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SHARPENING API CODE - MAC

ECOSTRESS TUTORIALS

This tutorial will show you how to use the ECOSTRESS Sharpening API code on MacOS.

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Prerequisites

Before you start this tutorial, make sure you have an Earthdata Login, Visual Studio Code downloaded and set up, and a Python Environment to work with. If you need help setting any of these up, please visit https://ecostress.jpl.nasa.gov/tutorials where you can follow along with the provided tutorials before proceeding with this one. This tutorial will walk you through an example of sharpening images of Dodger Stadium in summer of 2024, but you can follow along with whatever area and time of interest you want.

What is Sharpening and what is an API?

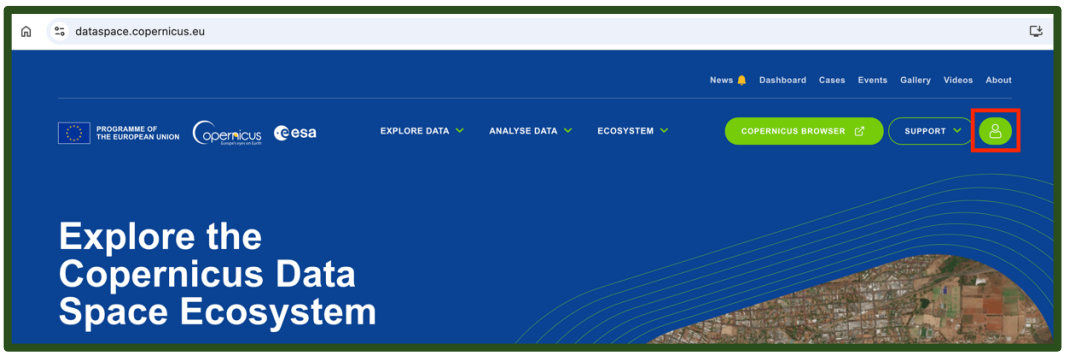
In remote sensing, image sharpening refers to enhancing the spatial resolution of satellite images in order to make them look more detailed. We use high resolution images to train a machine-learning model which is then used to sharpen low resolution images. In this code, 70-meter resolution ECOSTRESS data will be sharpened with 20-meter Sentinel-2 data. This tool also uses APIs (Application Programming Interfaces) to download both ECOSTRESS and Sentinel-2 data in your region and time of interest. If you have already downloaded ECOSTRESS data that you would like to sharpen, you can follow the Sharpening Code tutorial that only uses and API to download Sentinel-2 data.

What is Copernicus Data Space?

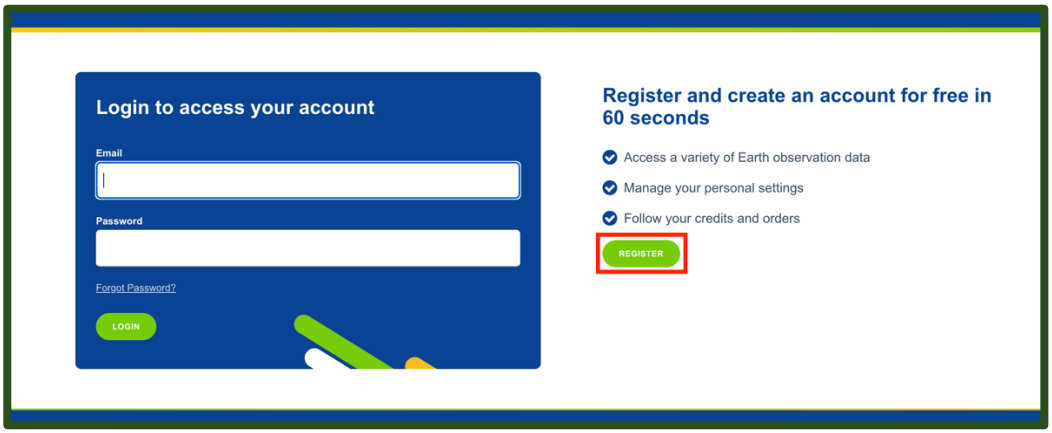
Copernicus Data Space is a European Space Agency platform that provides open data from the Copernicus Earth observation satellites, including Sentinel-2 data. We need a Copernicus Data Space login in order to create and use the Sentinel Hub API. An API, or Application Programming Interface, is a tool that allows your code to request and retrieve data from a server or database automatically.

CREATING A COPERNICUS LOGIN

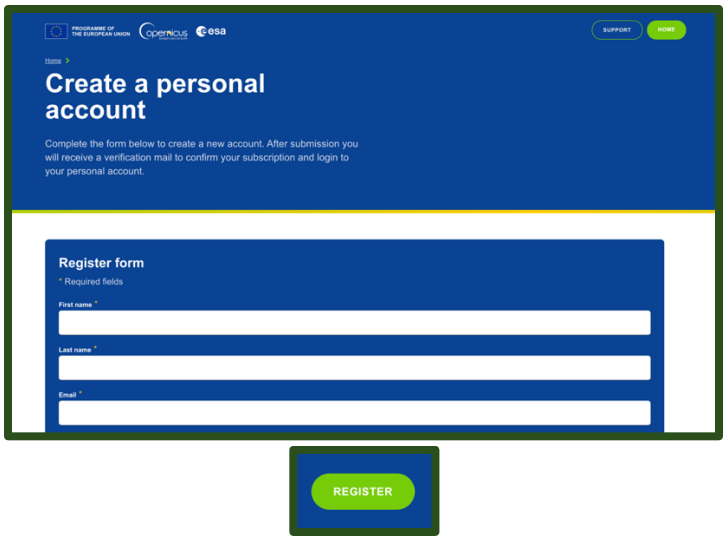
1. Start by going to https://dataspace.copernicus.eu/ or by searching the web for **Copernicus Data Space** and clicking on the first link. On the website, click the **green profile icon**.



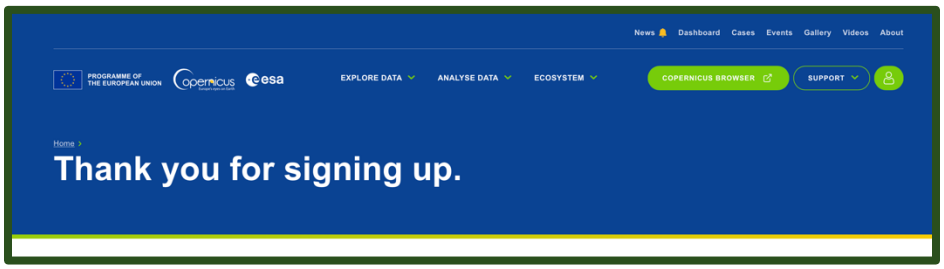
2. This will take you to the login page. If you already have an account, you can log in and move on to the next section of the tutorial. If you do not have an account, click the green register button.



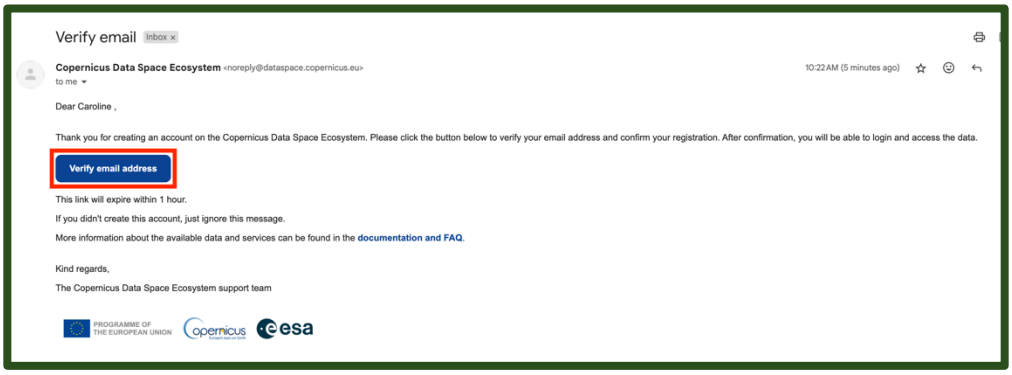
3. Fill out all of the required fields with your personal information, including marking off the check boxes at the bottom of the screen. When you are done, click the green register button.



