Lab Assignment #3 – Getting to Know Sentinel-2

1. Logistics

Date assigned: Monday, October 28, 2024

Date due: Monday, December 02, 2024 (via Moodle)

Points: 80 points

Please submit all homework as a single PDF file via Moodle.

In this lab, you will work with Sentinel-2 data. We will focus on the Berlin region and will explore different multispectral properties, vegetation classification, and differences in spatial resolution. We will also show you how to download your own data for an area of your choice.

2. Initial Setup and Data Sources

Sentinel-2

Sentinel-2 data are provided free of charge from the ESA. General information about the Sentinel-2 sensor are on the ESA website at https://earth.esa.int/web/sentinel/user-guides/sentinel-2msi/overview. We will use the MSI (MultiSpectral Instrument) onboard Sentinel-2. This is comparable to Landsat OLI, but has significant band differences (Figure 1). Sentinel-2 does not include a thermal IR sensor. Spatial resolution of the individual bands can be found here: https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/resolutions/spatial

Data from Sentinel-2 are accessible through the Copernicus Scientific hub (https://scihub.copernicus.eu/). You can open the hub (https://scihub.copernicus.eu/dhus/#/home) and then login (or sign up) to be able to download data. Again, we have provided the necessary data for the first part of the lab on Moodle.

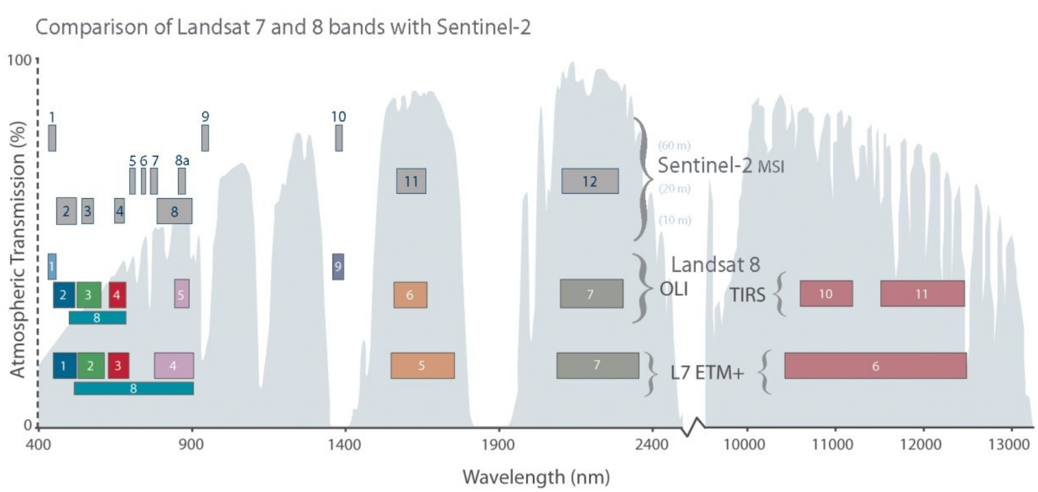


Figure 1: Comparison of Landsat and Sentinel-2 Spectral Bands

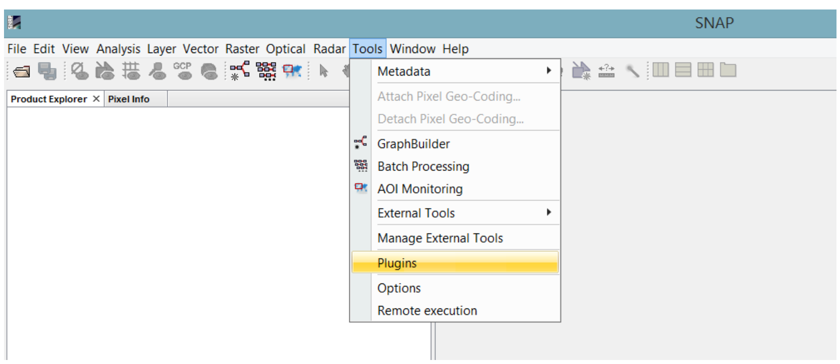
3. Using SNAP to Correct Sentinel-2 Data

Sentinel-2 data are a new addition to the optical remote sensing family, and are becoming increasingly widely used. Some of the bands are provided at 10m spatial resolution (e.g., https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/resolutions/spatial), which is a significant improvement over Landsat for many applications. While the time frame is rather short (since 2014), the Sentinel-2 mission is planned for at least the next 30 years, so the data will only become more valuable as time goes on.

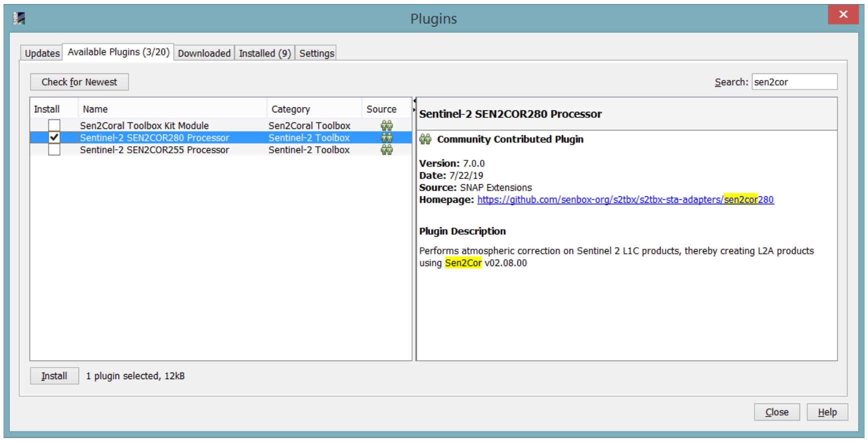
Unfortunately, ESA only provides the last ~6 months of data in a pre-processed format (see here for a format guide: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/processing-levels/level-1 and here: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/processing-levels/level-2).

However, they provide some very powerful tools to convert the Level 1C (TOA reflectance) to Level 2A (Bottom of Atmosphere reflectance) values. To do this, we will use the ESA SNAP Toolbox (https://step.esa.int/main/toolboxes/snap/).

