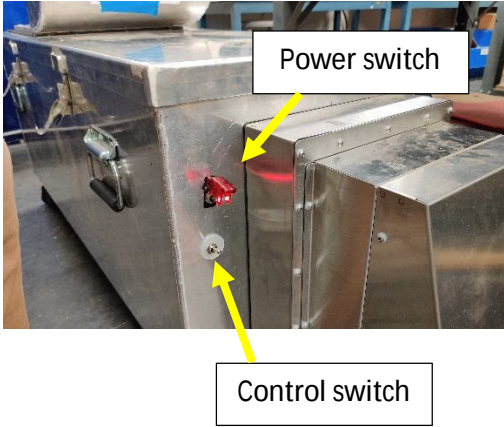


STEPS	DETAILS	BACKGROUND
Organize before deploying the EM27	1. Check the weather and make sure the conditions are favorable for testing. Ideal conditions are minimal to no cloud cover and minimal chance of precipitation. The EM27s can handle some cloud cover and should be able to keep tracking the sun after a couple minutes of cloud disturbance. More disturbance may call for realignment (discussed later).	Here are some potentially useful sites for monitoring weather conditions: • National Weather Center (NWS) forecasts: https://www.weather.gov/ - o Useful for hourly predictions. • GOES satellite view: https://weather.cod.edu/satrad/ - o Useful for viewing current cloud cover. • Radar: https://weather.cod.edu/satrad/nextrad/

The EM27s **CANNOT be rained on**. If deploying on a day with a **slight chance of precipitation or higher**, stay nearby to pack up the instrument quickly before the rain comes. Determine slight chance of precipitation or higher by using the hourly NWS weather forecast (see link in right column).

STEPS	DETAILS	BACKGROUND
Organize before deploying the EM27 (continued)	- Record the expected weather conditions in the digital lab notebook. - Get equipment organized. Most items needed for deployment will stay with the EM27s, but some may not (i.e., laptops). - Gather everything in the checklist and travel to the deployment site, in whatever order is required.	Checklist of items for deployment of a single EM27: - The EM27 in its travel case - EM27 enclosure + power cord (optional) - EM27 power cables - Ethernet cable - USB cable - Extension cord - The EM27 laptop - Laptop charger - Pressure sensor + datalogger - Hotspot + power cable, Ethernet cable
Optional: Set up the enclosure	- If using an enclosure, place it on relatively flat, level ground such that the enclosure is oriented north/south with the rounded hatch pointing south. If not using an enclosure, skip to step 16. - Locate the green power cord with one female and one male end. If you are setting up the enclosure after it has been stored in place at its location, the power cord is likely not plugged in and instead stored inside the enclosure itself. Open the enclosure by unlocking any locks hinging the top of the enclosure open. - Close the enclosure lid if you had to open it. - Partially closing and opening the lid will disengage the locking mechanism that holds the lid in place so you can fully close the lid.	

STEPS	DETAILS	BACKGROUND
Optional: Set up the enclosure (continued)	8. Connect the enclosure to power using the green cord and the electrical port on the outside of the enclosure. 9. Make sure the enclosure has power by checking the coolers. If the fans are turning, you have power. 10. Power the rounded EM27 hatch control using the red covered switch. The picture on the right shows the linear actuator power switch in the ON position. 11. Raise the hatch by toggling the bottom switch up. 12. Once the linear actuator has opened the EM27 hatch, flip the power switch to OFF and put the control switch back in neutral. 13. View the current conditions provided on the NWS page for your deployment site (https://www.weather.gov/). 14. Record current conditions in the lab notebook (temperature, humidity, dew point, wind speed/direction, cloud cover, etc.)	We want to limit the amount of time the enclosure is open in case the outside air is more humid than the air inside the box. This will help keep water vapor from condensing inside. 

