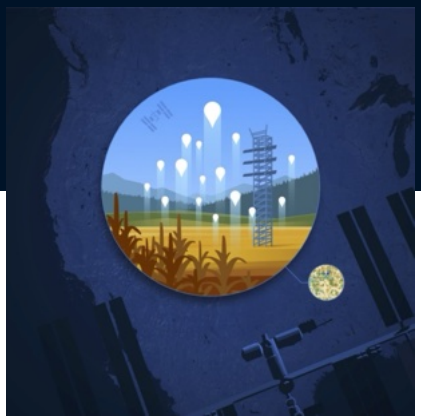


8

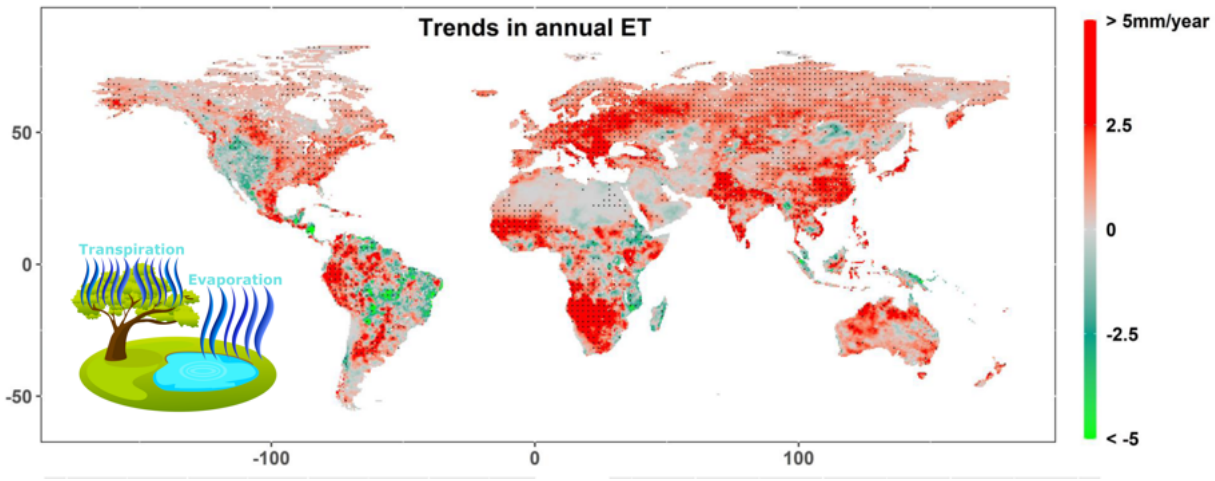
Evapotranspiration from ECOSTRESS

Quick Links To Sections

Objectives:

1. Familiarize yourself with the basics of evapotranspiration data derived from land surface temperatures. Recognize that estimates can be instantaneous or a daily average and that there are different algorithms.
2. Practice visualizing and interpreting the data from ECOSTRESS.

Motivation For Today's Tutorial: The Global Water Crisis



So far, we have used ECOSTRESS to examine land surface temperatures. Today, we will explore a variable that the United Nations considers to be at the center of the climate crisis: water.

ECOSTRESS uses land surface temperatures to estimate an important water variable: evapotranspiration (ET). ET is the sum of all processes that return water from the land surface to the atmosphere and is comprised of two components:

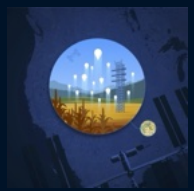
- Evaporation: process by which water is converted from a liquid on the earth's surface to vapor in the atmosphere. Evaporation can be from soil surfaces or from rainfall that is intercepted on plant surfaces.
- Transpiration: process by which water is lost from plants and returned to the atmosphere. The loss of water from plants is a consequence of the need for a permeable leaf surface that facilitates the uptake of CO_2 (e.g., through the stomata). Transpiration is a crucial component of the global terrestrial water cycle, as it returns around 60-70% of water from the ground to the atmosphere.

The figure above, adapted from Jianyu Liu et al. (2021), observes a trend of increasing ET for at least 80% of the Earth between 1980 and 2017, driven by anthropogenic changes to our climate.