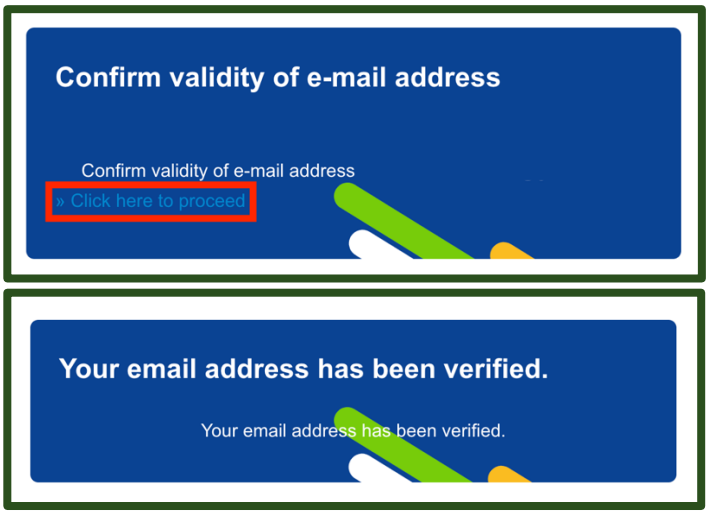
4. The window will now display **Thank you for signing up** and prompt you to verify your email. Open your email and look for the verification email.



5. Click the blue **Verify email address** button which will direct you back to the Copernicus Data Space website.



6. In the new window, click where it says **Click here to proceed**. It will then let you know that your email address has been verified.

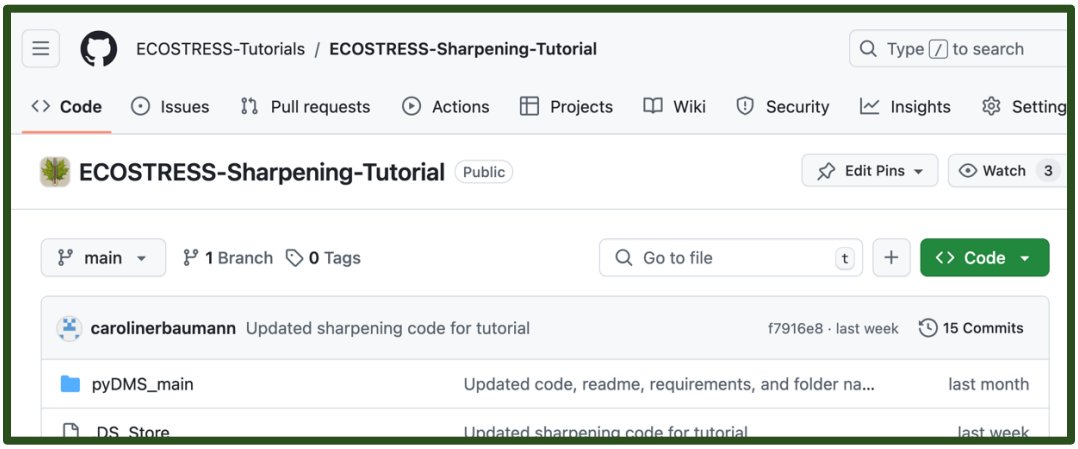


What is pyDMS?

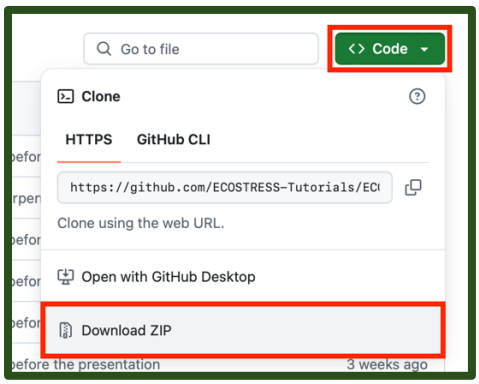
pyDMS is a Python library that implements the Data Mining Sharpened (DMS) algorithm, that is used to sharpen low resolution satellite imagery using high resolution data. We want to use this in our code, so we need to download and install it. We can download it from GitHub, which is an online platform used to store and share code.

DOWNLOADING CODE AND PYDMS FROM GITHUB

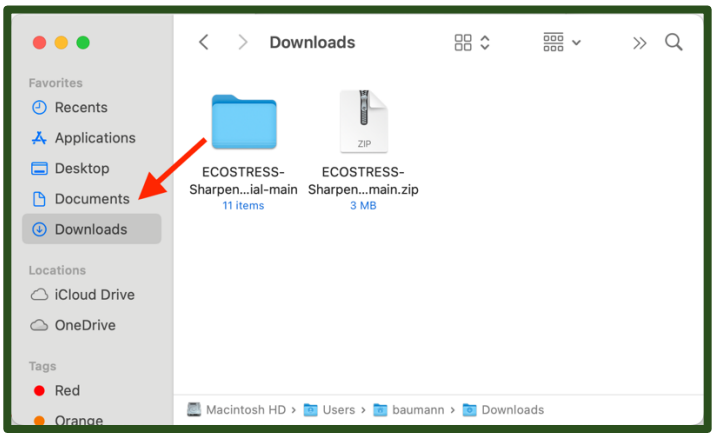
1. To access the pyDMS package and the code used in this tutorial, go to https://github.com/ECOSTRESS-Tutorials/ECOSTRESS-Sharpening-Tutorial.



2. At the top right, click the green button that says **<> Code**. In the dropdown select **Download ZIP**. A zip file containing everything in the GitHub repository will begin downloading.



3. Once the zip file has been downloaded, **double click** on it to un-zip it. This new folder will now function as your **project folder**. You can move it wherever you would like, but I am going to move mine to my documents.

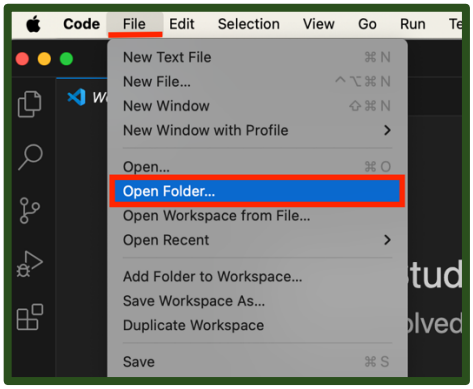


What is an OAuth client?

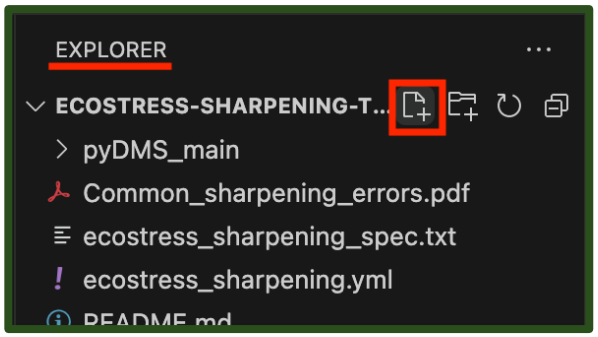
An OAuth client requests access to data on behalf of the user without needing their password. Instead, OAuth creates a secure token, or temporary key, that can be used to access the data for as long as you allow it. This ensures that your account details stay safe when downloading data.

CREATING A NEW OAUTH CLIENT

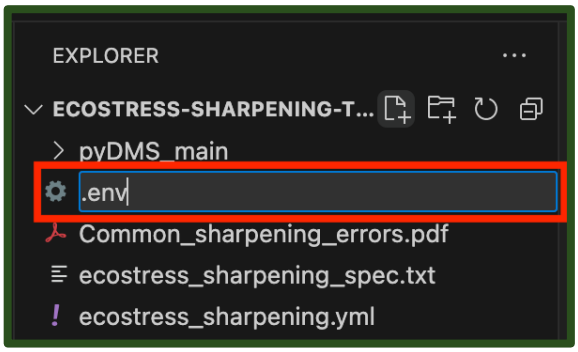
1. Open Visual Studio Code and get connected to your project folder by selecting **File > Open Folder.** In the pop-up finder window, select your project folder and click **Open**.



2. In the **EXPLORER** tab on the left, hover over the project folder and click the **new file icon**.

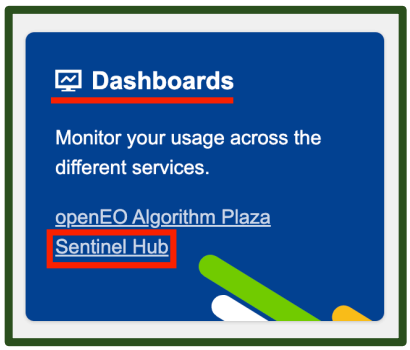


3. Name this new file **.env** and press enter.

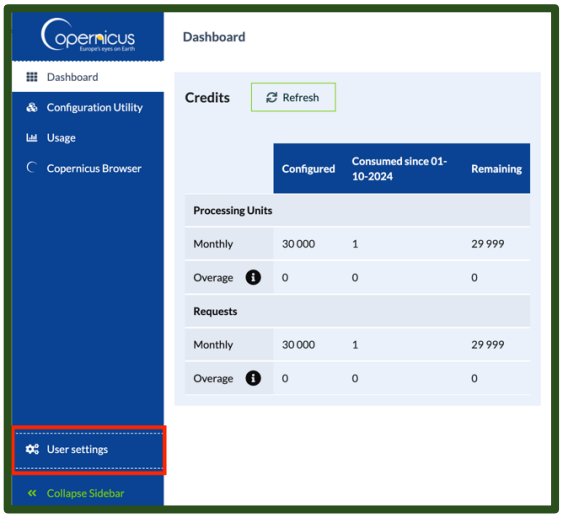


4. Next, in a browser window, go to https://dataspace.copernicus.eu/ or by search for **Copernicus Data Space** and log in. Then, click the **green profile icon**.