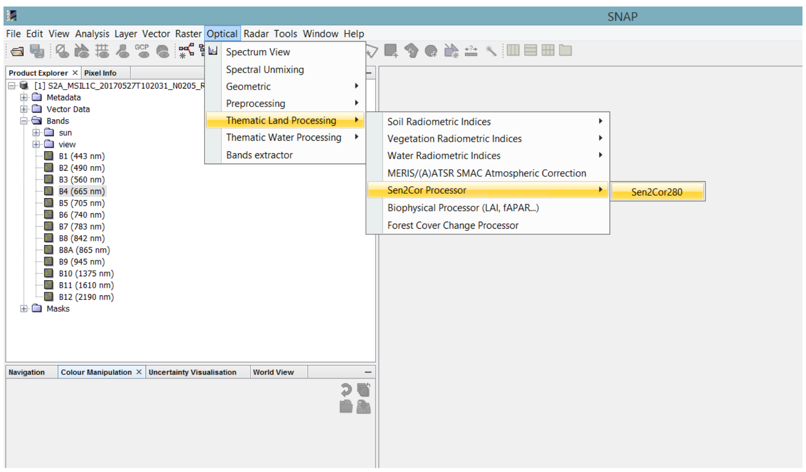
Make sure to select both the Setinel-1 and Sentinel-2 toolboxes – we will use both throughout this class. Once you have SNAP installed, we also need to install the sen2cor tool, which will perform the atmospheric corrections.



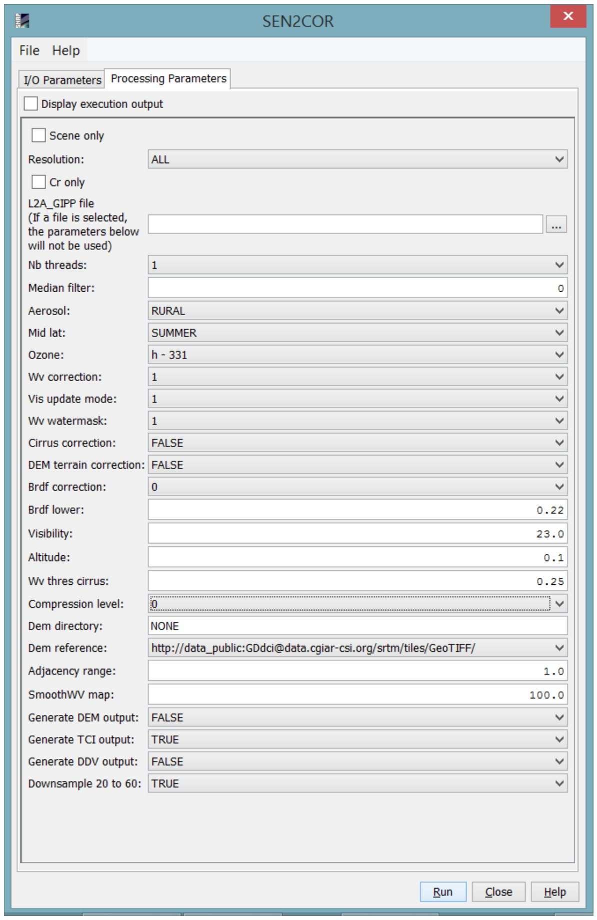
We want to install the Sen2Cor toolbox (version 2.8). **Note: If you use data from before ~Feb 2016, you will need to use Sen2Cor version 2.55, as the product metadata is slightly different for old data.**



SNAP will then restart, and we can start to work with the Sentinel-2 dataset.



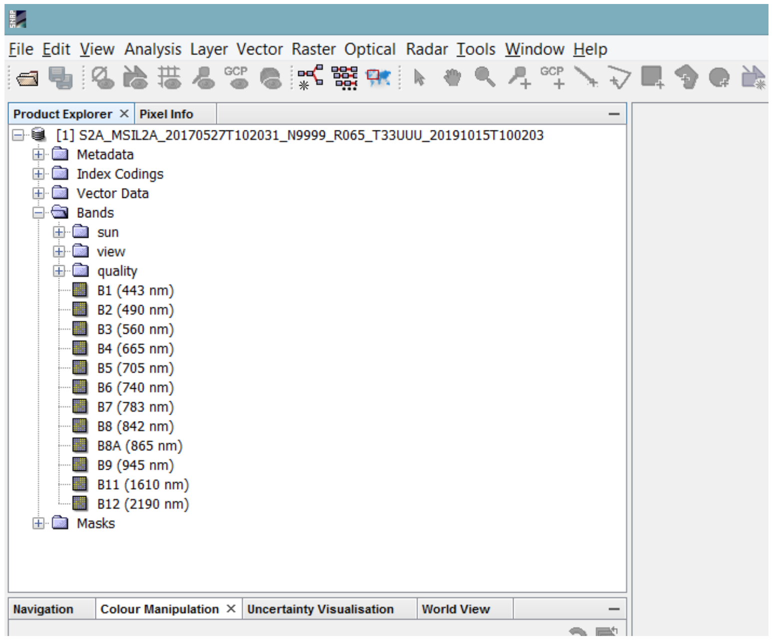
We can leave the default parameters here:



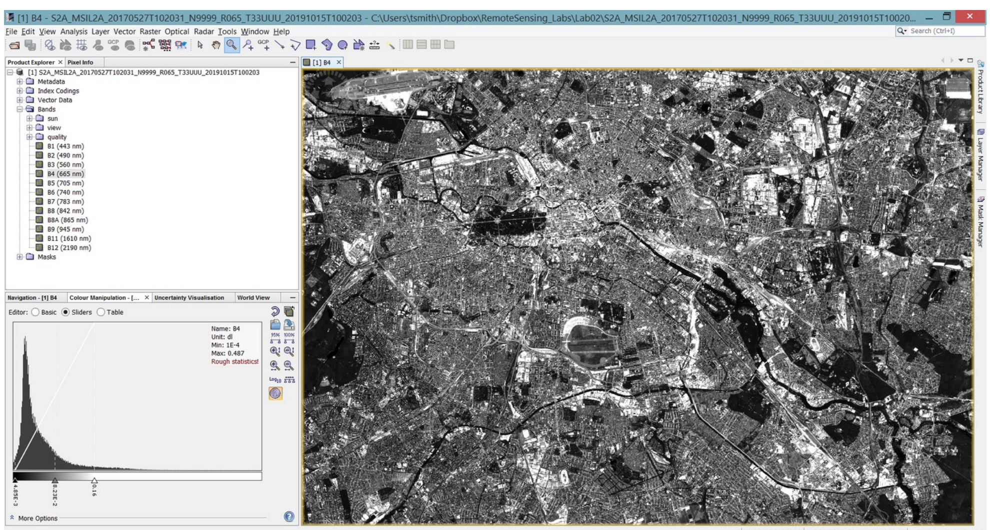
To speed things up, we provide a pre-processed L2A dataset derived from the L1C dataset. It takes ~20-40 minutes to run the L2A correction, so the next images are a quick walkthrough – we will start our work from the L2A data.