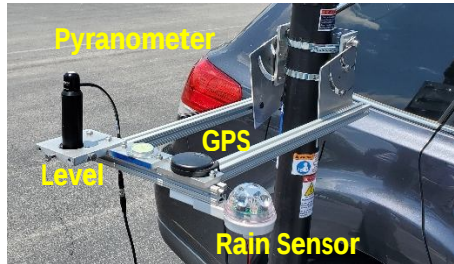
STEPS	DETAILS	BACKGROUND
Optional: Set up the enclosure (continued)	15. Set the cooler setpoint to three degrees greater than the dewpoint (in Fahrenheit) on the thermocouple readout (taped to the roof of the enclosure). a. To adjust the setpoint, hold the asterisk button and use the arrow keys to toggle to the correct temperature.	Linear actuator switches:  You should be able to access the thermocouple readout by reaching into the EM27 hatch when the enclosure lid is down. If this isn't possible, lift the lid of the enclosure to adjust the setpoint and close it once you are done.
Optional: Set up secondary instrumentation	16. If setting up the secondary instrumentation suite, first place the Hurry-Up mast inside the drive-on mounting plate at a location at least 5 m from any tree or building. If not deploying secondary instrumentation, skip to step 25. 17. Secure the mast plate with a car. 	The mast used here is a manual push-up telescoping mast created by Will-Burt (Orrville, Ohio, USA). Deploying away from tall objects is necessary to collect accurate data with the weather station.

STEPS

Optional: Set up secondary instrumentation (continued.)

DETAILS

18. Attach the pyranometer, level, GPS, and rain sensor housing to the mast.



Secure the housing by tightening the two hose clamps to the mast with a flathead screwdriver.



19. Adjust the angle of the housing until the instruments are level with the ground.

A level level:



20. Remove the green cap from the pyranometer so that it can collect data.

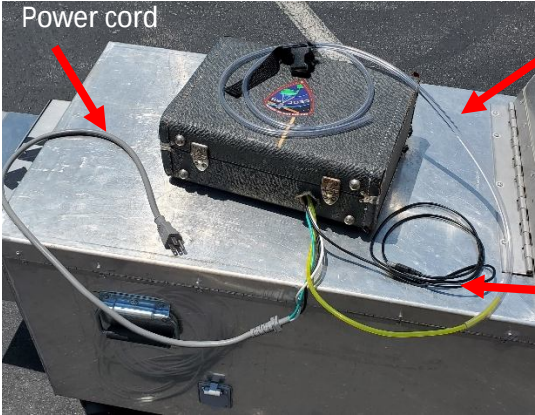


BACKGROUND

This housing was custom-built and designed such that the angle of the housing could be adjusted manually using adjustable bolts in curved slots. After loosening the bolts, the housing could be tilted to the appropriate angle then secured by tightening the bolt.



STEPS	DETAILS	BACKGROUND
Optional: Set up secondary instrumentation (continued.)	21. Anchor the weather station to the top of the mast. Ensure that the North arrow marked on the weather station is actually pointing North before securing the sensor. 22. Connect the weather station, pyranometer, GPS, and rain sensor to power and the datalogger. If using an enclosure, unique connectors are built into the side of the enclosure that are used for both power and data transfer to the datalogger.  North marker 	Unique connectors:  

STEPS	DETAILS	BACKGROUND
Optional: Set up secondary instrumentation (continued.)	23. Locate the datalogger/pressure sensor case and ensure that the pressure sensor sample tube is unobstructed.  Power cord 24. Plug in the datalogger/pressure sensor case to building power.	Sample tube USB connection for data retrieval from the logger
Set up EM27	25. Remove the EM27 from the travel case. 26. If using an enclosure, open the enclosure lid. Set the EM27 on the raised platform in the enclosure such that the mirrors can “look” out of the enclosure through the EM27 hatch. If not using an enclosure, skip to step 27.	There may be a plastic cover over the mirror housing on the EM27. Set this aside before moving the EM27. 

STEPS

Set up EM27
(continued)

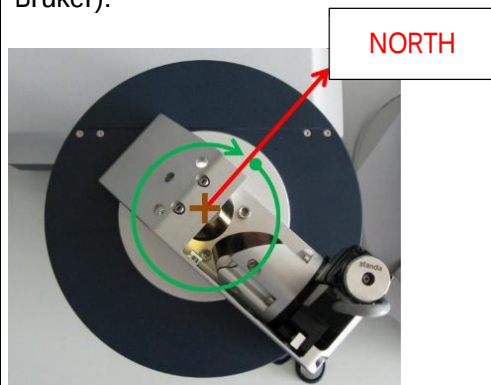
DETAILS

27. **If not using an enclosure**, place the EM27 on a flat testing surface (e.g., folding table) with the metal plane at the back of the mirror housing perpendicular to the North/South direction, with the metal plane farther South than the mirror.
28. Check to see if the EM27 is level by checking the bubble level located on the blue platform below Mirrors 1 and 2.
 - a. If the EM27 is level, skip to step 29.
 - b. If the EM27 is not level, adjust the platform/enclosure that the EM27 is on until the instrument is level.
29. Remove the lens cover from the body of the EM27.