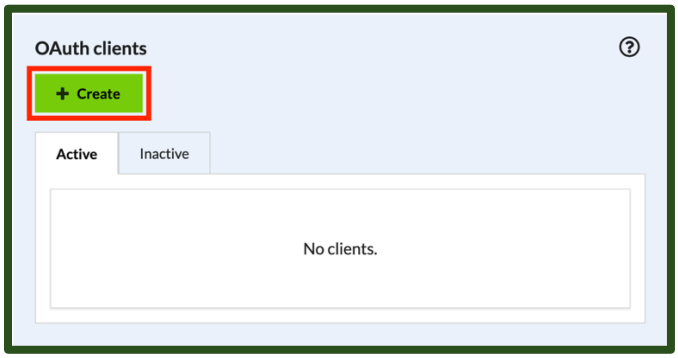
5. In the new window, find the box that says **Dashboards** and click the link that says **Sentinel Hub**.



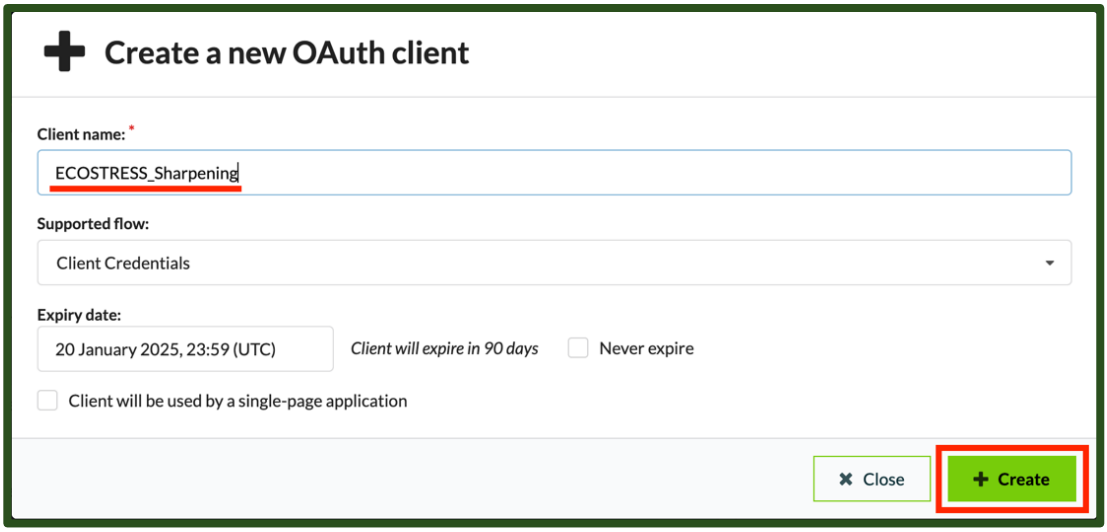
6. In the Dashboard window, click **User Settings** in the bottom right.



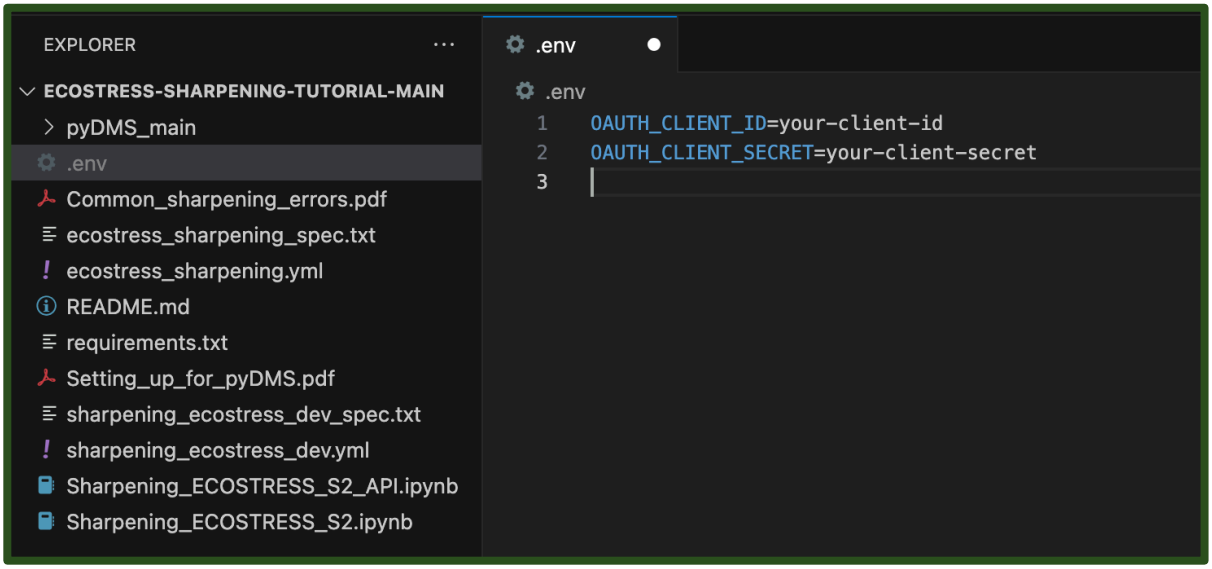
7. Look for the box titled **OAuth clients** and click the green **+Create** button.



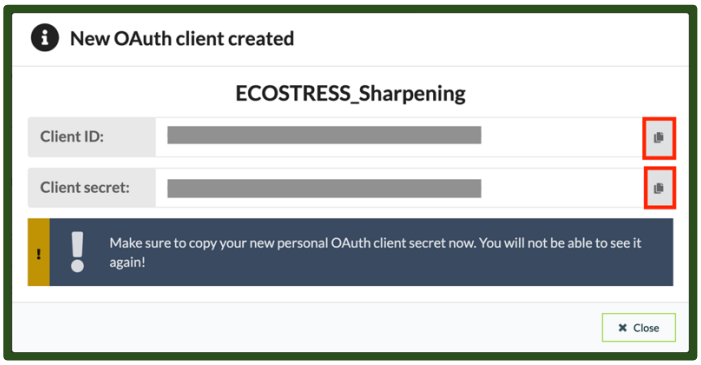
8. In the pop-up, type in a **Client name**. This name is just a way to identify the client for your organization and clarity. For example, I am going to name mine **ECOSTRESS_Sharpening**. Once you have entered a name, press the green **+Create** button.



9. A pop-up will appear with your Client ID and Secret. <u>Do not close this window because you will not be able to view it again once it is gone!</u> Navigate back to Visual Studio Code and open the **.env** file that you created. In the **.env** file, type:
    a. OAUTH_CLIENT_ID=your-client-id
    b. OAUTH_CLIENT_SECRET=your-client-secret

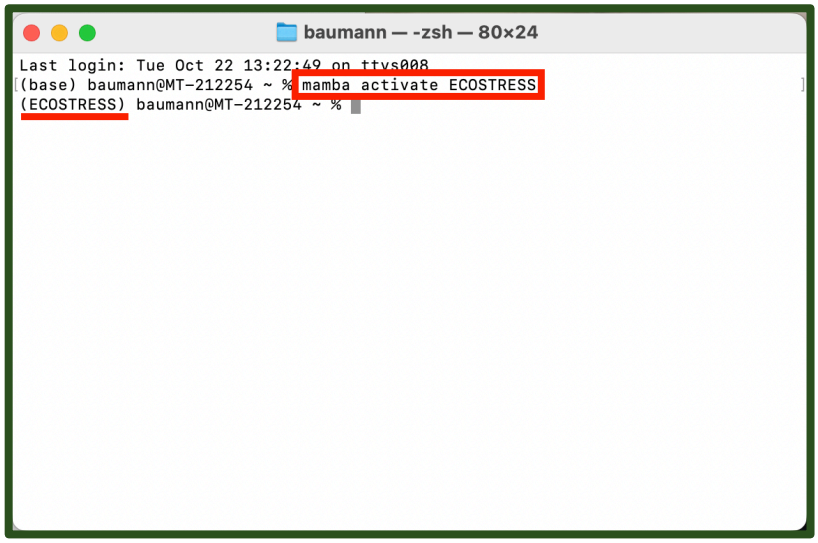


10. Replace **your-client-id** with the Client ID that was given in the Copernicus Data Space OAuth creation by copying and pasting. Do the same with **your-client-secret**. Save your .env file. You can now close the OAuth pop-up window.

