



EXERCISE 13 – TUTORIAL

Marine applications: deriving nearshore bathymetric model with Sentinel 2 data using SNAP software

1 | Exercise outline

In this exercise, we will:

- Learn the basic steps to derive near-shore bathymetry based on S2 images
- Preprocess the image to correct for atmospheric effects
- Identify and select appropriate bands for bathymetric analysis, particularly focusing on near-infrared (NIR) and shortwave infrared (SWIR) bands which penetrate water more effectively.
- Utilize empirical relationships to estimate water depth based on reflectance values in selected bands.
- Visualize the derived bathymetry map to interpret and analyze water depth variations across the coastal area.

2 | Background

Deriving bathymetry using Sentinel-2 data

Deriving bathymetry, or the measurement of water depth, using Sentinel-2 data involves leveraging the satellite's multispectral capabilities, particularly in the near-infrared (NIR) and shortwave infrared (SWIR) bands, to penetrate water and assess bottom reflectance. While Sentinel-2 imagery is primarily designed for land observation, it can still provide valuable information for coastal and shallow water applications.

Our approach to derive bathymetry from Sentinel-2 data involves exploiting the attenuation of light with depth in water. Water absorbs and scatters light as it penetrates deeper, with longer wavelengths like NIR and SWIR being less affected. By analyzing the reflectance values of these bands in shallow coastal areas, researchers can estimate water depth based on the relationship between reflectance and depth.

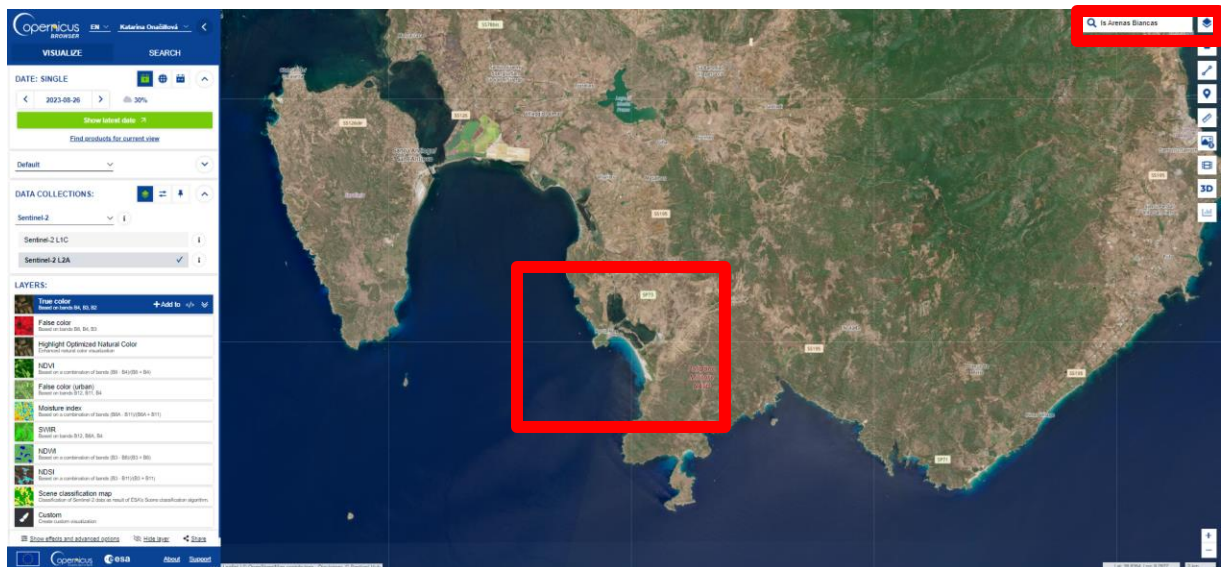
For bathymetric estimation in this exercise we use satellite imagery and empirical models that establish relationships between satellite-derived reflectance values and measured water depths from field surveys. By calibrating the model with ground truth data, researchers can predict water depth from reflectance values in Sentinel-2 bands.

Challenges in deriving bathymetry from Sentinel-2 data include atmospheric effects, water surface roughness, and bottom substrate variability. Additionally, accurate ground truth data for calibration and validation are essential for ensuring the reliability of bathymetric estimates.