8.1 ACCESSING ECOSTRESS WATER DATA THROUGH AppEEARS

8.1.1 ECOSTRESS Data Product Levels

Based on the amount of processing that is needed to create the data, ECOSTRESS has different levels of data "products." Land surface temperature (LST) data are the primary observation of ECOSTRESS and form the basis for the other products. LST is a Level 2 (ECO2) product, because it follows the calibration data in the Level 1 (ECO1) product. The level 3 (ECO3) data product is evapotranspiration, followed by



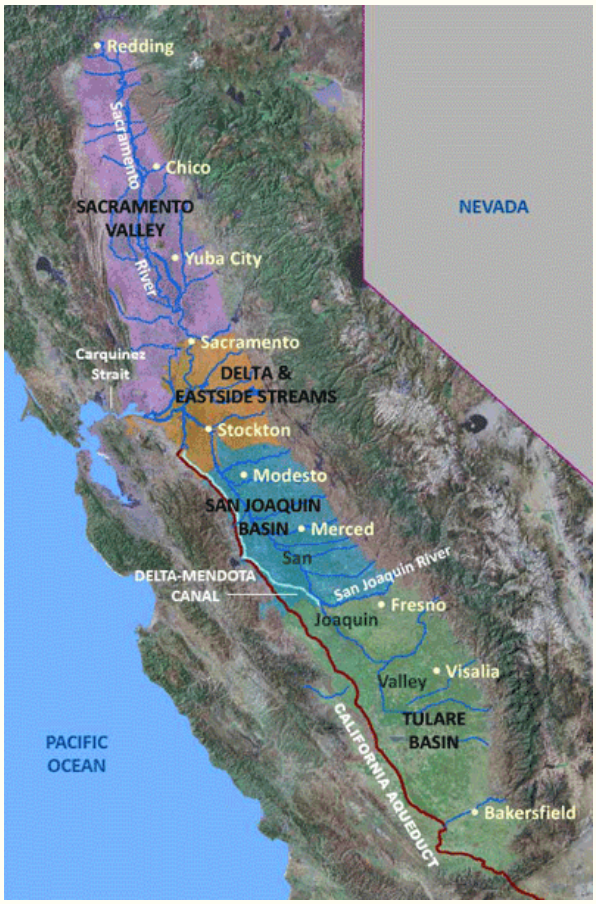
products derived from evapotranspiration (ET), such as the evaporative stress index (ESI) and water use efficiency (WUE). Later tutorials will introduce WUE and ESI, while we focus here on ET. This table gives an overview of the ECOSTRESS data products:

Data Product	Description	Pixel Size*	Temporal Resolution (days)
ECO1BRAD.001	Radiometric Calibration	70 x 70	Over continental United States and target areas**, every 1-7 days
ECO1BATT.001	Attitude and Ephemeris		
ECO1BMAPRAD.001	Radiometric Calibration		
ECO1BGEO.001	Geometric Calibration		
ECO2LSTE.001	Land Surface Temperature and Emissivity		
ECO2CLD.001	Cloud mask		
ECO3ETPTJPL.001	Evapotranspiration (PT-JPL model enhanced)		
ECO3ANCQA.001	Ancillary Data Quality		
ECO3ETALEXIU.001	Evapotranspiration (ALEXI model enhanced)	30 x 30***	
ECO4ESIPTJPL.001	Evaporative Stress Index derived from L3_ET_PT-JPL	70 x 70	
ECO4ESIALEXIU.001	Evaporative Stress Index derived from L3_ET_ALEXI	30 x 30***	
ECO4WUE.001	Water Use Efficiency	70 x 70	

*More accurately referred to as pixel spacing resolution (m) because of dependencies on ISS altitude, which varies.
**For more info, please visit ECOSTRESS Gmap to see where data has been acquired
***70 x 70 is resampled to 30 x 30 (meters)