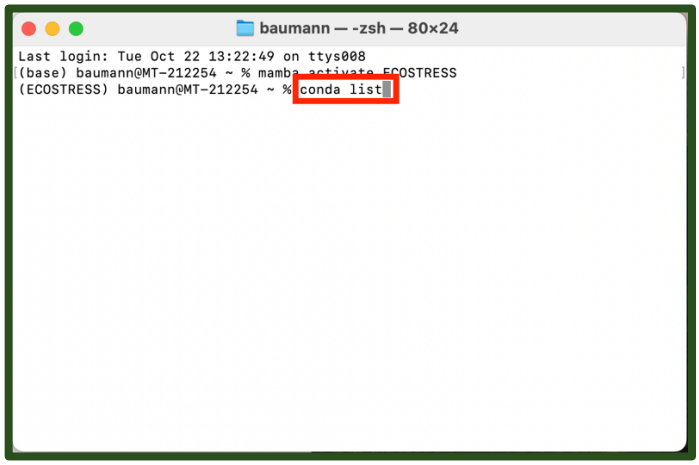


HOW TO INSTALL THE REQUIRED PACKAGES FOR YOUR ENVIRONMENT

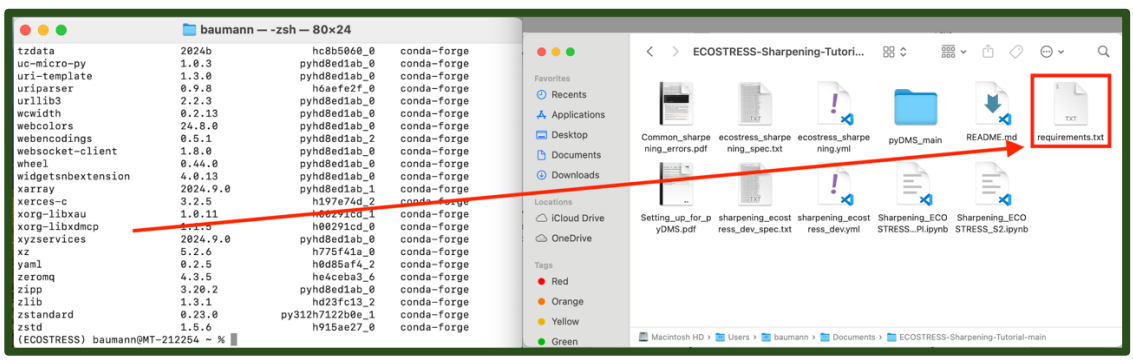
1. If you followed the creating an environment tutorial, you will need to install a few more packages to the ECOSTRESS environment you created. If you are working with a different environment, or using the ECOSTRESS environment from a previous tutorial, you can look at the different packages installed within your environment to see what you have and what you need.
    a. To do this, open the **terminal** and type **mamba activate** followed by the name of your environment. Press enter to run. You will know your environment has been activated when its name shows up in parentheses.



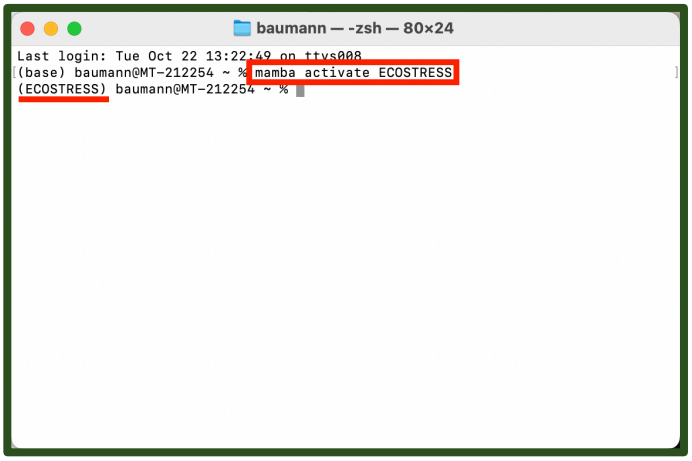
b. Then type **conda list** and press **enter** to run. This will list all the packages in your environment.



c. Compare this to the list of packages on the **requirements.txt** document that you downloaded from the GitHub as part of the main project folder. Take note of which ones you still need to install.

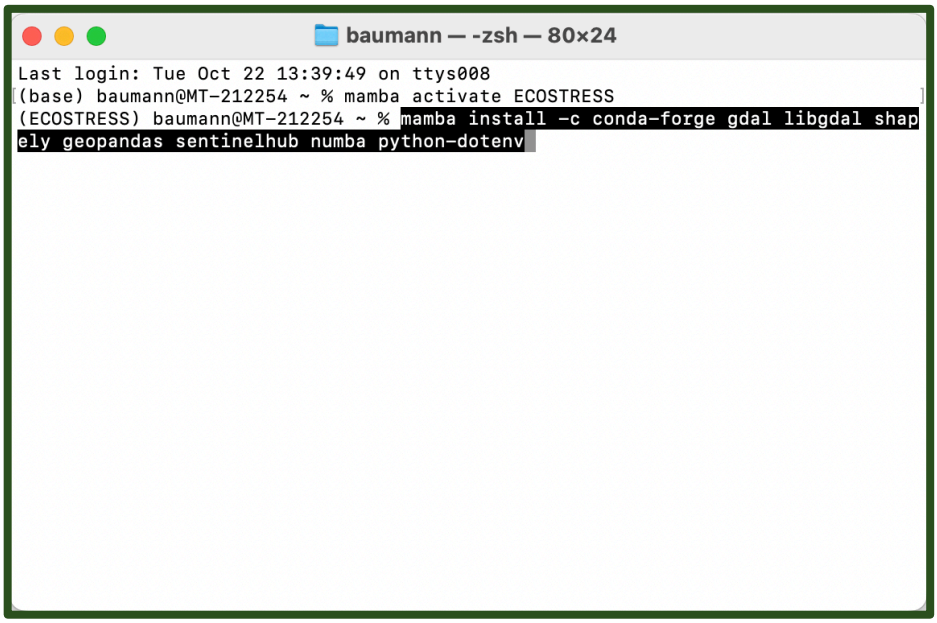


2. To install the remaining packages, first make sure that your environment is activated (its name should be listed at the start of the terminal command line in parentheses). If it is not activated, type **mamba activate** followed by the name of your environment and run it.



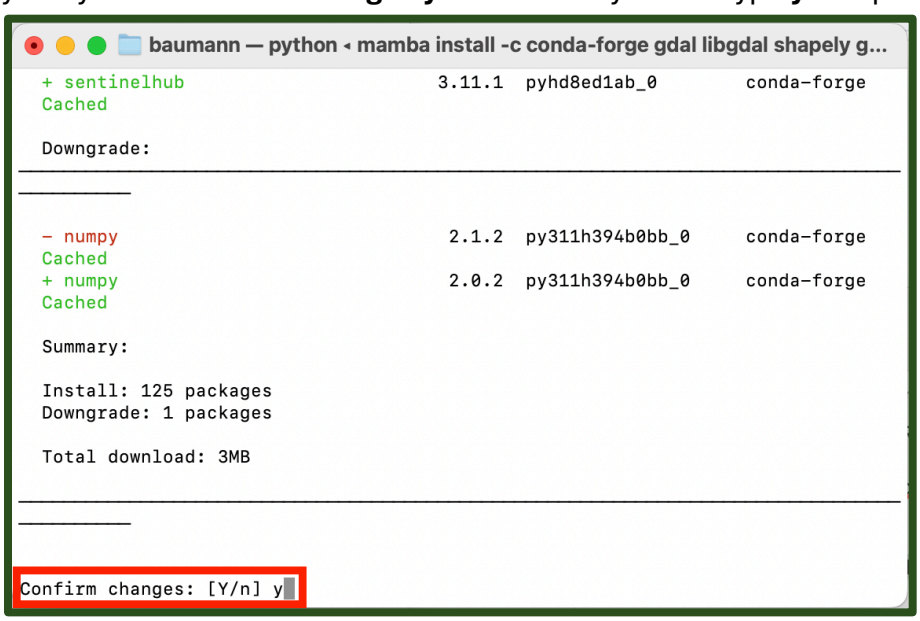
3. Then, type **mamba install -c conda-forge** followed by the name of all the packages you need to install. If you used the Creating an Environment ECOSTRESS tutorial, you can copy and paste this into the terminal and run it to get all the remaining packages installed:

mamba install -c conda-forge gdal libgdal shapely geopandas sentinelhub numba python-dotenv

