10

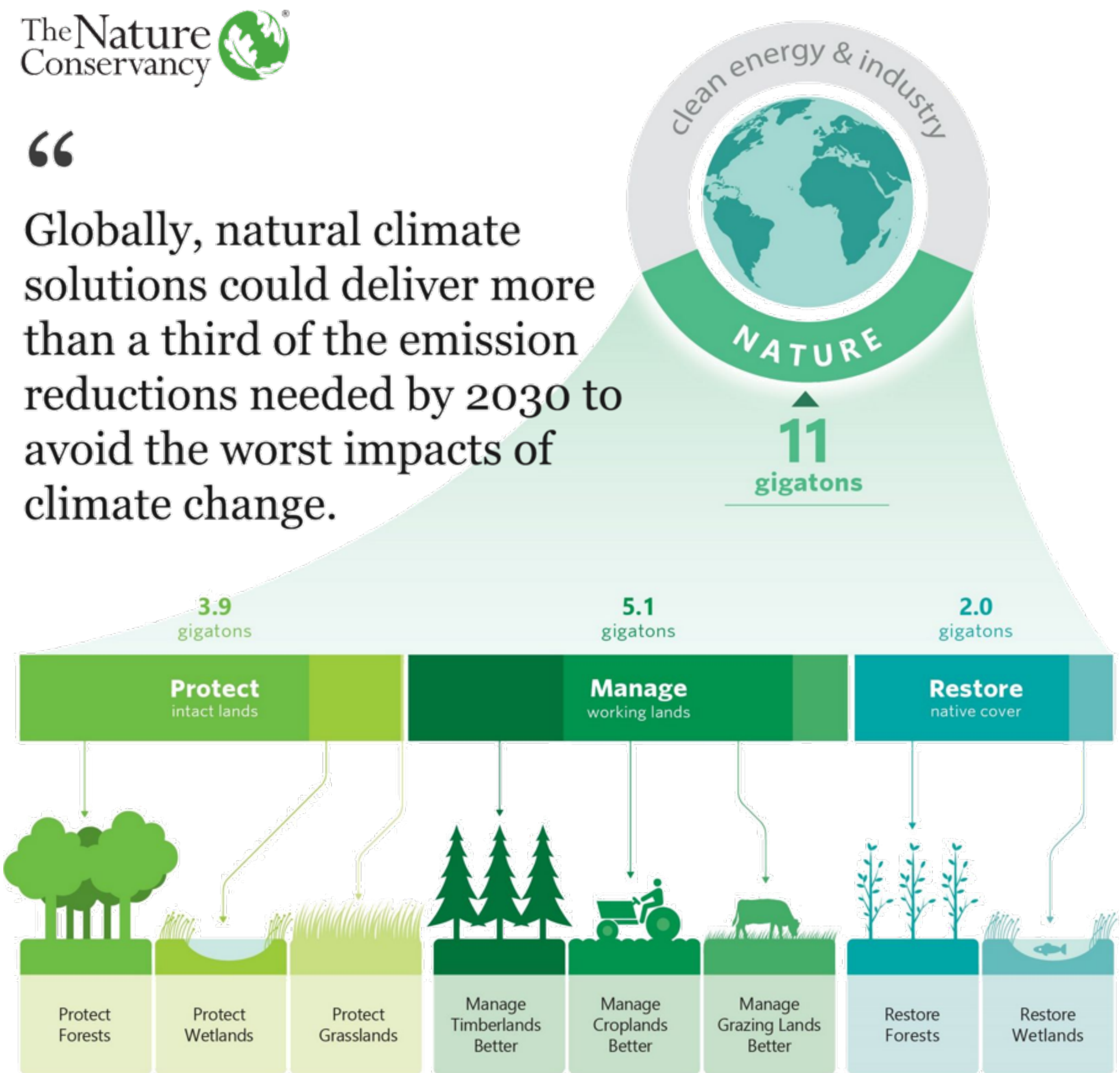
Estimating Coupled Carbon and Water Cycling in Plants

Quick Links To Sections

Objectives:

1. Identify how the different components of evapotranspiration that ECOSTRESS reports can be used to describe ecosystem function.
2. Develop hypotheses to compare two ecosystems in the context of natural climate solutions and create a NASA worthy map to address your hypotheses.