8.1.2 Today's Study Location: California's Central Valley

California's Central Valley

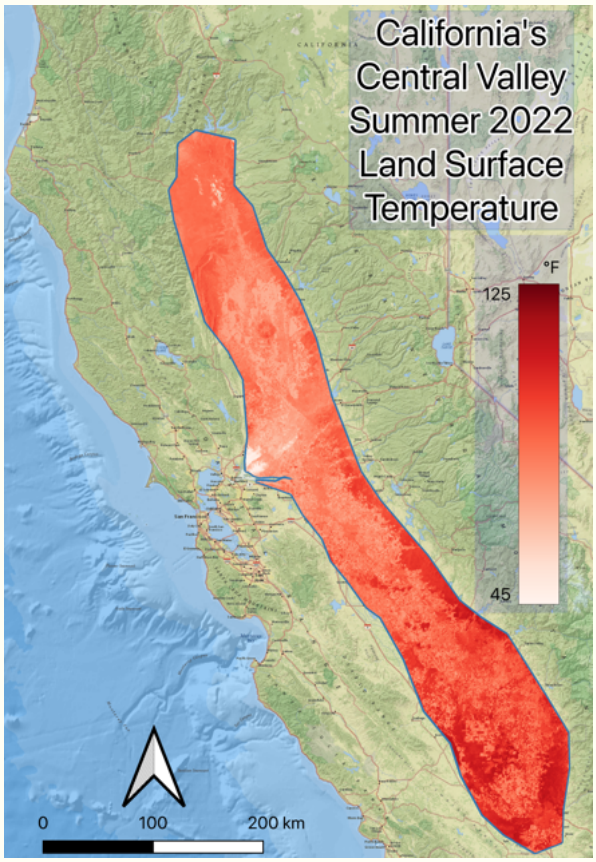


- A vast agricultural region covering 20,000 square miles drained by the Sacramento and San Joaquin Rivers.
- Approximately 75% of the irrigated land in California, and 17% of the irrigated land in the country, is in the Central Valley.
- Using less than 1% of U.S. farmland, the Central Valley produces $\frac{1}{4}$ of the food grown in the United States.
- About 20% of the nation's groundwater demand is supplied by pumping Central Valley aquifers, making it the second-most-pumped aquifer system in the U.S.
- As a result of climate change impacts in the Central Valley, there is a 93% likelihood of diminished groundwater delivery to millions of Californian households, businesses, and farms. There is also a 95% probability of reduced drought resilience for crops.

Hypotheses

Before we access the data, let's make some predictions about evapotranspiration:

- Given this map to the right, where we observe average land surface temperatures observed by ECOSTRESS during summer 2022, where would you expect evapotranspiration to be highest?
- Will hotter land surface temperatures correlate with higher rates of transpiration?
- To find out, we are going to download evapotranspiration data from ECOSTRESS, make a map of evapotranspiration, and compare that map with this land surface temperature map.



8.1.3 Downloading Evapotranspiration from AρρEEARS

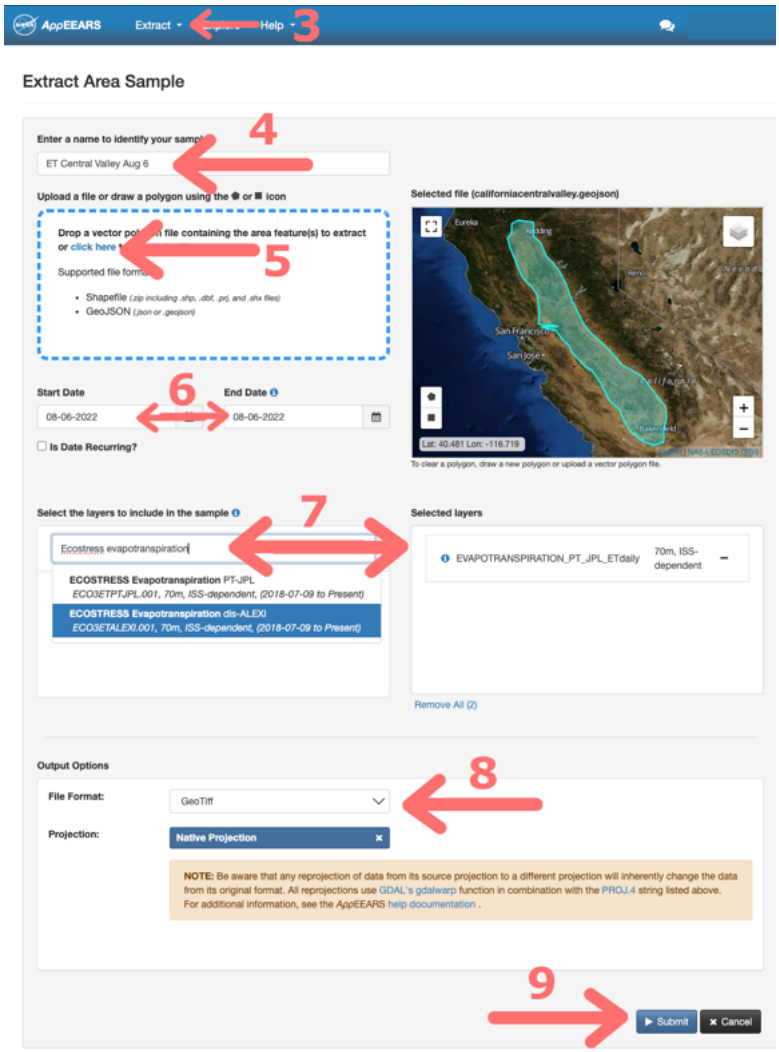
The procedure for downloading ET data through the AρρEEARS interface is the same as the previous tutorials on land surface temperature.