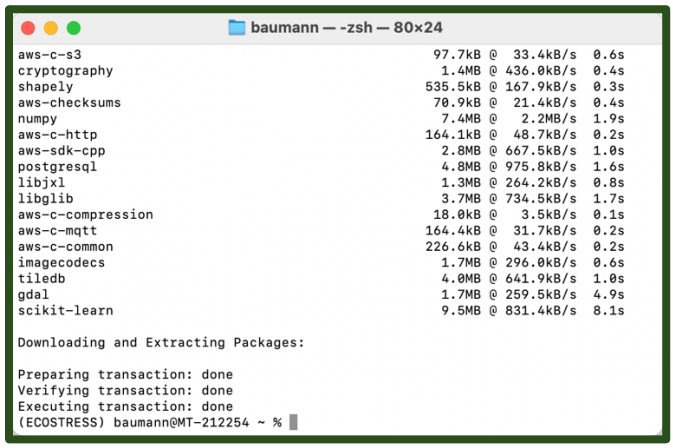


   a. However, it is best to list the packages in your own environment and make sure you are missing the same ones as me. If you are missing different ones, you can modify the command accordingly.

4. It may ask you to **Confirm changes y/n** for which you can type **y** and press enter.

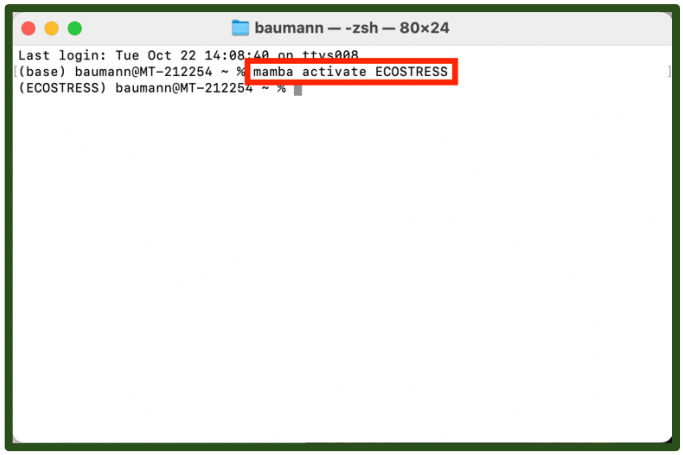


5. It should look something like this when it is done:



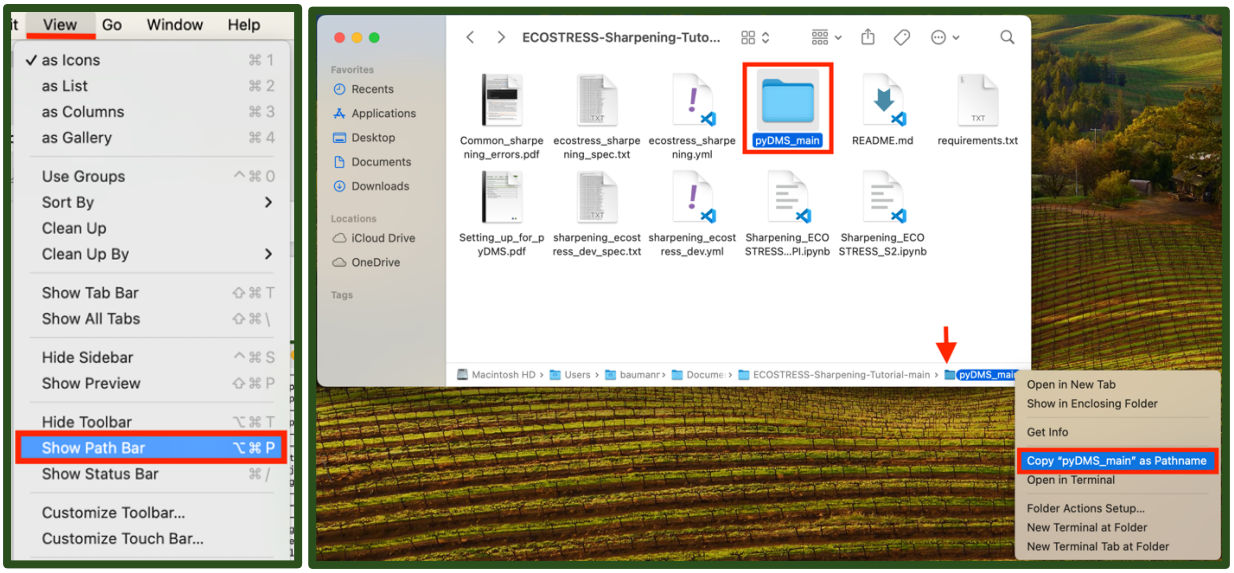
HOW TO INSTALL PYDMS

1. Open the terminal and activate your environment by typing **mamba activate** followed by the name of your environment.

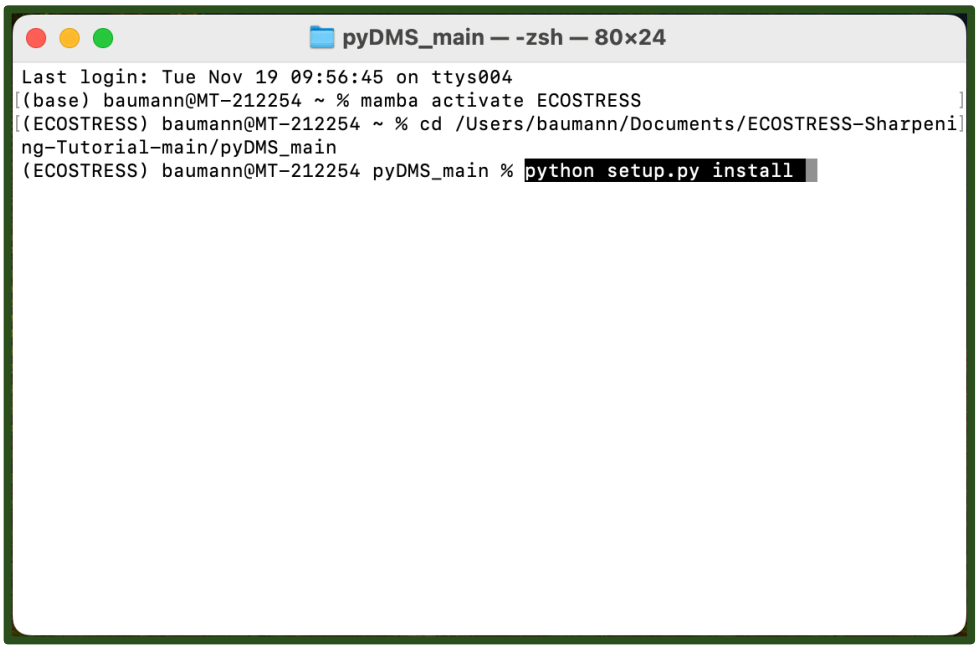


2. Then, change the directory to the pyDMS_main folder by typing the command **cd** followed by a space and the path to the folder.

a. To copy the path to the folder, go to **View > Show Path Bar**. Then in your finder, navigate to the folder. Find where the folder is listed in the path bar on the bottom of the window. Right click it and select **Copy "pyDMS_main" as Pathname**.

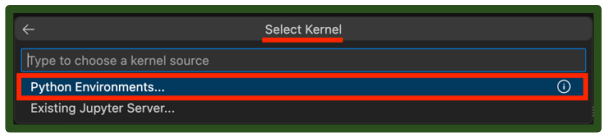


3. Then, in the terminal type **python setup.py install** and run it. Now you have an environment set up to run the downscaling code with.

