureau, Asheville, North Carolina, 1964.

[2] R. J. Johnston, "Choice in Classification: The Subjectivity of Objective Methods," Annals of the Association of American Geographers, LVIII, No. 3 (September, 1968), 577.

Another problem arises in a classification of characteristics in terms of the measurement units; temperature and precipitation are not commensurable variables. Therefore, temperature would dominate over precipitation due to the much larger magnitudes involved whereas in reality precipitation, at least in this study, should rank equally with temperature in importance. If one standardizes these data, the unit mean will be zero and the variation of temperature and precipitation for each station is measured in terms of standard deviation ($Z = \frac{x-\mu}{\sigma}$). According to Sneath and Sokal, this standardization of the data would make all character variances equal to unity; therefore, equal weighting of each of the variables when clustering would yield more satisfactory results.[3]

Taxonomic clustering is a multivariate technique for grouping weather stations which have similar mean monthly temperature and precipitation values. By use of a numeric taxonomic system (NTSYS), mean monthly temperature and precipitation values are grouped according to distances from each other in a multi-dimensional space. These mean monthly temperature and precipitation data represent a 24 dimensional space; each variable's distance with respect to all other variables is computed according to the Euclidean distance formula, i.e.,

$$D = \sqrt{(X_{2_1}-X_{1_1})^2 + (Y_{2_2}-Y_{1_2})^2 + \ldots + (Z_{2_{24}}-Z_{1_{24}})^2}.$$

In this distance calculation, all mean monthly temperature and precipitation values are taken into consideration simultaneously. There are various forms of taxonomic clustering. The average linkage clustering

[3]Peter H. A. Sneath and Robert R. Sokal, Numerical Taxonomy (San Francisco: W. H. Freeman and Company, 1973), p. 154.

(UPGMA)[4] is deemed most desirable to use in that it avoids extreme values in the calculations which are typical of other forms of clustering.[5] This ameliorates the climatic classes produced by smoothing any extremely objectionable values brought about by small-scale, local climatological influences.

When temperature and precipitation values are successfully clustered, the number of classes to be used must next be determined. If too few classes are chosen, a lack of distributional information as provided by considerable temperature and precipitation data will result; if too many classes are chosen, the broadscale climatic patterns of the coterminous United States, as intended in this investigation, cannot be revealed. No one particular number of classes is correct. Only through intense scrutiny of various number of classes can an appropriate classification system be decided upon. According to Sneath and Sokal, dendrograms consisting of 100 or more OTUs (Operational Taxonomic Units) should be divided into at least 10 classes.[6] When more than 100 values are used for statistical manipulation, experience and theory indicate that usually between 10 and 20 classes are desirable.[7]

The number of classes is ultimately determined by class boundary decisions. Determination of class boundaries must be made, however, as objectively as possible. According to Sneath and Sokal, the line

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[4]Unweighted Pair-Group Method Using Arithmetic Averages.

[5]Sneath and Sokal, op. cit., p. 228.

[6]Ibid., p. 201.

[7]Paul G. Hoel, Elementary Statistics (New York: John Wiley & Sons, Inc., 1960), p. 9.

delimiting a certain rank must be straight with respect to some one similarity level and not one which bends up and down according to preconceived whims.[8] These straight lines are called phenon lines and are used to group mean monthly temperature and precipitation data in accordance to their average similarity or dissimilarity, weighting each OTU in each cluster equally (see Figure 2). The use of these phenon lines is used to objectively formulate appropriate class boundaries which in turn will ascertain the number of climatic regions to be used in this study.

The above-mentioned decision-making pertaining to the determination of the number of classes used, based on boundary selection, is aided by the use of mean monthly temperature and precipitation climographs constructed for each weather station. Core weather stations within each cluster exhibit similar climograph configurations. As marginal weather stations within each cluster are examined, a gradual change in their climograph configuration is noted. However, the configuration of these climographs should appear more similar to the configurations within the core of its cluster than to the core weather station's climograph of adjacent regions.

Mean monthly temperature-precipitation climographs have been constructed for each weather station by use of a Cal Comp plotter operated by an 1130 IBM computer at The University of Oklahoma. A scale of the abscissa and ordinate was dependent on the width of the paper used for plotting the data and by the range of the data for all selected weather stations in the coterminous United States. Equal

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[8] Sneath and Sokal, _op. cit._, p. 294.

EXAMPLE OF PHENON LINES ON PHENOGRAM OF UPGMA CLUSTERING

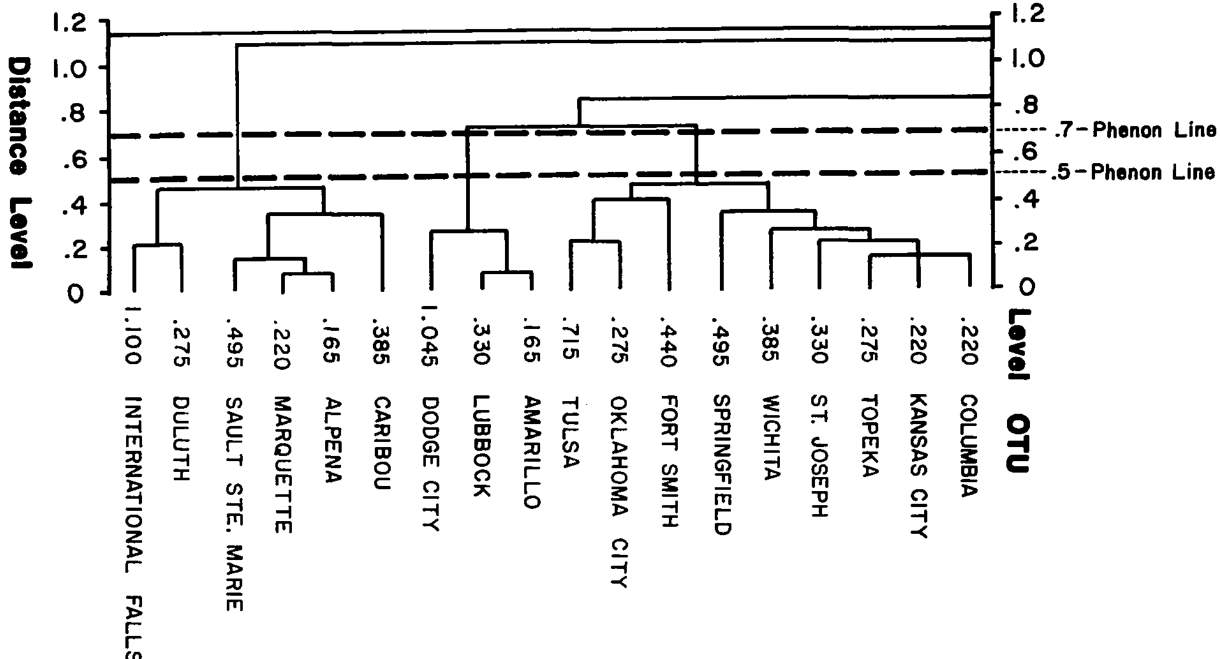

Figure 2

SOURCE: AUTHOR'S CALCULATIONS.

lengths along the abscissa and ordinate were used for every 2 inches of precipitation and 10°F of temperature, respectively (see Figure 3).

Climographs of mean monthly temperature and precipitation convey a considerable amount of information concerning climatic controls operating at any one place for each month of the year. When an objective classification technique is applied to these data, similar configurations and positions of the climographs along the ordinate and abscissa result where congeneric mean monthly temperature and precipitation combinations occur and, most probably, similar climatic controls are in operation, especially where the weather stations are adjacent to each other. The climatic controls responsible for the characteristic mean monthly temperature and precipitation values may then be sought for each group of stations.

Component Factor Analysis

A genetic climatic classification system is ideally based on a number of climatic controls which reflect the origin of climatic types over space. According to Critchfield, explanations are often theoretical, incomplete, and difficult to quantify.[9] Nevertheless, climatologists have attempted to list the numerous climatic controls which affect the magnitude and variability of mean monthly temperature and precipitation which form climatic types at any particular place (see Table 1). Decisions on the number of climatic controls and the degree of interrelationships between these controls vary among climatologists. Some of these controls are static in nature, such as elevation and

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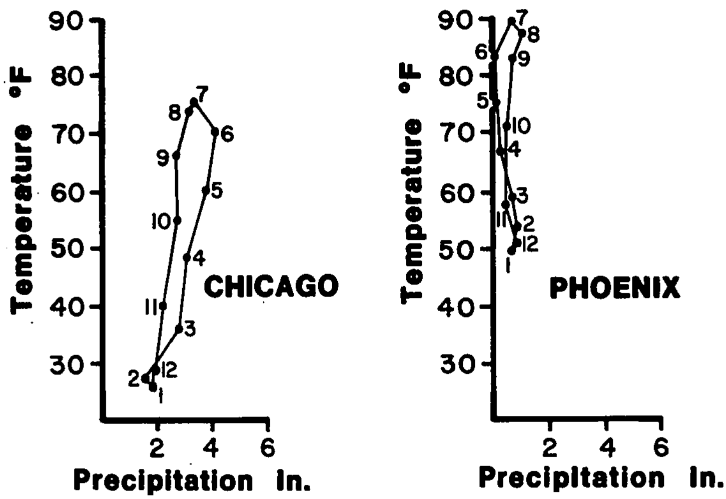
[9]Howard J. Critchfield, General Climatology (3rd ed.; Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1974), p. 142.

EXAMPLE OF WEATHER STATION CLIMOGRAPHS



1 =	JANUARY	7 =	JULY
2 =	FEBRUARY	8 =	AUGUST
3 =	MARCH	9 =	SEPTEMBER
4 =	APRIL	10 =	OCTOBER
5 =	MAY	11 =	NOVEMBER
6 =	JUNE	12 =	DECEMBER

Figure 3

SOURCE: LOCAL CLIMATOLOGICAL DATA WITH COMPARATIVE DATA, 1964.

latitude, while others are dynamic, such as pressure systems and wind fields. Most certainly a number of these controls overlap with each other to a large degree. Naturally, a complete set of climatic controls which thoroughly explains the existence of climate types at any place is desired. But how many climatic controls are there and to what degree do these controls duplicate each other? Clearly, a complete listing of all climatic controls is impossible; however, many of the more genetically significant and obvious climatic controls are mutually recognized.

If most of the variation in the configuration and position along the temperature and precipitation axes of climographs for any weather station's temperature and precipitation data is explained by a few independent and significant climatic controls, a sound genetic climatic classification system can be developed which is useful in climatological analysis and important pedagogically. To accomplish this, several significant climatic controls were defined and operationalized, and, subsequently, a multivariate technique which collapses the total mix of variables to a manageable number of identifiable, significant, and independent climatic controls has been applied. Factor analysis is the multivariate technique which extracts these independent climatic controls from the entire mix of variables. The meaningfulness of this technique is contingent on the variability of the data. According to Rummel, if data have variability that are not random or chance variations, then this type of analysis will delineate meaningful variables, called factors, "of patterned relationships, of underlying order, or of causal uniformities."[10] Also, if tests of statistical significance are

[10]R. J. Rummel, Applied Factor Analysis (Evanston, Illinois: Northwestern University Press, 1970), p. 13.

applied, the data must have a multi-normal frequency distribution or at least must be measured on an interval scale. Finally, factor analysis assumes linearity in the data.[11] The variability of data collected for the selected climatic controls in this investigation is not random or chance variation. The variation of these climatic controls is dictated by the size of the study area, distribution of landforms, general circulation of the atmosphere, latitude, size of water bodies and ocean currents to mention a few of the factors influencing the variation of data collected. Scrutiny of data as they are collected with respect to their distribution over the coterminous United States is one means of verifying this fact. Furthermore, all of these data have been measured on an interval scale and objections raised against mandatory linearity of the data are "the dimensions themselves may involve complex functions of a nonlinear variety," and secondly, the "degree to which these equations reflect "reality" is gauged by the economy with which they order and relate these sensations....The distinction between models need not be based on which is closer to "reality" but on which is able to predict observations with the least bother."[12] With a large number of variables, complexity and confusion through many transformations of these data are a certainty. Therefore, raw data have been used in this factor analysis technique.

There are numerous factor analysis models, each model designed for a specific purpose. Component factor analysis is the model best suited for the purpose of this study. With this model, the total

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[11] Ibid., pp. 17-18.

[12] Ibid.

variance of all variables is taken into account and the untanglement of the interrelationship between climatic controls is performed.[13] For a full discussion of this technique, see Rummel.[14]

Briefly, an intercorrelation matrix of all variables is calculated which represents a matrix of similarity coefficients. Geometrically, these similarity coefficients are represented by vectors in a multi-dimensional space. These vectors are then fitted to two factor axes so as to maximize the sum of squares. Loading values represent the geometric distance of these vectors from the origin of the factor axes. Additional factor axes are positioned in space and residual variance of the variables are loaded on these, thereby reducing the total variation of the original mix of variables.

Since the last factors account for a small amount of variance, part of this representing random error variance, a reduction in the number of climatic controls is accomplished. By factoring these data to the trivial variance, most of the total variation of the data matrix is taken into account.[15] However, just where does this trivial variance begin? There are several methods used in determining this cut-off point in the factoring process. The method used in this study was one whereby all factors with eigenvalues less than one were excluded since none of these factors would account for at least the total variance of one variable.[16] To facilitate the interpretation of the factors, the factor

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[13]Norman H. Nie. et al., SPSS Statistical Package for the Social Sciences (2nd ed.; New York: McGraw-Hill Book Company, 1975), pp. 470-471.

[14]Rummel, op. cit., pp. 1-617.

[15]Ibid., p. 351.

[16]Ibid., p. 362.

axes have been rotated in such a manner so as to position them amidst distinct clusters of vectors which are closely related to each other. Finally, factor scores for each case have been calculated. These scores are interpreted in the same fashion as data on any variable. The strength or weakness of each factor, climatic control, over the coterminous United States can then be assessed.

Discriminant Analysis

Once the significant and independent climatic controls are interpreted and their spatial variability inspected, the problems of how to determine which climatic controls are significant and to what extent they influence either singularly or in combination the determined a priori climatic regions based on mean monthly temperature and precipitation arise. This is a critical phase of research in this study since a genetic climatic classification system requires the knowledge of causes of the distinct climatic types formulated by the NTSYS clustering technique. Discriminant analysis has been used to decide which climatic controls are operating to a large degree in a priori established climatic regions. This technique uses the factors selected from component factor analysis, i.e., the significant, independent climatic controls, as discriminating variables to form one or more linear combinations. These linear combinations are of the form: $Di = d_{i_1}Z_1 + d_{i_2}Z_2 + \ldots + d_{i_p}Z_p$ where d represents weighting coefficients, and Z is the standardized value of the discriminating factors.[17] These functions are then used to maximize the separation of groups. Therefore, a weather station's

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[17]Nie, _et al._, _op. cit._, p. 435.

likelihood of belonging to an already established mean monthly temperature-precipitation climatic region is calculated by means of these discriminant functions.

Actual classification of individual weather stations is achieved by means of classification functions, one for each group. These classification functions are derived "...from the pooled within-groups covariance matrix and the centroids for the discriminating variables."[18] The equations are of the form: $Ci = c_{i_1}V_1 + c_{i_2}V_2 + \ldots + c_{i_p}V_p + c_{i_o}$ where Ci is the classification score per group, c is the classification coefficient (c_{i_o} is the constant), and V is the raw score on the discriminating variable. The coefficients of these classification functions are used to select the most significant climatic controls with respect to classification for each region. For further discussion of this technique, see Nie.[19]

Most stations previously classified will belong to the same class based on these climatic controls. Undoubtedly, there will be a few stations which will not be classified according to the NTSYS clusters. This is to be expected since not all of the variation of the initial 25 climatic controls is included within the factors and, surely, the listing of climatic controls does not include all possible climatic controls.

There are several assumptions or statistical tests related to discriminant analysis. Firstly, a linear discriminant function is most

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[18] Ibid., p. 445.

[19] Ibid., pp. 434-467.

appropriate when the groups' covariance matrices are about equal.[20] However, since many of the groups consisted of fewer weather stations than the total number of groups, this test could not be performed. But according to Nie, this multivariate technique is robust, and this assumption need not be strongly adhered to.[21] Secondly, if the resultant NTSYS clusters have greatly unequal-sized groups, interpretation of classification tables may be difficult. According to Morrison, the effective sample size is governed by the smaller sized group.[22] Due to the uneven distribution of weather stations over the coterminous United States that are used in this study, unequal-sized NTSYS clusters of stations have resulted. Therefore, care in the interpretation of these results for this technique must be used. Thirdly, considerable bias results in the classification procedure if one classifies the same individuals that are used in calculation of the discriminant functions.[23] In this particular calculation, the classification of the weather stations based on climatic controls will not be of prime concern since only the discriminant and classification functions are closely examined to decide which climatic controls are significantly operating in each a priori established climatic class. Finally, there is the assumption of a multivariate normal distribution. Again, according to Nie, since this is a robust technique, this assumption need not be strongly adhered

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[20] David A. Aaker, Multivariate Analysis in Marketing: Theory and Application (Belmont, California: Wadsworth Publishing Company, Inc., 1971), p. 140.

[21] Nie, *et al.*, *op. cit.*, p. 435.

[22] Aaker, *op. cit.*, p. 140.

[23] *Ibid.*

to.[24] In addition, numerous transformations of factor scores would have contributed considerable complexity and confusion to the model. Therefore, raw factor score data have been used.

A stepwise discriminant analysis was deemed the most suitable model to use in this study since the influence of a combination of climatic controls will be considered simultaneously. The climatic control which is the most important discriminator from the total mix is chosen by means of a selection criterion. A second climatic control is then searched out which, in combination with the first climatic control, can discriminate better than any other two climatic controls. These two climatic controls combine with a third climatic control which act in combination as better discriminators than any other three climatic controls and is continued in this manner through all climatic controls selected. If any climatic control does not meet an initial F test, it is eliminated from the group and cannot be subsequently selected. This method reveals the most significant climatic controls operating together which best discriminate between weather stations over the coterminous United States. In this particular case, the Wilks' lambda test, which is the overall multivariate F ratio, is used as the selection criterion. According to Eisenbers and Avery, the size of the Wilks' lambdas can be used to order the climatic controls with respect to their discriminatory power.[25] With small Wilks' lambda values, a great amount of discriminatory power is present in the climatic controls

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[24]Nie, et al., op. cit., p. 435.

[25]Robert A. Eisenbers and Robert B. Avery, Discriminant Analysis and Classification Procedures (Lexington, Massachusetts: Lexington Books, D. C. Heath and Company, 1972), p. 70.

selected. First, the best univariate variable is chosen. Then, the "best" two variable subset, which contains the "best" univariate variable as one of the two, is chosen. This process is continued through the entire set of variables. Therefore, the "best" subset of variables at each stage a variable is entered into the calculations contains the minimum Wilks' lambda value.[26]

Use of Test Weather Stations

If the above-mentioned techniques result in meaningful information, the development of a genetic climatic classification system will be successful since: (1) a priori climatic classes for the coterminous United States based on mean monthly temperature and precipitation will be established; (2) significant and independent climatic controls derived from the same weather stations as used in the development of climatic classes will be selected; and (3) causal information concerning which climatic controls, operating singularly or in combination, are of primary importance, both in the coterminous United States and in each climatic region. Subsequently, maps, graphs, and tables of these most important climatic controls per climatic region are displayed along with characteristic climographs to enhance the pedagogic usefulness of this climatic classification system.

A genetic classification system of this nature will apply to any weather station in the coterminous United States provided that only broadscale climatic controls are of concern and will not be limited to only those weather stations used in this investigation. This system is

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[26] Ibid., p. 74.

not concerned with local or chance influences which may produce an anomalous climatic condition at a weather station.

If discriminant functions are calculated for mean monthly temperature and precipitation for existing weather stations, other test weather stations with known mean monthly temperature and precipitation data can be classified based on the already derived equations. This technique is referred to as the holdout method.[27] These data of unclassified stations do not enter into the calculation of the various functions. After classification is completed, the weather stations are assigned to specific climatic classes and tests the reliability of the a priori regions in which the important climatic controls operating within each region are known.

To verify this fact, 154 test weather stations which were not used in the original NTSYS clustering technique have been selected from core and transitional locations from each climatic region (see Figure 4)[28] (for listing of stations, see Appendix II). Mean monthly temperature and precipitation data (1931-1960) from the test stations were classified by discriminant functions calculated from the 254 first-order weather stations. Most of the test stations were classified correctly in their respective regions. The weather stations not correctly classified occur mainly in transition zones. The size of regions and lack of data points in the determination of regional boundaries contribute to the incorrect classification of those weather stations.

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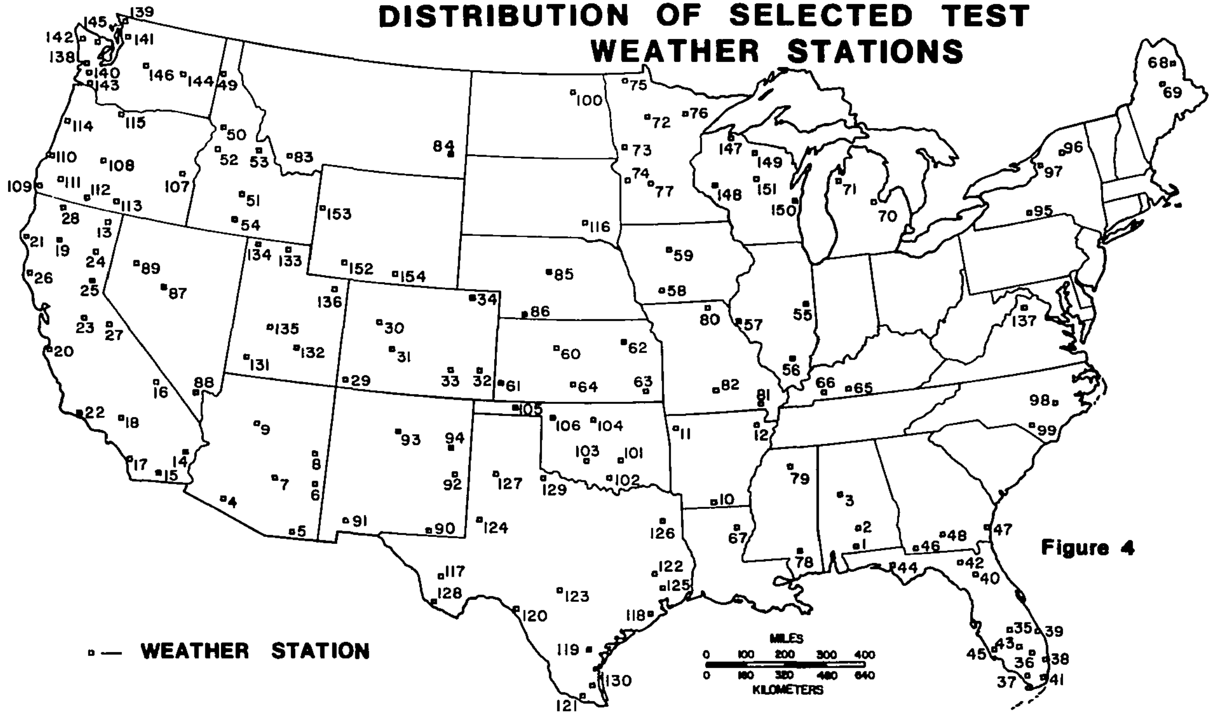
[27] Ibid., p. 21.

[28] Climatography of the United States, No. 81-1 through 81-42, Decennial Census of United States Climate--Monthly Normals of Temperature, Precipitation, and Heating Degree Days, U. S. Department of Commerce, Luther H. Hodges, Secretary, Weather Bureau, F. W. Reichelderfer, Chief, Washington, D.C., 1962.

DISTRIBUTION OF SELECTED TEST WEATHER STATIONS



▫— WEATHER STATION

Figure 4

CHAPTER III

DEFINING AND OPERATIONALIZING CLIMATIC CONTROLS

The following section of this paper defines the climatic controls selected for this investigation. Also, in order for these climatic controls to be used in the component factor analysis, they must be operationalized, i.e., reduced to a form so that they may be entered into calculations. See Table 2 for a listing of those climatic controls which are defined and operationalized in this study.

Latitude

Latitude represents a north-south angular measurement in degrees and minutes over the earth from the equator to either pole. Weather stations selected for this study are within the middle latitudes (see Figure 5). The intensity of solar radiation that is received over the illuminated hemisphere varies as the cosine of the zenith angle of the sun.[1] This variation in the intensity of solar radiation closely approximates the north-south decrease in the mean annual temperature due to earth-sun geometry (see Figure 6).[2] However, it should not be implied that insolation is the sole factor determining the annual course of air

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[1]P. R. Crowe, Concepts in Climatology (New York: St. Martin's Press, 1971), p. 3.

[2]Hans Neuberger and John Cahir, Principles of Climatology (New York: Holt, Rinehart and Winston, Inc., 1969), p. 7.

TABLE 2

CLIMATIC CONTROLS USED IN THIS INVESTIGATION

Static Climatic Controls
(1) Latitude (2) Elevation (3) Continentality (4) Orographic Effect

Dynamic Climatic Controls

Ocean Currents

(5) Ocean Current Effect During January
(6) Ocean Current Effect During July

Sky Cover

(7) Mean Sky Cover
(8) Annual Sky Cover Variability

Wind Velocity

(9) Mean Wind Velocity
(10) Annual Wind Velocity Variability

Cyclones

(11) Total Number of Cyclones
(12) Annual Variability of Cyclones

Anticyclones

(13) Total Number of Cyclones
(14) Annual Variability of Anticyclones

TABLE 2-(Continued)

Pressure System
(15) Mean Annual Pressure
(16) Annual Variability of Pressure
Air Masses
(17) Continental Polar - (cP)
(18) Continental Tropical - (cT)
(19) Maritime Polar - (mP)
(20) Maritime Tropical - (mT)
(21) Continental Polar--Continental Tropical - (cP-cT)
(22) Continental Polar--Maritime Polar - (cP-mP)
(23) Continental Tropical--Maritime Polar - (cT-mP)
(24) Continental Tropical--Maritime Tropical - (cT-mT)
(25) Maritime Polar--Maritime Tropical - (mP-mT)

PARALLELS FOR 5° LATITUDE

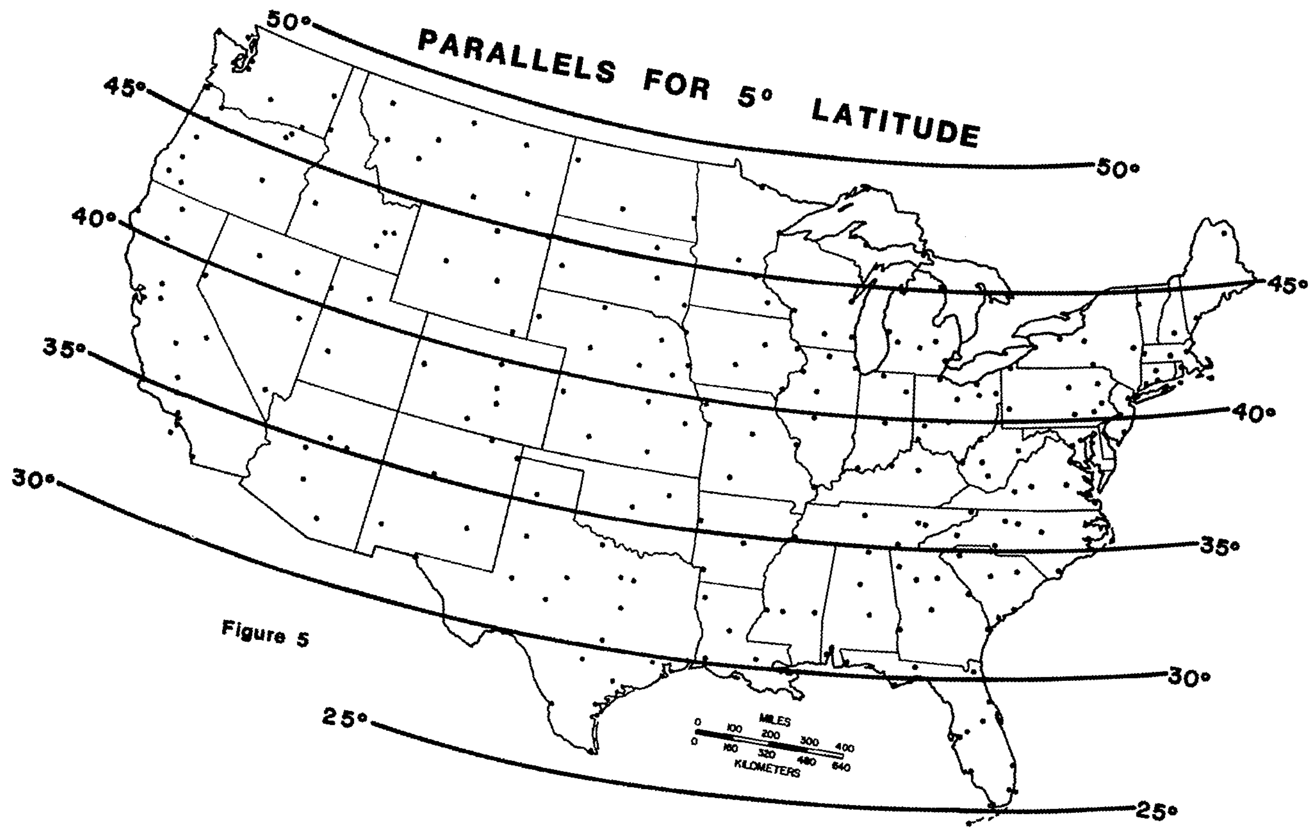

Figure 5

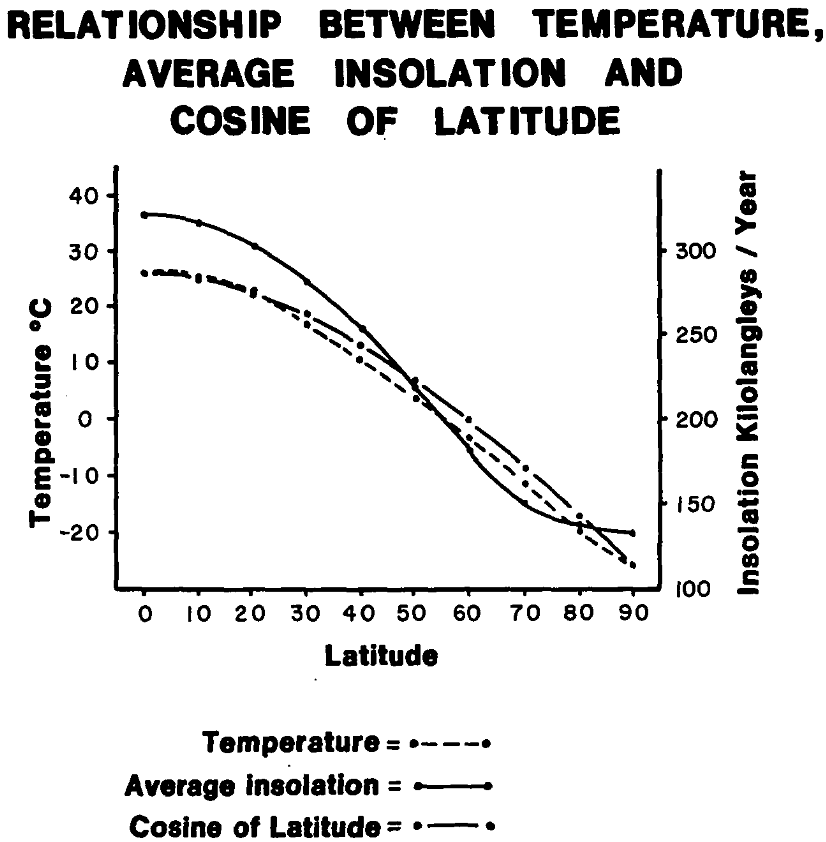

Figure 6

SOURCE: NEUBERGER AND CAHIR, PRINCIPLES OF CLIMATOLOGY, 1969 AND AUTHOR'S CALCULATIONS.

temperature at a weather station.[3] Numerous other factors are intimately involved. But since mean insolation and temperature are highly correlated and their magnitudes decrease similarly as a trigonometric function from the equator to the pole, the cosine of the latitude for each weather station should be a potent factor in explaining the annual march of temperature. Therefore, the cosine of the latitude of each climatic station was used for the first climatic control.

Elevation

Elevation above sea level significantly affects the temperature of a place. Normally, an inverse relationship exists with a decrease in temperature through increasing elevation in the free atmosphere, but large variations in this lapse rate are commonly observed. Temperatures near the surface are considerably influenced by the temperature of the surface itself. Due to the variability of surface materials, the temporal and spatial changes in the vertical temperature near ground level differ markedly from those layers of air aloft. This average decrease in temperature is not only characteristic in the free atmosphere, but also applies to the temperature as measured along sloping terrain.[4] This may not be true over plateaus and over extensive mountain areas, however, due to the lack of ventilation and mixing when winds are light.[5] Since this investigation pertains to only broadscale climatic patterns, a mean lapse rate should be regarded as an important factor

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[3] Crowe, op. cit., p. 18.

[4] Neuberger, op. cit., p. 106.

[5] Ibid.

with respect to the suppression of mean monthly temperatures for stations at higher elevations. This suppression of temperature will generally reflect higher elevations above sea level, especially throughout the western United States (see Figure 7). Therefore, elevation above sea level measured in feet was collected for each weather station.

Continentality

According to Currey "any comprehensive classification of climates can be modified so that all classes of extratropical climates reflect continentality as a classification criterion."[6] This is obviously based on the fact that the earth's surface is made up of land and water with different mean specific heats. Other factors taken into consideration, such as horizontal and vertical movements of water, translucency of water, and evaporation, all result in much different temperature variation characteristics between land and water. The surface temperature of land is much more variable, temporally, compared with water surface temperatures at the same latitude.

According to Stamp, continentality refers to "The climate of extremes, with maximum and minima occurring soon after the summer and winter solstices, respectively," or as "A climate of large daily and annual ranges of temperature as in the interior of a continent.[7] These continentality measurements most commonly include annual range of temperature and latitude of a particular place. Most indices of

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[6]Donald R. Currey, "Continentality of Extratropical Climates," Annals of the Association of American Geographers, LXIV, No. 2 (June, 1974), 270.

[7]John E. Oliver, "An Air Mass Evaluation of the Concept of Continentality," The Professional Geographer, XXII, No. 2 (March, 1970), 83.

ELEVATION ABOVE SEA LEVEL

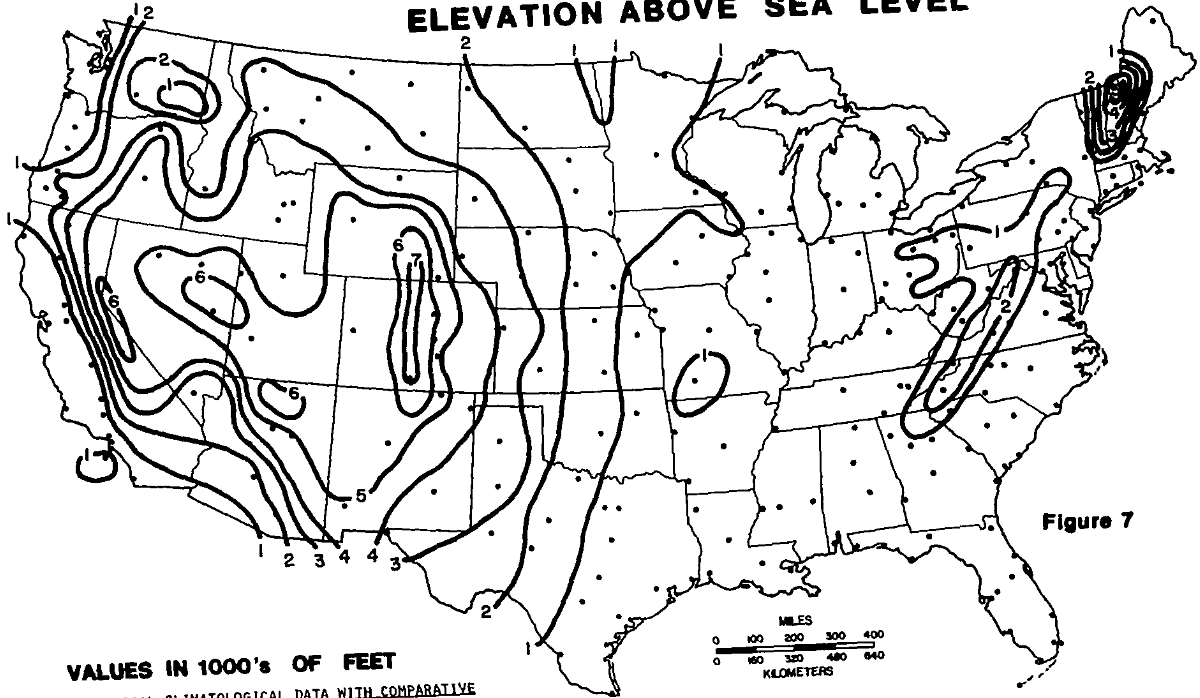

Figure 7

VALUES IN 1000's OF FEET

SOURCE: LOCAL CLIMATOLOGICAL DATA WITH COMPARATIVE DATA, 1964.

continentality are computed from the following general form: $k = MA/\sin\phi + n$, where k is the continentality coefficient in percentage, A is the average annual temperature range, ϕ is the geographic latitude, and M and n are constants.

Oliver has recently proposed a new method for determining continentality which is primarily based on air mass influence on climatic stations. This method was uncovered by plotting monthly temperature and precipitation values for stations on a climograph and extracting air mass dominance from them.[8] His formula has the following form: $c = L \cos A$, where L is the length, in millimeters, of a temperature-precipitation's long axis, and A is the angle of deviation of the long axis from a vertical line. Figure 8 represents the type of nomogram Oliver used. Continentality, therefore, is represented by the long axis on a climograph, which reflects the annual range of temperature, and the angle of deviation from a vertical line is associated with precipitation amounts necessarily brought about by moist air mass intrusions.

Continentality indices from both a conventional method and Oliver's formula were computed for a number of climatic stations in Arizona in a pilot study. The relative indices were similar, and, therefore, either of the two approaches may be used to obtain the necessary data for this climatic control (see Table 3). Since this study uses temperature-precipitation climographs, the Oliver method was chosen for the purpose of conformity, and indices for each of the 259 weather stations were calculated (see Figure 9).

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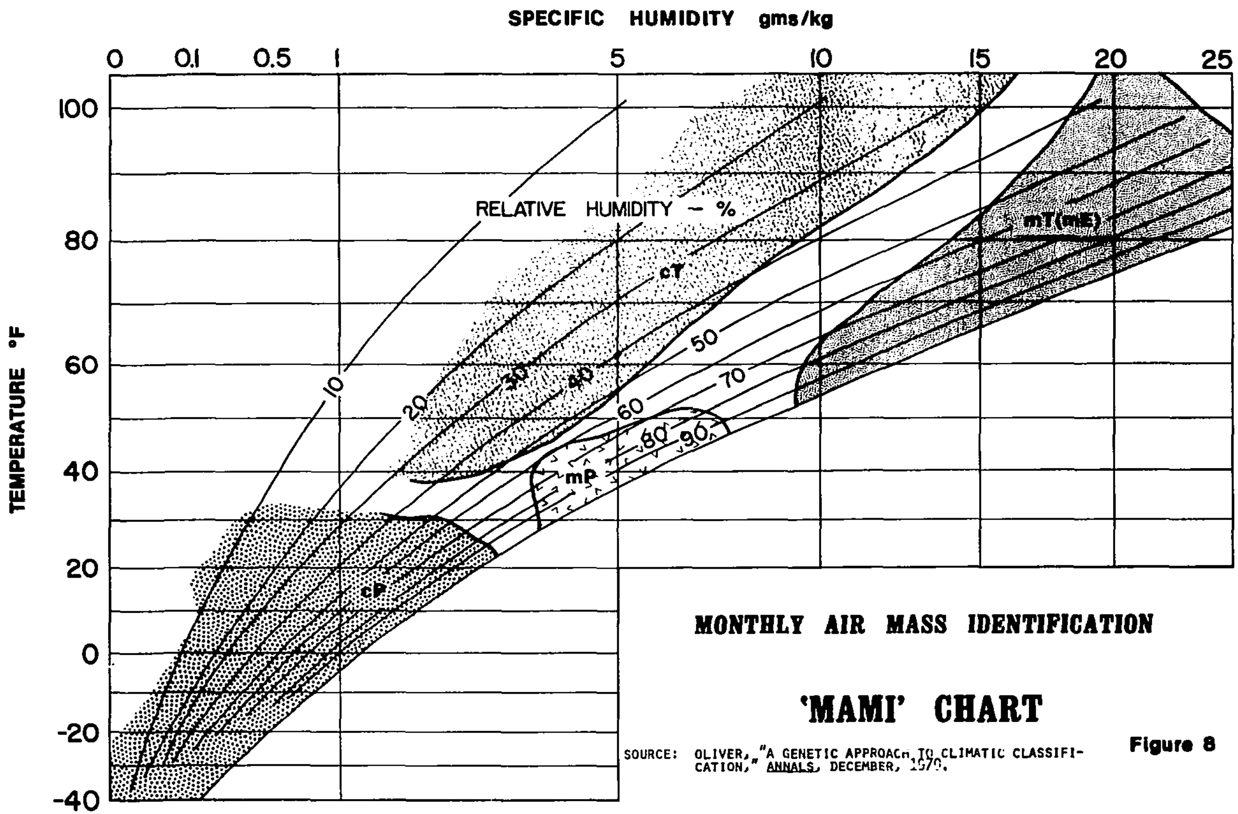
[8] _Ibid._, p. 84.



MONTHLY AIR MASS IDENTIFICATION

'MAMI' CHART

SOURCE: OLIVER, "A GENETIC APPROACH TO CLIMATIC CLASSIFICATION," ANNALS, DECEMBER, 1970.

Figure 8

TABLE 3[a]

CALCULATION OF CONTINENTALITY VALUES BY DIFFERENT METHODS

Sample Arizona Weather Stations	Gorczynski's Continentality Index	Oliver's Continentality Index
Winslow, Arizona	61.3 (1)	9.88 (1)
Phoenix, Arizona	48.5 (2)	8.00 (2)
Yuma, Arizona	47.6 (3)	7.80 (3)
Tucson, Arizona	44.7 (4)	7.29 (4)

Gorczyski's Formula:[b]
$K = (1.7\ A/\sin\phi) - 20.4$
where A is the annual range in temperature (°C),
ϕ is the geographic latitude

Oliver's Formula:[c]
$C = L \cos A$
where L is the length of climograph's long axis,
A is the angle of deviation of long axis from a vertical line.

[a]Source of values - author's calculations.

[b]Source: V. Conrad and L. W. Pollak, Methods in Climatology (Cambridge, Massachusetts: Harvard University Press, 1962), p. 297.

[c]Source: John E. Oliver, "An Air Mass Evaluation of the Concept of Continentality," op. cit., p. 86.

CONTINENTALITY OF THE UNITED STATES
BY USE OF OLIVER'S INDEX

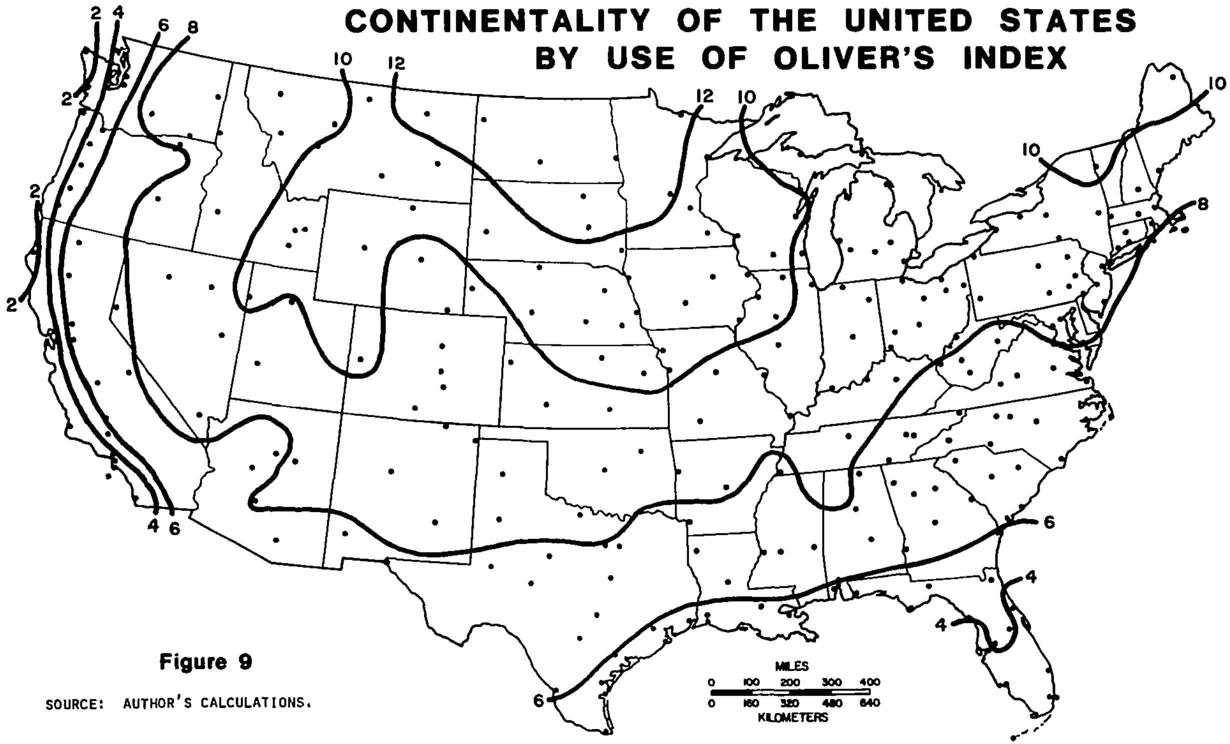


Figure 9

SOURCE: AUTHOR'S CALCULATIONS.

Ocean Currents

The degree of influence that ocean currents exert on adjacent land areas with respect to temperature and precipitation is well-known but difficult to operationalize. Not only must one consider large variations of this influence inland from the coast, but also changes in sea surface temperatures paralleling the coast. These variables are further complicated by varying temperature effects between winter and summer seasons. A warm current will moderate temperatures along a coast to a larger degree during winter than during the summer season. Conversely, a cold current has greater moderating effects on temperature along a coast during the summer season.[9]

The variability of magnitude and range of sea surface temperatures are considerable latitudinally from winter to summer along the East and West Coasts of the United States. These variations must be related to other climatic controls, such as the migration of pressure systems, and, ultimately, to the earth's heat balance. These large variations of sea surface temperatures are evident when sea surface temperatures are plotted against latitudes.

Mean surface water temperatures along the West Coast between 33°N and 48°N differ markedly between summer and winter in terms of magnitude and rate of change (see Figures 10, 11, and 12). During the winter months a gradual increase in coastal surface water temperatures occurs. This increase ranges from 48°F at 48°N to about 58°F at 33°N (see Figure 10). The individual station data reveal a similar rate of increase in temperature and represent a good fit with respect to the

[9] Glenn T. Trewartha, An Introduction to Climate (4th ed.; New York: McGraw-Hill Book Company, 1968), p. 116.

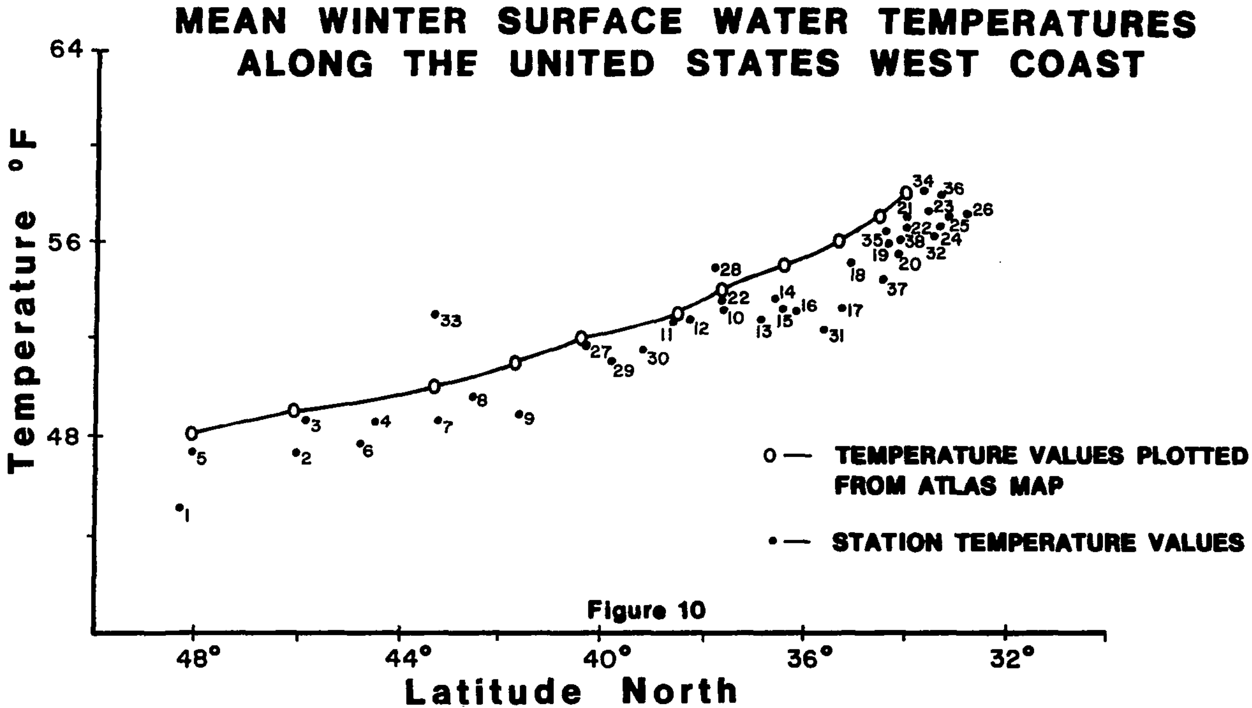


Figure 10

SOURCE: THE NATIONAL ATLAS OF THE UNITED STATES, 1970.

SOURCE: UNIVERSITY OF CALIFORNIA SCRIPPS INSTITUTE OF OCEANOGRAPHY, SURFACE WATER TEMPERATURES AT SHORE STATIONS, UNITED STATES WEST COAST, 1972.

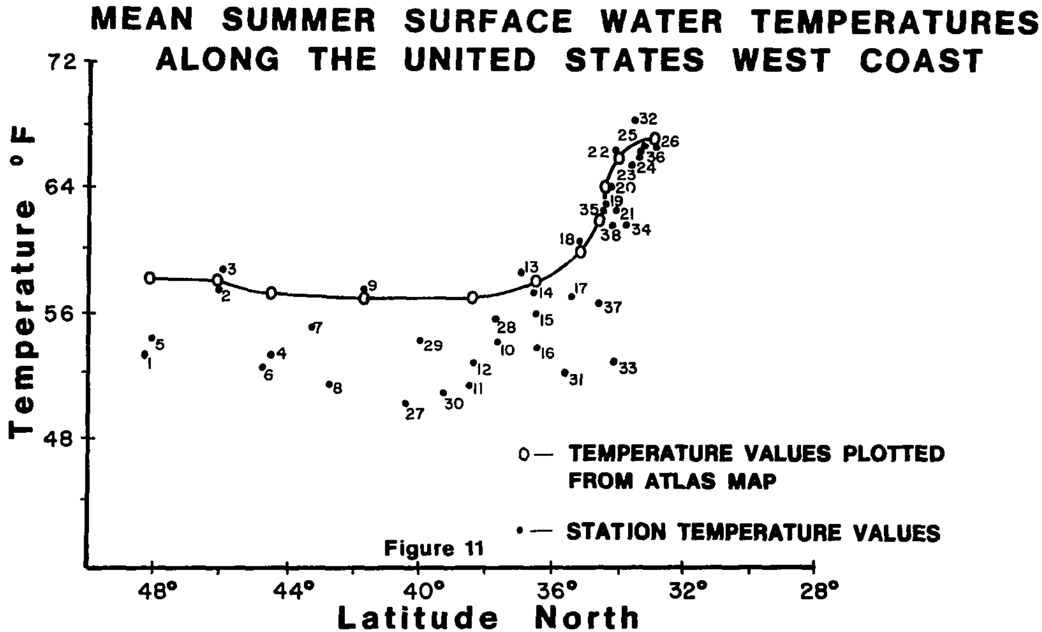
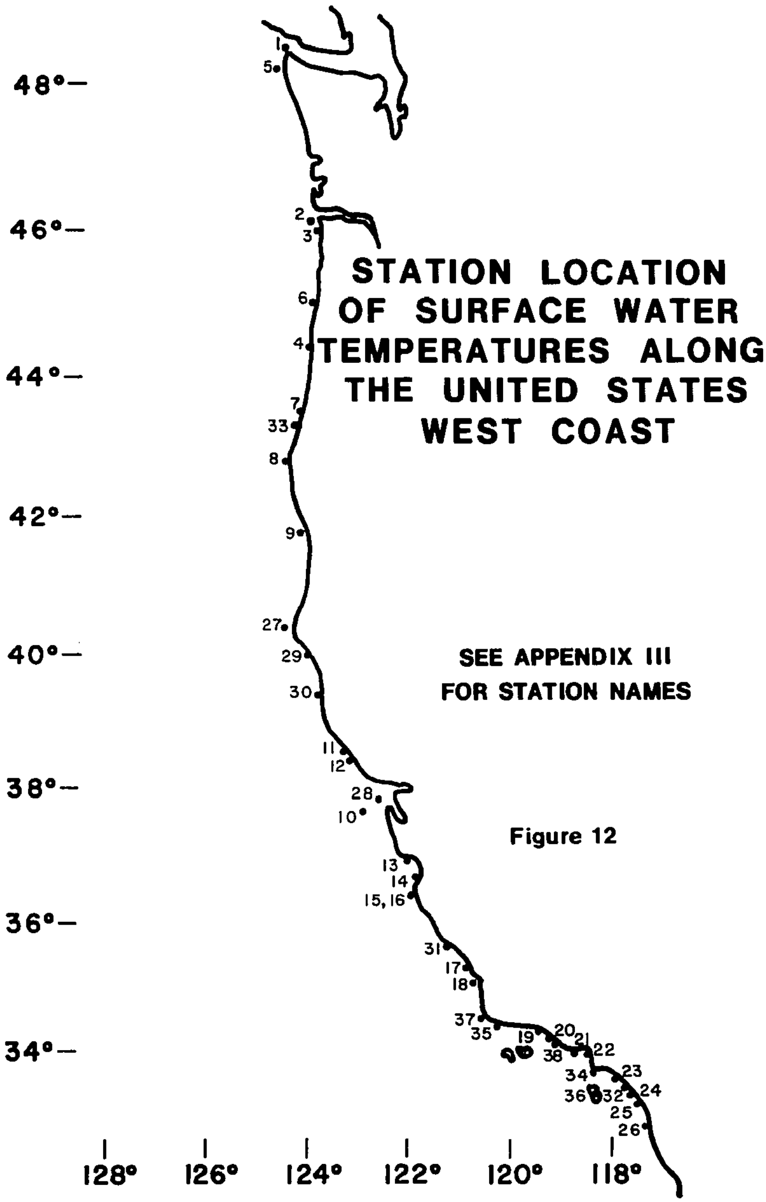


Figure 11

SOURCE: THE NATIONAL ATLAS OF THE UNITED STATES, 1970.

SOURCE: UNIVERSITY OF CALIFORNIA SCRIPPS INSTITUTE OF OCEANOGRAPHY, SURFACE WATER TEMPERATURES AT SHORE STATIONS, UNITED STATES WEST COAST, 1972.



STATION LOCATION OF SURFACE WATER TEMPERATURES ALONG THE UNITED STATES WEST COAST

SEE APPENDIX III FOR STATION NAMES

Figure 12

interpolated temperature values. However, the summer coastal surface water temperatures are almost a constant 58°F from 48°N to 36°N with slightly lower temperatures between 38°N to 42°N (see Figure 11). The station data are even notably lower between the latter two latitudes. According to Trewartha, lowest coastal water temperatures occur at approximately 40°N where a maximum difference between air and water temperatures exists.[10] From 36°N to 33°N, a rapid increase in temperatures is evident resulting in a rise of 9°F. These two different coastal temperature profiles are attributed to the position and intensity of the Pacific Subtropical High in conjunction with a cold upwelling between winter and summer seasons.[11] These physical factors are of the utmost significance regarding the precipitation regime along the West Coast.

The profiles for surface water temperatures along the East Coast are similar between winter and summer (see Figures 13, 14, 15, and 16). The differences in magnitude per latitude, of course, are large. During the summer season, a rather large increase of about 19°F in surface water temperatures occurs between 43°N to 34°N (see Figure 13). From 34°N to 28°N the mean temperature is constant at 80°F and then begins to rise in more southerly latitudes. The most obvious reason for the decrease in coastal surface water temperatures northwards of about 34°N is the configuration of the coastline resulting in a lessening influence of the Gulf Stream.[12] Northwards of Cape Hatteras, the coastline bends north to northwestwards, whereas the Gulf Stream is flowing in a northeasterly

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[10]Glenn T. Trewartha, The Earth's Problem Climates (Madison: The University of Wisconsin Press, 1961), p. 270.

[11]Ibid., p. 269.

[12]William L. Donn, Meteorology (3d ed.; New York: McGraw-Hill Book Company, 1965), p. 432.

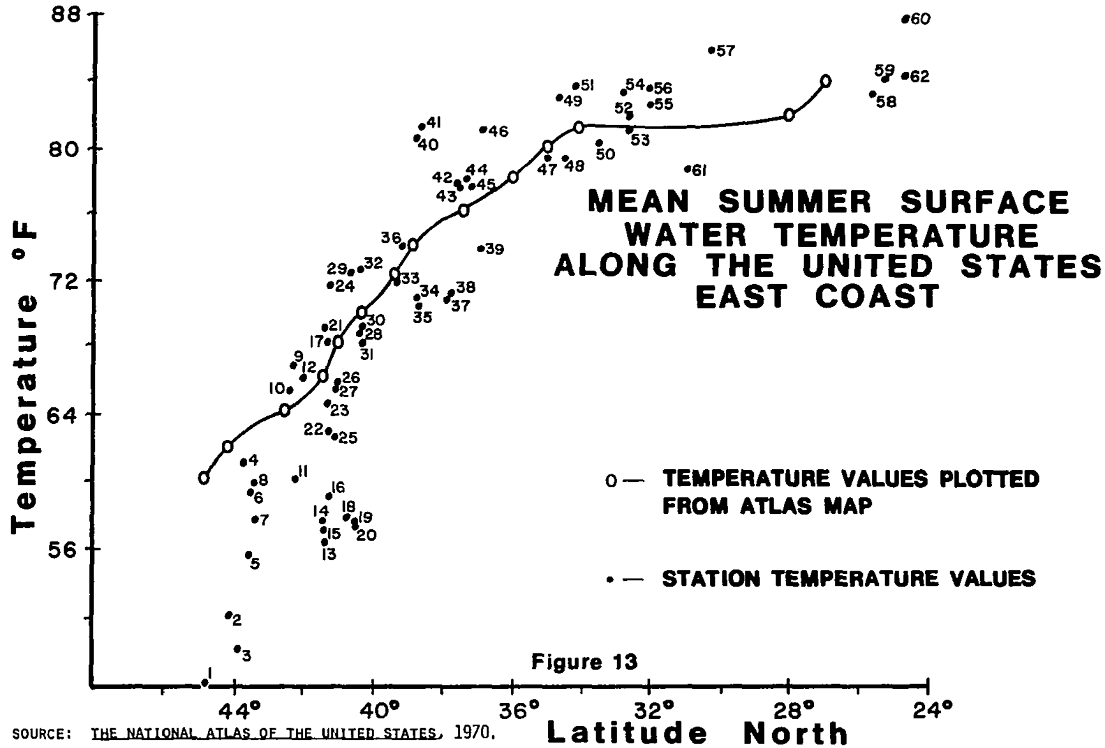


Figure 13

SOURCE: THE NATIONAL ATLAS OF THE UNITED STATES, 1970.

SOURCE: DEAN BUMPUS, SURFACE WATER TEMPERATURES ALONG ATLANTIC AND GULF COASTS OF THE UNITED STATES, WOODS HOLE OCEANOGRAPHIC INSTITUTION, 1957.

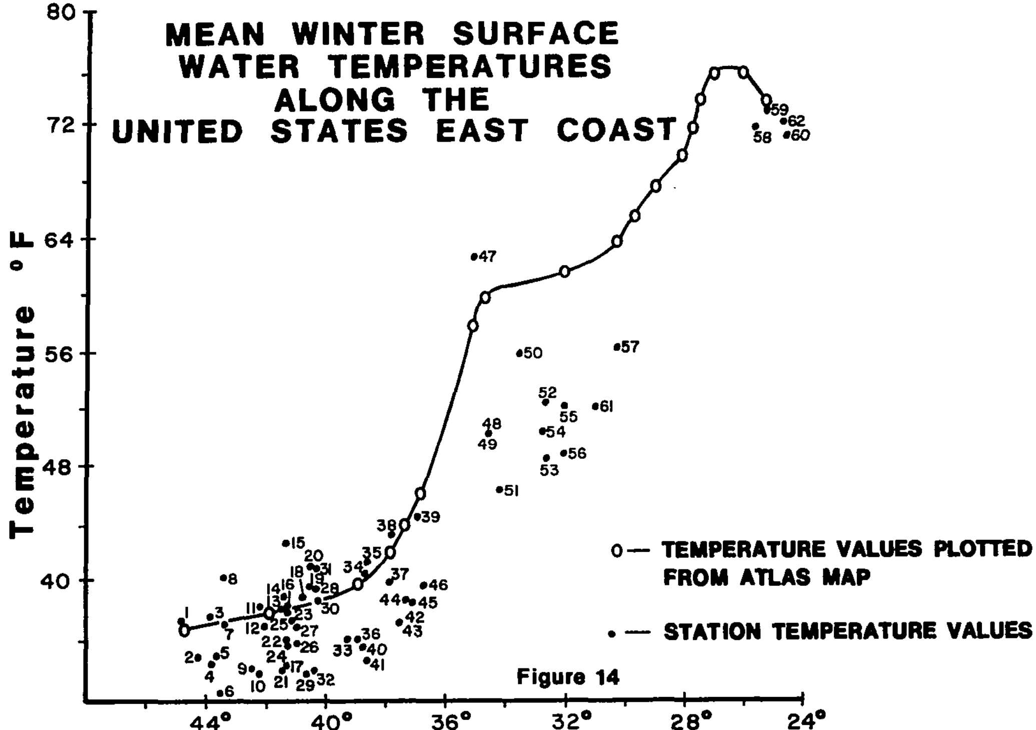
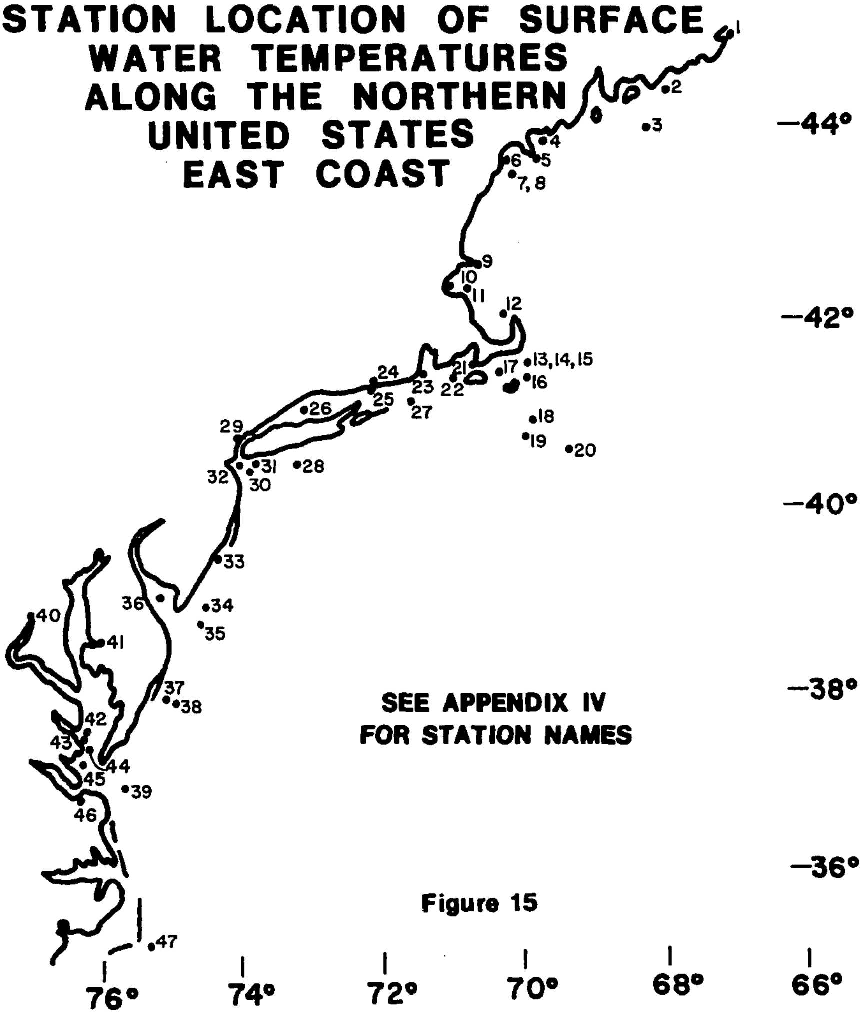


Figure 14

SOURCE: THE NATIONAL ATLAS OF THE UNITED STATES, 1970.

SOURCE: DEAN BUMPUS, SURFACE WATER TEMPERATURES ALONG ATLANTIC AND GULF COASTS OF THE UNITED STATES, WOODS HOLE OCEANOGRAPHIC INSTITUTION, 1957.

STATION LOCATION OF SURFACE WATER TEMPERATURES ALONG THE NORTHERN UNITED STATES EAST COAST



SEE APPENDIX IV FOR STATION NAMES

Figure 15

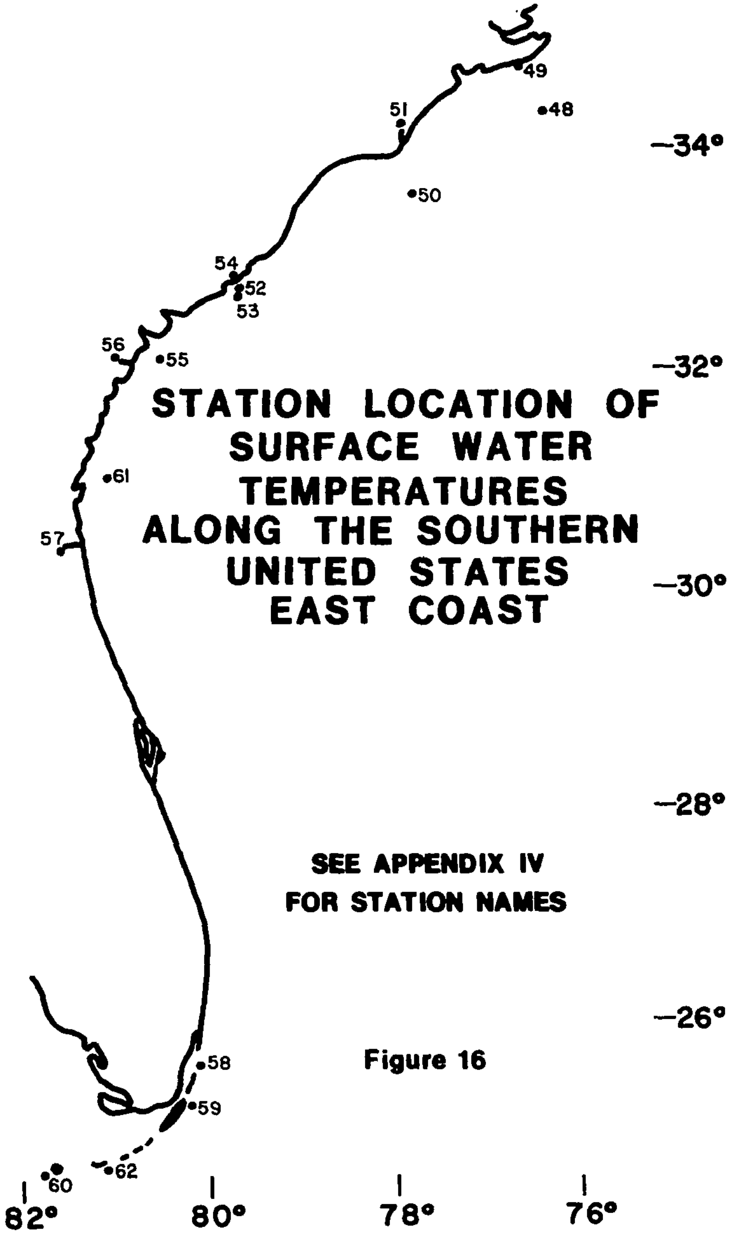

49
48
51
34°
50
54
52
53
56
55
32°
STATION LOCATION OF SURFACE WATER TEMPERATURES ALONG THE SOUTHERN UNITED STATES EAST COAST
61
57
30°
28°
SEE APPENDIX IV FOR STATION NAMES
26°
58
59
62
60
82°
80°
78°
76°

Figure 16

direction. The cooling effects of the Labrador Current strengthen northwards along the coast from this point. Station data coincide well with this mean profile. A similar rapid increase in surface water temperatures occurs from 38°N to 34°N during the winter season (see Figure 14). An abrupt increase in temperature of about 18°F is observed. Then, as during the summer season, a relatively constant temperature is apparent southwards along the coast to about 31°N. A rapid increase in surface water temperature again occurs to 27°N; then it begins to decrease southwards. Since the rate of increase is not as great from 31°N to 27°N as it is northwards below the bench-like portion of the profile, the diminishing effects of the Gulf Stream due to the coastline configuration is again evident. Station data did not coincide well with the mean temperature profile where the bench-like portion of the profile is located. Most station data were lower with respect to the mean temperature profile. Pockets of cooler water in sheltered bay areas may be responsible for these anomalies.

The problem of ocean current effects inland is just as complex. If the effect of all other climatic controls is eliminated, mixing of maritime air with continental air occurs inland, even though it does so at a decreasing rate. According to Meigs, as one moves inland from bodies of water, the temperatures at first change rapidly, then gradually level off to approximate uniformity.[13] However, temperatures generated inland are influenced greatly by wind direction. Naturally, when the

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[13] Peveril Meigs, Geography of Coastal Deserts, UNESCO, Arid Zone Research—XXVIII, United National Educational, Scientific and Cultural Organization, Place de Fontenoy, Vaillant-Carmanne, S.A., Liege (Belgique), 1966, 13.

wind blows onshore, a weather station's temperature farther inland will be affected more so than with little wind or a seasonal wind. When weather station temperatures are reduced to sea level and plotted by latitude, the effects of warm and cold ocean currents during winter and summer are portrayed.

During the month of July, the cold California Current has a greater moderating effect inland than does the Gulf Stream along the East Coast (see Figure 17). The greatest increase in surface water temperature along the West Coast, particularly inland to about 100 miles, is south of 44°N. Throughout these lower latitudes, a distinct temperature profile emerges. This profile is represented by a rapid increase in temperature inland to about 40 miles from the coast and then a gradually smaller temperature increase with distance occurs. At higher latitudes the rate of temperature increase is not as pronounced. There is even a slight decrease in temperature between 44°N and 48°N for an inland distance of about 5 miles. The different profile at these higher latitudes can be attributed to warmer surface water temperatures. According to Trewartha, south of about 38°N to 40°N the surface water temperature along the coast is colder than the air circulating around the Pacific high.[14] This is primarily due to the position of this high pressure cell which induces a cold water upwelling. To the north the upwelling is not as intense. Warmer coastal surface water temperatures are observed at 46°N and 48°N than farther south (see Figure 17).

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[14]Trewartha, The Earth's Problem Climates, op. cit., p. 269.

LATITUDINAL JULY TEMPERATURE CHANGE INLAND FROM UNITED STATES WEST COAST

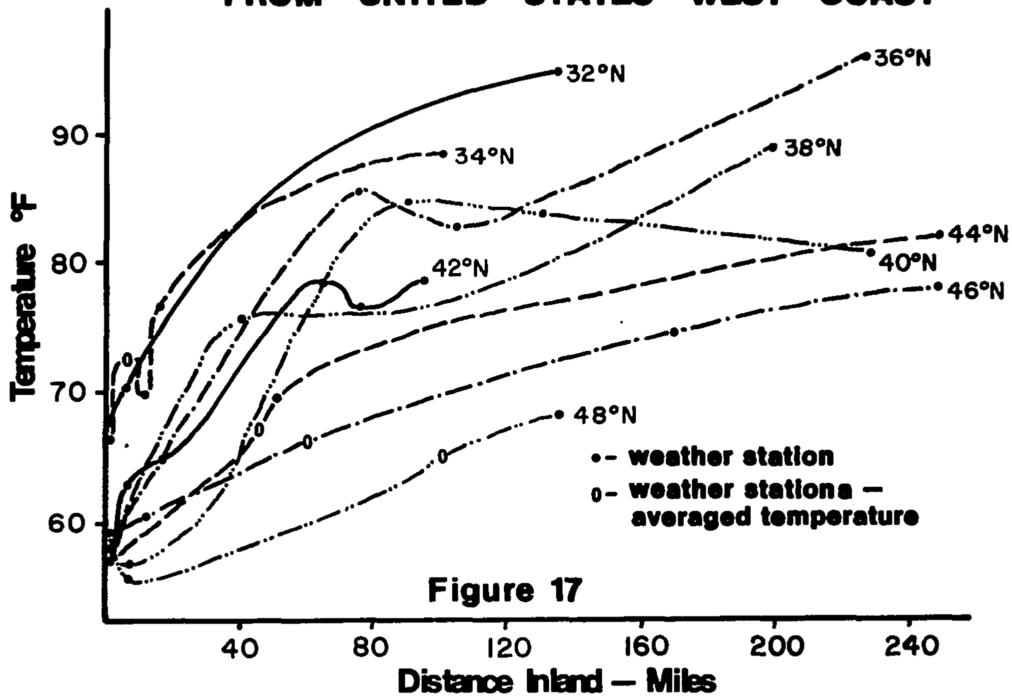


Figure 17

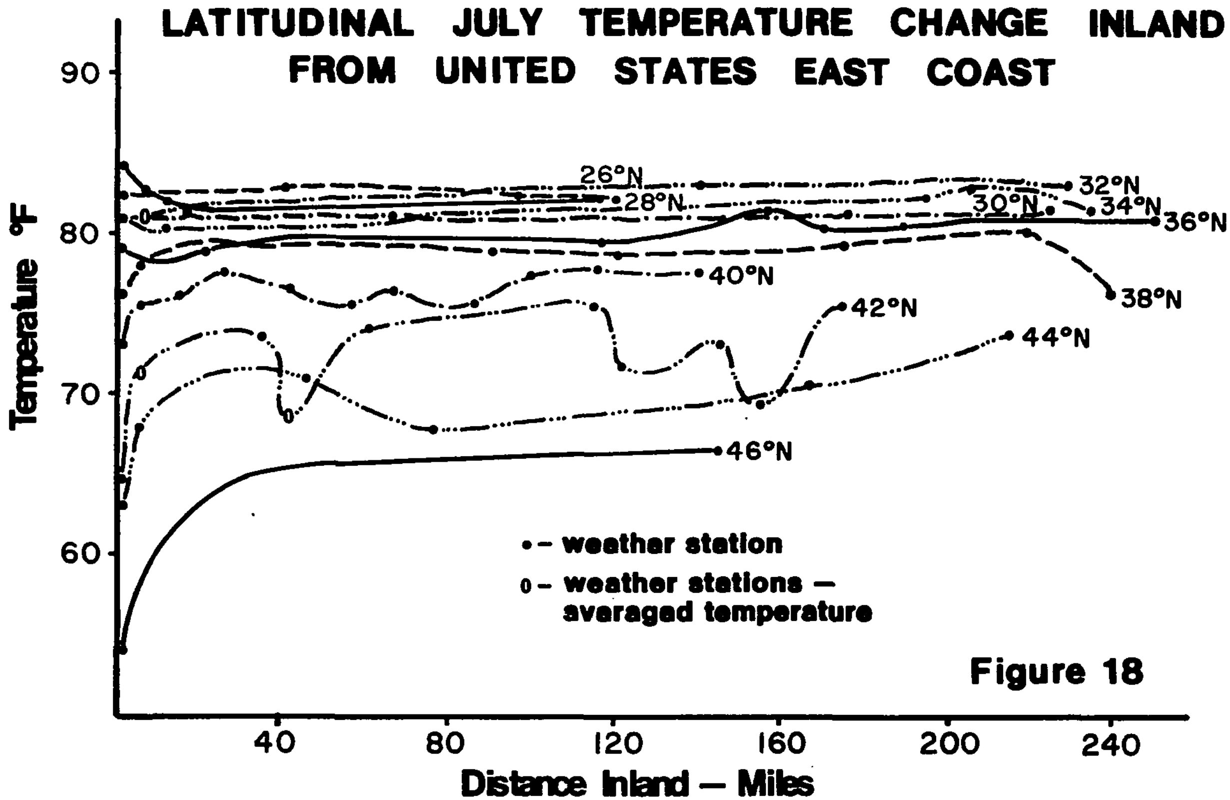
SOURCE: AUTHOR'S CALCULATIONS.

Along the East Coast south of $40^{\circ}N$ the warm Gulf Stream has little moderating influence inland over the warm surface of the summer season. At higher latitudes, $42^{\circ}N$ to $46^{\circ}N$, an abrupt increase in temperature is noted inland to about 20 miles (see Figure 18). Here, the cooler water from the Labrador Current produces a temperature profile similar to those along the West Coast but for a shorter distance inland.

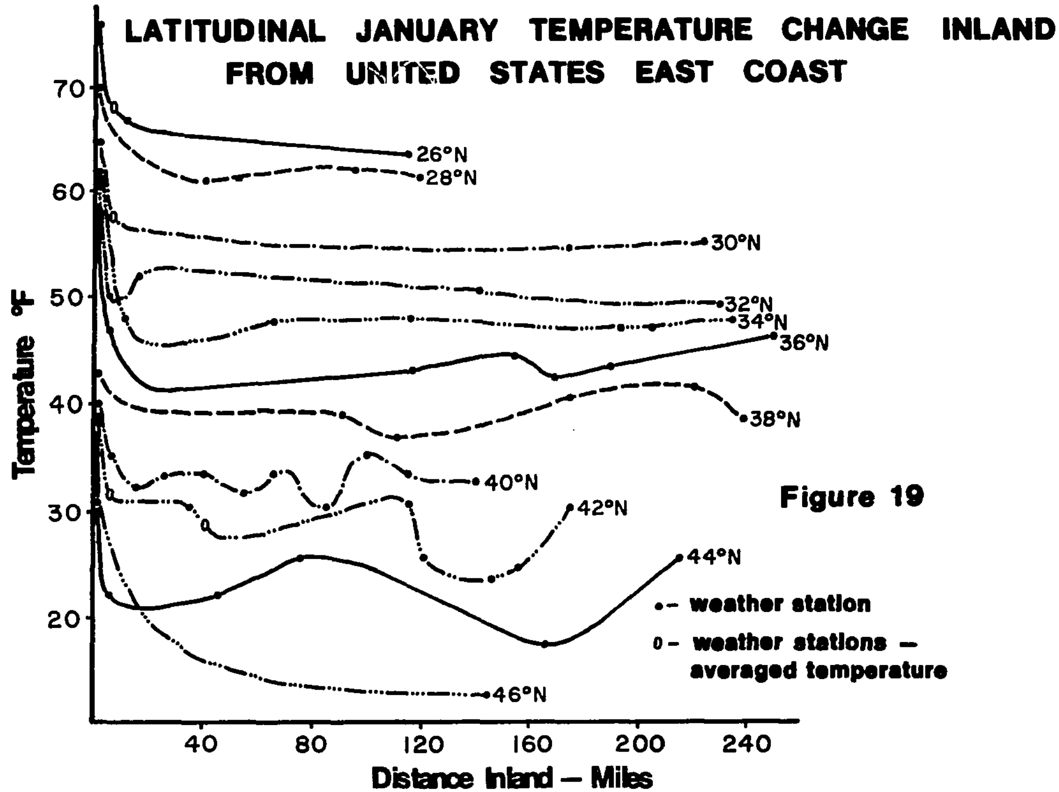
During the month of January, the warm Gulf Current has a pronounced moderating effect inland along the East Coast, when the effect of the California Current, particularly at low latitudes, is rather subdued (see Figure 19). Along the East Coast a large variation in surface water temperatures exists and a sharp decrease in temperature occurs within 5 to 10 miles inland. The specific heat of the land surface combined with the prevailing westerly winds restricts this moderating influence of the Gulf Stream to a narrow strip along the coast.

Surface water temperatures along the West Coast are similar for a 16° range of latitude. At all latitudes, an abrupt decrease in temperature occurs inland for 5 or 10 miles. The magnitude of change is not nearly as great as along the East Coast. But due to colder surface temperatures inland at higher latitudes, a greater decrease in temperature is observed from $42^{\circ}N$ to $48^{\circ}N$ (see Figure 20).