Motivation For Today's Tutorial : Natural Climate Solutions



Natural climate solutions are actions that scientists have identified to protect, manage, and restore nature to reduce greenhouse gas emissions and store carbon. Combined with the transition away from fossil fuels, natural climate solutions offer immediate and cost-effective ways to address the climate crisis, while also supporting healthy and thriving ecological communities and ecosystems.

Examples of natural climate solutions include reforestation, agriculture and timber management, and protection of ecosystems known to capture and store large amounts of carbon. Less carbon in the atmosphere reduces the greenhouse effect, which is needed to achieve the goal of the Paris Climate Agreement of maintaining warming below 2 ° C. Climate scientists use remote sensing data, such as evapotranspiration and water use efficiency from ECOSTRESS, to help assess the impact of natural climate solution actions.

10.1 ACCESSING ECOSTRESS ET COMPONENT & WUE DATA THROUGH A$\rho\rho$EEARS

10.1.1 ECOSTRESS Evapotranspiration (ET) & Water Use Efficiency (WUE) Data Variables

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)

In the last tutorial, we learned that ECOSTRESS uses land surface temperatures to estimate evapotranspiration (ET), the sum of all processes that return water from the land surface to the atmosphere (evaporation + transpiration). The Level 3 (ECO3) ET data that we worked with last time (ET_{inst} & ET_{daily}) represent the total ET, but ECOSTRESS also has data that allow us to track the individual components of ET:

ECOSTRESS Evapotranspiration PT-JPL ✖
ECO3ETPTJPL.001, 70m, ISS-dependent, (2018-07-09 to Present)

EVAPOTRANSPIRATION_PT_JPL_ETcanopy ✚
EVAPOTRANSPIRATION_PT_JPL_ETinterception ✚
EVAPOTRANSPIRATION_PT_JPL_ETsoil ✚

- ET_{canopy} = transpiration of water from the leaves (through stomata in higher plants)
- $ET_{interception}$ = evaporation of water off of the surface of the plants
- ET_{soil} = evaporation of water from the soil

Water use efficiency (WUE), or the amount of carbon plants take up per unit of water lost, is a Level 4 (ECO4) ECOSTRESS data product:

ECOSTRESS Water Use Efficiency ✖
ECO4WUE.001, 70m, ISS-dependent, (2018-07-09 to Present)

Water_Use_Efficiency_WUEavg ✚

Southern Pine Forests

Table 1. Regional NCE (Tg C yr^{-1}, Mean ± Their Stand Deviation) for Land Covers of the Conterminous U.S. Over the Period of 2001 to 2005

Region	Croplands	Rangelands/Pasture	Urban	Forests	Shrublands	Grasslands	Other[a]	Total
Southeast	−9 ± 12	−2 ± 2	−1 ± 0	176 ± 26	0 ± 0	0 ± 1	−7 ± 1	156 ± 33
Midwest	−6 ± 17	−1 ± 3	0 ± 0	59 ± 11	0 ± 0	1 ± 4	12 ± 3	66 ± 35
Northeast	−2 ± 3	0 ± 0	−3 ± 1	43 ± 10	0 ± 0	0 ± 0	0 ± 1	39 ± 11
Northern Great Plains	13 ± 42	3 ± 25	0 ± 0	4 ± 2	0 ± 0	0 ± 1	0 ± 0	20 ± 65
Southwest	2 ± 11	0 ± 16	1 ± 1	7 ± 11	5 ± 22	1 ± 2	0 ± 1	15 ± 57
Northwest	3 ± 6	0 ± 1	0 ± 0	11 ± 5	0 ± 2	0 ± 0	0 ± 0	14 ± 12
Southern Great Plains	2 ± 29	−2 ± 32	0 ± 0	14 ± 4	0 ± 0	0 ± 1	0 ± 0	13 ± 65
Total	4 ± 80	−3 ± 60	−3 ± 2	313 ± 40	6 ± 22	1 ± 7	5 ± 3	323 ± 191

[a]Includes wetlands, mangrove, and bare lands.