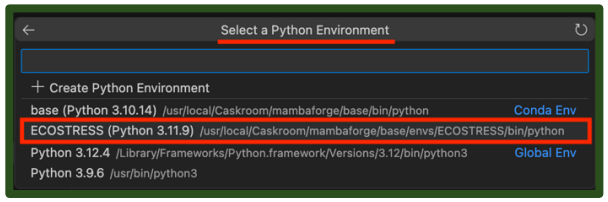


SETTING UP AND RUNNING THE CODE

1. In **Visual Studio Code**, open the **Sharpening_ECOSTRESS_S2_API.ipynb** Jupyter Notebook. At the top of the file there is a lot of information about how the code works that you can read if you are interested. Scroll down to the block of code that is used to **import libraries**. Click into the code and press **Shift + Enter** to run it.
    a. At the top of the window, a pop up will appear prompting you to **select a kernel** to run your code with. Click on **Python Environments ...**

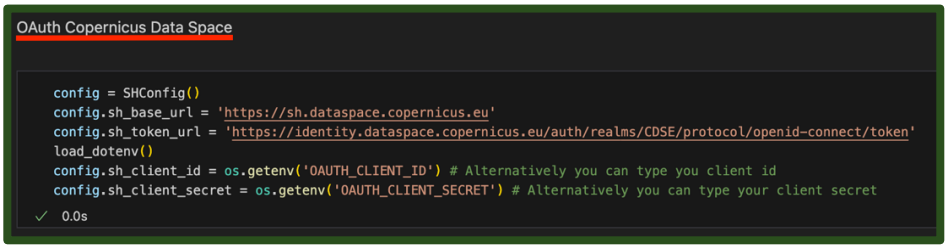


    b. Select the **ECOSTRESS** environment that you created, or another one if you have a different one you want to use.

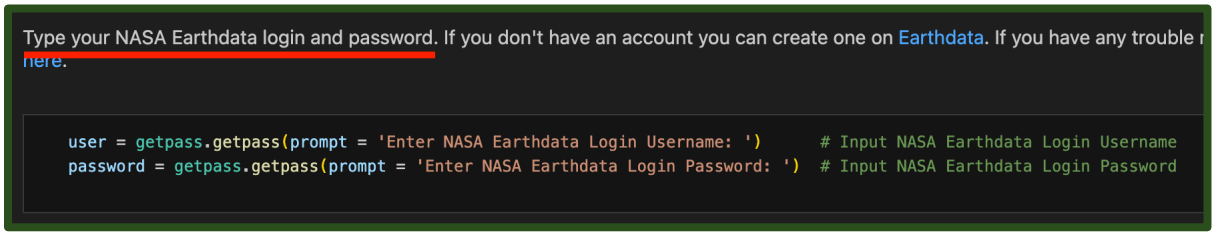


    c. You will know it is done running when a green check mark appears on the bottom left of the cell.

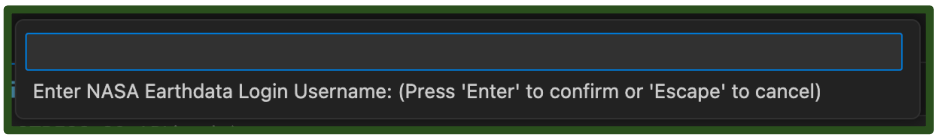
2. Next, scroll down to the section of the code under **OAuth Copernicus Data Space.** If you followed this tutorial and set up your OAuth in a **.env** file, you should be able to press **Shift + Enter** to run this block of code. If you set up your OAuth in another way, you may need to adjust the code accordingly.



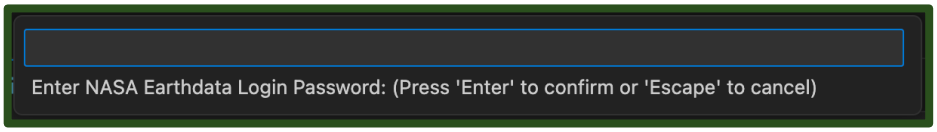
3. Next, find the block of code under **Type your NASA Earthdata login and password** and press **Shift + Enter** to run it.



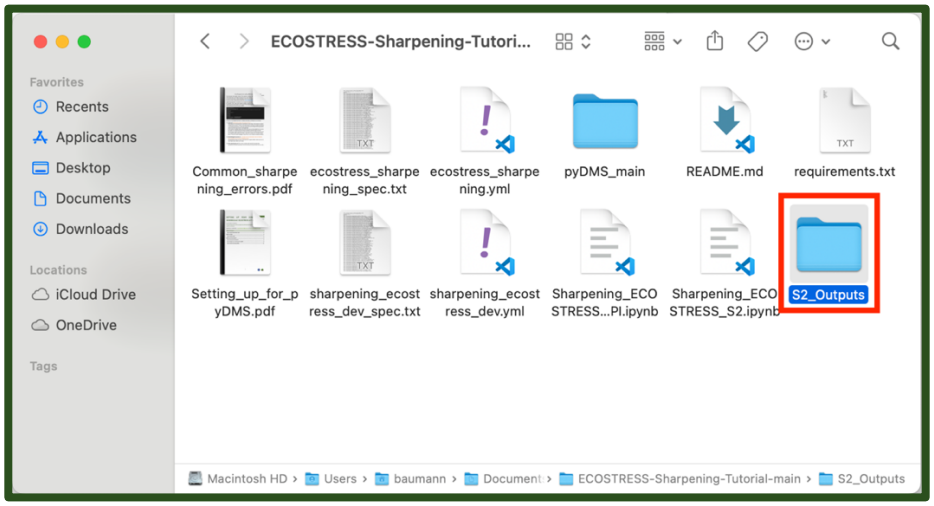
   a. At the top of the Visual Studio Code window, an input box will appear prompting you to **Enter NASA Earthdata Login Username:**. Type in your username and press enter.



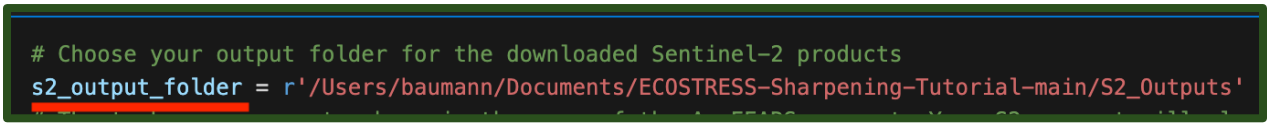
   b. Then, it will prompt you to **Enter NASA Earthdata Login Password:**. Type this in and press enter.



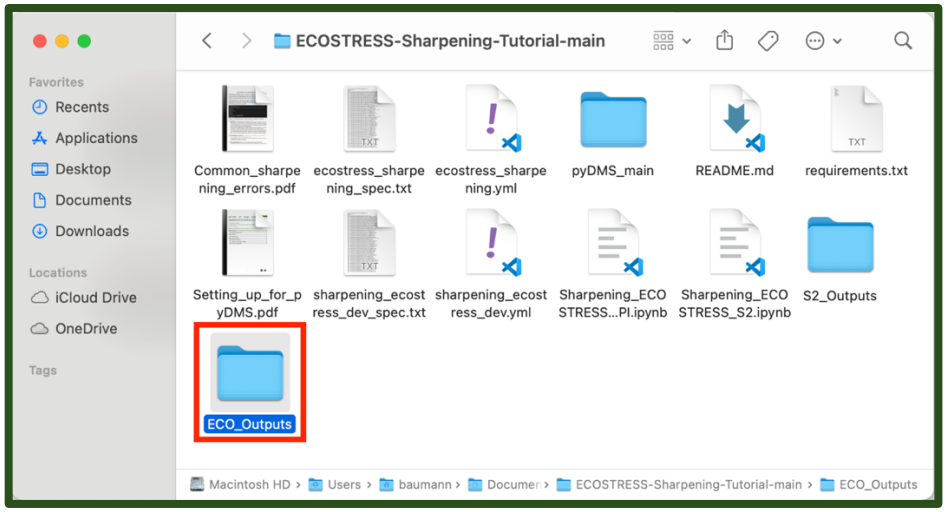
4. In the next block of code, find the variable called **s2_output_folder**. Set this variable to the path of an output folder for the Sentinel 2 imagery. I am going to do this by creating a **new folder** in my **project folder** and copying its path into the code. Make sure the path still has **r** in front and is wrapped in quotes.



Example:



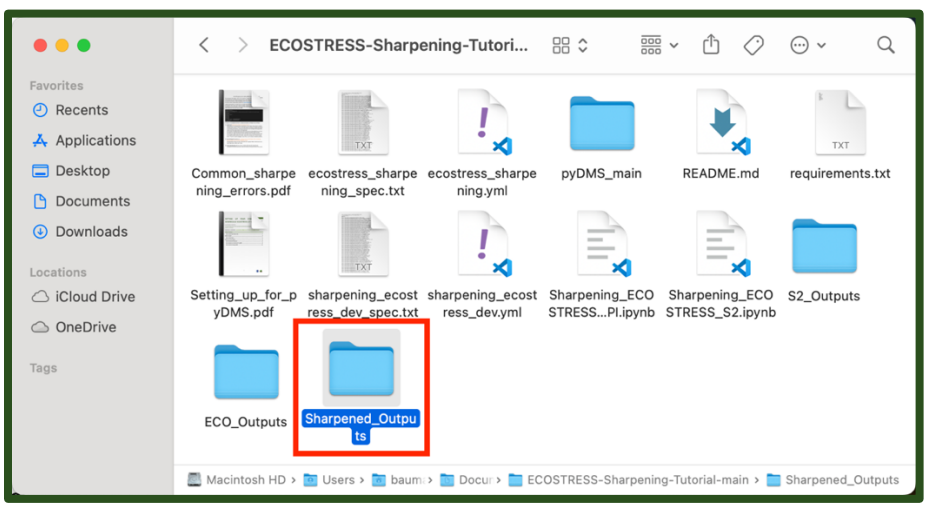
5. Then find the variable titled **eco_output_folder** and set it to the path of an output folder for the ECOSTRESS imagery. Again, I am going to create a **new folder** for this in the main **project folder** and copy its path into the code. Make sure the path still has **r** in front and is wrapped in quotes.