From the above analyses, it was observed that when elevation above sea level is nullified, a mean annual temperature departure for any weather station at a specific latitude may represent the influence of ocean currents if the station has a coastal position. Specifically, San Diego is a good example of this phenomenon with a low mean annual temperature as a result of the cold California Ocean Current compared

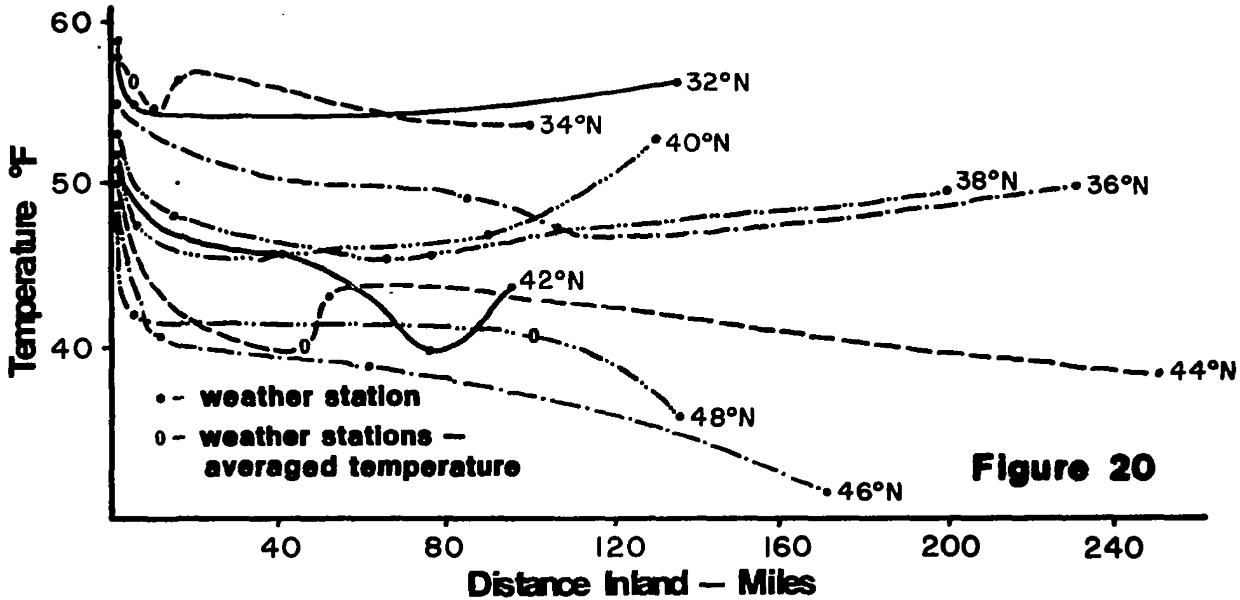


SOURCE: AUTHOR'S CALCULATIONS.



SOURCE: AUTHOR'S CALCULATIONS.

LATITUDINAL JANUARY TEMPERATURE CHANGE INLAND FROM UNITED STATES WEST COAST



SOURCE: AUTHOR'S CALCULATIONS.

with an inland station such as Yuma, Arizona at about the same latitude. Yuma, reduced to sea level, has a mean annual temperature which is 11°F warmer than that of San Diego. This contrast in temperature is better exemplified by comparing summer month temperatures of the two stations (see Table 4).

TABLE 4

SUMMER MONTH TEMPERATURES °F REDUCED TO SEA LEVEL FOR SAN DIEGO AND YUMA*

	June	July	August	September
San Diego	66.6	70.5	72.2	70.3
Yuma	87.8	94.9	93.1	88.7

*Author's calculations.

In this particular study, only the prominent ocean currents along the eastern and western coastal areas of the United States are investigated. The effects of any ocean current from the Gulf of Mexico were discounted. A close scrutiny of data reveals that the cold California Current will have a marked influence on temperature for coastal stations, especially during the summer months, whereas the warm Gulf Stream will noticeably stand out for coastal stations in the eastern United States during the winter months.

The maximum distance inland from the ocean used in this study to determine ocean current effects was 100 miles. According to Meigs, each coastal sector should be analyzed separately, but the penetration of coastal influences on daily maximum temperatures is about 50 to 100 miles from the coast.[15] If average January and July temperatures reduced to sea level for these coastal stations were used to establish temperature departures from average surface sea water temperatures near the coast at the same latitude, cold and warm ocean current effects might be discerned.

Therefore, mean summer and winter sea surface temperatures for the East and West Coasts which were plotted against latitude were used as reference temperature values. These sea surface temperatures were interpolated from the National Atlas of the United States, 1970.[16] These values were partially verified by plotting mean January and July sea-surface temperatures at selected sites along the coasts which were collected by Woods Hole Oceanographic Institute and the University of California Scripps Institution of Oceanography. Some discrepancies are noted, especially along the East Coast during the winter, but these differences are to be expected due to the irregularity of the coast with varying degrees of exposure and can generally be discounted.

Mean temperature departures for all weather stations reduced to sea level within 100 miles were then calculated for January and July for the East and West Coasts. Negative values, especially during July, indicate cold current effects whereas positive values, especially during January, indicate the presence of warm currents.

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[15] Meigs, op. cit., p. 13.

[16] The National Atlas of the United States of America, United States Department of the Interior, Geological Survey, Washington, D.C., 1970, p. 83 (William T. Pecora, Director, U.S.G.S.).

Mean Sky Cover and Variability

Mean sky cover and sky cover variability are significant climatic controls in that they affect the amount of incoming and outgoing solar and terrestrial radiation which, in turn, is related to magnitudes and variabilities of mean annual and monthly temperature at weather stations. Unlike water vapor, a cloud which is composed of water droplets and ice crystals acts as a black body and absorbs and radiates in all wave lengths.[17] Therefore, during the day, much solar radiation, depending on the cloud type, is absorbed in the cloud, preventing daytime temperatures to rise as high as cloudless conditions would permit. During the night, terrestrial radiation is absorbed in clouds and is not lost to space; thus, temperatures remain higher. During the course of 24 hours, the net effect on the average temperature at a station may be negligible, but with the lack of solar radiation reaching the ground over a longer period of time, cooler temperatures will result. Not only should mean sky cover be examined but also its variability if the mean monthly temperature pattern is to be understood at any weather station.

The spatial distribution and variability of mean annual cloudiness on a broad scale over the United States is rather simple (see Figure 21). The greatest range of mean annual cloudiness is observed between the Desert Southwest with little cloudiness to the Pacific Northwest where much cloudiness prevails. Between these two regions a rapid change occurs, particularly along the West Coast and more mountainous regions. A rather sharp change in mean annual cloudiness is also

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[17]Trewartha, An Introduction to Climate, op. cit., p. 31.

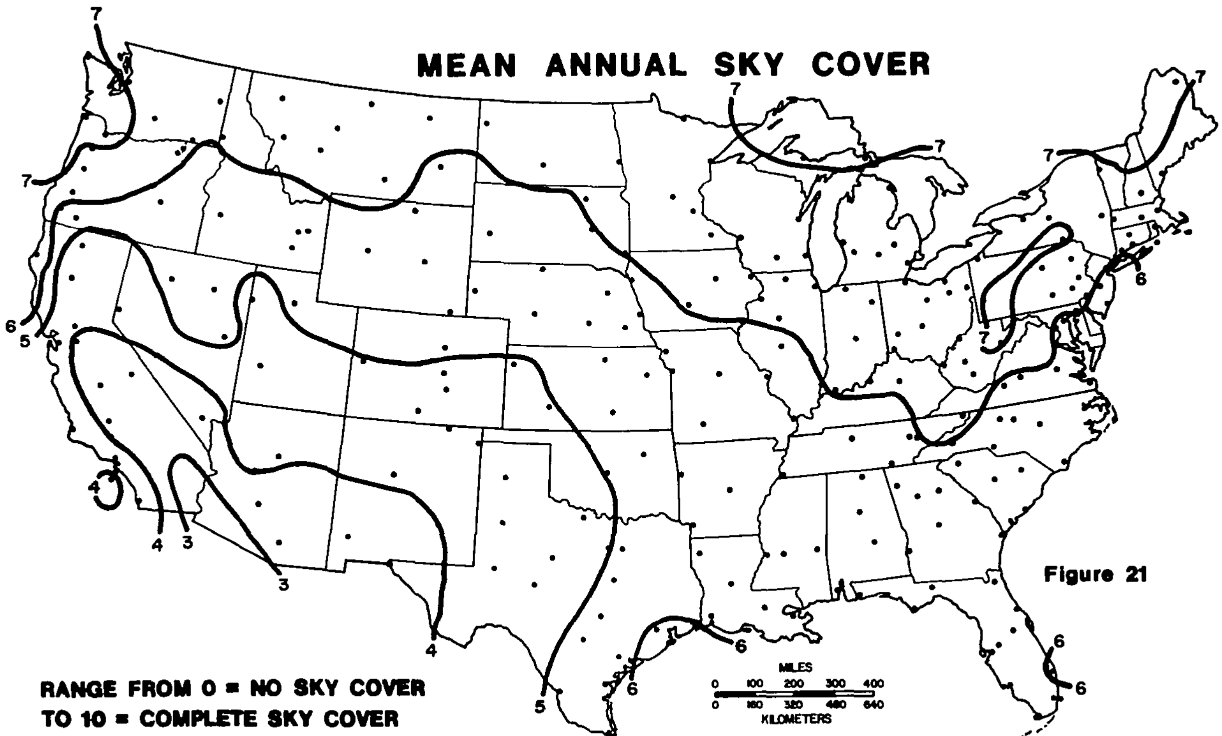

Figure 21

SOURCE: LOCAL CLIMATOLOGICAL DATA WITH COMPARATIVE DATA, 1964.

detected to a smaller degree over the Appalachian Mountains. The least spatial variation with mean annual sky cover values ranging between 5 and 6 is typical of the central and southeastern portions of the United States.

The amount and variability of cloudiness is necessarily related to other climatic controls such as air masses, pressure systems, and storms. The degree of interdependence has been accounted for during the component factor analysis. Regardless of the fact that some duplication is obvious, it is most likely this climatic control will add some significant contribution in the explanation of climatic types.

Mean annual sky cover from sunrise to sunset, where sky cover is expressed as range from 0 for no clouds to 10 for complete sky cover, has been collected for stations from Local Climatological Data. A small number of these values are missing in which case the nearest station's data were substituted. Variability of sky cover has been indicated by standard deviation values of mean monthly sky cover.

Mean Wind Velocity and Variability

Although wind is often regarded an element of weather and climate, it also functions as a control and as such influences each of the other elements including temperature and precipitation.[18] Not only is it a control but "...a powerful determinant of air temperature and moisture conditions of a place."[19] Wind has two major components: direction and velocity. Wind velocity is considered here as a separate

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[18] Ibid., p. 3.

[19] Ibid., p. 65.

climatic control. Wind direction is incorporated into the derivation of an orographic index.

Wind velocity is an important factor to consider, both directly and indirectly. Wind velocity has a direct effect on vegetation and structures, sometimes to the extent of causing damage. Indirect effects include rates of evaporation, which affect the sensible temperature, erosion, and human comfort to mention a few.[20] Wind speeds vary areally and altitudinally. The primary reasons for this variation are due to friction, confrontation, and movement of different air masses. If certain areas of the coterminous United States have greater wind velocities and variability, different temperature and moisture patterns will be reflected.

Not only is there a general increase in wind velocities in the free atmosphere with an increase in elevation, but also with higher ground elevations.[21] This fact, in addition to elevation above sea level, may aid in the determination of highland type climates. Also, with stronger winds and steep slopes, a number of dynamic reactions take place.[22] This has a bearing on the precipitation pattern in mountainous areas. More importantly, however, wind velocities may denote seasonal changes of major wind patterns at a place as related to the general circulation of the atmosphere. According to Landsberg, the increase in wind velocity at all elevation levels between winter and summer is quite

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[20] Helmut Landsberg, Physical Climatology (2nd ed.; DuBois, Pennsylvania: Gray Printing Co., Inc., 1960), p. 208.

[21] Neuberger, *op. cit.*, p. 110.

[22] Crowe, *op. cit.*, p. 426.

marked at Miami with a shift from westerly to easterly winds.[23] This is related to the movement of the jet stream and consequently affects the precipitation pattern at a station. Furthermore, a latitudinal difference in wind velocity on both the East and West Coasts was noted.

Certain mean annual wind velocity patterns in the United States, such as a large increase along the Northwest Coast, are evident; however, considerable complexity exists (see Figure 22). Physiographic regions are most likely responsible for some of the pattern that does exist. Except for Tatoosh Island in the Northwest, highest mean annual wind velocities encompass the Great Plains just east of the Rocky Mountains. In addition, an isolated area of high values occurs near Lakes Erie and Ontario. Smallest mean annual wind velocity values are common throughout the Rocky and Appalachian Mountains and in the southern, southwestern, and western parts of the United States.

Therefore, mean annual wind velocity and standard deviation of mean monthly wind velocities for variability for each climatic station are used as climatic controls in this investigation. The original data were recorded in the Local Climatological Data for most of the 259 weather stations used in this study. In those few instances where data were missing, the nearest station which has recorded values was used.

Orographic Barriers

It is a well-known fact that where mountain ranges lie athwart major wind currents over the earth's surface, an upward forced ascent of a portion of this air usually results. When this forced ascent occurs,

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[23]Landsberg, op. cit., p. 210.

MEAN ANNUAL WIND VELOCITY

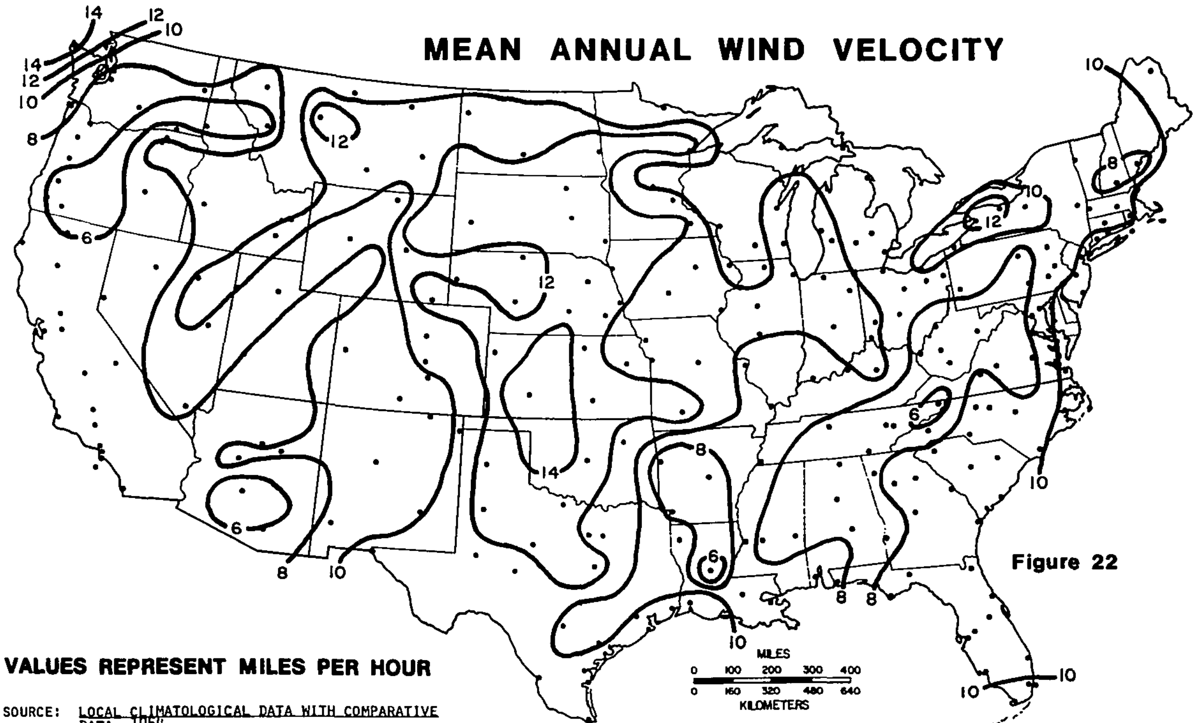

Figure 22

VALUES REPRESENT MILES PER HOUR

SOURCE: LOCAL CLIMATOLOGICAL DATA WITH COMPARATIVE DATA, 1964.

adiabatic cooling increases the relative humidity with increased probability of precipitation. As the air descends on the lee side of a mountain range, the air temperature increases with a decreasing relative humidity and little precipitation falls. This is evident in the United States where diverse climates exist between the windward and lee sides of the Coastal Range, Cascade and Sierra Nevadas, and Rocky Mountains.

Care must be used, however, in attributing a large portion of the precipitation on the windward side of mountains only to forced ascent. According to Trewartha, other indirect effects of mountains are also important. These are: "(1) their production of strength turbulence of both a mechanical and a convective nature; (2) their obstructing and slowing effect upon the progress of cyclonic storms; (3) orographically conditioned convergence in horizontal currents; and (4) the trigger effect of highlands that give the initial upthrust to conditionally or convectively unstable air masses.[24] Nevertheless, when examining the nature of orographic precipitation, direct factors affecting both seasonal and areal distribution of precipitation, such as the strength of wind, the angle at which winds meet the mountain barrier, and the degree of contrast between land and water temperatures should be measured.[25] Due to the complexity of most mountainous terrain, other variables, such as the scale and general slope of the relief obstacle, should also be examined, especially when a deductive approach to explain the nature and distribution of these clouds is employed.[26]

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[24]Trewartha, An Introduction to Climate, op. cit., p. 151.

[25]Ibid., p. 152.

[26]Crowe, op. cit., p. 424.

From a perusal of materials related to orographic precipitation, it was decided that mean annual wind direction and topographic slope represented two significant variables in the derivation of an orographic index. Other climatic controls used in this study, such as wind velocity and continentality, may contribute to this climatic control in the component factor analysis. One major difficulty in operationalizing this climatic control, however, is scale. Just how far upstream or downstream, parallel to the mean wind direction, from each weather station should measurements extend? Since various scaled phenomena--micro, meso, and macro--are all important in producing a peculiar climate at a mountain weather station, the decision on operationalizing this climatic control is difficult at best. Other problems such as how high, long, rough, and broad is a particular mountain range are also extremely pertinent.

According to Crowe, a mountain system is considered wide if it is a hundred or more miles across.[27] If a persistent and deep wind meets such a mountain barrier, theory suggests that a significant distortion of wind direction is induced. On the other hand, significant climatic differences are noted for shorter distances. Philipsburg, Pennsylvania and State College, Pennsylvania in the Allegheny Mountains are only 20 miles from each other. However, State College on the lee side of this mountain range receives 6 per cent less precipitation than does Philipsburg for corresponding years.[28] From these accounts and on the basis of the scale and purpose of this investigation, a transect of 50 miles

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[27] *Ibid.*, p. 425.

[28] Landsberg, *op. cit.*, p. 299.

from which the mean annual wind prevails from all weather stations was selected. This distance is arbitrary but is probably as good as any other distance for a study at this scale.

The following simple relationship was then used to ascertain an index of orography: Orographic effect $= \frac{\text{elevation in feet}}{\text{distance in miles}}$,

where the elevation value is the difference between the station's elevation and the elevation at the end of the 50 mile line segment <u>or</u> the elevation difference along the line segment which is greater than any other difference along the 50 miles. One thousand foot contour intervals from aeronautical charts were used and with the aid of spot elevations, estimated to the nearest 250 foot level.[29] Negative values were used for a lee side situation and positive values represent windward conditions.

<u>Cyclones and Anticyclones and Their Variability</u>

Cyclones and anticyclones have a powerful influence on the type of weather which exists at a place from day to day and, consequently, exert a strong influence on the climate of an area. The distribution of cloud cover, wind current patterns, and vertical motion of air partially govern the climate of a place since these factors to a certain degree determine the amount of insolation, advection of air with certain temperature and moisture properties, and atmospheric stability.

The direction and rate of movement of these systems vary seasonally with strength and position of upper air waves and the jet stream.

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[29]<u>Sectional Aeronautical Charts</u>, Bureau of Air Commerce, Department of Commerce, Coast and Geodetic Survey, Washington, D. C.

The direction and rate of movement over an area as they are governed by the jet stream need not be gradual.[30] But there are preferred tracks across the United States for both cyclones and anticyclones, and where a greater frequency of cyclones and anticyclones occurs, the climate along these tracks is reflected in temperature and precipitation characteristics per weather station.

Information concerning the monthly frequency of cyclones and anticyclones was obtained from Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere.[31] These monthly frequencies of cyclones and anticyclones are recorded per 5^{o} latitude-longitude grid section for the 20-year period of records (1909-14 and 1924-37) for the entire study area. The use of the number of different low and high pressure centers within the 5^{o} latitude-longitude grid sections during a 20-year period, rather than the number of days when a low or high pressure center of any type was within the grid sections, to avoid the inclusion of thermal lows and hurricanes.[32] Therefore, tracks of these systems are revealed. Each weather station in a 5^{o} latitude-longitude grid section was assigned the total annual number of cyclones and anticyclones during this 20-year period. Since the annual variability of these systems is a significant factor, standard deviation of the twelve monthly number of cyclones and anticyclones per grid section has been calculated and used as a climatic control for each station.

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[30]Neuberger, op. cit., p. 80.

[31]William H. Klein, Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere (Washington, D.C.: U. S. Department of Commerce, Weather Bureau, Research Paper No. 40, 1957), pp. 1-60.

[32]Ibid., p. 22.

Pressure Systems and Variability

According to Trewartha, pressure ranks among the most important climatic controls mainly through its effect on temperature and precipitation.[33] When the distribution and intensity of pressure patterns for an area, such as the United States, is known, one can deduce the location of fields of convergence and divergence of air that are significantly involved in the formation of temperature and precipitation regimes.

Organization of these pressure patterns into systems are caused either by thermal or mechanical factors. The systems vary greatly in size, intensity, and configuration. Large semi-permanent high and low pressure systems, which are more statistical in nature than real, migrate, intensify, and weaken on a seasonal basis. The wind field is greatly influenced by their configuration which contributes to seasonal temperature and precipitation characteristics at a weather station. Superimposed on these semi-permanent pressure systems are smaller transient systems--the cyclone and anticyclone. The cyclone and anticyclone will be included as separate climatic controls, as discussed above, due to their own distinctive characteristics.

If the distribution of mean monthly pressure values per weather station is examined, the seasonal configuration, intensity and migration of semi-permanent pressure systems are revealed. Their meaning and independence as a climatic control may then be assessed by the component factor analysis.

Mean monthly pressure values based on the 30-year period from 1931-60 as listed in the Climatic Atlas of the United States for 90 of

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[33]Trewartha, An Introduction to Climate, op. cit., p. 65.

the 259 climatic stations are used in this study.[34] In addition, monthly isobaric maps of the United States at a 2 millibar interval were drawn. From the listed data and interpolation of pressure values from the maps, mean annual pressure values and standard deviations for monthly variability were calculated for use as climatic controls.

Air Masses

Finally, air mass frequency may be added as a substantive climatic control. The type of air mass and the frequency of occurrence at any weather station will surely influence its temperature-precipitation regime.

An air mass is a large body of air with relatively homogeneous characteristics, especially temperature and humidity. These bodies of air tend to establish these characteristics when they are in contact with a given surface for a length of time. The location of these source regions where air masses are generated are important in terms of determining the climate of a place. According to Landsberg, the position of a locality or region with respect to various source regions will ultimately govern its climate.[35]

Since these air masses move away from their source region, a transformation in temperature and humidity characteristics occur. With changing characteristics, the air mass may acquire completely different properties. This problem, in addition to the fact that air masses, especially at high latitudes, may be drastically different from season to season, hamper classification of these bodies of air.

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[34] Climatic Atlas of the United States (Washington, D.C.: U. S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service, June, 1968), pp. 79-80.

[35] Landsberg, *op. cit.*, p. 223.

Typically, air masses are classified in terms of high or low latitude or land or water surface. The usual divisions include continental polar, maritime polar, continental tropical, and maritime tropical. Arctic and equatorial classes are also frequently included. But there exists a considerable amount of variability in the properties of various air masses which develop over the same source region, and this presents a serious problem in comparative studies which include more than one source region. According to Showalter, it is possible to make some reasonable standardization of air mass classification for synoptic purposes but that any classification falls far short of definitely identifying the thermodynamic properties of the different air masses.[36]

Oliver has recently devised a nomogram for monthly air mass identification at a weather station by using mean monthly minimum temperature and early morning relative humidity.[37] Continental tropical, continental polar, maritime polar, and maritime tropical or equatorial are included on the nomogram. Early morning relative humidity and mean minimum monthly temperature per weather station are used to identify the air mass type. However, from a sampling of weather stations in the United States, numerous plots were located in transition zones on the nomogram. Obviously, a weather station with a monthly air mass type between cT and cP air masses is distinctly different from one which is in transition

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[36] Albert K. Showalter, "Further Studies of American Air-Mass Properties," Monthly Weather Review, LXVII (July, 1939), 212.

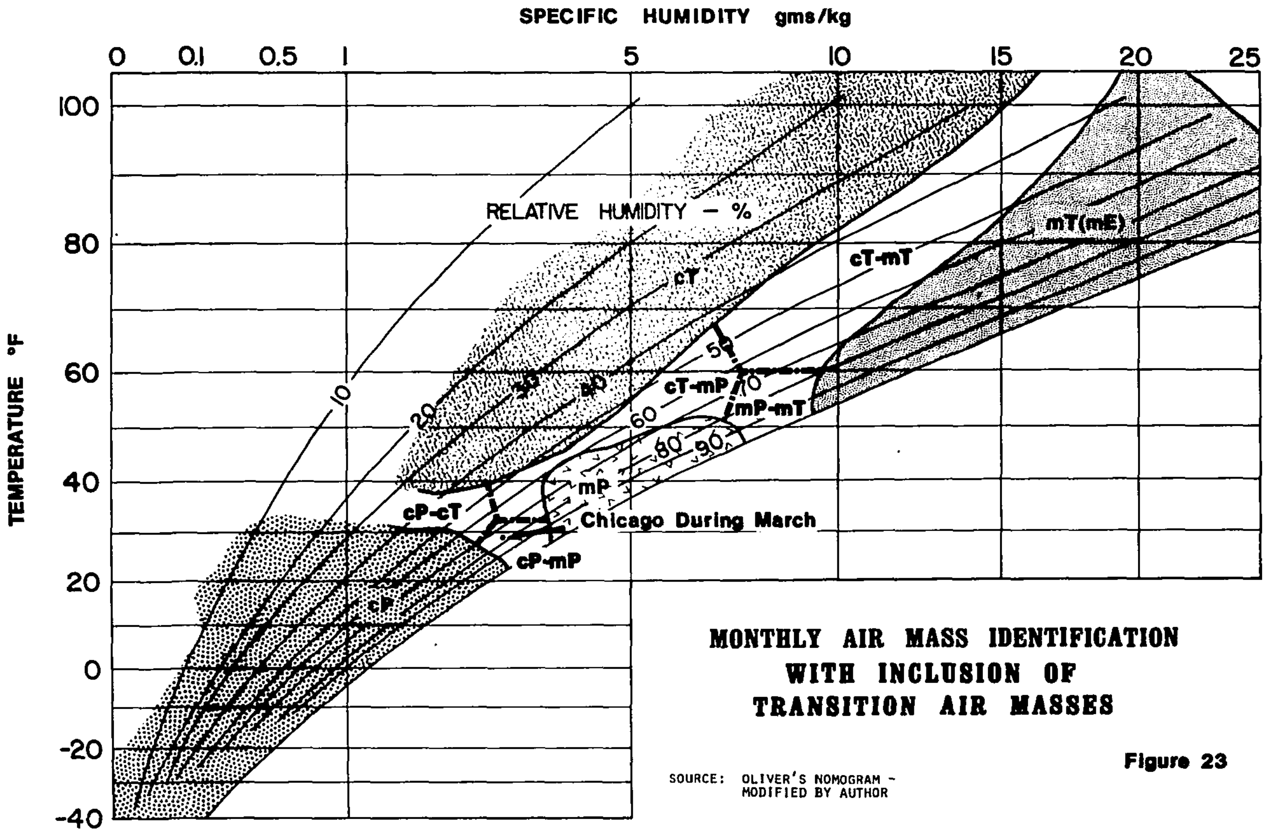
[37] John E. Oliver, "A Genetic Approach to Climatic Classification," op. cit., p. 628.

between mT and cT air masses. It was therefore decided to place boundary lines in the transition zones on this nomogram (see Figure 23).

Temperatures of 32°F and 60°F were used as central reference points for the division of transition zones due to their location with respect to adjacent air mass boundary lines. Three lines were projected perpendicularly to each of the two reference points from the dominant air mass zones. Five transition air mass types were thus established--cP-cT, cP-mP, mP-cT, mT-mP, and cT-mT. One example of a weather station dominated by a transition air mass type for the month of March is Chicago, Illinois. Chicago has a March mean minimum monthly temperature of 29.0°F and an early morning (6 A.M.) relative humidity of 78 per cent. The air mass type for Chicago for the month of March is cP-mP (see Figure 23).

Therefore, early morning relative humidity, usually 4 A.M. values, and mean monthly minimum temperatures from Local Climatological Data were used to find air mass type for each station for all 12 months. In those few instances where data were missing, the nearest station with data was used as a substitute.

By using months per station in which a certain air mass type dominates, an index related to variability of air mass type was calculated. A percentage value of the occurrence of a particular air mass type at a weather station for all 12 months was calculated for all 259 weather stations. The dominance of any one air mass type at a weather station per month was revealed and recorded (see Figures 24-35). Nine climatic controls, one for each air mass type, have been extracted from these calculations.

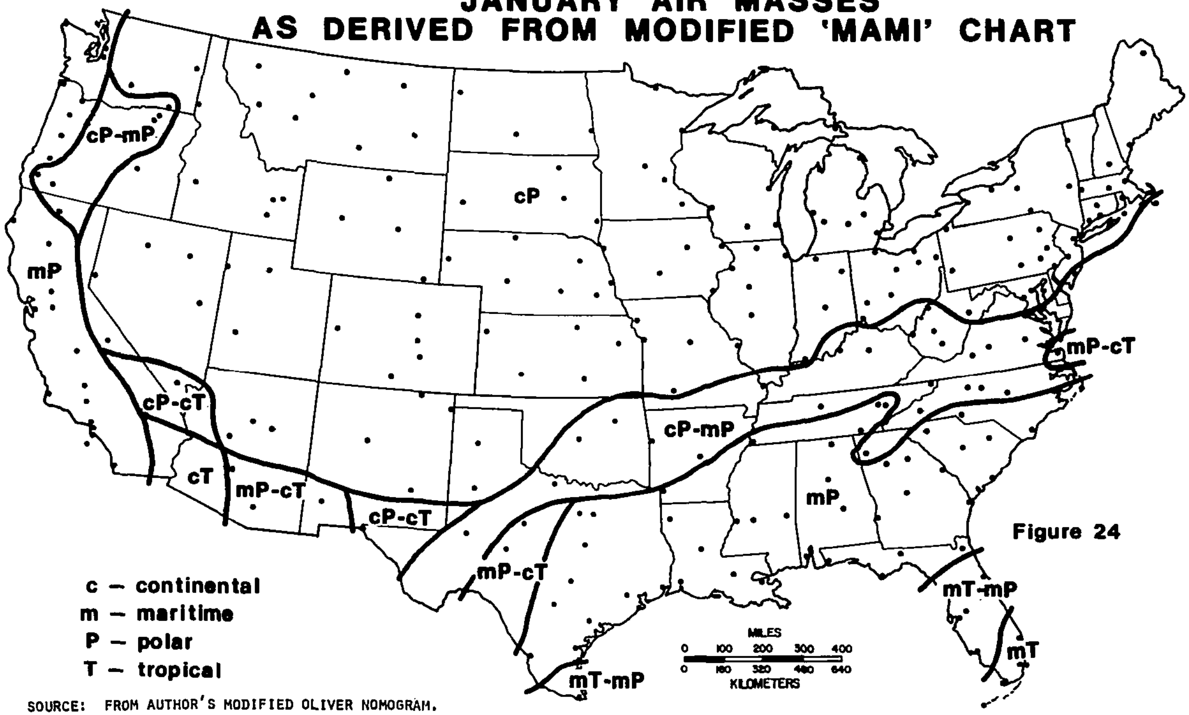


MONTHLY AIR MASS IDENTIFICATION WITH INCLUSION OF TRANSITION AIR MASSES

Figure 23

SOURCE: OLIVER'S NOMOGRAM - MODIFIED BY AUTHOR

JANUARY AIR MASSES
AS DERIVED FROM MODIFIED 'MAMI' CHART

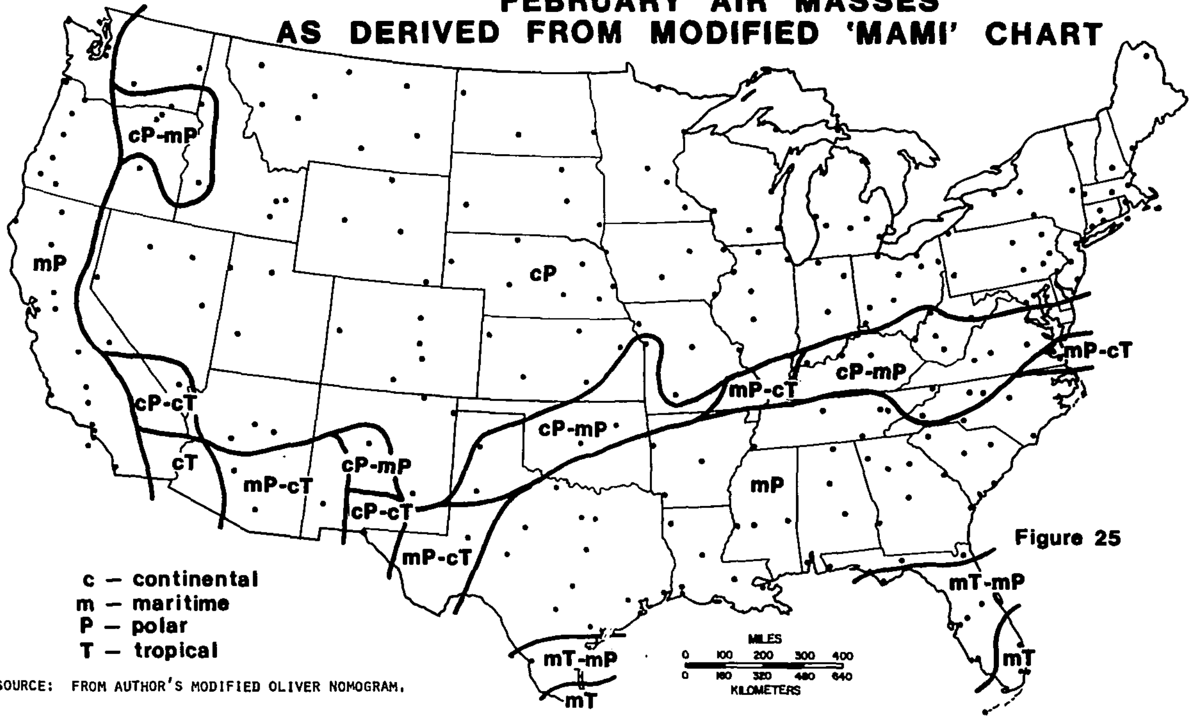


c — continental
m — maritime
P — polar
T — tropical

Figure 24

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

FEBRUARY AIR MASSES AS DERIVED FROM MODIFIED 'MAMI' CHART



c – continental
m – maritime
P – polar
T – tropical

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

Figure 25

MARCH AIR MASSES AS DERIVED FROM MODIFIED 'MAMI' CHART

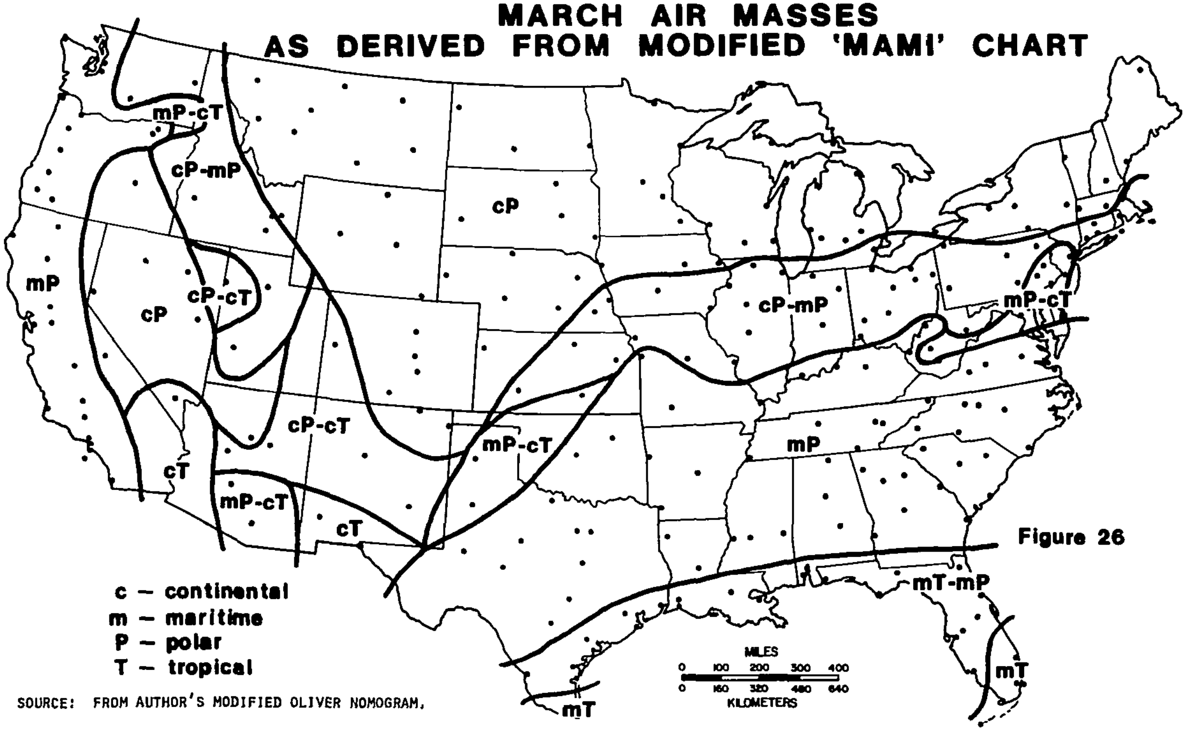


Figure 26

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

APRIL AIR MASSES AS DERIVED FROM MODIFIED 'MAMI' CHART

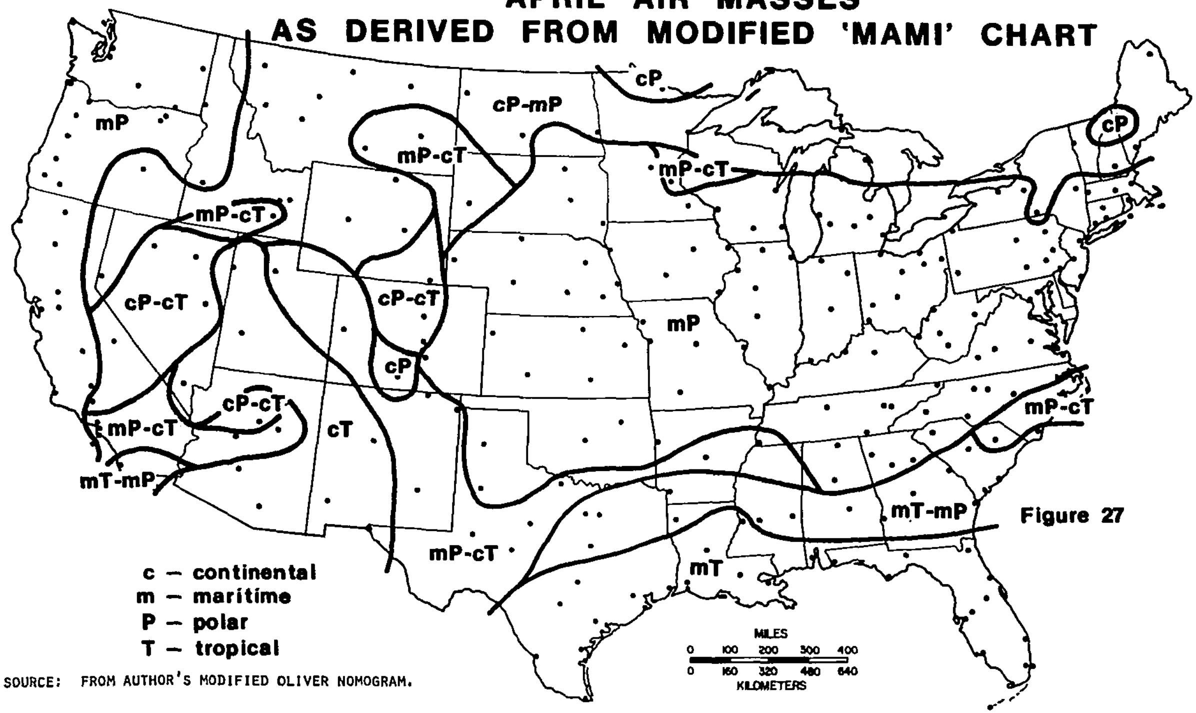
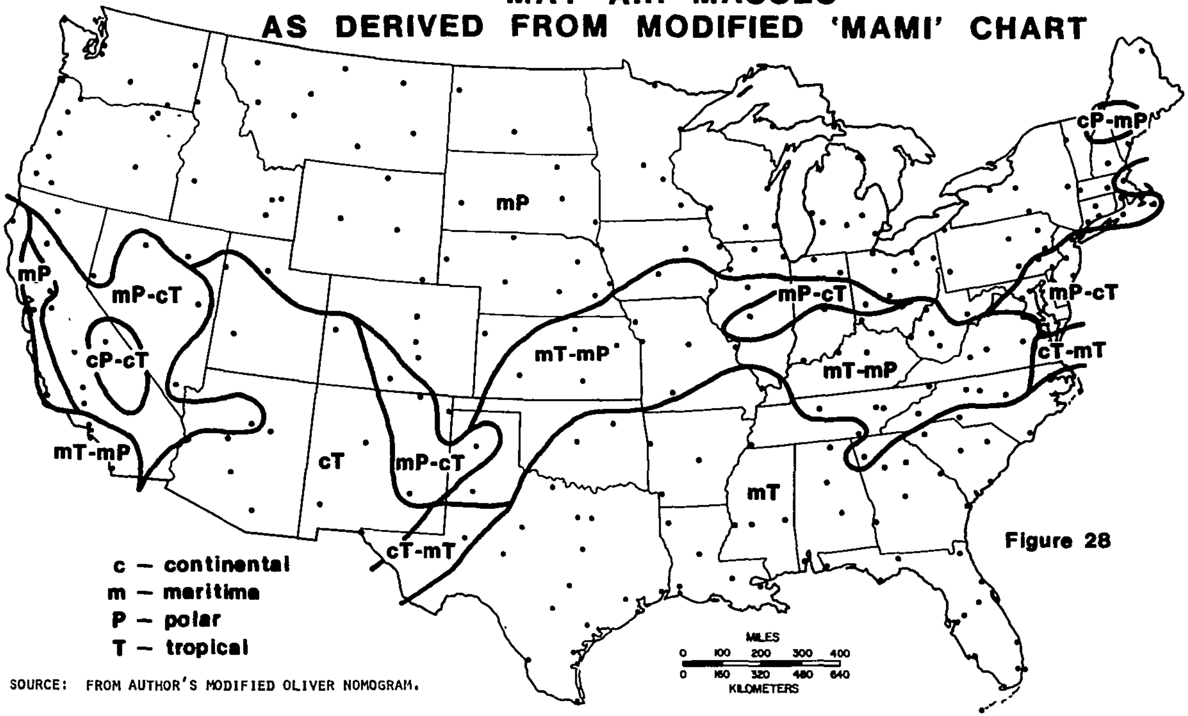


Figure 27

c – continental
m – maritime
P – polar
T – tropical

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

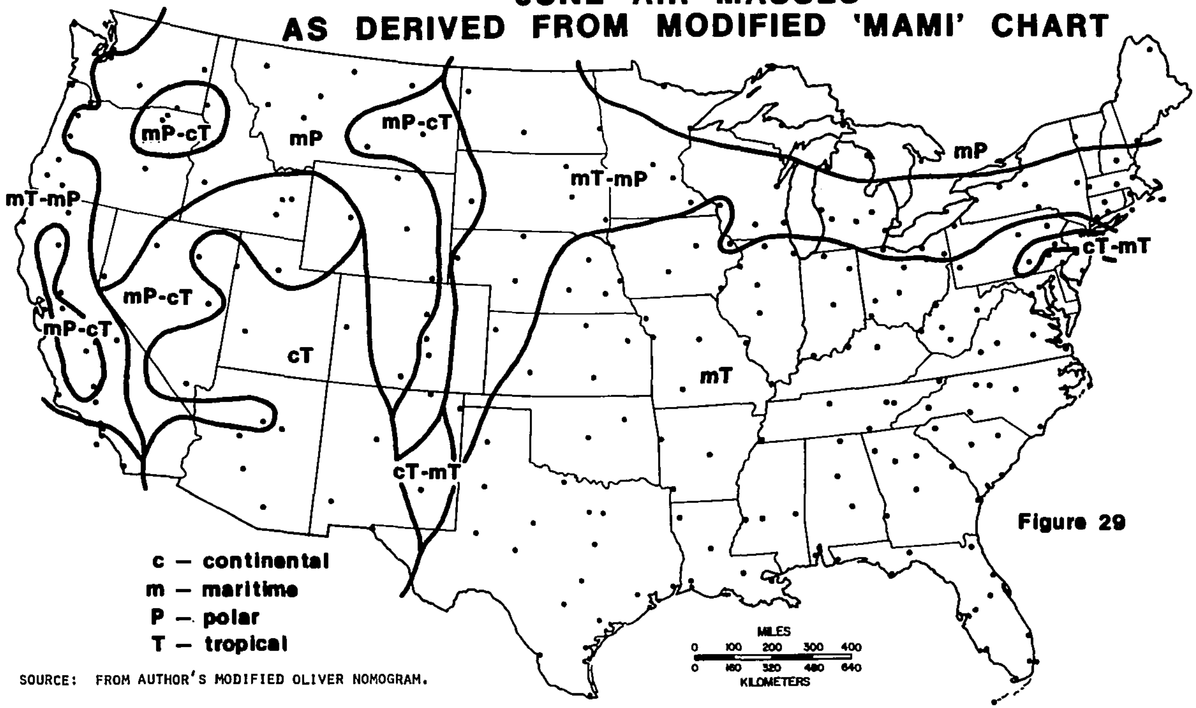
MAY AIR MASSES
AS DERIVED FROM MODIFIED 'MAMI' CHART



SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

Figure 28

JUNE AIR MASSES AS DERIVED FROM MODIFIED 'MAMI' CHART

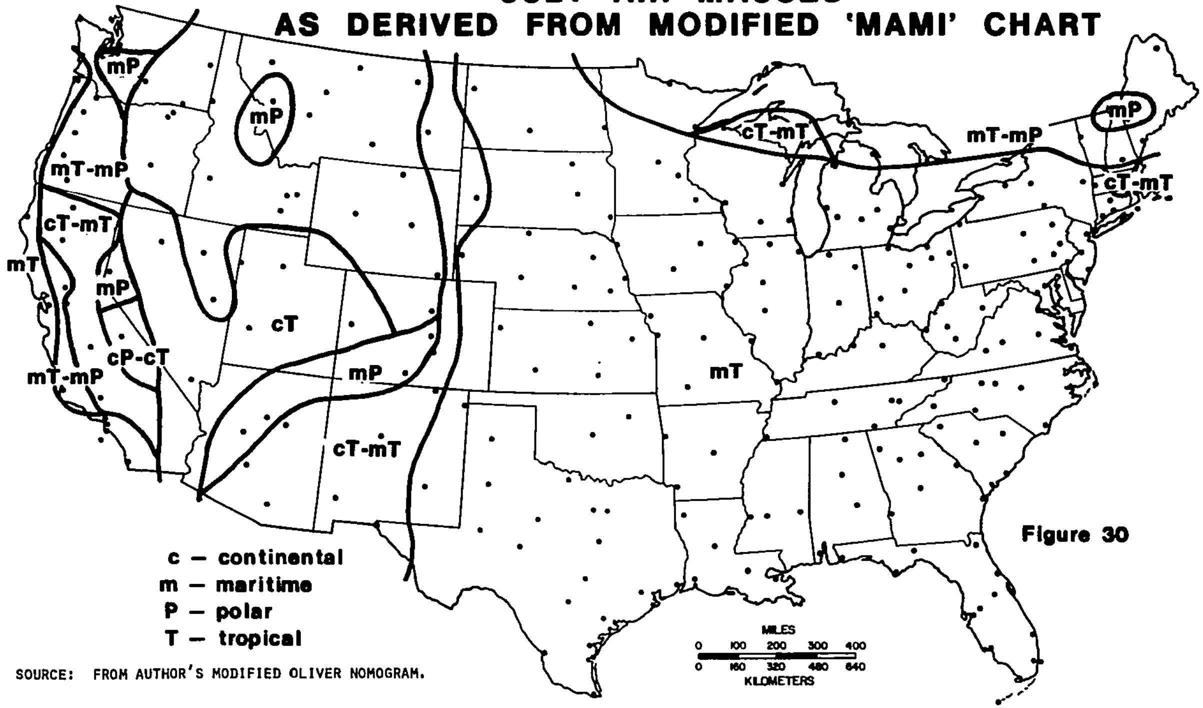


c — continental
m — maritime
P — polar
T — tropical

Figure 29

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

JULY AIR MASSES
AS DERIVED FROM MODIFIED 'MAMI' CHART

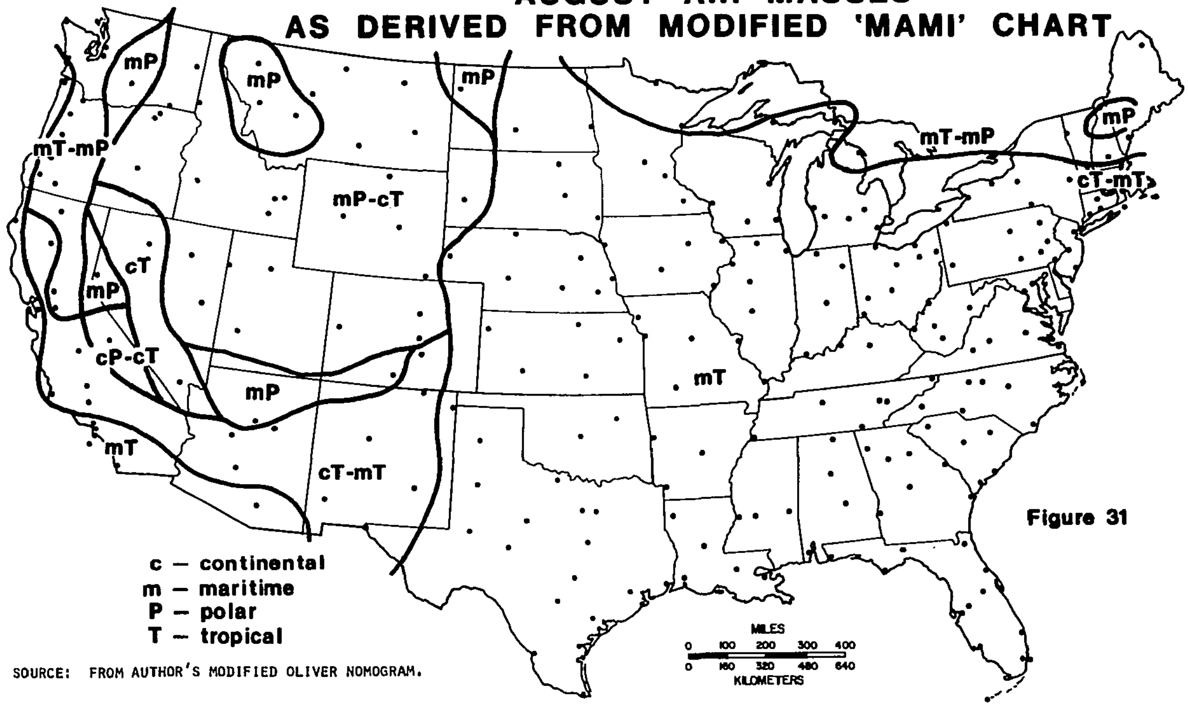


c — continental
m — maritime
P — polar
T — tropical

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

Figure 30

AUGUST AIR MASSES
AS DERIVED FROM MODIFIED 'MAMI' CHART

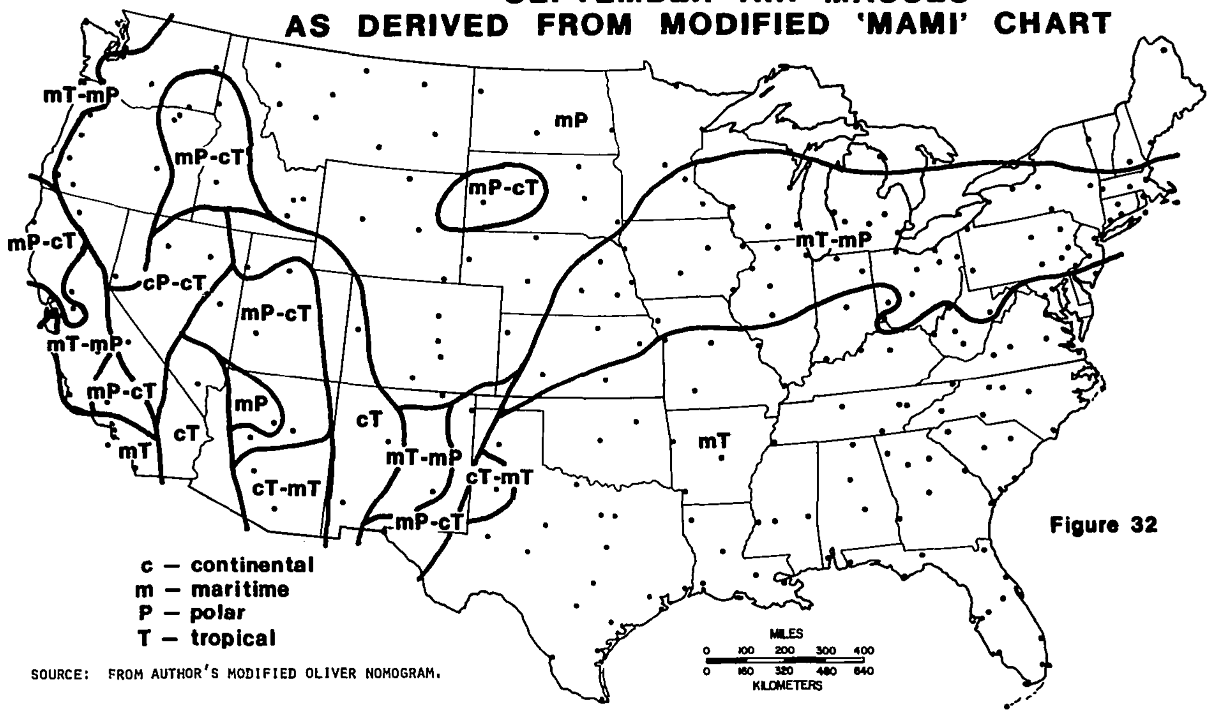


c — continental
m — maritime
P — polar
T — tropical

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

Figure 31

SEPTEMBER AIR MASSES AS DERIVED FROM MODIFIED 'MAMI' CHART



SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

Figure 32

OCTOBER AIR MASSES AS DERIVED FROM MODIFIED 'MAMI' CHART

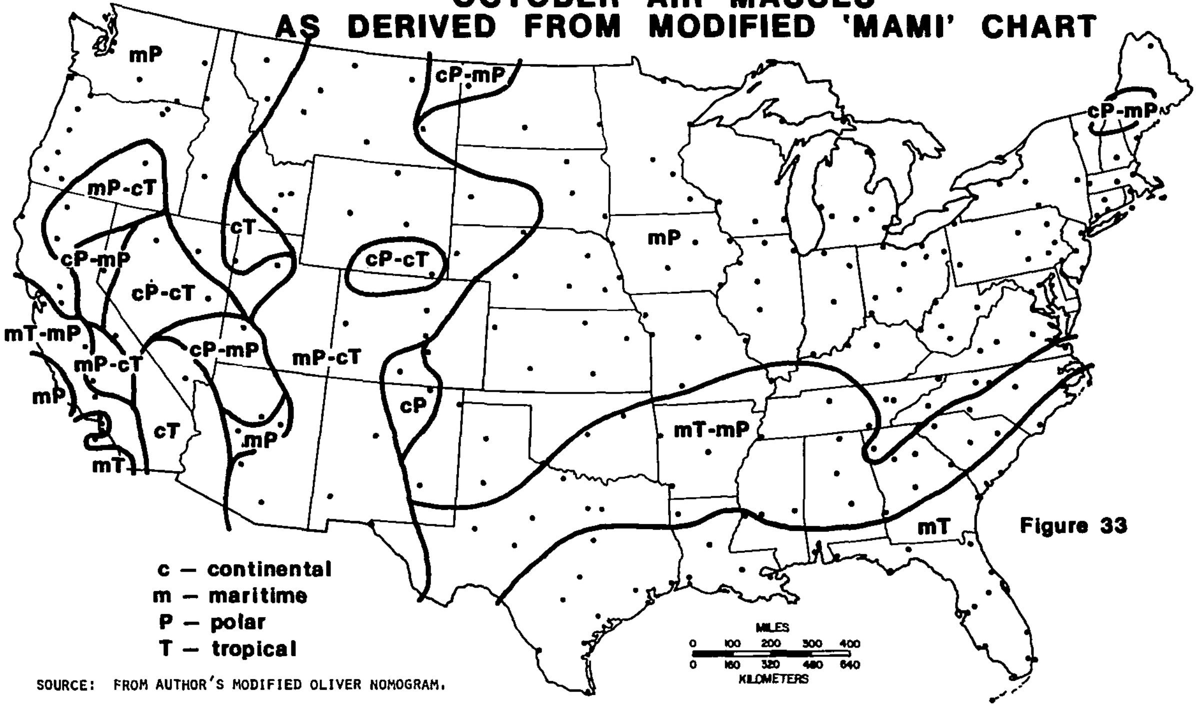


Figure 33

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

NOVEMBER AIR MASSES AS DERIVED FROM MODIFIED 'MAMI' CHART

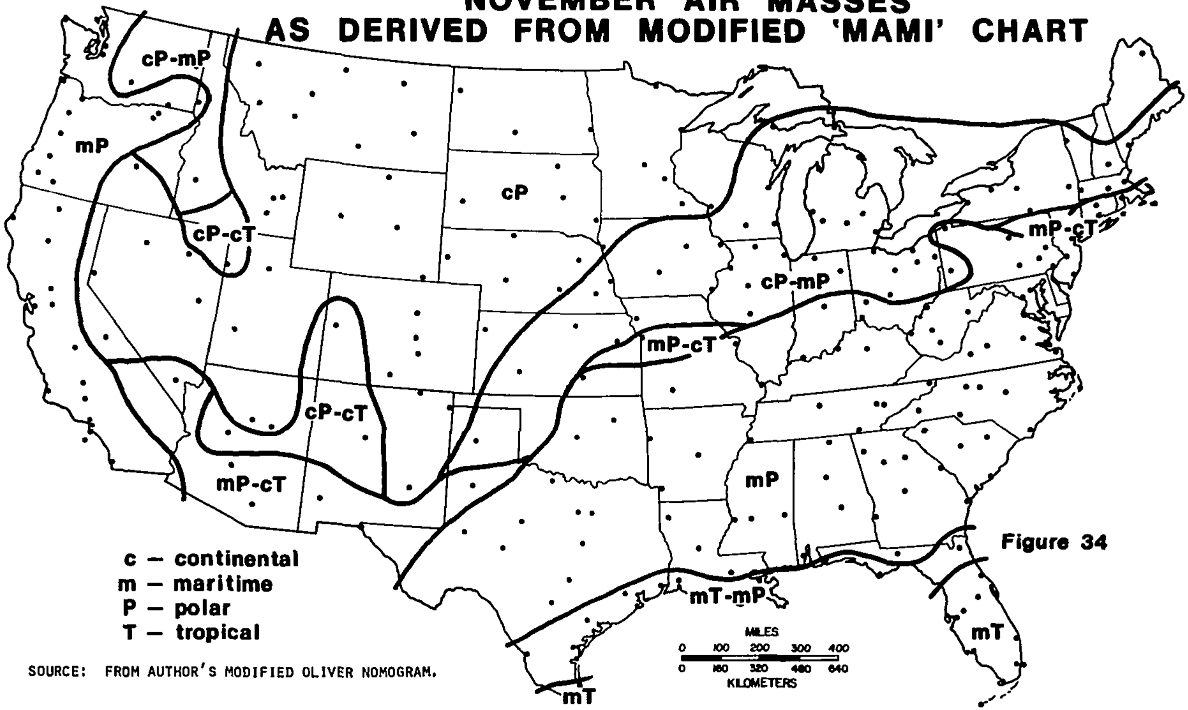


Figure 34

c — continental
m — maritime
P — polar
T — tropical

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

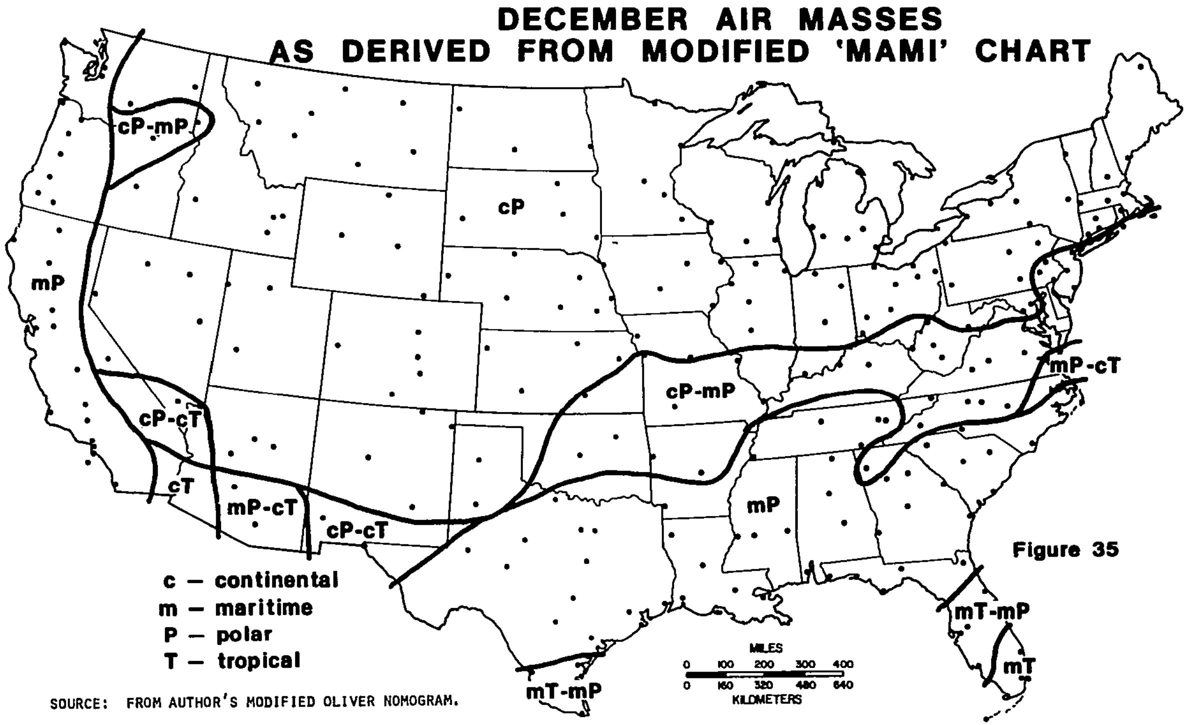


Figure 35

SOURCE: FROM AUTHOR'S MODIFIED OLIVER NOMOGRAM.

CHAPTER IV

ANALYSIS OF MEAN MONTHLY TEMPERATURE AND PRECIPITATION DATA AND CLIMATIC CONTROLS

Taxonomic Clustering of Mean Monthly Temperature and Precipitation

Selected regions of the United States consisting of 78 first-order weather stations were first chosen for the purpose of verifying the notion that within group variation is small and between group variation is large. An intercorrelation matrix was calculated and the results inspected. High correlation values were evident between weather stations within the same group, whereas low or negative correlation values existed between weather stations that were not in the same group (see Table 5). With assurance that a valid classification system can be developed, the numerical taxonomy system was used for the purpose of clustering weather stations.

Next, since the mean monthly temperature and precipitation values are measured in different units and temperature values always exceed precipitation numerically in the United States, all mean monthly temperature and precipitation values were standardized by station (by columns, i.e., all January temperatures, all February temperatures, etc.) so that the two variable unit values are commensurable for taxonomic clustering.

TABLE 5[a]

CORRELATION COEFFICIENTS FOR MEAN MONTHLY TEMPERATURE AND PRECIPITATION VALUES FOR SELECTED WEATHER STATIONS IN THE COTERMINOUS UNITED STATES

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Tucson	1.0									
2.	Winslow	.96	1.0								
3.	Bridgeport	-.86	-.83	1.0							
4.	New Haven	-.90	-.88	.98	1.0						
5.	Orlando	.47	.38	-.48	-.53	1.0					
6.	Savannah	.47	.39	-.43	-.50	.88	1.0				
7.	Cape Hatteras	-.18	.24	.43	.37	.33	.30	1.0			
8.	Rochester	-.85	-.79	.95	.94	-.54	-.48	.38	1.0		
9.	Roswell	.96	.95	-.90	-.94	.55	.51	-.19	-.88	1.0	
10.	Albuquerque	.98	.98	-.88	-.92	.45	.42	-.23	-.86	.98	1.0

[a]Source: Author's calculations

The printed output included a phenogram with implied distances between each adjacent weather station. In addition to the phenogram, a cophenetic correlation value was calculated. This value represents the degree of similarity between real computed distances in multi-dimensional space and distances represented on the phenogram which are printed in two dimensions. With a correlation value of 1.0, no distortion exists between implied and real distances. With smaller values, more distortion is indicated. According to Schnell, values of less than 0.7 usually yield uncertainty in the evaluation of the groupings. The correlation value in this case was 0.776 which is higher than 0.7 which Schnell considers as a minimum value to accept with any degree of confidence.[1]

From a cursory inspection of the phenogram, many distinct clusters of weather stations are evident with many of the grouped stations seemingly spatially contiguous. If these clusters of weather stations can be objectively classified and are contiguous, regionalization of climatic types over the coterminous United States may be accomplished.

For the determination of class boundaries, all distance values between each weather station were plotted on a graph (see Figure 36). An extremely irregular pattern was noted with a considerable number of small distance values and few large distance values. Most of the smaller distance values are below 0.4 whereas the few larger values are generally greater than 0.7. To minimize the number of major groupings of weather stations, a distance value of 0.7 was selected to establish major classes. The 0.7 phenon line resulted in 24 major groups. This number of major

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[1]Dr. Gary Schnell, Associate Professor of Zoology, The University of Oklahoma, 1974.

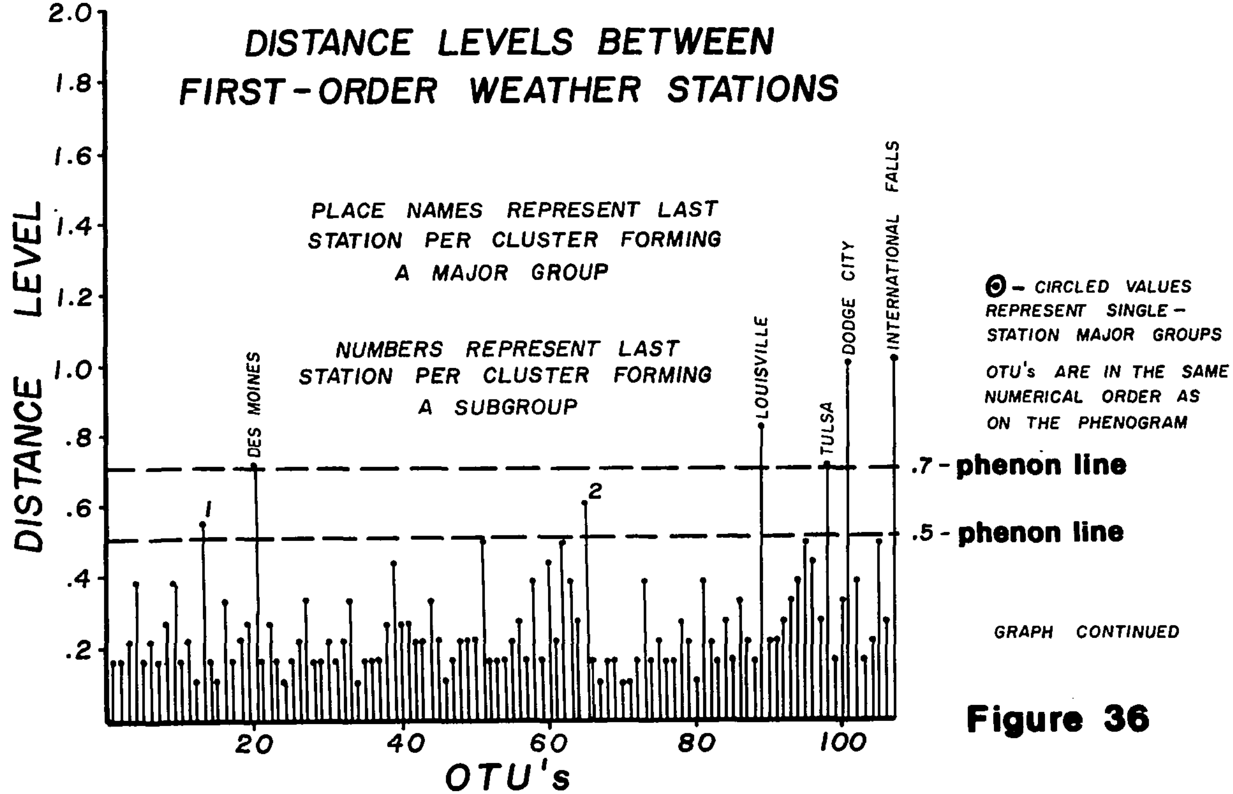


Figure 36

SOURCE: AUTHOR'S CALCULATIONS.

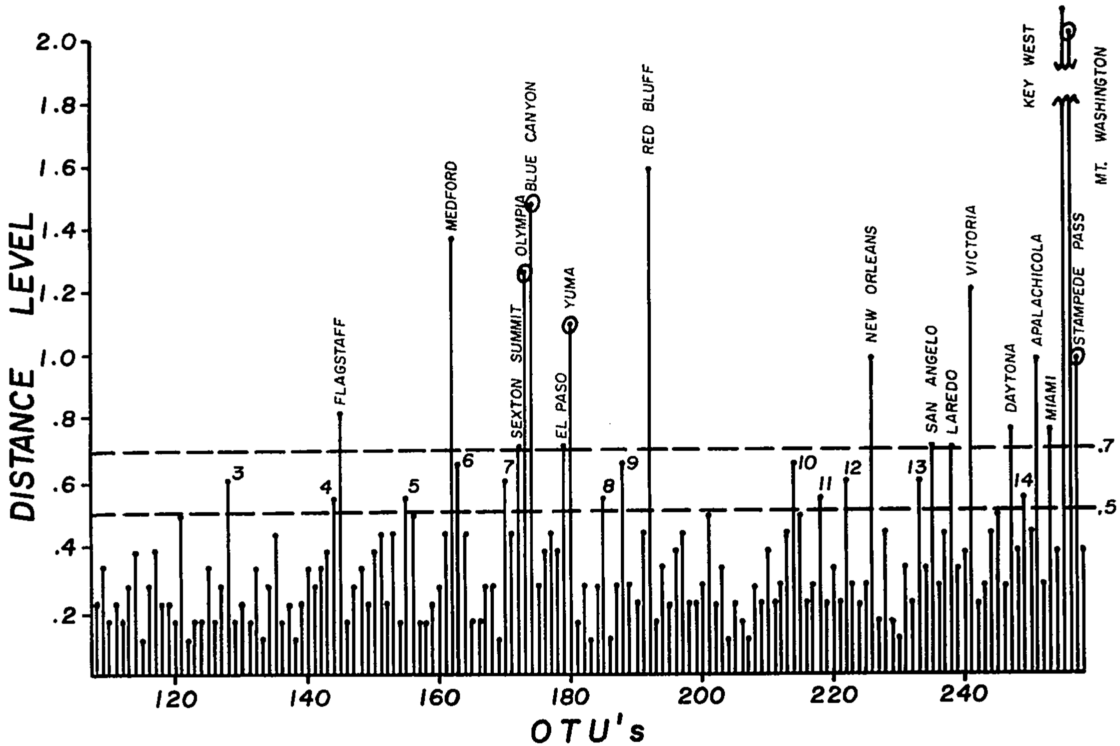


Figure 36 — continued

groups represents more climatic regions than the 10 to 20 groups suggested previously. However, upon further inspection, 5 weather stations—Olympia, Blue Canyon, Yuma, Mt. Washington, and Stampede Pass—constituted such extreme mean monthly temperature and precipitation values that they did not group with other weather stations, i.e., they formed single-station "regions." Since a single weather station should not form the basis of a climatic region, they were eliminated from this investigation. Therefore, 19 major climatic regions consisting of 254 weather stations resulted from the NTSYS clustering technique (see Figures 37 and 38).

The 19 major climatic groups were next delineated on a map of the United States (see Figure 39). Contiguity was prevalent for most of the climatic regions. Two notable exceptions were Regions 6 and 7 in the western United States. Region 6 includes the Great Basin, Rocky Mountains, and the northern portion of the Great Plains and is interrupted by the Columbia and Colorado Plateau. Region 7 includes the Columbia and Colorado Plateaus and the eastern part of the Sierra Nevada Mountains and is interrupted by the Great Basin. Only one additional weather station was some distance from its respective group of weather stations--Burlington, Vermont. The decision of which climatic region is most appropriate for Burlington was made during a discriminant analysis calculation--that of Region 5.

To visually verify the resulting major climatic groups, the mean monthly temperature-precipitation climographs constructed for each weather station by the Cal Comp plotter were scrutinized. Generally, there was a considerable degree of similarity between climographs within

PHENOGRAM REPRESENTING MAJOR CLIMATIC GROUPS OF WEATHER STATIONS

BASED ON MEAN MONTHLY TEMPERATURE AND PRECIPITATION DATA

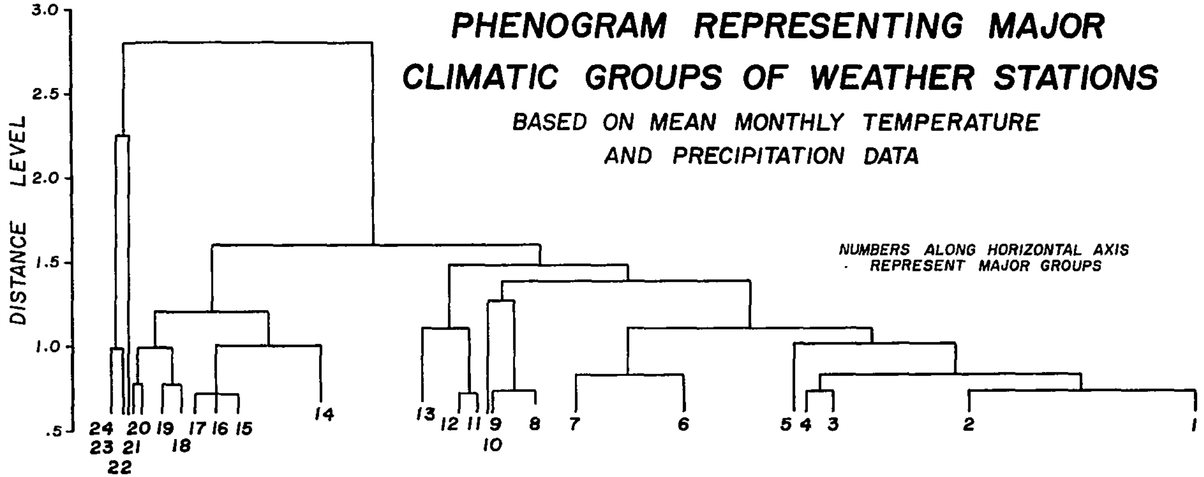
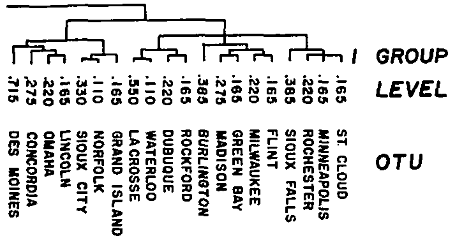


Figure 37

SOURCE: AUTHOR'S CALCULATIONS.

PHENOGRAM FOR STANDARDIZED MEAN MONTHLY TEMPERATURE AND PRECIPITATION DATA



OTU's REPRESENT FIRST-ORDER WEATHER STATIONS IN THE COTERMINOUS UNITED STATES

Figure 38

SOURCE: AUTHOR'S CALCULATIONS.

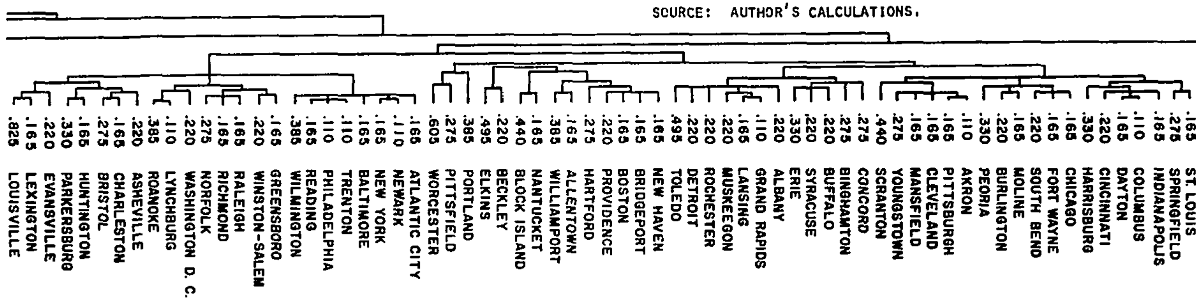
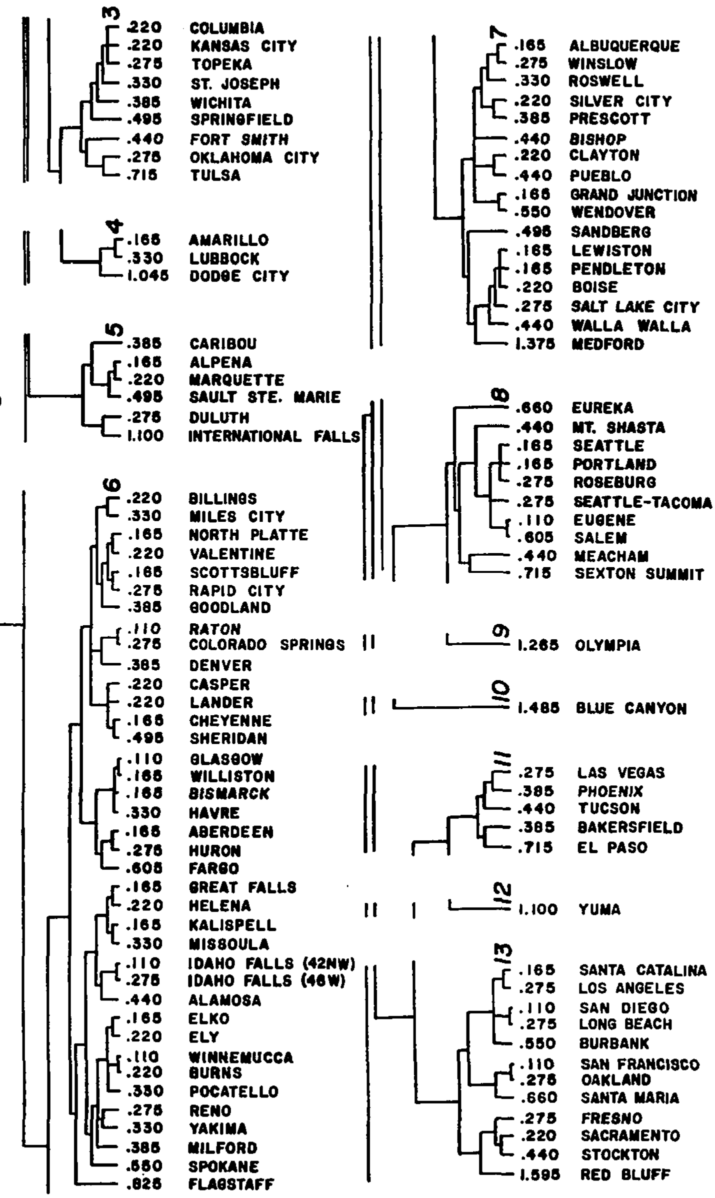


Figure 38 — continued



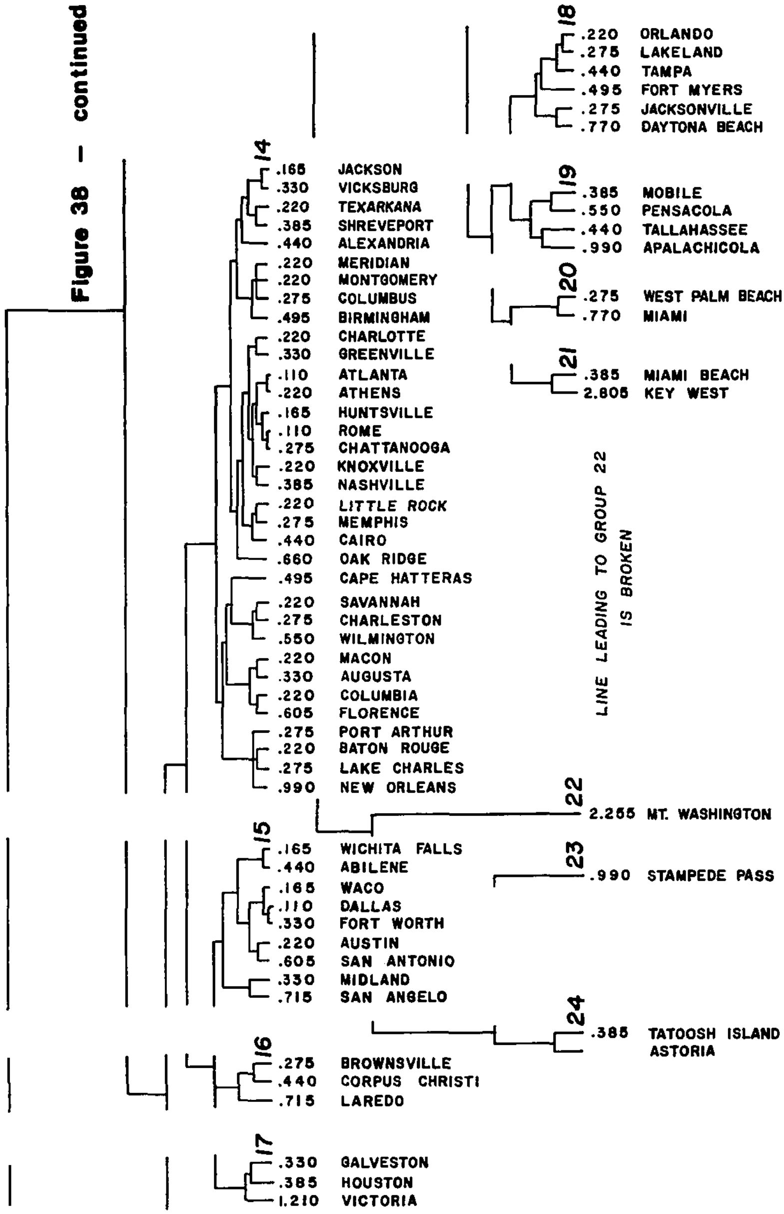


Figure 38 — continued

NINETEEN MAJOR CLIMATIC REGIONS FROM NTSYS CLUSTERING

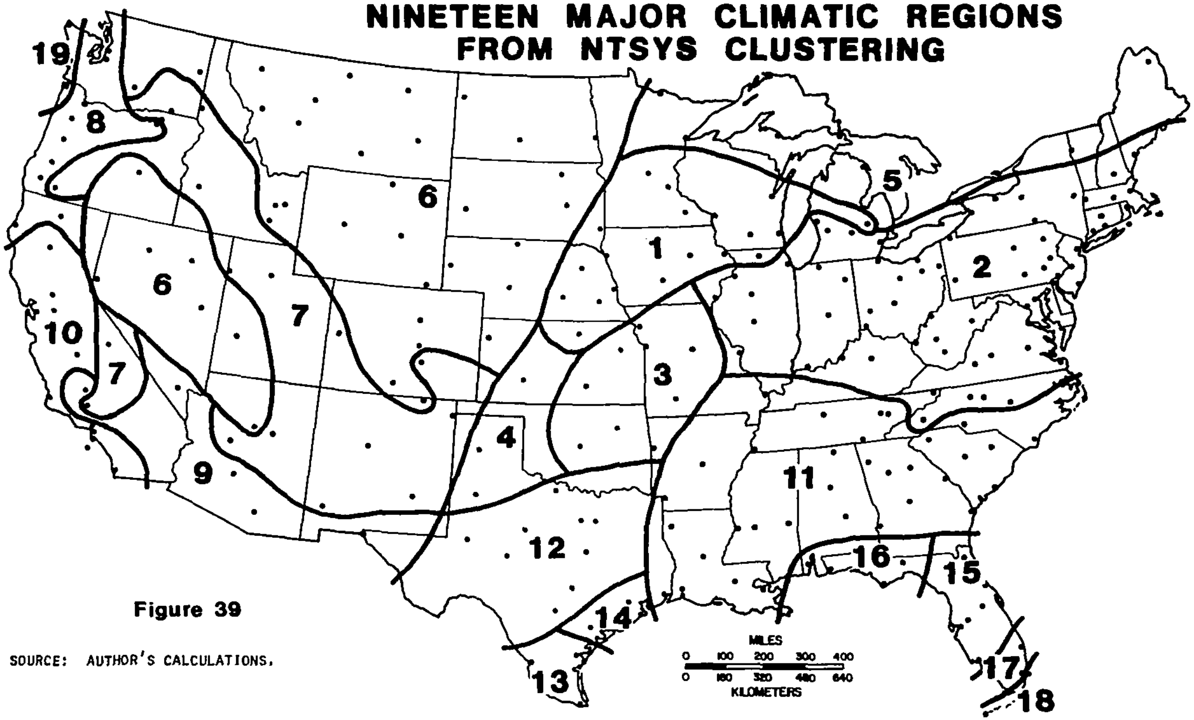


Figure 39

SOURCE: AUTHOR'S CALCULATIONS.

major groups. Annual temperature ranges and extreme values in conjunction with precipitation totals were quite homogeneous. This was especially true for "core" groupings, i.e., weather stations which were not near a class break. However, usually in groups with a large number of stations covering considerable land area, noteworthy changes in the configuration of climographs occurred. Since these different configurations were evidenced as clusters of weather stations within major groupings, and since a change in the configuration of a climograph indicates a change in the character of the climate possibly due to a different interplay of climatic controls, the formation of subgroups was suggested.