- Longleaf pine (*Pinus palustris*) ecosystems once occupied 90 million acres in the Southeastern United States.
- Timber harvest, land conversion, and wildfire suppression reduced the longleaf pine ecosystems to only 3.2 million acres. Fire is a part of their natural life cycle.
- Characterized by a tall overstory and a grassy forest floor, there has been a recent movement to restore these forests.
- Scientists have discovered that longleaf can tolerate droughts and capture more carbon than other trees, which gives them potential as a natural climate solution, especially since forests of the Southeast are already known to capture more carbon than any other forest region in the U.S.

Hypotheses

- Today, we are going to compare two forests. Loblolly pine is a species used by the forest products industry and longleaf pine is a species researchers hope to restore to mitigate climate change. We are going to compare longleaf pine in a wet coastal site to loblolly pine in a dry upland site.
- Given what you have just read, write predictions about:

1) How would you predict the water use efficiency to compare between the two species? Why might you expect this?
2) How would you predict the transpiration, evaporation, and interception (i.e., the components of ET) to compare between the two sites? Why might you expect this?

- You should write down your predictions and submit them as part of your "Map of the Week" assignment.

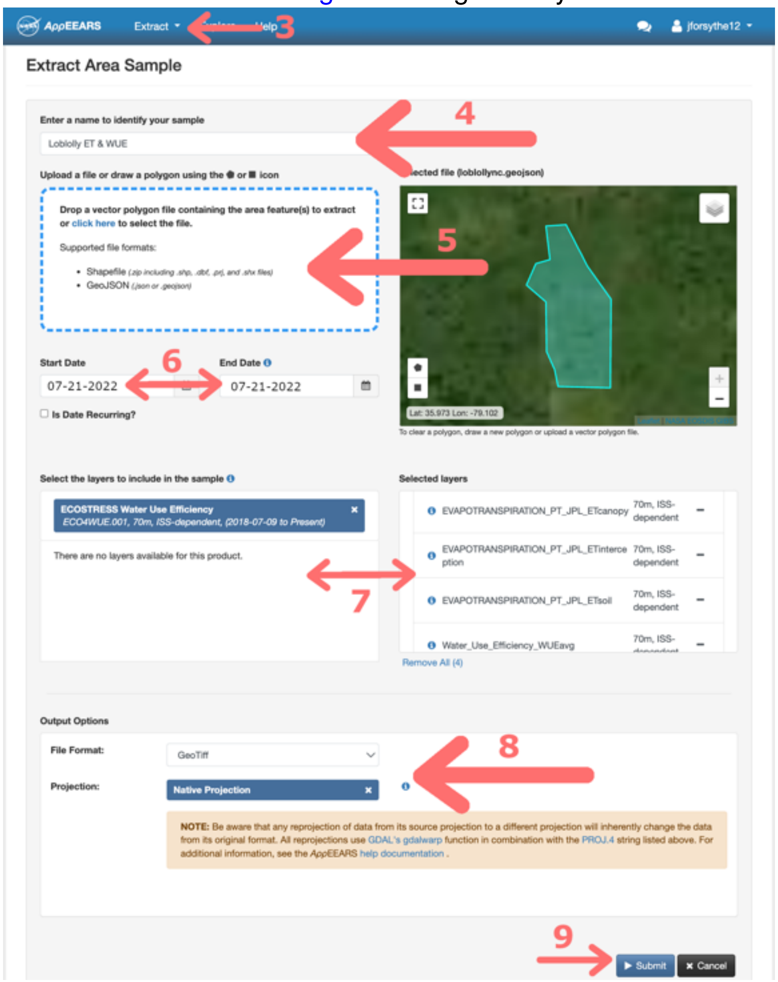
10.1.2 Requesting loblolly pine ET & WUE data from A$\rho\rho$EEARS

The procedure for downloading ET component and WUE data through the A$\rho\rho$EEARS interface is the same as in the previous tutorials on land surface temperature.
1. First, begin by downloading these two GeoJSON files, saving them somewhere you can remember (as always, we suggest creating a folder for each tutorial):

1. Longleaf Pine (South Carolina Wet Coastal Environment): LongleafSC.geojson
2. Loblolly Pine (North Carolina Dry Upland Environment): LoblollyNC.geojson

NOTE: 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*.