1. Since we are focusing on California's Central Valley, begin by downloading the file CaliforniaCentralValley.geojson and saving it somewhere you can remember. I recommend a folder containing all the files for this tutorial. Depending on your web browser, you may need to right-click and select *Save as*. Some web browsers may even display the contents of the GeoJSON file instead of prompting you to save it. If this happens, you can select the *File* dropdown menu and click on *Save as*.

NOTE: A .geojson file is an alternative to the shapefiles we have used to date. QGIS can import or export either format. An advantage of GeoJSON is that it is self-contained and does not need to be zipped before importing into AρρEEARS.

2. Go to https://appeears.earthdatacloud.nasa.gov/ and login with your credentials.
3. Use the *Extract* dropdown menu to select *Area*. Next select *Start a New Request*.
4. Enter a useful name for the request you are going to submit, such as "ET Central Valley Aug 6, 2022."
5. Drag and drop (or use the *click here to select the file* link) to upload the GeoJSON file CaliforniaCentralValley.geojson. The map should be updated with a polygon encompassing California's Central Valley.
6. Update the *Start* and *End* Date Fields for our preselected date of interest: 08/06/2022 to 08/6/2022.

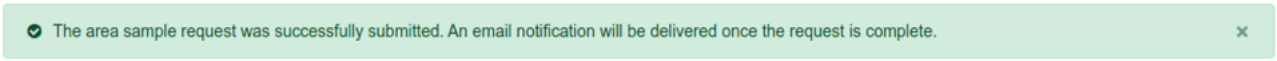
7. Under *Select the layers to include in the sample* type the words “ECOSTRESS” and “Evapotranspiration.” Then scroll until you can click on *ECOSTRESS Evapotranspiration PT-JPL*. From there, scroll until you see *EVAPOTRANSPIRATION_PT_JPL_ETdaily* option. Click on the “+” signs to add that layer to your cart. Next, clear the selection of the current category using the small “x” to the right of the *ECOSTRESS Evapotranspiration PT-JPL* box.



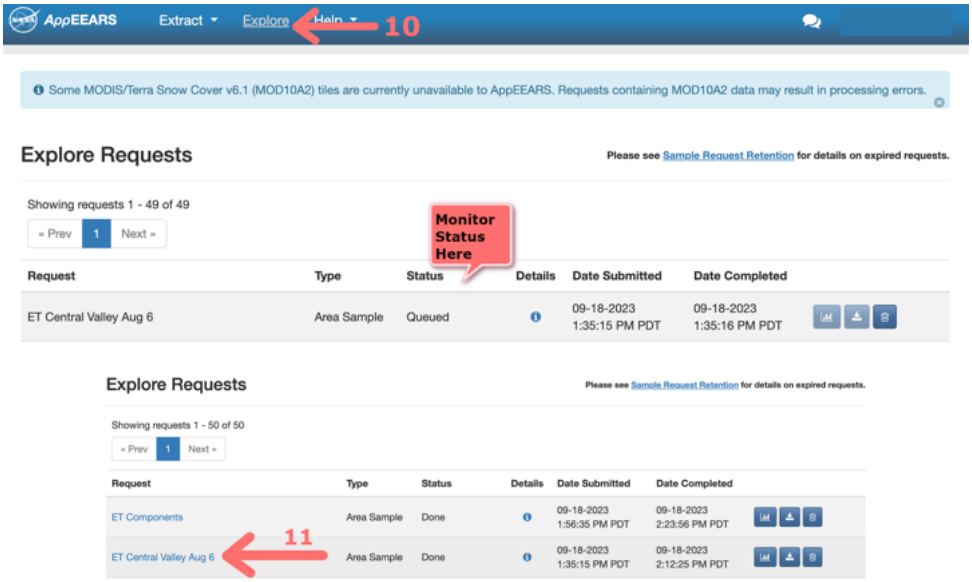
NOTE: There are two models that can estimate evapotranspiration based on ECOSTRESS’s measurement of land surface temperature. One model, “PT-JPL”, is the most versatile and likely the best choice for most cases, including our experiment here today. The other option “DisALEXI-JPL” has a different set of equations associated with it. If you are interested in evapotranspiration in agricultural settings, consider DisALEXI; otherwise, or if you are unsure, stay with PT-JPL.