Subgroups were formed by using the same distance values as were used in forming major classes. From inspection of individual mean monthly temperature-precipitation climographs and the necessity of limiting the number of subgroups to a manageable size, a distance value of 0.5 was used in establishing secondary groups. This resulted in the formation of 23 subgroups (see Figure 40). Two stations--Eureka, California and Flagstaff, Arizona--formed single-station subregions. However, since subregions are not analyzed mathematically in this investigation, these two weather stations were not omitted. From inspection of individual climographs within subgroups, a much greater degree of homogeneity, especially with regard to climograph configuration similarity, was noted. These major groups and subgroups derived from the standardized mean monthly temperature and precipitation values form the bases for analysis of climatic types in the coterminous United States. A close examination of these climatic types should yield information concerning their genesis since a specific combination and sequence of

MAJOR CLIMATIC REGIONS AND SUBREGIONS FROM NTSYS CLUSTERING

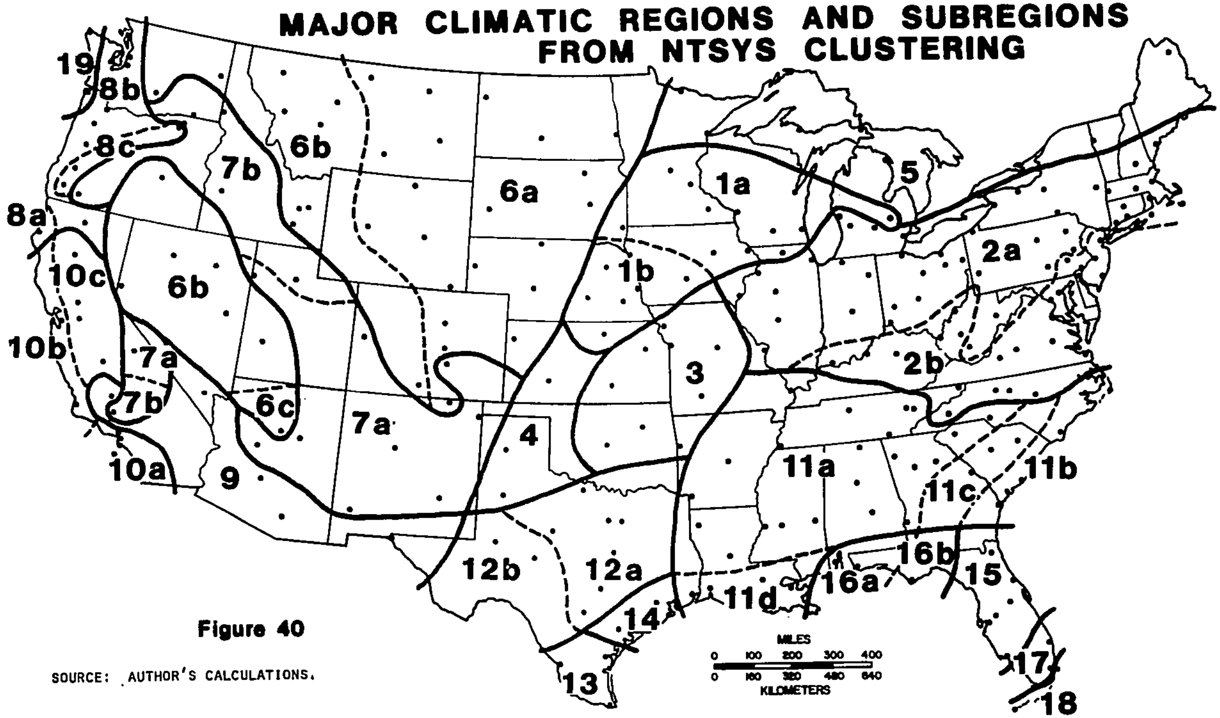


Figure 40

SOURCE: AUTHOR'S CALCULATIONS.

climatic controls are most likely responsible for the similarities revealed.

Component Factor Analysis of Climatic Controls

An intercorrelation matrix was first calculated from the 25 arrays of data representing climatic controls (see Appendix VI). From this intercorrelation matrix a reduced number of climatic controls, called factors, are extracted. This is accomplished by combining those climatic controls that are highly correlated with each other. A total of 7 factors, which are statistically independent, had eigenvalues greater than 1.0 and accounted for 74.3 per cent of the total variation of the 25 arrays of data (see Table 6).[2]

Communality values, which may range as high as 1.0, indicate that most of the 25 climatic controls contributed highly to the composition of the factors (see Table 7). Only three variables contributed less than 0.60 of their total variation to the composition of the 7 factors. The low value (0.44) of orographic effects most likely reflects its complexity and difficulty in operationalizing a satisfactory index. Consequently, its role as a discriminating variable should be weak with a possible exception of the most mountainous regions. Two transition air mass types, cP-mP and cT-mT, also have low communality values of 0.50. These air mass types are quite distinct from the other climatic controls. This is evident from inspection of the intercorrelation matrix (see Appendix VI). These two climatic controls have low correlation values between each of the other climatic controls. Since they are so

[2]An eigenvalue is a latent root of a characteristic equation--see Rummel, op. cit., pp. 95-100.

TABLE 6[a]

VARIATION OF CLIMATIC CONTROLS EXPLAINED BY FACTORS

Factor	Eigenvalue	% of Variation—Unrotated Factors	Cumulative %—Unrotated Factors
I	6.1	24.3	24.3
II	4.5	17.9	42.2
III	2.5	10.0	52.3
IV	1.9	7.4	59.7
V	1.4	5.7	65.4
VI	1.2	4.7	70.1
VII	1.1	4.2	74.3

[a]Source: Author's calculations.

TABLE 7[a]

COMMUNALITIES OF 25 CLIMATIC CONTROLS OVER SEVEN FACTORS

Climatic Control	Elevation	Cosine of Latitude	Mean Annual Wind Velocity	Mean Sky Cover	Variability of Mean Annual Wind Velocity
Communality	.73	.93	.68	.78	.69
Climatic Control	Variability of Mean Sky Cover	Continen-tality	Orographic Effect	Mean Press-ure	Variability of Mean Pressure
Communality	.73	.85	.44[b]	.83	.83
Climatic Control	January Ocean Currents	July Ocean Currents	Total Number of Lows	Varia-bility of Total Number of Lows	Total Number of Highs
Communality	.81	.84	.85	.73	.84
Climatic Control	Variability of Total Number of Highs	cP Air Mass	cP-mP Air Mass	mP Air Mass	cP-cT Air Mass
Communality	.60	.82	.50[b]	.74	.80
Climatic Control	cT Air Mass	mP-cT Air Mass	mT-mP Air Mass	mT Air Mass	cT-mT Air Mass
Communality	.74	.76	.66	.91	.50[b]

[a]Source: Author's calculations.

[b]Underlined values are less than .50.

distinct, much of their total variation is accounted for in the trivial variance. Therefore, the usefulness of these two air mass types as discriminating variables are most likely limited.

A varimax rotation was applied to these seven factors. The factor loadings reveal the underlying structure of each factor for subsequent interpretation (see Table 8). Spatial analysis is enhanced by examining the associated factor scores which have been mapped for all 254 weather stations in the coterminous United States.

Factor I explains 18.1 per cent of the total variance and is therefore the most significant of the seven factors. High positive loadings on this factor are continentality, total number of lows, variability of total number of lows, and cP air mass whereas the cosine of latitude and mT air mass load high negatively. This factor appears to suggest the continental storm track (see Figure 41). During the 20 years of records used in this investigation, the annual number of lows throughout the southeast United States and West Coast have been small compared to more interior and northeasterly sections of the country. During any month of the year for the 20 years, a scanty 0 to 10 storm systems were counted in these areas.[3] These lower latitude areas, particularly the southeast United States, are dominated by mT air from May through September (see Figures 24-35). By contrast, generally at higher latitudes, large numbers of storms develop during winter and transition seasons and converge in the northeast United States. For example, 34 storms were counted for the 20-year period during March over Utah. During the month of August this number decreased to

[3] William H. Klein, op. cit., pp. 23-34.

TABLE 8[a]

MATRIX OF ROTATED FACTOR LOADINGS

	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII
Elevation	.33	.54	.12	.31	.23	.36	-.18
Cosine of Latitude	-.71	.20	-.25	.10	-.56	.09	.02
Mean Annual Wind Velocity	.40	.13	-.06	-.02	-.23	-.02	.67
Mean Sky Cover	.26	-.69	.34	-.10	.08	-.31	.07
Variability of Mean Annual Wind Velocity	-.05	-.10	.05	.17	.04	.05	.80
Variability of Mean Sky Cover	-.13	.19	.12	.16	.78	.13	-.12
Continentality	.77	.07	.29	.40	.03	-.07	.04
Orographic Effect	-.16	-.16	-.06	-.24	-.12	-.18	.53
Mean Pressure	.35	-.68	.42	-.07	.01	-.24	-.09
Variability of Mean Pressure	.00.	-.69	-.02	.43	.12	.36	-.15
January Ocean Currents	-.13	.04	.05	-.86	-.23	.01	.07
July Ocean Currents	.26	.14	.32	.74	-.30	-.01	.07
Total Number of Lows	.89	-.03	.14	.08	-.13	.02	.09
Variability of Total Number of Lows	.83	.16	-.04	-.02	-.06	.11	.03

TABLE 8[a]--(Continued)

	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII
Total Number of Highs	.46	-.36	.67	.18	.01	-.15	-.03
Variability of Total Number of Highs	.05	-.01	.65	.18	.22	-.20	-.26
cP Air Mass	.86	.07	.07	.21	.09	.03	-.10
cP-mP Air Mass	.12	-.14	.63	-.03	.03	-.09	.24
mP Air Mass	-.18	-.30	-.19	-.12	.48	-.57	-.09
cP-cT Air Mass	.04	.15	-.08	-.01	.08	.87	-.08
cT Air Mass	.03	.21	.03	-.04	.11	.83	-.02
mP-cT Air Mass	.08	.71	.32	-.07	.31	.09	-.21
mT-mP Air Mass	-.14	-.52	-.55	-.02	.06	-.18	.19
mT Air Mass	-.58	-.21	-.07	.02	-.70	-.17	.10
cT-mT Air Mass	.03	.68	-.13	-.10	-.01	.03	.06
% of Variation--Rotated Factors	18.1	13.9	9.4	8.0	8.5	9.6	6.8
Cumulative %--Rotated Factors	18.1	32.0	41.4	49.4	57.9	67.5	74.3

*Factor loadings of .50 or greater are underlined.

[a]Source: Author's calculations.

CONTINENTAL STORM TRACK
FACTOR I

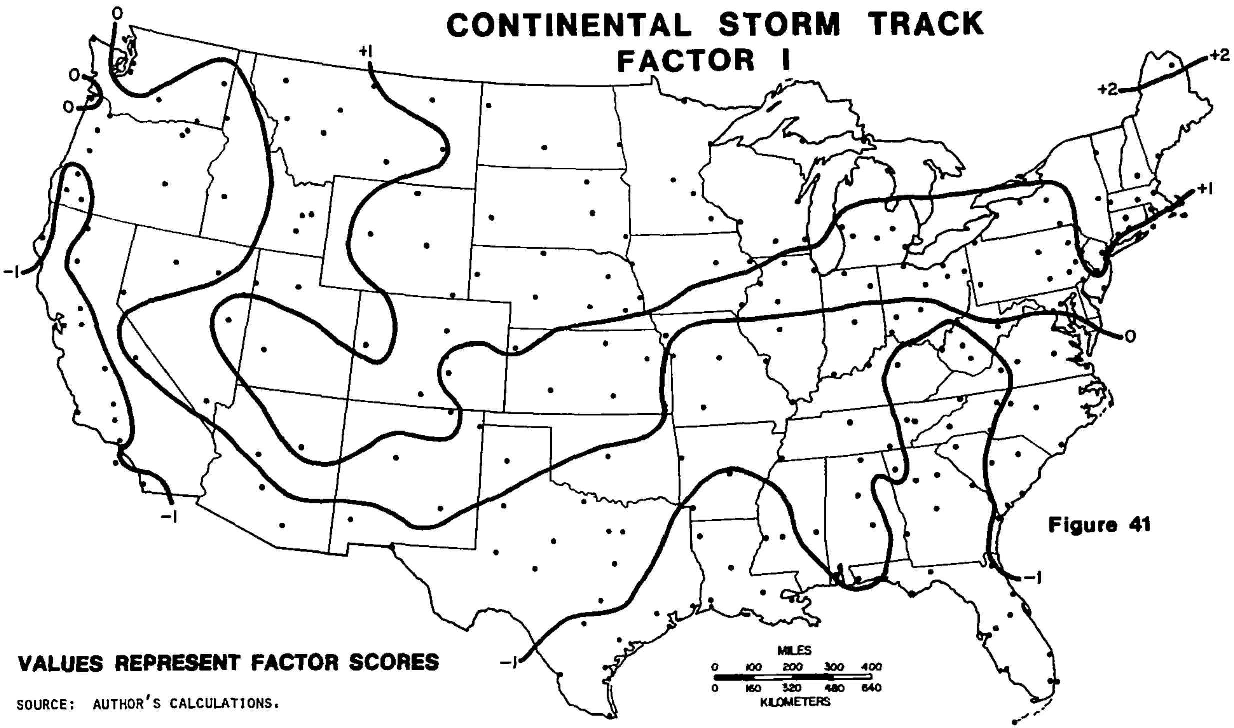


Figure 41

VALUES REPRESENT FACTOR SCORES

SOURCE: AUTHOR'S CALCULATIONS.

approximately 10 storms.[4] These continental areas in the United States are dominated by cP air mass from November to April. Also, the factor score pattern over the continental portion of the United States closely coincides with the Oliver index continentality map in addition to other continentality maps such as the one developed by Conrad (see Figure 9).[5] This factor should aid considerably in discriminating between characteristics of continental and coastal weather stations.

Factor II explains 13.9 per cent of the total variance and is the second most significant factor. High positive loadings on this factor are elevation, annual variability of mean pressure, and mP-cT and cT-mT air masses. High negative loadings on this factor are mean sky cover and mean annual pressure. These loadings strongly suggest that this factor represents solar radiation receipt variability over the United States. Large positive factor scores are evident throughout the Desert Southwest extending into the San Joaquin Valley of California (see Figure 42). This area has the least mean annual sky cover in the United States with values of 30-40 per cent of the possible total (see Figure 21). During the summer months, the persistent thermal low develops throughout this region with mean monthly pressure values of 1008 mb. and lower.[6] During the winter season, pressure values are relatively high, 1018 mb., which contributes to high mean monthly pressure variability. This region is dominated by cT air mass and cT transition air masses during the entire

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[4]William H. Klein, _op. cit_., pp. 23-34.

[5]Trewartha, _op. cit_., p. 254.

[6]_Climatic Atlas of the United States_, _op. cit_., pp. 79-80.

SOLAR RADIATION RECEIPT
FACTOR II

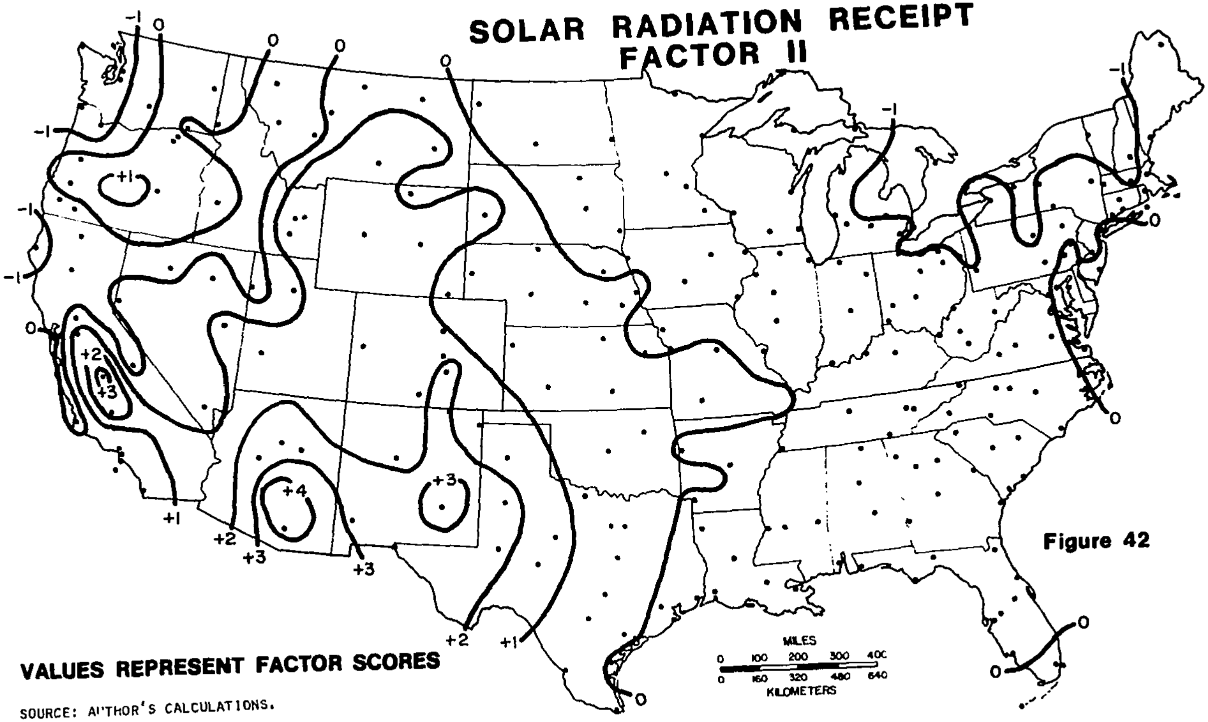

Figure 42

VALUES REPRESENT FACTOR SCORES

SOURCE: AUTHOR'S CALCULATIONS.

year. The northward extension of positive factor scores is the result of higher elevations in the United States, particularly the Rocky Mountains. Factor scores with magnitudes in the order of -1.0 are observed in the northeast and northwest sections of the United States. These areas have high mean sky cover with little variability of mean annual pressure. The mean monthly pressure in these regions ranges from 1013 mb. to 1019 mb.[7] Furthermore, no cT transition air masses are indicated for these areas during the year (see Figures 24-35). This factor will be helpful in discriminating between weather stations in the southwest United States from those in other regions.

Factor III explains 9.4 per cent of the total variance. High positive loadings on this factor are total number of highs, annual variability of total number of highs, and cP-mP air mass. A high negative loading on this factor is mT-mP air mass. From these high loadings and observation of the distribution of factor scores over the United States, special emphasis must be placed on winter-time high pressure systems (see Figure 43). The most salient feature over the United States is centered over the Columbia Plateau where highest positive factor scores occur. This region coincides with the location of a persistent, stagnant anticyclone which produces cold and dry weather during the winter months.[8] A large high pressure cell is evident over this region from November through February.[9] As many as 56 highs have been recorded over 20 years during the months of December and January

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[7] Ibid., pp. 79-80.

[8] Robert DeCourcy Ward, The Climates of the United States (Boston: Ginn and Company, 1925), p. 73.

[9] Climatic Atlas of the United States, op. cit., pp. 79-80.

WINTER-TIME HIGH PRESSURE SYSTEMS
FACTOR III

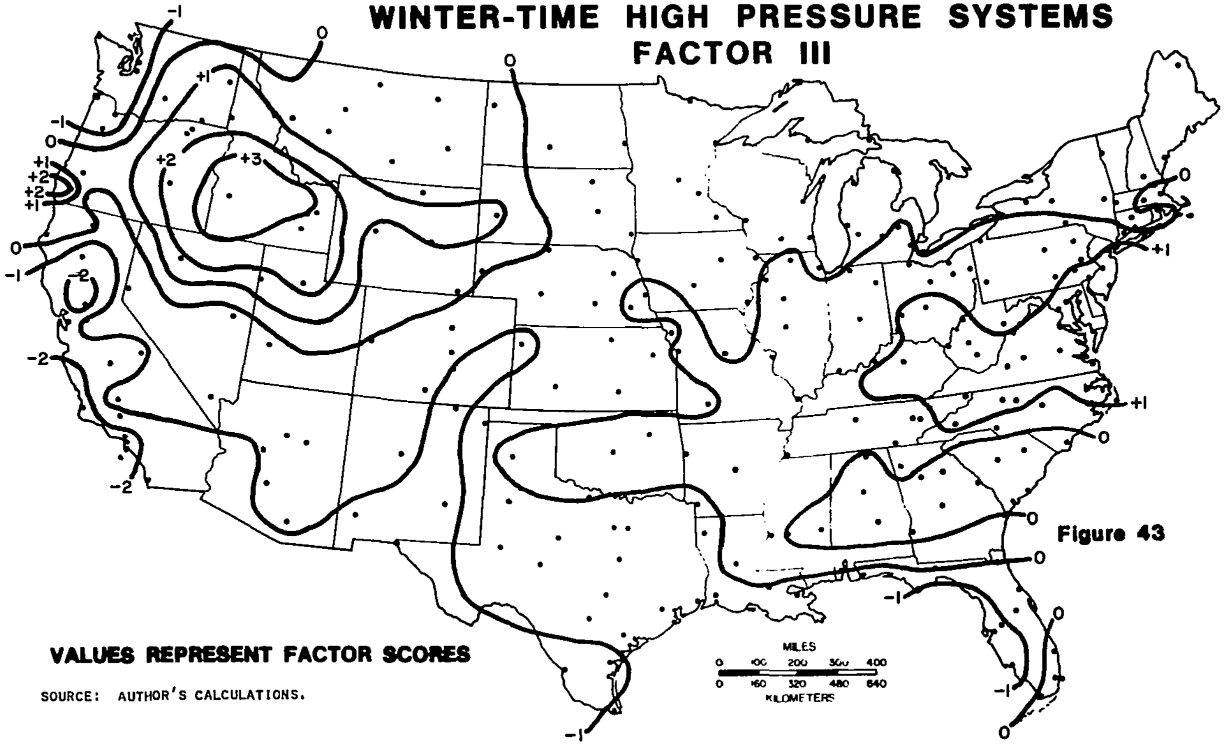

Figure 43

VALUES REPRESENT FACTOR SCORES

SOURCE: AUTHOR'S CALCULATIONS.

with fewer than 10 for the summer months.[10] This region is dominated by a cP-mP air mass from November through April (see Figures 24-35). Positive factor scores are also observed in the east-central United States. Numerous high pressure cells develop over this area during October through December (about 35 per month for 20 years records).[11] This high pressure cell is vividly displayed on a 5-day normal sea-level pressure chart for October 8 through 12.[12]

Negative factor scores are observed throughout a large area of California, southern Arizona, and eastern New Mexico and Colorado. Smaller areas are noted for western Florida and Washington. No cP-mP air mass prevails in any of these areas during the year. However, mT-mP air mass is evident along the West Coast of the United States during the summer months and in Florida during winter. Few high pressure cells occur during the year for any of these areas. This absence of high pressure cells, with little annual variability, practically surrounds the Columbia Plateau during the winter season with the fewest number of highs occurring in California.[13] This factor will be useful in discriminating between weather stations throughout the Columbia Plateau, where distinctive winter-time weather characteristics are observed, from surrounding weather stations.

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[10] William H. Klein, _op. cit._, pp. 35-46.

[11] _Ibid._, pp. 44-46.

[12] James F. Lahey, Reid A. Bryson, and Eberhard W. Wahl, _Atlas of Five-Day Normal Sea-Level Pressure Charts for the Northern Hemisphere_ (Madison: The University of Madison Press, 1958).

[13] Klein, _op. cit._, pp. 35-46.

Factor IV explains 8.0 per cent of the total variance. There are only two high loadings on this factor, one negative and one positive. These two loadings represent ocean currents for January and July, respectively. From inspection of the factor score map, it is readily apparent that only the Pacific and Atlantic Coasts have negative factor scores. The values range from about -1.0 along the Carolinas and Maine to -4.0 at Eureka on the West Coast (see Figure 44). All of these negative values represent large contrasts from the sea surface water temperatures along the coast to a maximum of 100 miles inland for January and/or July. Eureka, with the greatest negative departure, at approximately 40°N, has one of the greatest increases of temperature inland during the month of July (see Figure 17). From a sea surface water temperature of about 57°F, the temperature rises to 84°F 100 miles inland. The intense upwelling at this latitude, as previously mentioned, is partly responsible for this strong ocean current effect. This rapid increase in temperature inland is also noted farther south along the southern California coast (see Figure 17). The high negative values along the Washington coast are the result of a winter ocean current effect. Sharp increases in temperature inland are not observed at 46°N and 48°N during July, but during January a large decrease in temperature occurs from the coast to 10 miles inland (see Figure 20). Cold land surface temperatures contrast sharply to the mild coastal temperatures.

The greatest negative departures along the East Coast are north of Cape Hatteras and south of Rhode Island. This coastal section is strongly influenced by ocean currents during both January and July.

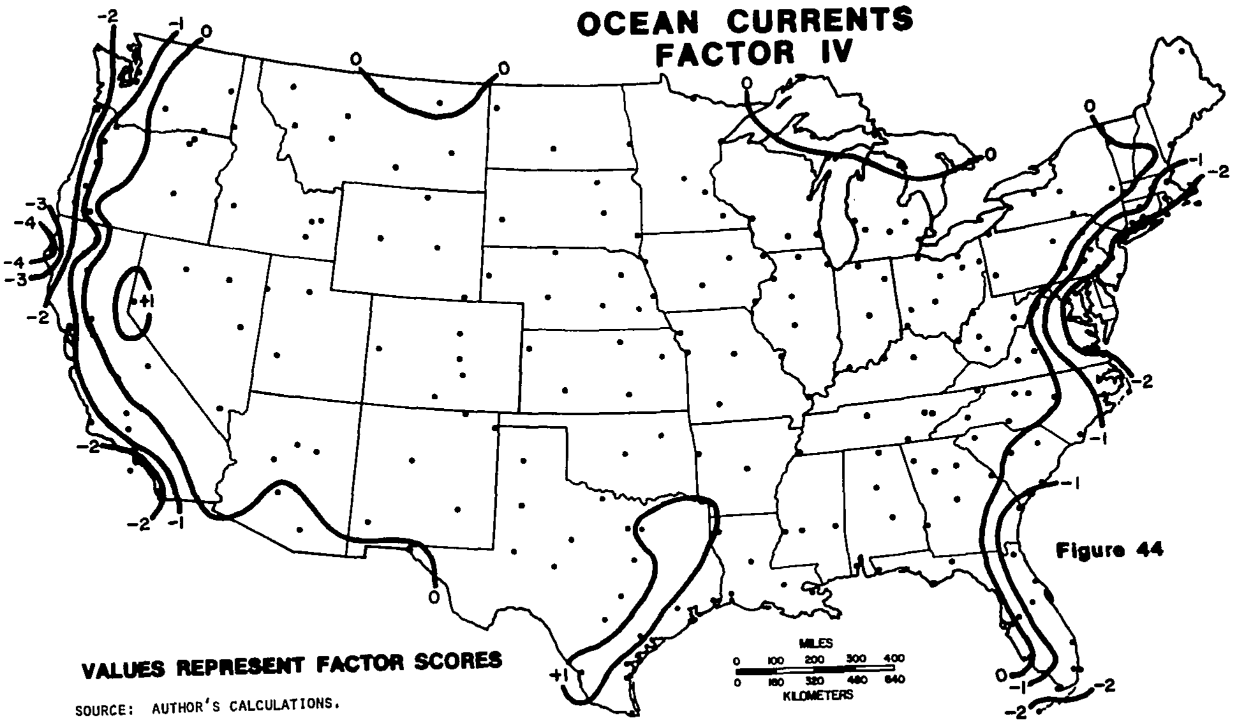

Figure 44

VALUES REPRESENT FACTOR SCORES

SOURCE: AUTHOR'S CALCULATIONS.

Typically, a decrease in temperature occurs inland along the entire East Coast during January with the exception of 38°N (see Figure 19). However, during July, only north of 36°N are abrupt temperature increases inland observed (see Figure 18). Due to the northwestward bending of the coastline at 35°N, the Gulf Stream does not affect this area as energetically as it does farther south, but the influence of the cold Labrador Current becomes increasingly stronger. Therefore, cool coastal water and a warm land surface temperature inland combined with the January ocean current effect result in these lower factor scores north of 35°N. This factor will be useful in discriminating between coastal and inland weather stations.

Factor V explains 8.5 per cent of the total variance. A high positive loading on this factor is variability of mean sky cover. Also, mP air mass has a positive loading of 0.48 which would indicate some degree of relevance. High negative loadings on this factor are cosine of latitude and mT air mass. This factor best expresses maritime cloud variability. From observation of the factor score map, four areas in the United States have factor scores greater than ±1.0 (see Figure 45). Firstly, the northwest United States has high positive factor scores. Tatoosh Island has the highest value of +3.2. Secondly, Florida has high negative values with -2.0 and greater observed in the southern portion of the state. Finally, the coast of Texas and from Cape Hatteras to Rhode Island have moderately high negative values.

Latitude is important in this factor since it is related to the monthly distribution of maritime tropical and polar air masses. Along the coast of Texas and the southern part of Florida, mT and/or mT

MARITIME CLOUD VARIABILITY
FACTOR V

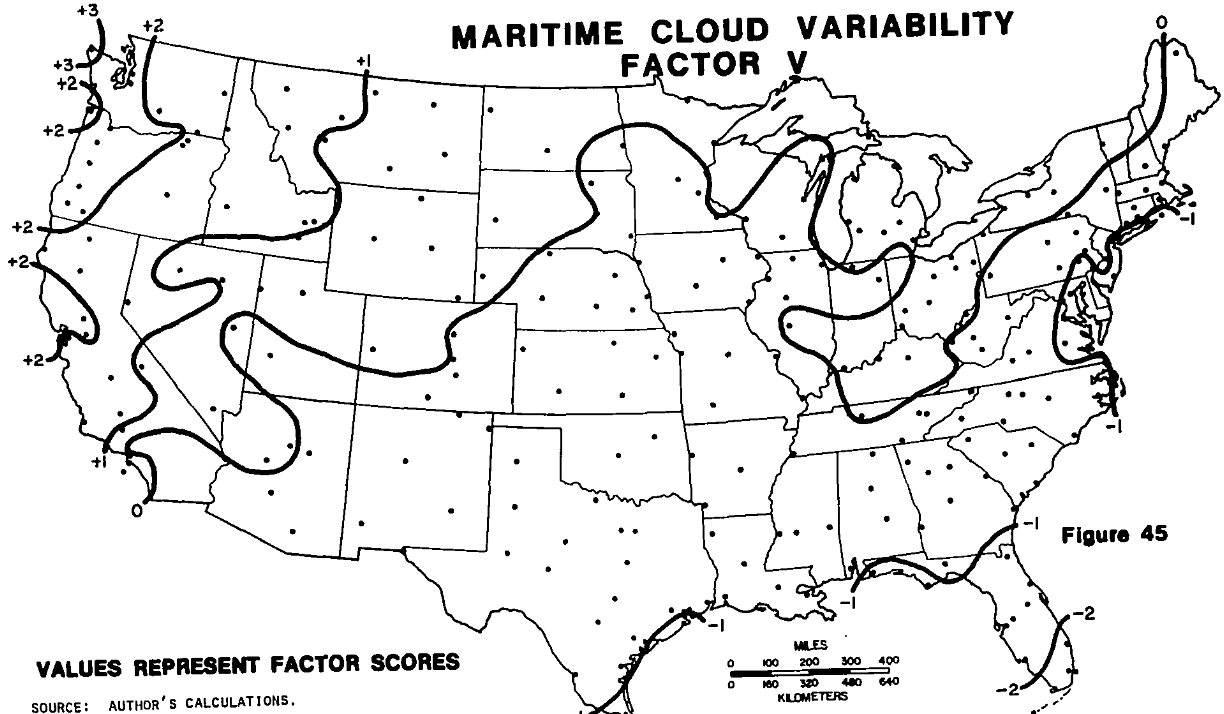

Figure 45

VALUES REPRESENT FACTOR SCORES

SOURCE: AUTHOR'S CALCULATIONS.

transition air masses are predominant throughout the year (see Figures 24-35). Only during the winter months does mT-mP air mass appear in these regions on the monthly air mass maps. Along the East Coast of the United States, mT air mass prevails for a longer period of time than in the northwest United States. In contrast, the northwestern part of the United States is dominated by mP and mP transition air masses throughout the year.

Annual cloud variability differs strikingly between the northwesterly and the southeast-easterly areas of the country (see Table 9). Generally, large annual variations in mean sky cover are observed in the northwest United States. Clear skies during the summer months, under the influence of the Pacific subtropical high pressure cell, are the general rule. With the weakening and southward displacement of this high pressure cell, much cloudiness occurs during the winter. Exceptions to this are Tatoosh Island, Astoria, and Eureka which are coastal weather stations. Evidently, these three weather stations experience much cloudiness even during the summer months due to moist onshore breezes over cool sea surface temperatures. Throughout the southeastern and eastern parts of the United States, little seasonal variability in sky cover is evident (see Table 9). This factor will aid in discriminating between the maritime northwest and southeast United States weather stations.

Factor VI explains 9.6 per cent of the total variance which is a slightly greater degree of explanation than either Factors IV or V. High positive loadings on this factor are cP-cT air mass and cT air mass. A high negative loading on this factor is mP air mass. This factor suggests

TABLE 9[a]

MAXIMUM, MINIMUM AND ANNUAL VARIANCE OF SKY COVER FOR SELECTED UNITED STATES WEATHER STATIONS

Weather Station	Minimum Sky Cover in Tenths	Time of Occurrence	Maximum Sky Cover in Tenths	Time of Occurrence	Annual Standard Deviation of Sky Cover
1. Atlantic City	5.0	October	6.5	February	.40
2. Miami	4.3	February	6.1	September	.63
3. Brownsville	4.7	July, August, October	6.8	March	.83
4. Eugene	3.6	July	8.8	December	1.72
5. Spokane	3.4	July	8.6	December	1.66
6. Red Bluff,	1.2	July	6.8	December	2.00
7. Eureka	6.0	September	7.5	December	.45
8. Astoria	6.4	September	8.6	December	.74
9. Tatoosh Island	6.5	September	8.1	December	.50

[a]Source: Local Climatological Data with Comparative Data, 1964.

a continental moisture index. From the factor score map, Yuma and from Las Vegas north and then northeastwards to Wendover have factor scores over +3.0 (see Figure 46). These two locations have cT air mass dominating throughout much of the year (see Figures 24-35). For example, cT air mass is observed at Yuma in every month of the year except August. During August cT-mT air mass dominates. The occurrence of cT-mT air mass at Yuma coincides with the month of greatest precipitation (0.50"). The moisture in August is the result of a change in position of large-scale circulation features and places Yuma under a flow of moist air from the Gulf of Mexico.[14] Las Vegas is dominated by cT air mass for the 8 warmer months of the year. However, due to cooler temperatures at a higher latitude than Yuma, cT transition air masses (mP-cT and cP-cT) dominate from November through February. Lower negative factor scores from -2.0 to -3.0 appear to bridge these two locations along the Arizona-Mexico border northwards through western New Mexico and Colorado but is difficult to verify due to the paucity of first-order weather stations. Two areas with factor scores greater than -1.0 are observed in the San Joaquin and Willamette Valleys. A high frequency of mP air mass dominates these regions particularly during the cooler months of the year (see Figures 24-35). This factor will be useful in discriminating between continental arid weather stations in the southwestern part of the United States from surrounding weather stations.

Factor VII explains 6.8 per cent of the total variance. High positive loadings on this factor are mean annual wind velocity,

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[14]Trewartha, The Earth's Problem Climates, op. cit., p. 275.

CONTINENTAL MOISTURE INDEX
FACTOR VI

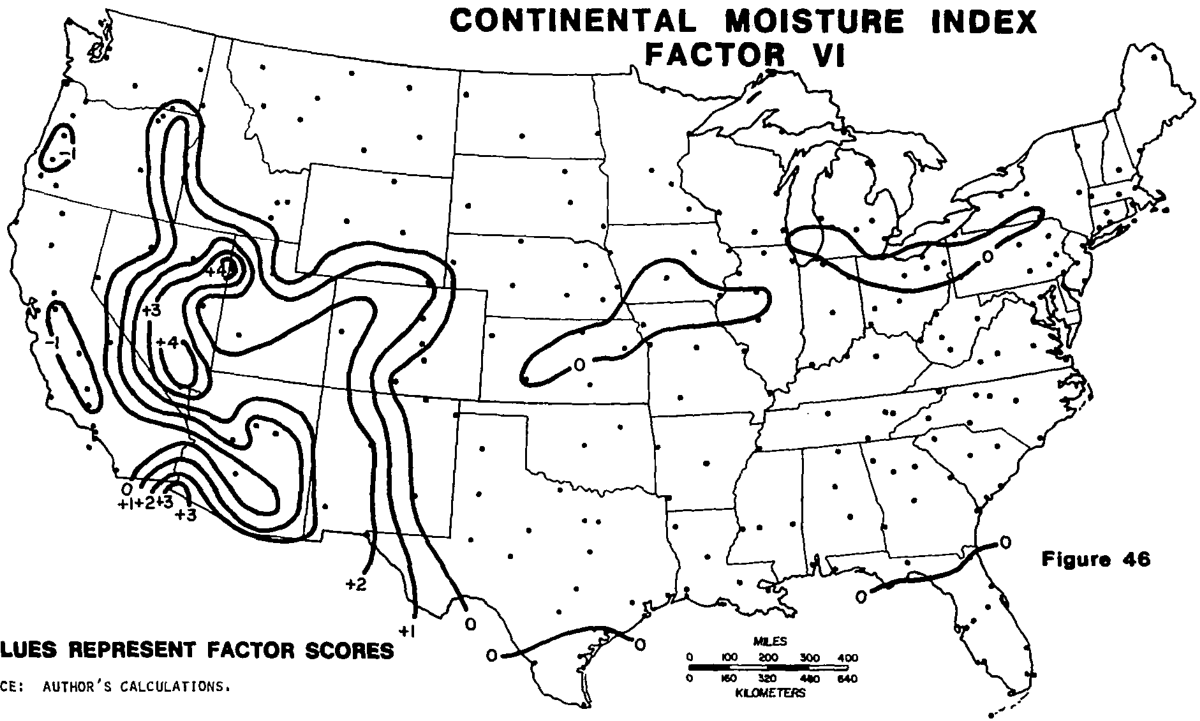

Figure 46

VALUES REPRESENT FACTOR SCORES

SOURCE: AUTHOR'S CALCULATIONS.

variability of mean annual wind velocity, and orographic effects. There are no high negative loadings. Since the orographic effect loading is not as high as either mean annual wind velocity and variability of mean annual wind velocity, this factor appears to represent wind strength variability. The irregularlity of the topography over the United States does contribute to the complex distribution of this factor as revealed on the factor score map (see Figure 47). Several generalizations can be stated concerning the interpretation of this factor and the distribution of factor scores. Lowest factor scores of -1.0 and greater are concentrated in the intermountain and mountain regions of western United States. Apparently, the weather stations in these regions, such as Helena and Salt Lake City, have relatively low mean wind strength with little annual variability even though their orographic indices are high (see Table 10). Other areas with factor scores greater than -1.0 but less than -2.0 have similar mean wind strength and variability but smaller orographic effect indices, such as Columbia, Tucson, and Los Angeles (see Table 10). Weather stations throughout the central part of the United States from Brownsville, Texas to the Great Lakes have positive factor scores. These weather stations, such as Springfield and Oklahoma City, have high mean annual wind velocity and annual variability (see Table 10). Other noteworthy weather stations with high positive factor scores which are not in the central part of the United States are San Francisco, Tatoosh Island, and Great Falls (see Table 10). The explanation for high wind strengths at these three weather stations is varied. San Francisco receives the effects of strong advection of ocean

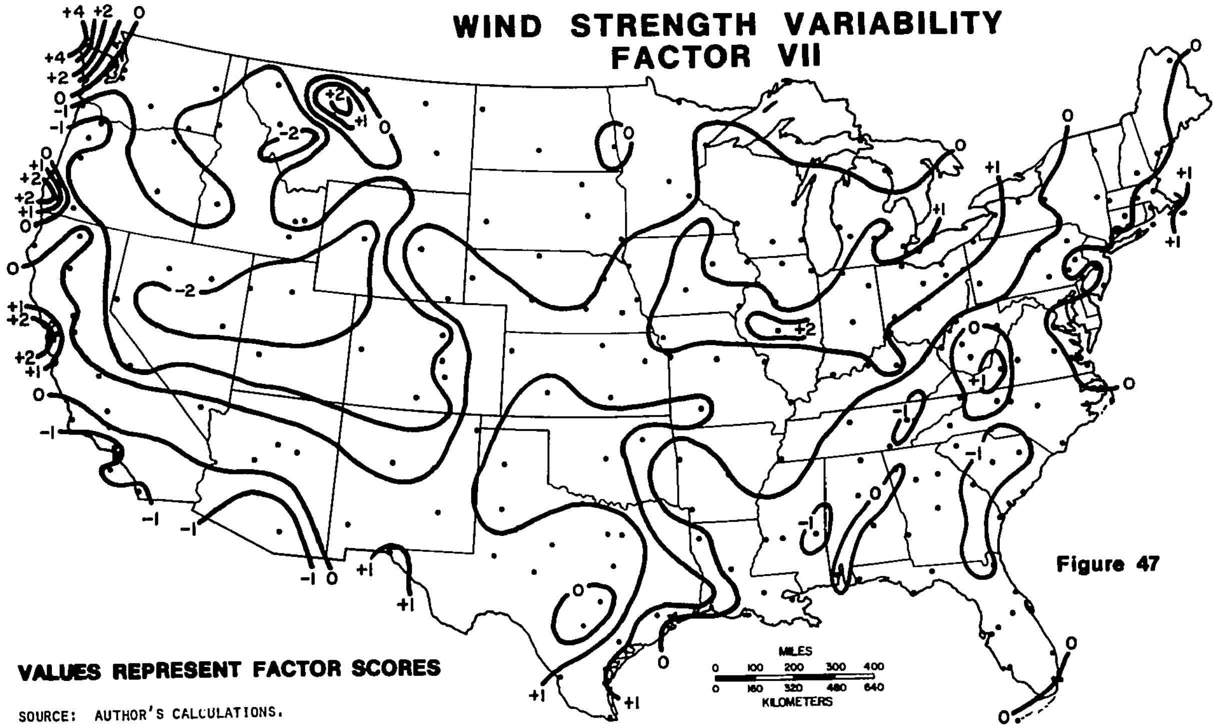

Figure 47

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 10[a]

WIND STRENGTHS, VARIABILITIES, OROGRAPHIC EFFECT INDICES AND FACTOR SCORES FOR SELECTED UNITED STATES WEATHER STATIONS

Weather Station	Mean Annual Wind Velocity (mph)*	Standard Deviation of Mean Annual Wind Velocity	Orographic Effect Index	Factor Score
1. Helena	8.0	.8	-242.9	-2.1
2. Salt Lake City	8.8	.9	-321.0	-2.9
3. Columbia	7.0	.9	- 3.6	-1.2
4. Tucson	7.8	.3	- 98.2	-1.3
5. Los Angeles	6.9	.7	+ 2.0	-1.3
6. Springfield	11.7	2.3	- 13.7	+2.2
7. Oklahoma City	13.8	1.4	+ 8.7	+1.8
8. San Francisco	10.5	2.8	+ .2	+2.6
9. Tatoosh Island	14.4	3.9	- 17.8	+4.7
10. Great Falls	13.7	2.2	- 42.1	+2.1

[a]Source: Local Climatological Data with Comparative Data, 1964 and author's calculations.

air which is channeled through the Bay.[15] Tatoosh Island has higher wind strengths due to its high latitudinal position in the United States and is significantly affected by the annual migration of the jet stream core.[16] Finally, Great Falls is on a plateau between two rivers and receives strong "chinook" winds during the winter season.[17] From the above observations, this factor will help in discriminating between weather stations with low mean annual wind strength and annual variability, especially in areas with a rugged topography, from those weather stations which have high mean annual wind strength and much annual variability.

Discriminant Analysis of Climatic Factors

From a stepwise discriminant analysis, a listing of the most significant climatic factor and combination of climatic factors were first listed (see Table 11). Continental storm track is the "best" factor in terms of discriminatory power. The relatively low Wilks' lambda value of 0.316 indicates the usefulness of this factor in assigning weather stations into one of the 19 regions. When continental storm track is combined with maritime cloud variability, the "best" 2 climatic factors in terms of discriminatory power are indicated by a 0.093 Wilks' lambda value. This value is low and suggests that these 2 factors assign weather stations into the most probable region with a high degree of likelihood. Then, solar radiation receipt is combined

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[15] *Ibid.*, p. 272.

[16] Landsberg, *op. cit.*, pp. 210-211.

[17] *Local Climatological Data*, Great Falls, Montana, 1964.

TABLE 11[a]

LISTING OF SIGNIFICANT CLIMATIC FACTORS BY RANK

Climatic Factors	Wilks' Lambda
Continental Storm Tracks	.316
Maritime Cloud Variability	.093
Solar Radiation Receipt	.037
Ocean Currents	.015
Winter-time High Pressure Systems	.007
Continental Moisture Index	.004
Wind Strength Variability	.002

[a]Source: Author's calculations.

with continental storm tracks and maritime cloud variability to represent the "best" three climatic factors in the discrimination process, and, by the same logic, ocean currents, winter-time high pressure systems, continental moisture index, and wind strength variability enter into the calculations, respectively. The low Wilks' lambda values for any of the above-mentioned combination of climatic controls suggest that they are good discriminators.

Calculation of standardized discriminant function coefficients confirms the stepwise ranking of the climatic factors. Three discriminant functions were calculated which accounted for 93.6 per cent of the total 7 possible discriminant functions. Eigenvalues for the 3 discriminant functions were those greater than 1.0 (see Table 12). By assessing the magnitude, either positive or negative, of the standardized coefficients for each factor, the same ranking of the climatic factors is evident (see numbers in parenthesis next to coefficients in Table 12). Spatial significance of these functions over the United States is disclosed from discriminant scores, one for each weather station per function.

Discriminant Function I explains 50.8 per cent of the total variation of the possible 7 discriminant functions. Maritime cloud variability is the most significant loading on this function. The discriminant score map for this function is similar to the maritime cloud variability factor score map (see Figure 48). Continental moisture index and wind strength variability factors load higher on Function I than on Functions II or III, but they are not as important as solar radiation receipt. Also, the ocean current factor is more highly significant than

TABLE 12[a]

STANDARDIZED DISCRIMINANT FUNCTION COEFFICIENTS

Climatie Factor	Function I	Function II	Function III
Continental Storm Track	-.11	-.87 (1)	+.11
Solar Radiation Receipt	-.41	+.06	-.71 (3)
Winter-time High Pressure Systems	+.14	-.43 (5)	+.02
Ocean Currents	+.21	-.26	-.59 (4)
Maritime Cloud Variability	-.79 (2)	+.01	+.31
Continental Moisture Index	-.28 (6)	+.04	-.20
Wind Strength Variability	+.21 (7)	-.03	+.15
Relative Percentage	50.8	28.8	14.0
Eigenvalue	8.2	4.7	2.3

[a]Source: Author's calculations.

DISCRIMINANT FUNCTION I - SCORES

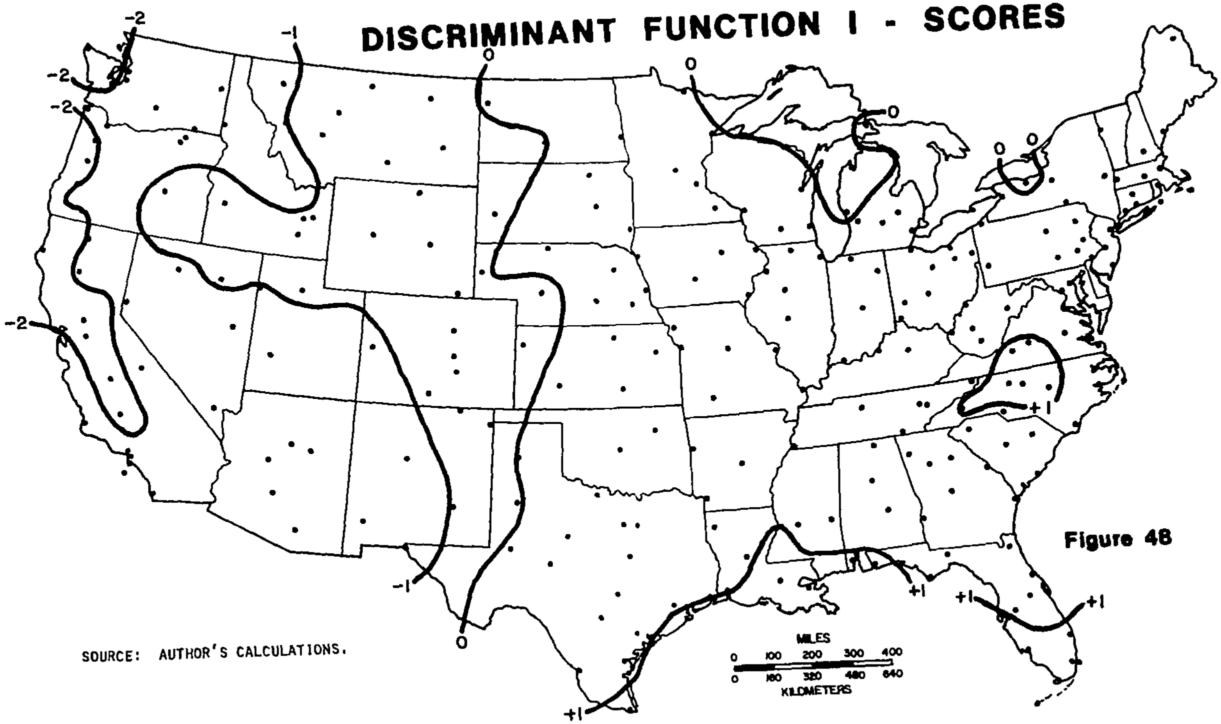

Figure 48

SOURCE: AUTHOR'S CALCULATIONS.

wind strength variability. From the loadings of the standardized discriminant function coefficients, negative discriminant scores of -1.0 and greater are observed in the southwestern and far western sections of the United States. Positive discriminant scores of 1.0 and greater are concentrated along the Gulf Coastal states. The small area of discriminant scores of +1.0 and greater in North Carolina coincide with positive factor scores for wind strength variability.

Discriminant Function II explains 28.8 per cent of the total variation. Continental storm track loads considerably higher than any other climatic factor on this function. Winter-time high pressure systems and ocean currents are of secondary importance in the interpretation of this function. The discriminant score map appears similar to the continental storm track factor score map (see Figure 49). Discriminant scores of -1.0 and greater occur in the north-central part of the United States with a westward extension to the Columbia Plateau. This westward extension is coincident with the location of high factor scores for winter-time high pressure systems. Positive discriminant scores of 1.0 and greater are in the extreme southern and western portions of the United States. A similar pattern along the West Coast is noted on the factor score map of ocean currents.

Discriminant Function III explains 14.0 per cent of the total variation. Solar radiation receipt and ocean currents have high loadings on this function. Maritime cloud variability is of secondary importance in the interpretation of this discriminant function. The discriminant score map is most similar to the solar radiation receipt factor score map (see Figure 50). Negative discriminant scores are

DISCRIMINANT FUNCTION II - SCORES

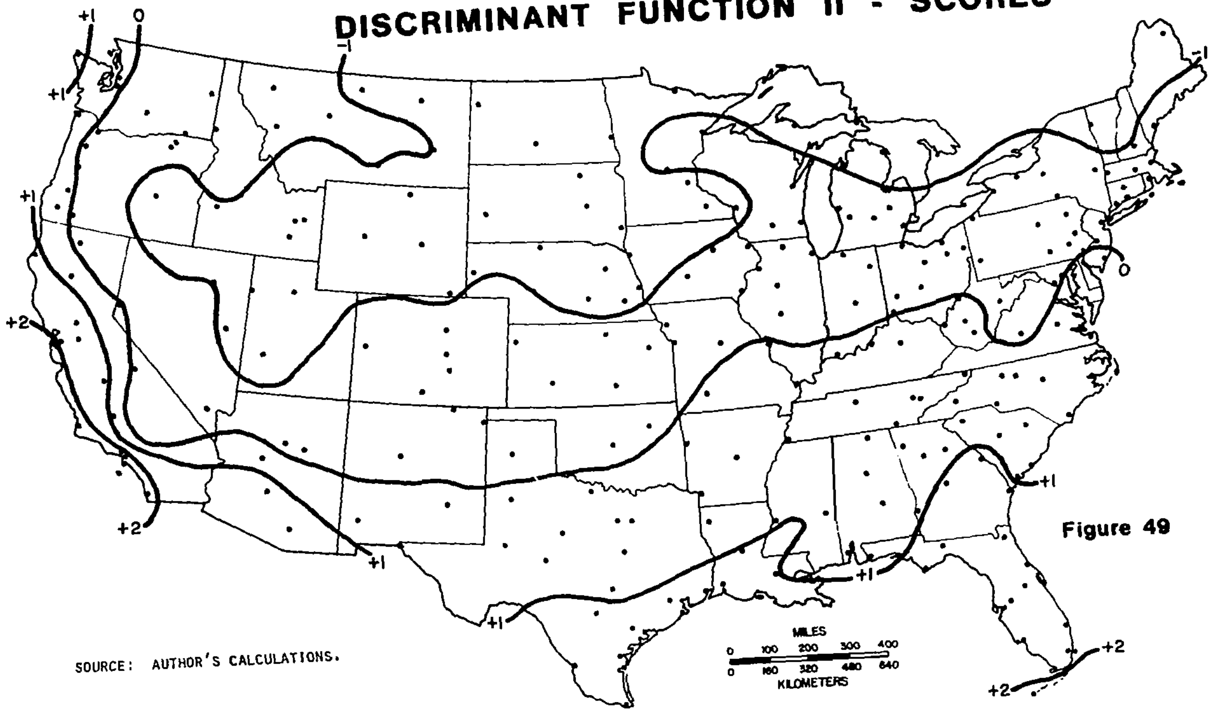

Figure 49

SOURCE: AUTHOR'S CALCULATIONS.

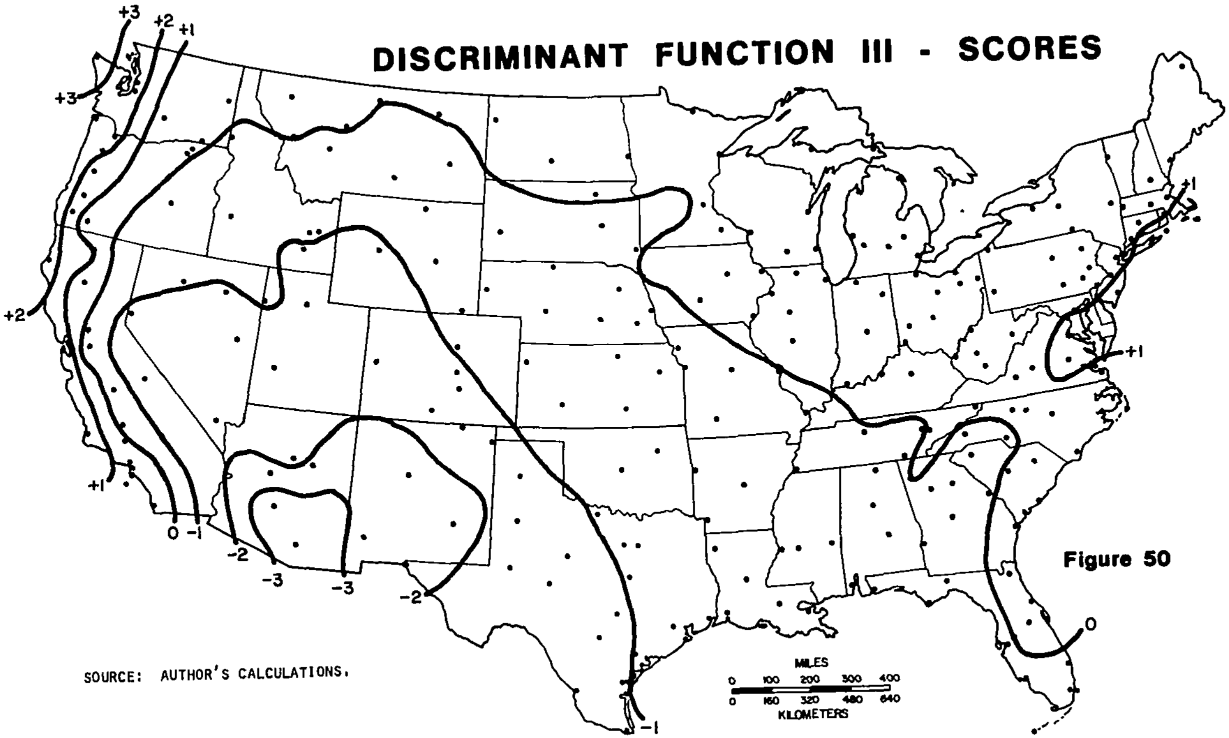

Figure 50

SOURCE: AUTHOR'S CALCULATIONS.

observed in the southwestern part of the United States with values greater than -3.0 in Arizona. High positive values occur along the West Coast. The highest value is at Tatoosh Island (3.7) where a high maritime cloud variability factor score is observed. In addition, positive discriminant scores of 1.0 and greater extend from Richmond, Virginia northwards to Boston, Massachusetts. This coastal section is strongly influenced by ocean currents as indicated on the factor score map.

Next, 19 classification functions were calculated for the purpose of identifying the most likely region a weather station is to be assigned based on the 7 climatic factors[18] (see Appendix VII for entire listing of classification equations). Use of discriminant scores and the pooled within-groups covariance matrix for the discriminant functions are used in the derivation of these classification equations.[19] Each of the classification coefficients are multiplied by the raw values of the discriminating climate factors.[20] Therefore, the coefficients act as weights and indicate which of the climatic factors are most important in terms of assigning a weather station to its corresponding region.

From a cursory inspection of the coefficients of each classification equation, excluding the constants, continental storm track and maritime cloud variability represented the highest weightings in all but one group. Solar radiation receipt was the highest coefficient in Region 9--those stations in the southwestern United States desert.

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[18] Nie, op. cit., p. 445.

[19] Ibid.

[20] Ibid.

However, this is not surprising since the stepwise discriminant process selected these three climatic factors as the "best" three for discriminating between weather stations in the United States; and they represented the three highest coefficients in the discriminant functions. Many of the coefficients, even though they do not represent the highest value for an equation, do have high weights which will aid in the classification process. A careful between-group inspection of the classification coefficients will reveal these. For example, Region 15, which represents the northwestern United States coastal region, has a large negative ocean current classification coefficient. The magnitude of this coefficient is considerably larger than for any other group. Obviously, ocean currents is an important discriminator for this particular region.

Many different combinations of climatic factors are observed <u>within</u> each of the 19 classification equations, and many striking differences of climatic factors are noted <u>between</u> the 19 groups. A thorough between-group analysis of these differences will be detailed in the ensuing chapter--region by region--in a search for uniqueness of each region.

Finally, a check on the adequacy of the derived discriminant functions was made. According to Nie, by classifying the cases used to derive the functions in the first place and comparing predicted group membership with actual group membership, one can empirically measure the success in discrimination by observing the proportion of correct classifications.[21] Certainly, not all of the weather stations will be

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[21] <u>Ibid.</u>, p. 445.

classified correctly in the a priori climatic regions. This will be noticeable especially in marginal or transition zones where, in reality, combinations of climatic factors are operating concomitantly between two or more climatic regions. However, there will be "core" areas within each climatic region where most neighboring weather stations are classified correctly. In these "core" areas, a specific combination and intensity of climatic factors are operating together to produce a distinctive mean monthly temperature and precipitation regime.

A total of 70.1 per cent of all weather stations were correctly classified into the a priori mean monthly temperature-precipitation regions by means of the 7 discriminatory climatic factors. Generally, in those regions where a greater number of weather stations occur, there is a greater number of incorrect classifications (see Table 13). This is contrary to what usually results. According to Morrison, when one group is much larger than the others, almost all individuals are classified as the larger group.[22] When this results, interpretation of the classification procedure can be difficult.

By omitting all weather stations which were incorrectly classified and placing a boundary line around all correctly classified weather stations, climatic factor "core" regions were constructed (see Figure 51). These "core" regions occur where a specific combination and intensity of climatic factors are operating congruously but are independent of climatic factors operating in surrounding regions.

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[22] Aaker, _op_. _cit_., p. 137.

TABLE 13[a]

CLASSIFICATION OF FIRST-ORDER WEATHER STATIONS' CLIMATIC FACTORS
INTO A PRIORI CLIMATIC REGIONS

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	90.0%		5.0%		5.0%														
2	8.7%	58.0%	20.3%		8.7%	1.4%					2.9%								
3			88.9%								11.1%								
4			33.3%	66.7%															
5					100.0%														
6	10.5%			2.6%	5.3%	71.1%	10.5%												
7				5.9%		17.6%	41.2%	5.9%	23.5%	5.9%									
8							10.0%	60.0%							30.0%				
9							40.0%		60.0%										
10										100.0%									
11		2.9%	2.9%								76.5%						2.9%	14.7%	
12												77.8%					22.8%		
13													66.7%	33.3%					
14														100.0%					
15															100.0%				
16																66.7%	33.3%		
17																	66.7%	33.3%	
18																25.0%		75.0%	
19														50.0%					50.0%

[a]Source: Author's calculations.

CLIMATIC FACTOR CORE REGIONS OF FIRST-ORDER WEATHER STATIONS

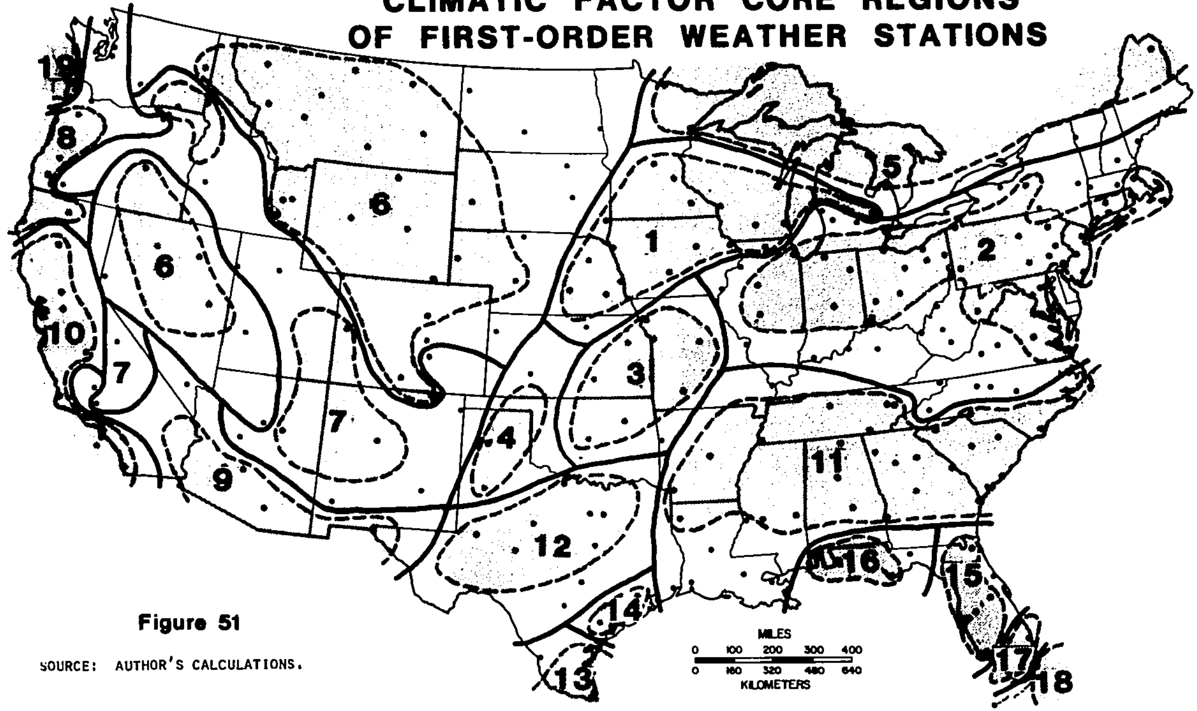

Figure 51

SOURCE: AUTHOR'S CALCULATIONS.

Testing the Reliability of A Priori Climatic Regions by Use of Discriminant Functions

If the a priori climatic regions are homoegenous, weather stations not previously used in this study should enter into those regions which are most similar in terms of their mean monthly temperature and precipitation characteristics. Exceptions to this will arise due to local anomalous influences and for those weather stations which are in transition areas of climatic regions, especially where a dearth of weather stations exist. When they are classified properly, climatic factors which determine a characteristic mean monthly temperature and precipitation pattern are known. This is particularly true for the "core" regions of climatic factors.

Calculation of discriminant functions from mean monthly temperature and precipitation was performed to facilitate further classification of weather stations to the a priori climatic regions. As mentioned previously, the Holdout Method of discriminant analysis was used for these calculations. These 154 weather stations are in central and marginal zones of each a priori climatic region (see Figure 52). Due to the paucity of first-order weather stations throughout the western mountain states, a greater number of weather stations, particularly in marginal zones for Regions 6 and 7, were selected for this part of the country. From the numerous weather stations in marginal zones of all a priori climatic regions, slightly different climatic region boundary lines resulted with a higher degree of accuracy in all regions but primarily in the western part of the United States.

As was expected, almost all of the 254 first-order weather stations (94.1 per cent) were correctly classified (see Table 14).

DISTRIBUTION OF SELECTED TEST WEATHER STATIONS RELATIVE TO A PRIORI CLIMATIC CLASS BOUNDARIES

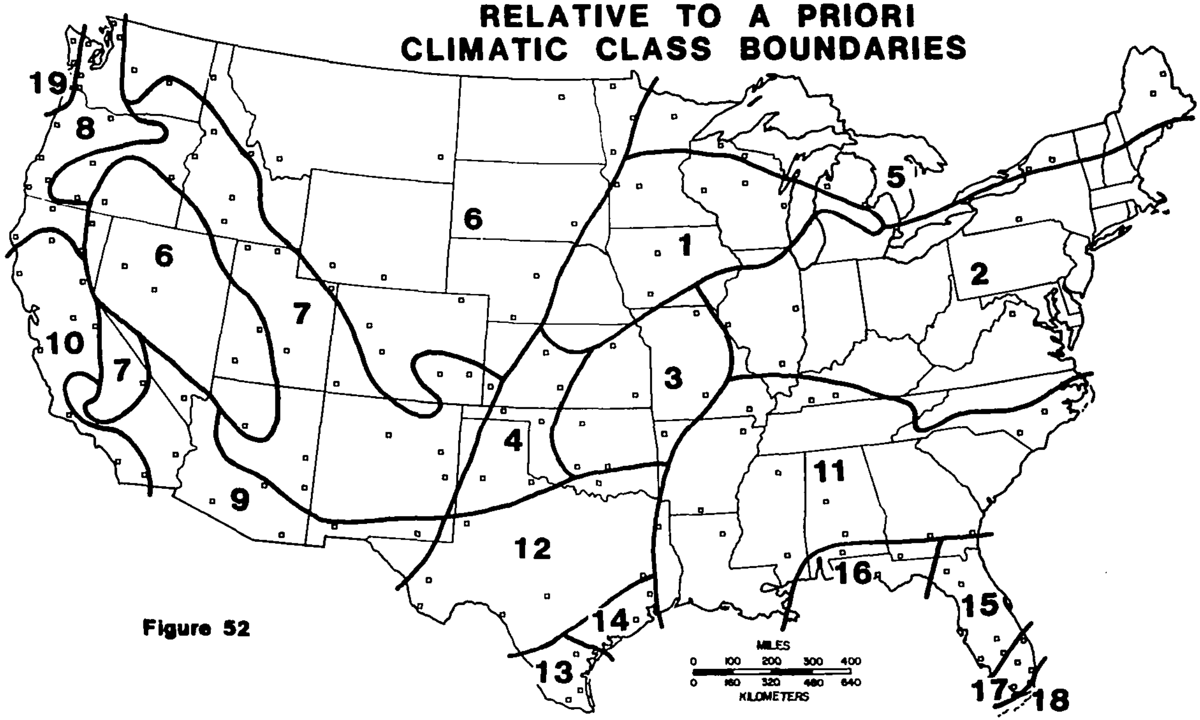

Figure 52

TABLE 14[a]

CLASSIFICATION OF FIRST-ORDER WEATHER STATIONS' MEAN MONTHLY TEMPERATURE AND PRECIPITATION INTO A PRIORI CLIMATIC REGIONS

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	85.0%			5.0%	10.0%														
2	2.9%	97.1%																	
3	22.2%		77.8%																
4				100.0%															
5					100.0%														
6						94.7%	5.3%												
7				5.9%		11.8%	76.5%		5.9%										
8								100.0%											
9									100.0%										
10										100.0%									
11											97.1%							2.9%	
12												88.9%					11.1%		
13													100.0%						
14														100.0%					
15															100.0%				
16																100.0%			
17																	100.0%		
18																		100.0%	
19																			100.0%

[a]Source: Author's calculations.

Those first-order weather stations which were misclassified are all in marginal climatic region zones. From inspection of those test weather stations that were misclassified, none were in a central area of a climatic region with respect to surrounding first-order weather stations! Of the 154 test weather stations, a surprisingly high 72.7 per cent were correctly classified (see Table 15). This percentage is considered high since many of these weather stations were purposely selected from marginal zones. Also, many of these test weather stations in different climatic regions which were correctly classified are close to each other. For example, Brewton, Alabama was correctly classified in Region 16 whereas Greenville, Alabama, less than 60 miles to the north, was correctly classified in Region 11.

From the classification of the test weather stations and first-order weather stations, new climatic boundary lines were drawn (see Figure 53). Disparities between the new climatic boundary line and the a priori climatic region boundary lines are most evident through the central part of the United States from Minnesota through Texas, and the western United States mountain and intermountain region. The position of the western boundary line of Regions 1 and 4 with respect to the eastern boundary line of Regions 6, 7, and 9 has always been problematical since this represents the dry-humid (Köppen's B/H) division. Kendall displayed the uncertainty of the position of this boundary line by classifying temperature-precipitation data for numerous weather stations throughout this area by use of Köppen's system from 1914 through 1931 for each year. A great variation in the position of the B/H line occurred.[23] However,

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[23]Henry Madison Kendall, "Notes on Climatic Boundaries in the Eastern United States," Geographical Review, XXV (1935), 123.

TABLE 15[a]

CLASSIFICATION OF TEST WEATHER STATIONS' MEAN MONTHLY TEMPERATURE AND PRECIPITATION INTO A PRIORI CLIMATIC REGIONS

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	88.8%	11.2%																	
2		85.7%	14.3%																
3			100.0%																
4	16.7%		16.7%	50.0%								16.7%							
5		14.3%			85.7%														
6	15.4%					69.2%	15.4%												
7				13.6%		27.3%	54.5%		4.5%										
8							11.1%	77.8%											11.1%
9							14.3%		85.7%										
10							11.1%	33.3%		55.6%									
11		18.2%									81.8%								
12				25.0%					12.5%		12.5%	25.0%	12.5%	12.5%					
13													100.0%						
14														100.0%					
15															100.0%				
16																100.0%			
17															40.0%		60.0%		
18																		No Test Stations	
19																			100.0%

[a]Source: Author's calculations.

CLIMATIC REGIONS BASED ON FIRST-ORDER AND TEST WEATHER STATIONS

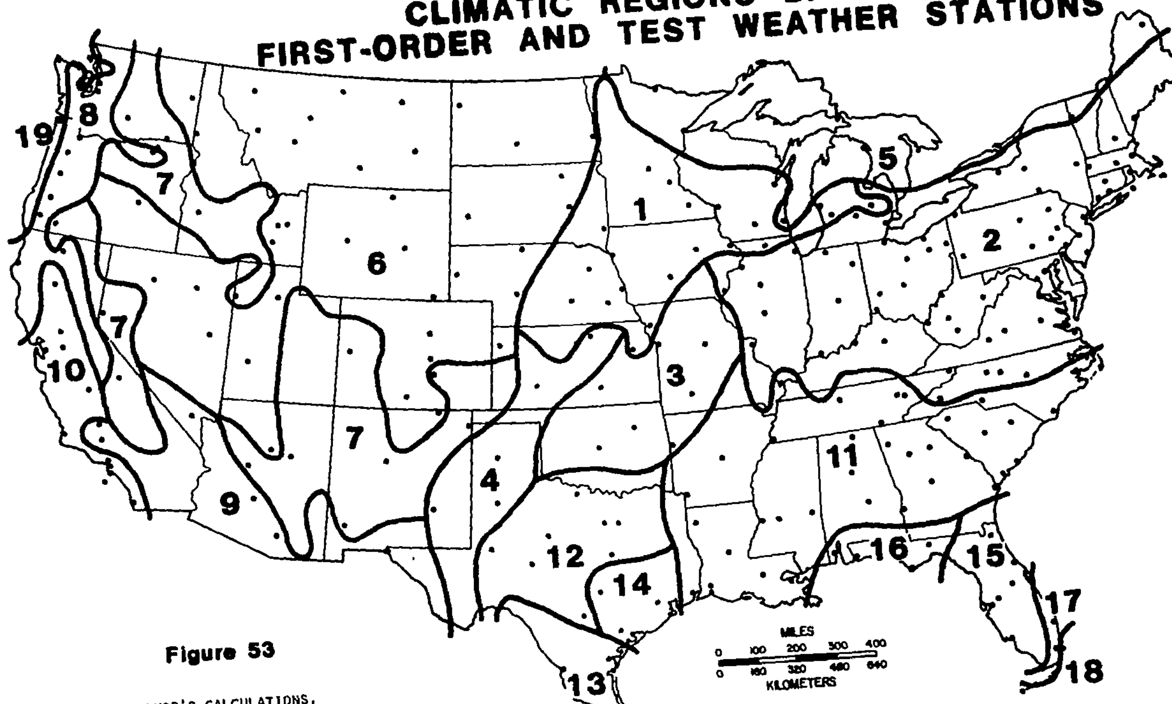

Figure 53

SOURCE: AUTHOR'S CALCULATIONS.

many of the boundary line changes in this study, particularly in the western part of the United States, are due to a sparsity of first-order weather stations and an unavoidable incorrect initial interpolation of its position. Other boundary line changes are observed where abrupt changes in the mean monthly temperature and precipitation characteristics occur from one weather station to the next, some of which are quite close together. Combinations and intensities of climatic factors change frequently in this area which is evident from the climatic factor "core" regions map (see Figure 51).

Examples of these abrupt boundary line changes are observed between Bellingham and Concrete, Washington; Meacham and Pendleton, Oregon; Grants Pass and Medford, Oregon; and Bisbee and Clifton, Arizona. At least one of the two weather stations per set is outside a "core" climatic factor region. The different mean monthly temperature and precipitation characteristics, as governed by the climatic factors, between each set of weather stations is apparent when their monthly data are scrutinized.

Bellingham is near the terminus of the Strait of Georgia on the east side of Vancouver Island. On the other hand, Concrete is farther inland in the Skagit River Valley, and it is near the end of the Strait of Juan De Fuca which is open to the Pacific Ocean to the west. Concrete's summer temperatures are slightly higher than at Bellingham, but a similar temperature pattern for these two stations is noted (see Table 16). However, mean monthly precipitation amounts are different, especially during the winter season. Concrete receives more than twice as much precipitation as does Bellingham from November through March.

TABLE 16[a]

MEAN MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION
AT BELLINGHAM (1) AND CONCRETE (2), WASHINGTON

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature (1)	36.8	39.5	43.0	48.0	53.2	57.8	61.0	60.6	56.7	50.1	43.1	39.6	49.1
Precipitation (1)	4.14	3.22	3.11	2.26	1.82	1.93	.99	1.10	1.98	3.64	4.51	4.89	33.59
Temperature (2)	36.7	40.1	44.5	51.3	57.3	61.1	65.4	65.2	61.2	53.3	43.7	39.2	51.6
Precipitation (2)	8.80	7.03	6.76	4.12	2.87	2.75	1.30	1.50	3.57	7.03	9.10	10.38	65.21

[a]Source: Climatography of the United States, No. 81-1 through 81-42, Decennial Census of United States Climate—Monthly Normals of Temperature, Precipitation, and Heating Degree Days, United States Department of Commerce, Luther H. Hodges, Secretary, Weather Bureau, F. W. Reichelderfer, Chief, Washington, D.C.: 1962.

Also, the annual total amount of precipitation for Concrete (65.21 inches) is similar to Tatoosh Island (77.69 inches). Location of these weather stations relative to surrounding topography and resulting wind direction and moisture supply represents large differences in mean monthly precipitation between these two stations.[24]

Differences in elevation are significant with respect to mean monthly temperature and precipitation between Meacham and Pendleton, Oregon. The elevation above sea level at Pendleton just to the north of the Blue Mountains is 1482 feet. Meacham is in the Blue Mountains and has an elevation of 4050 feet. Consequently, mean monthly temperatures at Meacham are lower and mean monthly precipitation is higher (see Table 17). A large mean annual precipitation difference of 21.49 inches is the primary reason for these two stations to enter into different a priori climatic regions.

Grants Pass and Medford are both in river valleys in western Oregon. However, Grants Pass is closer to the coast and is on the east side of a more extensive river valley than Medford. The mean monthly temperature of these two stations is similar, but Grants Pass receives 11.29 inches more precipitation than Medford (see Table 18). The more interior and sheltered location of Medford with respect to wind flow and moisture supply is obviously responsible for the notable discrepancy between the two weather stations and results in different climatic classifications.[25]

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[24]Trewartha, <u>The Earth's Problem Climates</u>, <u>op</u>. <u>cit</u>., p. 271.

[25]<u>Ibid</u>.

TABLE 17[a]

MEAN MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION
AT MEACHAM (1) AND PENDLETON (2), OREGON

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature (1)	26.0	29.1	33.3	40.8	48.0	53.7	63.4	61.7	55.7	46.3	34.4	29.8	43.5
Precipitation (1)	4.20	4.00	3.96	2.80	2.45	2.45	.50	.53	1.46	2.84	4.15	4.53	33.87
Temperature (2)	31.7	36.9	44.1	51.5	59.1	65.3	73.6	71.4	64.2	53.2	40.8	36.0	52.3
Precipitation (2)	1.42	1.18	1.20	1.09	1.12	1.17	.22	.28	.63	1.18	1.40	1.49	12.38

[a]Source: Climatography of the United States, No. 81-1 through 81-42, Decennial Census of United States Climate--Monthly Normals of Temperature, Precipitation, and Heating Degree Days, United States Department of Commerce, Luther H. Hodges, Secretary, Weather Bureau, F. W. Reichelderfer, Chief, Washington, D.C.: 1962.