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, maybe something like "Loblolly ET and WUE".
5. Drag and drop (or use the *click here to select the file* link) to upload the GeoJSON file *LoblollyNC.geojson*. The map should be updated with a polygon around a forest in North Carolina.

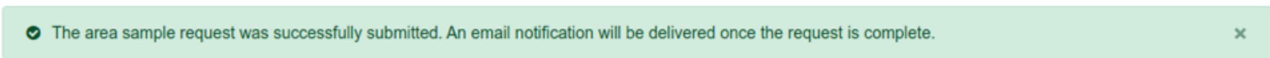
6. Update the *Start* and *End* Date Fields for our preselected date of interest: 07/21/2022 to 07/21/2022.
7. Under *Select the layers to include in the sample* type the words "ECOSTRESS" and "Evapotranspiration." Select *ECOSTRESS Evapotranspiration PT-JPL*. Click on the "+" signs to add the following layers to your cart:

- *EVAPORTRANSPIRATION_PT_JPL_ETcanopy*
- *EVAPORTRANSPIRATION_PT_JPL_ETinterception*
- *EVAPORTRANSPIRATION_PT_JPL_ETsoil*

Next, clear the selection of the current category using the small "x" to the right of the *ECOSTRESS Evapotranspiration PT-JPL* box.
Then, under *Select the layers to include in the sample* type the words "ECOSTRESS" and "WUE." Select *ECOSTRESS Water Use Efficiency*. Click on the "+" signs to add the following layers to your cart:

- *Water_Use_Efficiency_WUEavg*

Clear the selection of the current category using the small "x" to the right of the *ECOSTRESS Water Use Efficiency* box.
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:

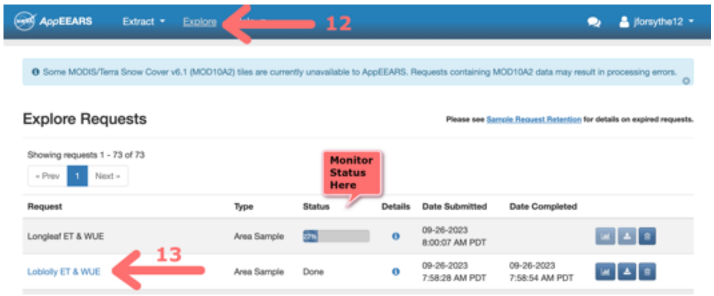


10.1.3 Requesting longleaf ET & WUE data from A$\rho\rho$EEARS

10. In the meantime, we are going to create a second request for this tutorial, as we need data for longleaf pines to compare to the loblolly pine data we just requested. Use the *Extract* dropdown menu to select *Area*. Next select *Start a New Request*. Enter a useful name to distinguish this request from the other, maybe something like "Longleaf ET and WUE". Drag and drop (or use the *click here to select the file* link) to upload the GeoJSON file *LongleafSC.geojson*. The map should be updated with a polygon around a forest on the coast of South Carolina.
11. Repeat steps 6 - 9 above to retrieve the ET component and WUE data for the longleaf pine site on 7/26/2022.

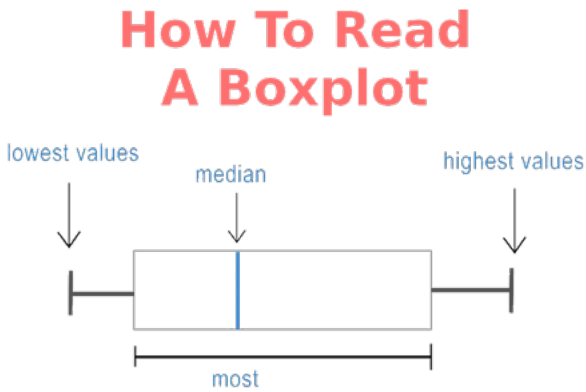
NOTE: You may have noticed the dates are different for the longleaf and loblolly sites. Unfortunately, the two sites are too far apart to have a pass on the same day.