4. Working with L2A Data

In SNAP, we can load the zipped Sentinel-2 file directly – we don’t need to extract it first. Once you open the file, there are several bands available:

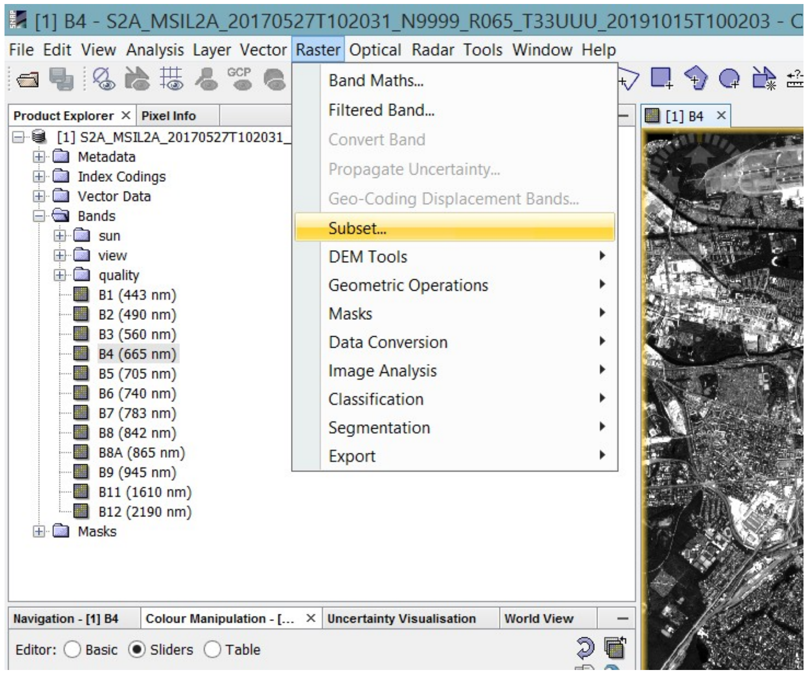


Since the data is already atmospherically corrected, there are also quality bands, cloud masks, and other useful information included with the file. You can open any band by double clicking it, or look at its metadata by right clicking:

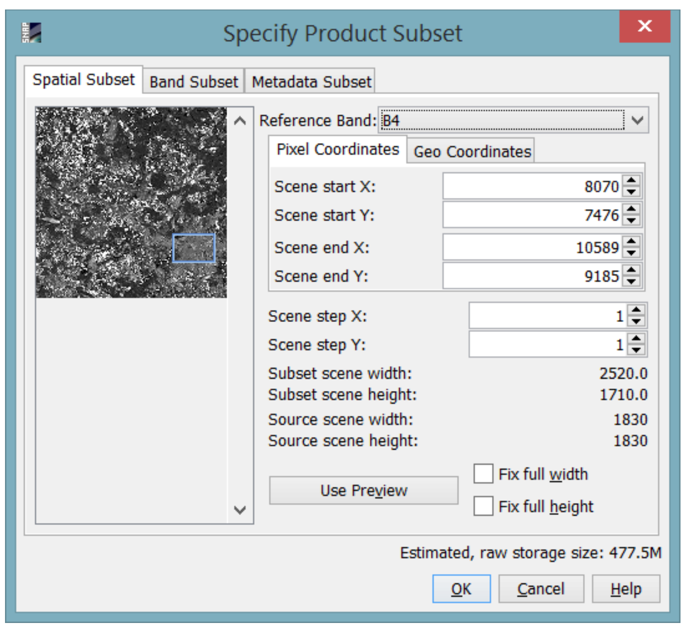


Notice how high-resolution the data is – Bands 2,3,4, and 8 are provided at 10m resolution. These allow us to compute things like the NDVI at very high spatial resolution.

Before we start working, let's clip the data down to a smaller region. Feel free to choose any part of the image that you find interesting.

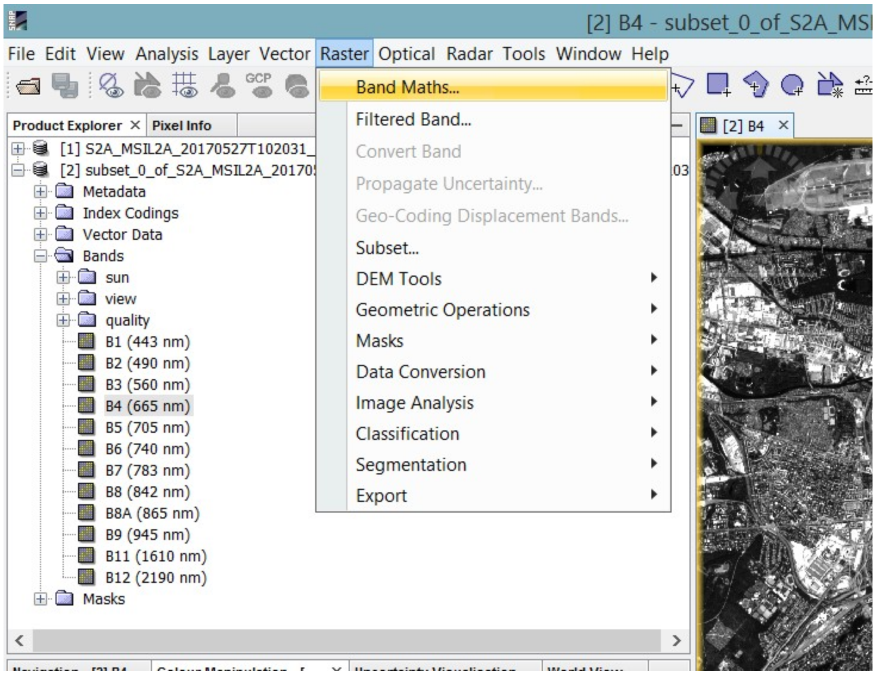


We can either define our own region, or simply zoom around on an image until we have an acceptable study area:



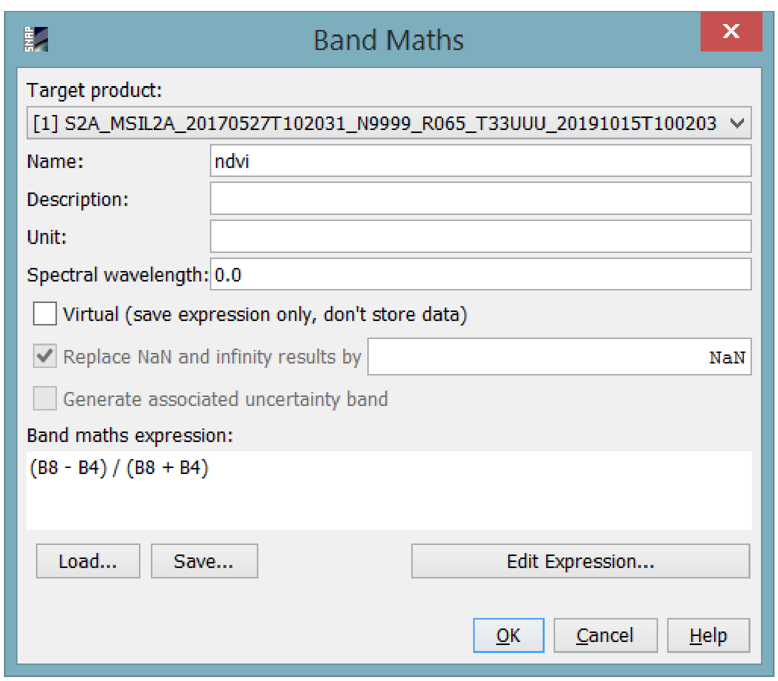
SNAP won't save the data immediately – it rather stores clips as virtual rasters. We can open this up and make sure we like our clipped area before proceeding with the next steps.

As in QGIS, we can use a raster calculator to generate NDVI, NDWI, or whatever other index is interesting. This can be found here:

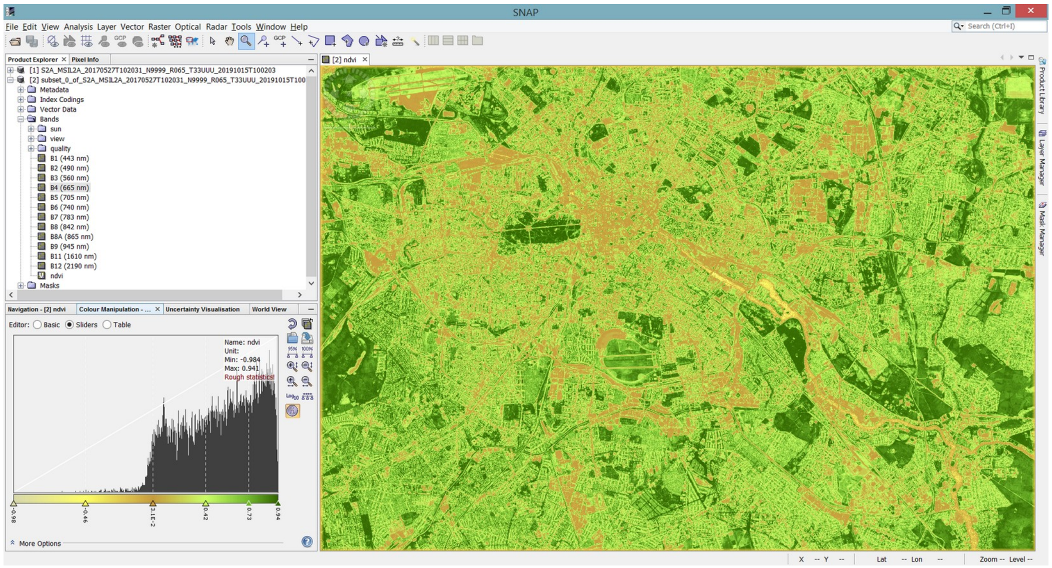


Let's first do an NDVI calculation. **NOTE – The bands we use for Sentinel-2 are different than from Landsat!** For Sentinel-2 NDVI, we want Bands 4 and 8. Make sure you untick 'Virtual' on this step! Otherwise the data won't be properly saved.

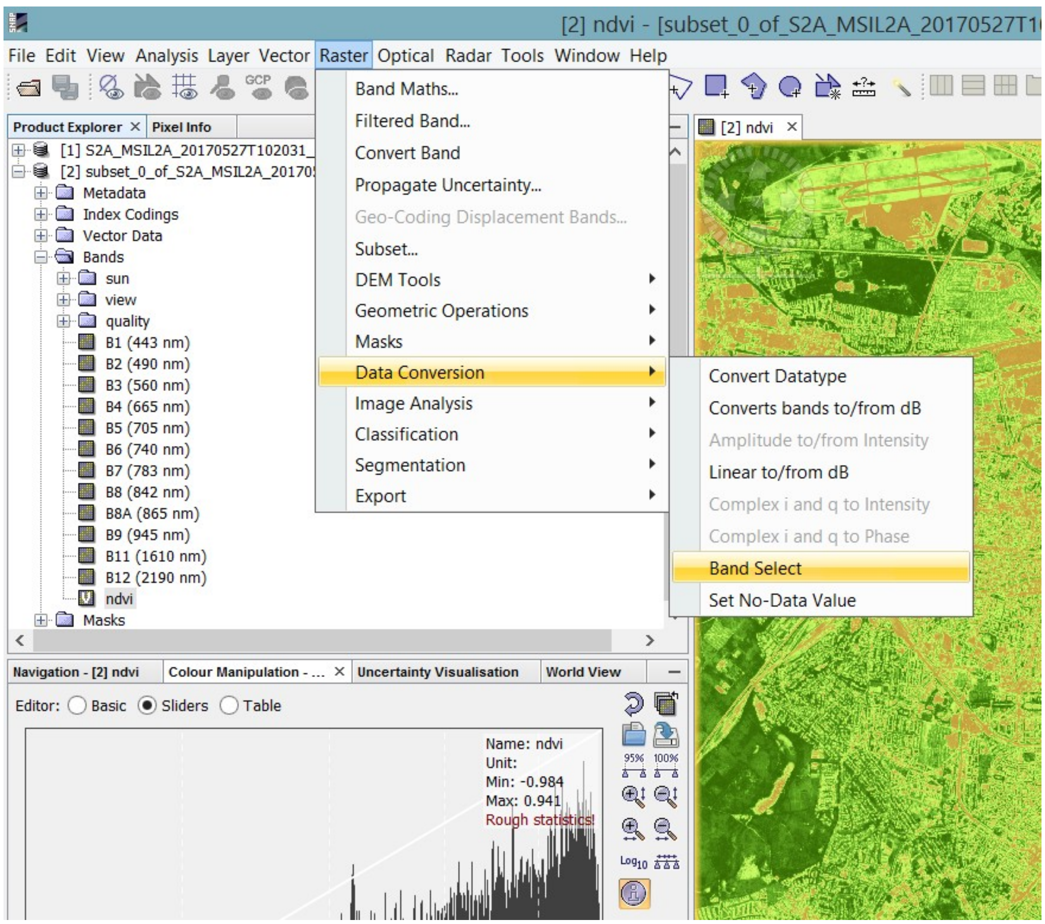
NDVI = (B8 - B4) / (B8 + B4)