Despite these challenges, Sentinel-2's frequent revisits and high spatial resolution make it a valuable tool for coastal and shallow water bathymetry mapping, aiding in coastal zone management, environmental monitoring, and habitat mapping. Ongoing research continues to refine and improve bathymetric estimation techniques using Sentinel-2 data.

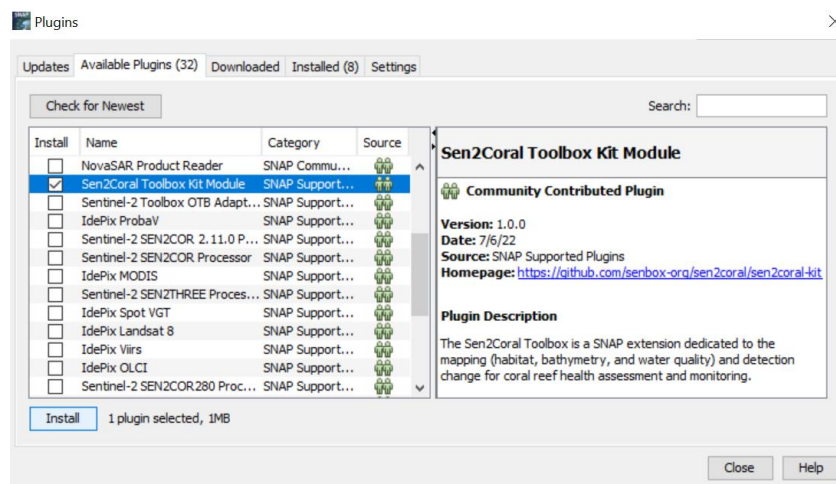
2.1 Study area and data used

For this exercise, we will use Sentinel-2B image of the area Is Arenas Blancas, south of Cagliari, with its expanse of white sand, a vivid blue seabed and dunes covered in greenery behind it, using the Tile Number *32SMJ* downloaded for 26 August 2023 from the Dataspace Copernicus Open Access Hub [https://dataspace.copernicus.eu/].



2.2. SNAP – Sen2Coral

Open SNAP Desktop and check if the Sen2Coral Toolbox that we will need for this exercise is installed. The Sen2Coral Toolbox is a SNAP extension dedicated to the mapping (habitat, bathymetry, and water quality) and detection change for coral reef health assessment and monitoring. Navigate to Tools – Plugins and check whether the Sen2Coral Toolbox is Installed in the Installed tab. If it doesn't appear there, go to Available plugins and install it. To complete the installation process, restart of the application is needed. After that, you can check if it was installed successfully – Navigate to Optical – Thematic Water Processing – Sen2Coral plugin should be there.



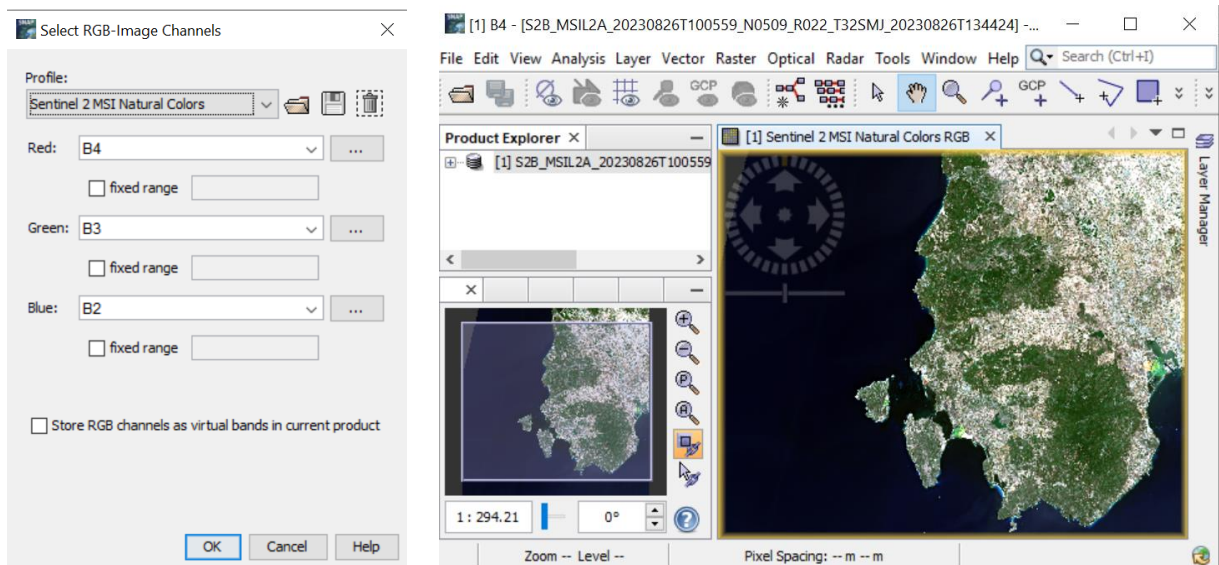
2.3. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open downloaded Sentinel-2 product (unzipped) by double click on the metadata „MTD_MSIL2A.xml“ inside the folder. The opened products will appear in Product Explorer window.