TABLE 18[a]

MEAN MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION
AT GRANTS PASS (1) AND MEDFORD (2), OREGON

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature (1)	39.2	43.4	48.0	53.7	59.4	64.6	70.6	69.4	64.4	54.7	44.5	40.7	54.4
Precipitation (1)	5.82	4.50	3.20	1.69	1.63	.91	.26	.18	.71	2.71	3.94	5.52	31.07
Temperature (2)	36.9	41.6	45.8	51.6	58.0	64.2	72.0	70.7	64.7	54.0	43.4	38.4	53.4
Precipitation (2)	3.14	2.40	1.78	1.06	1.47	1.02	.21	.18	.60	1.94	2.60	3.38	19.78

[a]Source: Climatography of the United States, No. 81-1 through 81-42, Decennial Census of United States Climate--Monthly Normals of Temperature, Precipitation, and Heating Degree Days, United States Department of Commerce, Luther H. Hodges, Secretary, Weather Bureau, F. W. Reichelderfer, Chief, Washington, D.C.: 1962.

Finally, Bisbee and Clifton are classified into different climatic regions. Bisbee is in the southern reaches of the Galiuro Mountains close to the Arizona-Mexico border. Clifton is farther north in the San Francisco River Valley. The mountain influence of Bisbee results in lower mean monthly and annual temperatures and increases its mean monthly and annual precipitation with respect to surrounding weather stations at lower elevations, such as Clifton (see Table 19). Bisbee receives 5.47 inches more precipitation and is 5.5^{o}F cooler for its mean annual temperature than Clifton.

The above examples represent a sample of sets of weather stations where abrupt climatic boundary line changes occur and separate the stations into different climatic regions. Other abrupt boundary line changes are observed between climatic regions (see Figure 53). These irregular boundary lines are most evident in mountain regions where changes in combinations and intensity of climatic factors are rapid. Furthermore, these changes in regional boundary lines are real in terms of separating distinctively different mean monthly temperature and precipitation characteristics as was revealed from the above examination of 8 weather stations.

Final climatic factor "core" regions which were extracted from first-order weather station data have been placed within climatic regions based on first-order and test weather stations (see Figure 54). These regions and their subregions are now fully analyzed by use of the previously calculated classification coefficients to provide insight on their uniqueness.

TABLE 19[a]

MEAN MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION
AT BISBEE (1) AND CLIFTON (2), ARIZONA

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature (1)	45.3	48.4	53.4	60.6	67.8	76.4	77.2	75.0	72.3	63.9	53.5	47.8	61.8
Precipitation (1)	1.31	1.15	.83	.42	.16	.78	3.63	4.43	1.93	.89	.63	1.18	17.34
Temperature (2)	46.6	51.8	58.1	66.2	74.4	83.4	86.6	85.1	80.7	70.3	56.3	48.5	67.3
Precipitation (2)	.91	.91	.72	.37	.25	.39	1.84	2.38	1.64	.91	.53	1.02	11.87

[a]Source: Climatography of the United States, No. 81-1 through 81-42, Decennial Census of United States Climate-Monthly Normals of Temperature, Precipitation, and Heating Degree Days, United States Department of Commerce, Luther H. Hodges, Secretary, Weather Bureau, F. W. Reichelderfer, Chief, Washington, D.C.: 1962.

CLIMATIC FACTOR CORE REGIONS BASED ON FIRST-ORDER AND TEST WEATHER STATIONS

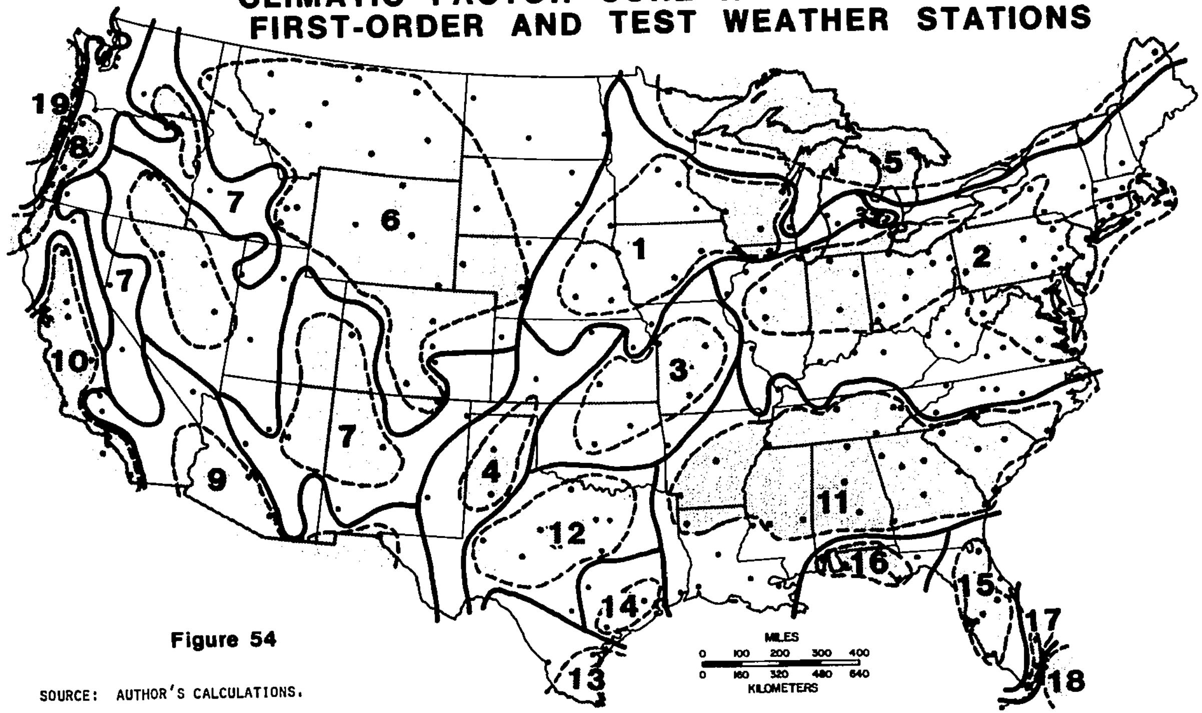


Figure 54

SOURCE: AUTHOR'S CALCULATIONS.

CHAPTER V

AN ANALYSIS OF NINETEEN CLIMATIC REGIONS AND THEIR SUBREGIONS

Final climatic boundary lines have been positioned with respect to 408 weather stations in the United States to form 19 climatic regions as determined by mean monthly temperature and precipitation characteristics. An average of all mean monthly temperature and precipitation values per region was then calculated for the construction of <u>mean</u> climographs. Each of these mean climographs for 19 climatic regions is unique in some respect which reflects variation in climatic factors operating over the United States (see Figure 55). Averages of mean monthly temperature and precipitation values for all weather stations within subregions were also calculated for the purpose of constructing mean subregional climographs. The changes within the configuration of these mean subregional climographs indicates a more subtle change in the nature of climatic factors within major climatic regions. Therefore, a more detailed analysis, particularly in transition areas adjacent to surrounding climatic regions, is possible.

Since each mean climograph's configuration is considered distinctive from others in the United States, explanations for these differences are sought. However, the number of adjacent climatic regions for any particular climatic region analyzed varies considerably. For

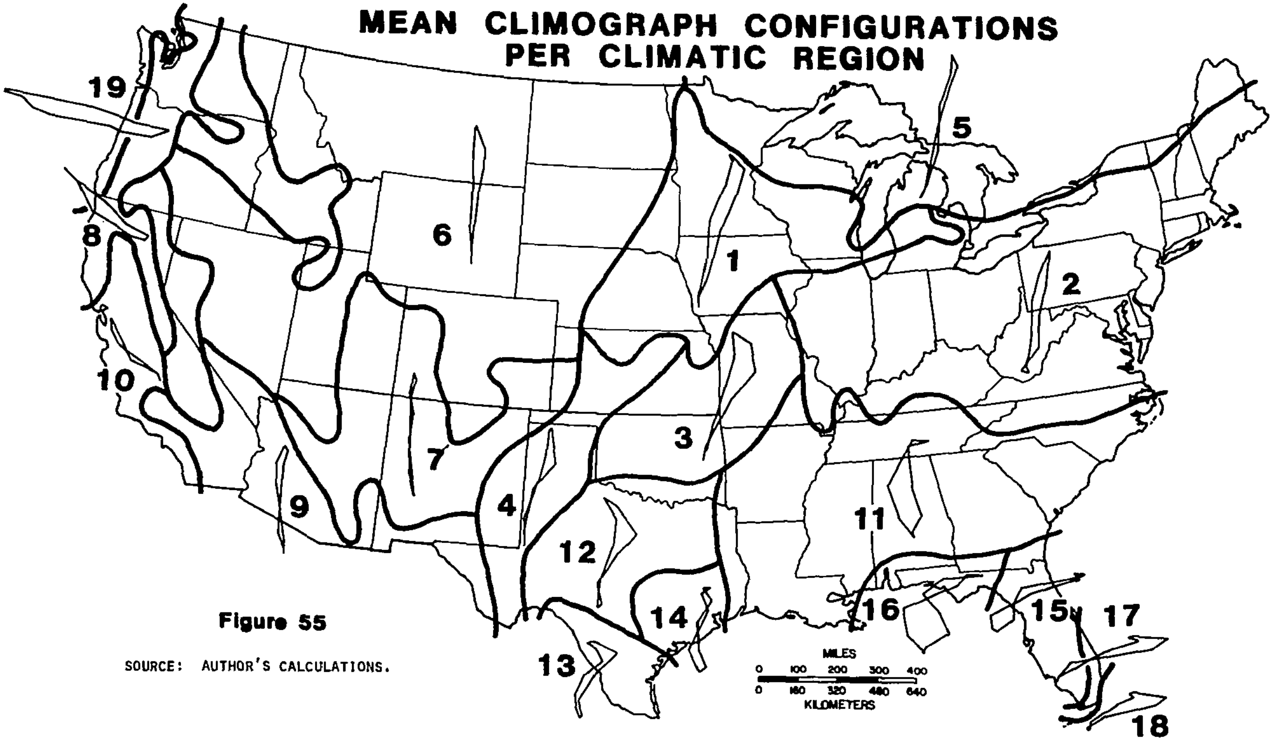


Figure 55

SOURCE: AUTHOR'S CALCULATIONS.

example, Region 19, along the northwest Pacific Coast, is adjacent only to Region 8. On the other hand, Region 6 is adjacent to 6 other climatic regions. In the case of numerous adjacent climatic regions, the number of important climatic factors examined concerning the distinctiveness of the mean climograph's configuration relative to surrounding regions is large. Furthermore, since only specific months pertaining to the mean climograph may be unique for a climatic region, high component loadings of the important climatic factors, with available monthly data, must be examined. However, if all high component loadings for each climatic region were examined with respect to numerous surrounding climatic regions, an exorbitant number of components would result. Therefore, only the most obviously important component loadings of climatic factors which contribute to the uniqueness of the mean climograph have been selected for discussion.

To limit the discussion of each climatic region to those climatic factors which are deemed most significant relative to mean monthly temperature and precipitation characteristics, differences between classification coefficients of each climatic region and respective coefficients for all adjacent climatic regions were calculated. The range in differences for the 19 climatic regions was large. For example, maximum coefficient differences for Region 9, the Desert Southwest, with respect to its four surrounding regions ranged from 5.2 for winter-time high pressure systems to 12.9 for maritime cloud variability. This is in contrast to Region 18, the Florida Keys, with only one adjacent region which has coefficient differences ranging from 0.5 for continental storm track to 1.3 for ocean currents. However, even though a large range between the 19 climatic regions exists, the largest maximum coefficient differences for <u>each</u> region should represent climatic factors which are primarily responsible for the uniqueness of the region's mean temperature-precipitation climograph.

Three climatic factors, those with the highest coefficient differences for each climatic region with respect to adjacent regions, were chosen to explain the genesis of the dissimilarities between the mean climograph configurations. Hence, an explanation for the uniqueness of each mean climograph is sought. However, where there was more than one adjacent climatic region, more than one large coefficient difference was possible. For instance, in Region 6, coefficient differences for maritime cloud variability of 10.7, 7.9, 7.9, 5.0, 3.7 and 3.2 were calculated with respect to the 6 adjacent climatic regions. Obviously, the intensity of maritime cloud variability differs significantly in these surrounding climatic regions, more so in some than in others. It was decided to analyze all coefficient differences with values greater than 4.9. Consequently, maximum coefficient differences with respect to an adjacent region for the 3 climatic factors were selected for analysis in addition to any other difference coefficient greater than 4.9 for the same 3 climatic factors (see Table 20).

From an inspection of those coefficient differences selected, it is readily apparent that in numerous cases the same climatic factor is significant for 2 climatic regions which are adjacent to each other. Therefore, the same component loadings would be analyzed in the same manner twice to reveal the distinctiveness of their mean climographs. To avoid this type of repetition, duplicate climatic factors, where

TABLE 20[a]

CLIMATIC FACTORS ANALYZED TO REVEAL DIFFERENCES BETWEEN MEAN CLIMOGRAPHS

Region	Climatic Factor	Adjacent Region	Coefficient Difference
1	Maritime Cloud Variability	6	7.9
	*(Solar Radiation Receipt	6	5.7)
	Continental Storm Track	3	5.0
2	Continental Storm Track	11	6.0
	*(Maritime Cloud Variability	5	4.4)
	Winter-time High Pressure Systems	11	2.7
3	*(Continental Storm Track	1	5.0)
	Solar Radiation Receipt	4	3.9
	Winter-time High Pressure Systems	12	2.4
4	Maritime Cloud Variability	9	12.9
	*(Maritime Cloud Variability	7	11.1)
	Maritime Cloud Variability	6	7.9
	*(Solar Radiation Receipt	9	9.6)
	*(Continental Moisture Index	9	7.0)
	Continental Moisture Index	7	5.7
5	Solar Radiation Receipt	6	5.4
	Continental Storm Track	2	4.5
	Maritime Cloud Variability	2	4.4
6	Maritime Cloud Variability	8	10.7
	*(Maritime Cloud Variability	1	7.9)
	*(Maritime Cloud Variability	4	7.9)
	Maritime Cloud Variability	9	5.0
	*(Solar Radiation Receipt	9	8.8)
	Solar Radiation Receipt	1	5.7
	*(Solar Radiation Receipt	5	5.4)
	*(Ocean Currents	8	8.8)
7	Maritime Cloud Variability	4	11.1
	Maritime Cloud Variability	8	7.5
	Continental Storm Track	10	8.3
	*(Ocean Currents	8	7.5
	*(Ocean Currents	10	6.4)
8	*(Maritime Cloud Variability	6	10.7)
	*(Maritime Cloud Variability	7	7.5)
	Ocean Currents	6	8.8
	Ocean Currents	7	7.5

TABLE 20--(Continued)

Region	Climatic Factor	Adjacent Region	Coefficient Difference
	*(Continental Storm Track	10	6.5)
	Continental Storm Track	6	5.9
9	*(Maritime Cloud Variability	4	12.9)
	*(Maritime Cloud Variability	6	5.0)
	Solar Radiation Receipt	4	9.6
	Solar Radiation Receipt	6	8.8
	Solar Radiation Receipt	10	7.4
	Solar Radiation Receipt	7	5.2
	Continental Moisture Index	4	7.0
10	*(Continental Storm Track	7	8.4)
	Continental Storm Track	9	6.6
	Continental Storm Track	8	6.5
	*(Solar Radiation Receipt	9	7.4)
	Ocean Currents	7	6.4
	Ocean Currents	9	5.7
11	*(Continental Storm Track	2	6.0)
	Solar Radiation Receipt	12	3.7
	Maritime Cloud Variability	15	3.2
12	Continental Storm Track	4	4.6
	Maritime Cloud Variability	13	4.2
	*(Solar Radiation Receipt	11	3.7)
13	*(Maritime Cloud Variability	12	4.2)
	Continental Storm Track	12	2.9
	Solar Radiation Receipt	12	2.5
14	Solar Radiation Receipt	12	3.0
	Maritime Cloud Variability	12	3.0
	Continental Storm Track	12	2.2
15	Continental Storm Track	11	4.0
	Maritime Cloud Variability	17	3.7
	Ocean Currents	16	2.5
16	Maritime Cloud Variability	11	2.7
	*(Ocean Currents	15	2.5)
	Continental Storm Track	15	2.3
17	*(Maritime Cloud Variability	15	3.7)
	Winter-time High Pressure Systems	15	1.8

TABLE 20—(Continued)

Region	Climatic Factor	Adjacent Region	Coefficient Difference
	Ocean Currents	18	1.3
18	*(Ocean Currents	17	1.3)
	Solar Radiation Receipt	17	1.2
	Maritime Cloud Variability	17	1.1
19	Solar Radiation Receipt	8	3.9
	Wind Strength Variability	8	3.0
	Ocean Currents	8	2.5

Note: Values in parenthesis represent those climatic factors eliminated for their respective climatic region and are examined with respect to another region.

[a]Source: Author's calculations.

they existed, were eliminated from one of the two regions. In view of the fact that each mean climograph is unique, and therefore, substantially different from the mean climographs of surrounding regions, an attempt to equalize the number of significant climatic factors analyzed per region governed the elimination procedure. This resulted in 2 to 5 climatic factors for each of the 19 regions analyzed (see Figure 56).

In the subsequent analysis, place names have been assigned to each major climatic region to aid the reader in associating its mean climograph to a particular section of the United States. These place names are primarily related to physiographic regions, location with respect to the United States, or the name of a state (see Figure 57). Each subregion is identified by an alphabetical symbol (see Figure 58).

Upper Midwest Region - Region 1

The Upper Midwest Region extends from northwestern Minnesota southwestward to northern Kansas, which approximates a portion of Köppen's B/H boundary, then converges across northern Iowa and southern Wisconsin, finally terminating in eastern Michigan (see Figure 59). This central United States climatic region consists of 21 first-order and 13 test weather stations (see Appendices VIII and IX). The weather stations within this climatic region are characterized by continental conditions with warm summers and cold winters. The mean temperature for July is a warm 74.4°F but reaches a cold 19.0°F during January. This annual range of 55.4°F is greater than any other climatic region in the United States. A rather typical continental precipitation regime is noted for this region with more rain falling during the warm season. June is the

CLIMATIC FACTORS ANALYZED PER REGION WITH RESPECT TO SURROUNDING REGIONS

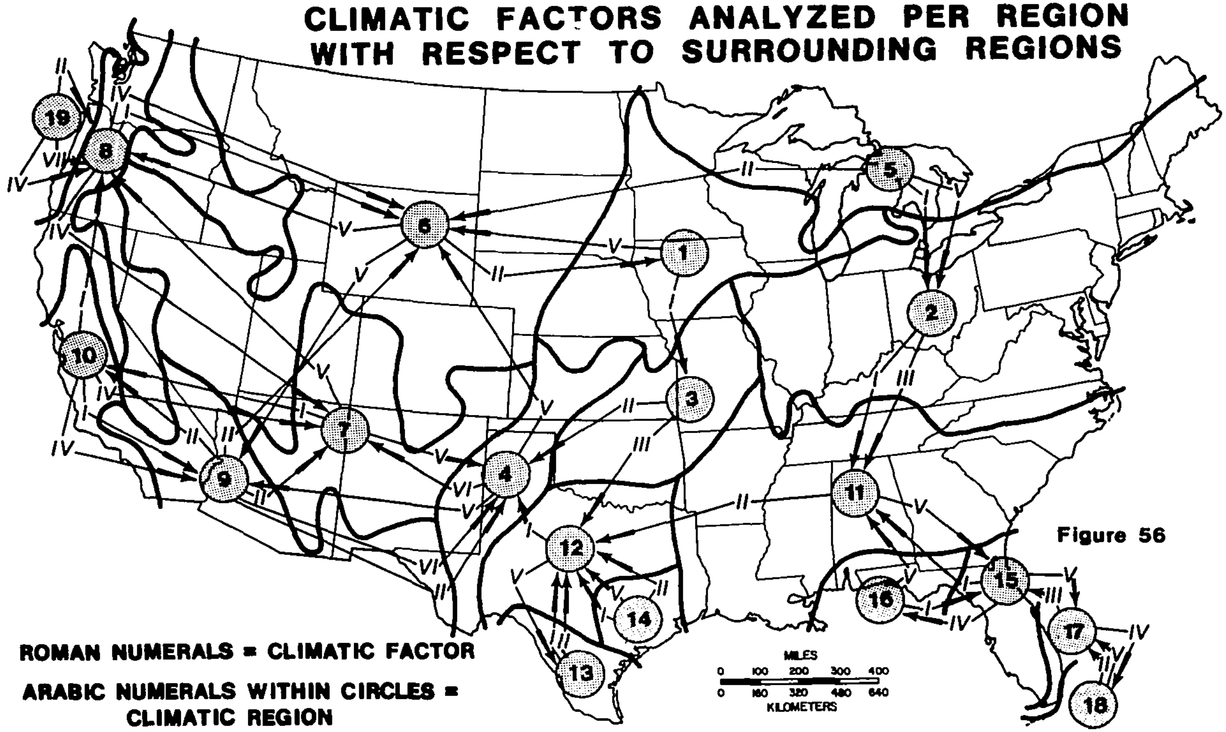


Figure 56

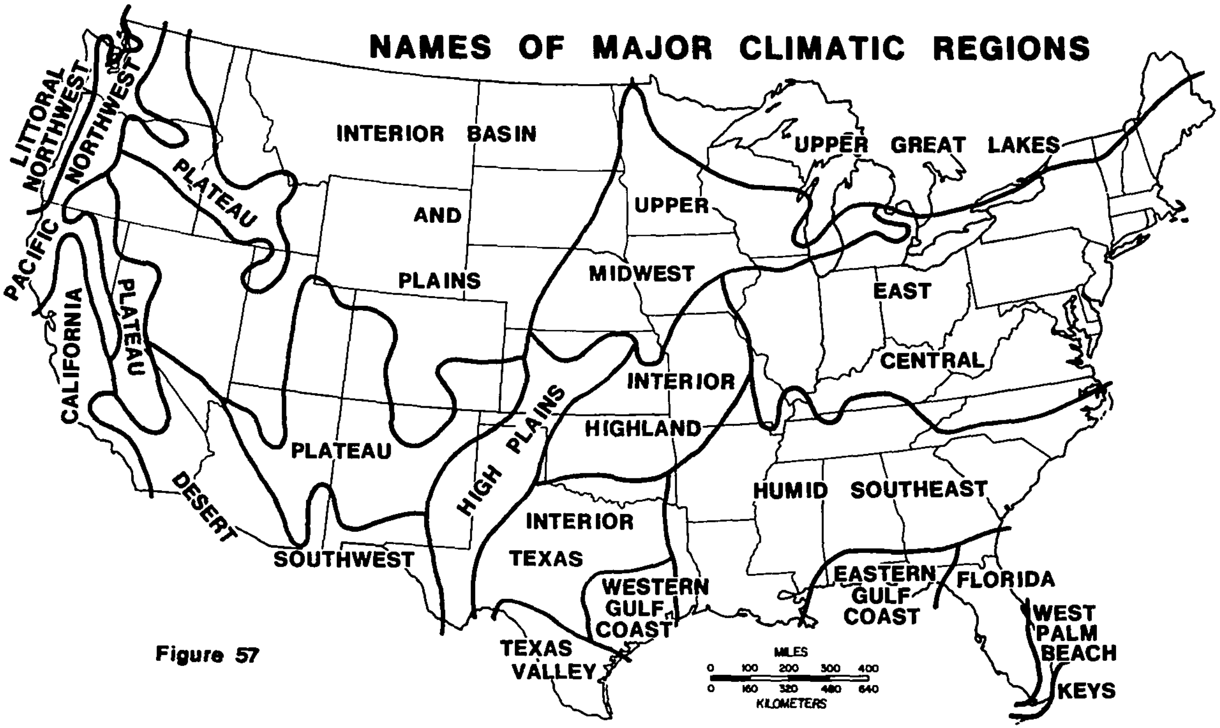

NAMES OF MAJOR CLIMATIC REGIONS
LITTORAL NORTHWEST
NORTHWEST
PACIFIC
CALIFORNIA
PLATEAU
PLATEAU
INTERIOR BASIN
AND
PLAINS
PLATEAU
DESERT
SOUTHWEST
HIGH PLAINS
UPPER
MIDWEST
INTERIOR
HIGHLAND
INTERIOR
TEXAS
TEXAS
VALLEY
WESTERN
GULF
COAST
UPPER GREAT LAKES
EAST
CENTRAL
HUMID SOUTHEAST
EASTERN
GULF
COAST
FLORIDA
WEST
PALM
BEACH
KEYS
MILES
0 100 200 300 400
0 160 320 480 640
KILOMETERS

Figure 57

MAJOR AND SUBREGIONAL CLIMATIC CLASSES INDICATED BY NUMBERS AND LETTERS

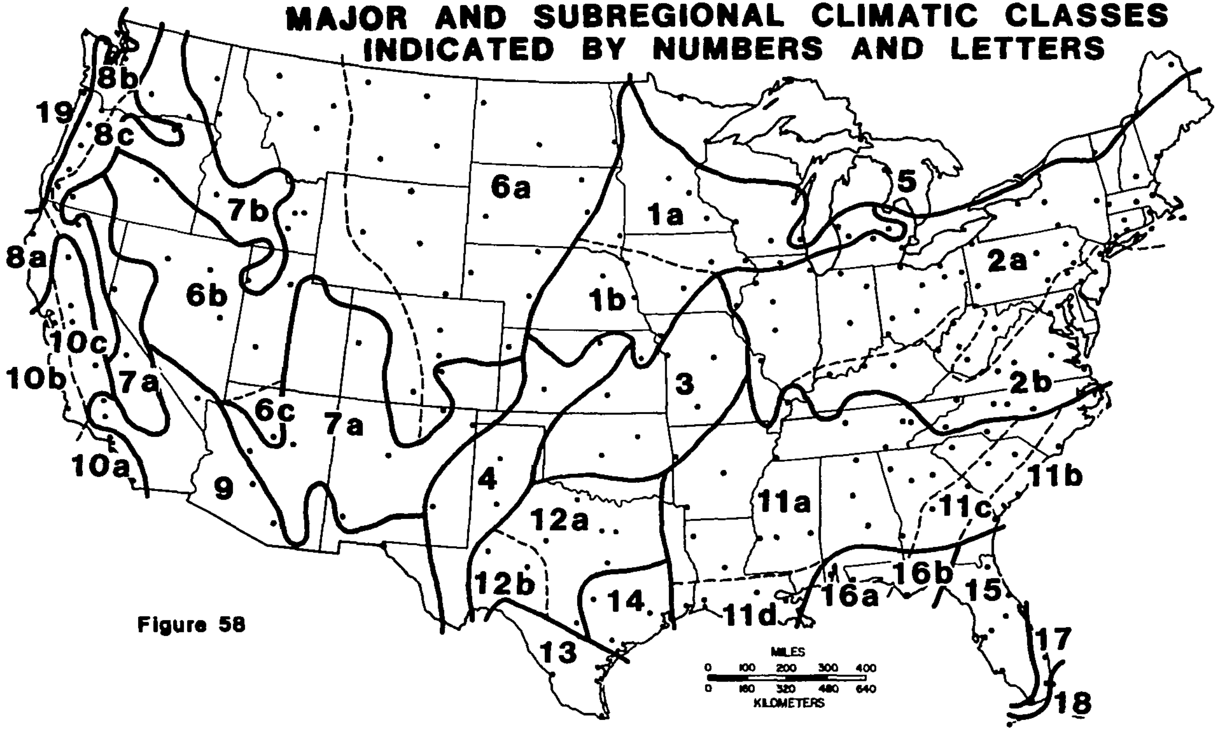


Figure 58

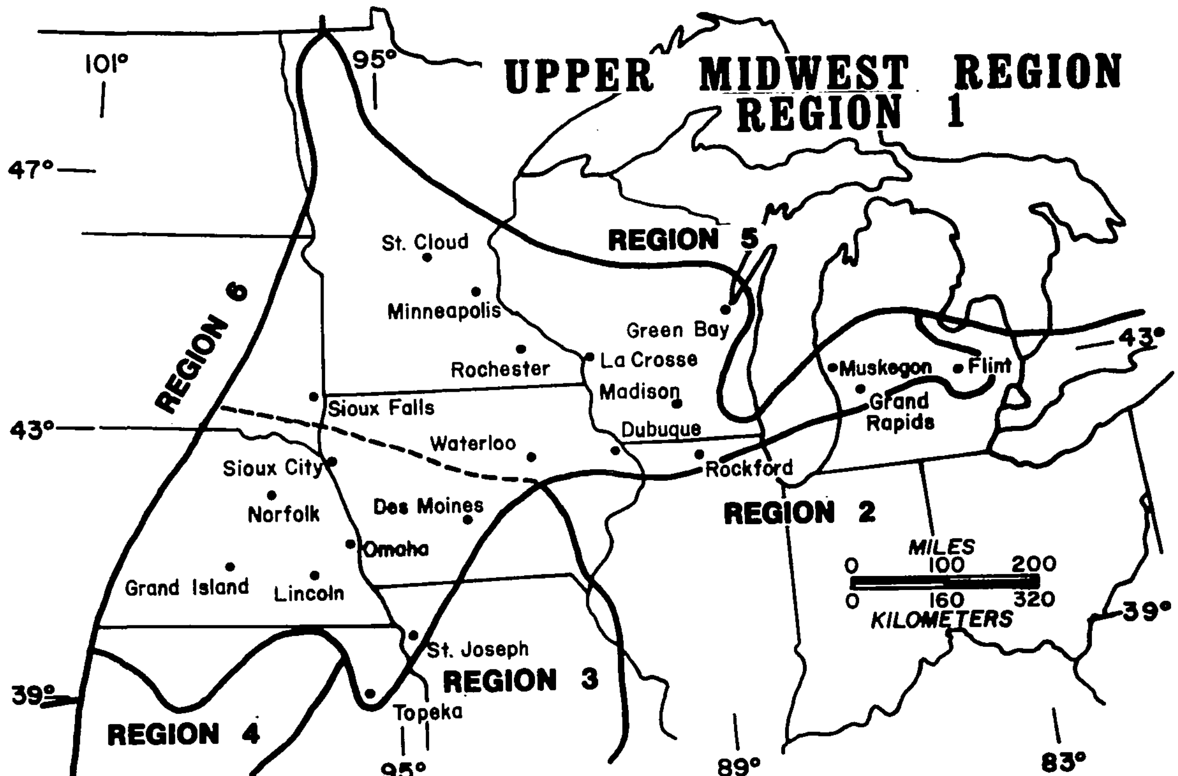

UPPER MIDWEST REGION
REGION 1
REGION 2
REGION 3
REGION 4
REGION 5
REGION 6
101°
95°
47°
43°
39°
89°
83°
St. Cloud
Minneapolis
Rochester
Sioux Falls
Waterloo
Sioux City
Norfolk
Des Moines
Omaha
Grand Island
Lincoln
St. Joseph
Topeka
Green Bay
La Crosse
Madison
Dubuque
Rockford
Muskegon
Flint
Grand Rapids
MILES
0 100 200
0 160 320
KILOMETERS

Figure 59

wettest month of the year with 4.18 inches in contrast to a dry 1.00 inches during February. The relatively low annual total precipitation of 27.63 inches reflects the closeness of this climatic region to Köppen's dry regions to the west.

The distinctiveness of the mean climograph for this region is observed in its extreme length (see Figure 60). This mean climograph is longer with respect to the temperature axis than in any other climatic region. In addition, the winter months of December, January, and February are positioned extremely low along the temperature axis. Several pronounced changes in monthly precipitation also enhance the distinctiveness of this mean climograph. July is decidedly drier than June and somewhat drier than August. This is observed as a narrow, sharp-angled feature of the climograph configuration which points towards the temperature axis. Finally, October stands out as a relatively dry month when compared with September with 1.02 inches less precipitation. Consequently, a pronounced sharp angle which trends toward the temperature axis is depicted. This feature is observed in the rudimentary form to the north and east in the Upper Great Lakes Region and East Central Region.

The uniqueness of this mean climograph compared with surrounding regions is recognized in terms of large classification coefficient differences between the Upper Midwest Region and the Interior Basin and Plains Region to the west and the Interior Highland Region to the south (see Table 21). A large classification coefficient difference for solar radiation receipt and maritime cloud variability is observed between the Upper Midwest Region and Region 6 to the west with moderately high

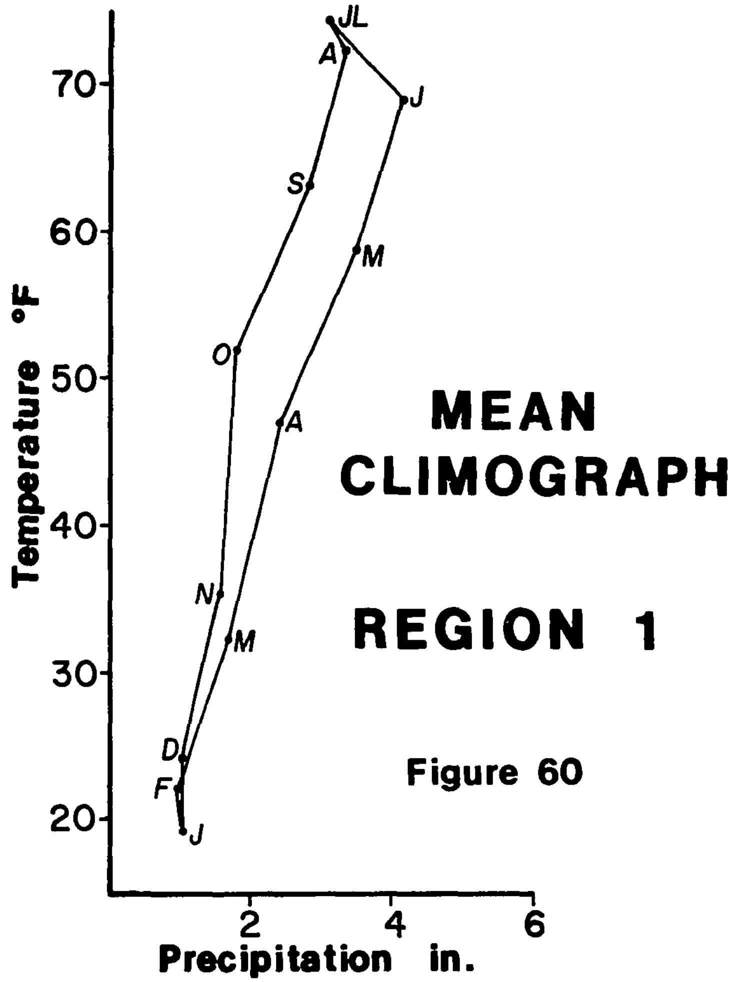


Figure 60

	J	F	M	A	M	J	
Temp. °F	19.0	22.0	32.2	47.1	58.9	68.9	
Precip. In.	1.04	1.00	1.71	2.44	3.51	4.18	Average
	J	A	S	O	N	D	47.5°
Temp. °F	74.4	72.4	63.3	51.9	35.4	24.1	27.64"
Precip. In.	3.12	3.38	2.83	1.88	1.56	1.05	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 21[a]

CLASSIFICATION COEFFICIENTS FOR THE UPPER MIDWEST AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 1	5	2	3	4	6	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	+5.1	+6.1	+1.7	+ .1	+ .7	+5.0	(5.0)
(2) Solar Radiation Receipt	-2.3	-2.0	-3.1	-1.3	+2.6	+3.4	(5.7)
(3) Winter-time High Pressure Systems	+1.9	+1.2	+2.1	+ .9	+ .1	+1.5	1.8
(4) Ocean Currents	+2.1	+ .2	+ .3	+2.3	+2.4	+1.0	1.9
(5) Maritime Cloud Variability	-3.0	+1.2	-3.2	-4.7	-3.0	+4.9	(7.9)
(6) Continental Moisture Index	-1.6	-1.0	-1.8	-1.5	- .4	+1.7	3.3
(7) Wind Strength Variability	+1.3	- .1	1.5	+1.9	+1.9	-1.9	3.2

Names of Above Climatic Regions

1 Upper Midwest Region
5 Upper Great Lakes Region
2 East Central Region
3 Interior Highland Region
4 High Plains Region
6 Interior Basin and Plains Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest difference values for three climatic factors. Coefficients that are underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

negative values compared with moderately high positive values, respectively. Furthermore, a high positive continental storm track value in the Upper Midwest Region sharply differs from the extremely small positive value for Region 3.

From the above observed significant climatic factors, the following climatic factor components are analyzed to genetically describe the uniqueness of the Upper Midwest Region's mean climograph compared with Region 3: (1) latitude — with respect to the low position of the mean climograph along the temperature axis; (2) continentality -- with respect to the extreme length of the mean climograph; (3) cP air mass -- with respect to the low position of the mean climograph along the temperature axis; and (4) total number of lows and highs and variability of the number of lows — with respect to the July and October sharp-angled features representing drier months than those immediately before and/or after these 2 months. In addition, the following climatic components are observed to be genetically significant in distinguishing the Upper Midwest Region's mean climograph from Region 6: (1) mP-cT, mT-cT, and mT air masses -- with respect to the distance of the mean climograph away from the temperature axis which indicates total annual precipitation.

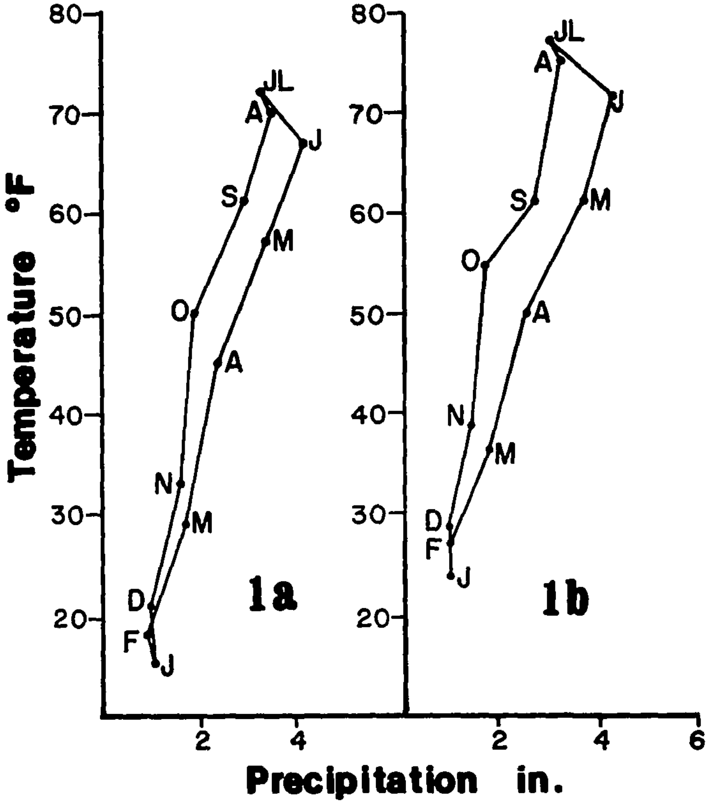
Latitude and Continentality

The mean climograph for the Upper Midwest Region is positioned low along the temperature axis. This reflects the low mean annual temperature of 47.5°F which is surpassed only by two other climatic regions in the United States--Region 5 with 40.9°F and Region 6 with 45.6°F. This low mean annual temperature sharply contrasts with Region 3 to the south which is 10.7^{o} warmer. However, there is a large difference in the range of latitude between these two climatic regions. The Upper Midwest Region's northernmost latitude is approximately 48^{o}N and extends southwards to central Kansas. The Interior Highland Region extends from central Kansas and Iowa southwards to approximately $34^{o}30'$N. This large difference in latitude between these climatic regions is not only revealed by their mean annual temperatures but is also displayed in their mean winter temperatures. The mean January temperature for the Upper Midwest Region is 19.0^{o}F compared with 34.6^{o}F for Region 3, and, consequently, it extends much farther down along the temperature axis.

The transition from higher to lower latitudes with respect to the position of the mean climograph along the temperature axis in the Upper Midwest Region is more easily visualized upon inspection of the mean subregional climographs (see Figure 61). Subregion 1a has a mean annual temperature which is 5.9^{o}F cooler than Subregion 1b to the south. Also, since Subregion 1a has a mean January temperature which is 8.5^{o}F cooler than Subregion 1b, the position of the two mean subregional climographs along the temperature axis appears markedly different.

The range of mean annual temperatures between the Upper Midwest Region and the Interior Highland Region of 9.1^{o}F is large. In view of this fact, the mean climograph appears considerably longer. Much of this difference is accounted for during the winter season. Only a 6.5^{o}F difference is noted between these two regions during the warmest month, July, whereas a 15.6^{o}F difference exists during January. Since Region 3 is closer to a large body of water, the Gulf of Mexico, a smaller degree of continentality is observed in this region compared

MEAN SUBREGIONAL CLIMOGRAPHS



REGION 1

Figure 61

SOURCE: AUTHOR'S CALCULATIONS.

with the Upper Midwest Region. From the map of Oliver's index of continentality, the Upper Midwest Region generally has values which range from 10 to 12. This same index for Region 3 ranges from 8 to 10 (see Figure 9).

The transition of decreasing continentality values from the Upper Midwest Region to Region 3 is seen on the mean subregional climographs (see Figure 61). A significantly longer mean climograph is observed for Subregion 1a in the northern part of this region than for Subregion 1b. The difference in the mean annual range of temperature between these two subregions is 3.9°F, and, again, the mean winter temperatures constitute the greatest contrast.

cP, mT, mT-cT, and mP-cT Air Masses

The Upper Midwest Region is dominated by cP air mass from December through February. Furthermore, cP air mass dominates most of subregion 1a during the months of November and March. With the dominance of this dry, cold air mass over the Upper Midwest Region, little precipitation, mainly in the form of snow, and bitterly cold temperatures prevail for the duration of this time period. In the Interior Highland Region to the south, only the northern portion is dominated by cP air mass from December through February. Therefore, this climatic factor component, cP air mass, acts in a similar manner as does latitude. Thus, the explanation for the low position of the mean climograph along the temperature axis for the Upper Midwest Region which reflects the cold winter temperatures during which time little precipitation falls is reinforced.

During these same winter months, November through March, cP air mass is also dominant throughout all or most of the Interior Basin and Plains Region to the west. Consequently, the mean climograph for Region 6 and the Upper Midwest Region is similar along the lower portion of the axis in terms of mean monthly temperature and precipitation. However, from April through October, significantly different air mass dominance is observed between these two regions. During April and October, most of the Upper Midwest Region is under the influence of mP air mass. This air mass dominance extends into the eastern portion of Region 6, but most of the central and western sections is dominated by cP-mP air mass, especially in April, and cT-mP air mass, particularly in October. The prevalence of these two drier continental air masses during these time periods throughout much of Region 6 is reflected on the mean climograph by less precipitation. Large differences in air mass dominance during May and September are not as striking since most of these climatic regions are influenced by mP air mass. However, some cT and cT transition air masses are noted in the western part of Region 6, and mP-mT air mass is observed in the southern portion of the Upper Midwest Region; hence, drier conditions in Region 6 are indicated and are revealed on the mean climograph. Finally, during the summer months, the Upper Midwest Region is predominantly influenced by mT air mass which extends into the eastern section of Region 6. But, most of Region 6 is dominated by drier cT-mP air mass. Consequently, much more rainfall is observed on the mean climograph for the Upper Midwest Region during the warm season. Due to the more abundant mean monthly precipitation totals from especially April through October in the Upper

Midwest Region, 14.07 inches more precipitation is received during the year than in Region 6. This difference is seen on the mean climographs in terms of a diagonal orientation of the climograph axis for the Upper Midwest Region as opposed to a vertical orientation of the climograph axis, which is positioned close to the temperature axis, for Region 6.

Total Number and Variability of Lows and Total Number of Highs

During the month of July, the mean climograph for the Upper Midwest Region reveals a striking, sharp-angled feature directed towards the temperature axis. This sharp angle represents an unexpected secondary minimum of precipitation in this continental climatic region. An abrupt decrease in precipitation is also noted in the Interior Highland Region to the south but appears entirely different on the mean climograph since an increase in rainfall during August does not follow. Another sharp angle on the mean climograph is observed for the month of October. This is formed by a rapid decrease in precipitation from September to October with little change in rainfall from October to November.

The nature of these sharp-angled features have been analyzed and are associated with a variation in pressure systems, both aloft and at the surface. According to Trewartha, at least a partial explanation for decreased rainfall in July is associated with anticyclonic circulation and an attendant dry northerly tongue of air.[1] Furthermore, during this month an increased frequency of surface anticyclones is evidenced. From mid-September to the end of September a decrease in the

[1] Ibid., p. 285.

number of anticyclones occurs, but is again followed by a strong increase in the number of anticyclones by late September and early October.[2] This increased anticyclonic activity may be more prevalent in the southern portion of this region since a drier autumn is revealed on the mean subregional climograph, 1b, which, as a consequence, forms a larger opening within its framework than in the subregional climograph for 1a (see Figure 61).

Significant climatic factor components which support the above explanation for these sharp-angled features are total number and variability of lows and total number of highs. Weather stations in two 5° latitude by 5° longtidue grid cells in which total number of lows and highs were recorded for a 20-year period were examined. One cell is in the Upper Midwest Region whereas the other cell is in the Interior Highland Region, both of which slightly overlap into adjacent climatic regions to the east. Firstly, a larger number of lows occurred in the Upper Midwest Region's cell, 221, compared with the cell in Region 3 with 136. Secondly, a higher standard deviation is noted for the Upper Midwest Region's cell of 5.0 compared with Region 3, with 2.9. Finally, a large number of highs occurred in the Upper Midwest Region's cell, 209, compared with 134 for Region 3.[3] Therefore, large differences are evident between these two regions for all three climatic factor components. However, further insight is gained if the number of lows and highs for specific months are inspected.

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[2] _Ibid_., p. 288.

[3] Klein, _op_. _cit_., pp. 23-46.

In the Upper Midwest Region, few lows occurred during the month of July compared with June and August, but in Region 3 approximately the same number occurred in each of the three months (see Table 22). During these same months, a large number of highs were observed for the Upper Midwest Region compared with about one-half the number in Region 3. The large number of highs during July combined with few lows in the Upper Midwest Region certainly indicates decreased amounts of precipitation. During the months of September, October, and November, similar observations are made (see Table 22). Few lows occurred during October compared with September and November in the Upper Midwest Region, and about the same number of lows occurred in each of the three months for Region 3. Also, a larger number of highs occurred in October than in September and November in the Upper Midwest Region, and this number was larger than those highs which occurred in Region 3 during October. This at least partially explains the October sharp-angled feature in the Upper Midwest Region which is entirely absent in Region 3.

In summary, the mean climograph for the Upper Midwest Region is distinct from Regions 3 and 6 due to the following characteristics: (1) a long climograph axis positioned low along the temperature axis due to a high latitude, a continental location, and dominance of cP air during the winter season; (2) a greater distance of the mean climograph away from the temperature axis, particularly during summer, due to the absence of mP-cT and mT-cT air masses but a dominance of mT air mass; and (3) two pronounced sharp-angled features on the mean climograph during July and October, specifically due to a small number of lows and a large number of highs, but generally from a large number of lows and highs during the entire year with a large variability of lows.

TABLE 22[a]

TOTAL NUMBER OF LOWS AND HIGHS FOR TWO GRID CELLS FOR THE UPPER MIDWEST REGION AND REGION 3 FOR A TWENTY-YEAR PERIOD

Region	June	July	August	September	October	November
	LOWS			LOWS		
1	20	10	16	16	12	22
3	9	8	9	9	9	11
	HIGHS			HIGHS		
1	15	18	21	15	20	17
3	9	8	8	8	14	10

[a]Source: William H. Klein, Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere. Washington, D.C., U. S. Department of Commerce, Weather Bureau, Research Paper No. 40, 1957, pp. 23-46.

East Central Region - Region 2

The East Central Region extends from eastern Iowa and Missouri to the Atlantic Ocean and from the Upper Great Lakes Region in the northeastern part of the United States southwards to North Carolina and Tennessee (see Figure 62). The East Central Region consists of 67 first-order and 10 test weather stations (see Appendices VIII and IX). This climatic region is characterized by warm summer and cool winter temperatures. The mean temperature for July, the warmest month, is 74.1°F compared with 30.2°F for January, the coldest month. Since there is an oceanic moderating effect in this climatic region, especially for weather stations nearest the ocean, the mean annual range in temperature of 43.9°F is markedly less than those observed for regions to the north and west, but predictably it is greater than Region 11 to the south. An adequate amount of rainfall which is evenly distributed throughout the year is received in this climatic region. The wettest month is July with 3.81 inches compared with 2.68 inches during February, the driest month. The total average annual precipitation is 39.61 inches.

The uniqueness of the mean climograph for the East Central Region is evidenced in its extreme vertical orientation with a rather narrow "opening" within the framework of its configuration (see Figure 63). Therefore, only a small variation in mean monthly precipitation occurs throughout the year. The moderate distance of the mean climograph away from the temperature axis indicates the absence of a dry season.

The uniqueness of the mean climograph for the East Central Region with respect to surrounding climatic regions is assessed in

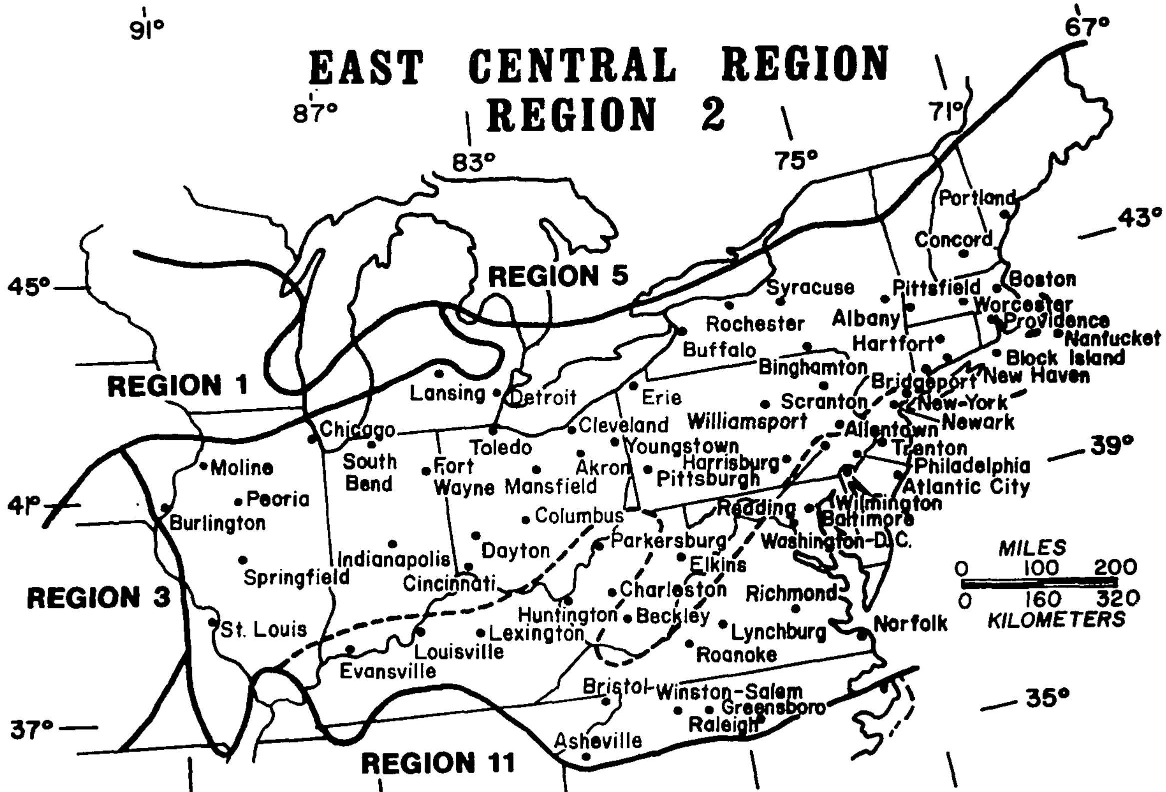
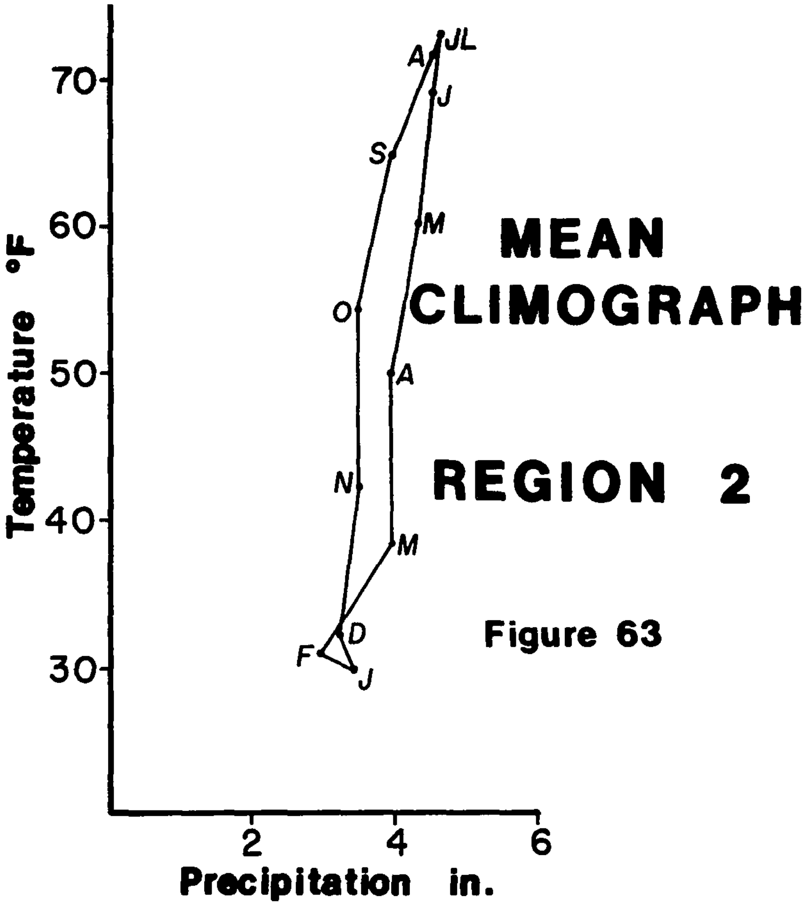

EAST CENTRAL REGION
REGION 2
REGION 1
REGION 3
REGION 5
REGION 11
91°
87°
83°
75°
71°
67°
45°
43°
41°
39°
37°
35°
79°
Portland
Concord
Boston
Syracuse
Pittsfield
Worcester
Providence
Nantucket
Rochester
Albany
Hartford
Block Island
Buffalo
Binghamton
Bridgeport
New Haven
Lansing
Detroit
Erie
Scranton
New-York
Chicago
Toledo
Cleveland
Williamsport
Allentown
Newark
South Bend
Fort Wayne
Mansfield
Akron
Youngstown
Harrisburg
Pittsburgh
Trenton
Philadelphia
Atlantic City
Moline
Peoria
Burlington
Columbus
Reading
Wilmington
Baltimore
Washington-D.C.
Parkersburg
Elkins
Indianapolis
Dayton
Springfield
Cincinnati
Charleston
Richmond
Huntington
Beckley
Lynchburg
Norfolk
St. Louis
Lexington
Louisville
Roanoke
Evansville
Bristol
Winston-Salem
Greensboro
Raleigh
Asheville
MILES
0 100 200
0 160 320
KILOMETERS

Figure 62



	J	F	M	A	M	J	
Temp. ^{o}F	29.9	30.9	38.4	49.8	60.1	69.0	
Precip. In.	3.42	2.99	3.92	3.96	4.37	4.54	Average
	J	A	S	O	N	D	51.3^{o}
Temp. ^{o}F	73.2	71.7	64.8	54.2	42.1	32.1	46.70"
Precip. In.	4.69	4.59	3.99	3.50	3.51	3.22	

SOURCE: AUTHOR'S CALCULATIONS.

accordance with the largest classification coefficient differences for three climatic factors. These are continental storm track and winter-time high pressure systems between this climatic region and Region 11 to the south and maritime cloud variability between the East Central Region and Region 5 to the north (see Table 23). The East Central Region has a low positive continental storm track value compared with a moderately high negative value for Region 11, and this region has a fairly low positive winter-time high pressure system value compared with a small negative value for Region 11. Maritime cloud variability, as a significant climatic factor in distinguishing this climatic region from Region 5 to the north, will be examined upon analysis of the Upper Great Lakes Region to avoid repetition.

From an examination of mean climograph differences between the East Central Region and Region 11 to the south, the following climatic factor components are observed as significant: (1) latitude -- with respect to the difference of the mean climograph's position along the temperature axis; (2) continentality -- with respect to the length of the mean climograph axis; (3) cP, mT, cP-mP, and mT-mP air masses -- with respect to the position of the mean climograph along the temperature axis; and (4) total number of highs and their variability -- with respect to the extreme vertical orientation of the mean climograph.

Latitude and Continentality

Since the East Central Region and Region 11, to the south, are large climatic regions encompassing much of the eastern portion of the United States, a large mean difference in latitude is obvious. The

TABLE 23[a]

CLASSIFICATION COEFFICIENTS FOR THE EAST CENTRAL AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 2	5	1	3	11	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	+1.7	+6.2	+5.1	+ .1	-4.3	(6.0)
(2) Solar Radiation Receipt	-3.1	-2.0	-2.3	-1.3	-2.4	1.8
(3) Winter-time High Pressure Systems	+2.1	+1.2	+1.9	+ .9	- .6	(2.7)
(4) Ocean Currents	+ .3	+ .2	+2.1	+2.3	+1.3	2.0
(5) Maritime Cloud Variability	-3.2	+1.2	-3.0	-4.7	-5.3	(4.4)
(6) Continental Moisture Index	-1.8	-1.0	-1.6]	-1.5	-2.1	.8
(7) Wind Strength Variability	+1.5	- .1	+1.3	+1.9	+ .6	1.6)

Names of Above Climatic Regions

2 East Central Region
5 Upper Great Lakes Region
1 Upper Midwest Region
3 Interior Highland Region
11 Humid Southeast Region

[a]Source: Author's calculations.

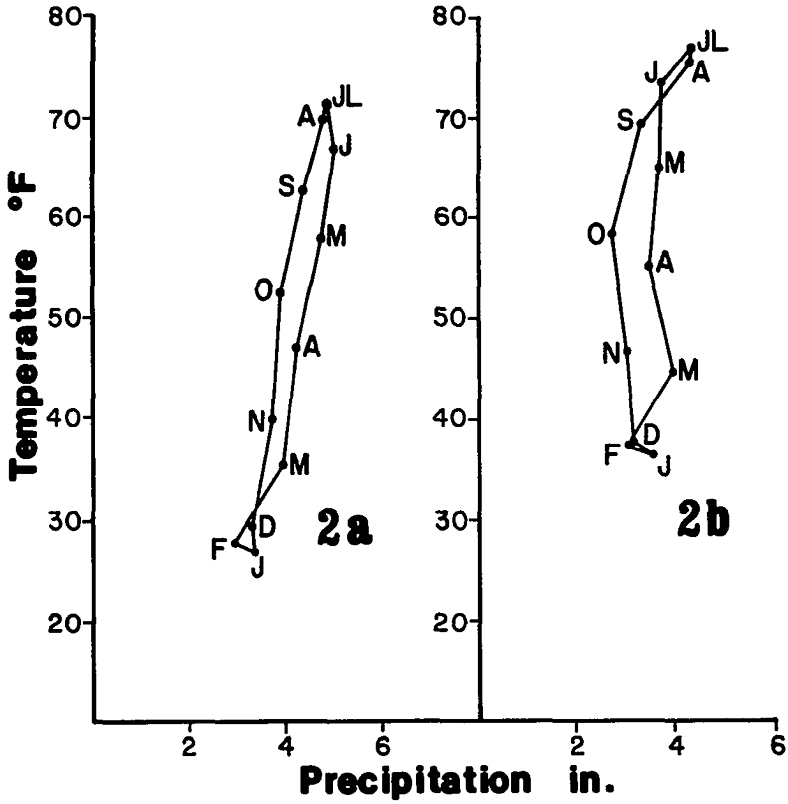
Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically for this climatic region if they are not repetitious according to Table 20.

northernmost reaches of the East Central Region are in Maine at approximately 46°N. The Humid Southeast Region extends southwards to the Gulf of Mexico at approximately 30°N. This difference in latitude is vividly revealed on the mean climographs for these two climatic regions. The mean climograph for the East Central Region located at a higher latitude is positioned much lower, particularly during the winter season, along the temperature axis. The mean July temperature for the East Central Region is 6.9°F lower than Region 11, and the mean January temperature is 16.2° lower. This latitudinal difference is clearly indicated by comparing their respective mean annual temperatures which are 51.9°F for the East Central Region and 63.8°F for Region 11.

The transition from high to lower latitudes and the accompanying change of the mean climograph's position along the temperature axis within the East Central Region is clearly apparent when the two mean subregional climographs are compared with each other (see Figure 64). Subregion 2a, to the north, has a mean annual temperature of 49.0°F which is 1.9°F cooler than Subregion 2b. Again, the most obvious difference is seen between the mean temperature of the coldest month of January. Subregion 2a has a mean January temperature of 26.7°F compared with 36.4°F for Subregion 2b.

The difference in length of the mean climograph between the East Central Region and Region 11 is indicated by their mean annual range in temperature. The East Central Region has a range which is 9.3°F greater than Region 11. At least a partial explanation for this difference is continentality. Even though the eastern portion of the East Central Region lies near the Atlantic Ocean, the eastern part of

MEAN SUBREGIONAL CLIMOGRAPHS



REGION 2

Figure 64

SOURCE: AUTHOR'S CALCULATIONS.

Region 11 does also. But, in addition, the southern part of Region 11 borders the Gulf of Mexico. Differences in the amount of continentality between these climatic regions are discerned from an examination of continentality indices. From Oliver's continentality map, most continentality indices in the East Central Region range from 8 to 10, whereas in Region 11 to the south, most continentality values range from 6 to 8; hence, these values are related to the different lengths of the two mean climographs (see Figure 8).

Air Masses — cP, mT, cP-mP, and mT-mP

From December through February, cP air mass dominates Subregion 2a and cP-mP dominates most of Subregion 2b. During this time of the year, most of Region 11 to the south is dominated by a milder mP air mass. Consequently, a colder, drier air mass dominates the East Central Region compared with Region 11. This is reflected in the mean climograph for the East Central Region with its colder mean temperatures and less precipitation during the winter season. Therefore, the mean climograph is positioned lower and closer to the temperature axis than the mean climograph for Region 11.

During the transition season, Region 11 to the south is dominated by mT air during May and September whereas the East Central Region is under the influence of a somewhat cooler mT-mP air mass. Likewise, during April and October, warmer mT and mT-mP air masses persist in the more southerly climatic region compared with cooler mP air mass in the East Central Region. The result of the varying air mass domination in these two regions during the transition seasons is observed on their mean climographs. The mean monthly temperatures for the Upper Midwest Region during these 4 months are considerably cooler than the corresponding months in Region 11. Therefore, the mean temperatures for the transition months are observed to be positioned much lower along the temperature axis in the East Central Region.

Total Number of Highs and Their Variability

The mean climograph axis for the East Central Region was described in terms of its extreme vertical orientation, i.e., practically parallel to the temperature axis. This type of configuration is sharply in contrast to the mean climograph configuration observed for Region 11. One of the greatest differences occurs during the summer season, particularly July. Similar mean monthly rainfall values during this season in the East Central Region contribute to the vertical orientation of its mean climograph, but, to the south during July, an abrupt increase in precipitation and a small increase in the mean temperature produce a portion of the mean climograph which essentially appears horizontal, i.e., parallel to the precipitation axis. An increase in precipitation over the east and southeast sections of the United States is expected during the summer season, but why is there such an abrupt increase during July in Region 11 and only a hint of an increase during this month in the East Central Region? A partial explanation to this question may be obtained from an examination of the total number of highs and their variability.

The total number of highs and their variability for these two climatic regions were examined by use of two representative 5^{o} latitude by 5^{o} longitude grid cells. The representative grid cell for the East Central Region is in the northeast section of this region which includes most of Pennsylvania and much of New York. It overlaps slightly into Region 5 to the north. The grid cell in Region 11 is in the southeastern part of the region and overlaps slightly into Regions 15 and 16 to the south. The values of total number of highs and their variability in the East Central Region, 236 and 5.8, respectively, are considerably higher than those values observed in the grid cell for Region 11 of 152 and 4.5, respectively. However, these values are not directed to the summer months, particularly the month of July. From an inspection of 3 summer months--June, July, and August--a large difference in the number of occurrences of high pressure systems between these two regions is noted (see Table 24).

TABLE 24[a]

TOTAL NUMBER OF HIGHS FOR TWO 5° LATITUDE BY 5° LONGITUDE GRID CELLS FOR THE EAST CENTRAL REGION AND REGION 11

Region	June	July	August
2	17	18	33
11	10	8	8

[a]Source: Klein, _op. cit._, pp. 35-46.

The number of highs in the East Central Region is much greater than those of Region 11. Furthermore, a slight decrease in number of highs in Region 11 is noted from June to July. The above combination of total number of highs suggests that precipitation is somewhat suppressed in Region 2 during the warmest season when maximum convective activity is expected, but in Region 11, fewer highs, especially during July and August, coincide with greater rainfall.

In summary, the mean climograph for the EAst Central Region is unique and therefore different from Region 11 due to the following characteristics: (1) a longer mean climograph which is positioned lower along the temperature axis due to a higher latitude and a more continental location; (2) the low position of the mean climograph along the temperature axis due to a greater frequency of cP and cP-mP air mass dominance and cooler transition seasons due to a smaller frequency of mT and mT-mP air mass dominance; and (3) an extreme vertical orientation of the mean climograph due to a larger number of high pressure systems during the summer season as well as during the entire year with much variability.

Interior Highland Region - Region 3

The Interior Highland Region extends from southern Iowa to southern Oklahoma and from western Oklahoma and central Kansas to western Illinois (see Figure 65). This central climatic region consists of 7 first-order and 10 test weather stations (see Appendices VIII and IX). Weather stations in this region are characterized by a relatively large mean annual range in temperature. July, the warmest month, reaches a warm 80.9^{o}F compared with a 34.6^{o}F for the coldest month of January. This interior climatic region receives the greater portion of its precipitation during the warmer half of the year. The primary maxima is observed during late spring when 4.95 inches of rain falls during May. A secondary maxima occurs during September when 3.52 inches of precipitation occur. The winter months of December, January, and February are the driest during the year, each month receiving less than 2 inches of rain.

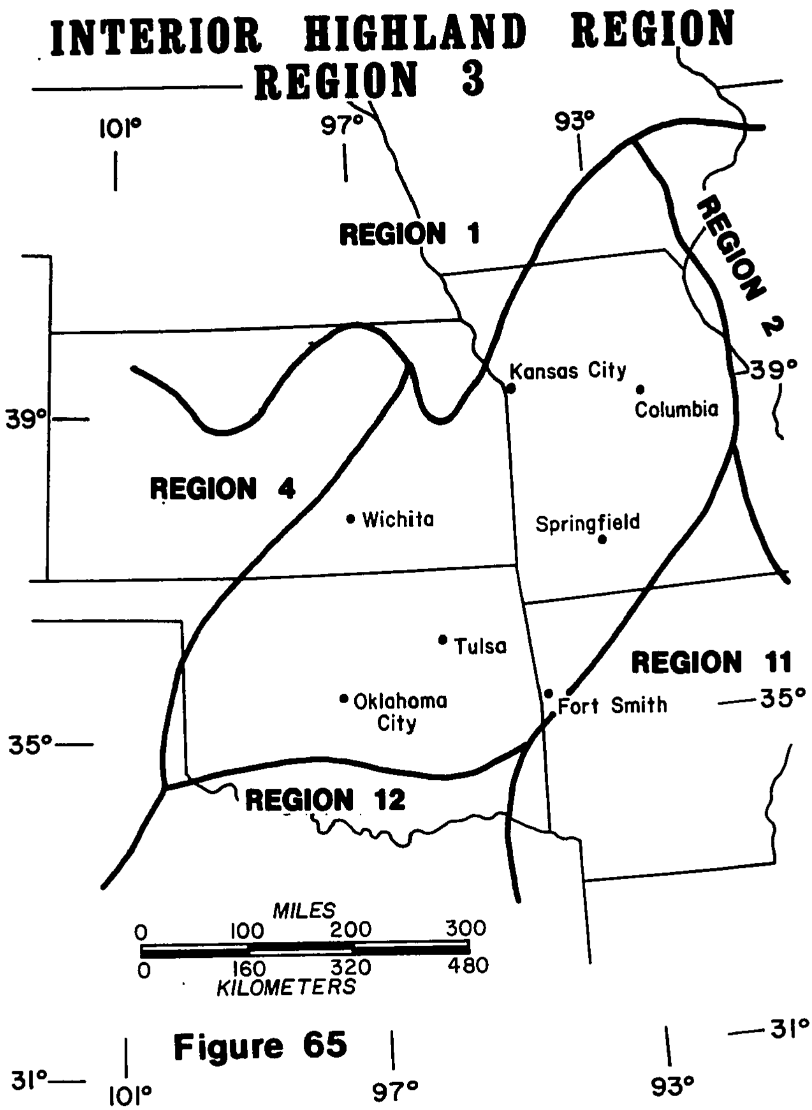
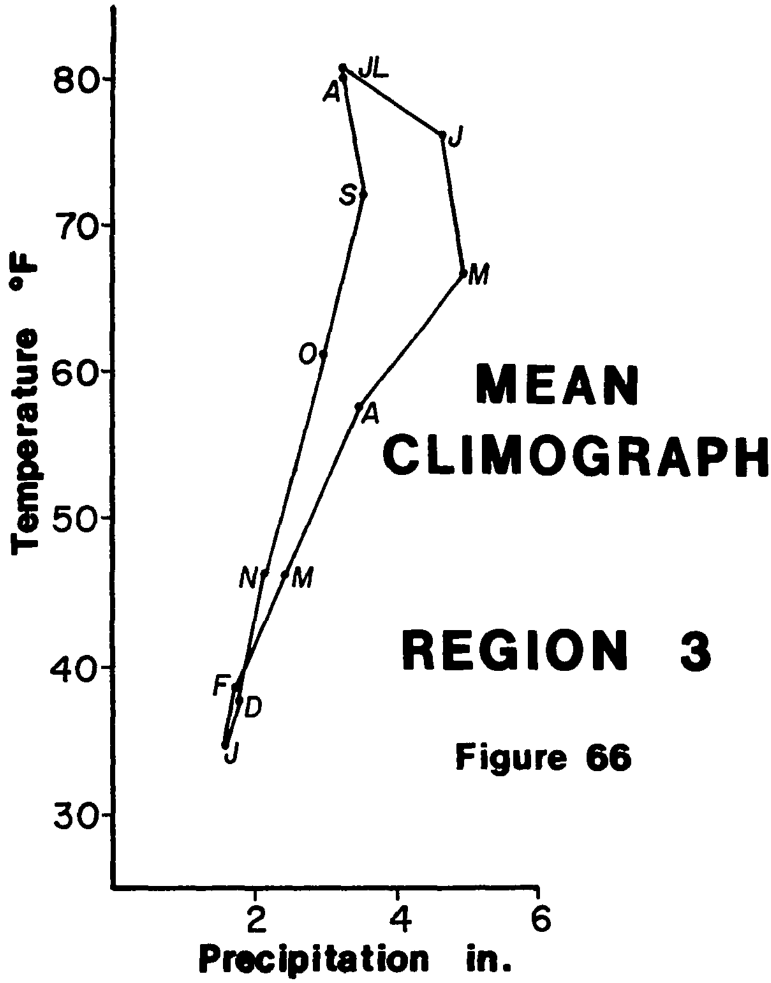

INTERIOR HIGHLAND REGION
REGION 3
101°
97°
93°
REGION 1
REGION 2
REGION 4
REGION 11
REGION 12
39°
35°
31°
Kansas City
Columbia
Wichita
Springfield
Tulsa
Oklahoma City
Fort Smith
MILES
0 100 200 300
0 160 320 480
KILOMETERS

Figure 65



	J	F	M	A	M	J	
Temp. °F	34.6	38.5	46.2	57.8	66.7	76.3	
Precip. In.	1.60	1.78	2.44	3.48	4.95	4.62	Average
	J	A	S	O	N	D	58.2°
Temp. °F	80.9	80.2	72.0	61.1	46.4	37.8	35.76"
Precip. In.	3.24	3.27	3.52	2.98	2.12	1.76	

SOURCE: AUTHOR'S CALCULATIONS.

Although this mean climograph represents a major climatic region and is unique from surrounding regions in terms of its total configuration, transitional features representing precipitation between the more humid regions to the east and subhumid regions to the west are clearly evident. This is most obvious upon inspection of the distance of the mean climograph away from the temperature axis (see Figure 66). This transition is also apparent latitudinally in terms of temperature with respect to the vertical position of the mean climograph along the temperature axis. Therefore, the fact that this climatic region is transitional in nature implies that its mean climograph contains some features in its configuration that are to a certain extent similar, but, on the other hand, differences are also displayed, more so for some surrounding regions than others. For example, the sharp-angled feature of the mean climograph for May representing the primary maxima of precipitation is entirely absent in regions to the north and east. The sharp angle on the climograph representing a secondary maxima of precipitation during September is absent for all surrounding regions with the exception of Region 12. In addition, distinct from all surrounding climatic regions, the area of "opening" within the framework of the climograph configuration during the transition and warm seasons is larger than any other surrounding region. This indicates that a greater difference in precipitation between the spring and autumn seasons occurs relative to adjacent climatic regions.

Marked differences between the Interior Highland Region and surrounding climatic regions in terms of classification coefficient differences are evident (see Table 25). The largest coefficient

TABLE 25

CLASSIFICATION COEFFICIENTS FOR THE INTERIOR HIGHLAND AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 3	4	1	2	11	12	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	+.1	+.7	<u>+5.1</u>	+1.7	-4.3	-3.9	(5.0)
(2) Solar Radiation Receipt	-1.3	<u>+2.6</u>	-2.3	-3.1	-2.4	+1.3	(3.9)
(3) Winter-time High Pressure Systems	+.9	+.1	+1.9	+2.1	- .6	<u>-1.5</u>	(2.4)
(4) Ocean Currents	+2.3	+2.4	+2.1	+ .3	+1.3	+2.1	2.0
(5) Maritime Cloud Variability	-4.7	-3.0	-3.0	-3.2	-5.3	-4.1	1.7
(6) Continental Moisture Index	-1.5	- .4	-1.6	-1.8	-2.1	- .1	1.1
(7) Wind Strength Variability	+1.9	+1.9	+1.3	+1.5	+.6	+.8	1.3

Names of Above Climatic Regions

3	Interior Highland Region
4	High Plains Region
1	Upper Midwest Region
2	East Central Region
11	Humid Southeast Region
12	Texas Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

difference is observed for continental storm track between the Interior Highland Region with a coefficient value of +0.1 and Region 1 to the north with a value of +5.1. However, this climatic factor was previously analyzed with respect to these two regions, and will not be repeated. Two other climatic factors of significance are solar radiation receipt and winter-time high pressure systems. The Interior Highland Region has a coefficient value of -1.3 for solar radiation receipt compared with +2.6 for Region 4 to the west. In addition, the Interior Highland Region has a low positive winter-time high pressure system coefficient of +.9 compared with -1.5 for Region 12 to the south.

The following climatic factor components are observed as significant in distinguishing the Interior Highland Region from Region 4 in terms of their mean climographs: (1) mean sky cover — with respect to the distance of the mean climograph away from the temperature axis which indicates the annual average sum of precipitation; and (2) mP-cT, mT-cT, and mT-mP air masses -- with respect to the large area of "opening" within the framework of the upper end of the mean climograph and the distance of the mean climograph away from the temperature axis which relates generally to the annual march of precipitation, particularly during the transition and warm seasons. Furthermore, the following climatic factor components are important in discriminating between the mean climographs of the Interior Highland Region and Region 12 to the south: (1) total number of highs and their variability — with respect to the position and orientation of the mean climograph away from the temperature axis during the winter season as related to mean monthly precipitation; and (2) cP-mP and mT-mP air masses -- with respect to the position of the mean climograph along the temperature axis.

Mean Sky Cover

One of the more noteworthy differences between the mean climograph for the Interior Highland Region and the High Plains Region to the west is observed in their distances away from the temperature axis. Precipitation values for all months of the year are positioned farther away from the mean climograph's temperature axis for the Interior Highland Region than values of Region 4. This fact is reflected in their mean annual precipitation values. The Interior Highland Region receives 35.76 inches of rainfall during the year compared with 18.07 inches for Region 4, a difference of 17.69 inches! When one considers that these are adjacent climatic regions of relatively small size, this variation in mean annual rainfall is large and represents a sharp gradient.

A partial explanation for this rapid change in mean annual precipitation between these regions is observed in the difference of mean sky cover (see Figure 21). The mean annual sky cover value markedly decreases from the east to the west across these climatic regions with smallest values occurring in the western part of Region 4. By averaging the mean sky cover values for these two climatic regions, a significant difference is noted. The average value for the Interior Highland Region is 5.4 compared with 4.5 for Region 4. Hence, the possibility for precipitation in the Interior Highland Region is notably greater.

Air Masses — mP-cT, mT-cT, mT-mP, and cP-mP

Largest mean monthly precipitation differences between the Interior Highland Region and the High Plains Region occur during the transition season; the maximum difference is 2.24 inches during May.

One reason for these variations is air mass dominance. The Interior Highland Region is dominated by mT-mP or similar moist air masses during the spring and autumn seasons, whereas at least a portion of Region 4 is influenced by drier mT-cT and mP-cT air masses (see Figures 24-35). As a result, drier conditions prevail in Region 4 and less precipitation falls, but a smaller difference in mean monthly precipitation during the autumn months is observed between these two regions. This is quite likely due to relatively drier cT transition air mass dominance during the spring season in Region 4 compared with autumn. Therefore, the difference in mean monthly precipitation between spring and autumn is greater for the Interior Highland Region and accounts for the large "opening" within the framework of the upper portion of the climograph configuration.

A salient feature observed between mean climographs of the Interior Highland Region and Region 12 to the south is the difference in position of the mean climograph along the temperature axis, particularly during the winter season. The mean January temperature for the Interior Highland Region is 10.9°F lower than in Region 12. However, only a 3.3°F difference is observed between these regions during July. Consequently, a longer, lower mean climograph position along the temperature axis is readily obvious for the Interior Highland Region. The difference in the position of these mean climographs is partially explained by dominance of a colder air mass during the winter season. During 4 of the coldest months, November through February inclusively, cP-mP air mass dominates at least a part of the Interior Highland Region compared with the dominance of a milder air mass in Region 12 (see Figures 24-35).

Furthermore, a 1-month delay in the dominance of mT-mP air mass from Region 12 to the Interior Highland Region as it progresses northwards during spring and vice versa during autumn, yields cooler mean temperatures during these transition seasons in the Interior Highland Region. This further adds to the difference in appearance between the two mean climographs.

Total Number of Highs and Their Variability

From inspection of the mean climograph for the Interior Highland Region and Region 12, a vertical orientation of the axis is noted during the cold season for Region 12 versus a diagonal orientation for the Interior Highland Region; i.e., little change in mean monthly precipitation occurs during this time of the year over Region 12 whereas the driest month in the Interior Highland Region is the coldest month. Although the difference in classification coefficients for winter-time high pressure systems between these climatic regions is small, total number of highs and their variability as climatic factor components may furnish a partial explanation for the different orientations of their mean climograph axis during this time of the year.

By use of 5^{o} latitude by 5^{o} longitude areas, grid cells which encompass these climatic regions are used to compare total number of highs and their variability for these climatic regions. A greater total number of highs is noted in the Interior Highland Region especially when compared with the grid cell positioned over the western portion of Region 12. Furthermore, the Interior Highland Region reveals more variability of total number of highs in terms of standard deviation compared with the western position of Region 12 but less variability when compared with the eastern portion of this region. As a result, this climatic factor component is more difficult to assess. But, if one analyzes the total number of highs for the cool season of the Interior Highland Region with the western portion of Region 12, more highs are noted over the Interior Highland area (see Table 26). Consequently, the potential for a relatively larger amount of precipitation exists and is evident on the mean climograph during the winter in this drier western part of Region 12.

In summary, the mean climograph for the Interior Highland Region is unique from Regions 4 and 12 due to the following characteristics: (1) a greater distance away from the temperature axis than Region 4 due to a greater mean sky cover; (2) a larger "opening" within the framework of the upper end of the mean climograph due to the distribution of moist and dry air masses during the transition seasons; (3) a lower position along the temperature axis, especially with respect to Region 12, due to a prolonged period of cP and mP transition air mass dominance; and (4) a diagonal orientation of the mean climograph axis reflecting drier conditions during the cold season due to a higher frequency of high pressure systems.

High Plains Region - Region 4

The High Plains Region represents a narrow, elongated climatic region which, according to Kendall, is generally within the B/H transition zone.[4] This region averages approximately 150 miles wide and extends from northern Kansas southwards into the Big Bend area of Texas (see Figure 67). This narrow climatic region consists of 5 first-order and 8 test weather stations (see Appendices VIII and IX). A typical continental precipitation

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[4] Kendall, *op. cit.*, p. 122.

TABLE 26[a]

NUMBER OF HIGH PRESSURE SYSTEMS OVER A TWENTY-YEAR PERIOD
FOR THE INTERIOR HIGHLAND REGION AND WEST
PORTION OF REGION 12 DURING WINTER

Interior Highland Region						
	Western Portion of Region			Eastern Portion of Region		
Months	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.
Number of Highs	16	12	14	18	15	10

Region 12						
	Western Portion of Region			Eastern Portion of Region		
Months	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.
Number of Highs	10	8	10	12	18	12

[a]Source: William H. Klein, Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere. Washington, D.C., U. S. Department of Commerce, Weather Bureau, Research Paper No. 40, 1957, pp. 23-46.