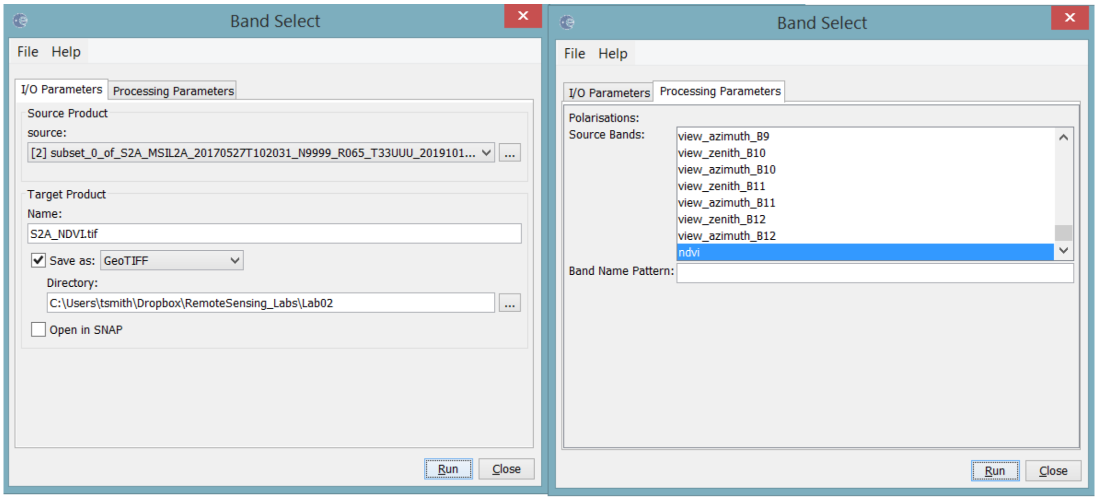
If we look at the data, we should see something similar to the Landsat NDVI we created.



Let’s export this and compare it to the NDVI from Landsat. There are a few ways to do this, but the simplest is to use the ‘Band Select’ tool:



We can then select only the NDVI band to export, and save it with a useful filename:

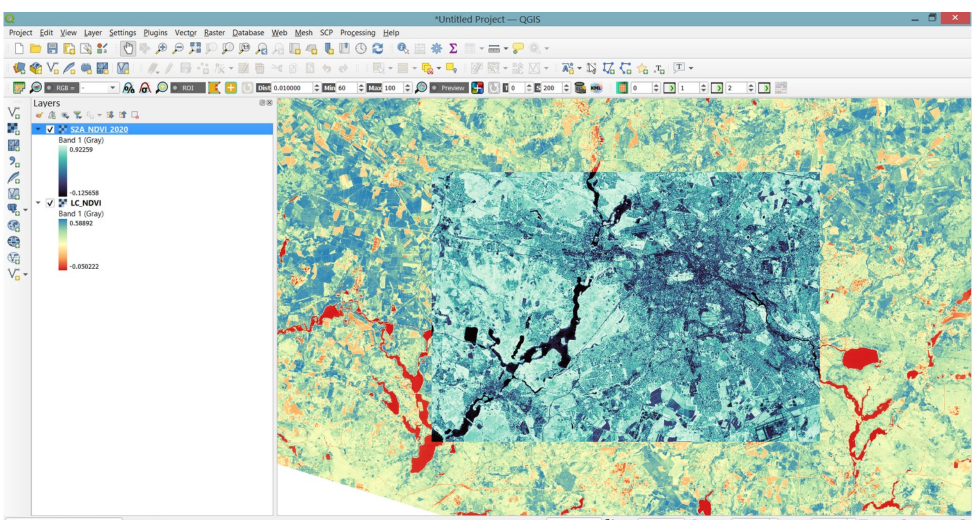


<u>**IMPORTANT – SNAP can be quite funny about exporting data into GeoTIFF data. If you run into any issues, you should try to export the data as a 'GeoTIFF-BigTIFF', as sometimes the GeoTIFF writer in SNAP yields empty datasets.**</u>

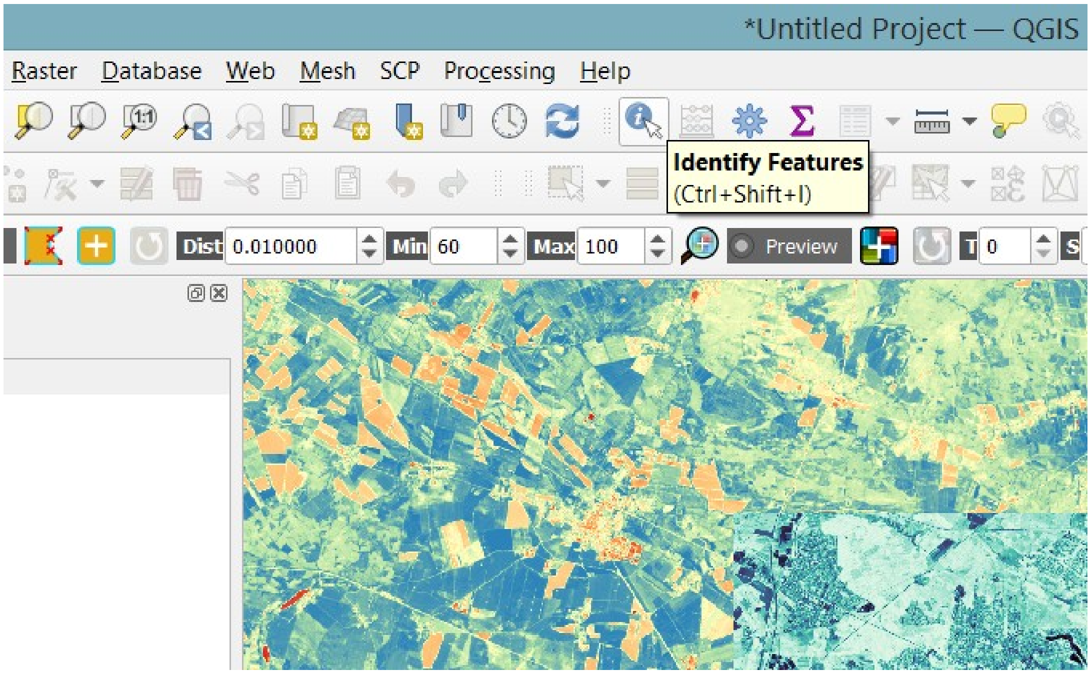
<u>**Question 1:**</u> Following the same steps, generate an NDWI image for the same area from the Sentinel-2 data. Make sure you use the appropriate bands (see Figure 1 of this lab for details of how the Landsat and Sentinel bands overlap). Include a scale bar, legend, color scale, etc with your map. (20 points).