Example:

```
# Folder where all the ECOSTRESS products will be downloaded. This folder will then contain a subdirectory r
eco_output_folder = r'/Users/baumann/Documents/ECOSTRESS-Sharpening-Tutorial-main/ECO_Outputs' # In the newl
```

6. Finally, find the variable titled **dst_dir**. Set it to a path of a folder to store the final sharpened images. Once again, I am going to create a **new folder** for this in the main **project folder** and copy its path into the code. Make sure the path still has **r** in front and is wrapped in quotes.

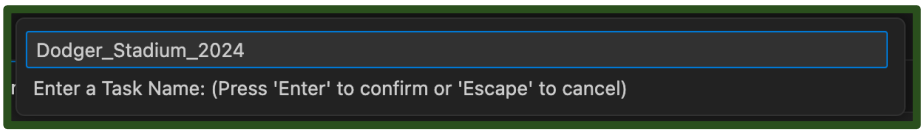


Example:

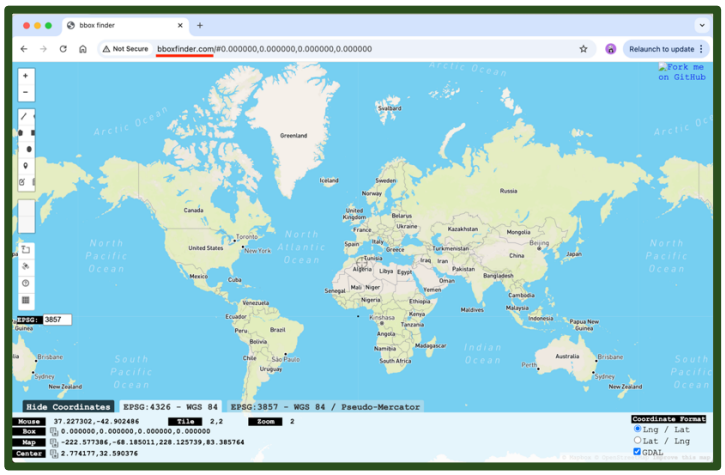
```
# Folder where all the sharpened ECOSTRESS LST files will be written for the scene of interest
dst_dir = r'/Users/baumann/Documents/ECOSTRESS-Sharpening-Tutorial-main/Sharpened_Outputs'
```

7. Once all your variables are set, press **Shift + Enter** to run the code. At the top of the window, another input box will appear asking you to enter a **task name**. This is just the name of the request that will be named in AppEEARS. Enter a name and then press enter.

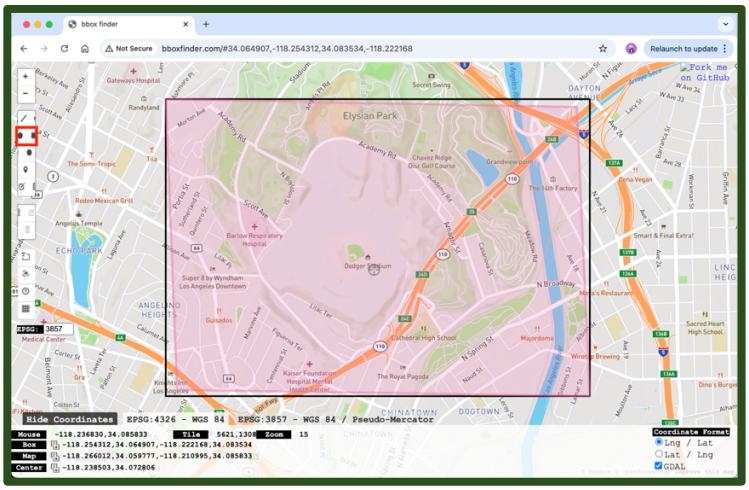
Example:



8. Scroll down to the next block of code under **Set the parameters for the products to be downloaded** and find the variable titled **aoi_coords_wgs_84**. We need to set this variable equal to the coordinates of a bounding box for our study area. To get these coordinates, click on the link in the code or search the web for **bboxfinder.com**.

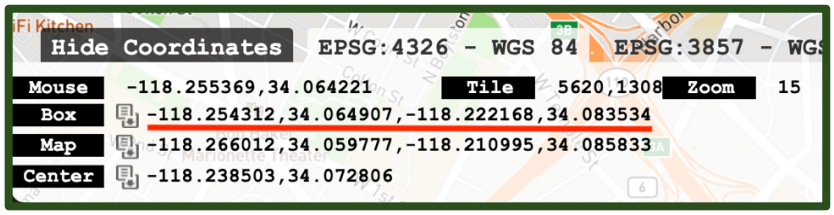


9. On the website, **zoom into** your area of interest on the map. Then click the **draw a shape icon**. Click on the map to create a box around your area of interest and click on the first point you made to close the box.



10. Then, at the bottom of the screen, **copy** the coordinates listed after **Box**. Go back to Visual Studio Code and **Paste** these coordinates into the variable.

Example:




```
# The coordinates of the bounding box of your choosing, in lat lon : (xmin,ymin,xmax,ymax)
# Use the http://bboxfinder.com to find your box easily (already in the right order)
aoi_coords_wgs_84 = (-118.254312,34.064907,-118.222168,34.083534) # example
```

11. Next, you can set the resolution of the Sentinel 2 data by adjusting the variable called **s2_res**. For now, I will leave it at 20.

```
# Choose the
s2_res = 20
```

12. You can also specify the **collection** of ECOSTRESS images that you want to use. At the time of this tutorial's creation, collection 2 is still being processed, so I am going to set this to **1**. Please refer to https://ecostress.jpl.nasa.gov/data for information about collection processing.

```
# Set the desir
eco_collec = 1
```

13. Finally, we need to change the **interval** variable to represent the start and end date for which we are interested in getting data. Make sure to enter these dates in the **"YYYY-MM-DD"** format.

Example:

```
# Choose your time interval (beginning, end) in the
interval = ("2024-06-01", "2024-08-31") # example
```

14. Once all of the variables are set, run this block of code by pressing **Shift + Enter.**

```
# The coordinates of the bounding box of your choosing, in lat lon : (xmin,ymin,xmax,ymax)
# Use the http://bboxfinder.com to find your box easily (already in the right order)
aoi_coords_wgs_84 = (-118.254312,34.064907,-118.222168,34.083534) # example

# Choose the resolution of the Sentinel data in meters 10 or 20, this will be the final resolution of the downscaled image. I would advise 20m at all times until
s2_res = 20
# Set the desired collection for the ECOSTRESS product to be downloaded (1 or 2). Pay attention Collection 2 hasn't been reprocessed for the full years of servic
eco_collec = 1

# Choose your time interval (beginning, end) in the format (YYYY-MM-DD). You'll get a S2 image from the tile with the lowest cloud coverage available in the inte
interval = ("2024-06-01", "2024-08-31") # example

startYear,startMonth,startDay = interval[0][:4],interval[0][5:7],interval[0][8:]
endYear,endMonth,endDay = interval[1][:4],interval[1][5:7],interval[1][8:]

✓ 0.0s                                                                    Python
```

15. Continue to the next block of code and press **Shift + Enter** to run it. The bounding box is limited to **2500 pixels**, so if you get an error about this you will need to **reduce** the size of your bounding box and re-run that block of code.

```
aoi_bbox = BBox(bbox = aoi_coords_wgs_84,crs=CRS.WGS84)
aoi_size = bbox_to_dimensions(aoi_bbox,resolution = s2_res)
print(f"Image shape at {s2_res} m resolution: {aoi_size} pixels") # The size of the box to 2500 pixels in each direction
if (aoi_size[0]>2499 or aoi_size[1]>2499) :
    raise(ValueError("The box is limited to 2500 pixels in each direction, try again with a smaller bounding box."))
✓ 0.0s
Image shape at 20 m resolution: (150, 101) pixels
```

16. Run the next **four** blocks of code including:
    a. **Download the S2 image with the previously defined parameters.**

Download the S2 image with the previously defined parameters.

```
# Request scripts, based off the sentinelhub documentation
# This script will be used to download all the S2 whose resolution is 20m or below
evalscript_all_bands_u20 = """
    //VERSION=3
    function setup() {
        return {
            input: [{
                bands: ["B02","B03","B04","B05","B06","B07","B08","B8A","B11","B12"],
                units: "REFLECTANCE"
```

    b. **Authentication and Token Retrieval for NASA AppEEARS API**

Dowloading ECOSTRESS scenes

This part is based off the ECOSTRESS API tutorials available here.