NOTE: Additionally, the PT-JPL model estimates two different evapotranspiration products. One, *EVAPOTRANSPIRATION_PT_JPL_ETinst* is a modelled estimation of the instantaneous evapotranspiration for the precise moment the satellite made the observation. The other, *EVAPOTRANSPIRATION_PT_JPL_ETdaily*, is a modelled estimation of the sum total amount of evapotranspiration all daylight hours. While the instantaneous data is useful for making comparisons between two land covers (especially if they are in the same satellite pass), while the daily is useful for agricultural settings. Today we are going to use the daily.

8. Under *Output Options*, we want to use GeoTIFF (Geographic Tagged Image File Format; essentially an image file where the corresponding geographic information is embedded in the file) and *Native Projection* for projection.
9. Click *Submit* to complete the data request. At the top, you should see a green banner:

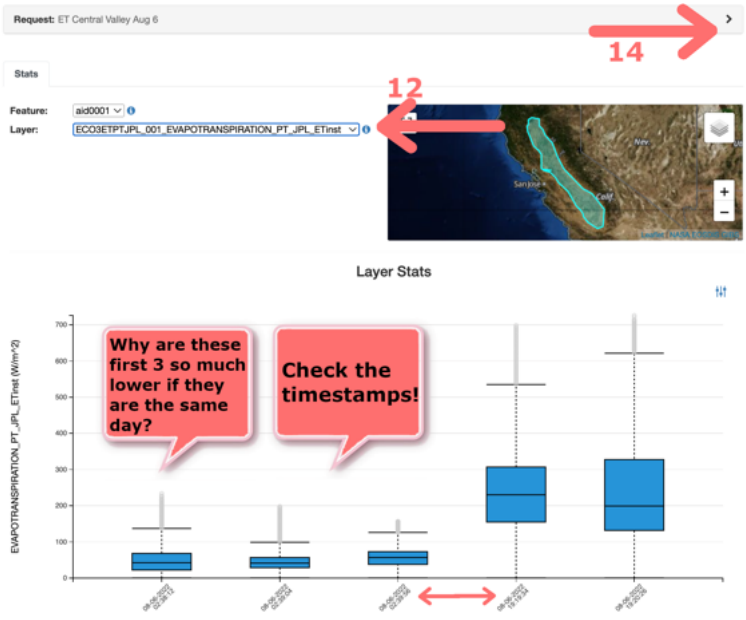


10. Use the *Explore* drop-down at the top to monitor the status of your request. It will likely be available quickly, given that it is only one day's worth of data.