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



10.1.4 Visualizing loblolly pine ET Component Data in A$\rho\rho$EEARS

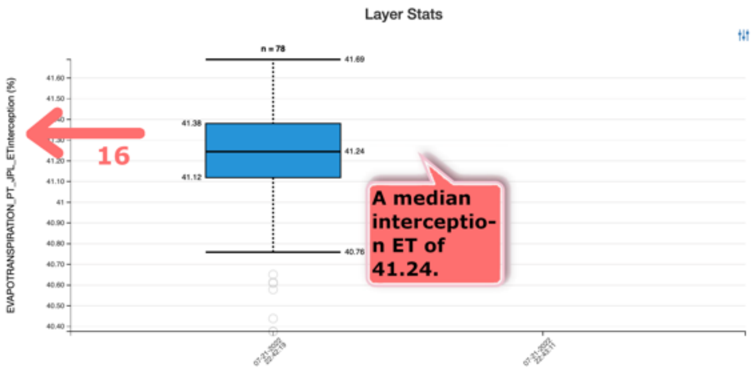
13. When your first request ("Loblolly ET and WUE") is complete, use the link on the *Explore* page to access the details. Let's check out the data. First, a quick review of boxplots:



14. Our goal for the analysis of the evapotranspiration components is not to visualize the data in space, but rather to compare the differences between the two forest ecosystems (loblolly vs. longleaf pine) as a whole. As a result, there is no need to download the GeoTIFF files and import the layers into QGIS. We can explore the data with the A$\rho\rho$EEARS interface to get the information we need.
15. First, select the *EVAPOTRANSPIRATION_PT_JPL_ETcanopy* layer:

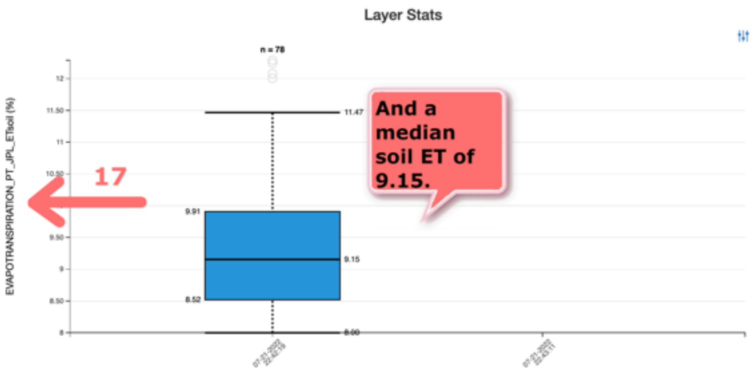
Notice that the median value for the canopy component of evapotranspiration is 49.57. This means that the median value for pixels in our area of interest is 49.57, which means that 49.57% of the total evapotranspiration (the “EVAPOTRANSPIRATION_PT_JPL_ETinst” variable) is coming from canopy transpiration. Although the overall distribution of the data is skewed towards higher values, there is no need to worry, as the range of the data (minimum to maximum observed value) is about 3%. Since our analysis is mostly concerned with the relative percentages of the different components of ET (canopy vs. interception vs. soil), it is reasonable to simply use the median value.

16. Next, select the *EVAPOTRANSPIRATION_PT_JPL_ETinterception* layer.



Here, we observe that 41.24% of total evapotranspiration is coming from interception.

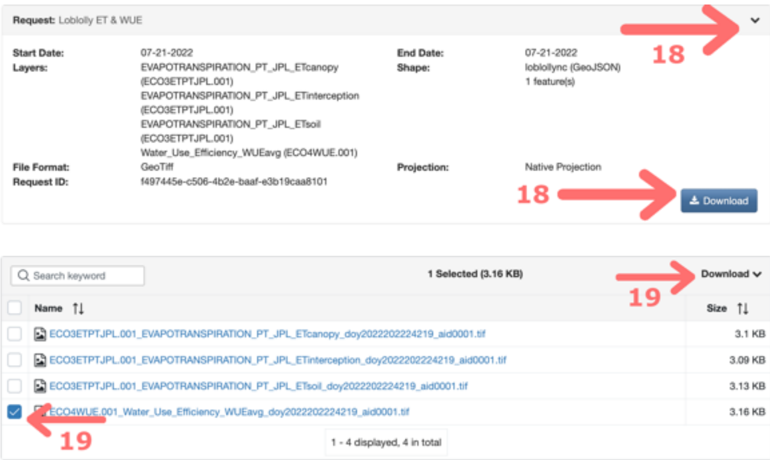
17. Finally, select the *EVAPOTRANSPIRATION_PT_JPL_ETsoil* layer.