To remove the lens cover, pull the cover away from the body of the EM27 until it is detached, **making sure to not touch the third mirror or lens in the process.**
30. If using an enclosure, place the fabric EM27 collar around the mirror platform like the picture in step 26 Connect the Velcro to the enclosure as best as possible. Make sure to not obstruct the thermocouple readout in the process.

BACKGROUND

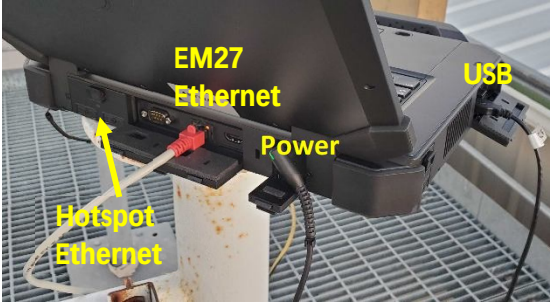
Mirror housing alignment (courtesy of Bruker):



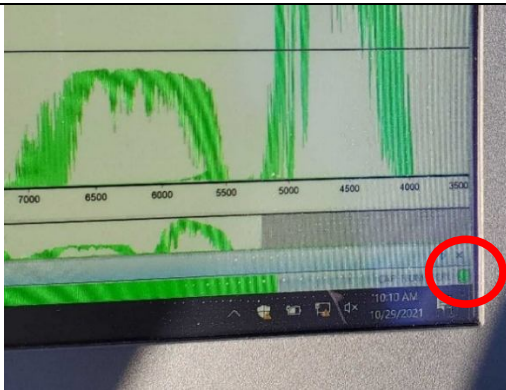
Small terry towels are useful for folding and placing under table legs or travel case wheels to make the system level.

Lens location:



STEPS	DETAILS	BACKGROUND
Connect the EM27 to power and laptop	31. If using an enclosure, connect the EM27, laptop, hotspot, and datalogger case power cords to the power strip located inside the enclosure. Also connect these cords to their respective devices. If not using an enclosure, connect the all power cords (e.g., EM27, laptop, hotspot, and datalogger case) directly to the building or mobile power supply. Also connect these cords to their respective devices. Cable configuration on field laptop:  The EM27 Ethernet cable must be plugged into the correct port for everything to work properly. 32. Connect the USB and Ethernet cables to the EM27 and the laptop. 33. If using an enclosure, make sure that the open end of the clear tube connected to the datalogger case is positioned outside of the enclosure. If not using an enclosure, skip to step 34.	If using an enclosure, the laptop and datalogger case can be kept inside the enclosure to keep them cool. If not using an enclosure, try to keep the equipment in the shade to avoid overheating effects. Cable configuration on the back of the EM27:  The metal enclosure acts as a Faraday cage, so the hotspot will not be able to work properly if inside the enclosure without antennae on the outside. Keep the hotspot outside of the enclosure unless you have supplementary antennae (future editions of the procedure will include this).

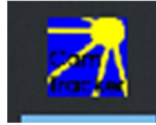
STEPS	DETAILS	BACKGROUND
Connect the EM27 to power and laptop (continued)	34. Connect the hotspot Ethernet cable (white cable with clear connections) to the hotspot and the field laptop. 	The pressure sensor needs to be able to sample ambient air outside of the enclosure to accurately measure pressure. Hotspot Ethernet connection Hotspot power connection
EM27 Startup	35. Turn the laptop on and log in. 36. Press the ON/OFF button on the back of the EM27 and make sure the light above it eventually stays green.  37. Open OPUS using the icon at the bottom of the screen. The password for OPUS is OPUS 	Note: the touch pad on the laptop is difficult to use. Use the attached stylus on the touch screen for more effective interfacing. The light above the ON/OFF button should flash red and green several times before staying green. Avoid opening OPUS versions not pinned to the taskbar at the bottom of the screen. These versions may not be compatible with the EM27 anymore.