HIGH PLAINS REGION
REGION 4

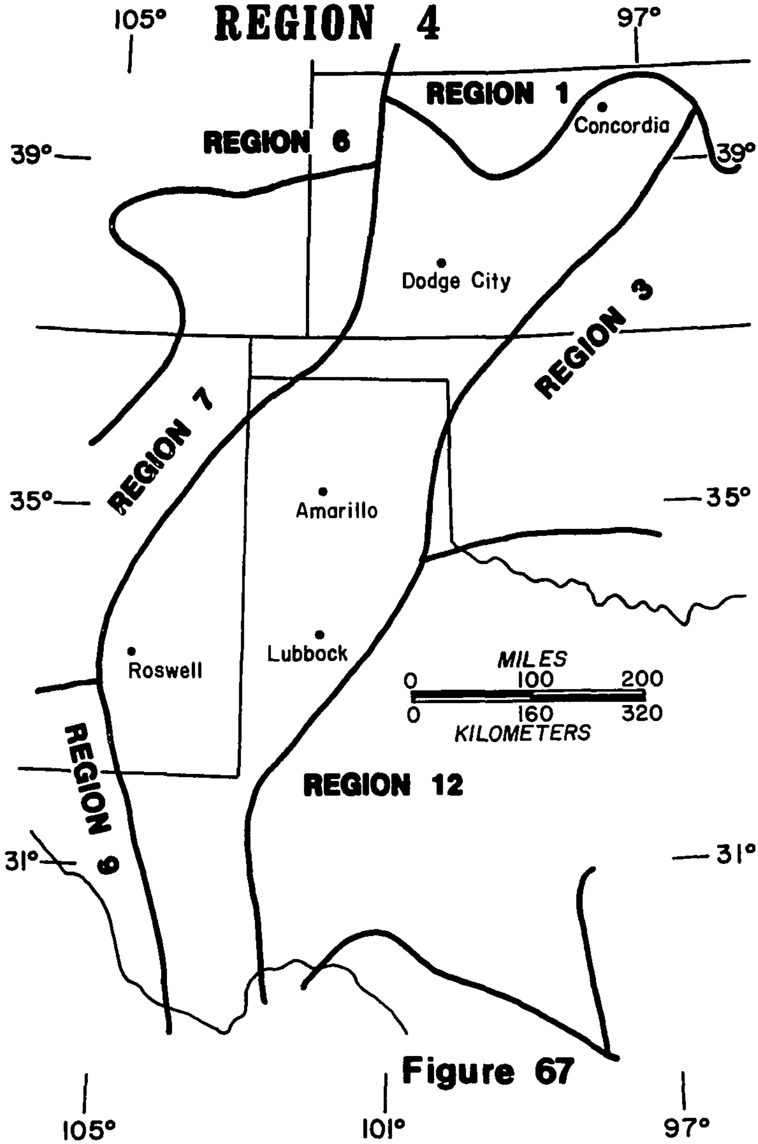
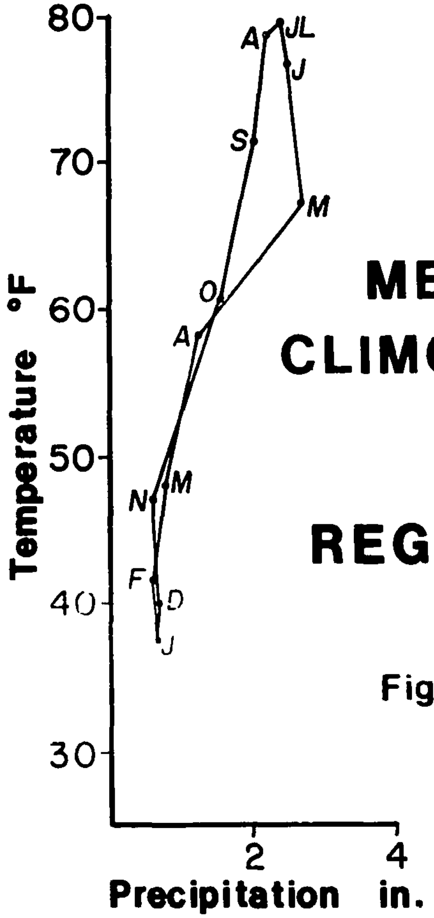


Figure 67

regime is characterized by the mean climograph with a small mean annual total and maximum amounts occurring during late spring and summer. The total annual rainfall is only 18.07 inches with May representing the month with the greatest rainfall of 2.71 inches. February, the driest month, receives only 0.60 inches of rain. Due to the somewhat interior location, a rather large mean annual temperature range of 42.1°F is observed. A mild mean annual temperature of 58.8°F with warm summer temperatures reflects the relatively low latitude of this region.

The uniqueness of the mean climograph for this climatic region is seen in its closeness to the temperature axis but with an abrupt increase in precipitation during May in addition to similar amounts of precipitation falling during the entire summer season (see Figure 68). The primary maxima occurring during May forms an obvious sharp angle in the climograph configuration. Furthermore, a gradual decrease in precipitation from August to January is regular and is depicted as nearly a straight line. This type of precipitation regime forms a relatively large "opening" within the upper portion of the climograph from April through October. However, due to similar precipitation values for April and October, March and November, and February and December, exceedingly small "openings" in the lower portion of the mean climograph approximates a single line with a slight diagonal orientation. No other climograph in an adjacent climatic region can be described in this manner, and, therefore, it is considered as a unique configuration.

Large classification coefficient differences between the High Plains Region and Regions 6, 7, and 9 were observed (see Table 27). More specifically, high positive maritime cloud variability values were



MEAN CLIMOGRAPH

REGION 4

Figure 68

	J	F	M	A	M	J	
Temp. °F	37.5	41.5	48.0	58.1	66.9	76.6	
Precip. In.	.63	.60	.80	2.71	2.52	2.44	Average
	J	A	S	O	N	D	58.8°
Temp. °F	79.6	78.6	71.2	60.7	47.1	39.9	18.07"
Precip. In.	2.44	2.25	2.05	1.57	.61	.65	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 27[a]

CLASSIFICATION COEFFICIENTS FOR THE HIGH PLAINS AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 4	3	12	9	7	6	1	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	+ .7	+ .1	-3.9	-.8	+1.0	+5.0	+5.1	4.6
(2) Solar Radiation Receipt	+2.6	-1.3	+1.3	<u>+12.2</u>	7.0	+3.4	-2.3	(9.6)
(3) Winter-time High Pressure Systems	+ .1	+ .9	-1.5	-3.7	-1.1	+1.5	+1.9	3.6
(4) Ocean Currents	+2.4	+2.3	+2.1	-1.0	- .3	+1.0	+2.1	3.4
(5) Maritime Cloud Variability	-3.0	-4.7	-4.1	<u>+9.9</u>	<u>+8.1</u>	<u>+4.9</u>	-3.0	(12.9)
(6) Continental Moisture Index	- .4	-1.5	-1.1	<u>+6.6</u>	<u>+5.3</u>	+1.7	-1.6	(7.0)
(7) Wind Strength Variability	-1.9	+1.9	+ .8	-3.5	-2.9	-1.9	+1.3	5.4

Names of Above Climatic Regions

4 High Plains Region
3 Interior Highland Region
12 Interior Texas Region
9 Desert Southwest Region
7 Plateau Region
6 Interior Basin and Plains Region
1 Upper Midwest Region

[a]Source: Author's calculations.

Note: Coefficients with parenthesis have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

indicated for Regions 7 and 9, a moderately high positive value was observed for Region 6, and a moderately high negative value was observed for the High Plains Region. A high positive solar radiation receipt value was calculated for Region 9, and a low positive value was indicated for the High Plains Region. Finally, moderately high positive continental moisture index values were observed for Regions 9 and 7 and a small negative value was observed for the High Plains Region. To avoid repetition, maritime cloud variability with respect to Region 7, solar radiation receipt with respect to Region 9, and continental moisture index with respect to Region 9 are discussed elsewhere in this chapter.

From examination of mean climograph differences, the following climatic factor components are observed as significant between the High Plains Region and Regions 6 and 9: (1) latitude -- with respect to the intermediate position of the mean climograph along the temperature axis compared with Regions 6 and 9; (2) variability of mean sky cover -- with respect to the above-mentioned sharp angle on the mean climograph for the month of May which represents the primary precipitation maxima and the "opening" in the upper portion of the mean climograph; and (3) mT and mP air masses — with respect to the distance of the mean climograph away from the temperature axis. The following climatic factor components are significant in distinguishing the mean climograph configuration of the High Plains Region from Region 7: (1) mP, cP-cT, and cT air masses -- with respect to the distance of the mean climograph away from the temperature axis in addition to its position along the temperature axis.

Latitude

Even though the southern portion of the High Plains Region extends farther south than does Region 9, only two test weather stations are in this area of the Big Bend of Texas (see Figure 53). The majority of first-order and test weather stations are north of 34°N which is in the northern section of Region 9. Furthermore, 6 first-order and test weather stations in the High Plains Region are farther north than any weather station in Region 9. This fact is thus reflected on the mean climograph of the High Plains Region with a higher position along the temperature axis. The mean monthly maximum temperature for the High Plains Region is 79.6°F compared with 87.6°F for Region 9, and the minimum mean monthly temperatures for these two regions are 37.5°F and 47.9°F, respectively.

In contrast to Region 9, much of Region 6 is north of the High Plains Region. In fact, the majority of first-order and test weather stations are north of the latitude which coincides with the northern boundary of the High Plains Region and extends to the Canadian border. Therefore, the position of the mean climograph along the temperature axis is higher for the High Plains Region than for Region 6. The maximum mean monthly temperature for the High Plains Region is 79.6°F compared with 70.2°F for Region 6, and the minimum mean monthly temperatures for these two regions are 37.5°F and 21.6°F, respectively.

Variability of Mean Sky Cover

From inspection of the mean climograph for the High Plains Region, a relatively pronounced sharp angle representing the primary precipitation maxima is noted for the month of May. Subsequently, a gradual decrease in mean monthly precipitation is observed into the winter season. According to Trewartha, this primary precipitation maxima is caused by surface air flow primarily from the Gulf of Mexico to the heated land combined with a high frequency of frontal disturbances.[5] However, even though the land surface continues to heat after May, a decrease in precipitation is evident. The probable reason for this is an anticyclonic flow which prevails over the Texas region during the summer months at the 750-500 mb level.[6] This decrease in precipitation after May is noted in mean sky cover data.

Firstly, when standard deviation values of mean sky cover for the only two first-order core weather stations (see Figure 54), Amarillo and Lubbock, in the High Plains Region are compared with some first-order core weather stations in Regions 6 and 9, much different values are evident (see Table 28).

TABLE 28[a]

STANDARD DEVIATIONS OF MEAN SKY COVER FOR SELECTED FIRST-ORDER CORE WEATHER STATIONS IN THE HIGH PLAINS REGION AND REGIONS 6 AND 9

High Plains Region		Region 6		Region 9	
Amarillo	.60	Billings	1.11	Phoenix	.89
Lubbock	.55	Great Falls	1.13	Tucson	.98

[a]Source: Author's calculations.

[5]Trewartha, _op. cit._, p. 280.

[6]_Ibid._

Variability of mean sky cover in the High Plains Region is considerably less. Secondly, and probably more significant, the mean sky cover values for the High Plains Region are highest for the month of May compared with other spring and summer months. This is not the case for Regions 6 and 9 (see Table 29).

TABLE 29[a]

MEAN MONTHLY SKY COVER FOR APRIL, MAY, AND JUNE FOR SELECTED FIRST-ORDER CORE WEATHER STATIONS FOR THE HIGH PLAINS REGION AND REGIONS 6 AND 9

High Plains Region				Region 6				Region 9			
	Apr.	May	June		Apr.	May	June		Apr.	May	June
Amarillo	5.1	5.2	4.3	Billings	7.0	6.5	5.9	Phoenix	2.6	2.8	1.9
Lubbock	4.7	4.9	3.9	Great Falls	7.2	6.8	6.5	Tucson	3.5	2.8	2.2

[a]Source: Local Climatological Data with Comparative Data, 1964.

During the autumn season, smaller mean sky cover values with only a slight decrease in magnitude from August through October is reflected by the gradual decrease in mean monthly precipitation into the winter months and is represented virtually by a straight line on the mean climograph. This gradual decrease in precipitation during the late summer-autumn season combined with the primary precipitation maxima during May creates a notable "opening" in the upper portion of the mean climograph in which its configuration is unique compared with the mean climographs for Region 6 and 9 to the west.

Air Masses -- mT, mP, cT, and cP-cT

Although the mean annual precipitation in the High Plains Region is only 18.07 inches, more precipitation falls annually in this climatic region than in some regions to the west, i.e., Region 6, 7, and 9. Typical of a continental climate, much of the rain falls during the warm season. During the winter season, comparable amounts of precipitation are evidenced in all four climatic regions. Consequently, the distance away from the temperature axis for the lower portion of the mean climograph is approximately the same for the High Plains Region as it is for the 3 climatic regions to the west, but the upper portion of the mean climograph is noticeably farther away from the temperature axis. The reason for this difference in precipitation during the warmer season is partially revealed by examining the distribution and duration of various air masses.

During the warmer months of the year, from May through September, most or all of the High Plains Region is dominated by warm, moist mT air mass (see Figures 24-35). In contrast, Regions 6, 7, and 9 are not influenced by mT air but by cooler mP air during May, June, and September, particularly in Region 6 but also to a smaller degree in Region 7, and by drier cT air especially during May, June, and July in the southern section of Region 7 and parts of Region 9. The distribution and duration of these various air masses during the warm season over these climatic regions indicate that at least the potential for more precipitation is greater in the High Plains Region than in Regions 6, 7, and 9.

One other air mass which was revealed as a significant climatic factor component is cP-cT air. This air mass dominates portions of

Region 7 during the transition season when mP and mP transition air masses are evidenced in the High Plains Region. During this time of the year, little difference is observed in mean monthly precipitation between these two climatic regions; however, mean monthly temperatures are about $5^{o}F$ warmer in the High Plains Region. Therefore, the dominance of the colder cP-cT air mass in Region 7 versus a milder mP air mass in the High Plains Region may be considered important with respect to the higher position of the mean climograph along the temperature axis for the High Plains Region.

In summary, the mean climograph for the High Plains Region is unique from Regions 6, 7, and 9 due to the following characteristics: (1) an intermediate position of the mean climograph along the temperature axis compared with Regions 6 and 9 due to latitude and its higher position compared with Region 7 due to cP-cT air mass; (2) a sharp-angled feature in the mean climograph during May representing the primary precipitation maxima due to a greater mean sky cover than in other spring months, and an "opening" in the upper end of the mean climograph due to a gradual decrease in precipitation during the autumn months coincident with a small mean sky cover change combined with the May sharp-angled feature; (3) the greater distance of the upper portion of the mean climograph away from the temperature axis with respect to Regions 6, 7, and 9 due to mP, mT, and cT air masses.

Upper Great Lakes Region - Region 5

The Upper Great Lakes Region extends from north-central Minnesota across the Great Lakes to northern Maine (see Figure 69). This northern United States climatic region consists of 8 first-order and 6 test weather

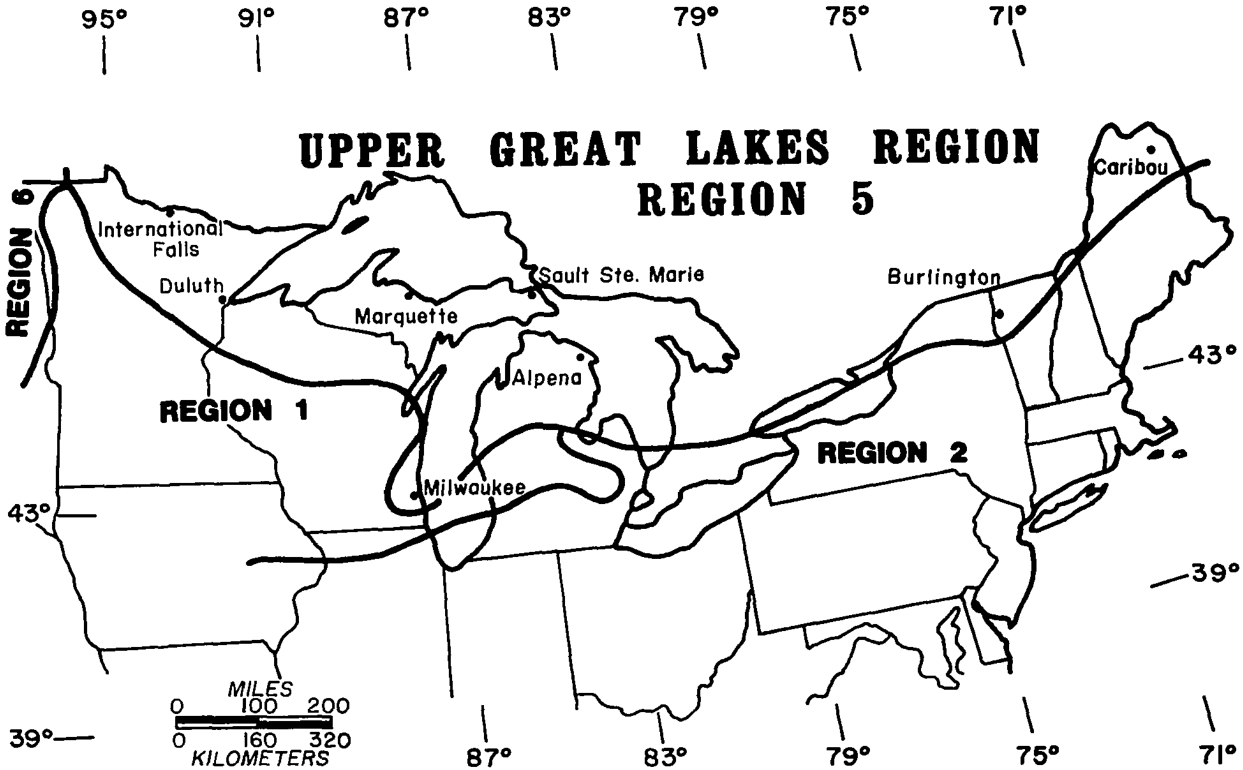
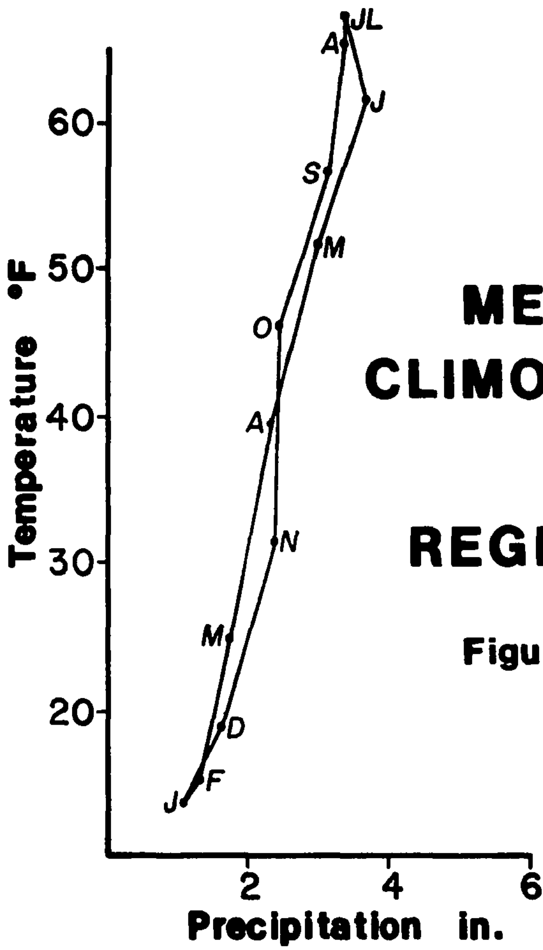

UPPER GREAT LAKES REGION
REGION 5
95°
91°
87°
83°
79°
75°
71°
REGION 6
International Falls
Duluth
Marquette
Sault Ste. Marie
Burlington
Caribou
Alpena
Milwaukee
REGION 1
REGION 2
43°
39°
MILES
0 100 200
0 160 320
KILOMETERS

Figure 69

stations (see Appendices VIII and IX). The weather stations in this climatic region are characterized by an extreme mean annual range in temperature. The representative mean July temperature for weather stations in this climatic region is a mild 67.2°F, but the mean January temperature is 13.6°F, which is the lowest mean monthly temperature for any major climatic region in the United States. The total precipitation for the Upper Great Lakes Region averages 29.98 inches per year and is moderately well-distributed with somewhat greater amounts falling during the summer months. For example, June, the wettest month, receives 3.68 inches of precipitation compared with 1.33 inches during February, the driest month.

The uniqueness of this climatic region's mean climograph is observed in its extreme length and narrowness (see Figure 70). No other mean climograph extends as low along the temperature axis; only the Upper Midwest Region, which is an adjacent region, has a longer temperature axis; the annual march of precipitation nearly forms a straight line from January to July and then back to January. Only small "openings" in the mean climograph are observed from spring to autumn. This aspect of the mean climograph differs from surrounding climatic regions, Regions 1, 2, and 6, where different precipitation values between the two transition seasons produce more area within the framework of the mean climograph configuration.

The distinctiveness of this mean climograph compared with mean climographs of surrounding regions is assessed in terms of large classification coefficient differences between the Upper Great Lakes Region and Region 2 to the south and Region 6 to the west (see Table 30). A



MEAN CLIMOGRAPH

REGION 5

Figure 70

	J	F	M	A	M	J	
Temp. °F	13.6	15.2	24.8	39.4	51.6	61.4	
Precip. In.	1.58	1.33	1.74	2.33	2.98	3.68	Average
	J	A	S	O	N	D	40.9°
Temp. °F	67.2	65.3	56.5	46.1	31.3	18.6	29.98"
Precip. In.	3.35	3.40	3.15	2.44	2.37	1.63	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 30

CLASSIFICATION COEFFICIENTS FOR THE UPPER GREAT LAKES AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 5	2	1	6	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	+6.2	+1.7	+5.1	+5.0	(4.5)
(2) Solar Radiation Receipt	-2.0	-3.1	-2.3	+3.4	(5.4)
(3) Winter-time High Pressure Systems	+1.2	+2.1	+1.9	+1.5	.9
(4) Ocean Currents	+ .2	+ .3	+2.1	+1.0	1.9
(5) Maritime Cloud Variability	+1.2	-3.2	-3.0	+4.9	(4.4)
(6) Continental Moisture Index	-1.0	-1.8	-1.6	+1.7	2.7
(7) Wind Strength Variability	- .1	+1.5	+1.3	-1.9	1.8

Names of Above Climatic Regions

5 Upper Great Lakes Region
2 East Central Region
1 Upper Midwest Region
6 Interior Basin and Plains Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

large classification coefficient difference for continental storm track is observed between the Upper Great Lakes Region with a high positive value and Region 2 to the south with a low positive value. In addition, a relatively high maritime cloud variability coefficient difference is noted between these two climatic regions. Region 2 has a moderately high negative coefficient value, whereas the Upper Great Lakes Region has a low positive value. Region 6, to the west, has a moderately high positive solar radiation receipt coefficient value compared with a moderately high negative value for the Upper Great Lakes Region.

From examination of mean climograph configuration differences, the following climatic factor components are observed as significant between the Upper Great Lakes Region and Region 2: (1) latitude -- with respect to the large difference of the mean climograph's position along the temperature axis; (2) continentality -- with respect to the length of the climograph axis; (3) cP, mT and mP air masses -- with respect to the position of the mean climograph along and distance from the temperature axis, i.e., the differences in mean monthly temperatures, particularly during the cooler season, and the total annual precipitation; and (4) variability of mean sky cover and variability of number of lows -- with respect to the difference in the "opening" of the mean climograph which reflects a variation in the annual march of precipitation. The following climatic factor components are significant in distinguishing the mean climograph configuration of the Upper Great Lakes Region from the one to the west in Region 6: (1) mean sky cover -- with respect to the angle of the mean climograph's axis from a vertical position in that greater seasonal variability of precipitation is evident in the Upper Great Lakes Region; and (2) mP-cT and mT-cT air masses -- with respect to the horizontal distance of the mean climograph away from the temperature axis, i.e., the difference in the total annual precipitation.

Latitude and Continentality

The mean climograph of the Upper Great Lakes Region is positioned low along the temperature axis with particularly outstanding cold winter temperatures. This is typical of high latitude climatic regions which are not excessively influenced by moderating oceanic effects. The mean annual temperature for the Upper Great Lakes Region is only 40.9^{o}F. To the south, Region 2 extends southwards to Tennessee and North Carolina. With these lower latitudinal weather stations, a much warmer mean annual temperature of 51.9^{o}F characterizes this climatic region. Consequently, the mean climograph is positioned much higher along the temperature axis and contrasts sharply with Region 5 to the north.

The difference in the length of the mean climograph between the Upper Great Lakes Region and Region 2 is pronounced. The mean annual range in temperature for the Upper Great Lakes Region is 53.6^{o}F which is almost 10^{o}F greater than the range for Region 2. This kind of difference observed in the mean annual range in temperature for these two climatic regions coincides with the distribution of continentality values (see Figure 9). From the Oliver index continentality map, values of 10 or greater were recorded for the majority of weather stations in the Upper Great Lakes Region. But, to the south, in Region 2, weather stations in West Virginia and Virginia have values less than 8. The fact that Region 2 is not as strongly influenced by continental effects as the

Upper Great Lakes Region is also observed on other continentality maps, i.e., Conrad's continentality map.[7]

Air Masses -- cP, mT, mP, mP-cT, and mT-cT

Much of the Upper Great Lakes Region is dominated by cP air mass from November through March (see Figures 24-35). This condition is evidenced by the fact that the mean monthly temperatures during the cold season are well below freezing; December, January, and February have mean temperatures below 20°F. This mean monthly air mass characteristic is in contrast to Region 2 in which the southern portion of this region is not influenced by mean monthly cP air mass for a single month of the year. The mean climograph for this region shows that the three coldest months have temperatures near 32°F. During July and August, the Upper Great Lakes Region is only partially dominated by mT air mass. This is compared with 4 summer months in which this air mass type prevails in parts of Region 2. Hence, a longer duration of warm temperatures is expected in Region 2. The mean climographs for these 2 regions reveal that 5 months in Region 2 have mean temperatures greater than 60°F compared with 3 months for the Upper Great Lakes Region. Large temperature differences are also noted during early spring and autumn between these 2 regions. For example, the mean temperature for March in the Upper Great Lakes Region is 24.8°F which is 14.0°F lower than the mean March temperature in Region 2 to the south. During March and April, mP air mass is dominant in Region 2 but is completely absent in the Upper Great Lakes Region which continues to be under the influence of cold cP and cP transition air masses.

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[7] Trewartha, The Earth's Problem Climates, op. cit., p. 254.

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[7] Trewartha, The Earth's Problem Climates, op. cit., p. 254.

The distance of the mean climograph away from the temperature axis, indicating the total amount of precipitation received at a weather station, varies markedly between the Upper Great Lakes Region and Region 2 during the cold season. The Upper Great Lakes Region, under the influence of cP air during winter, receives much less precipitation than weather stations to the south under mT air mass which has a greater capacity to hold moisture. Therefore, a diagonal orientation of the mean climograph axis for Region 2 is virtually absent. Due to this difference in wintertime precipitation, 11.98 inches less precipitation is received in the Upper Great Lakes Region per year. Although some of the largest mean monthly precipitation differences between these 2 climatic regions are observed during the winter months, particularly January, large differences continue into spring and then again during the autumn months. The mean March precipitation total for the Upper Great Lakes Region is 1.74 inches compared with 3.52 inches for Region 2. During these transition months, warmer, moist mP air mass is situated to the south of the Upper Great Lakes Region over all or a part of Region 2.

To the west, mP-cT and/or mT-cT air mass dominance occurs from April through October over various sections of the relatively dry Interior Basin and Plains Region. As a result, little precipitation falls during the summer months. When this condition is combined with the fact that little precipitation falls during the cold season, the result is a vertical mean climograph axis which is positioned near the temperature axis. In the Upper Great Lakes Region, no mP-cT or mT-cT air mass dominates during any month of the year. With an absence of cT transition air mass but some mT air mass dominance occurring during the summer season, a diagonal orientation of the mean climograph with respect to the temperature axis depicting modest warm-season amounts of precipitation is enhanced.

Mean Sky Cover and Variability of Mean Sky Cover and Variability of Number of Lows

Another noteworthy difference between the mean climographs of the Upper Great Lakes Region and Region 2 is the area or "opening" within the construct of the climographs. The difference is most obvious between the transition seasons, particularly September through November versus March through May. Small changes in precipitation totals between these transition months in the Upper Great Lakes Region produce a narrow mean climograph. Two significant climatic factor components in explaining this difference is variability of sky cover and variability of number of lows. From an inspection of variability of sky cover and number of lows in terms of standard deviation, no obvious conclusions are apparent. Large differences in standard deviation values for both climatic factor components are observed (see Figure 71). But, if monthly variation of precipitation is viewed relative to departures in the "opening" of the mean climographs, mean monthly precipitation for corresponding months during the transition seasons should be examined which vary with respect to changes in sky cover and number of lows. Scrutiny of sky cover and number of lows during two transition months--October and April--substantially explains the differences in area within the framework of the two mean climographs.

Briefly, during the month of October, the Upper Great Lakes Region receives only 0.42 inches less rainfall than Region 2 to the south.

VARIABILITY OF MEAN ANNUAL SKY COVER
AND NUMBER OF LOWS
FOR THE UPPER GREAT LAKES REGION

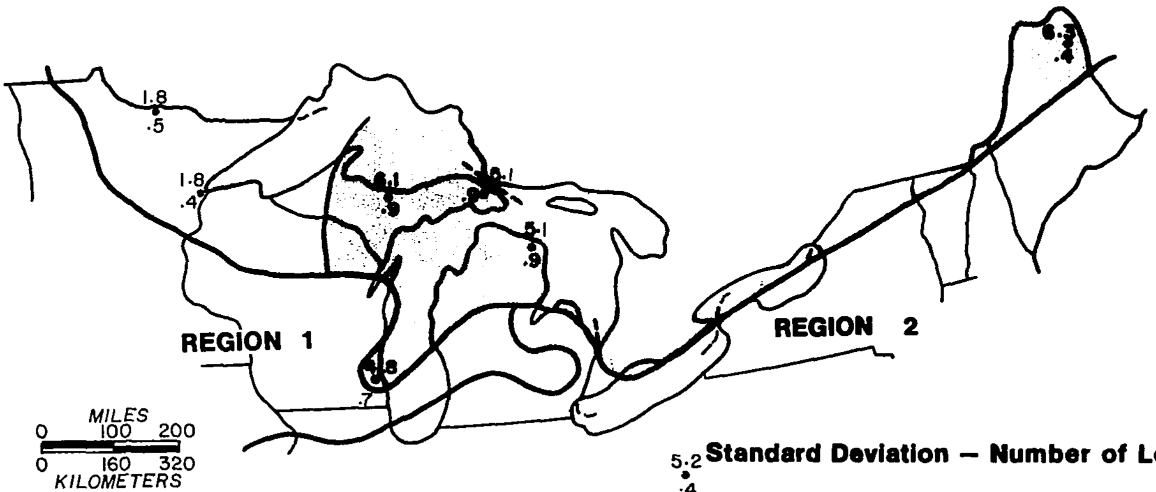

Figure 71

5.2 • .4 Standard Deviation – Number of Lows

Standard Deviation of Sky Cover

(– Values of Standard Deviation –
Number of Lows Greater Than 4.0

SOURCE: AUTHOR'S CALCULATIONS.

This value is smaller than is expected in view of the fact that the southern extremities of Region 2 are dominated by a warmer, moist mP-mT air mass during this month. However, mean October sky cover is considerably higher over the Upper Great Lakes Region (see Table 31). During the autumn season, a northward retreat of the major storm track reduces the cloudiness, and, hence, precipitation over particularly the western portion of Region 2.[8] However, much cloudiness accompanied by traveling disturbances is observed over the Upper Great Lakes Region. During April, the average cloudiness and number of lows are similar between these two regions, but with a warmer, moist mP air mass dominating Region 2 and cP-mP air mass prevalent in the Upper Great Lakes Region, 1.19 inches less rainfall is received in the latter climatic region. These differences primarily account for the narrowness of the mean climograph in the Upper Great Lakes Region as opposed to Region 2.

The most obvious difference between the mean climographs of the Upper Great Lakes Region and Region 6 to the west is the orientation of their axes. As a result of more summer-time precipitation in the Upper Great Lakes Region than in Region 6, and similar amounts between these two regions during the month of January, a diagonal orientation of the mean climograph axis is depicted for the Upper Great Lakes Region as opposed to a vertical axis for Region 6. Therefore, the total annual precipitation is naturally less in Region 6. This difference can be readily related to mean sky cover. High mean annual sky cover values occur over the entire Upper Great Lakes Region. However, to the west, these values decrease with minimum values in the far western portion of

[8] Ibid., p. 299.

TABLE 31

APRIL AND OCTOBER MEAN MONTHLY SKY COVER AND NUMBER OF LOWS FOR SELECTED WEATHER STATIONS IN THE UPPER GREAT LAKES REGION AND REGION 2

Region	Weather Station	Number of Lows April [b]	Mean April Sky Cover [a]	Number of Lows October [b]	Mean October Sky Cover [a]
Upper Great Lakes Region	Sault Ste. Marie	12	6.7	26	6.9
	Marquette	14	6.7	25	6.9
	Duluth	15	6.9	20	6.4
	Alpena	12	7.0	26	6.3
East Central Region	Chicago	17	6.7	17	5.2
	Peoria	17	6.7	17	4.8
	Springfield	14	6.6	20	4.6
	Louisville	14	6.6	20	4.8
	Lynchburg	16	6.0	28	4.7
	Norfolk	16	5.9	28	5.3
	Allentown	17	6.5	30	5.2
	Lexington	18	6.6	31	4.7

[a]Source: Local Climatological Data, 1964.

[b]Source: Klein, *op. cit.*, pp. 23-34.

Region 6, the Great Basin. Mean annual sky cover values range from 6.2 to 7.1 in the Upper Great Lakes Region to 5.2 for an average in the southwestern section of Region 6. This accounts for the large difference in annual precipitation totals between these two climatic regions. Furthermore, the greatest difference in mean monthly sky cover occurs during the summer months. For example, the mean monthly sky cover value during August for Elko is 2.9 compared with 6.0 for Marquette. Hence, drier conditions prevail, particularly during the warm season, to the west of the Upper Great Lakes Region which is vividly depicted upon inspection of the two mean climographs.

In summary, the mean climograph for the Upper Great Lakes Region is unique from Regions 2 and 6 due to the following characteristics: (1) a long climograph axis positioned low along the temperature axis due to a high latitude and a continental location; (2) a diagonal orientation of the mean climograph axis positioned farther away from the temperature axis during the summer season due to a dominance of cP air mass during the winter season, some mT air mass during summer, and an absence of cT transition air mass; (3) narrowness of the mean climograph combined with its diagonal orientation due to a higher mean sky cover, particularly during October, and a greater mean annual sky cover, especially during the summer season, compared with weather stations to the west.

Interior Basin and Plains Region - Region 6

The Interior Basin and Plains Region is the largest climatic region in the United States. Physiographically, this region includes the northern portion of the Great Plains, much of the Rocky Mountains, and most of the Intermontane Basin (see Figure 72). This climatic

INTERIOR BASIN AND PLAINS REGION
REGION 6

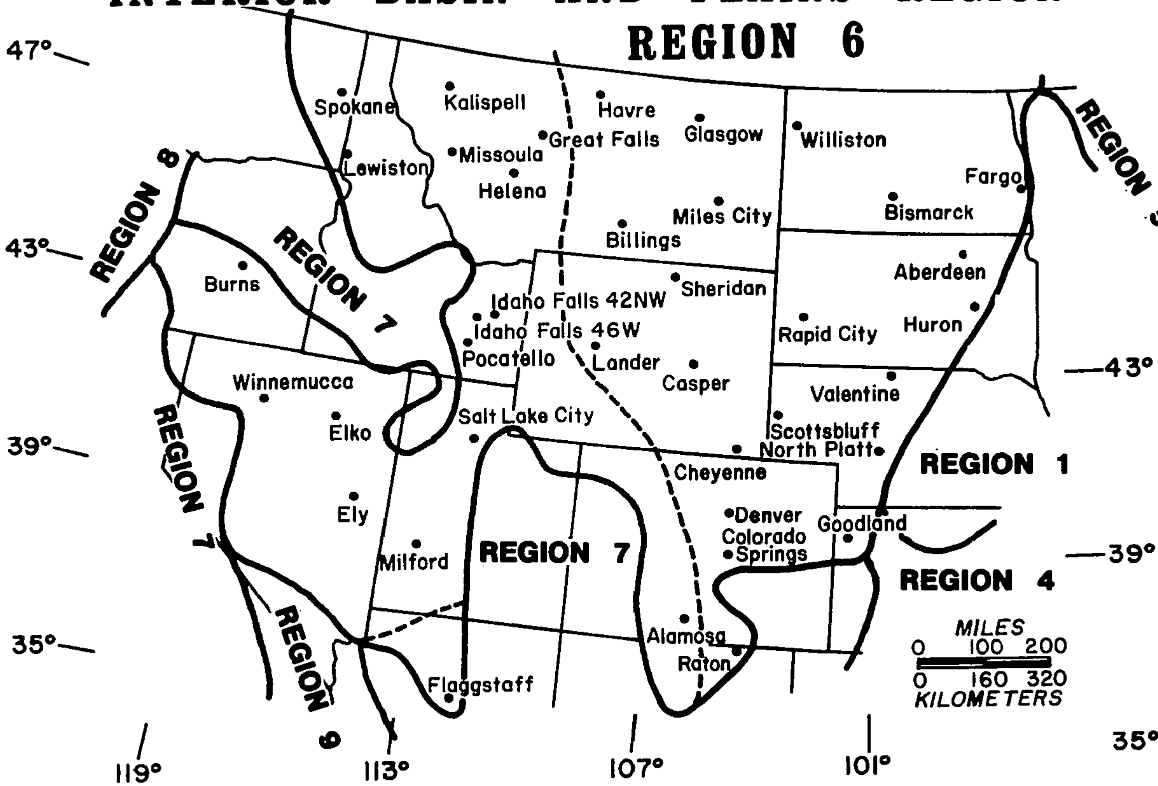

Figure 72

region consists of 38 first-order and 24 test weather stations (see Appendices VIII and IX). Because of the interior location of this climatic region, a large annual temperature range of 48.6°F is observed; July is the warmest month with a mean temperature of 70.2°F whereas January is the coldest month with a mean temperature of 21.6°F. Furthermore, with this interior location, a semi-arid climate is indicated with a scant 13.56 inches of precipitation per year. Maximum amounts of precipitation are received during the late spring. However, the month of maximum precipitation, June, receives only .93 inches more than the driest month of February.

The uniqueness of the mean climograph for this climatic region is observed in its nearly vertical orientation with respect to the precipitation axis and especially, its closeness to the temperature axis (see Figure 73). A minor exception to this vertical orientation is seen during the late spring season when there is a modest increase in mean monthly precipitation. This is represented by a slight diagonal orientation in that portion of the climograph. Another feature peculiar to this mean climograph is the gradual increase in the "opening" within its framework from winter to summer season. This can also be attributed to the late spring increase in precipitation. Finally, the climograph is positioned low along the temperature axis.

Large classification coefficient differences are observed between the Interior Basin and Plains Region and Regions 1, 4, 5, 8, and 9 (see Table 32). A moderately low positive solar radiation receipt value was calculated for the Interior Basin and Plains Region compared with a high positive value for Region 9 and moderately low negative values

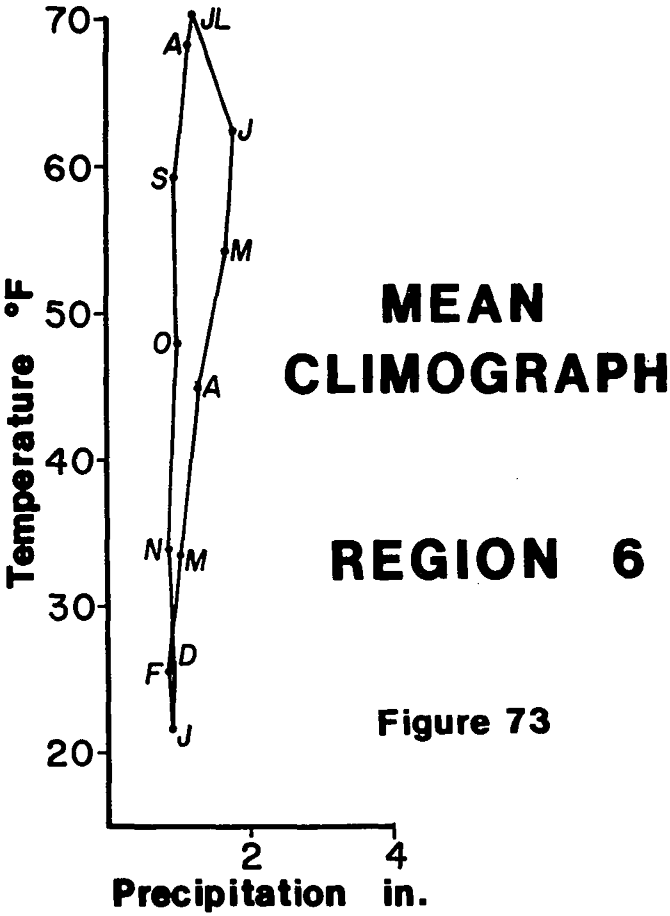

Figure 73

	J	F	M	A	M	J	
Temp. °F	21.6	25.5	33.5	44.8	54.2	62.3	
Precip. In.	.92	.85	1.02	1.26	1.66	1.78	Average
	J	A	S	O	N	D	45.6°
Temp. °F	70.2	68.2	59.2	48.0	33.8	26.1	13.56"
Precip. In.	1.21	1.15	.96	.99	.86	.90	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 32[a]

CLASSIFICATION COEFFICIENTS FOR THE INTERIOR BASIN AND PLAINS AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 6	5	1	4	7	9	8	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	+5.0	+6.2	+5.1	+.7	+1.0	-.8	-.9	5.9
(2) Solar Radiation Receipt	+3.4	-2.0	-2.3	+2.6	+7.0	+12.2	+2.9	(8.8)
(3) Winter-time High Pressure Systems	+1.5	+1.2	+1.9	+ .1	-1.1	-3.7	-3.3	5.2
(4) Ocean Currents	+1.0	+.2	+2.1	+2.4	- .3	-1.0	-7.8	(8.8)
(5) Maritime Cloud Variability	+4.9	+1.2	-3.0	-3.0	+8.1	+9.9	+15.6	(10.7)
(6) Continental Moisture Index	+1.7	-1.0	-1.6	- .4	+5.3	+6.6	+ 4.5	4.9
(7) Wind Strength Variability	-1.9	- .1	+1.3	+1.9	-2.9	-3.5	-2.8	3.8

Names of Above Climatic Regions

6 Interior Basin and Plains Region
5 Upper Great Lakes Region
1 Upper Midwest Region
4 High Plains Region
7 Plateau Region
9 Desert Southwest Region
8 Pacific Northwest Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

for Regions 1 and 5. A low positive ocean current value was observed for the Interior Basin and Plains Region compared with a high negative value for Region 8. Finally, a moderately high positive maritime cloud variability value was calculated for the Interior Basin and Plains Region compared with high positive values for Regions 8 and 9 and moderately low negative values for Regions 1 and 4. To avoid repetition, maritime cloud variability with respect to Regions 1 and 4, solar radiation receipt with respect to Regions 5 and 9, and ocean currents with respect to Region 8 are discussed elsewhere in this chapter.

The following climatic factor components are observed as significant in distinguishing the mean climograph of the Interior Basin and Plains Region from the mean climographs of Regions 8 and 9: (1) latitude -- with respect to the low position of the mean climograph along the temperature axis for the Interior Basin and Plains Region compared with Region 9; (2) mP air mass -- with respect to the low position of the mean climograph along the temperature axis for Region 6 compared with Region 8; and (3) variability of mean sky cover -- with respect to the vertical orientation of the mean climograph, and the closeness of the mean climograph to the temperature axis. The following climatic factor components are significant in distinguishing the mean climograph of the Interior Basin and Plains Region from that of Region 1: (1) mean sky cover -- with respect to the vertical position of the mean climograph which indicates little precipitation seasonality; and (2) mP-cT and mT-cT air masses -- with respect to the distance of the mean climograph away from the temperature axis, i.e., the difference in total annual precipitation.

Latitude

Most of the Interior Basin and Plains Region is in the northern part of the United States stretching to the Canadian border and is north of the Desert Southwest Region. From this standpoint, a significant difference in the average position of the mean climographs along the temperature axis is observed between these regions. The mean annual temperature for the Interior Basin and Plains Region is 45.6°F which is 21.9°F cooler than the mean temperature of the Desert Southwest Region. Both of these climatic regions are largely sheltered from ocean current effects and have rather large annual ranges in temperature; therefore, based primarily on latitude, the mean monthly maximum and minimum temperatures for the Interior Basin and Plains Region are notably lower than those of Region 9. July, the maximum mean monthly temperature for both regions, is 17.4°F cooler and January, the coldest month for both regions, is 26.3°F cooler for the Interior Basin and Plains Region versus Region 9.

Subregion 6a is transitional in terms of latitude to Region 9, but the subregional climograph indicates a lower summer season temperature than does the mean regional climograph (see Figure 74). This subregional climograph is represented by only two weather stations, Flagstaff and Williams. These weather stations are on a plateau which is approximately 7,000 feet above sea level. The low summer temperatures as indicated by the subregional climograph are typical of high altitude climates with summer daytime maximum temperatures for Flagstaff averaging between 75° to 85°F.[9]

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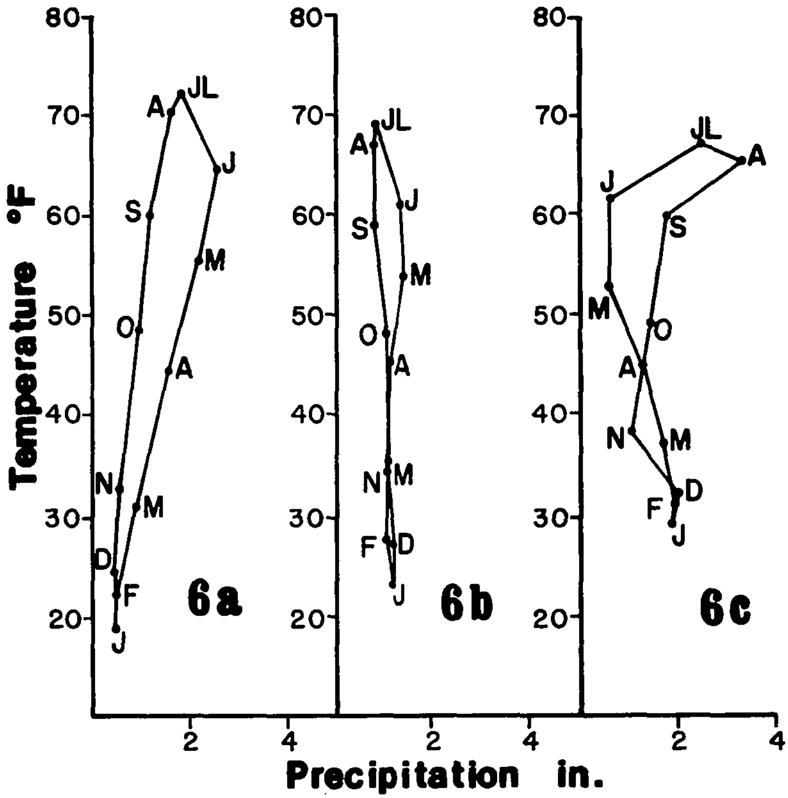
[9] Local Climatological Data, Flagstaff, 1964.

MEAN SUBREGIONAL CLIMOGRAPHS



REGION 6

Figure 74

SOURCE: AUTHOR'S CALCULATIONS.

Air Masses -- mP, mP-cT, and mT-cT

Generally, Region 7 is between the Interior Basin and Plains Region and Region 8 to the west. However, because of the irregular shape of Region 7 and the fact that it is not contiguous, the Interior Basin and Plains Region and Region 8 share a common boundary in central Oregon. As observed on the mean climograph for these two climatic regions, a grossly different temperature-precipitation regime exists. One of the many distinct differences is their position along the temperature axis, particularly during the winter season. The coldest month for the Interior Basin and Plains Region, January, has a mean temperature of 21.6^{o}F compared with 38.1^{o}F for the coldest month for Region 8. A partial explanation for this large discrepancy of winter temperatures is the dominance of mP air mass in Region 8. From November through April, the Interior Basin and Plains Region is dominated by cP and cP transition air masses (see Figures 24-35). Little or no mP air prevails in this region during the winter season. On the other hand, most or all of Region 8 is dominated by milder, moist mP air during this cold season. Consequently, mild temperatures typify the winter months in Region 8 in contrast to cold temperatures in the Interior Basin and Plains Region.

To the east, Region 1 is distinctly different from the Interior Basin and Plains Region, particularly in terms of precipitation during the warmer months of the year. Even though the primary maxima of precipitation occurs during the month of June for both climatic regions, the difference for this month is 2.40 inches. Similar large differences occur during most of the warmer months of the year. These large differences total 14.07 inches less precipitation per year in the Interior Basin and

Plains Region. The additional precipitation during the warm season in Region 1 is reflected in a diagonal orientation of the mean climograph with respect to the precipitation axis compared with a vertical orientation for the Interior Basin and Plains Region. This decrease in mean annual precipitation, especially during the warmer season, is clearly evident within the Interior Basin and Plains Region if mean subregional climographs are scrutinized (see Figure 74). Subregion 6a, which includes the Rocky Mountains and Interior Basin, has a late spring precipitation maxima as does Subregion 6a, which includes the northern part of the Great Plains, but considerably less rain falls. Again, using June as an example, Subregion 6b receives 1.31 inches less precipitation during this month than does Subregion 6a.

Part of the reason for the eastward increase in precipitation during the warmer season is the distribution and type of air mass dominance. From April through October, mP-cT and mT-cT air masses dominate over various parts of the Interior Basin and Plains Region. During this same period of time, mP, mT and mT transition air masses prevail throughout Region 1 and overlap into the eastern one-half of Subregion 6a. Drier conditions are therefore associated with continental air masses over the Interior Basin and Plains Region, particularly over the western portion, than to the east over the Upper Midwest Region where maritime air masses dominate during the warm season.

Mean Annual Sky Cover and Its Variability

Another climatic factor component which supports the differences of the mean climographs between the Interior Basin and Plains Region and Region 1 in terms of their precipitation regime is mean annual sky cover.

Since the Interior Basin and Plains Region is dominated by a drier air mass than the Upper Midwest Region, particularly during the summer months, it follows that the mean annual sky cover should be smaller. From Figure 21, this assumption is generally observed to be true. The lowest mean annual sky cover value for Region 1 is 5.4 at Grand Island compared with 4.3 at Flagstaff for the Interior Basin and Plains Region. However, throughout a narrow zone in the northern portion of the Interior Basin and Plains Region, mean annual sky cover values are similar or slightly higher than those observed in Region 1. Therefore, the lower mean annual sky cover values in the southern and southwestern portions of this climatic region presumably contribute to the differences of the mean climograph in terms of distance away from the temperature axis.

Finally, an analysis of mean annual sky cover variability may shed some light on a physical explanation for such a large difference in appearance of the mean climographs between the Interior Basin and Plains Region and Region 8 with respect to mean annual precipitation totals and seasonality. The Interior Basin and Plains Region receives 23.20 inches less precipitation per year than Region 8. Furthermore, the meager annual total rainfall in Region 6 is distributed evenly throughout the year. This is in sharp contrast to Region 8 where a striking winter maxima is noted. From this observation, greater mean annual sky cover variability should be evident in Region 8.

From a cursory inspection of standard deviation values of mean sky cover within the Interior Basin and Plains Region, less variability is observed in the eastern subregion. The range of standard deviation values in Subregion 6a is from 0.7 (4 first-order weather stations) to 1.2 and for Subregion 6b from 0.7 (1 first-order weather station) to 1.7. Standard deviation values for Region 8 range from as low as 0.5 at Eureka to 2.3 at Medford. However, only Eureka has a value of less than 1.0 and several weather stations, e.g., Medford, Roseburg, and Sexton Summit, have values of 2.0 or greater. The reason for the low standard deviation values for certain weather stations in Region 8, which seems paradoxical in view of the marked seasonality of precipitation, is the high occurrence of clouds during the summer months. But, according to Trewartha, little precipitation falls during this season due to the unusual poleward displacement along the Coast of an arm of the North Pacific subtropical cell of high pressure.[10] Therefore, with the exception of a minority of weather stations in Region 8, standard deviation values are smaller over the Interior Basin and Plains Region, particularly in Subregion 6a, than in Region 8. This fact is reflected in the mean climograph of the Interior Basin and Plains Region which displays a nearly vertical mean climograph with respect to the precipitation axis.

In summary, the mean climograph for the Interior Basin and Plains Region is unique from Regions 1, 8, and 9 due to the following characteristics: (1) a low position of the mean climograph along the temperature axis compared with Region 9 due to the difference in latitude; (2) a low position of the mean climograph along the temperature axis compared with Region 9 due to the difference in latitude; (2) a low position of the mean climograph along the temperature axis compared with

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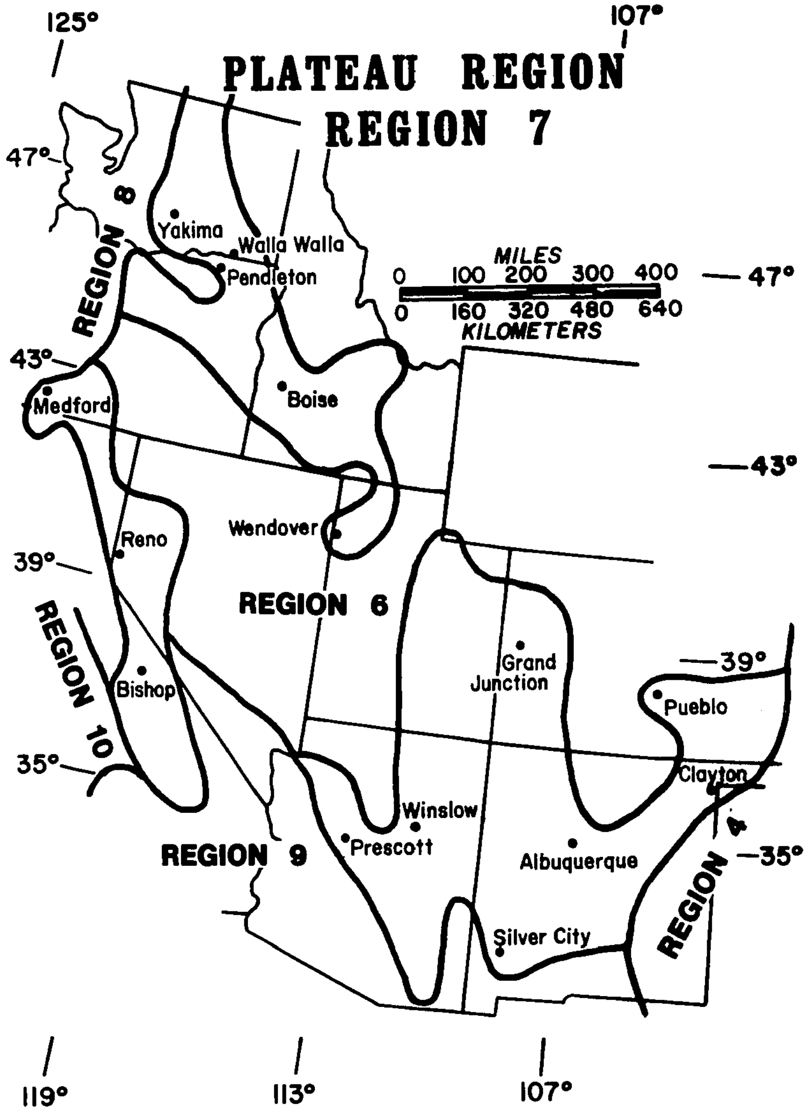
[10] Trewartha, _op. cit._, p. 269.

Region 8 due to mP air mass; (3) the closeness of the mean climograph to the temperature axis, especially during the warm season, compared with Region 1 due to the dominance of mP-cT and mT-cT air masses; (4) the closeness of the mean climograph to the temperature axis compared with the Upper Midwest Region due to mean annual sky cover; and (5) the vertical orientation of the mean climograph with respect to the precipitation axis compared with Region 8 due to the variability of mean annual sky cover.

Plateau Region - Region 7

The Plateau Region is the only non-contiguous climatic region in the coterminous United States. From the adjustment of boundary lines which was necessitated from the analysis of test weather stations, 3 separated areas form this climatic region (see Figure 75). The northernmost section closely coincides with the Columbia Plateau which includes the western half of Washington and Oregon and the southern portion of Idaho. The southern section includes the Colorado Plateau, centered over the Four Corners but extends eastward into the southeastern corner of Kansas and the Oklahoma Panhandle. The western part of this climatic region is elongated in a north-south direction and includes weather stations near or within the Sierra Nevada Mountains. This climatic region consists of 15 first-order and 19 test weather stations (see Appendices VIII and IX).

With the exception of the Desert Southwest Region, this is the driest climatic region in the coterminous United States. The average total annual rainfall is only 11.61 inches. An exceedingly even mean monthly rainfall distribution is observed in this region. Favored



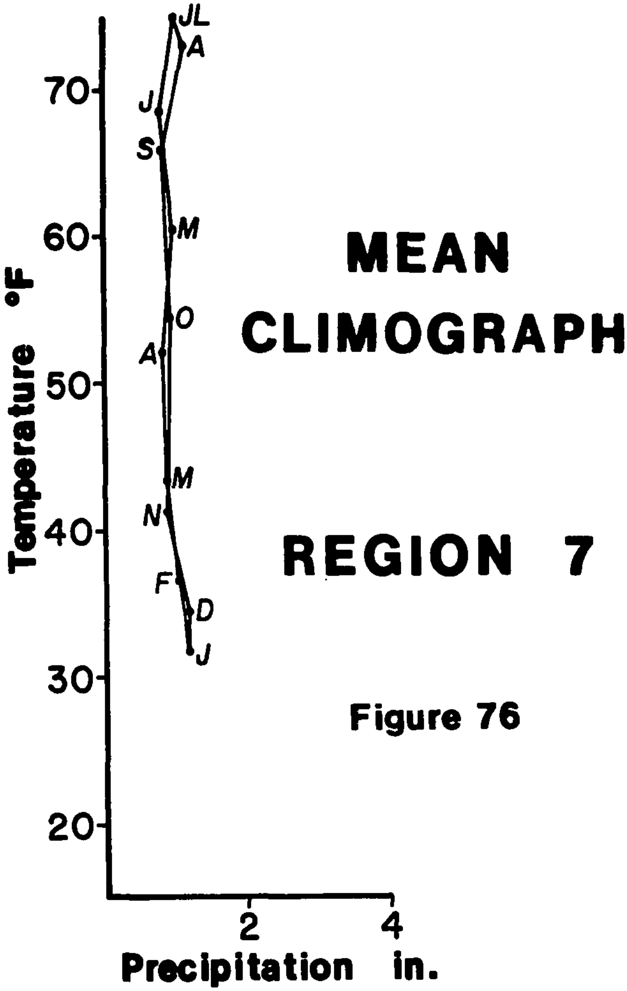
PLATEAU REGION
REGION 7
125°
107°
47°
43°
39°
35°
47°
43°
39°
35°
119°
113°
107°
MILES
0 100 200 300 400
0 160 320 480 640
KILOMETERS
REGION 8
REGION 6
REGION 9
REGION 10
REGION 4
Yakima
Walla Walla
Pendleton
Boise
Medford
Reno
Wendover
Bishop
Grand Junction
Pueblo
Clayton
Winslow
Prescott
Albuquerque
Silver City

Figure 75

seasons for precipitation are noted during winter and mid-summer. The highest mean monthly rainfall is 1.19 inches during January, and the lowest is 0.81 inches during September. Because of the somewhat interior location of this climatic region, a relatively large annual range in temperature of 43.5°F is observed. July, the warmest month, has a mean temperature of 75.1°F compared with January, the coldest month, with 31.6°F.

The uniqueness of the mean climograph for this climatic region is observed in its almost vertical orientation with respect to the precipitation axis with only negligible "openings" within its framework which practically forms a straight line (see Figure 76). This aspect of the mean climograph configuration reflects the evenness of mean monthly precipitation during the year. The climograph axis is also close to the temperature axis indicating the meagerness of rain throughout this part of the United States. Finally, the mean climograph is rather long as a consequence of a large annual temperature range.

From an examination of classification coefficients, three adjacent climatic regions, Regions 4, 8, and 10, are particularly different from the Plateau Region (see Table 33). The Plateau Region has a low positive continental storm track value compared with a high negative value for Region 10. The Plateau Region has a low negative ocean current value compared with moderately high negative values for Regions 8 and 10. Lastly, the Plateau Region has a high positive maritime cloud variability value compared with an exceedingly high positive value for Region 8 and a moderately low negative value for Region 4. To avoid repetition, ocean currents with respect to Regions 8 and 10 are discussed in their respective sections.



	J	F	M	A	M	J	
Temp. °F	31.6	36.4	43.3	52.1	60.4	68.5	
Precip. In.	1.19	1.04	.89	.82	.97	.82	Average
	J	A	S	O	N	D	53.0°
Temp. °F	75.1	73.0	65.8	54.5	41.2	34.4	11.61"
Precip. In.	.98	1.11	.81	.92	.89	1.17	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 33[a]

CLASSIFICATION COEFFICIENTS FOR THE PLATEAU AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions: 7	4	9	10	8	6	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	+1.0	+ .7	- .8	-7.4	- .9	+5.0	(8.4)
(2) Solar Radiation Receipt	+7.0	+2.6	+12.2	+4.8	+2.9	+3.4	5.2
(3) Winter-time High Pressure Systems	-1.1	.1	-3.7	-7.2	-3.3	+1.5	6.1
(4) Ocean Currents	-.3	+2.4	-1.0	-6.7	-7.8	1.0	(7.5)
(5) Maritime Cloud Variability	+8.1	-3.0	+9.9	+11.1	+15.6	+4.9	(11.1)
(6) Continental Moisture Index	+5.3	- .4	+6.6	+3.1	+4.5	+1.7	5.7
(7) Wind Strength Variability	-2.9	+1.9	-3.5	-2.7	-2.8	-1.9	4.8

Names of Above Climatic Regions

7 Plateau Region
4 High Plains Region
9 Desert Southwest Region
10 California Type Region
8 Pacific Northwest Region
6 Interior Basin and Plains Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

With respect to observed differences of mean climograph configurations, the following climatic factor components are evidently significant between the Plateau Region and Region 10: (1) latitude -- with respect to the much lower position of the mean climograph along the temperature axis during the cooler half of the year; (2) continentality -- with respect to the length of the mean climograph along the temperature axis; and (3) cP air mass — with respect to the position of the mean climograph along the temperature axis and distance away from the temperature axis, particularly during winter. The following climatic factor components are significant in distinguishing the mean climograph configuration of the Plateau Region from Regions 4 and 8: (1) latitude -- with respect to the position of the mean climograph along the temperature axis (2) variability of mean annual sky cover -- with respect to the vertical orientation of the mean climograph axis to the precipitation axis; and (3) mP and mT air masses — with respect to the position of the mean climograph along the temperature axis during the winter season compared with Region 8 and the distance of the mean climograph away from the temperature axis during the warm season compared with Region 4.

Latitude and Continentality

Even though the Plateau Region is not contiguous, weather stations within this climatic region are rather evenly distributed latitudinally from the Canadian to Mexican borders. Therefore, if elevation for weather stations is not grossly different, climatic regions north or south of the mean latitude of the Plateau Region will have different mean annual temperatures. Reflecting a lower latitudinal location, the mean annual temperatures for the Desert Southwest and California Type Regions are higher than the Plateau Region. The mean annual temperature for the Plateau Region is 53.0°F which is 7.8°F lower than the California Type Region and 14.5°F lower than the Desert Southwest Region. The difference between the Plateau Region and California Type Region is rather small considering its location. This is the result of the moderating cold California Current which suppresses the summer season temperatures. Obviously, a greater difference is observed when the 2 more southern climatic regions are compared with Subregion 7b which represents the northern section of the Plateau Region. This subregion is 2.9°F cooler than Subregion 7a to the west and south (see Figure 77).

In addition to a notable difference in mean annual temperature between the Plateau Region and the California Type Region, an exceedingly large difference in mean annual temperature range is evident. The Plateau Region has a mean annual temperature range of 43.5°F compared with 22.5°F for the California Type Region. The explanation for this difference is in their location with respect to the ocean. Much of the Plateau Region is east of the Cascade and Sierra Nevada Mountain Ranges and is sheltered from maritime influences. However, the California Type Region is along the Pacific Ocean and is greatly affected by maritime air, especially as it moves over the cold current during the summer season. This difference, which is easily seen on the mean climographs, is genetically revealed upon inspection of the Oliver index continentality map (see Figure 9). Along the California coast within the California Type Region, continentality index values from 2 to 6 are

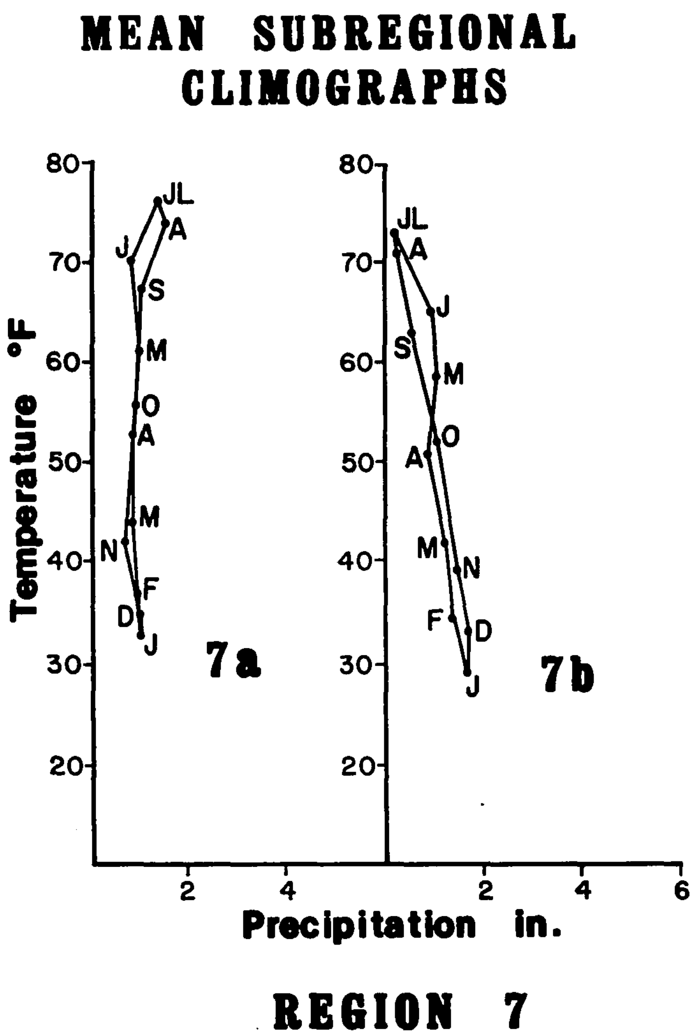


Figure 77

SOURCE: AUTHOR'S CALCULATIONS.

commonly observed. This contrasts sharply with values within the Plateau Region which typically range from 8 to 10.

Air Masses -- cP, mP, and mT

One of the most striking differences between the mean climographs for the Plateau Region and the California Type Region and to a smaller degree the Pacific Northwest Region is the downward extension of the climograph along the temperature axis. The coldest month for all 3 climatic regions is January, but the Plateau Region is 17.9°F colder than Region 10 and 6.5°F colder than Region 8. The reason for these discrepancies should not be attributed solely to latitude since the mean annual temperatures for the Plateau Region are only 7.8°F lower than the California Type Region and 1.7°F higher than the Pacific Northwest Region. However, if one examines the air mass dominance between these regions during the winter season, an additional explanation is revealed. From November through February, most of the Plateau Region is dominated by cP air mass while milder mP air mass dominates the California Type and the Pacific Northwest Regions (see Figures 24-35). Hence, one should certainly expect a colder winter season over the Plateau Region beyond any temperature differences governed simply by latitude.

The dominance of cP air mass over the Plateau Region is also significant in terms of the distance of the mean climograph away from the temperature axis. With the dominance of cold, continental air during the winter season, little precipitation occurs. From November through February an average of only 4.29 inches of rain falls. This differs markedly from the precipitation regime of the California Type Region in which during these same 4 months 11.56 inches of precipitation falls. A primary reason for this difference is the absence of cP air mass and dominance of mP air mass in Region 10. According to Trewartha, winter rains in Mediterranean California are associated with an overrunning of colder air masses by mT air, or with mT or mP air being forced up over highland barriers.[11] The cooler air, in which any mT air would overrun, is mP air according to the air mass distribution maps in this investigation.

Air mass dominance also plays an important discriminating role with respect to the distance of mean climographs away from the temperature axis for the Plateau Region and High Plains Region. This is particularly evident during the summer season. Mean monthly precipitation values for the High Plains Region from May through September are all higher by at least 1.00 inch compared with the Plateau Region. With the exception of May when mP-mT air mass dominates, the High Plains Region is dominated by mT air mass throughout these warmer season months (see Figures 24-35). During this same period of time, there is a notable absence of mT air over the Plateau Region since it is primarily dominated by cT, cT transition, and mP air masses. With the prevalence of generally drier air masses over the Plateau Region during the warmer season, little precipitation falls which results in a mean climograph which is close to the temperature axis.

Variability of Mean Annual Sky Cover

The mean climograph of the Plateau Region differs from the climograph of the Pacific Northwest Region in a similar manner regarding

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[11] Trewartha, An Introduction to Climate, op. cit., p. 288.

precipitation as it differed from the California Type Region, i.e., the amount of precipitation received during the winter season. The Pacific Northwest Region averages more than 4.5 inches of rain per month from November through February. The maximum monthly amount of 6.29 inches occurs in December. This value is 5.10 inches of rain more than the wettest winter month in the Plateau Region.

One climatic f[illegible]nent which is significant in explaining the difference i[illegible]s variability of mean annual sky cover. Th[illegible] sky cover varies considerably in both the [illegible] Northwest Region. In the Plateau Regi[illegible]s, ranging from 0.6 to 1.0, are observed [illegible] i.e., the eastern section of Subregion 7a. [illegible] range from 1.5 to 2.1. With the exception of Eureka w[illegible]r 0.5, the Pacific Northwest has standard deviation values which range from 1.1 to 2.3. From these observations, one may conclude that the southern portion of the Plateau Region is characterized by a smaller annual variation of sky cover than the Pacific Northwest.

Since variability of mean annual sky cover is related to the vertical orientation of the mean climograph along the precipitation axis for the Plateau Region, it is particularly appropriate to inspect the differences of mean monthly sky cover during the winter season. This time of the year represents the greatest discrepancy in precipitation between the Plateau Region and the Pacific Northwest Region. A transition from a low mean winter sky cover to high values is evident from the southern portion of the Plateau Region to the north and into the precipitation as it differed from the California Type Region, i.e., the amount of precipitation received during the winter season. The Pacific Northwest Region averages more than 4.5 inches of rain per month from November through February. The maximum monthly amount of 6.29 inches occurs in December. This value is 5.10 inches of rain more than the wettest winter month in the Plateau Region.

One climatic factor component which is significant in explaining the difference in winter precipitation is variability of mean annual sky cover. The variability of mean annual sky cover varies considerably in both the Plateau Region and the Pacific Northwest Region. In the Plateau Region low standard deviation values, ranging from 0.6 to 1.0, are observed in the southernmost section, i.e., the eastern section of Subregion 7a. In Subregion 7b, values range from 1.5 to 2.1. With the exception of Eureka with a value of 0.5, the Pacific Northwest has standard deviation values which range from 1.1 to 2.3. From these observations, one may conclude that the southern portion of the Plateau Region is characterized by a smaller annual variation of sky cover than the Pacific Northwest.

Since variability of mean annual sky cover is related to the vertical orientation of the mean climograph along the precipitation axis for the Plateau Region, it is particularly appropriate to inspect the differences of mean monthly sky cover during the winter season. This time of the year represents the greatest discrepancy in precipitation between the Plateau Region and the Pacific Northwest Region. A transition from a low mean winter sky cover to high values is evident from the southern portion of the Plateau Region to the north and into the

Pacific Northwest Region (see Table 34). These variations are reflected in the mean subregional climographs for the Plateau Region in addition to the Pacific Northwest Region. Subregion 7a, with most of the weather stations in the larger eastern section, receives less precipitation during the cold season than does Subregion 7b which has a common boundary with the Pacific Northwest Region. Therefore, the lower portion of the mean subregional climograph is closer to the temperature axis (see Figure 77). Naturally, the Pacific Northwest Region receives more precipitation than either Subregion 7a and 7b. Its lower portion of the mean climograph is distant from the temperature axis.

In summary, the mean climograph for the Plateau Region is unique from Regions 4, 8, and 10 due to the following characteristics: (1) a lower mean position and downward extension of the mean climograph with respect to the temperature axis due to latitude and cP air mass and a longer mean climograph axis which is related to continentality; (2) the shorter distance of the mean climograph from the temperature axis during winter with respect to Region 10 governed by cP and mP air masses and during the summer season with respect to Region 4 because of mT air mass dominance; (3) the distance of the mean climograph away from the temperature axis during winter with respect to Region 8 as related to variability of mean annual sky cover.

Pacific Northwest Region - Region 8

The Pacific Northwest Region is one of two climatic regions in the extreme northwestern part of the United States. It extends southward from the Canadian border to northern California where it bifurcates

TABLE 34[a]

MAXIMUM MEAN MONTHLY SKY COVER VALUES FOR DECEMBER THROUGH FEBRUARY FOR REPRESENTATIVE WEATHER STATIONS FROM SUBREGIONS 7A AND 7B AND THE PACIFIC NORTHWEST REGION

Subregion 7a			Subregion 7b			Pacific Northwest Region		
Weather Station	Sky Cover	Month	Weather Station	Sky Cover	Month	Weather Station	Sky Cover	Month
Albuquerque	4.8	Jan.	Wendover	6.3	Feb.	Seattle	8.7	Dec.
Clayton	5.0	Feb.	Boise	7.6	Dec.	Portland	8.0	Dec.
Prescott	4.9	Jan.	Yakima	8.0	Dec.	Roseburg	8.9	Dec.

[a]Source: Local Climatological Data with Comparative Data, 1964.

to include the northern two-thirds of the Sierra Nevada Mountains and approximately the northern one-third of the coast of California. Only the narrow Littoral Northwest Region restricts this climatic region from reaching the Pacific Coast along its entire length (see Figure 78). This climatic region consists of 10 first-order and 9 test weather stations (see Appendices VIII and IX). The precipitation regime of the Pacific Northwest Region is characteristic of western United States coastal weather stations, i.e., a pronounced winter maximum and summer minimum. December is the wettest month of the year with a mean rainfall of 6.29 inches compared with July, the driest month, which receives 0.41 inches. Because of the coastal position of this region, a small mean annual range in temperature is observed. July, which is only slightly warmer than August, has a mean monthly temperature of 65.2°F compared with January, the coolest month, with 38.1°F, producing a range of only 27.1°F which is low for this latitude.

The uniqueness of the mean climograph for the Pacific Northwest Region is observed in its diagonal orientation with respect to the precipitation axis (see Figure 79). The upper portion of the mean climograph is close to and the lower portion is distant from the temperature axis. Also, the mean climograph is relatively short with respect to the temperature axis when compared with most other mean climographs in the United States.

Large classification coefficient differences are observed between the Pacific Northwest Region and Regions 6, 7, and 10 (see Table 35). More specifically, an extremely small negative continental storm track value was calculated for the Pacific Northwest Region

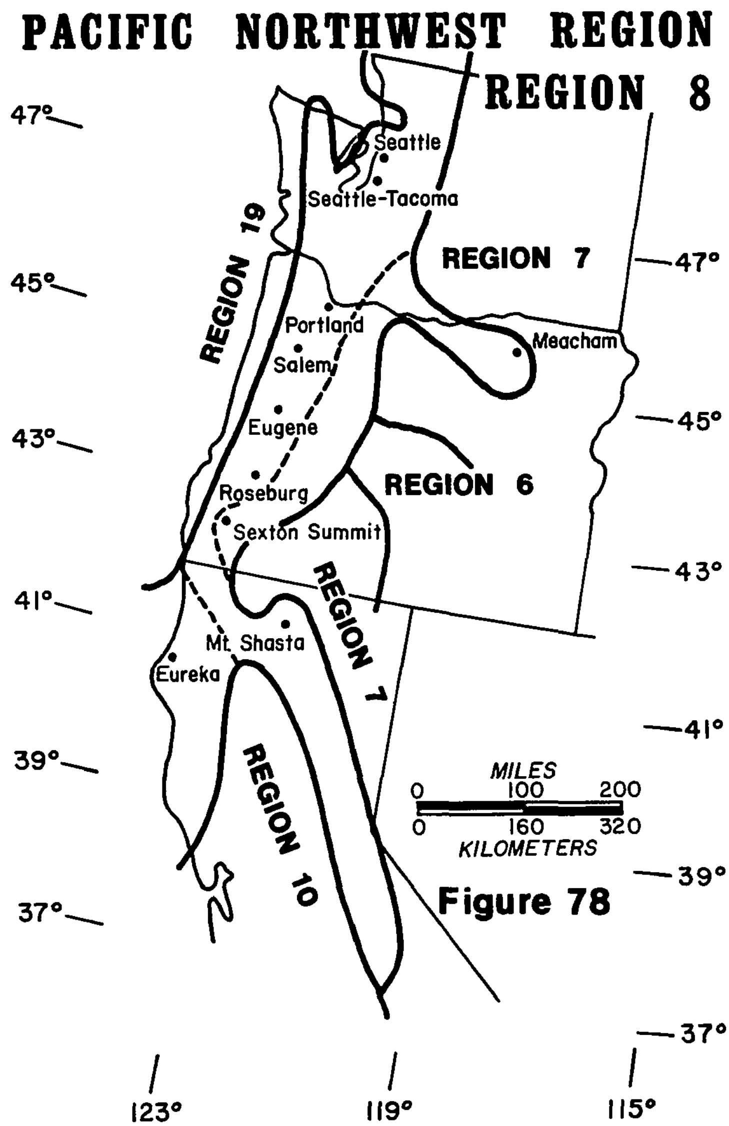
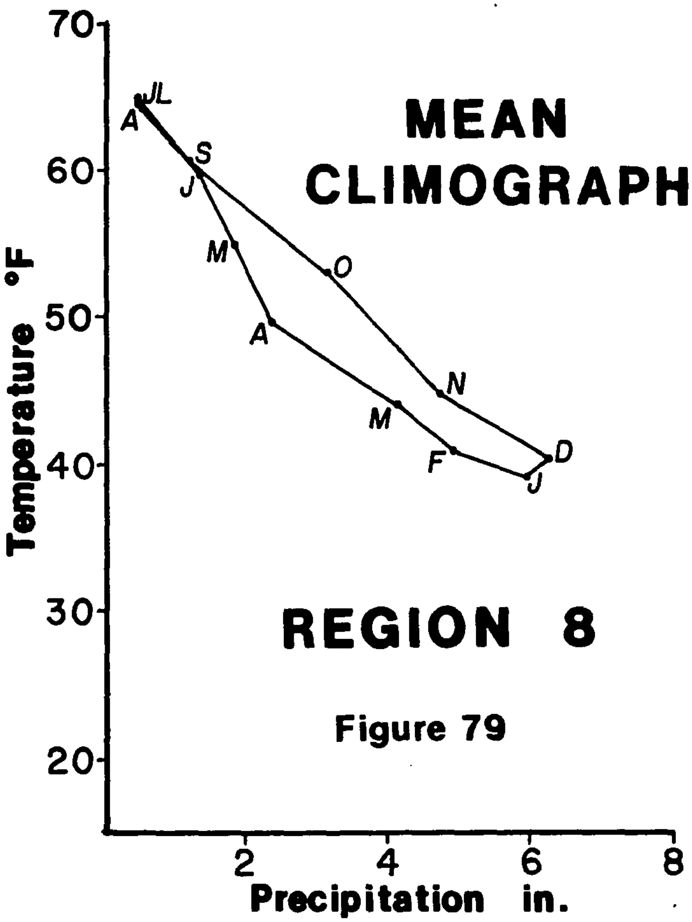

PACIFIC NORTHWEST REGION
REGION 8
REGION 7
REGION 19
REGION 6
REGION 7
REGION 10
Seattle
Seattle-Tacoma
Portland
Salem
Eugene
Roseburg
Sexton Summit
Meacham
Mt. Shasta
Eureka
MILES
0 100 200
0 160 320
KILOMETERS
47°
45°
43°
41°
39°
37°
123°
119°
115°

Figure 78



	J	F	M	A	M	J	
Temp. °F	38.1	40.9	44.2	49.5	54.9	59.7	
Precip. In.	5.95	4.94	4.11	2.35	1.83	1.32	Average
	J	A	S	O	N	D	51.3°
Temp. °F	65.2	64.5	60.7	53.0	44.7	40.5	36.76"
Precip. In.	.41	.48	1.19	3.17	4.72	6.29	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 35[a]

CLASSIFICATION COEFFICIENTS FOR THE PACIFIC NORTHWEST AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 8	10	7	6	19	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	- .9	-7.4	+1.0	+5.0	-2.4	(6.5)
(2) Solar Radiation Receipt	+2.9	+4.8	+7.0	+3.4	-1.0	4.1
(3) Winter-time High Pressure Systems	-3.3	-7.2	-1.1	-1.5	-5.6	4.8
(4) Ocean Currents	-7.8	-6.7	- .3	+1.0	-10.3	(8.8)
(5) Maritime Cloud Variability	+15.6	+11.1	+8.1	+4.9	+14.3	(10.7)
(6) Continental Moisture Index	+4.5	+3.1	+5.3	+1.7	+2.1	2.8
(7) Wind Strength Variability	-2.8	-2.7	-2.9	-1.9	+ .2	3.0

Names of Above Climatic Regions

8 Pacific Northwest Region
10 California Type Region
7 Plateau Region
6 Interior Basin and Plains Region
19 Littoral Northwest Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

compared with a moderately high positive value for Region 6 and a high negative value for Region 10. A moderately high negative ocean current value is observed for the Pacific Northwest Region compared with extremely small negative and positive values for Regions 7 and 6, respectively. Finally, a high positive maritime cloud variability value is noted for the Pacific Northwest Region compared with moderately high positive values for Regions 6 and 7. To avoid repetition, maritime cloud variability with respect to Regions 6 and 7, and continental storm track with respect to Region 10 are discussed elsewhere in this chapter.