So, the overall breakdown for the individual components of evapotranspiration is 49. 57% canopy transpiration, 41. 24% interception evaporation, and 9. 15% soil evaporation. You will report this in the write-up that accompanies your “Map of the Week” assignment along with longleaf pine data that you will complete on your own.

10.1.5 Downloading loblolly pine WUE Data

18. From the *Layer* dropdown menu, choose “Water_Use_Efficiency_WUEavg”, then expand the *Request* box above by clicking on the caret. Click the download button to continue.

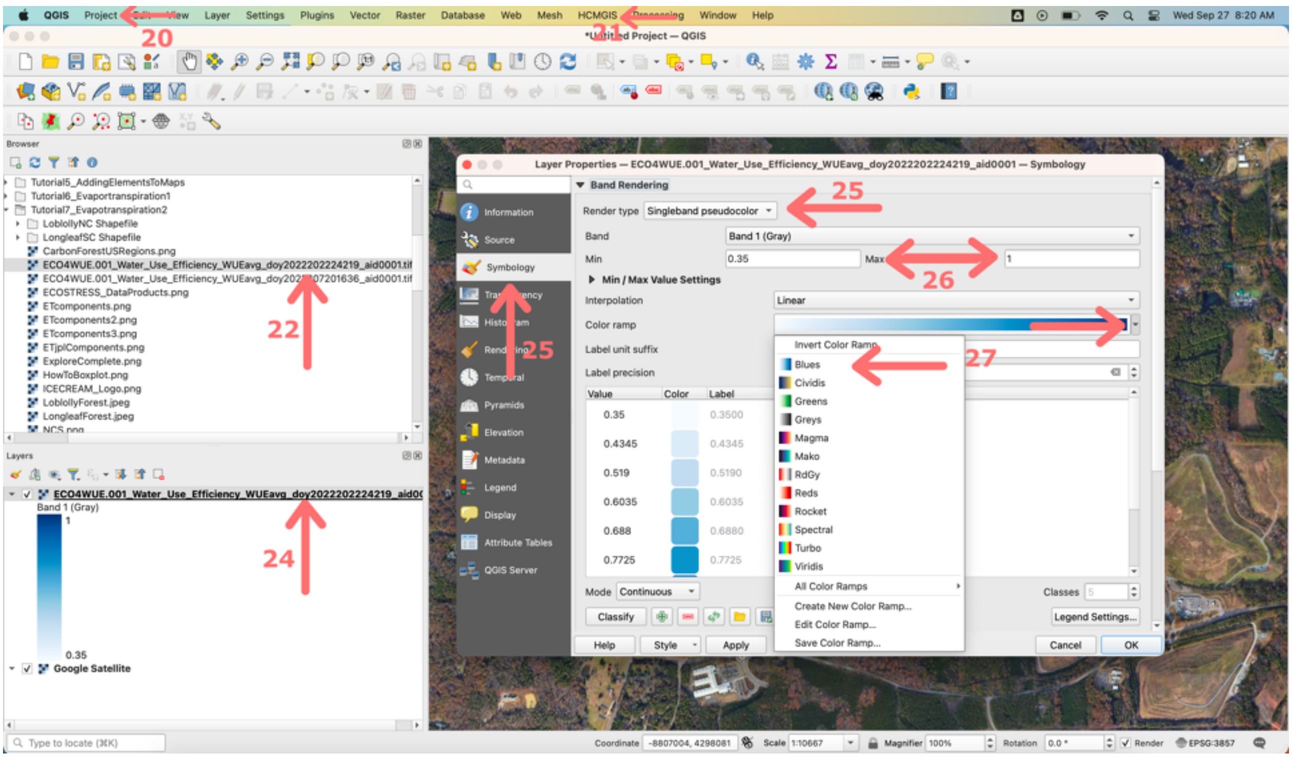


19. Select the following filename: ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif. Download the files using the *Download* button, that for some reason does not look much like a button, on the top right corner of the screen. Save the files somewhere you can remember.