STEPS	DETAILS	BACKGROUND																		
EM27 Startup (continued)	38. Ensure that everything is connected properly by checking the circle in the lower right-hand corner of the screen. - If it is green, continue. - If it is gray, wait a minute to see if it turns green. If not, ensure all connections are secure, restart OPUS, and check again. 39. Check to see if the time on the laptop is correct. If it is different, even by a minute, change the time manually.																			
CamTracker Startup	40. Open "CamTrackerConfig.txt" located in C:\Users\Public\Documents\Bruker\camtracker_3_9_1_0 41. Make sure the information on lines 9-11 match the information for the site you are testing at by using the table on the right. If testing at a site not listed in the table, use Google Maps to find the coordinates and https://apps.nationalmap.gov/elevation/ to find the ground-level elevation, which should be modified if setting up on a platform, building, etc.	<table> <tr> <th>Location</th><th>Site Code</th><th>Details (Latitude, Longitude in degrees; elevation in km)</th></tr> <tr> <td>Lamont, OK next to TCCON</td><td>LT</td><td>Lat: 36.6038 Lon: -97.4856 Elev: 0.3181 *</td></tr> <tr> <td>TRACER Main ARM Site</td><td>T5</td><td>Lat: 29.6692 Lon: -95.0595 Elev: 0.0079 *</td></tr> <tr> <td>TRACER UH Coastal Center Site</td><td>T6</td><td>Lat: 29.3884 Lon: -95.0425 Elev: 0.0055 *</td></tr> <tr> <td>TRACER UH Main Campus Site</td><td>T7</td><td>Lat: 29.7240 Lon: -95.3392 Elev: 0.0121 *</td></tr> <tr> <td>TRACER UH Aldine Site</td><td>T8</td><td>Lat: 29.9012 Lon: -95.3262 Elev: 0.0214 *</td></tr> </table> *: elevation includes 3 ft for deployment on a table or instrument travel case	Location	Site Code	Details (Latitude, Longitude in degrees; elevation in km)	Lamont, OK next to TCCON	LT	Lat: 36.6038 Lon: -97.4856 Elev: 0.3181 *	TRACER Main ARM Site	T5	Lat: 29.6692 Lon: -95.0595 Elev: 0.0079 *	TRACER UH Coastal Center Site	T6	Lat: 29.3884 Lon: -95.0425 Elev: 0.0055 *	TRACER UH Main Campus Site	T7	Lat: 29.7240 Lon: -95.3392 Elev: 0.0121 *	TRACER UH Aldine Site	T8	Lat: 29.9012 Lon: -95.3262 Elev: 0.0214 *
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TRACER UH Aldine Site	T8	Lat: 29.9012 Lon: -95.3262 Elev: 0.0214 *																		

STEPS**DETAILS****BACKGROUND**

42. Save the file and close it.

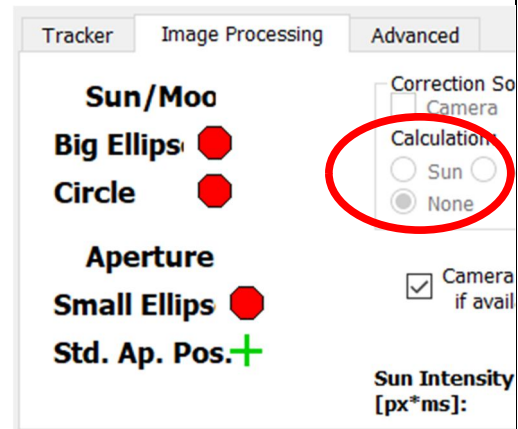
43. Open CamTracker.



44. If you modified the CamTracker configuration file, select “Read Configuration File” under the “Options” drop down menu.