From an examination of the mean climograph differences, the following climatic factor components are observed to be significant between the Pacific Northwest Region and Region 6: (1) <u>continentality</u> -- with respect to the length of the mean climograph along the temperature axis; and (2) <u>cP air mass</u> -- with respect to the downward extension of the mean climograph along the temperature axis and the distance of the lower portion of the mean climograph away from the temperature axis. The following climatic factor components are significant in discriminating between the mean climograph of the Pacific Northwest Region and the ones for Regions 6 and 7: (1) <u>January ocean currents</u> -- with respect to the high position of the lower portion of the mean climograph along the temperature axis during the winter season despite the high latitude for the Pacific Northwest Region; and (2) <u>July ocean currents</u> -- with respect to the relatively low position of the upper portion of the mean climograph during the summer season.

Continentality

The mean annual temperature range for the Pacific Northwest Region is only 27.1°F. This is 21.5°F less than that calculated for the Interior Basin and Plains Region immediately to the east. The reason for this large difference in mean annual temperature range is readily revealed upon inspection of continentality values in the Pacific Northwest Region and those which were calculated to the east of the Cascade Mountains. From an examination of the Oliver index continentality map, values throughout the Pacific Northwest Region range from 2 along the California Coast to 6 just west of the Cascade Mountains. These low values are distinctly different from the high values which were calculated for weather stations in the Interior Basin and Plains Region which vary from about 8 to over 12 (see Figure 9). The Pacific Northwest Region is obviously not sheltered to a large degree by topographic barriers from the Pacific Ocean as is the Interior Basin and Plains Region.

This abrupt transition of continental effects is displayed on the mean subregional climographs for the Pacific Northwest Region (see Figure 80). Subregion 8a consists of 2 weather stations, both of which are near the Pacific Ocean. The mean annual range in temperature for this climatic subregion is only 16.7°F. Moving inland to Subregion 8b, which includes much of the Willamette Valley-Puget Sound Region, a larger mean annual temperature range of 28.1°F—representative of the Pacific Northwest Region—is observed. Finally, Subregion 8c, which includes weather stations either east of the Cascade Mountains or near the Sierra Nevada Mountains, has the highest subregional mean annual

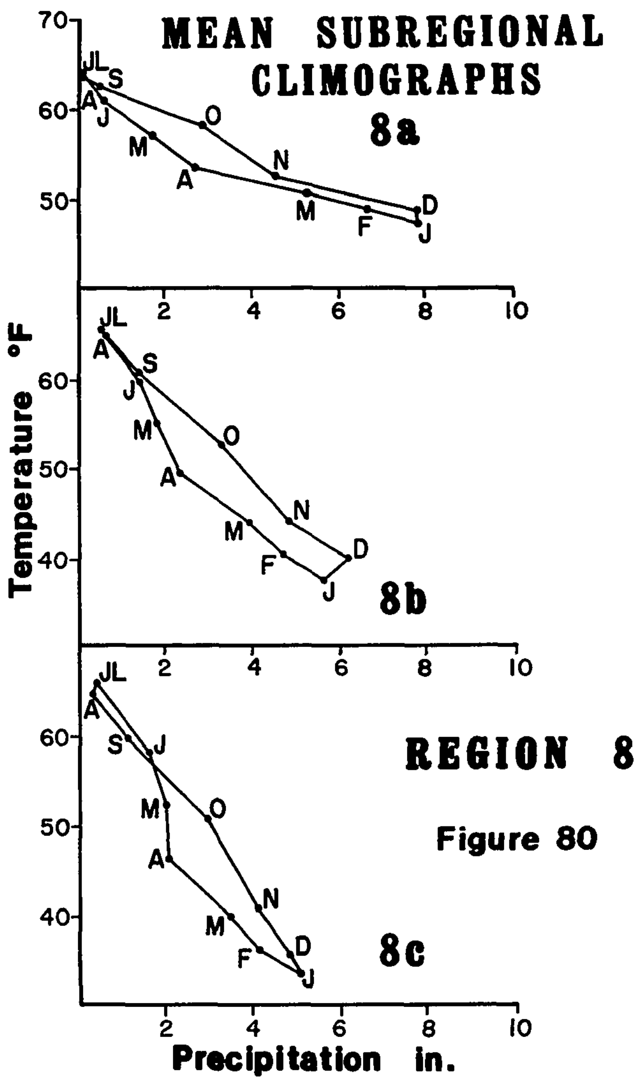


Figure 80

SOURCE: AUTHOR'S CALCULATIONS.

temperature range of 32.8°F. Again, these changes in mean annual temperature range which reflect the degree of continentality are readily observed on the Oliver index continentality map (see Figure 9).

cP Air Mass

The Pacific Northwest Region is characterized by a mild, moist winter season. January, the coolest month of the year, has a mean temperature of 38.1°F. This month is also wet with 5.95 inches of rain and is exceeded only by December with 6.29 inches. The winter season of the Interior Basin and Plains Region is totally different. The mean climograph extends much farther down along the temperature axis and is close to the temperature axis indicating a cold, dry winter season. One climatic factor component which is partially responsible for the climatic differences during winter between these two regions is cP air mass. From November through March, most of the Interior Basin and Plains Region is dominated by cP air mass; hence, cold temperatures with little precipitation occur (see Figures 24-35). However, the Pacific Northwest Region is not influenced by cP air mass during any winter month, but it is dominated by mild, moist mP air mass.

This transition is again noted on the mean subregional climographs. Subregion 8a, which is the coastal subregion, has the mildest winter temperatures and receives more precipitation during this season than the other two subregions. Subregion 8c, which is closest to the Interior Basin and Plains Region, has much cooler winter temperatures with less precipitation. Subregion 8b is intermediate to Subregions 8a and 8c in terms of winter temperatures and precipitation (see Figure 80).

Ocean Currents -- January and July

A sharp transition of ocean current factor score values is observed inland along the West Coast of the United States to about 150 miles (see Figure 44). This inland influence includes most of the Pacific Northwest Region. On the other hand, throughout the Interior Basin and Plains Region and the Plateau Region, factor score values range from 0 to 1.0 which indicate little, if any, influence from ocean currents. As described earlier, the cold California Current significantly modifies mean monthly temperatures at a coastal weather station, particularly during the summer season, and generally one notes cooler summer temperatures and milder winter temperatures in the Pacific Northwest Region compared with Regions 6 and 7. However, it is difficult during any winter or summer month to analyze, in absolute terms, the moderating effect the ocean current has on the mean monthly temperatures for the Pacific Northwest Region and Regions 6 and 7 due to their variation in latitude and irregular distribution of weather stations.

Possibly a better indicator as to the importance of ocean currents on the temperature regime of these regions is mean annual range in temperature. This aspect of the mean climograph was already analyzed for the Pacific Northwest Region and the Interior Basin and Plains Region regarding continentality. A large difference was noted. This same large difference is noted between the Pacific Northwest Region and the Plateau Region in which a difference of 16.4^{o}F was calculated. These large differences in mean annual temperature range divulge a steep gradient of both ocean current effect and continentality which is significant in discriminating between the climatic regime of the Pacific Northwest Region and Regions 6 and 7 to the east of the Cascade Mountains.

In summary, the mean climograph for the Pacific Northwest Region is unique from Regions 6 and 7 due to the following characteristics: (1) a relatively short mean climograph along the temperature axis which appears "flat" due to small continentality values; (2) the lower portion of the mean climograph is positioned relatively high and distant from the temperature axis due to the absence of cP air mass; (3) a relatively low position of the upper portion of the mean climograph and high position of the lower portion of the mean climograph along the temperature axis due to January and July ocean currents.

Desert Southwest Region - Region 9

The Desert Southwest Region extends from the Mojave Desert in south-central California to the extreme western section of Texas. It is bounded on the west and north by the Coastal Range, Sierra Nevada Mountains, and the Colorado Plateau and on the east by the Guadalupe-Santiago Mountain Ranges in western Texas. The Mexican-United States border is its southern boundary (see Figure 81). This southwestern United States climatic region consists of 6 first-order and 8 test weather stations (see Appendices VIII and IX). The Desert Southwest Region is the driest climatic region in the coterminous United States. Only 7.14 inches of rain is recorded during the year with June, the driest month, receiving a meager 0.19 inches. The primary precipitation maxima occurs during the summer with 0.99 inches of rain occurring during the wettest month of August. July closely follows

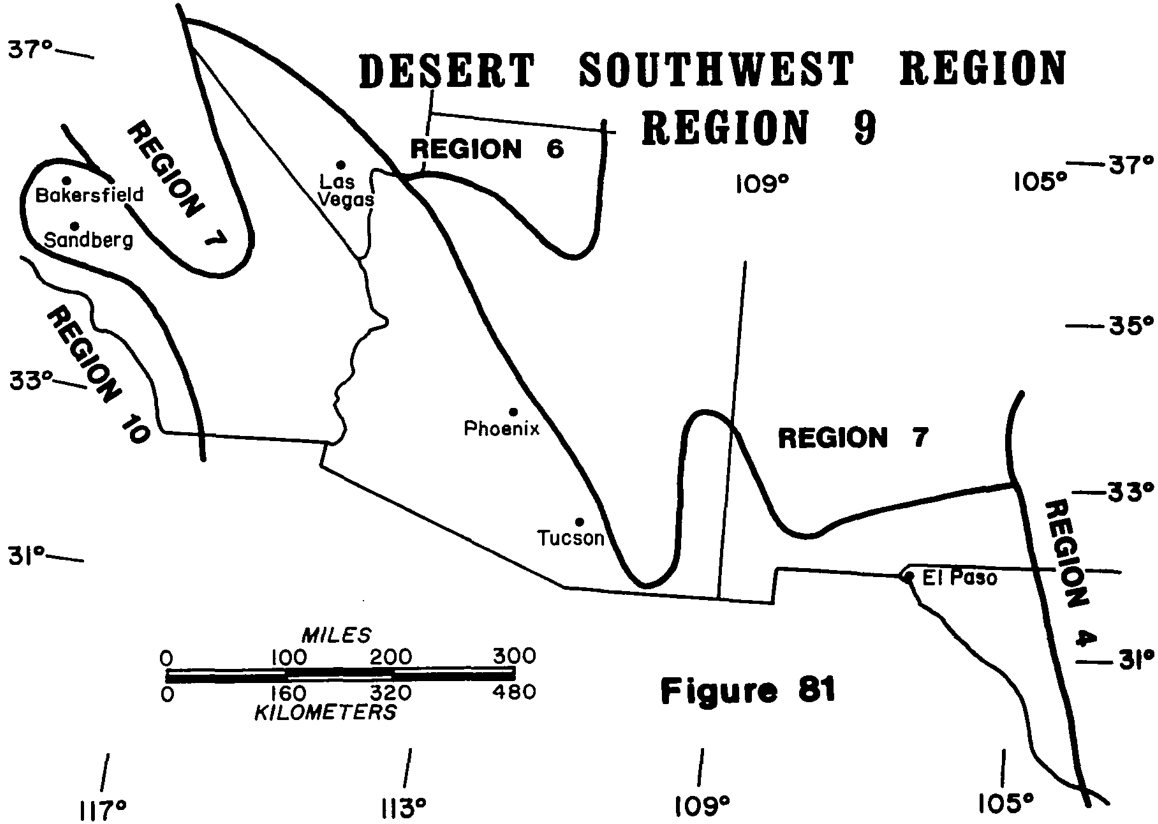
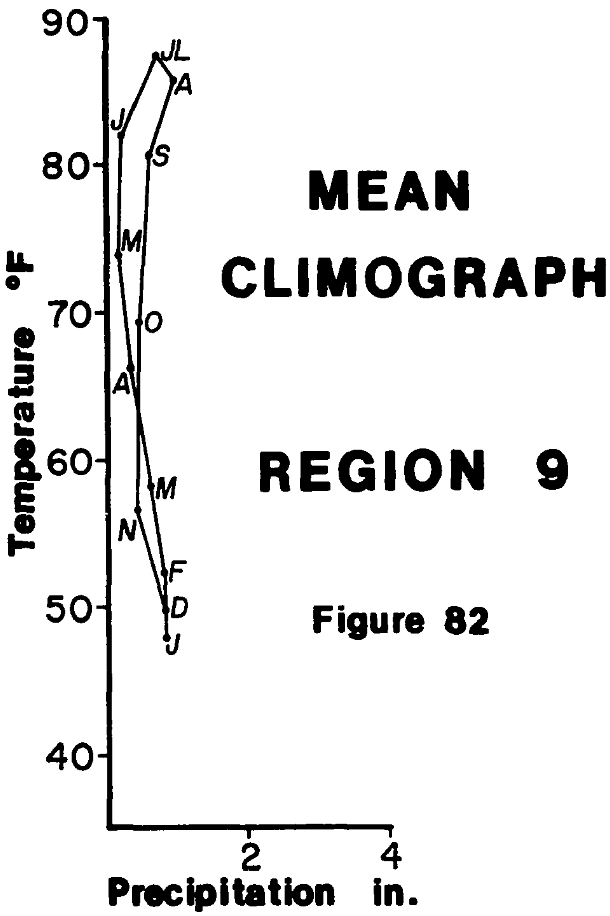

DESERT SOUTHWEST REGION
REGION 9
REGION 6
REGION 7
REGION 7
REGION 10
REGION 4
Bakersfield
Sandberg
Las Vegas
Phoenix
Tucson
El Paso
37°
33°
31°
37°
35°
33°
31°
109°
105°
117°
113°
109°
105°
MILES
0
100
200
300
0
160
320
480
KILOMETERS

Figure 81

with 0.72 inches. A secondary maxima occurs during the winter in which December represents the wettest winter month with 0.86 inches of rain. Hot summers and mild winters characterize the temperature regime for this climatic region. The maximum mean monthly temperature of 87.6°F occurs during July compared with January, the coolest month, with a mean temperature of 47.9°F.

The uniqueness of the mean climograph for the Desert Southwest Region is observed in its closeness to the temperature axis, particularly during the transition seasons (see Figure 82). The primary and secondary precipitation maxima during summer and winter produce a gentle geometric "arc" pointing away from the temperature axis. Since all mean monthly precipitation values are small, narrow "openings" within the framework of the mean climograph are observed, one in the upper portion of the climograph and one in the lower portion. Finally, the mean climograph is positioned high along the temperature axis.

Large classification coefficient differences are observed between the Desert Southwest Region and Regions 4, 6, 7, and 10 (see Table 36). More specifically, a high positive solar radiation receipt value was calculated for the Desert Southwest Region compared with low to moderately high positive values for Regions 4, 6, 7, and 10. A high positive maritime cloud variability value is observed for the Desert Southwest Region compared with a moderately low positive value for Region 6 and a moderately low negative value for Region 4. Finally, a moderately high continental moisture index value was calculated for the Desert Southwest Region compared with an extremely low negative value for the High Plains Region. To avoid repetition, maritime cloud



	J	F	M	A	M	J	
Temp. °F	47.9	52.2	58.2	66.0	73.7	82.0	
Precip. In.	.85	.82	.62	.37	.19	.20	Average
	J	A	S	O	N	D	67.6°
Temp. °F	87.6	85.8	80.7	69.4	56.5	49.6	7.14"
Precip. In.	.72	.99	.62	.47	.43	.86	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 36[a]

CLASSIFICATION COEFFICIENTS FOR THE DESERT SOUTHWEST AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 9	4	7	6	10	Maximum Coefficient Differences Between Climatic Regions
(1) Continental Storm Track	- .8	+ .7	+1.0	+5.0	-7.4	6.6
(2) Solar Radiation Receipt	+12.2	+2.6	+7.0	+3.4	+4.8	(9.6)
(3) Winter-time High Pressure Systems	-3.7	+ .1	-1.1	+1.5	-7.2	5.2
(4) Ocean Currents	-1.0	+2.4	- .3	+1.0	-6.7	5.7
(5) Maritime Cloud Variability	+9.9	-3.0	+8.1	+4.9	+11.1	(12.9)
(6) Continental Moisture Index	+6.6	- .4	+5.3	+1.7	+ 3.1	(7.0)
(7) Wind Strength Variability	-3.5	+1.9	-2.9	-1.9	-2.7	5.4

Names of Above Climatic Regions

9 Desert Southwest Region
4 High Plains Region
7 Plateau Region
6 Interior Basin and Plains Region
10 California Type Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

variability with respect to Regions 4 and 6 are discussed elsewhere in this chapter.

From an examination of mean climograph differences, the following climatic factor components are observed as significant in discriminating between the Desert Southwest Region and Regions 4, 6, 7, and 10: (1) elevation — with respect to the high position of the mean climograph along the temperature axis compared with the Plateau Region and the Interior Basin and Plains Region; (2) mean annual sky cover — with respect to the distance of the mean climograph away from the temperature axis; (3) cT, mP-cT, and mT-cT air masses — with respect to the geometric "arc" configuration of the mean climograph which represents a bimodal precipitation regime. The climatic factor component which is most significant in distinguishing the mean climograph of the Desert Southwest Region from the High Plains Region is cT air mass with respect to the distance of the mean climograph away from the temperature axis, particularly during the spring season.

Elevation

The mean annual temperature of the Desert Southwest Region is 67.5^{o}F. This is considerably higher than the Plateau Region and Interior Basin and Plains Region to the north which have mean annual temperatures of 53.0^{o}F and 45.6^{o}F. This is understandable in terms of latitudinal differences between these climatic regions. However, another component which is most likely significant in producing the mean annual temperature differences between these regions is elevation. With the exception of the northeastern section of the Interior Basin and Plains Region and the northern portion of the Plateau Region, weather stations in the Desert Southwest Region are at lower elevations (see Figure 7). All of the weather stations within the Desert Southwest Region are at less than 4,000 feet above sea level. In fact, Phoenix has an elevation above sea level of only slightly over 1,000 feet. On the other hand, numerous weather stations in Regions 6 and 7 are at elevations of over 5,000 feet above sea level. Consequently, lower mean monthly temperatures result in the lower position of the mean climograph along the temperature axis compared with the Desert Southwest Region.

Mean Annual Sky Cover

In the Desert Southwest Region, not a single month of the year receives more than 1.0 inches of rain. No other climatic region in the United States has this overall distinction of aridity. One important climatic factor component offered as a partial explanation for the exceedingly dry condition in this climatic region is mean annual sky cover. The lowest mean annual sky cover values in the United States are centered close to Yuma with increasing values radiating out to the west, north, and east (see Figure 21). No weather stations within the Desert Southwest Region has a mean annual sky cover value higher than 4.0. However, relatively high mean annual sky cover values are observed in certain areas of all surrounding climatic regions. For example, San Francisco, in Region 10, has a mean annual sky cover value of 4.7; Spokane, in Region 7, has a value of 6.6; Kalispell, in Region 6, has a value of 6.9; and Concordia, in Region 4, has a value of 5.0. These higher mean annual sky cover values for surrounding climatic regions contribute to higher rainfall values and a greater distance of the mean climograph away from the temperature axis.

Air Masses — mP-cT, mT-cT, and cT

The bimodal rainfall variation in the Desert Southwest Region is vividly depicted on the mean climograph in terms of the greater distance of the upper and lower ends away from the temperature axis. The geometric "arc," which was previously described, is distinct, but portions of this mean climograph configuration are evident in mean climographs of surrounding regions. For example, the lower end of the mean climograph for the California Type Region is distant from the temperature axis as is the upper end of the mean climograph for the High Plains Region. Apparently, the mean climograph for the Desert Southwest Region reflects transitional features from different precipitation regimes to the west and east. A knowledge of the temporal and spatial distribution of air mass types will shed light on the nature of the precipitation regime in the Desert Southwest Region compared with selected adjacent regions.

According to Trewartha, the winter rains in the Desert Southwest Region reflect the same controls that provide the strong winter maxima in California; i.e., low pressure disturbances which move in from the Pacific which transport moist maritime air.[12] The mP air dominates from November through March over the California Type Region. During this period of time, mP-cT air mass dominates over some to most of the Desert Southwest Region (see Figures 24-35). This modified mP

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[12]Trewartha, The Earth's Problem Climates, op. cit., p. 274.

air evidently contains the necessary moisture to produce the winter precipitation maxima in this climatic region.

During the spring season, April through June, cT air mass dominates the Desert Southwest Region (see Figures 24-35). This is the driest time of the year in this region. May receives a scant 0.19 inches of precipitation. To the east, mP, mP-mT, and mT air masses dominate over much of the High Plains Region. Due to the prevalence of these air masses, the precipitation maxima of 2.71 inches occurs during May. Therefore, the portion of the mean climographs representing the spring season for the Desert Southwest Region and the High Plains Region is totally different.

Finally, a large portion of the Desert Southwest Region is dominated by mT-cT air mass during July and August. This modified, moist mT air is pumped westward from the Gulf of Mexico around the south side of the North Atlantic subtropical anticyclone.[13] During this time, an abrupt increase of shower and thunderstorm activity is observed over the Desert Southwest Region. This increase in precipitation is seen on the mean climograph as the upper portion of the "arc" that projects away from the temperature axis in which August, the wettest month of the year, receives 0.99 inches of precipitation.

In summary, the mean climograph for the Desert Southwest Region is unique from Regions 4, 6, 7, and 10 due to the following characteristics: (1) a high position of the mean climograph along the temperature axis compared with Regions 6 and 7 partially due to elevation; (2) the closeness of the mean climograph to the temperature axis due to a small

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[13] <u>Ibid.</u>, p. 274.

mean annual sky cover; (3) a geometric "arc" configuration of the mean climograph as a result of the bimodal rainfall variation due to the dominance of mP-cT and mT-cT air masses during winter and summer, respectively, and cT air mass during May and June.

California Type Region - Region 10

The California Type Region includes a large portion of the state of California. Sections of the state that are not included in this climatic region are north of a line from Ukiah to Red Bluff, the Sierra Nevada Mountains, and the desert area in the southeastern part of the state (see Figure 83). This climatic region consists of 12 first-order and 5 test weather stations (see Appendices VIII and IX). These weather stations are characterized by extremely dry summers, with cool coastal and warm interior temperatures. July and August each receive less than 0.06 inches of precipitation. A temperature lag is noted for coastal weather stations where August represents the warmest month. Farther inland where higher summer temperatures occur, the temperature lag from oceanic effects is not observed. January is the wettest and coolest month throughout the region with a mean total of 2.93 inches of precipitation and mean temperature of 49.8^{o}F.

Certain similar characteristics between the configuration of the mean climograph for the California Type Region and Regions 8 and 19 to the north are apparent. In all 3 cases, a dry summer season and moderately wet to wet winter season produce a diagonal orientation of the mean climograph along the precipitation axis which is tilted downwards during the winter months (see Figure 84). However, upon further inspection, the mean climograph for the California Type Region differs

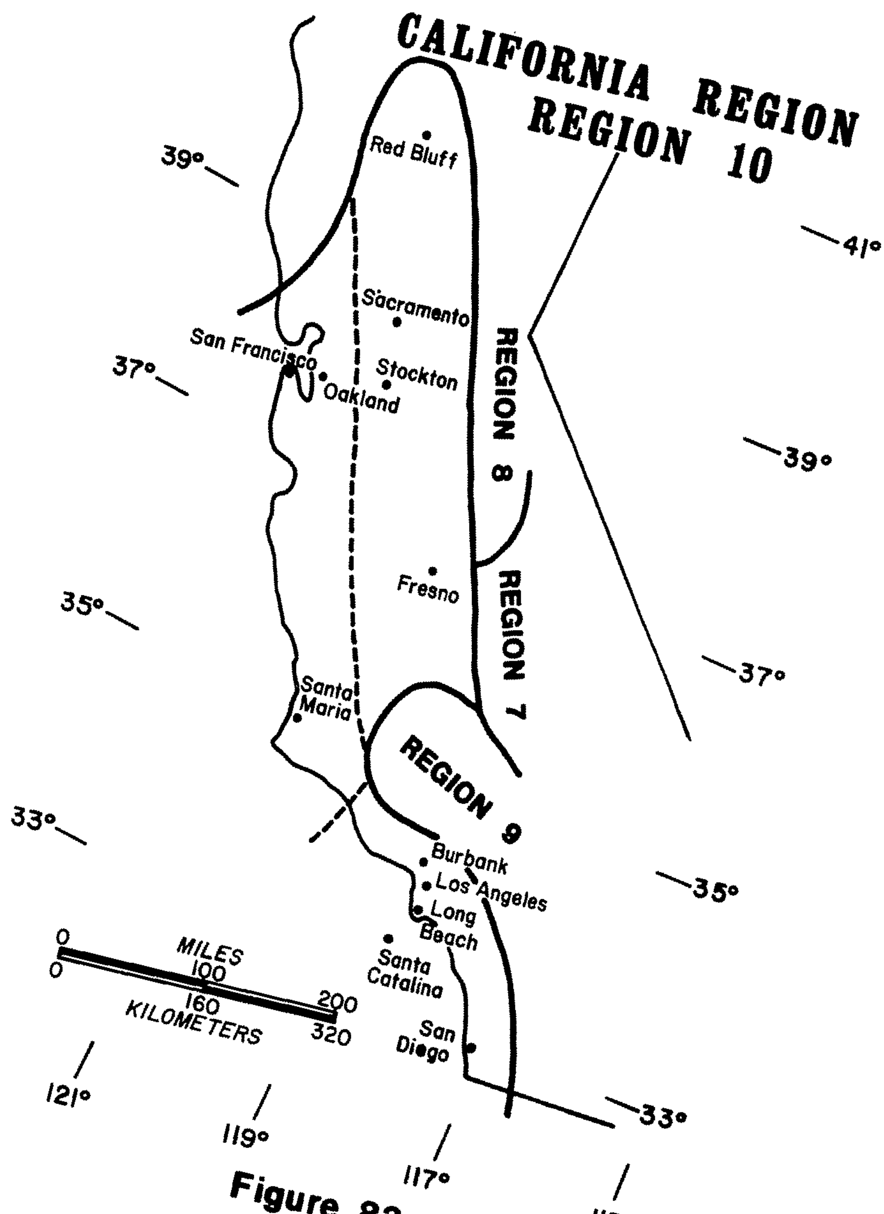

CALIFORNIA REGION
REGION 10
REGION 8
REGION 7
REGION 9
Red Bluff
Sacramento
Stockton
San Francisco
Oakland
Fresno
Santa Maria
Burbank
Los Angeles
Long Beach
Santa Catalina
San Diego
MILES
0
100
200
KILOMETERS
0
160
320
41°
39°
37°
35°
33°
39°
37°
35°
33°
121°
119°
117°
115°

Figure 83

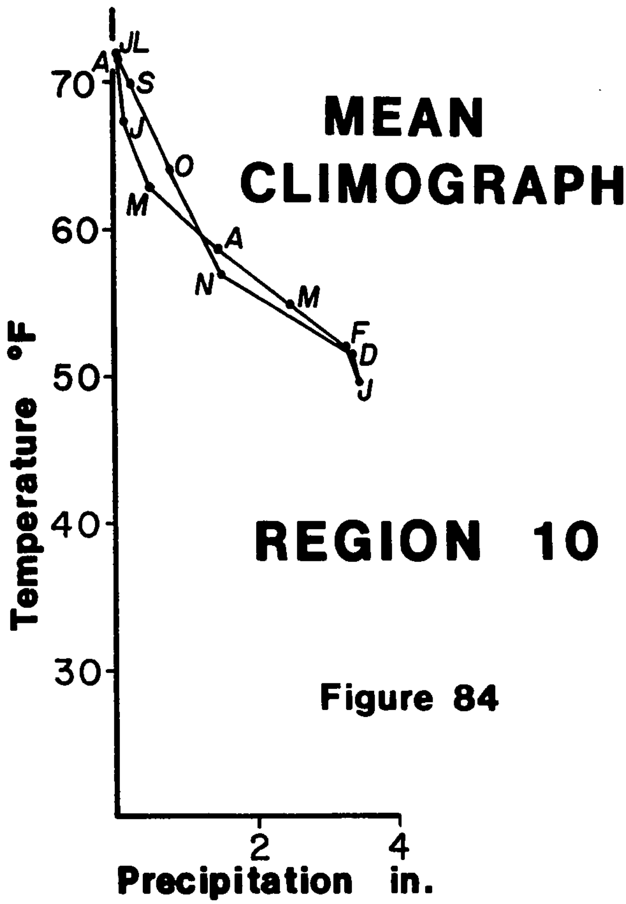


Figure 84

	J	F	M	A	M	J	
Temp. °F	49.5	51.9	54.8	58.7	62.8	67.2	
Precip. In.	3.45	3.27	2.49	1.43	.52	.18	Average
	J	A	S	O	N	D	60.8°
Temp. °F	72.0	71.6	69.9	63.8	56.7	51.4	17.27"
Precip. In.	.02	.05	.22	.80	1.52	3.32	

SOURCE: AUTHOR'S CALCULATIONS.

markedly from those of regions to the north due to a higher mean annual temperature and less annual precipitation. Therefore, the mean climograph is positioned higher along the temperature axis, and has a considerably shorter climograph along the precipitation axis. This type of orientation of the climograph is not evident in any other climatic region, such as the Plateau and Desert Southwest Regions to the west. Furthermore, the mean climographs for climatic regions to the east, such as the Desert Southwest Region and the Plateau Region, have a considerably longer climograph axis.

Large classification coefficients for continental storm track, solar radiation receipt, and ocean currents are observed as significant between the California Type Region and Regions 7, 8, and 9 (see Table 37). A relatively high negative continental storm track value was calculated for the California Type Region compared with values close to zero for Regions 7, 8, and 9. A moderately low positive solar radiation receipt value is observed for the California Type Region compared with a high positive value for the Desert Southwest Region. Finally, a moderately high negative ocean current value was calculated for the California Type Region compared with low negative values for Regions 7 and 9. To avoid repetition, continental storm track with respect to the Plateau Region and solar radiation receipt with respect to the Desert Southwest Region were discussed previously in this chapter.

From an examination of the mean climograph differences, the following climatic factor components are observed as significant between the California Type Region and Regions 8 and 9: (1) latitude -- with respect to the position of the climograph along the temperature

TABLE 37[a]

CLASSIFICATION COEFFICIENTS FOR THE CALIFORNIA TYPE AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 10	9	7	8	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-7.4	.8	+1.0	-.9	(8.4)
(2) Solar Radiation Receipt	+4.8	+12.2	+7.0	+2.9	(7.4)
(3) Winter-time High Pressure Systems	-7.2	-3.7	-1.1	-3.3	6.1
(4) Ocean Currents	-6.7	-1.0	- .3	-7.8	(6.4)
(5) Maritime Cloud Variability	+11.1	+9.9	+8.1	+15.6	4.5
(6) Continental Moisture Index	+3.1	+6.6	+5.3	+4.5	3.5
(7) Wind Strength Variability	-2.7	-3.5	-2.9	-2.8	.8

Names of Above Climatic Regions

10 California Type Region
9 Desert Southwest Region
7 Plateau Region
8 Pacific Northwest Region

[a]Source: Author's calculations.

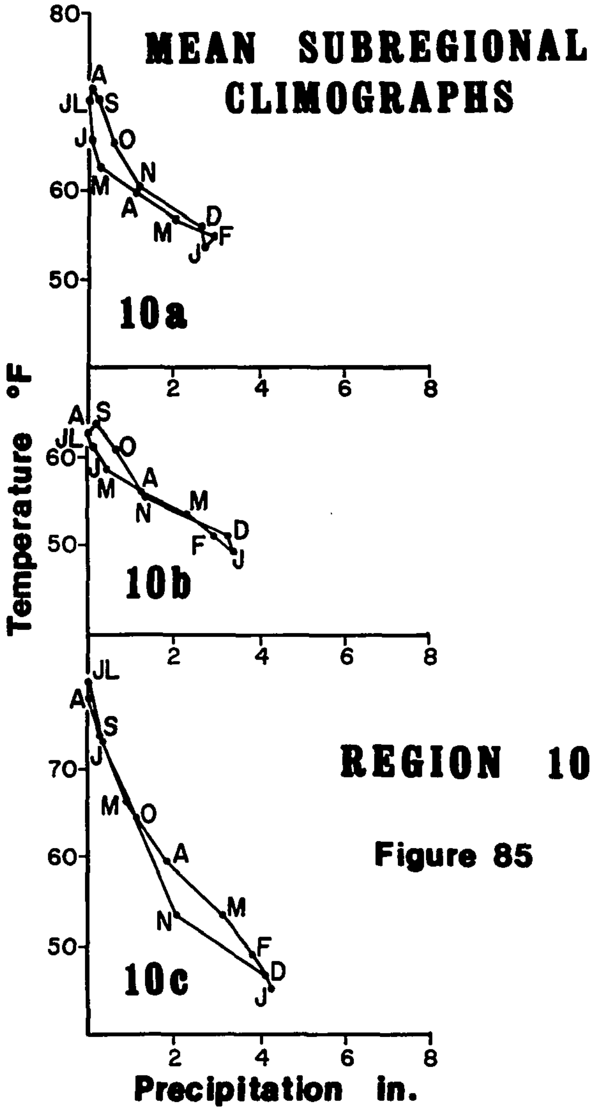
Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

axis; (2) continentality — with respect to the length of the mean climograph along the temperature axis; (3) total number of lows — with respect to the distance of the mean climograph to the temperature axis during the summer and winter seasons. The following climatic factor components are significant in distinguishing the mean climograph of the California Type Region from the Plateau Region and the Desert Southwest Region: (1) January ocean currents — with respect to the high position of the lower portion of the mean climograph along the temperature axis; (2) July ocean currents — with respect to the low position of the upper part of the mean climograph along the temperature axis.

Latitude and Continentality

One of the most important climatic factor components which distinguishes the California Type Region from the Pacific Northwest Region is latitude. This is clearly expressed by the mean annual temperature. The California Type Region has a mean annual temperature of 60.8°F which is 9.5°F greater than the Pacific Northwest Region. This decrease in mean annual temperature to higher latitudes is noted within the California Type Region when mean climographs for Subregions 10a and 10b are examined (see Figure 85). The mean climograph for Subregion 10b, at a higher latitude, is positioned much lower along the temperature axis than Subregion 10a resulting in a mean August temperature which is 8.3°F cooler.

Differences in latitude between the California Type Region and the Desert Southwest Region are not as discernible; nevertheless, the mean annual temperature for the California Type Region is 6.7°F cooler.



SOURCE: AUTHOR'S CALCULATIONS.

This difference in latitude is most evident during the summer season when the mean July temperature for the Desert Southwest Region is 87.6°F which is 15.6°F warmer than the warmest month in the California Type Region.

One of the most noticeable changes in mean climographs between the California Type Region and the Desert Southwest Region is in the length of mean climograph along the temperature axis. This is reflected in distinctly different mean annual temperature ranges between these 2 regions. The mean annual range in temperature for the California Type Region is 22.5°F compared with 39.7°F for the Desert Southwest Region. This difference corresponds to variation in continentality values throughout these climatic regions (see Figure 9). The increase in continentality from the Pacific Coast in the California Type Region to the Desert Southwest Region is vividly depicted upon examination of the mean subregional climographs. Subregions 10a and 10b are along the Pacific Ocean, whereas Subregion 10c is inland. The mean annual temperature range for Subregions 10a and 10b are 17.9°F and 14.8°F, respectively. A much greater mean annual temperature range of 34.7°F exemplifies the more interior location of Subregion 10c (see Figure 85).

Total Number of Lows

During the summer months, less precipitation falls in the California Type Region than in any other climatic region in the United States. An average of 0.02 inches of rain is recorded during July. The Pacific Northwest Region also receives little rain during the summer months, but it receives somewhat more than the California Type Region with 0.41 inches falling in July, the driest month. A distinctively greater difference in mean monthly precipitation is evident between these regions during the winter season. January, the wettest month of the year in the California Type Region, receives 3.45 inches of rain compared with 6.29 inches which falls during December in the Pacific Northwest Region.

One explanation for the differences in mean monthly rainfall during the winter and summer months between the California Type Region and the Pacific Northwest Region is the number of lows. The frequency of lows which occurred during a 20-year period within these regions may be sampled by examining 5^{o}E-W by 5^{o}N-S rectangles within the climatic regions in question.[14] The rectangular area for the Pacific Northwest Region includes the 4 most northern weather stations but overlaps into Region 19 to include Tatoosh Island and Astoria. The rectangular area examined in the California Type Region includes the 5 most southern weather stations. Within the 2 rectangular areas during the 20-year period, the Pacific Northwest Region experienced 113 low pressure disturbances compared with 58 for the California Type Region. Possibly of more significance, 13 more lows were recorded in January and 2 additional lows were recorded in July over the 20-year period in the Pacific Northwest Region compared with the California Type Region.

Ocean Currents

The short length of the mean climograph along the temperature axis for the California Type Region indicates a small mean annual range in temperature. This contrasts sharply with climatic regions to the

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[14]Klein, _op. cit._, pp. 23-34.

west, i.e., the Plateau and Desert Southwest Regions. The mean annual range in temperature for the California Type Region is 22.5°F compared with 43.5°F and 39.7°F for Regions 7 and 9, respectively.

One obvious explanation for the difference in mean climograph length is ocean current effect which tends to modify summer and winter season temperatures. This ocean current effect and its rapid decrease in intensity from the California Coast inland to the Plateau Regions and Desert Southwest Region is noted on the map of ocean current factor score values (see Figure 44). Upon further inspection, the mean subregional climographs also reveal ocean current effects from mean annual temperature ranges within the California Type Region. Maximum mean monthly temperatures are reached late in the summer season for Subregions 10a and 10b (see Figure 85). This is governed by the delayed heating of the ocean and its direct effect on adjacent land areas. Subregion 10b, with its highest mean monthly temperature occurring in September, is also influenced by the prevalence of low stratus clouds concomitant with reduction of insolation resulting in cool summer month temperatures.[15] Mean annual temperature ranges for Subregions 10a and 10b are 17.9°F and 14.8°F. The maximum mean monthly temperature for Subregion 10c, which is inland and includes the Sacramento-San Joaquin Valley, occurs during July (see Figure 85). Its mean annual temperature range of 34.7°F is much larger than the two coastal subregions.

In summary, the mean climograph for the California Type Region is unique from Regions 7, 8, and 9 due to the following characteristics:

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[15] Trewartha, _op. cit._, p. 272.

(1) an intermediate position of the mean climograph along the temperature axis compared with the Pacific Northwest Region and the Desert Southwest Region due to latitude; (2) a short mean climograph length along the precipitation axis which is closer to the temperature axis compared with the Pacific Northwest Region due to the total number of low pressure disturbances; and (3) a short mean climograph along the temperature axis compared with Regions 7 and 9 to the west due to ocean current effects.

<u>Humid Southeast Region - Region 11</u>

The Humid Southeast Region extends from eastern Texas to the Atlantic Coast and from the Eastern Gulf Coast Region northwards to southern Illinois, then southeastward to Cape Hatteras (see Figure 86). This climatic region contains 34 first-order and 12 test weather stations (see Appendices VIII and IX). The Humid Southeast Region is characterized by mild to warm temperatures with considerable precipitation throughout the year. The average annual temperature is 63.8°F, ranging from 46.4°F in January to 81.0°F in July. The mean annual precipitation of 49.37 inches is moderately well distributed throughout the year, but it does have 2 notable primary precipitation accents. July, the wettest month, receives 5.24 inches of rain compared with March, which represents the other primary precipitation maxima receiving 5.00 inches of rain. This region's mean climograph appears distinct in its summer and winter-early spring double precipitation maxima which form pronounced sharp-angled features (see Figure 87). Furthermore, the mean climograph is positioned considerably lower along the temperature axis than mean climographs for regions to the south and is more distant from the

HUMID SOUTHEAST REGION
REGION 11

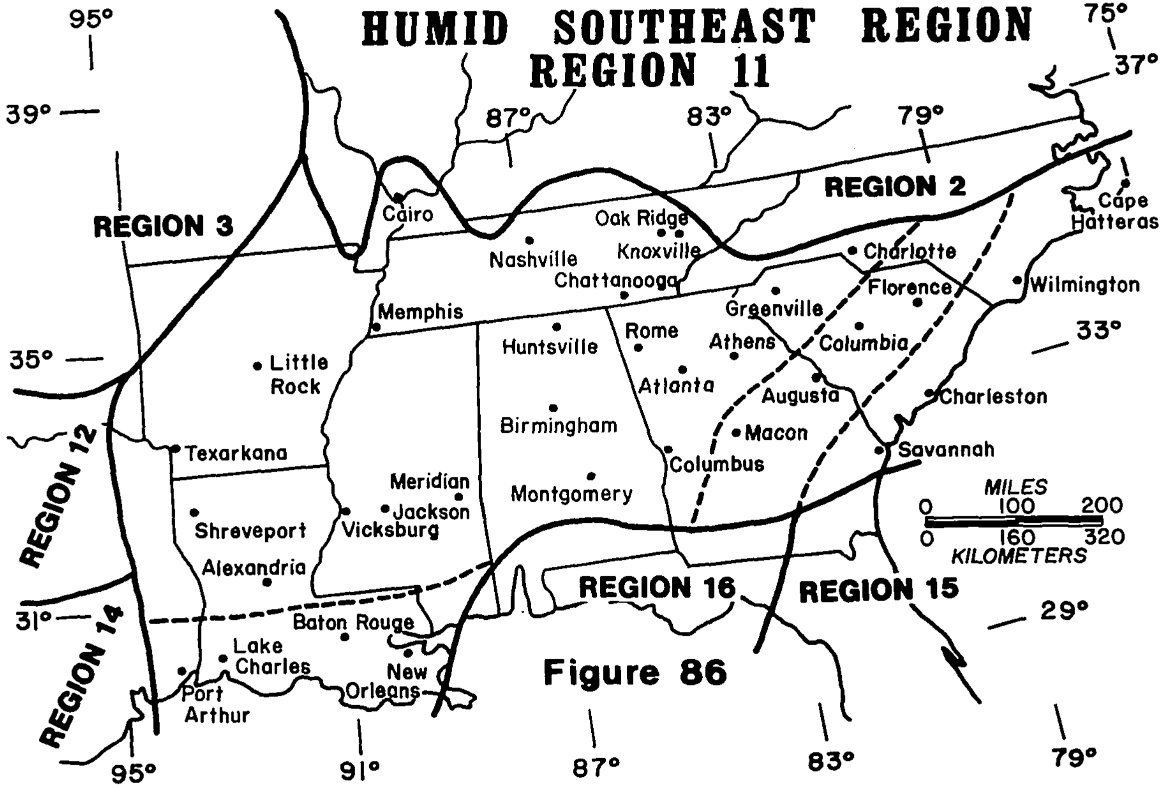
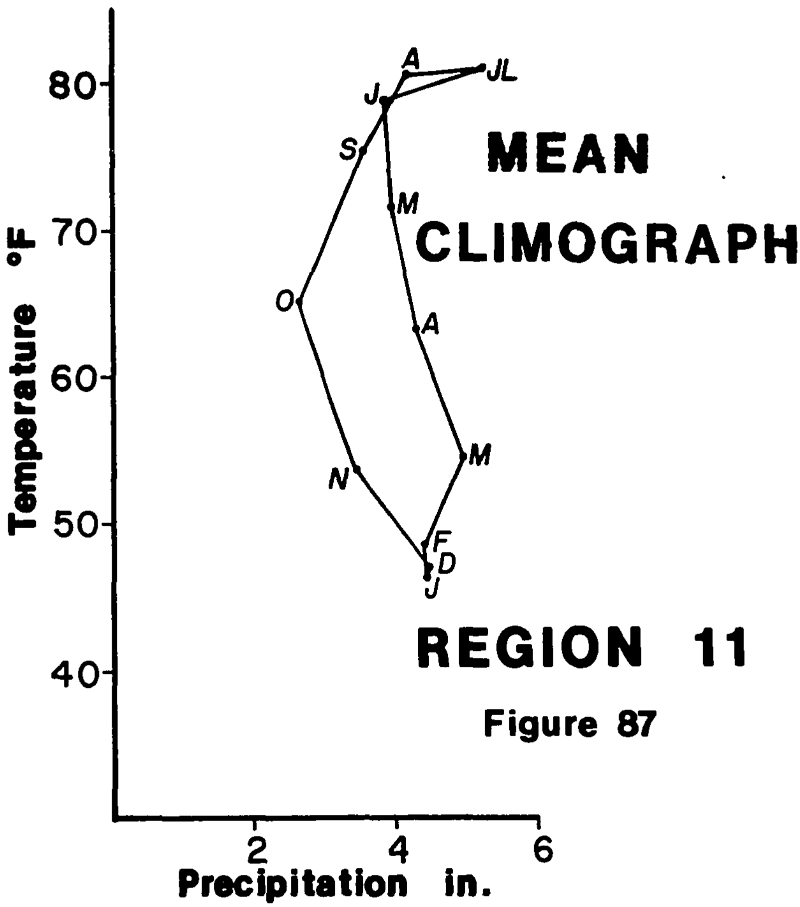


Figure 86



	J	F	M	A	M	J	
Temp. °F	46.4	48.6	54.5	63.3	71.5	78.8	
Precip. In.	4.47	4.41	5.00	4.31	3.99	3.90	Average
	J	A	S	O	N	D	63.8°
Temp. °F	81.0	80.5	75.3	65.2	53.6	47.0	49.72"
Precip. In.	5.24	4.20	3.57	2.68	3.46	4.49	

SOURCE: AUTHOR'S CALCULATIONS.

temperature axis than Region 12 to the west. Finally, a relatively dry October creates a large, extensive "opening" within the framework of the mean climograph.

Large classification coefficient differences were observed between the Humid Southeast Region and Regions 2, 12, and 15 (see Table 38). More specifically, a moderately low negative continental storm track value was calculated for the Humid Southeast Region compared with a low positive value for the East Central Region; a low negative solar radiation receipt value is observed for the Humid Southeast Region compared with a low positive value for the Interior Texas Region; and a moderately low negative maritime cloud variability value was calculated for the Humid Southeast Region compared with a moderately high negative value for the Florida Region. To avoid repetition, continental storm track with respect to the East Central Region is discussed elsewhere in this chapter.

From examination of mean climograph differences, the following climatic factor components are observed as significant between the Humid Southeast Region and the Interior Texas Region: (1) mean annual sky cover -- with respect to the distance of the mean climograph from the temperature axis; (2) mP-cT air mass -- with respect to the distance of the lower portion of the mean climograph away from the temperature axis. The following climatic factor components are significant in distinguishing the mean climograph configuration of the Humid Southeast Region from the Florida Region: (1) latitude and mT air mass -- with respect to the low position of the mean climograph along the temperature axis; (2) variability of mean annual sky cover -- with respect to the relatively dry

TABLE 38

CLASSIFICATION COEFFICIENTS FOR THE HUMID SOUTHEAST AND ADJACENT CLIMATIC REGIONS

Climatic Factors	11	2	3	16	12	14	15	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-4.3	+1.7	+.1	-5.8	-3.9	-6.1	-8.1	(6.0)
(2) Solar Radiation Receipt	-2.4	-3.1	-1.3	-3.0	+1.3	-1.7	-3.8	(3.7)
(3) Winter-time Pressure Systems	- .6	+2.1	+ .9	-1.0	-1.5	-2.0	-2.6	2.7
(4) Ocean Currents	+1.3	+ .3	+2.3	+2.0	+2.1	+2.1	- .5	1.8
(5) Maritime Cloud Variability	-5.3	-3.2	-4.7	-8.0	-4.1	-7.1	-8.5	(3.2)
(6) Continental Moisture Index	-2.1	(-1.8)	-1.5	-2.4	-1.1	-1.8	-1.8	1.0
(7) Wind Strength Variability	+ .6	+1.5	+1.9	+1.1	+ .8	+1.9	+ .9	1.3

Names of Above Climatic Regions

11 Southwest Subhumid Region
2 East Central Region
3 Interior Highland
16 Eastern Gulf Coast Region
12 Interior Texas Region
14 Western Gulf Coast Region
15 Florida Region

[a]Source: Author's calculations.

Note: Coefficient with parentheses have the greatest difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

October which forms a large opening within the framework of the mean climograph and the sharp-angled feature during July which represents a primary precipitation maxima but which is less pronounced than the one observed in the Florida Region.

Latitude and mT Air Mass

The mean position of the climograph for the Humid Southeast Region is markedly lower along the temperature axis than the mean climograph for the Florida Region. This is reflected in their mean annual temperatures of 63.8°F and 71.9°F, respectively. The most obvious explanation for this difference in mean annual temperature is latitude. The common boundary between these adjacent regions passes through southern Georgia, but the Humid Southeast Region extends northwards to southern Illinois and Missouri whereas the southern extension of the Florida Region terminates south of Miami. Cooler year-round mean temperatures therefore occur in the Humid Southeast Region.

This change in latitude is displayed in mean subregional climographs. Subregion 11a, the largest subregion, extends northwards into southern Illinois. The mean annual temperature for this subregion is 61.2° which is lower than the region's mean annual temperature. This is reflected in its lower position along the temperature axis compared with the mean subregional climograph for Subregion 11d which encompasses southern Louisiana with a mean annual temperature of 68.5°F (see Figure 88).

Upon further inspection of the mean climographs, largest mean monthly temperature discrepancies occur during the cooler season. For example, the Humid Southeast Region is only 0.6°F cooler during July but

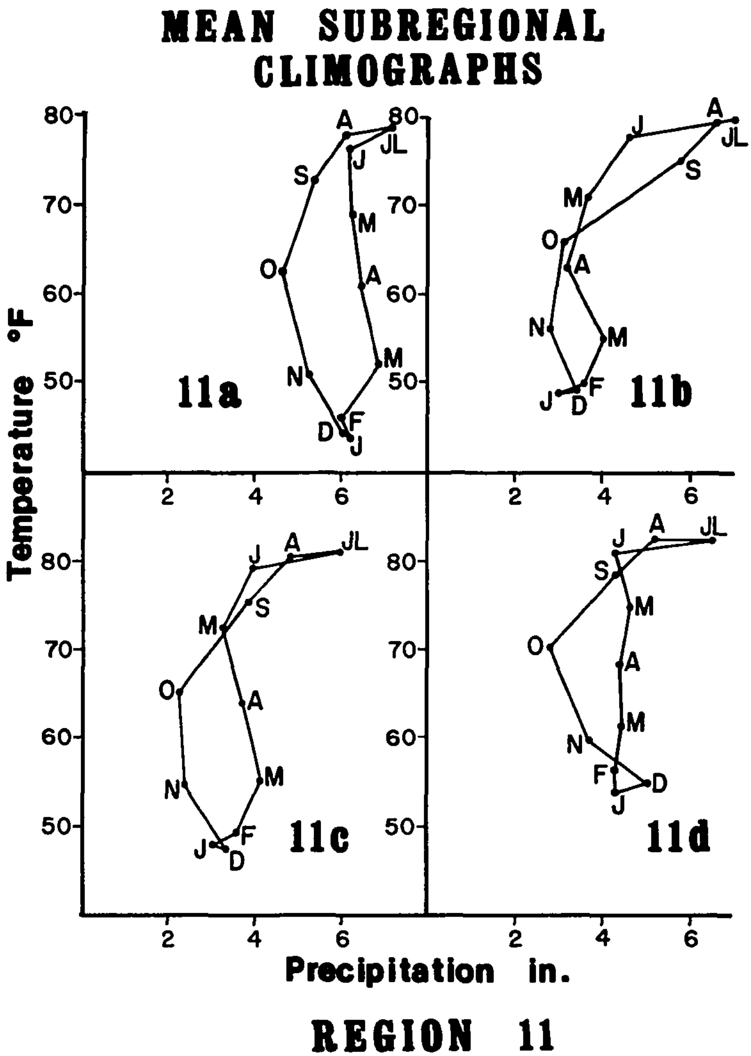


Figure 88

SOURCE: AUTHOR'S CALCULATIONS.

14.5°F cooler during January. Consequently, the lower portion of the mean climograph for the Humid Southeast Region extends conspicuously farther down along the temperature axis. However, the upper portion of the mean climographs along their temperature axes for both climatic regions are positioned at approximately the same height. One explanation regulating the heights of various portions of mean climographs is annual distribution of mT air mass dominance. During the cool season from November through February, little or no mT air mass dominates over the Humid Southeast Region. In contrast, only warmer mT and mT transition air masses predominate in the Florida Region. During the summer months, warm, moist mT air mass prevails over both the Humid Southeast Region and Florida Region, resulting in rather similar mean monthly temperatures.

mP-cT Air Mass and Mean Annual Sky Cover

A striking decrease in annual precipitation is observed from the Humid Southeast Region to the Interior Texas Region. The mean annual precipitation for these regions is 49.72 inches and 27.41 inches, respectively. Some of the greatest monthly contrasts in mean precipitation amounts occur during the winter and early spring. For example, mean March precipitation for the Humid Southeast Region is 5.00 inches which is 3.23 inches greater than the Interior Texas Region.

One significant climatic component factor related to this difference in mean precipitation is mP-cT air mass dominance. From January through April, mP-cT air mass prevails over a portion or close to the Interior Texas Region while moist mP air mass predominates in the Humid Southeast Region (see Figures 24-35). This lack of cT transition air mass over the Humid Southeast Region is reflected in the lower portions of the mean climograph which is conspicuously more distant from the temperature axis than that observed for the Interior Texas Region.

Another explanation for the larger mean annual precipitation amount in the Humid Southeast Region is mean annual sky cover. From an examination of mean annual sky cover, larger values are evident throughout the Humid Southeast Region. For example, the mean annual sky cover for the Interior Texas Region ranges from 4.4 at Midland to 5.5 at San Antonio; in the Humid Southeast Region these values range from 5.4 at Greenville to 6.0 at 3 weather stations.[16] These larger mean annual sky cover values for the Humid Southeast Region indicate more annual precipitation and are reflected in a greater average distance of the mean climograph away from the temperature axis.

One additional comment concerning the sharp-angled feature representing the summer precipitation maxima during July should be mentioned. According to Trewartha, a trough aloft, together with its tongue of deep, moist air, is positioned over this area.[17] This condition is favorable for strong convective shower activity.

Variability of Mean Annual Sky Cover

In the Humid Southeast Region, October is the driest month of the year with 2.68 inches of precipitation; since mean monthly rainfall is higher during the spring season, a large and extensive "opening" in

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[16] Local Climatological Data, Arkansas, Louisiana, Mississippi, Illinois, Tennessee, Alabama, Georgia, North Carolina and South Carolina, 1964.

[17] Trewartha, op. cit., p. 301.

in the mean climograph configuration is formed. To the south in the Florida Region, considerably more precipitation occurs during October compared with the spring season. Consequently, a different mean climograph configuration is formed with a smaller "opening" in its lower end.

This transition is vividly depicted upon observation of mean subregional climographs from a more interior location towards the Atlantic Coast. Subregion 11c is similar to the mean regional climograph in that October is much drier than March (see Figure 88). However, the mean subregional climograph for Subregion 11b which is along the Atlantic Coast reveals a much smaller precipitation difference between these months although March is somewhat wetter (see Figure 88). A smaller "opening" in the lower portion of the mean subregional climograph is therefore evident in Subregion 11b.

Although standard deviations of mean monthly sky cover values are homogeneous in the Humid Southeast Region and Florida Region, a notable difference in mean October sky cover values is observed (see Table 39). According to Trewartha, there is a maximum frequency of highs and few fronts during this time of the year throughout the Humid Southeast Region.[18] Hence, smaller mean sky cover values are expected in this climatic region. These facts then explain the difference in mean October precipitation between these climatic regions and, in addition, the explanation for the shorter distance for October to the temperature axis which forms a large "opening" in the mean climograph is revealed.

In summary, the mean climograph for the Humid Southeast Region is unique from the Interior Texas Region and Florida Region because of

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[18] Ibid., p. 299.

TABLE 39[a]

MEAN OCTOBER SKY COVER VALUES FOR SELECTED WEATHER STATIONS IN THE HUMID SOUTHEAST REGION AND FLORIDA REGION

Florida Region		Humid Southeast Region	
Weather Stations	Mean October Sky Cover	Weather Stations	Mean October Sky Cover
Jacksonville	5.4	Little Rock	4.3
Daytona Beach	5.6	Alexandria	3.7
Orlando	5.3	Montgomery	4.5
Lakeland	5.1	Macon	4.2
Tampa	5.1	Columbia	4.4
Fort Myers	5.0	Nashville	4.6

[a]Source: Local Climatological Data with Comparative Data, Florida, Arkansas, Louisiana, Alabama, Georgia, South Carolina, and Tennessee, 1964.

the following characteristics: (1) a lower mean position of the mean climograph along the temperature axis because of a higher latitudinal location and, especially, a lower position of the lower portion of the mean climograph along the temperature axis due to the lack of mT air mass dominance; (2) a greater distance of the mean climograph away from the temperature axis than the Interior Texas Region because of the lack of mP-cT air mass dominance and higher mean annual sky cover values; (3) a large and extensive "opening" within the framework of the mean climograph because of small mean October sky cover values with little precipitation compared with the Florida Region.

Interior Texas Region - Region 12

The Interior Texas Region includes a compact area from San Antonio on the southern border northwards into the southern portion of Oklahoma. It is bounded on the west by the Texas Panhandle and Big Bend and extends eastwards to near the Texas-Louisiana border (see Figure 89). This climatic region consists of 8 first-order and 3 test weather stations (see Appendices VIII and IX). The Interior Texas Region is characterized by a primary and secondary precipitation maxima. The month of May constitutes a pronounced primary maxima with a mean rainfall of 4.16 inches. A late summer-early autumn secondary maxima is noted with 2.75 inches of precipitation recorded in September. This climatic region is astride Koppen's B/H transition zone with 27.41 inches of rain per year. The mean annual range in temperature of 38.7°F is intermediate to adjacent north-south climatic regions. The mean temperature of 84.1°F in August is only 0.1°F lower than July, the

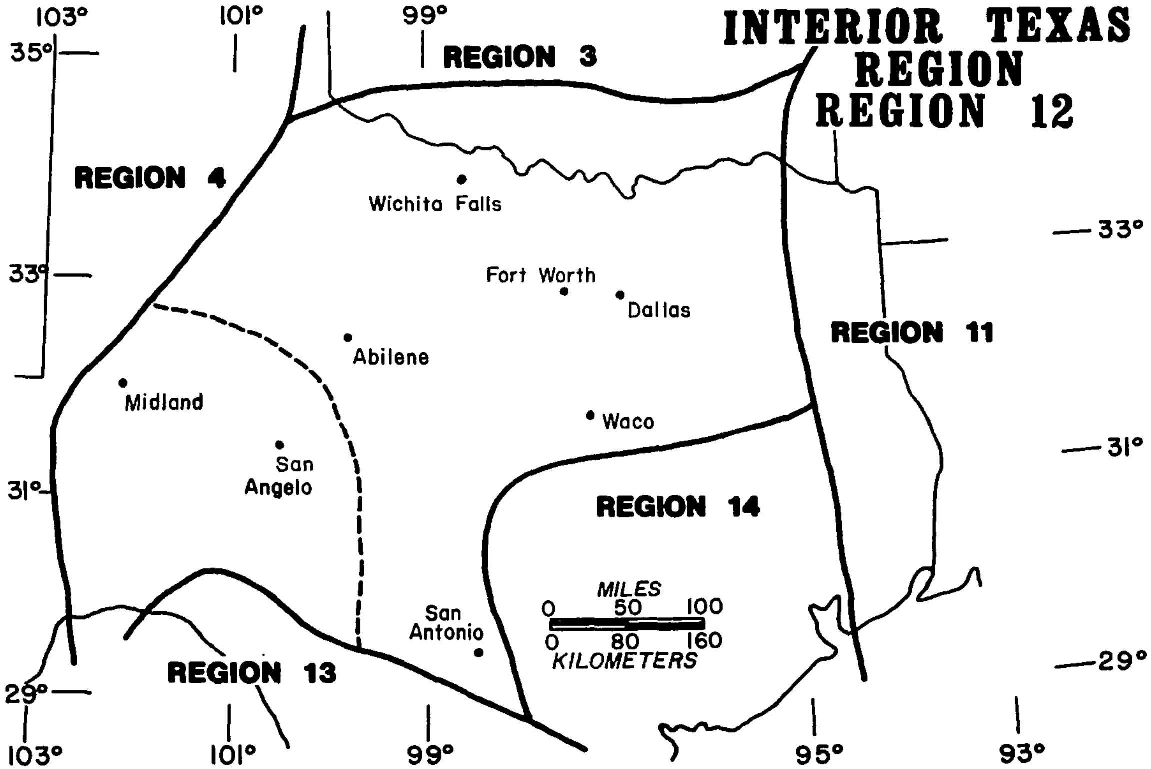
INTERIOR TEXAS
REGION
REGION 12
REGION 3
REGION 4
REGION 11
REGION 13
REGION 14
Wichita Falls
Fort Worth
Dallas
Abilene
Midland
Waco
San Angelo
San Antonio
MILES
0 50 100
0 80 160
KILOMETERS
103°
101°
99°
95°
93°
35°
33°
31°
29°

Figure 89

warmest month. The coldest mean monthly temperature for this region is January with 45.5°F.

The distinctiveness of the mean climograph for the Interior Texas Region is observed particularly in the upper portion where the primary precipitation maxima during May forms a pronounced sharp-angled feature pointed away from the temperature axis. Furthermore, due to considerably drier conditions during July and August and a secondary precipitation maxima occurring in September, the side of the mean climograph closest to the temperature axis appears collapsed (see Figure 90). Although the sharp angle and/or collapsed side are evident on mean climographs of certain adjacent climatic regions, such as Regions 3, 4, and 13, a large variation in the shape of these features in the configuration is evident.

The portion of the mean climograph which points in towards the temperature axis and creates the sharp-angled feature and collapsed side is analyzed with respect to another climatic region. Briefly, this portion of the mean climograph represents a mid-summer dry period which is associated with anticyclonic flow at the 750-500 mb. level.[19] This feature on the mean climograph is pronounced and, for the most part, produces the distinctiveness in this mean climograph configuration for the Interior Texas Region.

Moderately large classification coefficient differences between the Interior Texas Region and Regions 4, 11, and 13 are observed (see Table 40). A moderately low negative continental storm track value was

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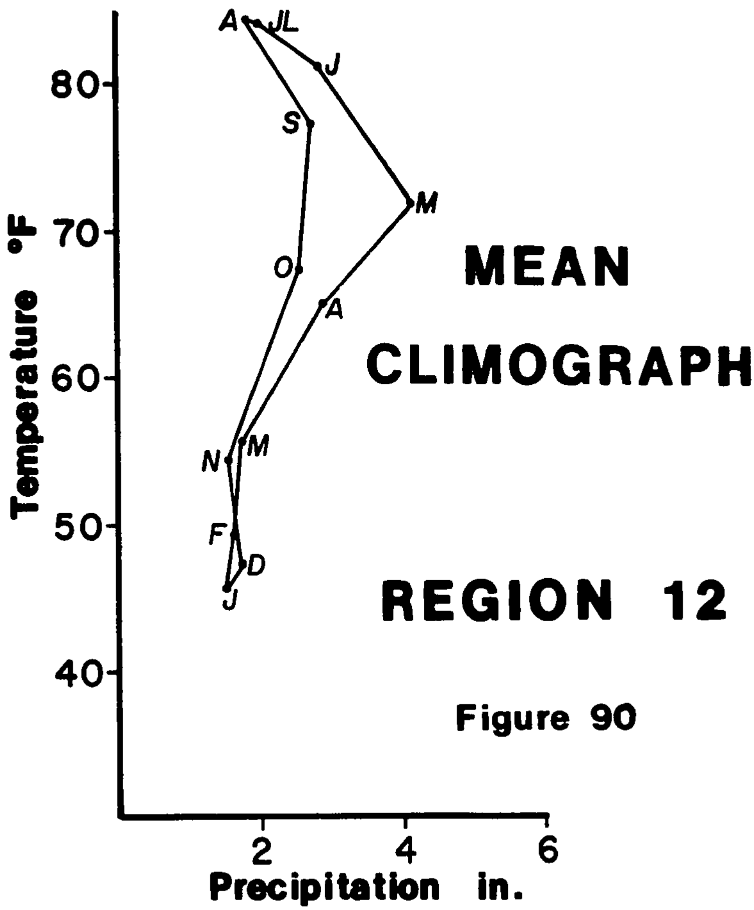
[19] Ibid., p. 280.



	J	F	M	A	M	J	
Temp. °F	45.5	49.1	55.8	65.0	72.7	81.1	
Precip. In.	1.53	1.67	1.77	2.90	4.16	2.83	Average
	J	A	S	O	N	D	65.3°
Temp. °F	84.2	84.1	77.2	67.3	54.3	47.3	27.41"
Precip. In.	2.04	1.83	2.75	2.59	1.57	1.77	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 40[a]

CLASSIFICATION COEFFICIENTS FOR THE INTERIOR TEXAS REGION AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 12	11	3	4	13	14	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-3.9	-4.3	+.1	+.7	-6.8	-6.1	(4.6)
(2) Solar Radiation Receipt	1.3	-2.4	-1.3	+2.6	-1.2	-1.7	(3.7)
(3) Winter-time High Pressure Systems	-1.5	-.6	+.9	+.1	-2.6	-2.0	2.4
(4) Ocean Currents	+2.1	+1.3	+2.3	+2.4	+2.7	+2.1	.8
(5) Maritime Cloud Variability	-4.1	-5.3	-4.7	-3.0	-8.3	-7.1	(4.2)
(6) Continental Moisture Index	-1.1	-2.1	-1.5	- .4	-1.4	-1.8	.7
(7) Wind Strength Variability	+.8	+.6	+1.9	+1.9	+2.7	+1.9	1.9

Names of Above Climatic Regions

12 Interior Texas Region
11 Humid Southeast Region
3 Interior Highland Region
4 High Plains Region
13 Texas Valley Region
14 Western Gulf Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

calculated for the Interior Texas Region compared with a low positive value for the High Plains Region; a low positive solar radiation receipt value is observed for the Interior Texas Region compared with a low negative value for the Humid Southeast Region; and a moderately low negative maritime cloud variability value was calculated for the Interior Texas Region compared with a relatively high negative value for the Texas Valley Region. To avoid repetition, solar radiation receipt with respect to the Humid Southeast Region is discussed elsewhere in this chapter.

From an examination of the mean climograph differences, the following climatic factor components are observed as significant between the Interior Texas Region and the High Plains Region: (1) latitude -- with respect to the position of the mean climograph along the temperature axis; and (2) continentality -- with respect to the length of the mean climograph along the temperature axis. The following climatic factor components are significant in distinguishing the mean climograph of the Interior Texas Region from the Texas Valley Region: (1) latitude -- with respect to the position of the mean climograph along the temperature axis; and (2) variability of mean annual sky cover -- with respect to the sharp-angled feature and collapsed appearance of the mean climograph which represent a primary and secondary precipitation maxima.

Latitude and Continentality

The Interior Texas Region is north of the Texas Valley Region but, for the most part, is south of the High Plains Region. This intermediate latitudinal location between Regions 4 and 13 is observed in their mean annual temperatures. The mean annual temperature of the Interior Texas Region is 65.3°F. This value is 7.3°F cooler compared with the Texas Valley Region to the south and 6.5°F warmer compared with the more northerly High Plains Region. These latitudinal differences between these three climatic regions are also reflected in their minimum mean monthly temperatures, all of which occur in January. The mean January temperature for the Interior Texas Region is 45.5°F whereas 58.0°F and 37.5°F are observed for the Texas Valley Region and High Plains Region, respectively.

A significant difference is also noted in mean annual temperature range between the Interior Texas Region and the High Plains Region. The temperature range for the Interior Texas Region is 38.7°F compared with 42.1°F for the High Plains Region. This difference is readily recognized in terms of mean climograph lengths along the temperature axis. These different lengths are related to continentality values observed in these regions. The Interior Texas Region is closer to the Gulf of Mexico, the nearest large body of water, and is less affected by continental conditions. This is verified upon inspection of the Oliver index continentality map (see Figure 9). All first-order weather stations in the Interior Texas Region, with the exception of Wichita Falls, have continentality values less than 8. However, all first-order weather stations in the High Plains Region have values over 8, and Concordia, far to the north in this region, has a value which is over 10.

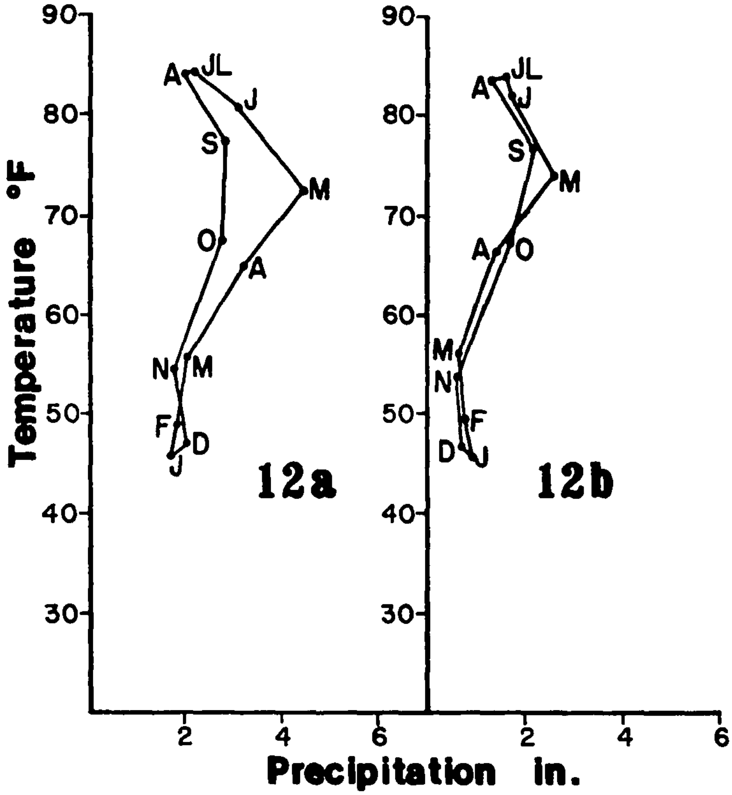
Variability of Mean Annual Sky Cover

The Texas Valley Region is characterized by a primary and secondary precipitation maxima which is similar to the Interior Texas Region. However, the time of occurrence for these regions is reversed. The primary maxima in the Interior Texas Region occurs during May and the secondary maxima occurs during September and October, but, in contrast, the primary maxima in the Texas Valley Region is in September and the secondary maxima is evidenced in May.

A transition of this precipitation maxima reversal is observed in the mean subregional climographs (see Figure 91). Subregion 12b consists of 2 first-order weather stations--Midland and San Angelo. With the exception of San Antonio in Subregion 12a, these weather stations in Subregion 12b are nearer the Texas Valley Region than weather stations in Subregion 12a, and, therefore, represent an intermediate location with respect to Subregion 12a and the Texas Valley Region. In this subregion it is observed that the primary and secondary precipitation maxima have practically merged on the mean subregion climograph and represent two primary precipitation maxima during May and September. Subregion 12a has a definite May primary and September secondary precipitation maxima similar to the mean climograph of the Interior Texas Region.

One possible explanation for the reversed primary and secondary precipitation maxima between the Interior Texas Region and the Texas Valley Region is variability of mean annual sky cover. But, after examining sky cover standard deviation values for all first-order weather stations in this region, no conclusion was drawn. The standard

MEAN SUBREGIONAL CLIMOGRAPHS



REGION 12

Figure 91

SOURCE: AUTHOR'S CALCULATIONS.

deviation values varied only slightly over the 2 regions, ranging from 0.5 at Midland to 0.9 at Fort Worth, Waco, and Corpus Christi. However, by examining relative differences of mean May and September sky cover values for these climatic regions, some insight is attained (see Table 41). There is relatively a greater mean September cloud cover in the Texas Valley Region compared with the Interior Texas Region which provides one necessary condition for the reversal of primary and secondary precipitation maxima occurrence.

In summary, the mean climograph for the Interior Texas Region is unique from the High Plains Region and Texas Valley Region due to the following characteristics: (1) an intermediate position of the mean climograph along the temperature axis because of latitude; (2) a shorter length of the mean climograph along the temperature axis relative to the High Plains Region because of continentality; (3) a sharp-angled feature and collapsed side which are evident on the mean climograph during the transition seasons which represent a primary and secondary precipitation maxima, which are reversed in the Texas Valley Region, due to relative mean monthly sky cover values.

Texas Valley Region - Region 13

The Texas Valley Region includes the southern triangular tip of Texas from Del Rio to Brownsville along the Mexican-United States border, then north and northeastwards along the Gulf Coast just beyond Corpus Christi and finally northwestwards towards Del Rio (see Figure 92). This climatic region consists of 3 first-order and 4 test weather stations (see Appendices VIII and IX). Mild to extremely warm mean monthly temperatures characterize the Texas Valley Region. January, the

TABLE 41[a]

MEAN MAY AND SEPTEMBER SKY COVER VALUES FOR TWO INTERIOR TEXAS REGION AND TWO TEXAS VALLEY REGION (*) WEATHER STATIONS

	May	Sept.		May	Sept.
Brownsville*	5.8	5.3	Corpus Christi*	6.1	5.0
Wichita Falls	5.1	3.7	Abilene	5.4	4.1
Difference	.7	1.6	Difference	.7	.9
Brownsville*	5.8	5.3	Corpus Christi*	6.1	5.0
Abilene	5.4	4.1	Wichita Falls	5.1	3.7
Difference	.4	1.2	Difference	1.0	1.3

[a]Source: Local Climatological Data with Comparative Data, Florida, Arkansas, Louisiana, Alabama, Georgia, South Carolina, and Tennessee, 1964.

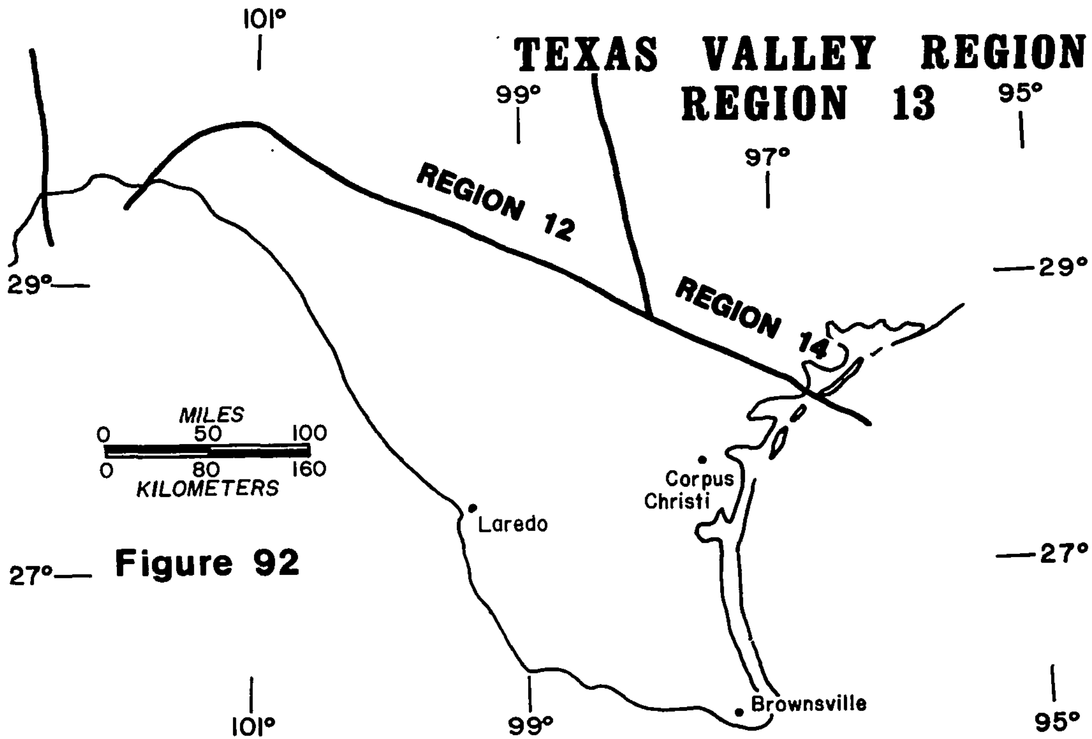
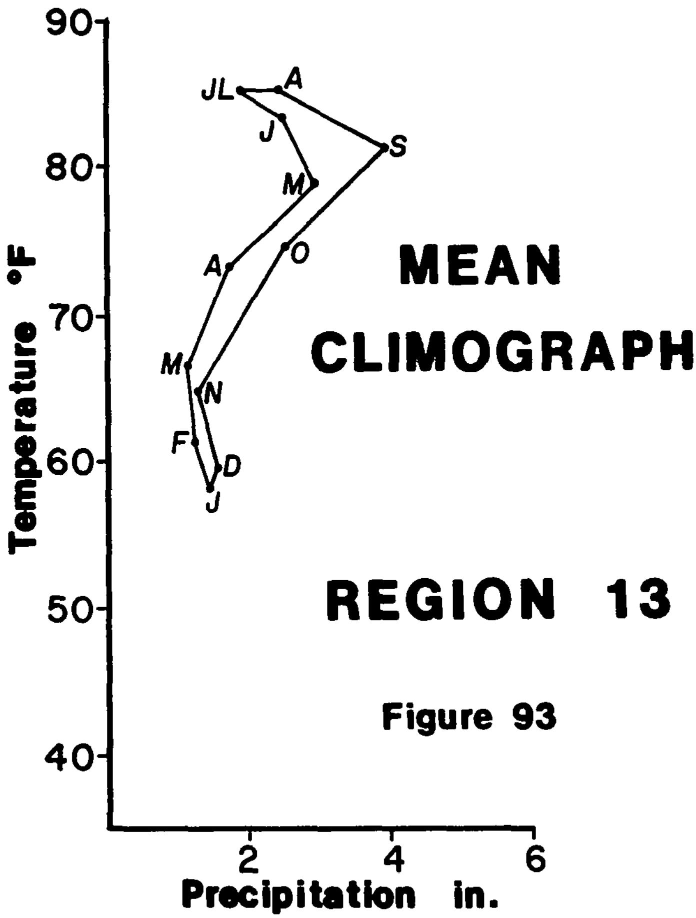

TEXAS VALLEY REGION
REGION 13
REGION 12
REGION 14
101°
99°
97°
95°
29°
27°
MILES
0
50
100
0
80
160
KILOMETERS
Laredo
Corpus
Christi
Brownsville

Figure 92

coolest month of the year, has a mean temperature of 58.0°F. July and August represent the warmest months of the year with a mean temperature of 85.1°F. Since both the mean minimum and maximum monthly temperatures are high, the Texas Valley Region is one of the warmest climatic regions in the United States with a mean annual temperature of 72.6°F. A small mean annual range in temperature of 27.1°F is noted. Only modest amounts of precipitation fall during the year. The mean annual total rainfall is 24.83 inches, similar to the amount received in the Interior Texas Region to the north, both of which are within the B/H transition zone. A striking primary and secondary precipitation maxima characterizes the precipitation regime in this region. The primary maxima occurs in September with 3.97 inches compared with 2.96 inches in May, representing the secondary maxima.

The distinctiveness of the mean climograph is observed in the shortness and high position along the temperature axis (see Figure 93). Furthermore, the primary and secondary precipitation maxima form pronounced sharp-angled features in the upper portion of the mean climograph which are pointed away from the temperature axis. At the top of the mean climograph, the mid-summer dry period is sharply pointed in towards the temperature axis.

Largest classification coefficients are observed between the Texas Valley Region and the Interior Texas Region (see Table 42). A moderately high negative continental storm track value was calculated for the Texas Valley Region compared with a moderately low negative value for the Interior Texas Region; and a high negative maritime cloud variability value was calculated for the Texas Valley Region compared



	J	F	M	A	M	J	
Temp. °F	58.0	61.3	66.5	73.2	78.8	83.3	
Precip. In.	1.48	1.30	1.15	1.75	2.96	2.52	Average
	J	A	S	O	N	D	72.6°
Temp. °F	85.1	85.1	81.2	74.6	64.7	59.4	24.83"
Precip. In.	1.91	2.43	3.97	2.52	1.29	1.55	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 42[a]

CLASSIFICATION COEFFICIENTS FOR THE TEXAS VALLEY AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 13	12	14	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-6.8	-3.9	-6.1	(2.9)
(2) Solar Radiation Receipt	-1.2	+1.3	-1.7	(2.5)
(3) Winter-time High Pressure Systems	-2.6	-1.5	-2.0	1.1
(4) Ocean Currents	+2.7	+2.1	+2.1	.6
(5) Maritime Cloud Variability	-8.3	-4.1	-7.1	(4.2)
(6) Continental Moisture Index	-1.4	-1.1	-1.8	.4
(7) Wind Strength Variability	+2.7	+ .8	+1.9	1.9

Names of Above Climatic Regions

13 Texas Valley Region
12 Interior Texas Region
14 West Gulf Coast Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

with a moderately low negative value for the Interior Texas Region. To avoid repetition, maritime variability with respect to the Interior Texas Region will be discussed elsewhere in this chapter.

From an inspection of the mean climograph differences, the following climatic factor components are observed as significant between the Texas Valley Region and Interior Texas Region:
(1) continentality -- with respect to the length of the mean climograph along the temperature axis; (2) mT and mP-mT air masses -- with respect to the high position of the mean climograph along the temperature axis during the winter season; and (3) mean annual sky cover -- with respect to the upward extension of the mean climograph along the temperature axis.

Continentality

One of the more noteworthy differences between the mean climographs of the Texas Valley Region and Interior Texas Region is the length of the climograph axis. A somewhat similar climograph configuration is observed between these regions, but the mean climograph for the Texas Valley Region appears compressed along the temperature axis. This difference is directly related to mean annual temperature range. The range for the Texas Valley Region is 27.1°F which is 11.6°F less than the Interior Texas Region.

This variation in mean annual temperature range is reflected in continentality values. Since much of the Texas Valley Region is near the Gulf of Mexico, less continentality is noted; hence, a smaller mean annual temperature range is evident. These smaller continentality values are observed on Oliver's index continentality map (see Figure 9).