Authentication and Token Retrieval for NASA AppEEARS API

```
api = 'https://appeears.earthdatacloud.nasa.gov/api/'  # Set the AppEEARS API to a
token_response = req.post('{}login'.format(api), auth=(user, password)).json() # In
token = token_response['token']# Save login token to a variable
head = {'Authorization': 'Bearer {}'.format(token)}  # Create a header to store tok
print(token_response)
```

    c. **Locate ECOSTRESS products and search for the layers of interest in our case: LST and QC**

Locate ECOSTRESS products and search for the layers of interest in our case : LST and QC

```
prods = ['ECO2LSTE.001','ECO_L2_LSTE.002']

lst_response = req.get('{}product/{}'.format(api, prods[1])).json()
print(list(lst_response.keys()))
if eco_collec == 1 :
    layers = [(prods[0],'SDS_LST'),(prods[0],'SDS_QC')]
elif eco_collec == 2 :
    layers = [(prods[1],'LST'),(prods[1],'QC'),(prods[1],'cloud_mask')]

# List of products and layers
```

d. **Formulate the AppEEARs request**

Formulate the AppEEARS request

```
# Takes the bounding box entered above and creates a polygon for the ECOSTRESS request
def polygon_from_bbox(bbox):
    long0, lat0, long1, lat1 = bbox
    return Polygon([[long0, lat0],
                    [long1,lat0],
                    [long1,lat1],
                    [long0, lat1]])

polyg = polygon_from_bbox(aoi_coords_wgs_84)

aoi_df = gpd.GeoDataFrame(pd.DataFrame(columns = ['bbox']),
        crs = 'epsg:4326',
```

17. Then find the next block of code under **Ping the API** and press **Shift + Enter** to run it. This code will check in with the AppEEARS request every 30 seconds and give you a report such as **queued** or **processing**. This code may take a while to run since it takes time for the requests to be fulfilled. You can leave this part of the code to run and come back later.

Ping the API

Ping the API every 30 seconds until the request is complete to display the status. It may occur that AppE

```
starttime = time.time()
while req.get('{}task/{}'.format(api, task_id), headers=head).json()['status'] != 'done':
    print(req.get('{}task/{}'.format(api, task_id), headers=head).json()['status'])
    time.sleep(30.0 - ((time.time() - starttime) % 30.0))
print(req.get('{}task/{}'.format(api, task_id), headers=head).json()['status'])
```

a. You will know you are ready to proceed when the code output says **done**.

```
...
processing
processing
processing
done
```

18. Run the block of code under **Download the ordered files** to download the ECOTRESS files to your computer.

Download the ordered files

```
# Set up output directory using input directory and task name
eco_dest_dir = os.path.join(eco_output_folder,task_name)
if not os.path.exists(eco_dest_dir):
    os.makedirs(eco_dest_dir)

bundle = req.get('{}bundle/{}'.format(api,task_id), headers=head).json()  # Call API and return bund

files = {}
for f in bundle['files']: files[f['file_id']] = f['file_name']
```

19. From here, your code should be ready to run the next **four** modules including:
    a. **Sort the downloaded files in appropriate sub-directories**

Sort the dowloaded files in appropriate subdirectories

```
# For each directory, if it doesn't exist already, create it and place the dowloaded files in

QC_dir = os.path.join(eco_dest_dir,'QC')
if not os.path.exists(QC_dir) :
    os.mkdir(QC_dir)
lst_dir = os.path.join(eco_dest_dir,'LST')
if not os.path.exists(lst_dir) :
    os.mkdir(lst_dir)
```

    b. **Preprocessing the QC files**

Preprocessing the QC files

The QC files are coded in 16 bits and thus can't be easily seen as a mask file. For convience, we write new Quality Flag (
Then, there are only four possible values:
0 when the pixel is of best quality, 1 for nominal quality, 2 if a cloud is detected and 3 if the pixel is not produced. In the
disregarded.
For more information on the QC files : https://lpdaac.usgs.gov/documents/423/ECO2_User_Guide_V1.pdf (section 2.4)

```
for file in os.listdir(QC_dir) :
    if not file.endswith('QF.tif') and not file.endswith('.xml') :
        file_qc = os.path.join(QC_dir,file)
        with rasterio.open(file_qc,'r') as f_qc :
            # Read the QC file, coded in 16 bits
```

Tip: If you get a Rasterio error similar to this, your files may have been corrupted. In order to fix this, go to your ECO_Outputs folder and delete everything. Then go back and run the **Download the ordered files**, **Sort the downloaded files in appropriate subdirectories,** and **Preprocessing the QC files** cells. The error should be resolved.

```
---------------------------------------------------------------------------
CPLE_OpenFailedError                      Traceback (most recent call last)
File rasterio/_base.pyx:310, in rasterio._base.DatasetBase.__init__()

File rasterio/_base.pyx:221, in rasterio._base.open_dataset()

File rasterio/_err.pyx:359, in rasterio._err.exc_wrap_pointer()

CPLE_OpenFailedError: '/Users/baumann/Documents/ECOSTRESS-Sharpening-Tutorial-main/ECO_Outputs/Dodger_Stadium_2024/QC/ECO2LSTE.001_SDS_QC_doy2024218172759_aid0001.t

During handling of the above exception, another exception occurred:

RasterioIOError                           Traceback (most recent call last)
Cell In[18], line 4
      2 if not file.endswith('QF.tif') and not file.endswith('.xml') :
      3     file_qc = os.path.join(QC_dir,file)
----> 4     with rasterio.open(file_qc,'r') as f_qc :
      5         # Read the QC file, coded in 16 bits
      6         qc_img = f_qc.read((1))
      7         qc_img[qc_img==-99999] = -1  # Nodata values are read as -99999, we change it to -1 so that the last two bits appear as 11 (which means pixel not pr
```

c. **Scaling the ECOSTRESS LST to normal Kelvin Scale**

Scaling the ECOSTRESS LST to normal Kelvin scale.

The LST product is actually scaled at 0.02, the GIS software takes that scale in account before c
Python it's easier to apply the scale rather than reading the metadata.

```
# If the scaled subdirectory doesn't already exist, create it
lst_dir_sc = os.path.join(eco_dest_dir,'LST_scaled')
if not os.path.exists(lst_dir_sc) :
        os.mkdir(lst_dir_sc)

# Scale each file
for file in os.listdir(lst_dir) :
        if file.endswith('.tif') :
```

d. **Unsampling using pyDMS**

i. Use the first block of code under this header if you want to process the entire extent of the image.

If you use this cell, then the output extent will be the extent of the orignal images downloaded.

```
useDecisionTree = True # You could change this to False if you want to use the Neural
files_sharpened = [] # list of the files sharpened
dst_dir_f= os.path.join(dst_dir, f"{task_name}-Results")
# Loop through the directory of LST images scaled
for file in os.listdir(lst_dir_sc) :
```

ii. Use the second block of code under this header if you only want to sample part of the image.

If you wish to sharpen only part of the image, for instance just the center of a city and not the suburbs, then use this cell.

```
useDecisionTree = True # You could change this to False if you want to use the Neural Network intead of the

files_sharpened = [] #list of the files sharpened
dst_dir_f = os.path.join(dst_dir, f"{task_name}-Results")
```

20. Once you have run these modules, you now have sharpened ECOSTRESS imagery! In order to see an **image plotted** of the sharpened scenes, you can run the block of code under the **Display** section.

Display

Plot one random sharpened image

```
# Pick one random sharpened file
file = random.choice(files_sharpened)
sharpened_file = os.path.join(dst_dir_f,file.replace('.tif','_sharp_S2.tif'))
raw_file = os.path.join(lst_dir_sc,file)
with rasterio.open(raw_file,'r') as lr_img :
    raw_lst = lr_img.read(1)
with rasterio.open(sharpened_file,'r') as shrp_img :
    shrp_lst = shrp_img.read(1)
```

a. Example of **Plot one random sharpened image:**