10.2 VISUALIZING ECOSTRESS WUE DATA IN QGIS

10.2.1 Adding a Google Satellite Basemap

20. Open QGIS and start a new project by selecting the *Project* menu, then *New*.
21. 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.



10.2.2 Add in WUE layer

22. Use the *browser* window to find the folder where you saved the WUE file:
ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif
23. Double-click the ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif file to add it to your map. Again, notice that they are now also listed in the *Layers* window.

NOTE: Our loblolly data is at a pretty fine scale and might be hard to see if your basemap is zoomed out at the global scale. QGIS can automatically zoom to your layer's area of interest by right clicking (ctrl-click on Mac) on the layer and selecting *Zoom to Layer(s).*

24. Now, you have ECOSTRESS WUE data on your map, but we need to change it from grayscale. Right-click (ctrl-click on Mac) on the layer name in the *Layers* window and select *Layer Properties*.
25. On the menu bar to the left, select *Symbology* and change *Render type* to Singleband pseudocolor.
26. QGIS has automatically determined the minimum and maximum values from the datafiles; however, we are going to want to compare two types of ecosystems and need to match them. Specify 0.35 as the minimum and 1 as the maximum.
27. Change the color ramp to something that you feel communicates WUE. I selected the "Blues" option. Click apply, then ok.
28. Finally, add the border from LoblollyNC.geojso 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*.

10.3 ADD MAP ELEMENTS

29. Following the procedure described in Tutorial #5 : Adding Elements To Maps, make a professional map complete with scalebars, labels, a legend, titles, and a North arrow. Include an inset that showcases the study region (North Carolina, USA) with this WUE as a basemap. This map will be your part of your map of the week assignment.

NOTE: It is not apparent in A$\rho\rho$EEARS, but the units for WUE are $gCkg^{-1}H2O$.

10.4 MAKE THE SAME MAP FOR LONGLEAF PINES

30. Follow the same procedure (steps 13 - 29) for our other request, "Longleaf ET & WUE":

1. Explore data for the ET components of the longleaf pine ecosystem in the A$\rho\rho$EEARS interface to determine the relative contributions of the canopy, interception, and soil to total evapotranspiration. Note the differences between longleaf and loblolly. Submit this as part of your write-up for the "Map of the Week".
2. Download the water use efficiency GeoTIFF for longleaf pines.
3. Visualize these WUE data in QGIS.
4. Make a second professional map with the same color ramp scale for the WUE of the longleaf pine complete with scalebars, labels, a legend, titles, and a North arrow.

5. Submit these two maps (one for longleaf, one for loblolly) as part of your "Map of the Week" assignment along with the write-up described below.

Map of the Week Assignments

1. Make a WUE map for longleaf pine of the same format as the loblolly pine map we made in the tutorial. It should include a basemap of water use efficiency with an inset that highlights the geographic region. The map should be complete with scalebars(s), north arrow(s), legend(s), title(s), and label(s). Submit this longleaf map alonside the loblolly we made in the tutorial today.
2. Provide a 1-2 paragraph description of your maps and ET component data that includes your relections on which tree species may be better suited to mitigate climate change given any differences in water use efficiency. Would you recommend that foresters plant longleaf pine trees instead of loblolly? Will longleaf pines have higher growth while minimizing water use? Address the limitations of your analysis.

Datafiles

In case you encountered any issues with the A$\rho\rho$EEARS database, here are copies of the ECOSTRESS GeoTIFF file for the loblolly WUE:

1. ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022202224219_aid0001.tif

And longleaf WUE:

1. ECO4WUE.001_Water_Use_Efficiency_WUEavg_doy2022207201636_aid0001.tif

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Recommended Citation: Forsythe, J.D., G.R. Goldsmith, and J.B. Fisher. 2023. Observing Earth from Above Tutorials. Chapman University. `https://jeremydforsythe.github.io/icecream-tutorials/`

This work is supported by funding from NASA ECOSTRESS Mission Grant #80NSSC23K0309 (I.C.E. C.R.E.A.M.: Integrating Communication of ECOSTRESS Into Community Research, Education, Applications, and Media).