45. In the “Tracker” tab, click “Initialize Tracker.”

46. Navigate to the “Imaging Processing” tab and click on the bubble next to the “Sun” option under “Calculation:”



STEPS

CamTracker
Startup
(continued)

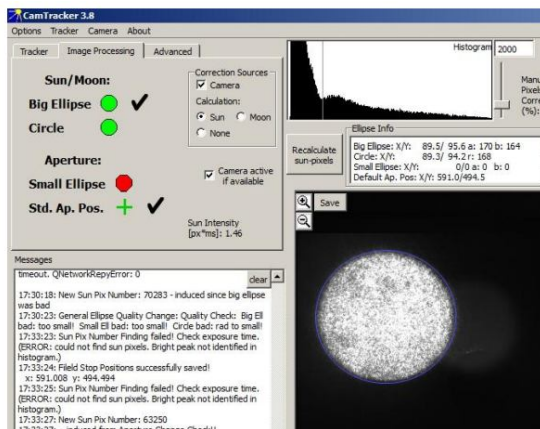
DETAILS

47. Navigate back to the "Tracker" tab and align the mirrors so they direct the sunlight into the EM27. Use the "+" and "-" buttons for Motor 1 and Motor 2 to rotate the elevation and azimuthal mirrors, respectively.

- c. Motor adjustment size can be changed by typing new values in the "size" box before clicking the "+" and "-" buttons.

First, make sure all incident light is being reflected from Mirror 2 into the tube to Mirror 3.

Then, make minor (~0.5 or less) motor adjustments while monitoring the histogram and camera preview in CamTracker. The histogram will grow when more light is present. The mirrors will be aligned when there is a circle of light in the center of the camera preview and there is a thin blue circle around the edge of the circle of light (shown below, minus the centered image requirement. Picture courtesy of Bruker)



BACKGROUND

Pieces of paper are useful for checking the alignment after Mirror 2 (the azimuthal mirror) and Mirror 3 (by the lens). Blocking incident light not from Mirror 1 (the elevation mirror) and blocking the light path from mirror to mirror and help identify alignment issues:



Blocking incident light:



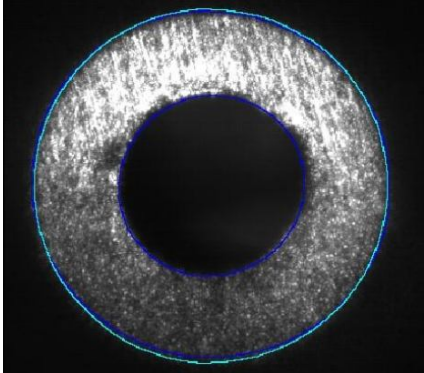
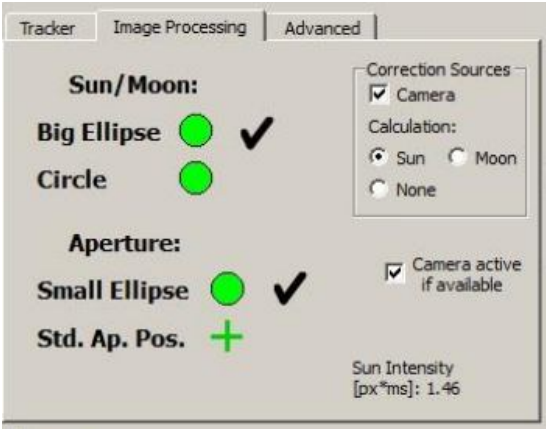
Blocking light path:

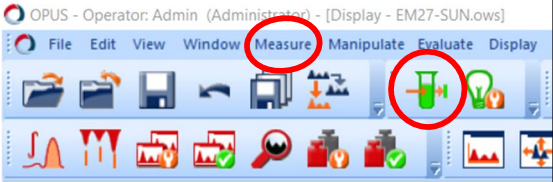
Proper alignment should result in the following observations:

- No sunlight reflected from mirror housing when looking at the sunlight reflected from Mirror 2.
- Perfect circles of light reflected from Mirrors 2, 3.
- Sharp edges of the circle reflected from mirror 3. Very minor adjustments can be made to make this happen (motor adjustments of around 0.02).