The southern one-half of the Texas Valley Region has values which are less than 6, but the Interior Texas Region has values which range from greater than 6 to over 8 in southern Oklahoma.

Air Masses — mT and mP-mT

The maximum mean monthly temperatures for the Texas Valley Region and the Interior Texas Region are similar. July is the warmest month in the Interior Texas Region with a mean temperature of 84.2°F, whereas in the Texas Valley Region July and August have a mean temperature of 85.1°F. However, mean temperatures during the winter months are totally different. For example, the mean January temperature for the Texas Valley Region is 58.0°F. This is 12.5°F warmer than the mean January temperature in the Interior Texas Region. From inspection of air mass dominance maps, a partial explanation of this difference is evident (see Figures 24-35). From November through March, warm mT and/or mP-mT air masses prevail in the Texas Valley Region. During this same period of time, mP air mass dominates most or all of the Interior Texas Region which results in cooler air during the winter season and a lower extension of the mean climograph along the temperature axis.

Mean Annual Sky Cover

One explanation for similar summer season temperatures for the Texas Valley Region and the Interior Texas Region, at a higher latitude, is mean annual sky cover. When mean annual sky cover is averaged for the 3 first-order weather stations in the Texas Valley Region, a higher value of 5.6 compared with the 4.9 value calculated for all first-order weather stations in the Interior Texas Region results. Furthermore, higher mean monthly sky cover values were consistently noted for the Texas Valley Region weather stations throughout the year.[20] Therefore, during the summer season, the higher mean sky cover would reduce insolation sufficiently in the Texas Valley Region to suppress the mean monthly temperatures and lower the position of the upper portion of the mean climograph along the temperature axis.

Two aspects of the mean climograph were not previously examined with respect to genesis due to the nature of climatic factor components used in this investigation. Firstly, a sharp-angled precipitation feature is obvious during the month of May. This is governed by the summer decline in precipitation correlative to the development of an upper-air ridge which dampens precipitation. This feature was discussed relative to the Interior Texas Region. Secondly, the primary precipitation maxima occurs in September instead of May as is the case in the Interior Texas Region. One explanation for this is the occurrence of tropical storms from June to October. In the Corpus Christi area, severe tropical storms average about 1 every 10 years and affects the rainfall totals during this period.[21] This added precipitation is most likely the primary reason for the sharp-angled feature pointed away from the temperature axis during September.

In summary, the mean climograph for the Texas Valley Region is unique from the Interior Texas Region due to the following characteristics: (1) a relatively short mean climograph along the temperature axis due to

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[20] Local Climatological Data -- For all Texas weather stations within the Texas Valley Region and Interior Texas Region.

[21] Local Climatological Data -- Corpus Christi, Texas, 1964.

low continentality values in the Texas Valley Region as a result of its close proximity to the Gulf of Mexico; (2) the lower portion of the mean climograph is positioned high along the temperature axis due to mT and mP-mT air mass dominance during the winter season; and (3) a relatively low position of the upper portion of the mean climograph compared with the Interior Texas Region, located at a higher latitude, due to higher mean sky cover values.

Western Gulf Coastal Region - Region 14

The Western Gulf Coast Region encompasses the southeastern portion of Texas. It extends from the Gulf of Mexico northwards to just beyond Austin and from slightly west of Victoria eastwards to near the Texas-Louisiana border (see Figure 94). This climatic region consists of 4 first-order and 3 test weather stations (see Apppendices VIII and IX). The Western Gulf Coast Region is characterized as warm and moist. The mean temperature for August, the warmest month, is 83.4°F while the coolest month of January has a mean temperature of 53.4°F. Variation in mean monthly precipitation is not large. However, the variation which does occur is quite irregular throughout the year. According to Trewartha, this region contains such a variety of profiles that homogeneity in the annual march of precipitation is lacking.[22] September represents the wettest month with 4.24 inches of rain, but July receives 4.16 inches, May receives 4.01 inches, and December receives 3.92 inches. March is the driest month of the year with 2.80 inches of rain. The total annual rainfall for the Western Gulf Coastal Region is 43.28 inches.

[22]Trewartha, op. cit., p. 296.

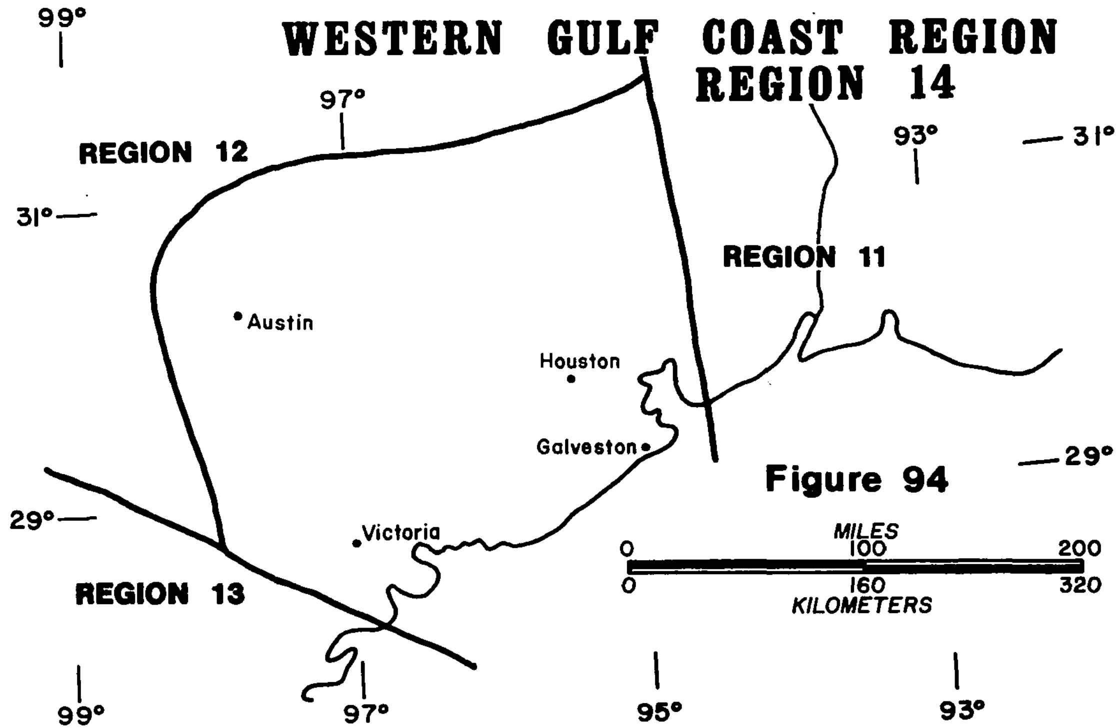
WESTERN GULF COAST REGION
REGION 14
REGION 12
REGION 11
REGION 13
Austin
Houston
Galveston
Victoria
99°
97°
95°
93°
31°
29°
MILES
0
100
200
0
160
320
KILOMETERS

Figure 94

The uniqueness of the mean climograph is observed in its high position and relatively short length along the temperature axis (see Figure 95). In addition, the mean climograph stands rather vertical with respect to the precipitation axis despite its irregular annual march of precipitation. This lack of homogeneity in the precipitation profile creates 4 separate "openings" within the mean climograph's framework.

A moderately high negative continental storm track value is observed for the Western Gulf Coast Region compared with a moderately low negative value for the Interior Texas Region; a low negative solar radiation receipt value was calculated for the Western Gulf Coast Region compared with a low positive value for the Interior Texas Region; and a moderately high negative maritime cloud variability value was calculated for the Western Gulf Coast Region compared with a moderately low negative value for the Interior Texas Region (see Table 43).

From an examination of mean climograph differences, the following climatic factor components are observed as significant between the Western Gulf Coast Region and the Interior Texas Region: (1) latitude -- with respect to the high position of the mean climograph along the temperature axis; (2) continentality -- with respect to the length of the mean climograph along the temperature axis; (3) mP-mT and mT air masses -- with respect to the high position of the lower portion of the mean climograph along the temperature axis; (4) mean annual sky cover -- with respect to the distance of the mean climograph away from the temperature axis, particularly during the summer season; and (5) total number of lows and their variability -- with respect to the vertical

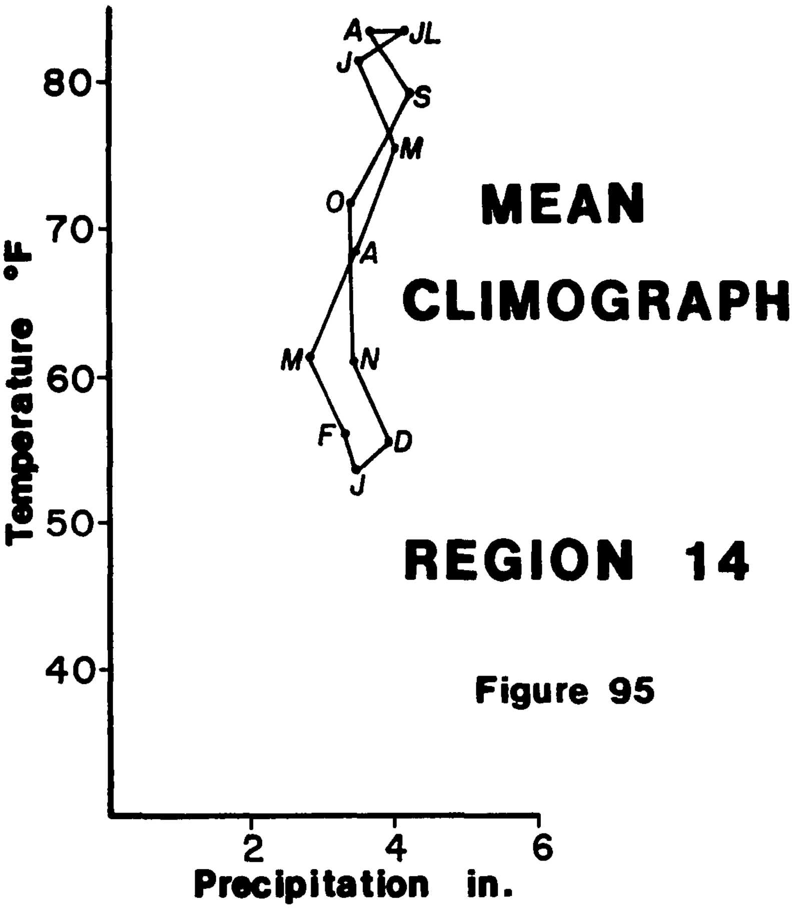

Figure 95

	J	F	M	A	M	J	
Temp. ^oF	53.4	56.0	61.2	68.4	75.4	81.3	
Precip. In.	3.46	3.32	2.80	3.42	4.01	3.51	Average
	J	A	S	O	N	D	69.1°
Temp. ^oF	83.3	83.4	79.0	71.5	60.7	55.4	43.28"
Precip. In.	4.16	3.62	4.24	3.39	3.43	3.92	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 43

CLASSIFICATION COEFFICIENTS FOR THE WEST GULF COAST REGION AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 14	12	11	13	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-6.1	-3.9	-4.3	-6.8	(2.2)
(2) Solar Radiation Receipt	-1.7	+1.3	-2.4	-1.2	(3.0)
(3) Winter-time High Pressure System	-2.0	-1.5	- .6	-2.6	1.4
(4) Ocean Currents	+2.1	+2.1	+1.3	+2.7	.8
(5) Maritime Cloud Variability	-7.1	-4.1	-5.3	-8.3	(3.0)
(6) Continental Moisture Index	-1.8	-1.1	-2.1	-1.4	.7
(7) Wind Strength Variability	+1.9	+ .8	+ .6	+2.7	1.3

Names of Above Climatic Regions

14 West Gulf Coast Region
12 Interior Texas Region
11 Humid Southeast Region
13 Texas Valley Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

orientation of the mean climograph to the precipitation axis from increased winter season precipitation compared with the Interior Texas Region.

Latitude, Continentality, and mT and mP-mT Air Masses

A comparison of mean climographs for the Western Gulf Coast Region and Interior Texas Region reveals 3 important features with respect to their position along the temperature axis: (1) the <u>mean</u> position of the mean climograph for the Western Gulf Coast Region is higher; (2) the lower portion of the mean climograph for the Western Gulf Coast Region is considerably higher; and (3) the length of the mean climograph for the Western Gulf Coast Region is shorter.

The primary reason for the higher <u>mean</u> position of the mean climograph along the temperature axis for the Western Gulf Coast Region is latitude. All first-order weather stations except San Antonio are at a higher latitude than any first-order weather station in the Western Gulf Coast Region. This latitudinal difference in location is reflected in a mean annual temperature for the Western Gulf Coast Region which is 3.8°F higher than the Interior Texas Region.

The considerably warmer cool season temperatures in the Western Gulf Coast Region are partially explained by air mass dominance. For example, the mean November temperature for the Western Gulf Coast Region is 60.7°F compared with 54.3°F for the Interior Texas Region. During March, April, and November, most of the Western Gulf Coast Region is dominated by warm mT or mP-mT air masses (see Figures 24-35). However, during these same months, the Interior Texas Region is dominated by cooler mP air mass. By and large, these differences in air mass dominance over the 2 climatic regions account for the higher position of the mean climograph during part of the cooler season for the Western Gulf Coast Region.

The mean annual temperature range for the Western Gulf Coast Region is 30.0°F. This is 8.7°F less than the Interior Texas Region. With a small mean annual temperature range, a shorter mean climograph length along the temperature axis is displayed. The difference in mean climograph length is attributed to the degree of continentality in the 2 climatic regions. Since the Western Gulf Coast Region is near the Gulf of Mexico, continentality index values are lower than those inland over the Interior Texas Region (see Figure 9).

Mean Annual Sky Cover

Mean annual precipitation for the Western Gulf Coast Region is 43.28 inches. This is considerably more than the 27.41 inches recorded in the adjacent Interior Texas Region. Because of the greater annual rainfall, all months represented on the mean climograph, with the exception of May, are positioned farther away from the temperature axis than are corresponding months on the Interior Texas Region's mean climograph. This is particularly noticeable during the winter and summer seasons. One possible explanation for this greater rainfall in the Western Gulf Coast Region is higher mean annual sky cover (see Table 44). The higher sky cover values in the Western Gulf Coast Region generally hold throughout the year. This may be of particular import in explaining the large difference in monthly rainfall during the summer season. For instance, 2.12 inches more rain is received in the Western Gulf Coast Region during July than in Region 12. During

TABLE 44[a]

MEAN ANNUAL AND JULY SKY COVER FOR THE WESTERN GULF COAST REGION AND INTERIOR TEXAS REGION

Weather Station	Mean Annual Sky Cover	July Sky Cover	Weather Station	Mean Annual Sky Cover	July Sky Cover
		Western Gulf Coast Region			
Austin	5.5	4.7	Houston	4.8	4.5
Victoria	5.8	4.6			
		Interior Texas Region			
Midland	4.4	4.6	Abilene	4.8	4.5
San Angelo	4.5	4.1	Wichita Falls	4.6	4.0
Fort Worth	5.0	3.9	Dallas	5.1	4.3
Waco	5.2	4.3	San Antonio	5.6	4.3

[a]Source: Author's calculations and Local Climatological Data with Comparative Data, 1964.

this month, a higher mean sky cover is recorded for all weather stations except San Antonio which is in the extreme southern section of the Interior Texas Region. A similar situation exists during the winter months when considerably more rain is recorded for the Western Gulf Coast Region.

Total Number of Lows and Their Variability

The mean climograph for the Western Gulf Coast Region is vertical with respect to the precipitation axis. This is distinctly dissimilar to climatic regions immediately to the west; i.e., the Texas Valley Region and the Interior Texas Region. Winter months in the Interior Texas Region are relatively dry and the mean climograph is close to the temperature axis. This contrasts to the Western Gulf Coast Region in which the winter months receive as much rain as does any other season. One explanation may be total number of lows and, especially, their annual distribution.

Total number of lows and their annual distribution were examined within two 5^{o} latitude by longitude grid cells. One grid cell included all first-order weather stations in the Interior Texas Region, except Midland and San Angelo, and Austin which was classified in the Western Gulf Coast Region. The other grid cell included all first-order weather stations in the Western Gulf Coast Region, except Austin and the Texas Valley Region. Apparently, a greater frequency of lows occur over the Interior Texas Region for the 20-year period of records, but by a <u>small</u> margin—119 versus 99.[23] Furthermore, 2 more lows were counted

[23]Klein, <u>op</u>. <u>cit</u>., pp. 23-34.

in December over the Western Gulf Coast Region and Texas Valley Region grid cell—11 versus 9.[24] These values are rather similar, but because of the proximity of the Western Gulf Coast Region to the Gulf of Mexico, normally more precipitation results during the passage of each disturbance. According to Trewartha, these disturbances are at their maximum intensity over the Gulf states in December through March and because of their proximity of the moisture source provided by the Gulf of Mexico, the individual winter disturbance yields more precipitation than its counterpart farther north.[25]

In summary, the mean climograph for the Western Gulf Coast Region is unique from the Interior Texas Region because of the following characteristics: (1) a higher mean position along the temperature axis due to a lower latitude; (2) a higher position of the lower portion of the mean climograph due to mT and mP-mT air masses; (3) a shorter mean climograph axis because of smaller continentality index values; (4) a greater distance from the temperature axis reflecting a greater annual rainfall due to higher mean annual sky cover; and (5) a vertical mean climograph axis due to a relatively high occurrence of low pressure disturbances, particularly during December, which normally yields more precipitation than disturbances farther north.

Florida Region - Region 15

The Florida Region includes most of the peninsula of Florida. This region extends from southern Georgia southwards, excluding the Florida Panhandle, to the southern boundary south of Cape Kennedy on the

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[24]*Ibid.*, pp. 23-34.

[25]Trewartha, *op. cit.*, p. 298.

East Coast to Cape Sable on the southern tip of the state (see Figure 96). There are 6 first-order and 8 test weather stations (see Appendices VIII and IX). Mild to hot temperatures characterize the Florida Region. The warmest month is August with a mean temperature of 81.9°F while January, the coolest month, has a mean temperature of 60.9°F. With such a mild winter season, a small mean annual range in temperature occurs. Seasonality in the annual march of precipitation highlights this climatic region. The mean annual rainfall is 52.80 inches, but 4 months, June through September, each receive more than 7.00 inches. Late autumn and winter are driest. November, the driest month, receives only 1.67 inches of rain.

The distinctiveness of the mean climograph for the Florida Region is observed in its short length, high position, and long diagonal orientation along the temperature axis compared with climatic regions north and west (see Figure 97). Furthermore, a tight clustering of summer season values, which indicate similar temperature and precipitation, form a small "opening" in the upper end of the mean climograph compared with the West Palm Beach Region. An "opening" in the lower portion of the mean climograph appears transitional in terms of area between climatic regions immediately to the north and west, and Region 17 to the south. This feature is formed from a relatively wet March and dry November.

Relatively large classification coefficient differences between the Florida Region and Regions 11, 16, and 17 were observed (see Table 45). More specifically, a high negative continental storm track value was calculated for the Florida Region compared with a

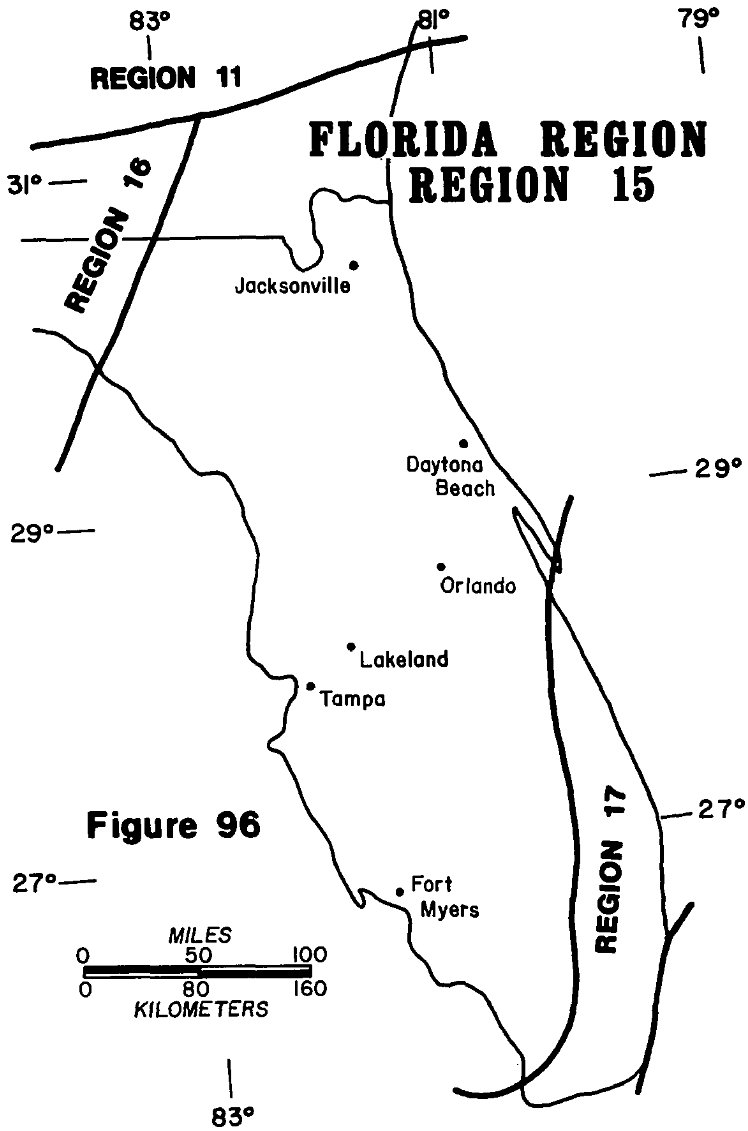
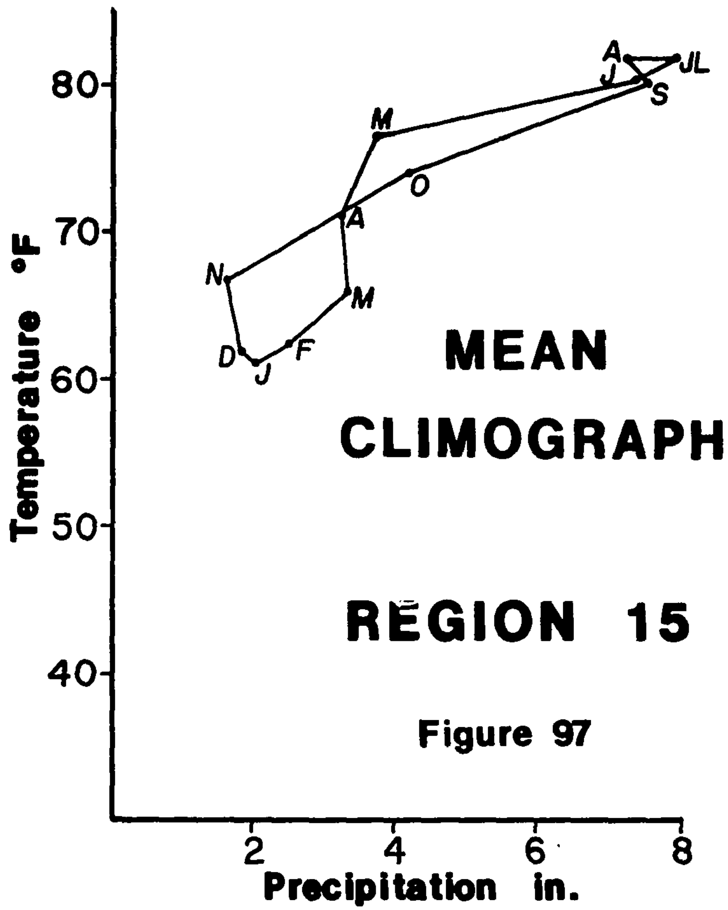

83°
81°
79°
REGION 11
FLORIDA REGION
REGION 15
31°
REGION 16
Jacksonville
Daytona
Beach
29°
29°
Orlando
Lakeland
Tampa
27°
27°
Fort
Myers
REGION 17
MILES
0
50
100
0
80
160
KILOMETERS
83°

Figure 96



	J	F	M	A	M	J	
Temp. °F	60.9	62.4	65.9	71.0	76.4	80.4	
Precip. In.	2.06	2.52	3.37	3.23	3.73	7.34	Average
	J	A	S	O	N	D	71.9°
Temp. °F	81.6	81.9	80.1	74.3	66.6	61.8	52.80"
Precip. In.	7.96	7.24	7.58	4.22	1.67	1.88	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 45[a]

CLASSIFICATION COEFFICIENTS FOR THE FLORIDA TYPE AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 15	11	17	16	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-8.1	-4.1	-9.1	-5.8	(4.0)
(2) Solar Radiation Receipt	-3.8	-2.1	-3.8	-3.0	1.4
(3) Winter-time High Pressure Systems	-2.6	- .6	- .8	-1.0	2.0
(4) Ocean Currents	- .5	+1.3	- .6	+2.0	(2.5)
(5) Maritime Cloud Variability	-8.5	-5.3	-12.2	-8.0	(3.7)
(6) Continental Moisture Index	-1.8	-2.1	-2.5	-2.4	.7
(7) Wind Strength Variability	+.9	+.6	+1.8	+1.1	.9

Names of Above Climatic Regions

15 Florida Region
11 Humid Southeast Region
17 West Palm Beach Region
16 Eastern Gulf Coast Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

moderately low negative value for the Humid Southeast Region. A low negative ocean current value is observed for the Florida Region compared with a low positive value for the Eastern Gulf Coast Region. Finally, a high negative maritime cloud variability value was calculated for the Florida Region compared with a higher negative value for the West Palm Beach Region.

From an inspection of the mean climograph differences, the following climatic factor components are observed as significant between the Florida Region and Regions 11, 16, and 17: (1) latitude — with respect to the intermediate position of the mean climograph along the temperature axis compared with climatic regions to the north and south; (2) ocean currents and continentality — with respect to the length of the climograph along the temperature axis; (3) mT air mass -- with respect to the high position of the lower part of the mean climograph compared with climatic regions immediately to the north and west and the similarity of summer month values, all with high temperatures and precipitation values; (4) variability of number of lows and mean sky cover — with respect to the "opening" in the lower portion of the mean climograph created by a relatively moist March and dry November.

Latitude

The Florida Region is between the Humid Southeast Region to the north and the West Palm Beach Region. These various locations are reflected in their mean annual temperature. The largest difference is observed between the Florida Region and the Humid Southeast Region due to a relatively large north-south extent of the latter region. The mean annual temperature for the Florida Region is 71.9°F. This is 8.1°F warmer than the mean annual temperature for the Humid Southeast Region. This marked difference is readily observed in the mean heights of the climographs along the temperature axis.

Continentality and Ocean Currents

The length of the mean climograph along the temperature axis is noticeably shorter for the Florida Region than Regions 11 and 16. Numerically, the mean annual range in temperature specifies the relative lengths. The range for the Florida Region is 15.7^{o}F which is 18.9^{o}F less than the Humid Southeast Region and 12.2^{o}F less than the Eastern Gulf Coast Region.

Two explanations to these mean annual temperature range variations are continentality and ocean current effect. Smallest continentality values in the coterminous United States, excluding the Pacific Coast, are observed throughout the peninsula of Florida. From Oliver's index continentality map, values less than 4.0 were calculated for all first-order weather stations in the Florida Region except for Jacksonville (see Figure 9). These continentality values increase north and northwestwards so that highest values of over 8.0 are common in the northern section of the Humid Southeast Region.

A substantial difference of mean annual temperature range, and, hence, the length of the mean climograph along the temperature axis, is also noted between the Florida Region and the Eastern Gulf Coast Region. The Florida Region's mean annual temperature range is 6.9^{o}F less. Again, latitude is one plausible explanation for this difference since all first-order weather stations in the Florida Region are at lower latitudes than those of Region 16. However, the largest mean monthly temperature discrepancies between these regions occur during the cooler season, and, therefore, the warm Gulf Stream may modify cool season temperatures to a greater degree in the Florida Region. From the ocean current factor scores, all first-order weather stations in the central and eastern coastal region of peninsula Florida are significantly influenced by ocean currents (see Figure 44). The distribution of this influence is also detected in January ocean current raw data. Therefore, cool season temperature modification may be stronger in the Florida Region. It should be remembered, however, that any ocean current effect from the Gulf of Mexico on adjacent coastal areas was not considered in this investigation. Since warm waters of the South Equatorial Current move through this body of water, some oceanic influence on adjacent weather stations is surmised.[26]

mT Air Mass

In addition, the lower portion of the mean climograph extends farther down along the temperature axis for the Humid Southeast Region than the Florida Region. Another explanation for this occurrence in addition to ocean current effect is mT air mass dominance. During April, October, and November, all or most of the Florida Region is dominated by mT air mass. However, little or no mT air prevails during these months in the Humid Southeast Region. During these same months, mean monthly temperatures for the Florida Region are 7.7°F, 9.1°F and 13.0°F warmer, respectively. These warmer mean monthly temperatures are distinctly evident in their higher positions along the temperature axis.

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[26]Donn, _op_. _cit_., p. 438.

From June through September, mT air mass dominates over much of the eastern half of the United States which includes the Florida Region. During this time over the Florida Region, the mT air extends aloft as a deep current of humid tropical air associated with an upper air trough. The activity of westerlies have diminished and the wind aloft backs from northwest to southwest or southeast. This combination produces abundant precipitation of the shower type frequently accompanied by thunder and lightning.[27] This explains the tight clustering of temperature-precipitation plots in the upper portion of the mean climograph from June through September.

Variability of Mean Annual Sky Cover and Total Number of Lows

The driest month of the year in the Florida Region occurs in November with 1.67 inches of rain. March is the wettest cool season month with a total of 3.37 inches of precipitation. Because of this variation in rainfall, a distinct "opening" in the lower portion of the mean climograph is observed. This "opening" is intermediate in area compared with climatic regions to the north and south. Partial causes related to this "opening" are observed in the monthly variability of mean annual sky cover and variability of total number of lows.

Little change in standard deviation values of mean annual sky cover is evident between the Florida Region and the West Palm Beach Region. However, mean November sky cover is generally higher for the 2 first-order weather stations in the West Palm Beach Region (see Table 46). The smaller mean November sky cover values for the Florida Region would

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[27]Trewartha, op. cit., p. 300.

TABLE 46[a]

MEAN NOVEMBER SKY COVER FOR THE FLORIDA REGION
AND WEST PALM BEACH REGION

West Palm Beach Region			
West Palm Beach	5.7	Miami	5.2
Florida Region			
Jacksonville	5.2	Daytona Beach	5.0
Orlando	4.9	Lakeland	4.7
Tampa	4.9	Fort Myers	4.6

[a]Source: Local Climatological Data with Comparative Data, 1964.

at least indicate less chance for precipitation. This conforms with the closeness of this portion of the mean climograph to the temperature axis compared with the West Palm Beach Region's mean climograph.

Variability of total number of lows is a significant climatic component which partially explains the relatively drier March in the Florida Region that, in addition to November, forms the intermediate sized "opening" in the lower portion of the mean climograph. This is observed by comparing the monthly frequency of low pressure disturbances over a 20-year period of 5^{o} latitude by longitude grid cells. Two grid cells are within the southeastern two-thirds of the Humid Southeast Region and one cell covers the peninsula of Florida which includes the Florida Region. The standard deviation of lows in the Humid Southeast Region grid cells is higher, 3.37 and 1.80, than the value counted for the grid cell which includes the Florida Region, 1.76.[28] However, similar values between two of the cells raise some doubt as to the usefulness of this climatic factor component in discriminating between the two regions.

But, if the month of March is examined, a smaller frequency of lows during the 20-year period is noted for the Florida Region. In the Florida Region, approximately 5 disturbances were counted for March compared with 12 and 18 lows for the two grid cells in the Humid Southeast Region. This reflects the lack of westerly circulation during the winter and early spring over peninsular Florida during which time decreased precipitation is observed. The well-developed winter

[28] Author's calculations.

depressions moving eastward in the westerlies are too distant north from the Florida Peninsula to produce much precipitation.[29]

However, because the Florida Region is farther north than the West Palm Beach Region, more precipitation is recorded in the former region; hence, the intermediate "opening" in the lower portion of the mean climograph.

In summary, the mean climograph for the Florida Region is unique from Regions 11, 16, and 17 because of the following characteristics: (1) an intermediate mean position of the mean climograph compared to climatic regions to the north and south because of its latitude; (2) the short length and high position of the lower portion of the mean climograph because of low continentality index values and possibly some January ocean current effect; (3) the high position of particularly the months of April, October, and November and the high, but similar, precipitation values during the summer months because of mT air mass dominance; (4) an intermediate size "opening" in the lower portion of the mean climograph because of less sky cover during November compared with the West Palm Beach Region and fewer lows during March compared with the Humid Southeast Region.

Eastern Gulf Coast Region - Region 16

The Eastern Gulf Coast Region includes the Florida Panhandle, extreme southwestern part of Georgia, and the southern portion of Alabama (see Figure 98). This climatic region consists of 4 first-order and 3 test weather stations (see Appendices VIII and IX). The Eastern

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[29]Trewartha, *op. cit.*, p. 303.

EASTERN GULF COAST REGION
REGION 16

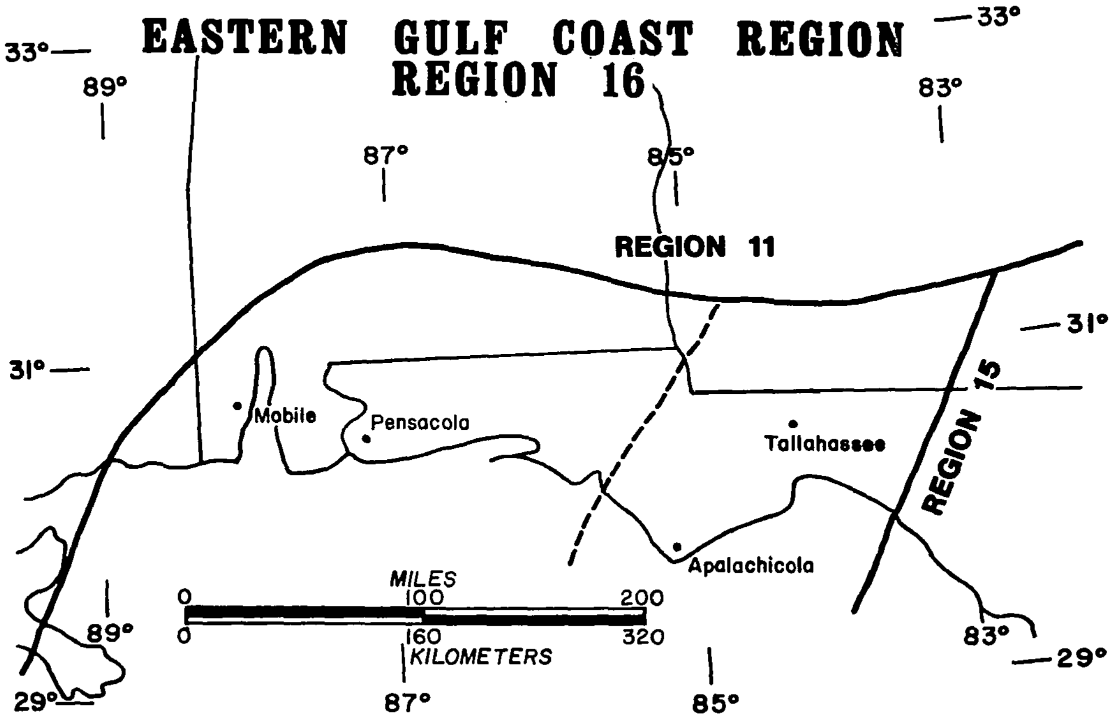
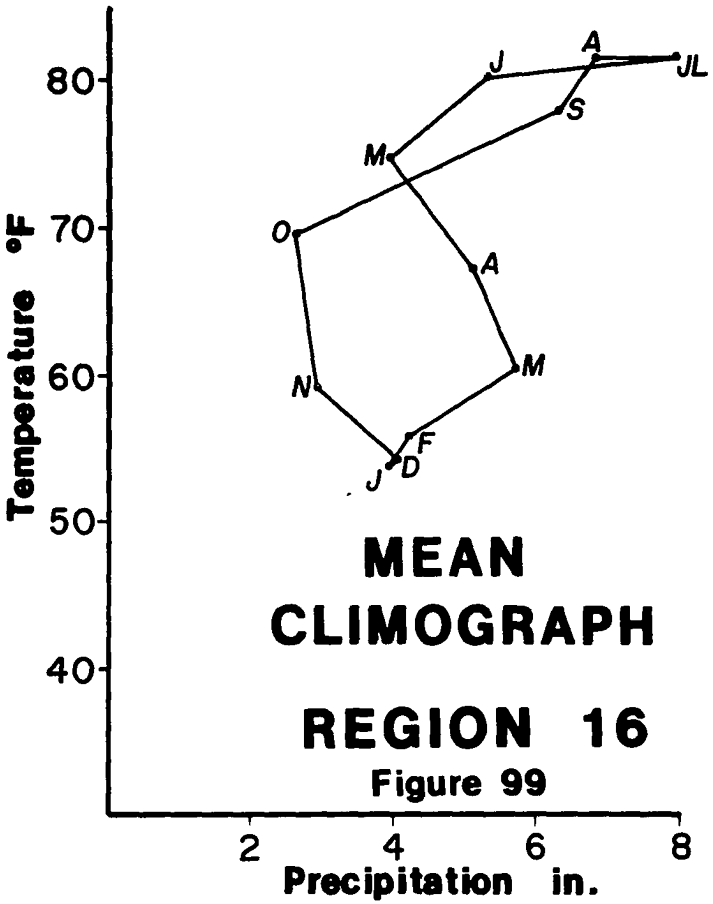


Figure 98

Gulf Coast Region is characterized by warm summers and mild winters. July, the warmest month, is 0.1°F warmer than August and has a mean temperature of 81.6°F. January is the coolest month with a mean temperature of 53.7°F. This climatic region is moist throughout the year with a mean total rainfall of 59.29 inches. Pronounced primary and secondary maxima are conspicuous during July and March with 7.99 and 5.73 inches of rain, respectively. October is the driest month with only 2.64 inches of precipitation.

Many features of the mean climograph for the Eastern Gulf Coast Region suggest that it is transitional to the Humid Southeast Region and the Florida Region. For example, the height and length of the mean climograph along the temperature axis are intermediate to the climographs for Regions 11 and 15. Furthermore, the secondary precipitation maxima during March is observed as a primary maxima in the Humid Southeast Region but becomes significantly less accented in the Florida Region. By combining these transitional features, a distinctively different mean climograph configuration results (see Figure 99).

Realtively low classification coefficient differences were calculated between the Eastern Gulf Coast Region and adjacent climatic regions (see Table 47). The largest differences are observed for maritime cloud variability in which a high negative value was calculated for the Eastern Gulf Coast Region compared with a moderately high negative value for the Humid Southeast Region. A low positive ocean current value was calculated for the Eastern Gulf Coast Region compared with a low negative value for the Florida Region. Finally, a moderately high negative continental storm track value is observed for the



	J	F	M	A	M	J	
Temp. °F	53.7	55.6	60.3	67.1	74.6	80.4	
Precip. In.	3.93	4.24	5.73	5.18	3.98	5.36	Average
	J	A	S	O	N	D	68.0°
Temp. °F	81.6	81.5	78.0	69.6	59.1	54.2	59.29"
Precip. In.	7.99	6.84	6.35	2.64	2.97	4.08	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 47[a]

CLASSIFICATION COEFFICIENTS FOR THE EASTERN GULF COAST AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 16	15	11	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-5.8	-8.1	-4.3	(2.3)
(2) Solar Radiation Receipt	-3.0	-3.8	-2.4	.8
(3) Winter-time High Pressure Systems	-1.0	-2.6	- .6	1.6
(4) Ocean Currents	+2.0	- .5	+1.3	(2.5)
(5) Maritime Cloud Variability	-8.0	-8.5	-5.3	(2.7)
(6) Continental Moisture Index	-2.4	-1.8	-2.1	.6
(7) Wind Strength Variability	+1.1	+ .9	+ .6	.5

Names of Above Climatic Regions

16 Eastern Gulf Coast Region
15 Florida Region
11 Humid Southeast Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

Eastern Gulf Coast Region compared with a high negative value for the Florida Region. To avoid repetition, the ocean current effect with respect to the Florida Region is discussed elsewhere in this chapter.

From an examination of mean climograph differences, the following climatic factor components are observed as significant between the Eastern Gulf Coast Region and the Florida Region: (1) latitude — with respect to the mean height of the climograph along the temperature axis; (2) continentality — with respect to the length of the mean climograph along the temperature axis; (3) mT air mass — with respect to the height of the lower portion of the mean climograph along the temperature axis; and (4) variability of total number of lows — with respect to the pronounced sharp-angled feature for March which represents a secondary precipitation maxima. The following climatic factor components are significant in distinguishing the mean climograph of the Eastern Gulf Coast Region from the Humid Southeast Region: (1) latitude — with respect to the mean climograph position along the temperature axis; (2) mP and mT air masses — with respect to the height of the lower portion of the mean climograph along the temperature axis; and (3) variability of mean sky cover — with respect to the pronounced, sharp-angled feature during July which represents the primary precipitation maxima.

Latitude and mP and mT Air Masses

The Eastern Gulf Coast Region is at an intermediate latitude between the Humid Southeast Region and the Florida Region, which is reflected in its mean annual temperature of 68.0°F. This temperature is 4.2°F higher than the mean annual temperature calculated for the

Humid Southeast Region and 3.9°F lower than the Florida Region. These differences in mean annual temperature are evident in the mean position of the climograph along the temperature axis, i.e., the mean position of the climograph for the Eastern Gulf Coast Region is higher than the Humid Southeast Region and lower than the mean climograph of the Florida Region. However, because of similar mean warm season temperatures, the upper portion of all 3 mean climographs are positioned at approximately the same height along the temperature axis; most of the change in height is viewed in the lower portion of the mean climograph.

One explanation for the north-south change in cool seasonal temperatures for these climatic regions is air mass dominance. From December through February, all or most of the Eastern Gulf Coast Region is dominated by mP air mass (see Figure 24-35). This air is cooler than the mT transition air mass observed to the south in the Florida Region. On the other hand, warmer mT and mT transition air masses dominate the Eastern Gulf Coast Region during October, November, March, and April while the Humid Southeast Region remains under the influence of cooler mP air mass. Thus, the air mass distribution for these climatic regions during the cooler season indicates that cooler temperatures are expected to the north of the Eastern Gulf Coast Region and warmer temperatures to the south; hence, an intermediate position of the lower portion of the mean climograph along the temperature axis results.

Continentality

Another significant feature of the mean climograph for the Eastern Gulf Coast Region which warrants some explanation is the length of the climograph along the temperature axis. The mean climograph for the Eastern Gulf Coast Region is longer than the climograph for the Florida Region but shorter than the climograph for the Humid Southeast Region. This intermediate length is reflected in its mean annual temperature range of 27.9°F which is 6.9°F greater than Region 15 and 6.7°F smaller than Region 11. One primary reason for this variation in mean annual temperature range is continentality. From an examination of Oliver's index continentality map, generally, values between 4 and 6 are observed for the Eastern Gulf Coast Region. However, values greater than 6 are common throughout the Humid Southeast Region and less than 4 over the Florida Region (see Figure 9).

Variability of Mean Annual Sky Cover

Primary precipitation maxima occur during July for the Eastern Gulf Coast Region and the Humid Southeast Region; however, an extended sharp-angled feature which is more distant from the temperature axis is observed on the mean climograph for the former climatic region. This more distant sharp-angled feature from the temperature axis for the Eastern Gulf Coast Region is directly related to a greater warm-season rainfall, e.g., July receives 2.75 inches more precipitation.

An explanation for this difference in warm-season rainfall between these climatic regions is evident in the variation of mean sky cover. However, little is inferred from an inspection of standard deviation values because of the similar values in both regions. But, if mean July sky cover for weather stations in each region is compared, one notices higher mean sky cover values in the Eastern Gulf Coast Region. The following mean July sky cover for weather stations along a transect from Tennessee through the Florida Panhandle illustrates this point: Nashville — 5.6; Chattanooga -- 6.0; Huntsville — 6.0; Montgomery — 6.2; and Pensacola — 6.8.[30] This depreciation in summer-season rainfall and attendant mean sky cover inland is probably associated with a decline in sea breeze influence. According to Trewartha, the summer precipitation maxima is strongest near the coast and declines inland which confirms the concept of the sea breeze as an important element making for low-level convergence during the warmer hours.[31]

Variability of Total Number of Lows

Finally, a noteworthy difference in the mean climograph configuration between the Eastern Gulf Coast Region and Florida Region is evident during March. This month represents a secondary precipitation maxima in the Eastern Gulf Coast Region and forms a pronounced sharp-angled feature which is distant from the temperature axis; only a subtle angle--hardly a precipitation maxima--is observed in the mean climograph during March for the Florida Region. The decline in the secondary precipitation maxima to a rudimental stage in the Florida Region apparently occurs from the west and north to the east and south. This is deduced from inspection of the 2 mean subregional climographs (see Figure 100). A more prominant March precipitation sharp-angled feature is noted for Subregion 16a which is in the western half of the Eastern Gulf Coast Region. During March, Subregion 16a receives 1.53 inches more precipitation than Subregion 16b.

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[30] Local Climatological Data, Tennessee, Alabama, and Florida, 1964.

[31] Trewartha, op. cit., p. 301.

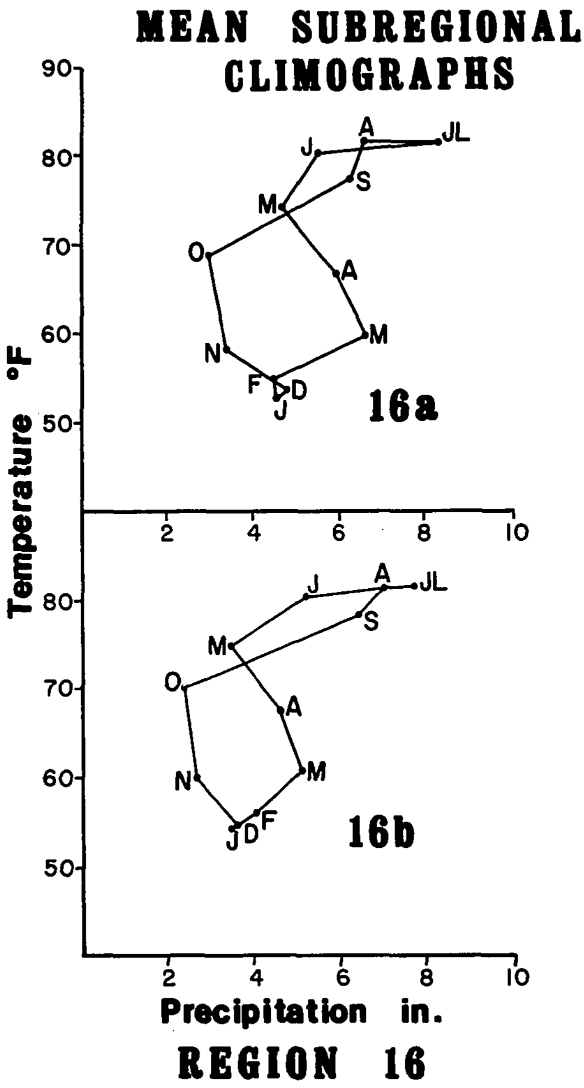

Figure 100

SOURCE: AUTHOR'S CALCULATIONS.

One reason for the decreased spring precipitation from Subregion 16a to the Florida Region is the location of the storm track. According to Trewartha, the decreased cool season precipitation in peninsula Florida as compared with that of the northern Gulf Coast may be attributed to the well-developed winter and early-spring depressions moving east and northeast from the Texas area. These are too distant from the Florida peninsula to deliver heavy precipitation.[32]

The location of the winter-early spring storm track is confirmed by examining variability of total number of lows in these regions during a 20-year period. Although standard deviation values do not appear useful in discriminating between the 2 climatic regions, much insight is provided from inspecting monthly variability of lows especially during winter and early spring. The maximum occurrence of lows over the Eastern Gulf Coast Region is during March. A decrease is observed from Subregion 16a to the Florida Region. For example, 8 lows occurred for this time period at Mobile in Subregion 16a compared with 12 lows at Tallahassee in Subregion 16b and 5 at Tampa in the Florida Region.[33] This decreased number of lows from the Eastern Gulf Coast Region to the southeast tends to substantiate the explanation for the pronounced sharp-angled feature of secondary precipitation maxima in the mean climograph for the Eastern Gulf Coast Region and the lack of the sharp-angled feature in the Florida Region.

In summary, the mean climograph for the Eastern Gulf Coast Region is distinct from the Humid Southeast Region and the Florida Region

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[32] Ibid., p. 303.

[33] Klein, op. cit., pp. 23-34.

because of the following characteristics: (1) an intermediate position of the mean climograph along the temperature axis, particularly in the lower portion, compared with the Humid Southeast Region and Florida Region because of latitudinal location and mP and mT air mass dominance during the cool season; (2) an intermediate length of the mean climograph compared with Regions 11 and 15 due to continentality; (3) a pronounced primary precipitation maxima which forms a sharp-angled feature in the mean climograph for July due to greater mean sky cover than the Humid Southeast Region; (4) a pronounced secondary precipitation maxima sharp-angled feature in the mean climograph for March because of the greater number of lows during this time of the year compared with the Florida Region.

West Palm Beach Region - Region 17

The West Palm Beach Region includes a narrow strip of land which extends along the east coast of Florida from north of West Palm Beach southwards to include Miami and then slices westwards to encompass most of the southern tip of the state (see Figure 101). This small climatic region includes only 2 first-order and 3 test weather stations (see Appendices VIII and IX). It is characterized by mild winter temperatures and extremely warm summer temperatures. August is the warmest month of the year and therefore reflects a seasonal temperature lag from its nearness to the Atlantic Ocean. Its temperature is 82.1^{o}F. January is the coolest month with a mean temperature of 66.4^{o}F. Consequently, this climatic region's mean annual temperature range of 15.7^{o}F is low. Summer and early autumn are the seasons of dominant rainfall.

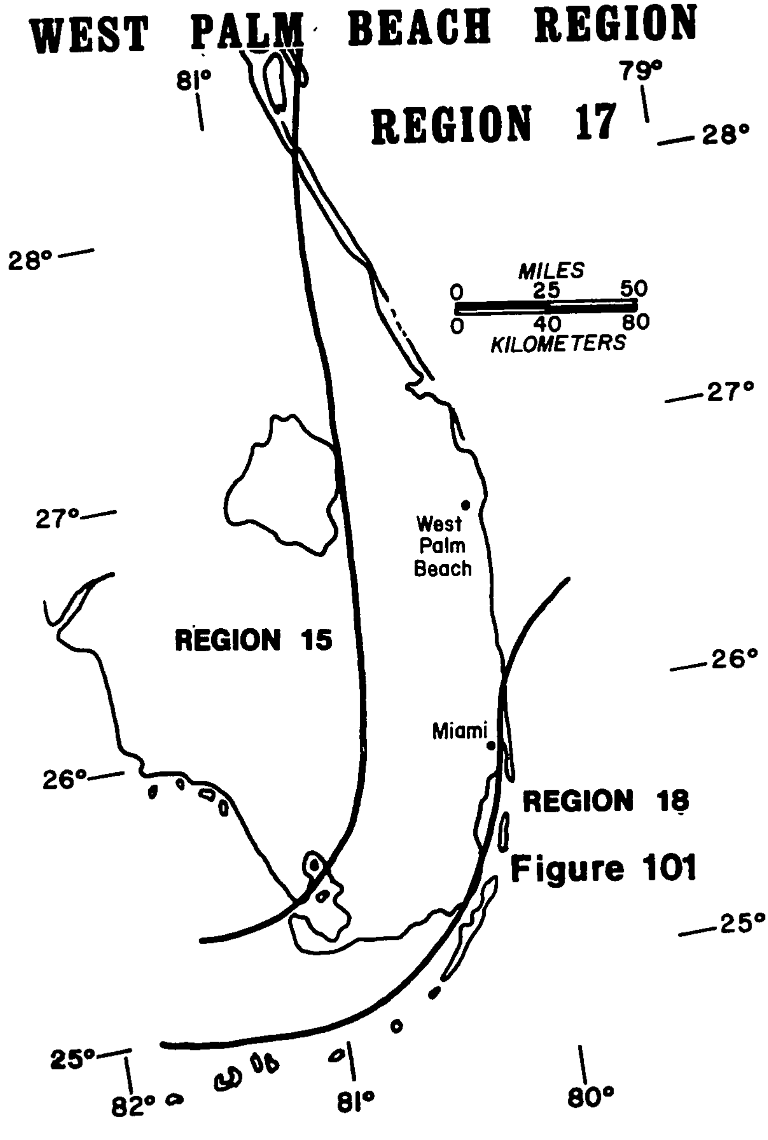

WEST PALM BEACH REGION
REGION 17
81°
79°
28°
28°
MILES
0
25
50
0
40
80
KILOMETERS
27°
27°
West
Palm
Beach
REGION 15
26°
26°
Miami
REGION 18
25°
25°
82°
81°
80°

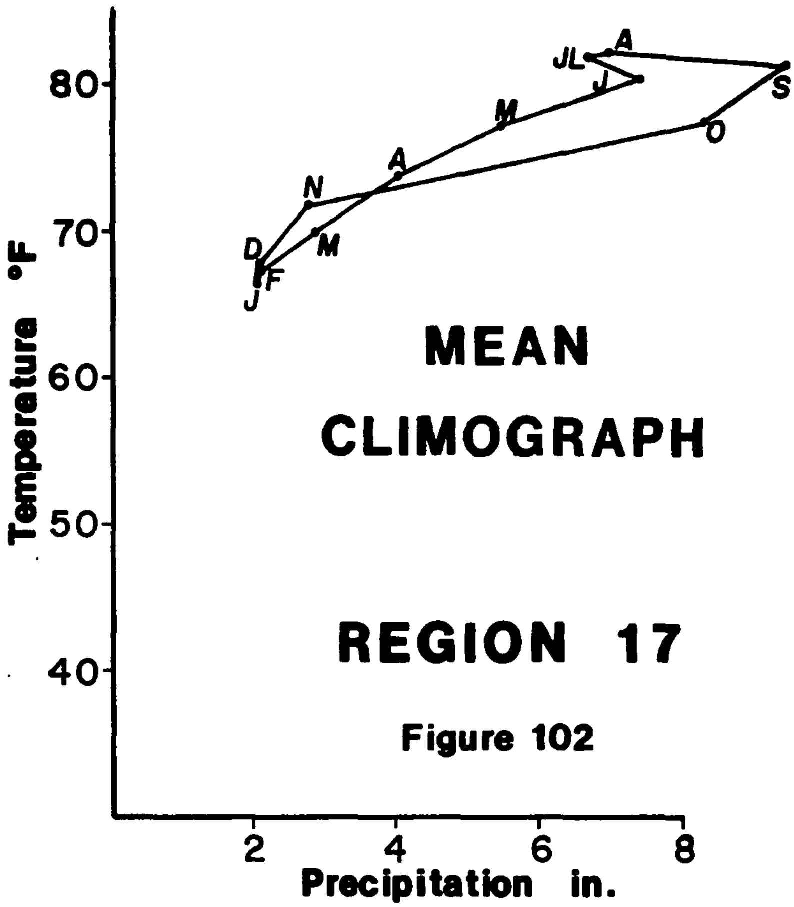
Figure 101

September, the wettest month, receives 9.44 inches of rain. In contrast, January is the driest month in which only 2.07 inches of rain falls.

The uniqueness of the mean climograph for the West Palm Beach Region is seen in its short length along the temperature axis compared with the Florida Region, but it is slightly longer than the mean climograph for the Keys Region (see Figure 102). Its shortness is directly attributed to the mild winter temperatures of the West Palm Beach Region. Furthermore, a long mean climograph along the precipitation axis from high summer season rainfall is evident. No other climatic region in the United States has more rain during September than is observed in the West Palm Beach Region.

Classification coefficient differences are not high between the West Palm Beach Region and Regions 15 and 18 (see Table 48). However, the highest difference was 3.7 for maritime cloud variability which is discussed elsewhere in this chapter to avoid repetition. Other relatively large coefficient differences include a low negative winter-time high pressure system value for the West Palm Beach Region compared with a moderately low negative value for the Florida Region and a low negative ocean current value for the West Palm Beach Region compared with a slightly higher negative value for the Keys Region.

From an examination of mean climograph differences between the West Palm Beach Region and Regions 15 and 18, the following climatic factor components are noted as significant: (1) mP-mT air mass and total number of highs — with respect to the position of the lower portion of the mean climograph along the temperature axis; and



	J	F	M	A	M	J	
Temp. °F	66.4	67.2	69.7	73.6	77.1	80.3	
Precip. In.	2.07	2.88	4.08	5.50	7.43	6.68	Average
	J	A	S	O	N	D	74.7°
Temp. °F	81.6	82.1	81.2	77.4	71.7	67.7	60.34"
Precip. In.	6.68	6.98	9.44	8.31	2.78	2.10	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 48[a]

CLASSIFICATION COEFFICIENTS FOR THE WEST PALM BEACH AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 17	15	18	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-9.1	-8.1	-9.6	1.0
(2) Solar Radiation Receipt	-3.8	-3.8	-2.6	1.2
(3) Winter-time High Pressure Systems	- .8	-2.6	-1.5	(1.8)
(4) Ocean Currents	- .6	- .5	-1.9	(1.3)
(5) Maritime Cloud Variability	-12.2	-8.5	-11.1	(3.7)
(6) Continental Moisture Index	-2.5	-1.8	-1.9	.7
(7) Wind Strength Variability	+1.8	+ .9	+2.4	.9

Names of Above Climatic Regions

17 West Palm Beach Region
18 Keys Region
15 Florida Region

[a]Source: Author's calculations.

Note: Coefficients with parentheses have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

(2) January ocean current — with respect to the slightly lower position of the lower portion of the mean climograph compared with the Keys Region.

mP-mT Air Mass and Total Number of Highs

The mean January temperature for the West Palm Beach Region is 5.5°F warmer than the Florida Region. Comparable differences exist during November, December, February, and March. As a result, the lower portion of the climograph is positioned higher along the temperature axis. One cause for the milder winter temperatures in the West Palm Beach Region is the absence of mP-mT air mass. During these winter months, mP-mT air mass prevails over a large portion of the Florida Region (see Figures 24-35). However, only mT air mass is observed during this same period of time over the West Palm Beach Region. This absence of maritime polar air during the winter season in the West Palm Beach Region results in the warmer mean monthly temperatures which are depicted on the mean climograph.

In conjunction with cooler transition polar air dominating during the winter months, the Florida Region has a greater total number of highs compared with the West Palm Beach Region. For example, at Jacksonville, a total of 153 highs were counted compared with 76 highs for the 20-year period farther south at Miami and West Palm Beach.[34] *
From a monthly standpoint, greatest discrepancies are noted during the cooler half of the year. A total of 21 highs were recorded for Jacksonville during February compared with 11 for Miami and West Palm

[34] Ibid., pp. 35-46.

*Totals are from author's calculations.

Beach.[35] The greater frequency of highs in the Florida Region are most likely associated with surges of cold continental polar air southwards which result in the lower mean monthly temperatures displayed on the mean climograph in the Florida Region compared with the warmer cool season temperatures in the West Palm Beach Region.

January Ocean Currents

Mean monthly temperatures during the winter season are somewhat cooler in the West Palm Beach Region than the Keys Region. This is observed in the lower downward extension of the mean climograph along the temperature axis. The mean January temperature for the West Palm Beach Region of 66.4°F is 3.0°F cooler than the Keys Region. One plausible explanation for this difference is January ocean currents. January ocean current indices for West Palm Beach and Miami of +7.2 and +8.1 are lower than the +10.3 and +12.1 values for Miami Beach and Key West in the Keys Region.[36] With this smaller moderating influence from the warm ocean current in the West Palm Beach Region, cooler mean winter month temperatures result.

One other feature which was not related to a climatic factor component but is noteworthy to comment on is the summer and early autumn rainfall maxima. The maximum of 9.44 inches is a high monthly value and is responsible for the long extension of the mean climograph along the precipitation axis. Furthermore, the precipitation maxima occurs in September which is unusually late in the year. An explanation for the September precipitation maxima is attributed to easterly

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[35] Ibid., p. 36.

[36] Author's calculations.

waves and hurricanes. The months of greatest frequency of tropical hurricanes are September and October. From June 1911 to 1964, winds of 60 miles per hour or more have occurred 8 times at Miami.[37]

In summary, the mean climograph for the West Palm Beach Region is unique from the Florida Region and the Keys Region because of the following characteristics: (1) a higher position of the lower portion of the mean climograph along the temperature axis compared with the Florida Region because of the absence of cooler mP-mT air mass and a lower number of high pressure cells; (2) a somewhat lower position of the lower portion of the mean climograph along the temperature axis because of a smaller moderating influence from January ocean currents than the Keys Region.

Keys Region - Region 18

The Keys Region includes the extreme southeastern and southern coastal sections of Florida in addition to the Florida Keys (see Figure 103). This small climatic region consists of 2 first-order weather stations (see Appendices VIII and IX). The Keys Region is characterized by a high mean annual temperature of 76.5°F, higher than any other climatic region, and a small annual range. August is the warmest month with a mean temperature of 83.3°F compared with 69.4°F for the coolest month of January. A moderately high annual rainfall total of 43.11 inches is considerably less than the 60.34 inches received in the West Palm Beach Region, but it has a similar summer-early autumn season dominance. September is the wettest month of the year and receives 7.05 inches of

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[37] Local Climatological Data with Comparative Data, Miami, Florida, 1964.

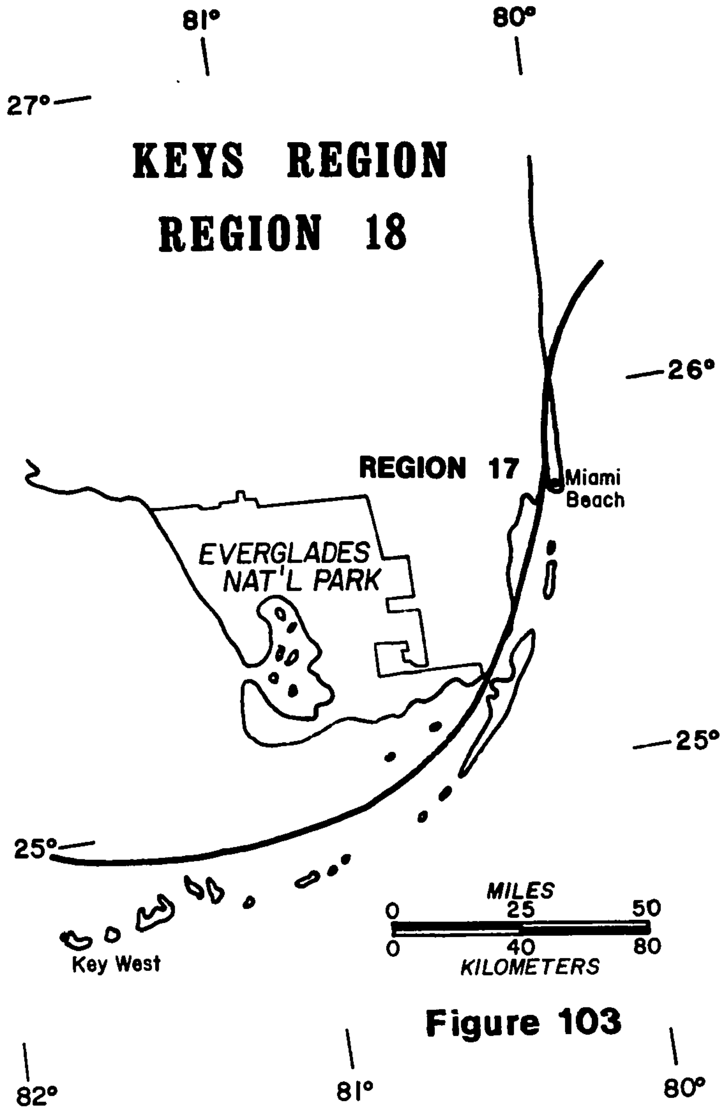
81°
80°
27°
KEYS REGION
REGION 18
26°
REGION 17
Miami Beach
EVERGLADES NAT'L PARK
25°
25°
MILES
0 25 50
0 40 80
KILOMETERS
Key West
82°
81°
80°

Figure 103

rain. The late annual occurrence of the precipitation maxima is attributed to tropical storms.[38]

Although there are obvious similarities between the mean climograph of the Keys Region and its only adjacent climatic region, the West Palm Beach Region, there are distinctive differences. The mean climograph for the Keys Region is positioned higher along the temperature axis than any other mean climograph in the United States, and the length of the mean climograph along the precipitation axis is markedly shorter than the West Palm Beach Region primarily because of less summer-early autumn rainfall (see Figure 104).

All classification coefficient differences between the Keys Region and West Palm Beach Region are low (see Table 49). The largest difference of 1.3 is observed for ocean currents, but to avoid repetition, this climatic factor is discussed elsewhere in this chapter. The next largest difference is solar radiation receipt in which the Keys Region has a slightly lower negative value of -2.6 than the West Palm Beach Region. The third climatic factor chosen is maritime cloud variability. Both climatic regions have high negative values but the Keys Region's value is somewhat lower.

From close scrutiny of mean climograph differences between the Keys Region and West Palm Beach Region, the following climatic factor components are observed as significant: (1) latitude -- with respect to the high mean position of the mean climograph along the temperature axis; and (2) mean annual sky cover and its variability -- with respect to the length of the mean climograph along the precipitation axis.

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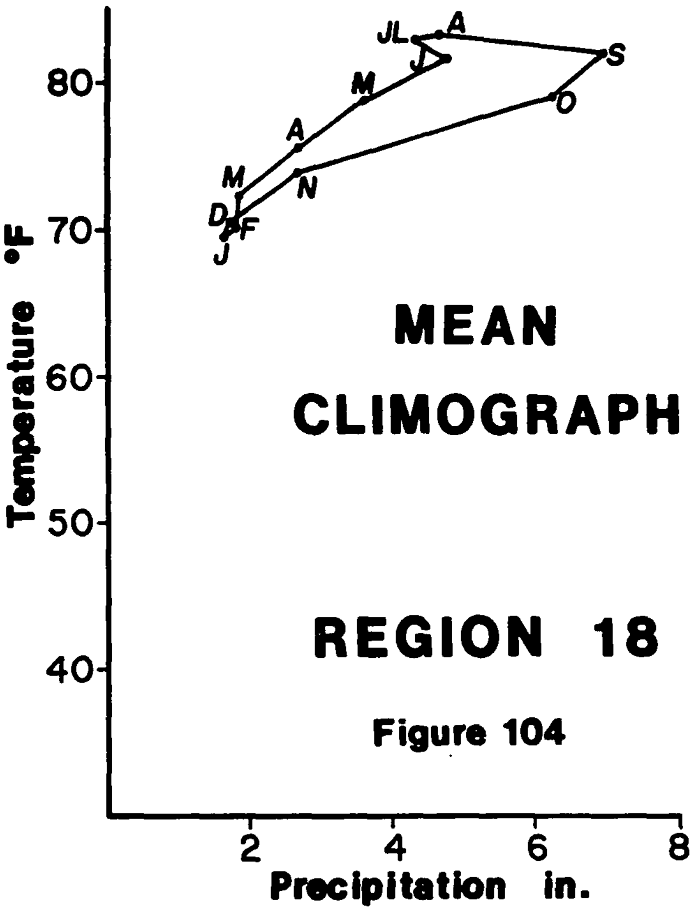
[38] Local Climatological Data with Comparative Data, Miami Beach, Florida, 1964.



	J	F	M	A	M	J	
Temp. °F	69.4	70.0	72.1	75.4	78.6	81.5	
Precip. In.	1.61	1.81	1.86	2.70	3.63	4.80	Average
	J	A	S	O	N	D	76.5°
Temp. °F	82.8	83.3	82.0	78.7	74.0	70.5	43.11"
Precip. In.	4.31	4.69	7.05	6.26	2.66	1.73	

SOURCE: AUTHOR'S CALCULATIONS.

TABLE 49

CLASSIFICATION COEFFICIENTS FOR THE KEYS REGION AND ADJACENT CLIMATIC REGION

Climatic Factors	Regions 18	17	Maximum Coefficient Differences Between Climatic Regions
(1) Continental Storm Track	-9.6	-9.1	.5
(2) Solar Radiation Receipt	-2.6	<u>-3.8</u>	(1.2)
(3) Winter-time High Pressure Systems	-1.5	- .8	.7
(4) Ocean Currents	-1.9	<u>- .6</u>	(1.3)
(5) Maritime Cloud Variability	-11.1	<u>-12.2</u>	(1.0)
(6) Continental Moisture Index	-1.9	- 2.5	.6
(7) Wind Strength Variability	+2.4	+ .8	.6

Names of Climatic Regions

<u>18</u> Keys Region
<u>17</u> West Palm Beach Region

[a]Source: Author's calculations.

Note: Coefficients with parenthesis have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

Latitude

The Keys Region is at a lower latitude than the West Palm Beach Region. This is exemplified by examining the locations of first-order weather stations in these regions. Miami and Miami Beach are at approximately the same latitude, 25°45'N, but West Palm Beach is at 26°44'N compared with a lower latitude of 24°31'N for Key West in the Keys Region. This latitudinal difference is reflected in the mean annual tmmperature. The Keys Region has a mean annual temperature of 76.5°F which is 1.8°F higher than the West Palm Beach Region. This difference is observed in the somewhat higher mean position of the mean climograph along the temperature axis for the Keys Region.

Mean Annual Sky Cover and Variability

Although a definite summer-early autumn rainfall maxima is observed for both the Keys Region and West Palm Beach Region, the Keys Region receives 17.23 inches less rain per year. Much of this disparity occurs during the warmer half of the year. For example, mean rainfall during September in the Keys Region is 7.05 inches compared with 9.44 inches during the same month in the West Palm Beach Region. One probable explanation for this difference in rainfall is less mean annual sky cover over the Keys Region. Mean annual sky cover values for Miami Beach and Key West are 5.2 and 5.3, respectively, compared with 6.1 and 5.7 for West Palm Beach and Miami.[39] This same relationship is noted during the summer months. The average September sky cover value for the Keys Region is 6.2 compared with 6.7 for the West Palm Beach Region.[40] Much of this

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[39] Local Climatological Data, Florida.

[40] Ibid.

variation in mean sky cover is most likely associated with convective shower activity during the summer season.

The mean annual number of days of thunderstorms over Key West is relatively small compared to other parts of the state, particularly the interior of the peninsula.[41] This phenomenon has been ascribed to special conditions prevailing over the peninsula which feel the effects of strong low-level convergence resulting from the afternoon sea breeze moving into the peninsula from both east and west.[42] But, the considerable thunderstorm activity at Miami cannot be attributed to this double sea-breeze convergence; furthermore, the Southeast Coast has days with little or no rain when the diurnal precipitation pattern remains unchanged over the interior.[43] It might therefore be deduced that decreased land-sea breeze activity as a precipitation mechanism is responsible for less mean sky cover and precipitation, particularly during the summer season, in the Keys Region.

In summary, the mean climograph for the Keys Region is distinct from the West Palm Beach Region due to the following characteristics: (1) a high mean position of the mean climograph along the temperature axis because of a lower latitudinal location; (2) a shorter length of the mean climograph along the precipitation axis due to smaller mean sky cover values, particularly during the warm season, which is probably associated with decreased thunderstorm activity.

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[41] Landsberg, _op. cit._, p. 259.

[42] Trewartha, _op. cit._, p. 302.

[43] _Ibid._

Littoral Northwest Region - Region 19

The Littoral Northwest Region encompasses a stretch of the Pacific Coast from Tatoosh Island southwards to the California-Oregon border. This is an exceedingly narrow climatic region which includes the Coastal Range along its eastern border (see Figure 105). This coastal climatic region consists of 2 first-order and 6 test weather stations (see Appendices VIII and IX). These weather stations receive copious amounts of precipitation during the cooler 6 months of the year with a mean December value of 13.47 inches. The summer season is considerably drier with a mean July total of 1.43 inches of precipitation. More precipitation falls in the Littoral Northwest Region, with a mean annual total of 81.47 inches, than in any other climatic region. The mean annual range in temperature is 18.5^{o}F which is only 5.0^{o}F greater than that of Region 18—the Keys Region. However, temperatures are cool during the entire year. The mean monthly temperature for the warmest month does not exceed 60^{o}F.

The uniqueness of the mean climograph for the Littoral Northwest Region is displayed in its extreme horizontal length along the precipitation axis (see Figure 106). This mean climograph extends horizontally from 1.39 inches of precipitation to 13.47 inches which represents a mean annual precipitation range of 12.08 inches. Due to the combination of a small range in the mean annual temperature and a large range in mean annual precipitation, a nearly horizontal mean climograph for the Littoral Northwest Region is exhibited. No other climatic region's mean climograph has these mean monthly temperature and precipitation characteristics.

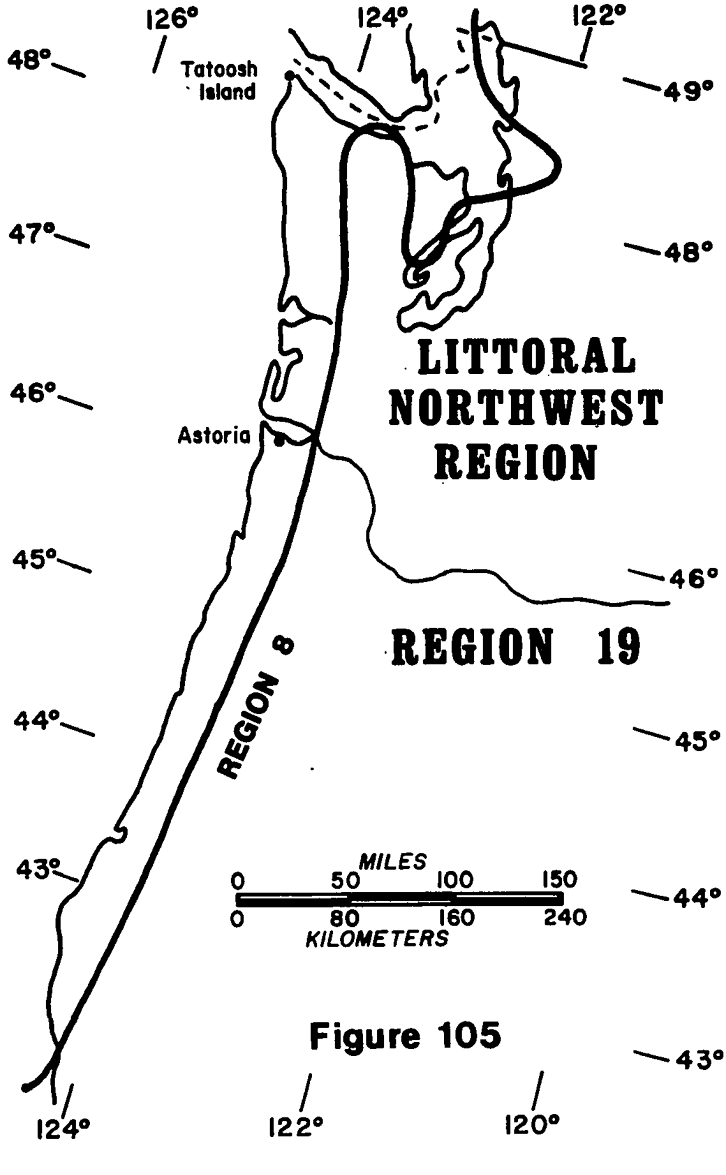
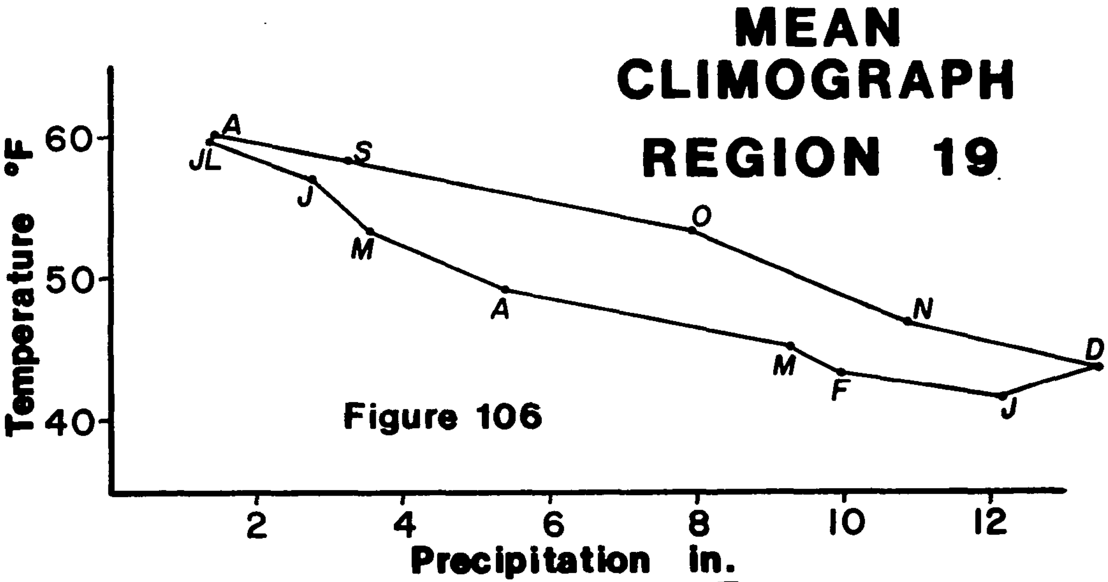

126°
124°
122°
48°
49°
Tatoosh
Island
47°
48°
LITTORAL
NORTHWEST
REGION
46°
Astoria
45°
46°
REGION 19
REGION 8
44°
45°
43°
MILES
0 50 100 150
0 80 160 240
KILOMETERS
44°
43°
124°
122°
120°

Figure 105



	J	F	M	A	M	J	
Temp. °F	41.5	43.3	45.1	49.1	53.4	57.0	
Precip. In.	12.17	9.96	9.29	5.40	3.53	2.78	Average
	J	A	S	O	N	D	50.9°
Temp. °F	59.7	60.0	58.2	53.3	46.9	43.6	81.47"
Precip. In.	1.39	1.43	3.23	7.92	10.90	13.47	

SOURCE: AUTHOR'S CALCULATIONS.

Only the Pacific Northwest Region is adjacent to the Littoral Northwest Region; therefore, all classification coefficient differences refer to these climatic regions (see Table 50). The largest classification coefficient differences are as follows: a low negative solar radiation receipt value is indicated for the Littoral Northwest Region compared with a low positive value for Region 8; an extremely low positive wind strength variability value is observed for the Littoral Northwest Region compared with a low negative value for Region 8; and a high negative ocean current value is observed for the Littoral Northwest Region compared with a moderately high negative value for Region 8.

The following climatic factor components are observed as significant between the Littoral Northwest Region and the Pacific Northwest Region: (1) mean annual sky cover -- with respect to the upward extension of the mean climograph along the temperature axis; (2) January and July ocean currents -- with respect to the length of the mean climograph along the temperature axis; (3) mean annual wind velocity and variability -- with respect to the extreme length of the mean climograph along the precipitation axis.

Mean Annual Sky Cover

August, with a mean monthly temperature of 60.0°F, is the warmest month in the Littoral Northwest Region. This mean temperature is 5.2°F cooler than the warmest month of July in the Pacific Northwest Region. A partial explanation for this difference in warm season temperatures is mean annual sky cover. The mean annual sky cover for the Littoral Northwest Region is substantially higher than the Pacific Northwest Region. The average value for this climatic factor component for the Littoral

TABLE 50[a]

CLASSIFICATION COEFFICIENTS FOR THE LITTORAL NORTHWEST AND ADJACENT CLIMATIC REGIONS

Climatic Factors	Regions 19	8	Maximum Coefficient Difference Between Climatic Regions
(1) Continental Storm Track	-2.4	- .9	1.5
(2) Solar Radiation Receipt	-1.0	+2.9	(3.9)
(3) Winter-time High Pressure Systems	-5.6	-3.3	2.3
(4) Ocean Currents	-10.3	(-7.8)	(2.5)
(5) Maritime Cloud Variability	+14.3	(+15.6)	1.3
(6) Continental Moisture Index	+2.1	+4.5	2.4
(7) Wind Strength Variability	+ .2	-2.8	(3.0)

Names of Above Climatic Regions

19 Littoral Northwest Region
8 Pacific Northwest Region

[a]Source: Author's calculations.

Note: Coefficient with parenthesis have the greatest coefficient difference values for three climatic factors. Coefficients underlined are specifically analyzed for this climatic region if they are not repetitious according to Table 20.

Northwest Region is 7.6 compared with 6.8 for Region 8.[44] This difference in sky cover is primarily due to the discrepancy observed during the summer season. The mean August sky cover for the Littoral Northwest Region averages 6.9 which is considerably higher than the 4.0 average during July for the Pacific Northwest Region. This difference during the summer season is attributed to the prevalence of low stratus clouds which commonly occur along the Pacific Coast and are responsible for reduced insolation and, consequently, lower mean monthly temperatures.

January and July Ocean Currents

The Littoral Northwest Region, which borders the Pacific Ocean, has one of the smallest mean annual temperature ranges in the United States. Even though the southern portion of the Pacific Northwest Region borders the Pacific Ocean, the mean annual temperature range of the Littoral Northwest Region is 8.6°F less. This is primarily due to the somewhat orographically sheltered location of those weather stations in Subregion 8b which includes the Willamette Valley and the Puget Sound. Consequently, cooler summer season temperatures and milder winters are experienced in the unsheltered Littoral Northwest Region.

The moderating effect of the cold California Current on temperature is particularly evident during the summer season during which time approximately a 5°F difference between these 2 regions is observed. A 3.4°F difference is observed in January. The greater moderating effect of the cold ocean current during the summer season and the decreased intensity inland, particularly in Subregion 8b, is clearly exhibited upon inspection of January and July ocean current indices (see Table 51).

[44]Author's calculations.