S2B_MSIL2A_20230826T100559_N0509_R022_T32SMJ_20230826T134424.SAFE

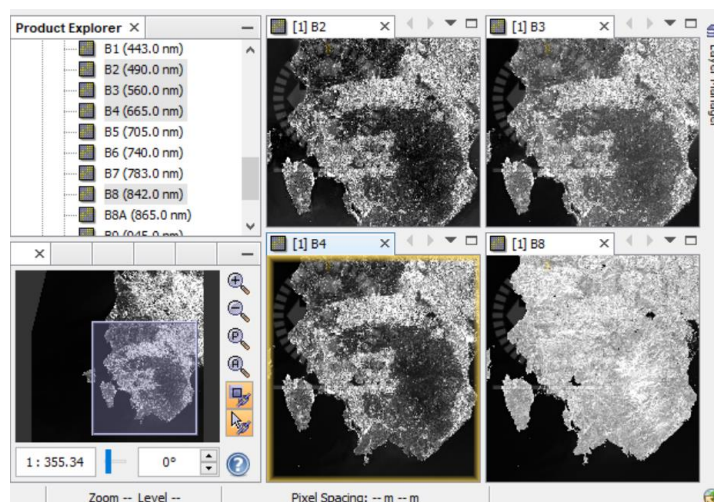
Display the product using e.g. True color composition:

Right click on the product – Open RGB Image Window – select Sentinel 2 MSI Natural Colors.



For this exercise, only bands with a spatial resolution of 10 meters will be employed: the Visible Blue (B2), Green (B3), Red (B4), and Near Infrared band (B8) due to their strong linear correlation with water depth. The NIR band is utilized for land masking.

To view these four bands in the View Window, navigate to the Bands folder of the image and double-click on them (B2, B3, B4, B8). Ensure synchronization of views by going to the Navigation tab in the lower left (red arrow) and confirming that the cursor and views are linked.



2.4 Resample

The Sentinel-2 products consist of 13 bands with varying resolutions, impacting their sizes. Since several operators in the SNAP toolbox cannot handle products with bands of different sizes, it is necessary to initially resample the bands to ensure uniform resolution.

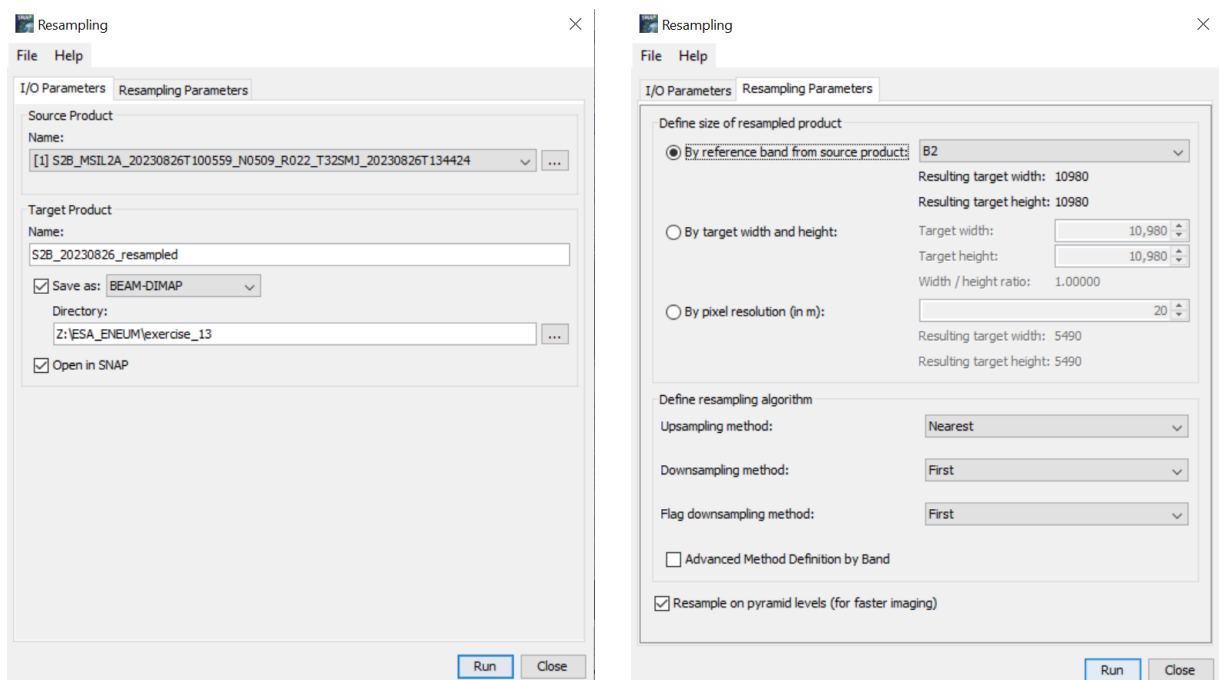
Navigate to Raster → Geometric → Resampling.