A good example of the light reflected from Mirror 3 when Mirrors 1 and 2 are aligned:



STEPS	DETAILS	BACKGROUND
CamTracker Startup (continued)	48. Once the mirrors appear to be aligned, remove any paper used for adjustments and click on the “Imaging Processing” tab. b. If there are green circles next to “Big Ellipse” and “Circle,” along with check marks by these same indicators, continue to step 49. c. If one of the above conditions is not met, adjust the mirrors to achieve better alignment and check again. 49. Once the good quality conditions are met in step 48, click the box next to “Camera” under the header that reads “Correction Sources.” 50. Wait for the EM27 to adjust. Watch the condition indicators and the sunlight reflection image in the “Image Processing” tab. 51. Once all indicators are green (image below courtesy of Bruker), CamTracker is working properly and should successfully track the Sun unless interrupted by clouds, night, etc.	The sunlight reflection should look as follows, with blue circles surrounding the inner and outer ellipses (courtesy of Bruker): 
		

STEPS	DETAILS	BACKGROUND
CamTracker Startup (continued)	52. Record the time, elevation and azimuth angles, as well as the motor offsets in the lab notebook. These can be useful for simplifying the alignment process during later deployments at the same site.	
Data Collection in OPUS	53. Keeping CamTracker open, navigate back to OPUS. 54. Take a single measurement by either clicking on the Measurement button (green test tube) in the main ribbon of the GUI or selecting “Advanced Measurement” from the “Measure drop-down menu. 	

STEPS	DETAILS	BACKGROUND
Data Collection in OPUS (continued)	55. Ensure that all the settings are appropriate. The most important are listed here: d. In the “Advanced” tab: i. File name: bl<Y><m><d>.ifg.00 00 ii. Path: either an existing or new folder of your chosen name under C:\Data iii. Resolution: 0.5 cm⁻¹ iv. Sample scan time: 2 scans v. Background scan time: 1 scans vi. Save data from: 100 to 15797.9 cm⁻¹ vii. Data blocks to be saved: Single Channel, Sample Interferogram e. In the “Optic” tab: i. Sample preamp gain: B ii. Background preamp gain: A f. In the “Acquisition” tab: i. Wanted high/low frequency limit: set to match the range given in the “Advanced” tab g. In the “FT” tab: i. Phase resolution: 12 ii. Phase correction mode: Mertz iii. Apodization function: Boxcar iv. Zerofilling factor: 2 56. Back in the “Basic” tab, click the “Sample Single Channel” button.	Add folders as needed or desired, just make sure you note where OPUS is saving data. The upper limit of the frequency range may not be accepted by OPUS. Just use the highest number allowed that is below 15798 cm⁻¹.

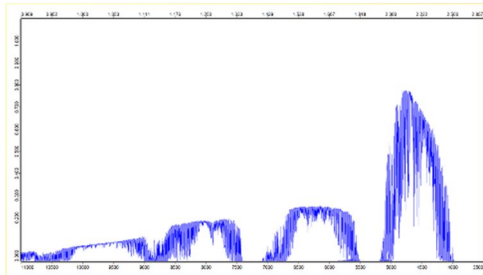
STEPS

Data
Collection in
OPUS
(continued)

DETAILS

57. Look at the interferogram in OPUS.
If it looks reasonable, skip to step
59.

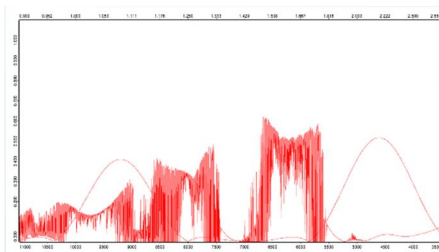
The interferogram should look
something like this when looking at
the interferogram generated by
both detector channels:



58. If the interferogram does not look
reasonable, go back to step 55, and
repeat until this point, using
different preamp gains in the
“Optic” tab until a reasonable
interferogram is generated.