TABLE 51[a]

JANUARY AND JULY OCEAN CURRENT INDICES FOR THE LITTORAL NORTHWEST REGION AND SUBREGION 8B

Littoral Northwest Region			Subregion 8b		
Weather Station	January Ocean Current Index	July Ocean Current Index	Weather Station	January Ocean Current Index	July Ocean Current Index
Tatoosh Island	+5.8	-28.8	Salem	+1.3	-19.3
			Eugene	+2.1	-18.1
Astoria	+3.4	-26.4	Roseburg	+3.5	-16.4
			Portland	+1.0	-18.9
			Medford	+1.3	- 9.9
			Olympia	+1.8	-22.3
			Seattle	+4.6	-21.2

[a]Source: Author's calculations.

Mean Annual Wind Velocity

The Littoral Northwest Region receives 44.71 inches more precipitation per year than does the Pacific Northwest Region! Winter is the wettest season of the year for each region, and it also is when the largest differences in rainfall are observed. An average of 13.47 inches of rain is recorded in the Littoral Northwest Region during December, the wettest month, compared with 6.29 inches in the Pacific Northwest Region.

According to Trewartha, much of the precipitation throughout these regions is associated with eastward moving occluded storms and the lifting effects of highlands.[45] However, throughout both of these climatic regions, a great areal variation in mean annual precipitation is expected where such a diverse terrain exists. For example, only modest amounts of precipitation are received in the Puget Sound which is usually attributed to the rainshadow effects of the Olympic Mountains and Vancouver Island.[46] Therefore, orographic effect must be an important climatic control in these climatic regions.

Wind strength variability as a climatic factor ranked second in importance as a discriminator between the Littoral Northwest Region and the Pacific Northwest Region. Mean annual wind velocity, variability of wind velocity, and orographic index are all high climatic factor components. However, little meaning is attained from an analysis of the distribution of orographic index values due to the large variation in magnitude for both regions. Only mean annual wind velocity and its

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[45]Trewartha, op. cit., p. 271.

[46]Ibid., p. 270.

variability for Tatoosh Island were easily distinguishable from the same components for the Pacific Northwest Region (see Table 52). However, if wind strength and variability are important components in terms of precipitation, a major problem arises, i.e., Astoria receives more precipitation than does Tatoosh Island. Possibly another variable such as wind direction, which was incorporated into the orographic index, should be scrutinized more carefully. This may afford a more plausible explanation in terms of winter season precipitation differences in these regions. The wind direction during the winter season is predominately from the east over the Littoral Northwest Region, and, according to Connor, this wind brings in cold air which drains from the interior of the continent and forms a temperature discontinuity between the cool easterlies of the mainland and along the Coast, and the mild mP air from the west.[47] Therefore, in conjunction with the wind strength, wind direction and the coastal location may also be significant as factors which contribute to the copious amounts of rain in this region, particularly during winter.

In summary, the mean climograph for the Littoral Northwest Region is unique from the Pacific Northwest Region due to the following characteristics: (1) a relatively low position of the upper portion of the mean climograph along the temperature axis due to high summer season sky cover; (2) the short length of the mean climograph along the temperature axis due to January and July ocean currents; and (3) the extreme length of the mean climograph along the precipitation axis possibly due to wind strength and direction with respect to a coastal location.

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[47] _Ibid._, p. 271.

TABLE 52[a]

WIND STRENGTH VARIABILITY FOR THE LITTORAL NORTHWEST REGION
AND THE PACIFIC NORTHWEST REGION

Weather Station	Mean Annual Wind Velocity	Wind Variability	Orographic Index
Littoral Northwest Region			
Tatoosh Island	14.4	3.9	-18
Astoria	8.3	.5	-45
Pacific Northwest Region			
Weather Station	Mean Annual Wind Velocity	Wind Variability	Orographic Index
Olympia	6.6	.7	-67
Sexton Summit	11.8	1.2	+237
Meacham	9.2	1.0	+70
Salem	7.3	.9	-14
Eugene	7.6	.7	-55
Seattle	10.2	.8	-13
Roseburg	4.5	.8	-30
Portland	7.7	1.8	-41
Eureka	6.8	.9	+1
Medford	4.7	1.0	-54

[a]Source: Local Climatological Data with Comparative Data, 1964, and author's calculations.

CHAPTER VI

SUMMARY AND OUTLOOK

From the regional analysis, significant climatic factor components were related to certain features or mean temperature-precipitation climographs which are characterized as unique from mean climographs for adjacent regions. These climatic factor components often indicate subtle but significant spatial changes in the genesis of the climate. However, certain mean climographs, not only in some adjacent regions but elsewhere in the United States, have similar features and, therefore, may be influenced by similar climatic factor components. From a recognition of the most salient different and similar features of mean climographs for the 19 climatic regions in the United States, a knowledge of the climatic factor components and/or climatic factors which produce these features is obtained. Therefore, a thorough and expedient means of understanding the genesis of climate over various areas in the United States is available.

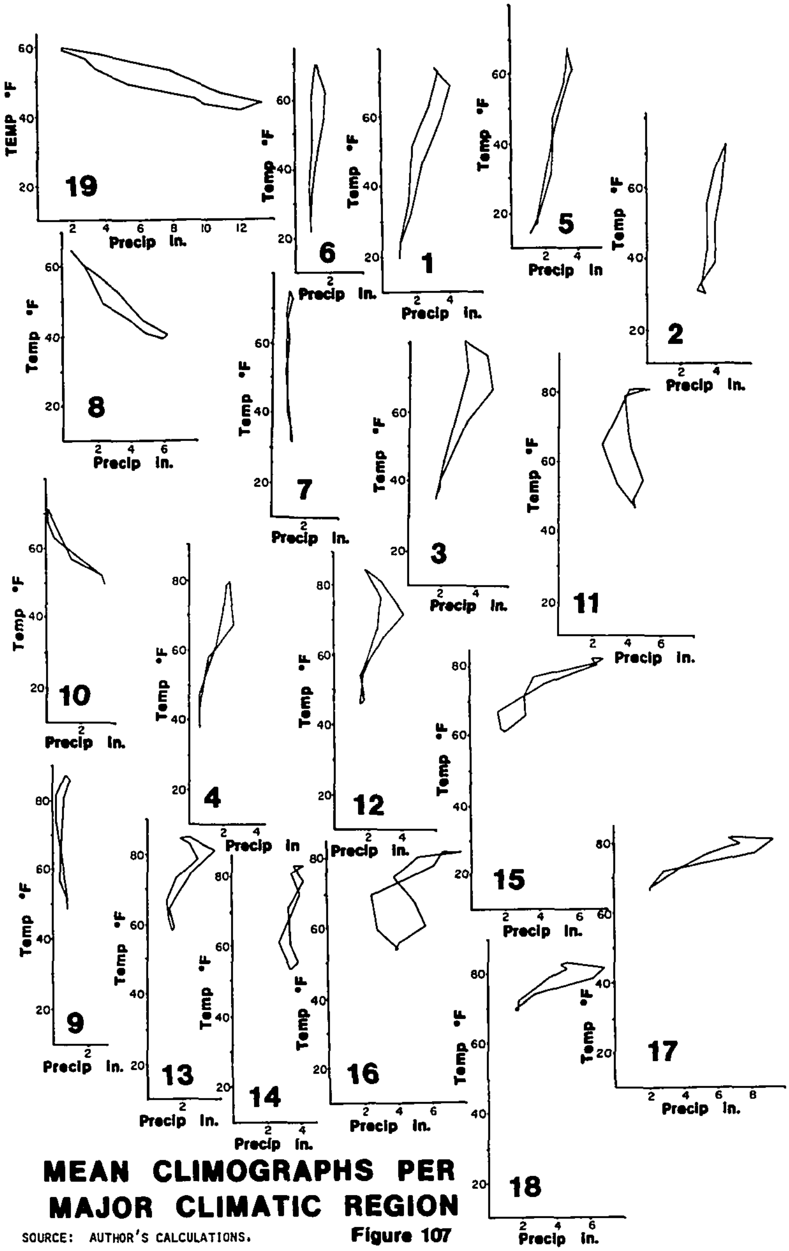
A summary of the climatic factor components related to the 19 distinctive mean climograph features which represent major climatic regions in the coterminous United States is first presented. These climatic factor components fall into 3 categories: those which are genetically significant, those which are not genetically significant, and those which are absent from this study. Relative to the uniqueness of mean climograph features, examples of genetically significant climatic factor components as related to mean climographs are presented and should prove useful in future similar climatological investigations and from a pedagogic standpoint. Reasons will be cited for the insignificance of some climatic factor components as related to mean climographs. Finally, genetically significant climatic factor components as related to mean climographs which were not included in this investigation are discussed. These should be incorporated in future climatic classification systems of this nature.

With respect to similar mean climograph features, groups of climographs are displayed which have some easily recognized common characteristics. In turn, the most significant climatic factor components and/or associative causes which produced these similar features are briefly discussed.

Climatic Factor Components Related to Unique Mean Climograph Features

The following comments pertaining to climatic factor components related to unique mean climograph features refer to Figure 107 in which all 19 mean climographs are displayed together. Their relative positions are similar to the locations of the major climatic regions in the United States. Each mean climograph is numbered in accordance to its climatic region. For the following examples only the region number of the mean climograph for the selected climograph feature will be stated.

One of the most useful and significant climatic controls in this study is latitude which reflected the mean position of the climograph along the temperature axis. This climatic control proved significant in a large number of climatic regions in the United States. Obviously,



MEAN CLIMOGRAPHS PER MAJOR CLIMATIC REGION

SOURCE: AUTHOR'S CALCULATIONS. **Figure 107** latitude is significant in the Upper Great Lakes Region (5) with its mean climograph positioned low along the temperature axis and the Keys Region (18) with its mean climograph positioned extremely high. But, in addition, latitude is significant as a discriminator between adjacent climatic regions. For example, the mean climograph for the High Plains Region (4) is intermediate in its mean position along the temperature axis compared with the Interior Basin and Plains Region (6) to the north and the Desert Southwest Region (9) to the southwest.

Continentality and January and July ocean currents were widely used in numerous climatic regions. These climatic controls are related to the length of the mean climograph along the temperature axis. For example, the mean climograph for the Upper Midwest Region (1), located in the interior of the United States, is longer than the one for the Interior Highland Region (3) which is closer to a large body of water. Conversely, the mean climograph for the Texas Valley Region (13), which borders the Gulf of Mexico, is shorter than the mean climograph for the Interior Texas Region (12). Ocean currents played a significant role for all 3 climatic regions along the Pacific Coast. For instance, the length of the mean climograph for the Pacific Northwest Region (8) is markedly shorter than the mean climograph for the Plateau Region (7). Ocean current effect was not as important along the Atlantic Coast, but where it was evident, January ocean currents were generally more significant in suppressing the downward extension of the mean climograph along the temperature axis. One such example was noted in the West Palm Beach Region (17) with less January ocean current effect, and, hence, a lower extension of the mean climograph, than the Keys Region (18).

Mean annual sky cover and its variability proved significant in numerous cases. However, because of the wide variation of values for these climatic controls, especially in large climatic regions with many weather stations, a clear spatial understanding was often elusive. This occurred frequently when standard deviation values for mean sky cover were examined. Often times, a month-by-month analysis was necessary to elucidate the implicit meaning. But, upon detailed inspection of mean sky cover, the explanation for various positions and configurations of a number of mean climographs was revealed, i.e., the size of an "opening" within the framework of a mean climograph, sharp angles which are conspicuous within the configuration of the mean climograph, the length of the mean climograph along the precipitation axis, the distance of the mean climograph away from the temperature axis, and the suppression of the upper portion of the mean climograph along the temperature axis. Examples of this relationship between mean sky cover and the position and configuration of the mean climograph are scattered throughout the United States.

For instance, the Humid Southeast Region (11) has a large and extensive "opening" in its mean climograph compared with the Florida Region (15). This is partially attributed to the precipitation minima during October during which time a small mean sky cover is observed. The Keys Region (18) has a mean climograph with a shorter length along its precipitation axis than the West Palm Beach Region (17) partially because of lower mean annual sky cover values. The Desert Southwest Region (19) has a mean climograph which is nearer the temperature axis than the High Plains Region (4) partly due to a smaller mean sky cover.

The upper portion of the mean climograph for the Western Gulf Coast Region (14) is suppressed in its upward extension because of higher mean sky cover compared with the Interior Texas Region (12). Finally, the mean climograph for the Eastern Gulf Coast Region (16) has a pronounced sharp-angled feature during the summer season because of high mean sky cover values compared with the Humid Southeast Region (11).

Total number of lows and their variability were not as significant in explaining mean climograph configurations as mean sky cover, but, because of their use in certain climatic regions, some contribution was noted. Again, standard deviation values were difficult to interpret because of great inter-regional or little intra-regional variability. Nevertheless, from an analysis of total number of lows, particularly on a monthly basis, sharp-angled features, a vertical orientation of the climograph axis, and a short climograph axis were at least partially explained regarding the position and configuration of mean climographs. Three such examples are presented.

For the mean climograph for the Upper Midwest Region (1), the narrow inward pointing sharp-angled feature during the summer season compared with a wider-angled feature noted in the Interior Highland Region (3) is explained by a fewer number of lows over the recorded 20-year period. The mean climograph for the California Region (10) is shorter along the precipitation axis than the Pacific Northwest Region (8) partially because of fewer lows during the winter season. The lower portion of the mean climograph for the Western Gulf Coast Region (14) is more distant from the temperature axis during the winter season than the Interior Texas Region (12) because of a greater number of lows resulting in a vertical climograph with respect to the precipitation axis.

Total number of highs and their variability were even less useful than low pressure disturbances. However, in a couple of climatic regions, a monthly analysis of highs aided in the explanation of an inwardly pointed sharp-angled feature and the vertical orientation of a mean climograph. In the Upper Midwest Region (1) a pronounced inwardly pointed sharp-angled feature representing a relatively dry October is explained by a greater number of highs than the Interior Highland Region (3) in which the sharp angle in the mean climograph is not formed. A vertical mean climograph for the East Central Region (2) is partially caused by a greater number of highs during the summer season which hinders summer season precipitation compared with the Humid Southeast Region (11) to the south which has an obvious sharp angle in its mean climograph pointed away from the temperature axis.

At least one air mass type loaded highly on 5 of the 7 climatic factors, and, therefore, considerable opportunity for use of these climatic factor components in explaining a mean climograph was present. Monthly air mass dominance proved useful in explaining a variety of positions and configurations of mean climographs throughout the United States. The manner in which the air mass type relates to the mean climograph is dependent on its temperature and moisture characteristics; i.e., warm, cold, wet, or dry. All 9 air mass types were significant as discriminators between certain climatic regions in some respect. Since transition air masses affected the position and configuration of mean climographs similarly to the non-transitional types, only examples for cP, mP, mT, and cT monthly air mass dominance are discussed.

A cold and dry air mass is cP. Where this air mass dominates, a lower extension of the mean climograph nearer the temperature axis results. The Upper Great Lakes Region (5) is dominated by cP air mass during the winter season. Consequently, its mean climograph extends farther down and is closer to the temperature axis than the mean climograph for the East Central Region (2). A cool, moist air mass is identified as mP air. The temperature of this air mass is intermediate to cP and mT air masses, and, therefore, may enhance or suppress the lower or upper portion of the mean climograph, depending on the season in which the air mass prevails. Also, this air mass type is usually related to the distance of the mean climograph from the temperature axis. For example, mP air mass predominates in the Eastern Gulf Coast Region (16) during the winter months. The lower portion of the mean climograph for this climatic region extends farther down and away with respect to the temperature axis than the lower portion of the mean climograph for the Florida Region (15). A third air mass type which is characterized by warm and humid conditions is mT air. This air mass raises the lower or upper portion of the mean climograph along the temperature axis compared with cP and mP air masses, and increases its distance away from the temperature axis. For instance, the lower portion of the mean climograph for the Western Gulf Coast Region (14) is higher and more distant from the temperature axis than the same portion of the mean climograph for the Interior Texas Region (12). This is because of the prevalence of mT air mass for the Western Gulf Coast Region during the winter season. Finally, cT air mass is warm and dry. Mean climographs related to this air mass type are near the temperature axis with particularly the upper portion positioned high. The closeness of a mean climograph to the temperature axis is observed for the Desert Southwest Region (9) during the spring season where cT air mass prevails compared with the High Plains Region (4) where mT transition air mass predominates.

With the exception of the Desert Southwest Region (9), elevation as a climatic factor component did not prove successful as a discriminator between climatic regions. This was somewhat unexpected since there is such a large variation in elevation in the western half of the United States. With weather stations at lower elevations but at the same latitude, a higher mean position of a climograph should be evident. This was clearly observed in the Desert Southwest Region (9) with its mean climograph positioned high along the temperature axis in which elevation was significantly lower in distinguishing it from the Interior Basin and Plains Region (6) and the Plateau Region (7). However, latitude is also obviously important and masks the real influence of elevation. Elevation loaded only relatively high on winter-time high pressure systems which was seldom used, and probably more important is that few mountain weather stations are listed in <u>Local Climatological Data</u> which was used for this study.

Wind strength variability was revealed as significant as a discriminator only once with respect to the Littoral Northwest Region (19) compared with the Pacific Northwest Region (8). This climatic factor primarily consists of mean annual wind velocity, its variability, and orographic effect. Presumably, these climatic factor components are reflected in the length of the mean climograph along the precipitation axis. This length is considerably greater for the Littoral Northwest Region (19) than for the Pacific Northwest Region (8). It should be recalled that a low communality value was calculated for orographic effect. This is probably related to the manner in which this climatic control was operationalized. Therefore, the infrequent use of wind strength variability in discriminating between climatic regions may suggest that especially the orographic index should be redefined.

Finally, mean pressure and its variability were not used as significant climatic factor components in discriminating between any adjacent climatic regions. Several reasons may be stated for the absence of these components as discriminators in this investigation. Firstly, they loaded on solar radiation receipt as a climatic factor in which mean sky cover and/or cT transition air masses were often observed as significant. Secondly, in large climatic regions, such as the Interior Basin and Plains Region (6), much variation in mean pressure values and standard deviation values was observed. Thirdly, in small irregularly-shaped climatic regions, broadscale pressure patterns did not coincide with regional boundaries, i.e., in certain cases adjacent regions were viewed to have similar pressure values and gradient. Possibly mean monthly pressure values would be more useful in a project of this scale.

On several occasions, significant climatic factor components were associated with other controls such as upper air circulation and tropical disturbances which were not incorporated in this study. These controls were, in addition, obviously associated with various distinctive portions of some mean climographs which were not explained by the climatic factor components. One such upper air control which is associated with several mean climograph configurations is the summer ridge of pressure with its dry current of northerly air which extends through the mid-section of the country. This ridge suppresses summer rainfall and is observed as an inward pointing of sharp-angled features during mid-summer (1), (3), (4), (12), and (13). During this same time of the year, an upper-air trough develops over the southeastern portion of the United States and produces favorable conditions for strong convective shower activity (11), (15), and (16). One additional example is the increased summer precipitation occurring over Florida concomitant with a wind change aloft from the northwest to southwest (15).

Climatic Factor Components Related to Similar Mean Climograph Features

From all 19 mean climographs for the United States, certain climograph features may be grouped in accordance to various criteria. Each group with one or more similar feature is generally related to one or two climatic factor components, climatic factors or associative cause. If these features are readily recognized by the climatology student, the probable cause in terms of climatic controls should be revealed. This will greatly enhance the student's comprehension of the physical reason a climatic type, as characterized by a mean climograph, exists for a weather station.

The following represents groups of the more obvious similarities of particular mean climograph features. Because of the various combinations of similarities, subgroups were formed. Each mean climograph is numbered the same as its region. The causes of these similar features in terms of climatic factor components and other associative causes not incorporated in this study were obtained from classification coefficient values and the regional analysis and are briefly discussed.

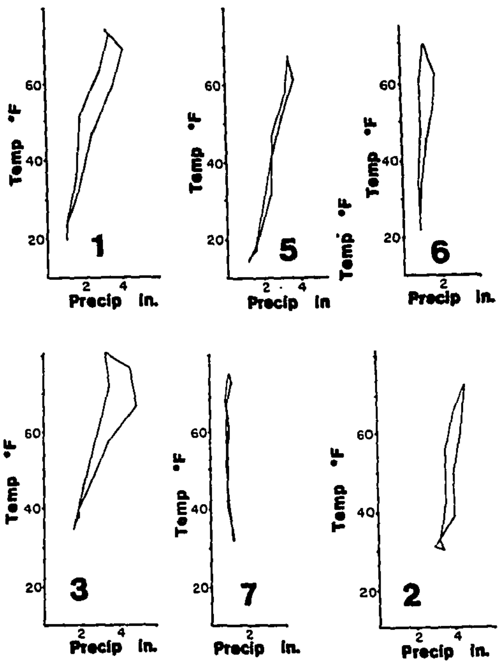
Groups Ia and Ib. Group Ia (see Figure 108) represents mean climographs which are extensive along the temperature axis. The mean annual range in temperature is over 43°F and the lowest portion of the climograph axis extends below 35°F. Continentality is a significant climatic factor component for climographs 1, 2, 5 and 7 as a discriminatory factor and for climographs 3 and 6 from the classification coefficients. The low extension of the mean climographs for all 6 regions is attributed to high latitude and/or cP or cP-mP air mass dominance during the winter season.

Group Ib (see Figure 109) represents mean climographs which are narrow and vertical with respect to the precipitation axis. The annual range in precipitation is less than 2 inches. Also, an angle measured from a line extending from the minimum monthly temperature to the maximum monthly temperature is less than 3° from a vertical line. Mean annual sky cover and its variability with respect to the similar distance from any point of the mean climograph to the temperature axis was the only common climatic factor component for all 4 climographs.

Groups IIa and IIb. Group IIa (see Figure 110) represents mean climographs which display a lack of continentality. Their lengths along the temperature axis are short with a mean annual temperature range of less than 25°F. Furthermore, measurements of an angle for each of these mean climographs from the monthly minimum temperature to the monthly maximum temperature is greater than 35° from a vertical line. January and/or July ocean current effects are significant climatic factor components

GROUP Ia

MEAN CLIMOGRAPH CHARACTERISTICS: LONG CLIMOGRAPHS WITH LOW EXTENSIONS



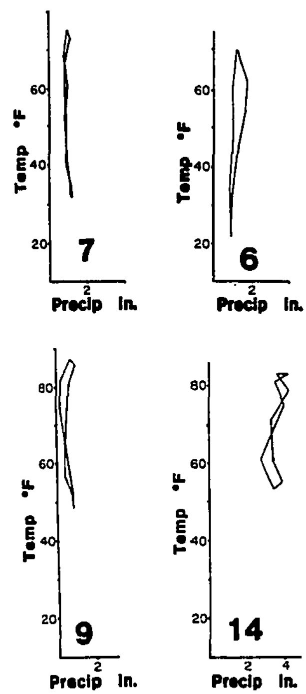
GENESIS: 1. HIGH DEGREE OF CONTINENTALITY
2. HIGH LATITUDE AND/OR cP, cP-mP AIR MASSES

Figure 108

SOURCE: AUTHOR'S CALCULATIONS.

GROUP Ib

MEAN CLIMOGRAPH CHARACTERISTICS: NARROW AND VERTICAL



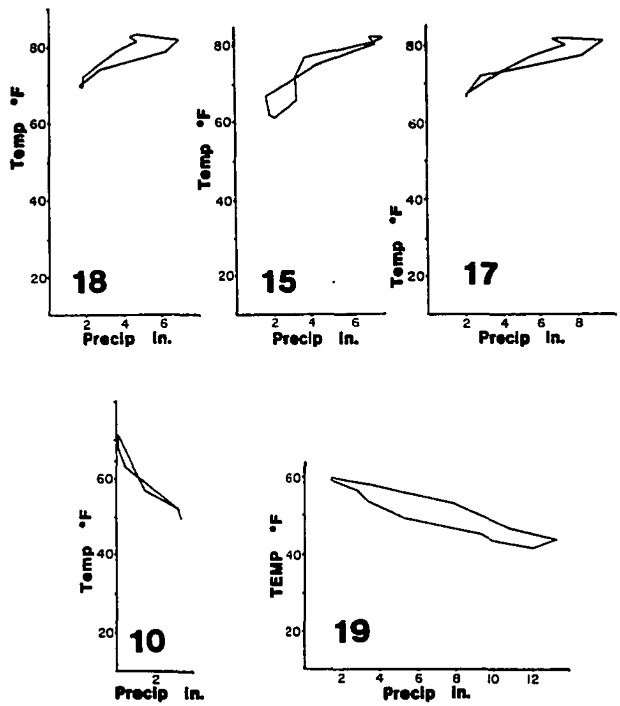
GENESIS: 1. MEAN ANNUAL SKY COVER
2. VARIABILITY OF MEAN ANNUAL SKY COVER

Figure 109

SOURCE: AUTHOR'S CALCULATIONS.

GROUP IIa

MEAN CLIMOGRAPH CHARACTERISTICS: SHORT MEAN CLIMOGRAPH ALONG THE TEMPERATURE AXIS



GENESIS: JULY AND/OR JANUARY OCEAN CURRENTS

Figure 110

SOURCE: AUTHOR'S CALCULATIONS.

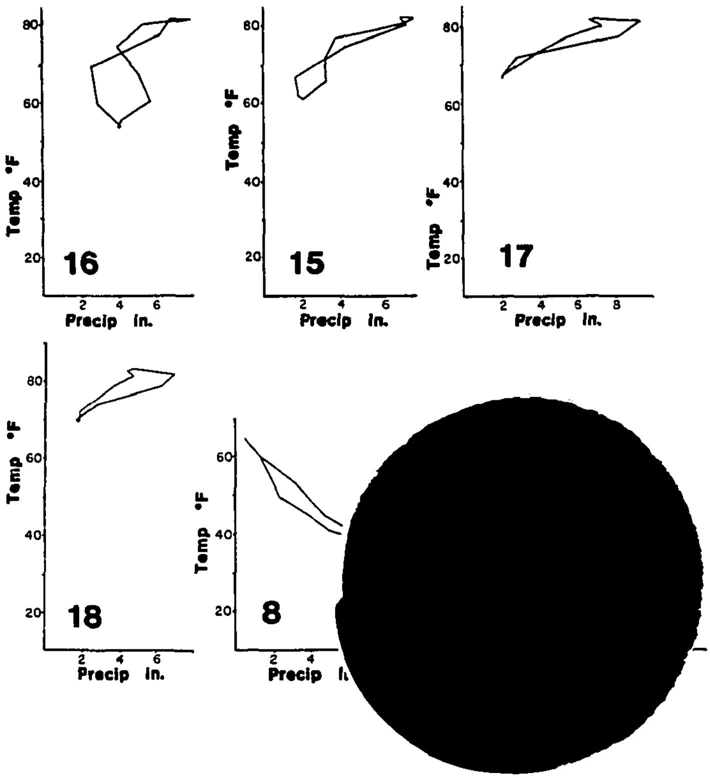
for these mean climographs, i.e., July for West Coast Regions and January for East Coast Regions.

Group IIb (see Figure 111) represents mean climographs which are extensive along the precipitation axis. They all have a mean annual precipitation range of over 5 inches. Also, the measurement of an angle from the monthly minimum precipitation to the monthly maximum precipitation is greater than 45° from a vertical line. Even though a winter maxima of precipitation occurs for Regions 8 and 19 as opposed to a summer maxima for the other regions, the cause is most likely similar. Variability of mean annual sky cover was discussed as a significant discriminator for Regions 15, 16, and 18. Moreover, Region 17 has a high negative maritime cloud variability value which includes variability of mean annual sky cover. All 4 of these regions are dominated by unstable mT air mass during their precipitation maxima. Variability of mean annual sky cover was not used in the regional analysis for Regions 8 and 19. But, these two regions have the highest positive maritime cloud variability values. Maximum precipitation occurs during the winter season when much higher sky cover occurs under an unstable mP air mass.

Groups IIIa and IIIb. Group IIIa (see Figure 112) and Group IIIb (see Figure 113) represent groups of mean climographs which have one common characteristic, i.e., they all have the upper portion of the mean climograph positioned low along the temperature axis. The upper portion of the mean climograph does not exceed $72^{\circ}F$. However, no other similarities between these 2 groups are evident. In fact, gross differences in the mean climograph configuration between these groups are obvious, and,

GROUP IIb

MEAN CLIMOGRAPH CHARACTERISTICS: EXTENSIVE MEAN CLIMOGRAPH ALONG THE PRECIPITATION AXIS



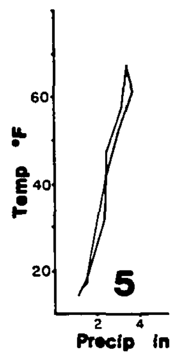
GENESIS: VARIABILITY OF MEAN ANNUAL SKY COVER

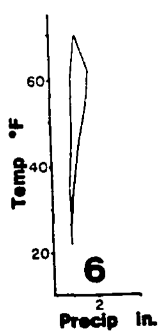
Figure 111

SOURCE: AUTHOR'S CALCULATIONS.

GROUP IIIa

MEAN CLIMOGRAPH CHARACTERISTICS: UPPER PORTION OF MEAN CLIMOGRAPH IS POSITIONED LOW ALONG THE TEMPERATURE AXIS





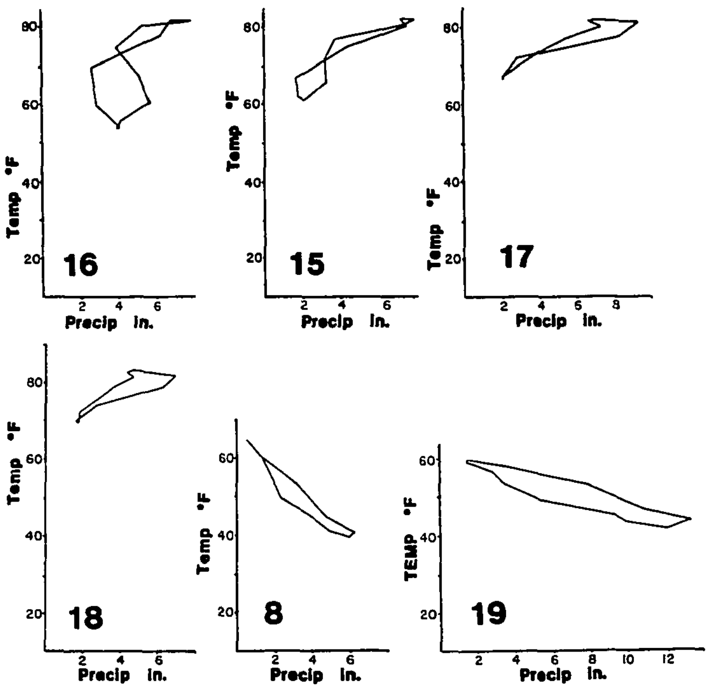
GENESIS: LATITUDE

Figure 112

SOURCE: AUTHOR'S CALCULATIONS.

GROUP IIb

MEAN CLIMOGRAPH CHARACTERISTICS: EXTENSIVE MEAN CLIMOGRAPH ALONG THE PRECIPITATION AXIS



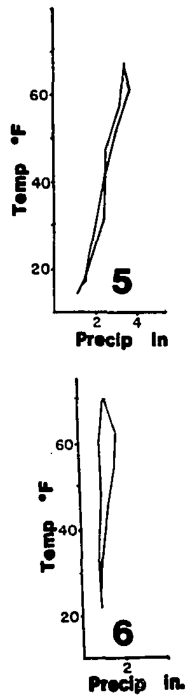
GENESIS: VARIABILITY OF MEAN ANNUAL SKY COVER

Figure 111

SOURCE: AUTHOR'S CALCULATIONS.

GROUP IIIa

MEAN CLIMOGRAPH CHARACTERISTICS: UPPER PORTION OF MEAN CLIMOGRAPH IS POSITIONED LOW ALONG THE TEMPERATURE AXIS



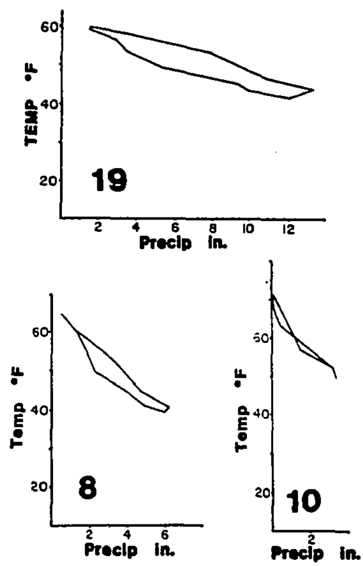
GENESIS: LATITUDE

Figure 112

SOURCE: AUTHOR'S CALCULATIONS.

GROUP IIIb

MEAN CLIMOGRAPH CHARACTERISTIC: UPPER PORTION OF MEAN CLIMOGRAPH IS POSITIONED LOW ALONG THE TEMPERATURE AXIS



GENESIS: JULY OCEAN CURRENT EFFECT

Figure 113

SOURCE: AUTHOR'S CALCULATIONS.

consequently, different causes are responsible for producing the low position of the upper portion of the mean climograph along the temperature axis.

In Group IIIa, extensive mean climographs are exhibited along the temperature axis. But, since these 2 mean climographs represent climatic regions at high latitudes, the entire climograph, including the upper portion, is positioned low along the temperature axis. Latitude was an important climatic factor component in the regional analysis for both Regions 5 and 6.

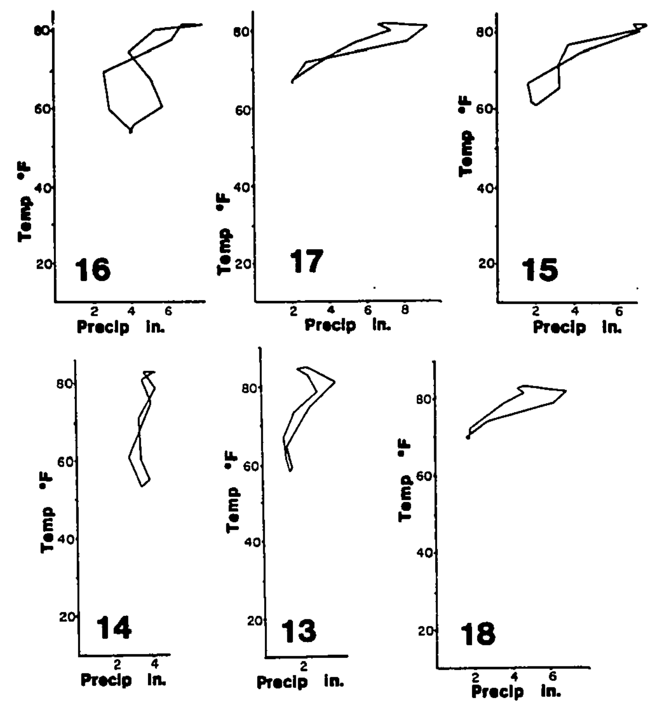
In Group IIIb, extensive mean climographs along the precipitation axis are displayed. These climographs represent climatic regions along the Pacific Ocean where ocean current effect suppresses warm season temperatures. This was indicated for Regions 8 and 10 in the regional analysis. Although ocean current effect was not used for Region 19 as an important discriminator to adjacent climatic regions, this region has the highest ocean current classification coefficient. Therefore, July ocean current effect is obviously the primary cause for the suppressed upper portion of their mean climograph.

Group IV. Group IV (see Figure 114) represents mean climographs which are positioned high along the temperature axis. The lowest portion of the mean climograph exceeds 53°F, the upper portion extends higher than 81°F, and the mean annual temperature is 67°F or higher.

From an inspection of the mean climograph's locations in the United States, low latitude is common to each region. From the regional analysis, latitude was a significant climatic factor component for Regions 14, 15, 16, and 18. High negative continental storm track

GROUP IV

MEAN CLIMOGRAPH CHARACTERISTIC: HIGH POSITION OF THE MEAN CLIMOGRAPH ALONG THE TEMPERATURE AXIS



GENESIS: 1. LOW LATITUDE
2. MT OR MT TRANSITION AIR MASS

Figure 114

SOURCE: AUTHOR'S CALCULATIONS.

values were calculated for Regions 13 and 17 which include latitude as a component. Therefore, latitude is significantly related to these mean climographs. In addition, mT or mT transition air mass was discussed as the probable cause for the high position of the lower portion of the mean climograph along the temperature axis for all regions except Region 18. But Region 18 has a high negative maritime cloud variability value which implies that mT air mass is a significant component. Therefore, low latitude and mT or mT transition air mass are primary causes producing the high position of the mean climographs along the temperature axis for this group.

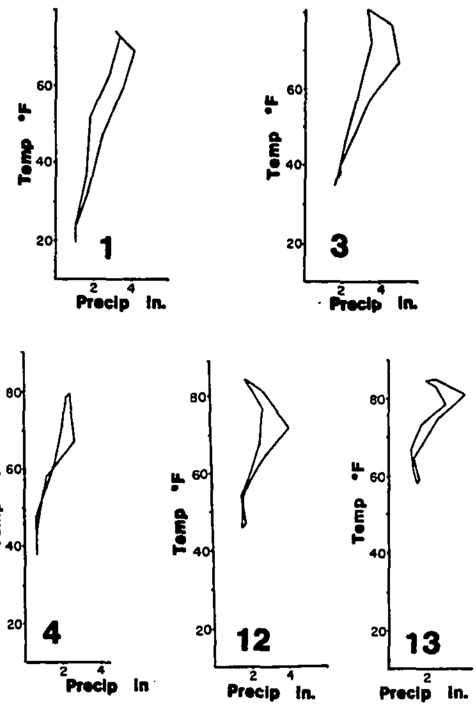
Groups Va, Vb, Vc, and Vd. The 4 subgroups constituting Group V all have rapidly changing precipitation characteristics during one or more periods of the year which form sharp angles in various portions of the mean climograph. The similarities of the following subgroups correspond to the period of year these sharp angles occur.

Group Va (see Figure 115) represents mean climographs with a sharp angle pointed away from the temperature axis during May or June, and a sharp-angled feature pointed towards the temperature axis during July or August. These climatic regions are contiguous and aligned in a north-south direction through the central United States.

A number of climatic factor components were used in the regional analysis in an attempt to explain these sharp-angled features. Air mass dominance and variability and mean annual sky cover were significant climatic factor components used to explain the May-June sharp-angled feature. Total number and variability of lows and highs were used to explain the July and August sharp-angled feature. However, consistency

GROUP Va

MEAN CLIMOGRAPH CHARACTERISTICS: SHARP-ANGLED PRECIPITATION FEATURES FOR MAY OR JUNE AND JULY OR AUGUST



GENESIS: 1. MT AIR MASS DOMINANCE AND VARIABILITY AND MEAN ANNUAL SKY COVER DURING MAY OR JUNE
ASSOCIATIVE CAUSE: INCREASED WARMING OF LAND SURFACE AND HUMID, UNSTABLE MARITIME AIR.
2. THE VARIABILITY AND NUMBER OF HIGHS AND LOWS DURING JULY OR AUGUST.
ASSOCIATIVE CAUSE: PREVAILING 750-500 MB. LEVEL ANTICYCLONE FLOW.

Figure 115

SOURCE: AUTHOR'S CALCULATIONS.

between some of these 5 mean climographs is lacking. Associative causes were discussed even though they are not climatic factor components used in this study. Trewartha stated that the expected increase in precipitation from April through May throughout this section of the country is the result of the heating land surface concomitant with increased humid, unstable maritime air.[1] The sharp decline in precipitation during July and August is the result of a prevailing 750-500 mb. level anticyclonic flow.[2] These explanations do lend credence to the climatic factor components discussed as significant to these features in the regional analysis. The increased heating of the land surface and increased flow of unstable humid air over these climatic regions during May and June are associated with mT air mass dominance, and variability and mean annual sky cover. During July and August, the prevailing upper-air ridge is associated with the smaller number of lows and increased frequency of high pressure systems observed over at least Region 1.

Group Vb (see Figure 116) represents mean climographs with a sharp angle away from the temperature axis during July which depicts the primary precipitation maxima, a rather sharp angle away from the temperature axis during March which forms a secondary precipitation maxima, and a rather sharp angle towards the temperature axis during October and November which represents a precipitation minima. The latter 2 described angles form a relatively large opening in the lower portion of the mean climograph.

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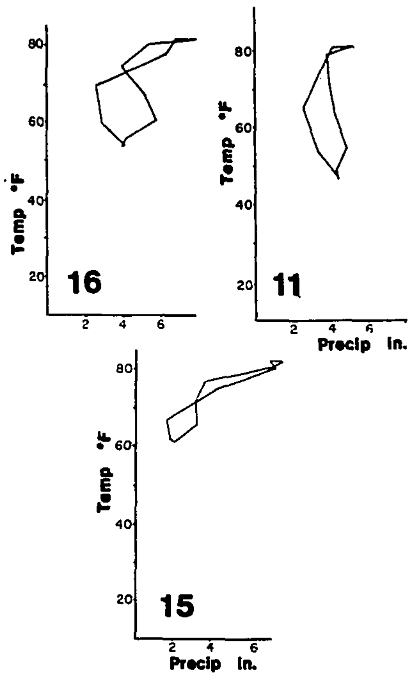
[1]Trewartha, The Earth's Problem Climates, op. cit., p. 280.

[2]Ibid.

GROUP Vb

MEAN CLIMOGRAPH CHARACTERISTICS: SHARP-ANGLED FEATURE AWAY FROM TEMPERATURE AXIS DURING JULY, SHORT-ANGLED FEATURE AWAY FROM TEMPERATURE AXIS DURING MARCH, RATHER SHORT-ANGLED FEATURE TOWARDS TEMPERATURE AXIS DURING OCTOBER OR NOVEMBER, RATHER LARGE OPENING IN THE LOWER PORTION OF THE MEAN CLIMOGRAPH



GENESIS: 1. MT AIR MASS DOMINANCE DURING JULY
2. VARIABILITY OF NUMBER OF LOWS AND MEAN SKY COVER DURING MARCH AND OCTOBER OR NOVEMBER

ASSOCIATIVE CAUSE: NUMBER OF HIGHS DURING MARCH AND OCTOBER OR NOVEMBER

Figure 116

SOURCE: AUTHOR'S CALCULATIONS.

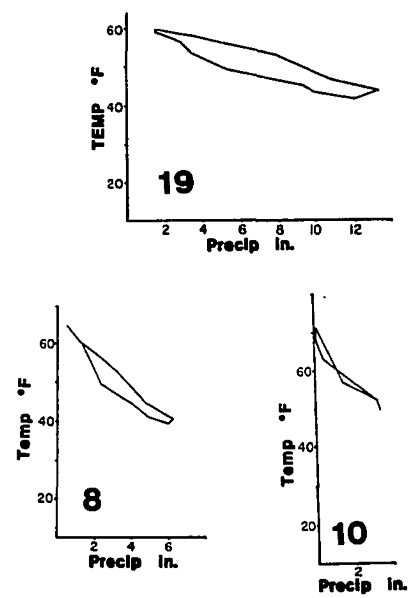
The cause of the extended sharp-angled feature during July was discussed previously with respect to Regions 15 and 16. This same cause, i.e., mT air mass dominance, was also revealed as significant in the regional analysis for Region 11. The 2 opposing angles in the lower portion of the mean climograph are produced by variability of low pressure systems and mean annual sky cover as related to the position of storm tracks. In addition, an associative cause which was not discussed as a significant climatic factor component is the number of highs. During the autumn season, a maximum number of high pressure systems are observed throughout these climatic regions. In contrast, March experiences a minimum frequency of highs; hence, a secondary precipitation maxima occurs.[3]

Group Vc (see Figure 117) represents a group of mean climographs which have a sharp-angled feature pointed towards the temperature axis. This feature is positioned near the temperature axis which represents a precipitation minima, and it occurs during the summer season. All 3 mean climographs are quite similar in their configuration and have a small temperature range. This was partially explained previously by January and July ocean current effect. However, a significant reason for the sharp-angled precipitation minimum in terms of a climatic factor component was detailed only for Region 10 in the regional analysis; i.e., the total number of lows. But, a widely known associative cause should be mentioned. These Pacific Coast climatic regions are influenced by the Pacific Subtropical High with its attendant subsidence which

[3] Ibid., p. 299.

GROUP Vc

MEAN CLIMOGRAPH CHARACTERISTIC: SHARP-ANGLED FEATURE TOWARDS THE TEMPERATURE AXIS DURING THE SUMMER SEASON



GENESIS: ASSOCIATIVE CAUSE: SUBTROPICAL HIGH PRESSURE SYSTEM WITH SUBSIDENCE

Figure 117

SOURCE: AUTHOR'S CALCULATIONS.

severely suppresses any tendency of precipitation during the summer season.

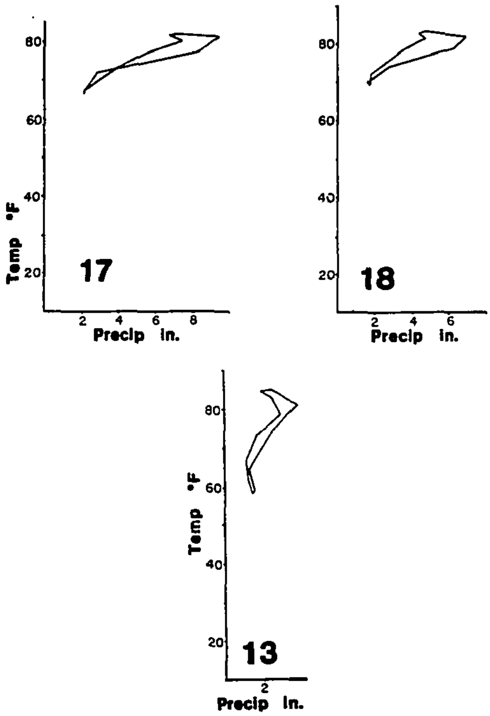
Group Vd (see Figure 118) represents a group of mean climographs with a conspicuous, sharp-angled feature pointing away from the temperature axis during September. This feature represents a primary precipitation maxima. All 3 climatic regions are dominated by mT air mass during this season, and high negative maritime cloud variability values are indicated. However, mT air mass was not a significant discriminator in the regional analysis with respect to adjacent climatic regions. But an important associative cause for the September precipitation maxima, which was discussed in the regional analysis, is the tropical storm which, when it occurs, increases the mean monthly precipitation for this month.

Groups VIa, VIb, and VIc. The subgroups representing Group VI were all discussed in the regional analysis section with reference to the distance of one or more portions of the mean climograph to the temperature axis. In each case, air mass dominance was at least partially the cause of this specific characteristic.

Group VIa (see Figure 119) represents mean climographs with one or more portions of its configuration near the temperature axis, i.e., little precipitation. The lower portions of mean climographs 1, 4, 5, 6, and 7 are near the temperature axis whereas the upper portions of mean climographs 6, 7, and 9 (June) are close to the temperature axis. Significant climatic factor components for the closeness of the lower portion were cP, mP-cT and cP-cT air mass dominance and cT and mT-cT air mass dominance for the closeness of the upper portion of the mean climograph.

GROUP Vd

MEAN CLIMOGRAPH CHARACTERISTIC: CONSPICUOUS, SHARP-ANGLED FEATURE WHICH POINTS TOWARDS THE TEMPERATURE AXIS DURING SEPTEMBER



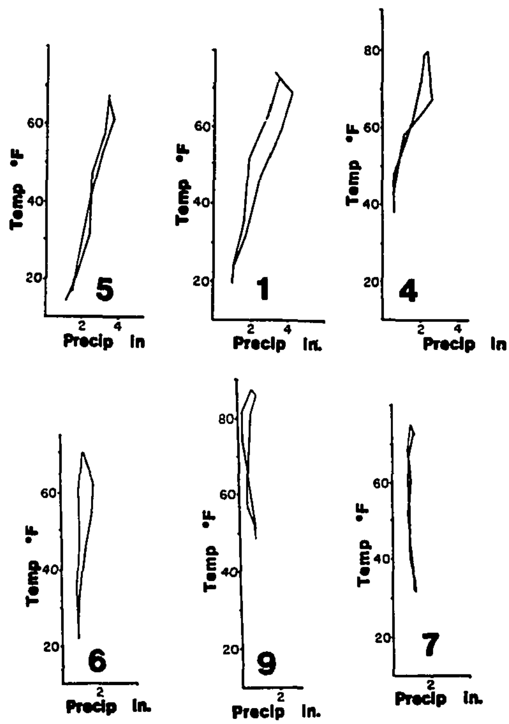
GENESIS: <u>ASSOCIATIVE CAUSE</u>: TROPICAL STORMS

Figure 118

SOURCE: AUTHOR'S CALCULATIONS.

GROUP VIa

MEAN CLIMOGRAPH CHARACTERISTIC: ONE OR MORE PORTIONS OF THE MEAN CLIMOGRAPH ARE CLOSE TO THE TEMPERATURE AXIS



GENESIS: DRY AIR MASSES--cP, cP-cT, mP-cT, mT-cT OR cT

Figure 119

SOURCE: AUTHOR'S CALCULATIONS.

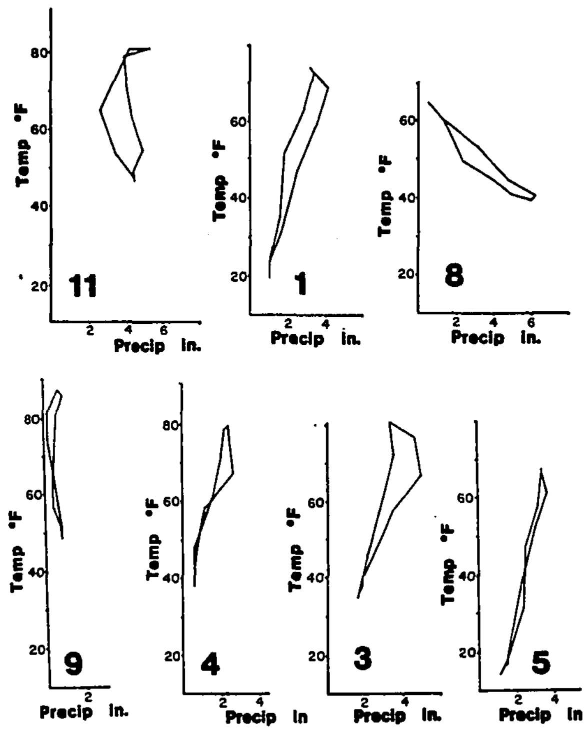
Group VIb (see Figure 120) represents mean climographs with one or more portions of its configuration relatively distant from the temperature axis, i.e., more precipitation. The lower portions of mean climographs 8, 9, and 11 are relatively distant from the temperature axis whereas the upper portions of mean climographs 1, 3, 4, 5, and 9 are relatively distant from the temperature axis. Significant climatic factor components for the relatively distant lower portions of the mean climograph from the temperature axis are mP air mass dominance and the absence of mP-cT and cP air mass dominance. Significant climatic factor components for the relatively distant upper portions of the mean climograph are mT, mT-mP, and mT-cT air mass dominance and the absence of cT air mass dominance.

Group VIc (see Figure 121) represents mean climographs with a combination of portions of the mean climograph near and relatively distant from the temperature axis. Three of the mean climographs--1, 4, and 5--have the lower portion of the configuration near the temperature axis and the upper portion relatively distant from the temperature axis. This results in a diagonal orientation of the mean climograph configuration. Mean climograph 9 has the extreme upper and the lower portion of its configuration relatively distant from the temperature axis, but June is near the temperature axis. This forms the before-mentioned "geometric arc" in the climograph configuration.

The specific air masses which influenced the distance of various portions of the mean climograph to the temperature axis were discussed relative to Groups VIa and VIb, but generally moist air mass dominance is related to relatively distant portions of the mean climograph to the

GROUP VIb

MEAN CLIMOGRAPH CHARACTERISTIC: ONE OR MORE PORTIONS OF THE MEAN CLIMOGRAPH ARE RELATIVELY DISTANT FROM THE TEMPERATURE AXIS



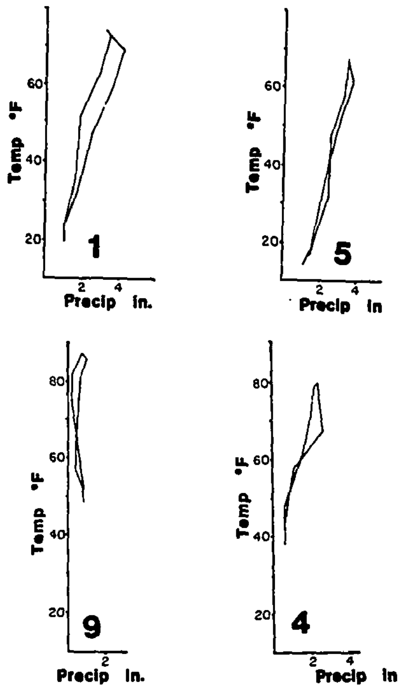
GENESIS: MOIST AIR MASS DOMINANCE--mP, mT, mT-mP, AND mT-cT BUT NO mP-cT, cP, AND cT AIR

Figure 120

SOURCE: AUTHOR'S CALCULATIONS.

GROUP VIc

MEAN CLIMOGRAPH CHARACTERISTICS: ONE PORTION OF THE MEAN CLIMOGRAPH IS NEAR THE TEMPERATURE AXIS AND ONE OR TWO PORTIONS OF THE MEAN CLIMOGRAPH ARE RELATIVELY DISTANT FROM THE TEMPERATURE AXIS



GENESIS: DRY AND MOIST AIR MASS DOMINANCE

Figure 121

SOURCE: AUTHOR'S CALCULATIONS.

temperature axis and dry air mass dominance is related to the portions of the climograph near the temperature axis.

Outlook

From this investigation, independent climatic factors and their components which operate in objectively derived climatic regions were genetically related to the distinctiveness and similarity of mean regional climographs. From an examination of the mean climograph configuration, students in geography and climatology will more easily grasp an understanding of the physical causes which produce a certain temperature-precipitation regime or climatic type. Furthermore, these climatic factor components should be of use in future genetic climatic classification systems.

In addition to the numerous contributions which were made in this paper to further a genetic climatic classification system for the United States which is of pedagogic significance, failure were encountered. These failures, however, are looked upon as positive aspects in this paper in that if they are overcome in future work, a more fruitful system may be developed. For example, since a highland region is not present in this classification system, future research should include additional mountain stations. Also, to avoid mathematical difficulties, additional stations should be added to several of the smaller regions. Since mean monthly temperature and precipitation data are used, some of the climatic controls which were difficult to interpret or were insignificant, such as sky cover, number of lows and highs, and mean pressure, should be analyzed by the month. Finally, upper air data would be extremely useful in explaining certain features of mean climograph.

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APPENDIX I

LISTING OF FIRST-ORDER WEATHER STATIONS USED IN THIS STUDY

<u>Alabama</u>
1 - Birmingham
2 - Huntsville
3 - Mobile
4 - Montgomery

<u>Arizona</u>
5 - Flagstaff
6 - Phoenix
7 - Prescott
8 - Tucson
9 - Winslow
10 - Yuma

<u>Arkansas</u>
11 - Fort Smith
12 - Little Rock
13 - Texarkana

<u>California</u>
14 - Bakersfield
15 - Bishop
16 - Blue Canyon
17 - Burbank
18 - Eureka
19 - Fresno
20 - Long Beach
21 - Los Angeles Airport
22 - Mt. Shasta
23 - Oakland
24 - Red Bluff
25 - Sacramento Airport
26 - Sandberg
27 - San Diego
28 - San Francisco Airport
29 - Santa Catalina
30 - Santa Maria
31 - Stockton

<u>Colorado</u>
32 - Alamosa
33 - Colorado Springs
34 - Denver
35 - Grand Junction
36 - Pueblo

<u>Connecticut</u>
37 - Bridgeport
38 - Hartford - Bradley Field
39 - New Haven

<u>Delaware</u>
40 - Wilmington

<u>District of Columbia</u>
41 - Washington National Airport

<u>Florida</u>
42 - Apalachicola
43 - Daytona Beach
44 - Fort Myers
45 - Jacksonville
46 - Key West
47 - Lakeland
48 - Miami Airport
49 - Miami Beach
50 - Orlando
51 - Pensacola
52 - Tallahassee
53 - Tampa
54 - West Palm Beach

Georgia
55 - Athens
56 - Atlanta
57 - Augusta
58 - Columbus
59 - Macon
60 - Rome
61 - Savannah

Idaho
62 - Boise
63 - Idaho Falls 46W
64 - Idaho Falls 42NW
65 - Lewiston
66 - Pocatello

Illinois
67 - Cairo
68 - Chicago Midway Airport
69 - Moline
70 - Peoria
71 - Rockford
72 - Springfield

Indiana
73 - Evansville
74 - Fort Wayne
75 - Indianapolis
76 - South Bend

Iowa
77 - Burlington
78 - Des Moines
79 - Dubuque
80 - Sioux City
81 - Waterloo

Kansas
82 - Concordia
83 - Dodge City
84 - Goodland
85 - Topeka
86 - Wichita

Kentucky
87 - Lexington
88 - Louisville

Louisiana
89 - Alexandria
90 - Baton Rouge
91 - Lake Charles
92 - New Orleans Airport
93 - Shreveport

Maine
94 - Caribou
95 - Portland

Maryland
96 - Baltimore Airport

Massachusetts
97 - Boston Airport
98 - Nantucket
99 - Pittsfield
100 - Worcester

Michigan
101 - Alpena
102 - Detroit City Airport
103 - Flint
104 - Grand Rapids
105 - Lansing
106 - Marquette
107 - Muskegon
108 - Sault Ste. Marie

Minnesota
109 - Duluth
110 - International Falls
111 - Minneapolis-St. Paul
112 - Rochester
113 - St. Cloud

Mississippi
114 - Jackson
115 - Meridian
116 - Vicksburg

Missouri
117 - Columbia
118 - Kansas City
119 - St. Joseph
120 - St. Louis Airport
121 - Springfield

Montana
122 - Billings
123 - Glasgow
124 - Great Falls
125 - Havre
126 - Helena
127 - Kalispell

128 - Miles City
129 - Missoula

Nebraska
130 - Grand Island
131 - Lincoln
132 - Norfolk
133 - North Platte
134 - Omaha Airport
135 - Scottsbluff
136 - Valentine

Nevada
137 - Elko
138 - Ely
139 - Las Vegas
140 - Reno
141 - Winnemucca

New Hampshire
142 - Concord
143 - Mt. Washington

New Jersey
144 - Atlantic City Airport
145 - Newark
146 - Trenton

New Mexico
147 - Albuquerque
148 - Clayton
149 - Raton
150 - Roswell
151 - Silver City

New York
152 - Albany
153 - Binghamton
154 - Buffalo
155 - New York LaGuardia Field
156 - Rochester
157 - Syracuse

North Carolina
158 - Asheville
159 - Cape Hatteras
160 - Charlotte
161 - Greensboro
162 - Raleigh
163 - Wilmington
164 - Winston-Salem

North Dakota
165 - Bismarck
166 - Fargo
167 - Williston

Ohio
168 - Akron-Canton
169 - Cincinnati Airport
170 - Cleveland
171 - Columbus Airport
172 - Dayton
173 - Mansfield
174 - Toledo
175 - Youngstown

Oklahoma
176 - Oklahoma City
177 - Tulsa

Oregon
178 - Astoria
179 - Burns
180 - Eugene
181 - Meacham
182 - Medford
183 - Pendleton
184 - Portland Airport
185 - Roseburg
186 - Salem
187 - Sexton Summit

Pennsylvania
188 - Allentown
189 - Erie
190 - Harrisburg
191 - Philadelphia Airport
192 - Pittsburgh Airport
193 - Reading
194 - Scranton
195 - Williamsport

Rhode Island
196 - Block Island
197 - Providence

South Carolina
198 - Charleston Airport
199 - Columbia
200 - Florence
201 - Greenville-Spartanburg

South Dakota
202 - Aberdeen
203 - Huron
204 - Rapid City
205 - Sioux Falls

Tennessee
206 - Bristol
207 - Chattanooga
208 - Knoxville
209 - Memphis Airport
210 - Nashville
211 - Oak Ridge

Texas
212 - Abilene
213 - Amarillo
214 - Austin
215 - Brownsville
216 - Corpus Christi
217 - Dallas
218 - El Paso
219 - Fort Worth
220 - Galveston
221 - Houston Airport
222 - Laredo
223 - Lubbock
224 - Midland
225 - Port Arthur
226 - San Angelo
227 - San Antonio
228 - Victoria
229 - Waco
230 - Wichita Falls

Utah
231 - Milford
232 - Salt Lake City
233 - Wendover

Vermont
234 - Burlington

Virginia
235 - Lynchburg
236 - Norfolk
237 - Richmond
238 - Roanoke

Washington
239 - Olympia
240 - Seattle Boeing Field
241 - Seattle-Tacoma Airport
242 - Spokane
243 - Stampede Pass
244 - Tatoosh Islands
245 - Walla Walla
246 - Yakima

West Virginia
247 - Beckley
248 - Charleston
249 - Elkins
250 - Huntington
251 - Parkersburg

Wisconsin
252 - Green Bay
253 - La Crosse
254 - Madison
255 - Milwaukee

Wyoming
256 - Casper
257 - Cheyenne
258 - Lander
259 - Sheridan

APPENDIX II

LISTING OF TEST WEATHER STATIONS

USED IN THIS STUDY

<u>Alabama</u>
1 - Brewton
2 - Greenville
3 - Tuscaloosa

<u>Arizona</u>
4 - Ajo
5 - Bisbee
6 - Clifton
7 - Globe
8 - St. Johns
9 - Williams

<u>Arkansas</u>
10 - Eldorado
11 - Fayetteville
12 - Jonesboro

<u>California</u>
13 - Alturas
14 - Blythe
15 - Brawley
16 - Death Valley
17 - Escondido
18 - Palmdale
19 - Redding
20 - Salinas
21 - Scotia
22 - Santa Barbara
23 - Sonora
24 - Susanville
25 - Truckee
26 - Ukiah
27 - Yosemite National Park
28 - Yreka

<u>Colorado</u>
29 - Cortez
30 - Glenwood Springs
31 - Gunnison
32 - Lemar
33 - Rocky Ford
34 - Sterling

<u>Florida</u>
35 - Avon Park
36 - Belle Glade Exp. Station
37 - Everglades
38 - Fort Lauderdale
39 - Fort Pierce
40 - Gainesville
41 - Homestead
42 - Lake City
43 - Moore Haven Lock 1
44 - Panama City
45 - Punta Gorda

<u>Georgia</u>
46 - Bainbridge
47 - Brunswick
48 - Tifton

<u>Idaho</u>
49 - Coeur d'Alene
50 - Grangeville
51 - Hailey
52 - McCall
53 - Salmon
54 - Twin Falls

Illinois
55 - Danville
56 - Mt. Vernon
57 - Quincy

Iowa
58 - Creston
59 - Fort Dodge

Kansas
60 - Hays
61 - Johnson
62 - Manhattan
63 - Parsons
64 - Pratt

Kentucky
65 - Bowling Green
66 - Hopkinsville

Louisiana
67 - Winnsboro

Maine
68 - Houlton
69 - Millinocket

Michigan
70 - Midland
71 - Traverse City

Minnesota
72 - Bemidji
73 - Fergus Falls
74 - Montevideo
75 - Roseau
76 - Virginia
77 - Willmar

Mississippi
78 - Hattiesburg
79 - University

Missouri
80 - Kirksville
81 - Poplar Bluff
82 - Salem

Montana
83 - Dillon
84 - Ekalaka

Nebraska
85 - Brokenbow
86 - McCook

Nevada
87 - Austin
88 - Boulder City
89 - Lovelock

New Mexico
90 - Carlsbad
91 - Deming
92 - Portales
93 - Santa Fe
94 - Tucumcari

New York
95 - Elmira
96 - Tupper Lake
97 - Watertown

North Carolina
98 - Kingston
99 - Lumberton

North Dakota
100 - Devils Lake

Oklahoma
101 - Ada
102 - Ardmore
103 - Chickasha
104 - Enid
105 - Hooker
106 - Woodward

Oregon
107 - Adrian
108 - Bend
109 - Brookings
110 - Canary
111 - Grants Pass
112 - Klamath Falls
113 - Lakeview
114 - Newport
115 - The Dalles

South Dakota
116 - Mitchell

<u>Texas</u>
117 - Alpine
118 - Angleton
119 - Beeville
120 - Del Rio
121 - Harlingen
122 - Huntsville
123 - Kerrville
124 - Lamesa
125 - Liberty
126 - Longview
127 - Plainview
128 - Presidio
129 - Quanah
130 - Raymondville

<u>Utah</u>
131 - Cedar City
132 - Hanksville
133 - Logan
134 - Park Valley
135 - Richfield
136 - Vernal

<u>Virginia</u>
137 - Winchester

<u>Washington</u>
138 - Aberdeen
139 - Bellingham
140 - Centralia
141 - Concrete
142 - Forks
143 - Longview
144 - Odessa
145 - Port Angeles
146 - Wenatchee

<u>Wisconsin</u>
147 - Ashland
148 - Eau Claire
149 - Rhinelander
150 - Sheboygan
151 - Wausau

<u>Wyoming</u>
152 - Green River
153 - Jackson
154 - Saratoga

APPENDIX III

STATION NAMES FOR SURFACE WATER TEMPERATURES ALONG UNITED STATES WEST COAST

1. Nesh Bay
2. Columbia River Lightship
3. Seaside Aquarium
4. Newport Marine Science Center
5. Umitilla Lightship
6. Depoe Bay
7. Charleston
8. Port Orford
9. Crescent City
10. Farallon Island
11. Fort Ross
12. Bodega Bay
13. Santa Cruz
14. Pacific Grove
15. Point Lobos; North Side
16. Point Lobos; South Side
17. Morro Bay
18. Avila
19. Santa Barbara
20. Ventura
21. Point Dume
22. Santa Monica
23. Balboa
24. San Clemente
25. Oceanside
26. La Jolla
27. Blunts Reef Lightship
28. Yerba Buena Lightship
29. Shelter Cove
30. Mendocino
31. Pt. Piedras Blancas
32. Dana Point
33. Cape Arago Light Station
34. Point Vicente
35. Gaviota
36. Avalon Bay
37. Point Arquello
38. Point Huenene
39. Point Lobos

APPENDIX IV

STATION NAMES FOR SURFACE WATER TEMPERATURES ALONG

UNITED STATES EAST COAST

1. Eastport, Maine
2. Petit Manan Island, Maine
3. Mount Desert Rock
4. Boothbay Harbor, Maine
5. Seguin Island
6. Portland, Maine
7. Portland Lightship
8. Boston Lightship
9. Race Points, Provincetown, Maine
10. Pollock Rip
11. Pollock Rip Lightship
12. Great Round Shoal Lightship
13. Cross Rip Lightship
14. Nantucket New So. Shoals Lightship
15. Nantucket Shoals Lightship
16. Nantucket Shoals Lightship
17. Woods Hole, Massachusetts
18. Vineyard Sound Lightship
19. Brenton's Reef
20. New London, Connecticut
21. Bartletts Reef
22. Stratford Shoal Lighthouse
23. Block Island, S.E. Light
24. Fire Island Lightship
25. New York City
26. Sandy Hook Lightship
27. Ambrose Lightship
28. Sandy Hook, New Jersey
29. Absecon Inlet, New Jersey
30. Five Fathom Bank
31. Five Fathom Bank Lightship
32. Fourteen Foot Bank
33. Winter Quarter Shoal Lightship
34. Winter Quarter Lightship
35. Chesapeake Lightship
36. Washington D.C. Potomac River

37. Bryans Point, Maryland
38. Windmill Point, Rappahannock River
39. Stingray Point Lighthouse, Chesapeake Bay, Virginia
40. Wolf Trap Bar, Chesapeake Bay
41. York Spit Lightship, Virginia
42. Norfolk, Virginia
43. Diamond Shoal Lightship
44. Cape Lookout, North Carolina
45. Beaufort, North Carolina Fisheries Laboratory
46. Frying Pan Shoals Lightship
47. Wilmington, North Carolina
48. Rattlesnake Shoal Lightship
49. Charleston Bar Lightship
50. Charleston, South Carolina
51. Martin's Industry Lightship
52. Savannah, Georgia
53. Jacksonville, Florida
54. Fowey Rocks Lightship, Florida
55. Carysfort Reef Lighthouse
56. Key West, Florida
57. Brunswick Lightship Station
58. Sombrero Key, Florida

APPENDIX V

A LISTING OF WEATHER STATIONS WHICH REPRESENT SUBREGIONAL BREAKS BY USE OF A .5 DISTANCE LEVEL PHENON LINE

1. LaCrosse, Wisconsin
2. Worcester, Massachusetts
3. Fargo, North Dakota
4. Spokane, Washington
5. Wendover, Utah
6. Eureka, California
7. Salem, Oregon
8. Burbank, California
9. Santa Maria, California
10. Oak Ridge, Tennessee
11. Wilmington, North Carolina
12. Florence, South Carolina
13. San Antonio, Texas
14. Pensacola, Florida

APPENDIX VI[a]

MATRIX OF CORRELATION COEFFICIENTS OF CLIMATIC CONTROLS

	EL	COSLT	MAWV	MSC	STDWV	STDSC	CONTIN	OROG	PRESS	STDPRESS	OCJAN	OCJY	TOLOWS	STDLOW	TOHIS	STDHIS	AM 1	AM 2	AM 3	AM 4	AM 5	AM 6	AM 7	AM 8	AM 9
EL	1.00																								
COSLT	-.19	1.00																							
MAWV	.07	.11	1.00																						
MSC	-.38	-.52	.05	1.00																					
STDWV	-.09	.05	.40	.11	1.00																				
STDSC	.30	-.30	-.22	-.13	-.16	1.00																			
CONTIN	.33	-.63	.27	.18	.02	.03	1.00																		
OROG	-.39	.14	.23	.12	.14	-.15	-.16	1.00																	
PRESS	-.49	-.02	-.26	.57	.03	-.04	-.19	.14	1.00																
STDPRESS	.70	.16	-.02	-.72	-.08	.37	.21	-.35	-.57	1.00															
OCJAN	-.31	.15	.04	-.07	-.09	-.21	-.40	.19	.10	-.29	1.00														
OCJY	.28	-.02	.16	.00	.09	-.03	.65	-.14	-.12	.28	-.54	1.00													
TOLOWS	.21	-.54	.38	.23	.06	-.17	.76	-.07	-.26	.03	-.14	.38	1.00												
STDLOW	.39	-.43	.38	.02	.02	-.08	.56	-.19	-.40	.18	-.08	.19	.80	1.00											
TOHIS	.05	-.54	.07	.58	.09	-.08	.61	-.07	.40	-.21	-.18	.39	.51	.25	1.00										
STDHIS	.31	-.20	-.18	.11	-.06	.32	.20	-.26	.17	.27	-.11	.20	.17	.11	.53	1.00									
AM 1	.54	-.66	.27	.19	-.05	.06	.74	-.22	-.32	.17	-.26	.36	.68	.63	.44	.17	1.00								
AM 2	-.05	-.31	.02	.31	.12	.00	.29	.03	.25	-.17	-.02	.21	.22	.08	.40	.17	.03	1.00							
AM 3	-.35	-.18	-.27	.24	.00	.13	-.20	.08	.36	-.36	.01	-.39	-.20	-.24	.01	-.09	-.27	-.07	1.00						
AM 4	.44	.05	-.06	-.38	-.04	.16	-.03	-.19	-.32	.40	-.02	-.01	.01	.08	-.21	.10	.09	-.16	-.43	1.00					
AM 5	.32	.03	-.08	-.37	-.06	.22	..00	-.17	-.34	.41	-.02	.02	.00	.08	-.18	.14	-.07	-.09	-.44	.63	1.00				
AM 6	.56	-.18	-.04	-.29	-.21	.42	.15	-.29	-.33	.52	-.04	.06	.01	.16	-.02	.32	.17	-.07	-.27	.20	.25	1.00			
AM 7	-.51	.11	.03	.16	.12	-.12	-.30	.26	.18	-.40	.04	-.28	-.16	-.16	-.19	-.28	-.26	-.17	.26	-.29	-.28	-.53	1.00		
AM 8	-.54	.76	.04	.00	.09	-.45	-.50	.30	.35	-.27	.21	-.02	-.42	-.44	-.24	-.26	-.58	-.14	-.10	-.29	-.28	-.46	.19	1.00	
AM 9	.21	.13	-.02	-.42	.00	.00	.03	-.10	-.53	.31	.03	.08	.01	.08	-.26	-.12	-.02	-.15	-.20	.20	.27	.34	-.12	-.25	1.00

[a]*Source:* Author's calculations

APPENDIX VII[a]

CLASSIFICATION COEFFICIENTS OF SEVEN CLIMATIC FACTORS PER CLIMATIC REGION

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9	Region 10	Region 11	Region 12	Region 13	Region 14	Region 15	Region 16	Region 17	Region 18	Region 19
Continental Storm Tracks	5.1	1.7	.1	.7	6.2	5.0	1.0	-.9	-.8	-7.4	-4.3	-3.9	-8.1	-9.1	-2.4	-6.8	-6.1	-5.8	-2.4
Solar Radiation Receipt	-2.3	-3.1	-1.3	2.6	-2.0	3.4	7.0	2.9	12.2	4.8	-2.4	1.3	-3.8	-3.8	-1.0	-1.2	-1.7	-3.0	-1.0
Winter-time High Pressure Systems	1.9	2.1	.7	.1	1.2	1.5	-1.1	-3.3	-3.7	-7.2	- .6	-1.5	-2.6	-..8	-5.6	-2.6	-2.0	-1.0	-5.6
Ocean Currents	2.1	.3	2.3	2.4	.2	1.0	-.3	-7.8	-1.0	-6.7	1.3	2.1	-.5	-.6	-10.3	2.7	2.1	2.0	-10.3
Maritime Cloud Variability	-3.0	-3.2	-4.7	-3.0	1.2	4.9	8.1	15.6	9.9	11.1	-5.3	-4.1	-8.5	-12.2	14.3	-8.3	-7.1	-8.0	14.3
Continental Moisture Index	-1.6	-1.8	-1.5	- .4	-1.0	1.7	5.3	4.5	6.6	3.1	-2.1	-1.1	-1.8	- 2.5	2.1	-1.4	-1.8	-2.4	2.1
Wind Strength Variability	1.3	1.5	1.9	1.9	- .1	-1.9	-2.9	-2.8	-3.5	-2.7	.6	.8	.9	1.8	.2	2.7	1.9	1.1	.2

[a]Source: Author's calculations.

APPENDIX VIII

LIST OF FIRST-ORDER STATIONS

BY CLIMATIC REGION

Region 1

1. St. Cloud
2. Minneapolis
3. Rochester
4. Sioux Falls
5. Flint
6. Green Bay
7. Madison
8. Rockford
9. Dubuque
10. Waterloo
11. LaCrosse
12. Grand Island
13. Norfolk
14. Sioux City
15. Lincoln
16. Omaha
17. Des Moines
18. Grand Rapids
19. Muskegon
20. Topeka
21. St. Joseph

Region 2

1. St. Louis
2. Springfield
3. Indianapolis
4. Columbus
5. Dayton
6. Cincinnati
7. Harrisburg
8. Chicago
9. Fort Wayne
10. South Bend
11. Moline
12. Burlington
13. Peoria
14. Akron
15. Pittsburgh
16. Cleveland
17. Mansfield
18. Youngstown
19. Scranton
20. Concord
21. Binghamton
22. Buffalo
23. Syracuse
24. Erie
25. Albany
26. Lansing
27. Rochester
28. Detroit
29. Toledo
30. New Haven
31. Bridgeport
32. Boston
33. Providence
34. Hartford
35. Allentown
36. Williamsport
37. Nantucket
38. Block Island
39. Beckley
40. Elkins
41. Portland
42. Pittsfield
43. Worcester
44. Atlantic City
45. Newark
46. New York
47. Baltimore
48. Trenton

49. Philadelphia
50. Reading
51. Wilmington
52. Greensboro
53. Winston-Salem
54. Raleigh
55. Richmond
56. Norfolk
57. Washington, D.C.
58. Lynchburg
59. Roanoke
60. Asheville
61. Charleston
62. Bristol
63. Lexington
64. Parkersburg
65. Evansville
66. Huntington
67. Louisville

Region 3

1. Columbia
2. Kansas City
3. Wichita
4. Springfield
5. Fort Smith
6. Oklahoma City
7. Tulsa

Region 4

1. Amarillo
2. Lubbock
3. Dodge City
4. Concordia
5. Roswell

Region 5

1. Caribou
2. Alpena
3. Marquette
4. Sault Ste. Marie
5. Duluth
6. International Falls
7. Milwaukee
8. Burlington

Region 6

1. Billings
2. Miles City
3. North Platte
4. Valentine
5. Scottsbluff
6. Rapid City
7. Goodland
8. Raton
9. Colorado Springs
10. Denver
11. Casper
12. Lander
13. Cheyenne
14. Sheridan
15. Glasgow
16. Williston
17. Bismarck
18. Havre
19. Aberdeen
20. Huron
21. Fargo
22. Great Falls
23. Helena
24. Kalispell
25. Missoula
26. Idaho Falls 42NW
27. Idaho Falls 46W
28. Alamosa
29. Elko
30. Ely
31. Winnemucca
32. Burns
33. Pocatello
34. Milford
35. Spokane
36. Lewiston
37. Salt Lake City
38. Flagstaff

Region 7

1. Albuquerque
2. Winslow
3. Silver City
4. Prescott
5. Bishop
6. Clayton
7. Pueblo
8. Grand Junction
9. Wendover
10. Reno
11. Pendleton
12. Boise
13. Walla Walla
14. Medford
15. Yakima

Region 8
1. Eureka
2. Mt. Shasta
3. Seattle
4. Portland
5. Roseburg
6. Seattle-Tacoma
7. Eugene
8. Salem
9. Meacham
10. Sexton Summit

Region 9
1. Las Vegas
2. Phoenix
3. Tucson
4. Bakersfield
5. El Paso
6. Sandberg

Region 10
1. Santa Catalina
2. Los Angeles
3. San Diego
4. Long Beach
5. Burbank
6. San Francisco
7. Oakland
8. Santa Maria
9. Fresno
10. Sacramento
11. Stockton
12. Red Bluff

Region 11
1. Jackson
2. Vicksburg
3. Texarkana
4. Shreveport
5. Alexandria
6. Meridian
7. Montgomery
8. Columbus
9. Birmingham
10. Charlotte
11. Greenville
12. Atlanta
13. Athens
14. Huntsville
15. Rome
16. Chattanooga
17. Knoxville
18. Nashville
19. Little Rock
20. Memphis
21. Cairo
22. Oak Ridge
23. Cape Hatteras
24. Savannah
25. Charleston
26. Wilmington
27. Macon
28. Augusta
29. Columbia
30. Florence
31. Port Arthur
32. Baton Rouge
33. Lake Charles
34. New Orleans

Region 12
1. Wichita Falls
2. Abilene
3. Waco
4. Dallas
5. Fort Worth
6. San Antonio
7. Midland
8. San Angelo

Region 13
1. Brownsville
2. Corpus Christi
3. Laredo

Region 14
1. Galveston
2. Houston
3. Victoria
4. Austin

Region 15
1. Orlando
2. Lakeland
3. Tampa
4. Fort Myers
5. Jacksonville
6. Daytona Beach

Region 16
1. Mobile
2. Pensacola

3. Tallahassee
4. Apalachicola

<u>Region 17</u>

1. West Palm Beach
2. Miami

<u>Region 18</u>

1. Miami Beach
2. Key West

<u>Region 19</u>

1. Tatoosh Island
2. Astoria

APPENDIX IX

LIST OF TEST STATIONS BY CLIMATIC REGION

Region 1
1. Willmar
2. Sheboygan
3. Fort Dodge
4. Wausau
5. Eau Claire
6. McCook
7. Creston
8. Montevideo
9. Hays
10. Roseau
11. Fergus Falls
12. Mitchell
13. Broken Bow

Region 2
1. Midland
2. Elmira
3. Winchester
4. Tupper Lake
5. Mt. Vernon
6. Danville
7. Watertown
8. Millinocket
9. Poplar Bluff
10. Hopkinsville

Region 3
1. Quincy
2. Fayetteville
3. Parsons
4. Kirksville
5. Ada
6. Enid
7. Manhattan
8. Salem
9. Woodward
10. Chickasha

Region 4
1. Pratt
2. Hooker
3. Plainview
4. Tucumcari
5. Portales
6. Carlsbad
7. Alpine
8. Lamesa

Region 5
1. Rhinelander
2. Virginia
3. Traverse City
4. Houlton
5. Bemidji
6. Ashland

Region 6
1. Ekalaka
2. Sterling
3. Devils Lake
4. Gunnison
5. Green River
6. Jackson
7. Saratoga
8. Dillon
9. Coeur d'Alene
10. Odessa
11. Bend
12. Lakeview
13. Austin
14. Cedar City
15. Williams
16. McCall
17. Grangeville
18. Salmon
19. Richfield

20. Logan
21. Vernal
22. Park Valley
23. Santa Fe
24. Alturas

Region 7

1. Lovelock
2. Johnson
3. Lemar
4. Glenwood Springs
5. Twin Falls
6. Wenatchee
7. The Dalles
8. Adrian
9. Globe
10. Cortez
11. Hailey
12. Hanksville
13. Deming
14. St. Johns
15. Rocky Ford
16. Yreka
17. Klamath Falls
18. Bisbee
19. Susanville

Region 8

1. Grants Pass
2. Longview
3. Bellingham
4. Centralia
5. Port Angeles
6. Scotia
7. Ukiah
8. Truckee
9. Yosemite

Region 9

1. Clifton
2. Blythe
3. Boulder City
4. Ajo
5. Death Valley
6. Brawley
7. Palmdale
8. Presidio

Region 10

1. Redding
2. Escondido
3. Salinas
4. Sonora
5. Santa Barbara

Region 11

1. Kingston
2. Greenville
3. University
4. Lumberton
5. Hattiesburg
6. Jonesboro
7. Eldorado
8. Winnsboro
9. Bowling Green
10. Tuscaloosa
11. Longview
12. Tifton

Region 12

1. Quanah
2. Kerrville
3. Ardmore

Region 13

1. Del Rio
2. Harlingen
3. Raymondville
4. Beeville

Region 14

1. Huntsville
2. Angleton
3. Liberty

Region 15

1. Lake City
2. Avon Park
3. Gainesville
4. Brunswick
5. Everglades
6. Moore Haven
7. Belleglade
8. Punta Gorda

Region 16

1. Panama City
2. Bainbridge
3. Brewton

Region 17

1. Homestead
2. Fort Lauderdale
3. Fort Pierce

<u>Region 18</u>
None

<u>Region 19</u>
1. Concrete
2. Newport
3. Aberdeen
4. Forks
5. Brookings
6. Canary