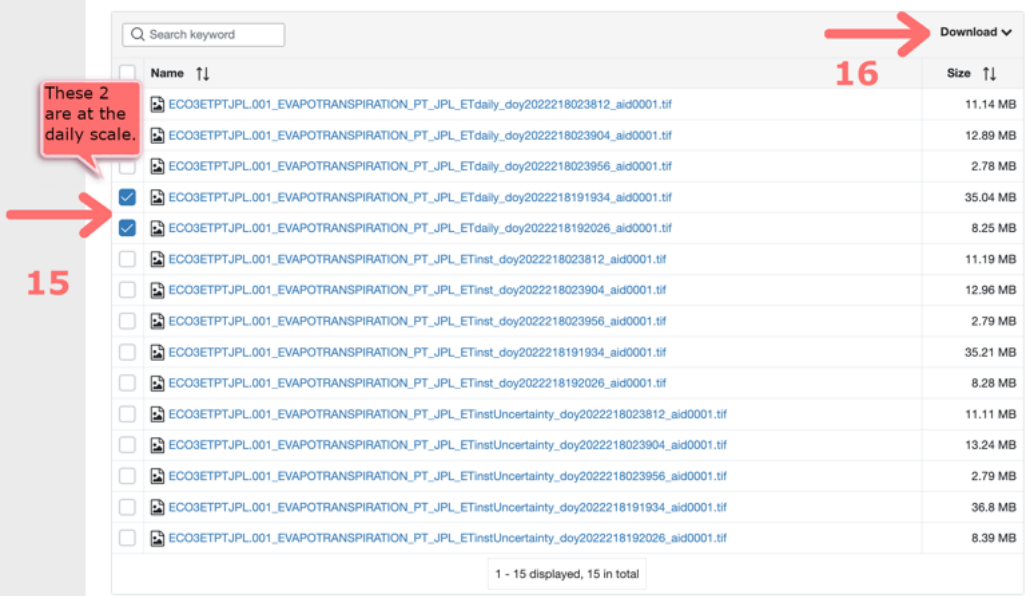
8.1.4 Data Check

11. When your request for ("ET Central Valley Aug 6, 2022") is complete, use the link on the *Explore* page to access the details. Let's check out the data!



12. Select the *ECOSTRESS Evapotranspiration PT-JPL* layer.
13. Notice that there were different overpasses by ECOSTRESS on the same day with very different values. Any ideas why? Checking the timestamps reveals the answer. The first three overpasses were at 02:00 in the morning when there is no sun and the plants are not transpiring.
14. To download the data from the daylight hours, select the small caret arrow in the gray box above and click on the *Download* button.
15. Select the following filenames:

- ECO3ETPTJPL.001_EVAPOTRANSPIRATION_PT_JPL_ETdaily_doy2022218192026_aid0001.tif
- ECO3ETPTJPL.001_EVAPOTRANSPIRATION_PT_JPL_ETdaily_doy2022218191934_aid0001.tif



NOTE: ECOSTRESS estimates evapotranspiration at two time scales. The first, *ET_inst*, stands for instantaneous evapotranspiration and is calculated at the moment of the satellite pass. The other, *ET_daily*, is an estimate of the total evapotranspiration for the day of the satellite pass.

16. Download the files using the *Download* button (that for some reason does not look much like a button) on the upper right corner of the screen. Save the files somewhere you can remember.