5. Comparing Landsat 8/Sentinel-2

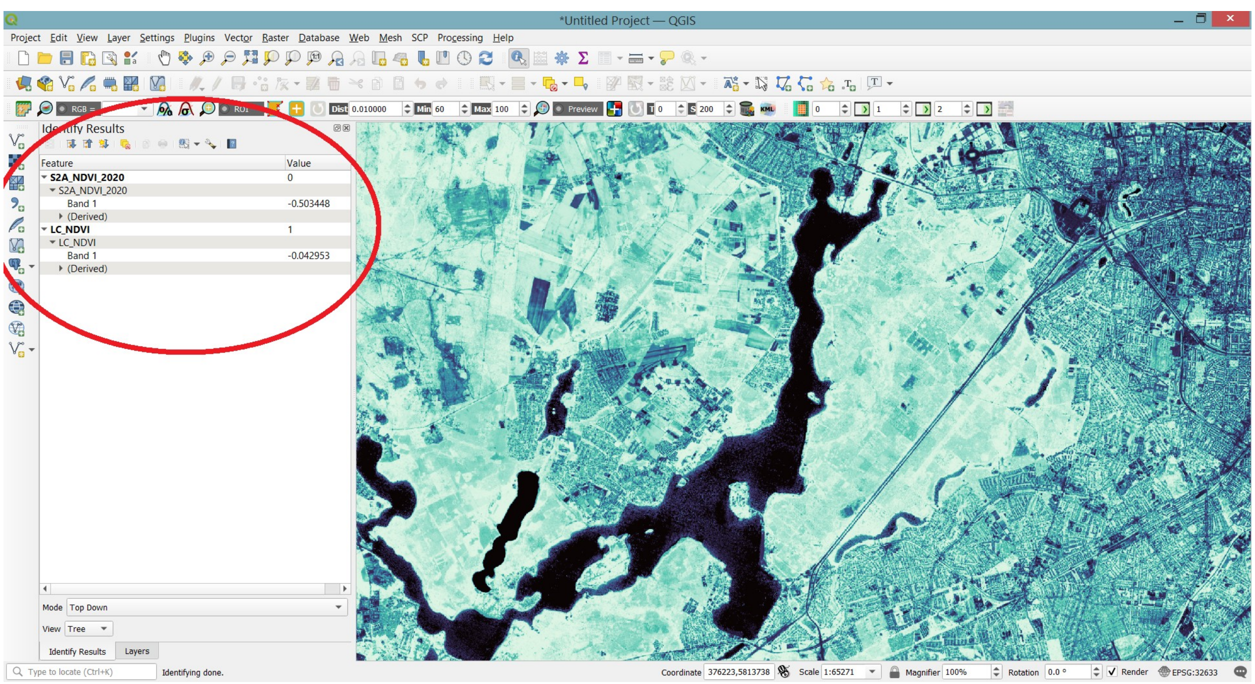
Now that we have the dataset saved, let's open it up in QGIS. We can also open up the Landsat 8 NDVI dataset for comparison:



The two datasets should line up, but the Sentinel-2 data is much higher resolution. We can see how closely the values match up using the 'Identify' tool:

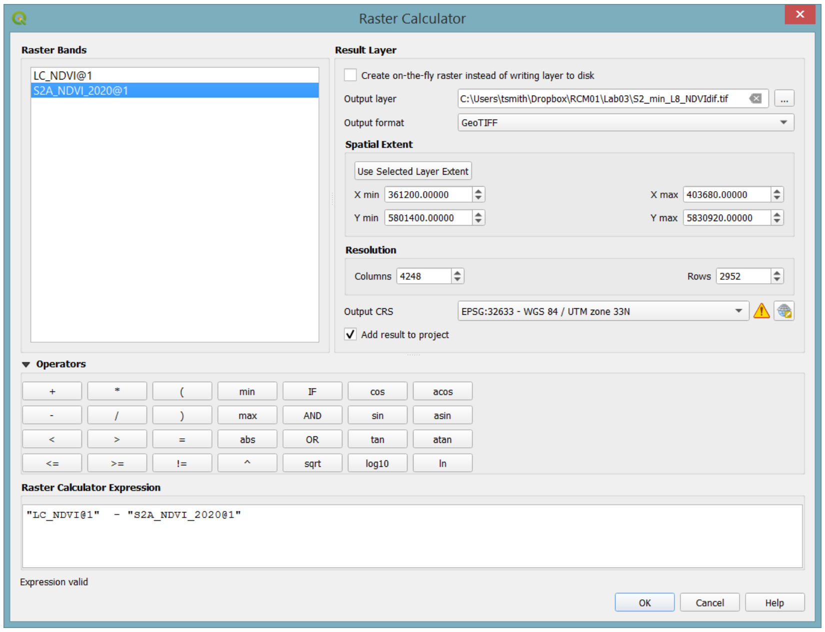


Clicking anywhere where both data sets overlap should give you two different values:

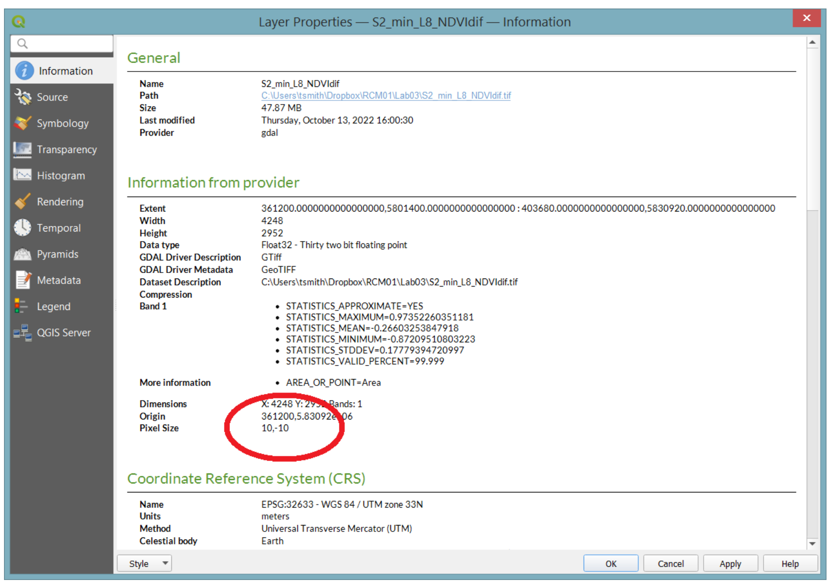


These values can be quite different! Why might that be?