59. Under the “Measure” drop-down
menu, select the “Repeated
Measurements” option.

BACKGROUND



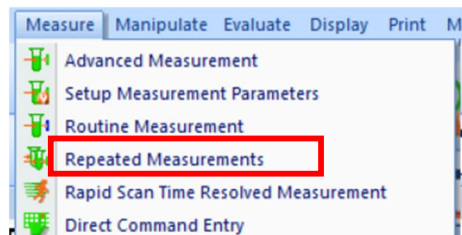
Unreasonable interferograms may be
warped or have pseudo sinusoidal
curves present like this interferogram:

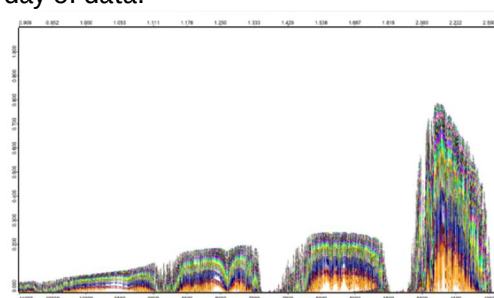
To view the interferogram generated by
both detector channels, click on the “2
CHN” button (highlighted in red below)
under the interferogram name in the
OPUS Browser that you want to view.



Other preamp gain combinations that
may work better depending on the
conditions:

- Sample gain of B, background
gain of C
- Sample gain of B, background
gain of B
- Sample gain of A, background
gains of A/B/C (only use if the
sun intensity is very low)



STEPS	DETAILS	BACKGROUND
Data Collection in OPUS (continued)	60. Adjust the settings according to Step 55 with the following exceptions: h. In the “Basic” tab: i. Repeat the measurement: 3000 times ii. Delay between measurements: 0 sec 61. Navigate to the “Check Signal” tab and wait for the signal to stabilize. 62. Record the amplitude and position in the lab notebook. 63. Click the “Save Peak Position” button. 64. Back in the “Basic” tab, click the “Repeated Sample Single Channel” button. 65. If using an enclosure, place the laptop inside the enclosure with the screen still open. Shut the lid to the enclosure so ensure the inside will stay conditioned.	This will ensure that the spectrometer collects data all day.
EM27 monitoring	66. If the EM27 appears to be operating as expected (CamTracker’s quality indicators are green, OPUS is recording reasonable looking interferograms), you can sit back and enter babysitter mode. Make sure to place the laptop in the shade if possible to avoid overheating. Recall that if there <i>is a slight chance or higher of rain/thunderstorms</i>, you must stay at the site so you can cover the EM27 or close the EM27 hatch on the enclosure before rain begins.	If set up properly, OPUS should gather spectra that look like the one shown in step 57 above. Throughout the day, interferogram peak magnitude will fluctuate according to the solar zenith angle (SZA). Here is an example of a full day of data: 

STEPS	DETAILS	BACKGROUND
EM27 monitoring (continued)	67. Throughout the day, especially if you have reason to believe that something (clouds, people, etc.) interrupted the column of air that the EM27 is analyzing, check CamTracker and OPUS to make sure everything is working as it was when you left it during step 66. Record observations in the lab notebook (i.e., sky cover, temperature, time window of deployment, purpose of deployment, any issues encountered, etc.).	If the EM27 stops tracking the sun due to a disturbance, realign the mirrors using the same process you used earlier.
Halt data collection and shut down EM27	68. If at the end of the day, OPUS is still trying to collect data, right click on the status bar at the bottom of the screen. 69. Halt the data collection by selecting the “Abort Task Group” option in OPUS. Move on to the next step only once the status bar says “No Active Task” like it did when you first opened OPUS. 70. Record what time you ended the data collection in the lab notebook. 71. Close OPUS. 72. With CamTracker open, record the elevation and azimuth angles, as well as the motor offsets in the lab notebook. 73. In the “Tracker” tab of CamTracker, click the button that reads “Move Tracker to park pos.” 74. Once both mirrors on the EM27 have stopped moving, close CamTracker.	CamTracker may ask if you really want to quit. Simply click ‘yes.’