8.2 VISUALIZING ECOSTRESS EVAPOTRANSPIRATION DATA IN QGIS

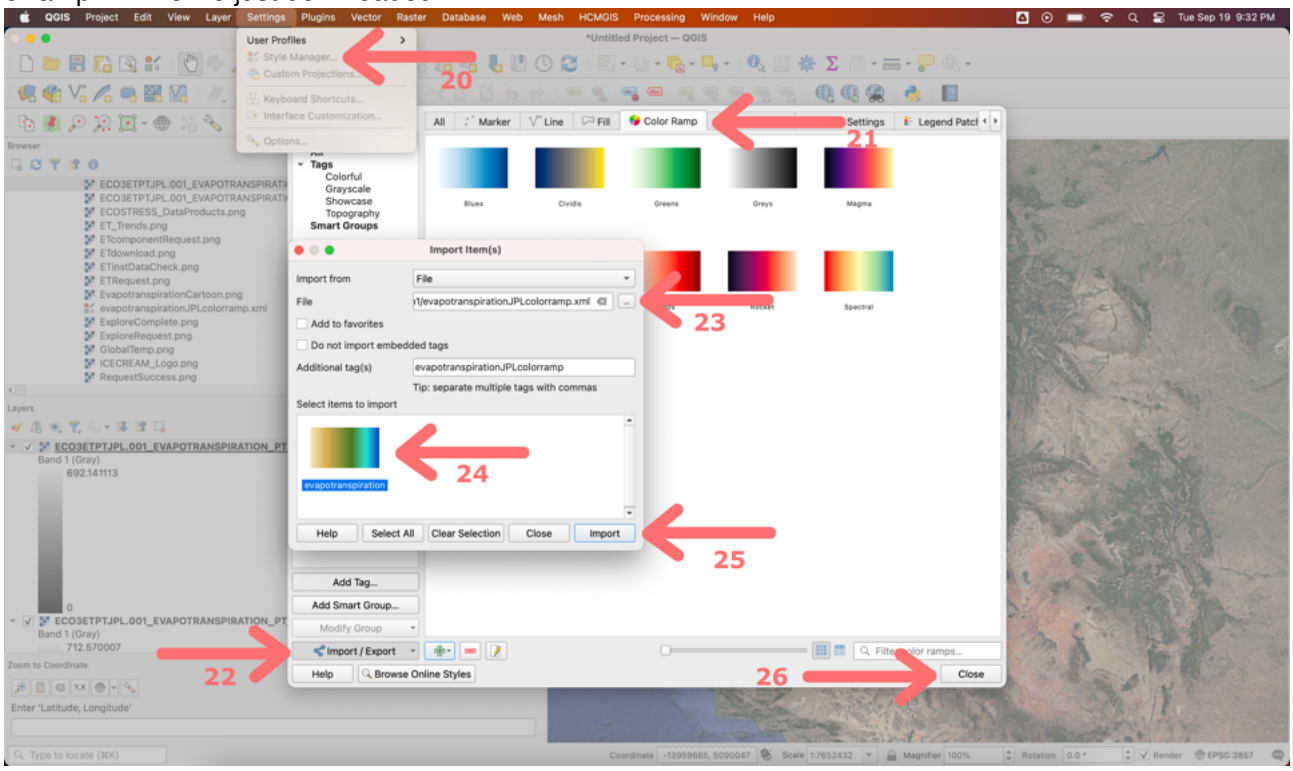
8.2.1 Adding a Google Satellite Basemap

17. Open QGIS and start a new project by selecting the *Project* menu, then *New*.
18. To add a basemap, find the *HCMGIS* menu bar, select *Basemap*, then pick your preferred map. For today's map, we will use *Google Satellite*. Note that clicking on a basemap type automatically adds a new layer to your map, as seen in the layer browser window.

8.2.2 Importing The NASA JPL Evapotranspiration Color ramp

NASA has specifically designed a color palette to use with ECOSTRESS evapotranspiration data.

19. Download the color ramp file here: evapotranspirationJPLcolorramp.xml and save it somewhere you can remember. Depending on your PDF viewer, you may have to right-click and then hit *Save As*.
20. From the *Settings* top menu, select *Style Manager*.
21. Select the “Color Ramp” tab.
22. Find and click on the *Import/Export* button.
23. To the right of the *File* input box click on the button with 3 dots (...). Select the evapotranspirationJPLcolorramp.xml file we just downloaded.



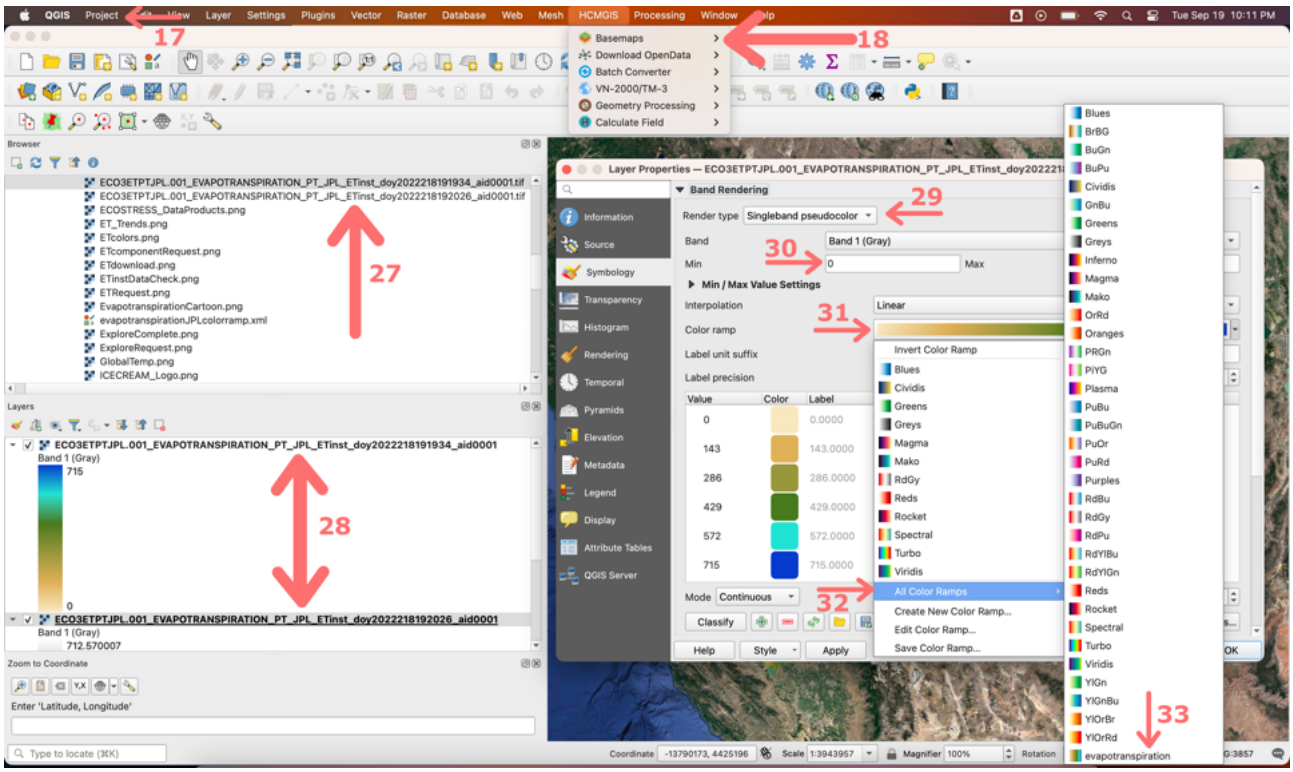
24. Click on the new “evapotranspiration” color ramp.
25. Click the *Import* button.
26. Click the *Close* button. We will use this color ramp in the next section of this tutorial.