We can compute these differences, even though the spatial resolutions do not perfectly match. Let's use the raster calculator:

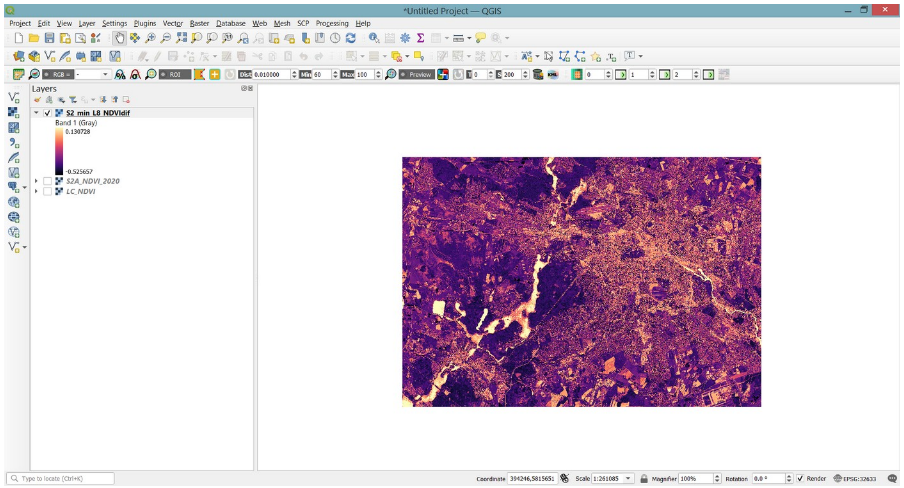


Notice that we end up with a 10m raster:

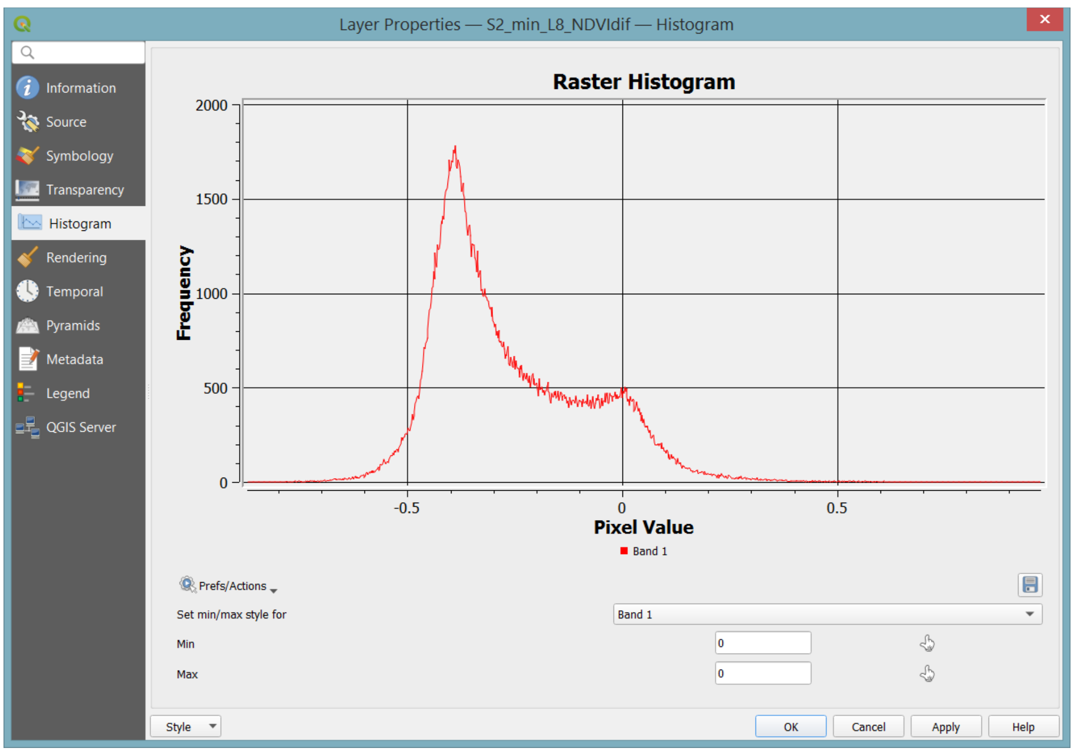


Which is the *smallest resolution of our two inputs*. The QGIS raster calculator *resamples the raster for us!*

Let's take a look at the map. Water stands out as being quite different between the two satellites:



We can see what the distribution of differences in our data is via the 'Histogram' tool:

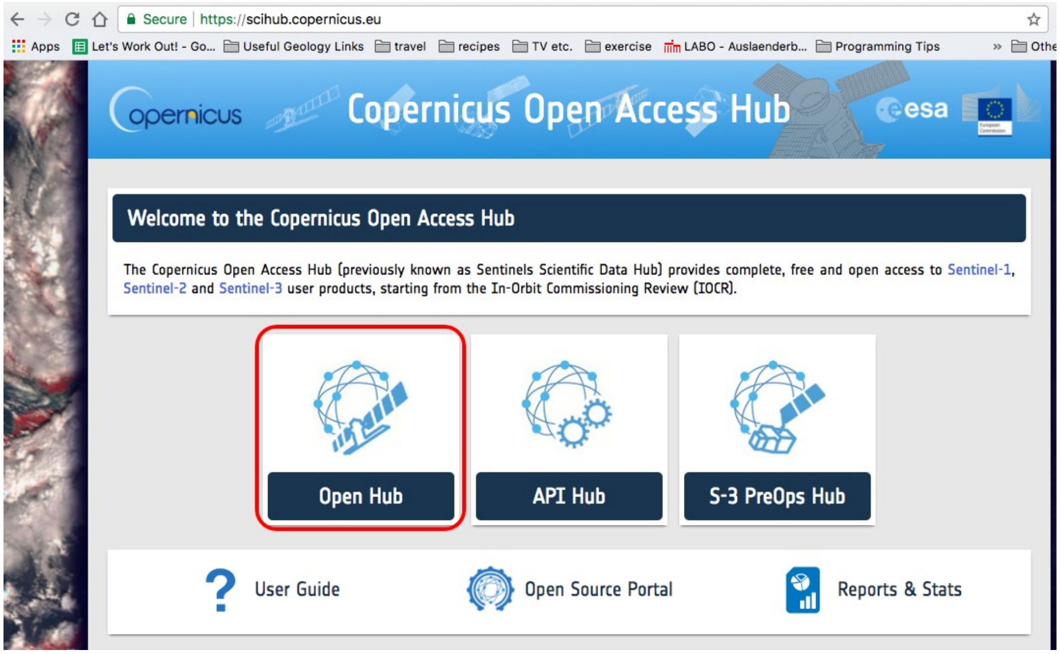


The data are not normally distributed around zero! There is a big bias in there – from this histogram, it is not ok to directly compare Sentinel-2 and Landsat NDVI values. A correction is required to get them on the same scale!

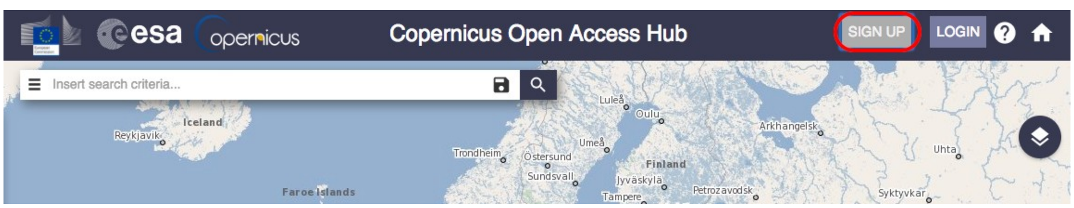
<u>Question 2:</u> Perform a similar comparison for NDWI. Are the values closer together or further apart? Include a map of the differences in NDWI between the two sensors, as well as a screenshot of the histogram. Why do you think NDWI is more (or less) similar than NDVI? (20 points).

6. Working with Your Own Data

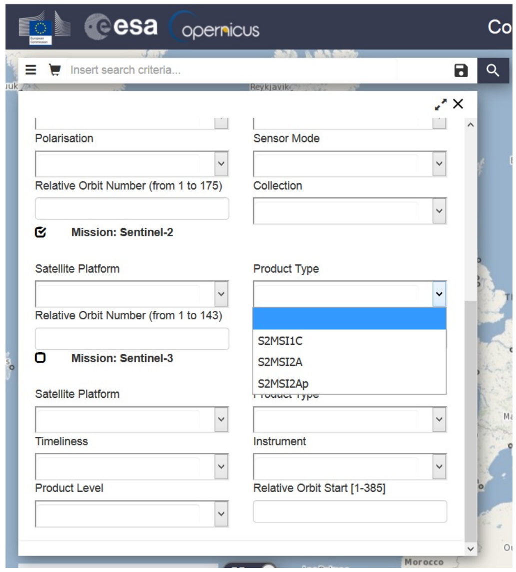
Sentinel data can be accessed through the **ESA Copernicus Open Science Hub** (https://scihub.copernicus.eu/).



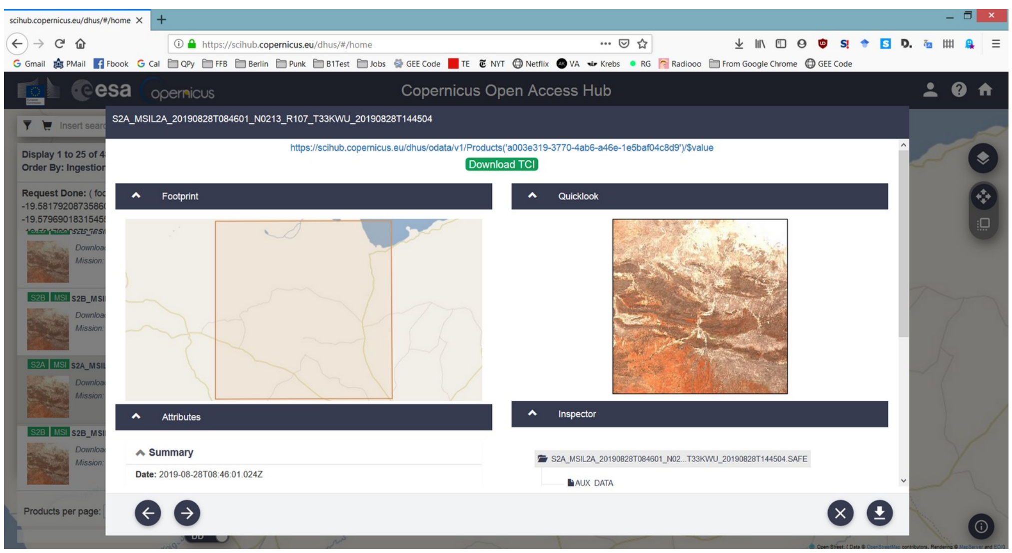
Sentinel-1 data is free, but you will need to create an account before you can download data.



Once you have a Copernicus SciHub account, you can search by panning the map to your area of interest (see options on bottom to Pan – Box – Polygon – Clear these allow you to navigate and select regions you're interested in. When you've navigated to your region of interest, use either the **Box** or the **Polygon** tool to highlight the specific area you want data for. Once you've done this, you can use the search criteria to specify what kind of data you want. For this exercise, you want to use **Sentinel-2 data**. You can choose to use L1C data, which is not atmospherically corrected, or L2A data, which is ready to use for further anlaysis. **If you use L1C data, for example for data older than ~6 months, you can correct it with sen2cor, as described in this lab (Section 10).**



Once you hit 'Search' you will have a list of available scenes. You can preview the scenes by clicking on the 'eye' icon:



This gives you some metadata, as well as a preview of the image. You can download individual images directly, or add them to your cart and download several at once. We will discuss this in more depth in Lab 3.

<u>Question 3:</u> Using your own data, generate band ratios of your choice (e.g, NDVI, NDWI, NDSI, or any other interesting metric) and create two (2) maps of your region using Sentinel-2 data. Each map should have a legend, scale bar, north arrow, color scale, etc. Explain where your data is located (for example, by giving each map a useful title), what time of year the data is from, and what the data shows (40 points).