STEPS	DETAILS	BACKGROUND
Optional: Prepare EM27 for next day deployment with enclosure	75. If not using an enclosure, skip to step 84. If using an enclosure, determine if you are going to be deploying at the same site the next day. 76. If you are deploying at the same site the next day, leave the EM27 powered on and connected to the computer. 77. Unplug the datalogger case from power to keep it from taking data overnight.	Leaving the EM27 on overnight will decrease your chances of dew forming on the external optics since the EM27 itself produces heat.
Optional: Prepare EM27 for next day deployment with enclosure (continued)	78. Check the NWS' predicted low temperature for the night. 79. Change the enclosure temperature set point to at least two degrees above the low temperature. 80. Lower the EM27 hatch using the toggle switches described in steps 10-12. 81. Close the enclosure lid for the night. 82. Secure the enclosure by locking the lid and chaining it to nearby permanent objects if able. 83. When deploying the next day, repeat the steps above as needed. Continue repeating these steps until you are ready to leave the site and then follow the remaining steps to properly store everything.	This is another safeguard to prevent dew from forming on the optics overnight.
Shut down and store the instruments	84. Power off the EM27. 85. Put the EM27 lens cap over the lens <u>without touching any of the mirrors or the lens itself.</u>	

STEPS	DETAILS	BACKGROUND
Shut down and store the instruments (continued)	86. Disconnect all cables from the EM27, laptop, and hotspot. 87. Gather the cords neatly using the provided twist-ties and/or cord holders. 88. Locate the large plastic bag used for cord storage. Place all cords in the bag except for the extension cord and enclosure power cord, if used. 89. Unplug the datalogger case from power but leave the power cables attached to the case. 90. Screw the port connectors back on the USB, power, and Ethernet ports on the EM27. 91. Place the EM27 back in the travel case as you found it earlier. The EM27's orientation within the travel case is very important to properly store it. See the pictures below for guidance.	

STEPS	DETAILS	BACKGROUND
Shut down and store the instruments (continued)	92. Place the laptop, cords (minus the extension cord and/or enclosure power cord), and ratchet strap in the case. For our EM27/travel case combination, use the following layout: Laptop Cord Bags Ratchet Strap 93. Once the case contents are properly stored, carefully put the lid back on the travel case. 94. If using an enclosure, unplug the enclosure power cord and store it inside the enclosure. 95. If using secondary instrumentation, unplug all instruments from power and store as necessary for future deployments. 96. Remove towels or other objects from beneath the testing surface (or enclosure) that may have been used to level the EM27. 97. Store everything <i>except for the laptop, hotspot, and datalogger</i> as needed.	

STEPS	DETAILS	BACKGROUND
Shut down and store the instruments (continued)	98. Set the laptop and hotspot up in a secure location such that they are both connected to power and to each other. <u>Sign out of Administrator, but do not power down the laptop.</u>	
Transfer data from field equipment	99. Within your EM27 data folder on the field laptop, create folders for every date you deployed. 100. Sort all the raw EM27 data files into the appropriate date folders. 101. Leave the laptop connected to the hotspot and building power. Every day at 19:00 CST, new directories and their contents within C:\Data will be automatically copied to Schooner via SCP. The following steps are for downloading data from the secondary instrumentation. 102. Plug the USB cord attached to the datalogger case to the field laptop. 103. On the field laptop, open LoggerNet using the desktop icon. 104. On the LoggerNet GUI, select “Connect” under the Main tab.   105. Make sure that “CR6Series” is listed under the “Stations” menu.	There is no mandatory naming convention for the date folders, but YYYYMMDD is customary.

STEPS	DETAILS	BACKGROUND
Transfer data from field equipment (continued)	106. Click on “CR6Series” to select it if it is not already selected. 107. Click the “Connect” button. Once the logger is connected, the “Connect” button will change to a “Disconnect” button.  108. Click on the “Custom” button in the same ribbon as the “Connect”/”Disconnect” button. 109. In In the Custom Collection screen, adjust the following settings: a. Collect Mode: Data From Selected Date and Time b. File Mode: Append to End of File c. File Format: ASCII Table Data, Long Header (TOA5) d. In the “Starting Date/Time” section, specify the date and time options as desired to save the appropriate data e. In the “Format Options” section, only select Include Timestamp, Include Record Number f. In the “Table Collection” section, select the necessary files to save 110. Once all settings have been adjusted, click “Start Collection.” A new popup window entitled “Data Collection Results” should appear when the collection is complete. 111. Click “Ok.” 112. The data will be saved in *.dat files located in the directory/directories specified in the “Table Collection” section mentioned above.	The “Append to End of File” option ensures that the new data you save is appended to the existing file instead of creating a new file or replacing an existing file. This is important to note when processing data for analysis.