8.2.3 Add in evapotranspiration layer(s)

27. Use the *browser* window to find the folder where you saved the two daily evapotranspiration .tif files:

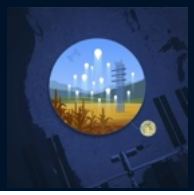
    - ECO3ETPTJPL.001_EVAPOTRANSPIRATION_PT_JPL_ETdaily_doy2022218192026_aid0001.tif
    - ECO3ETPTJPL.001_EVAPOTRANSPIRATION_PT_JPL_ETdaily_doy2022218191934_aid0001.tif

Double-click each file to add them to your map. Again, notice that they are now also listed in the *Layers* window.



28. Now you have the ECOSTRESS evapotranspiration data on your map. But wait, if you recall from our Death Valley Land Surface Temperature maps, QGIS does not know the type of data you are using and has defaulted to displaying the information in grayscale. For each of the evapotranspiration layers, right-click on the layer name in the *Layers* window and select *Layer Properties*.
29. On the menu bar on the left, select *Symbology* and change *Render type* to Singleband pseudocolor.
30. QGIS has automatically determined the minimum and maximum values from the datafiles; however, we have two files, so we need to match them. Specify 0 as the minimum and 400 as the maximum. Click apply.
31. To access the fancy new color ramp we just downloaded, click on the color ramp button.
32. Select *All Color Ramps*.
33. Select our new *Evapotranspiration* color ramp.
34. Finally, add the border from CaliforniaCentralValley.geojson by double clicking on it in the *Browser* window. Right-click (ctrl-click on Mac) on the layer in the *Layers* window and change the symbology to *outline red*.
35. Do you see evidence that warmer land surface temperatures in the Central Valley correspond to higher rates of transpiration?

NOTE: Data for the entire Central Valley available were not available, which is why the northern and southern most part of the outline do not have any color overlayed. This sometimes happens because of the orbit of the space station. If we were interested in filling in the gaps, we would look for passes plus or minus one week around the same time of day and form a composite image.



Make a Map Assignments

1. Watch the YouTube Video: Careers in Observing Earth from Above - Caroline Famiglietti
2. Make a map of evapotranspiration for an area of interest. Try to identify an interesting comparison or contrast based on some aspect of climate, edaphic (soil) conditions, plant community composition or structure, land use, or some disturbance. You could also consider comparing evaporation, transpiration and interception if you wish. If you complete your map and do not find strong differences, don't worry! The most important part of this exercise is to practice asking a question, collecting the data to answer your question, and thinking about what you found.
3. Find a classmate and compare maps. Is your classmate doing anything differently that can help improve your map? If so, revise accordingly!
4. Submit your evapotranspiration map, along with a short description. In particular, your description might address any interesting observations and address any limitations of your analysis.

Datafiles

In case you encountered any problems with the AρρEEARS database, here are copies of the ECOSTRESS GeoTIFF files for the Central Valley of California. ET_{daily}:

1. ECO3ETPTJPL.001_EVAPOTRANSPIRATION_PT_JPL_ETdaily_doy2022218192026_aid0001.tif
2. ECO3ETPTJPL.001_EVAPOTRANSPIRATION_PT_JPL_ETdaily_doy2022218191934_aid0001.tif

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