In the I/O Parameters tab, set the name for the "Target Product," as S2B_20230826_resampled and set the Directory where the resampled product will be saved.

In the Resampling Parameters tab, under "Define size of resampled product," select: By reference band from source product: B2.

Click **Run**. After the process is completed, if a window appears, click **OK**. Close the Resampling Window.

A new product [2], named **S2B_20230826_resampled** appeared in the **Product Explorer** Window.



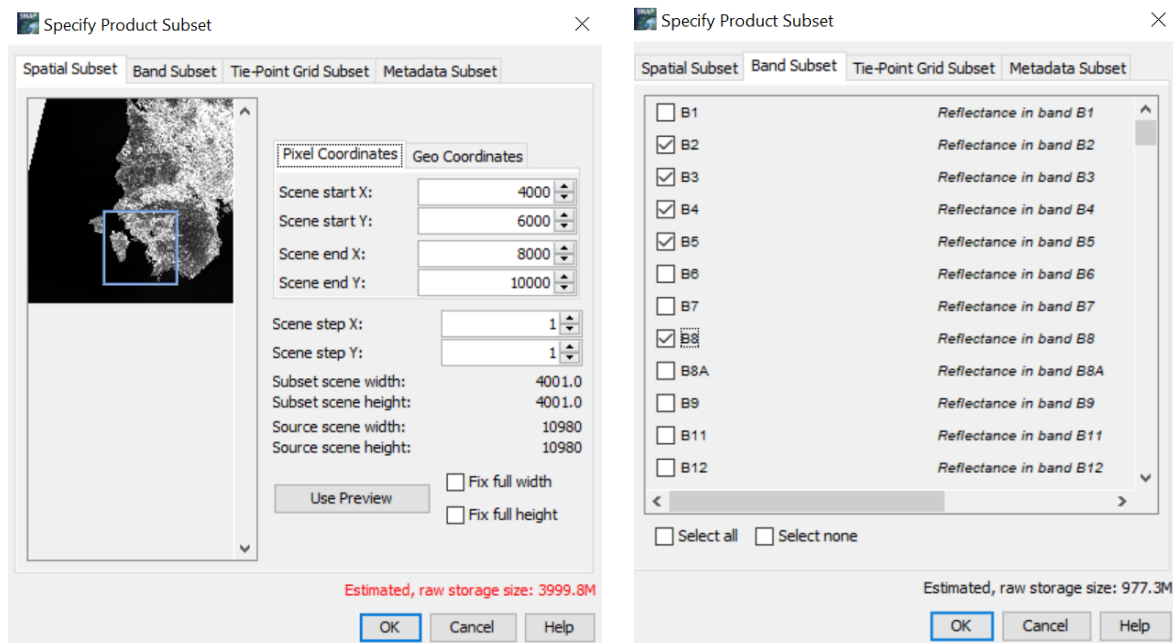
2.5 Subset

The initial phase of the methodology involves reducing the original size and number of bands in the image. To accomplish this, choose the Sentinel-2 resampled product in the Product Explorer, then proceed to **Raster -> Subset**.

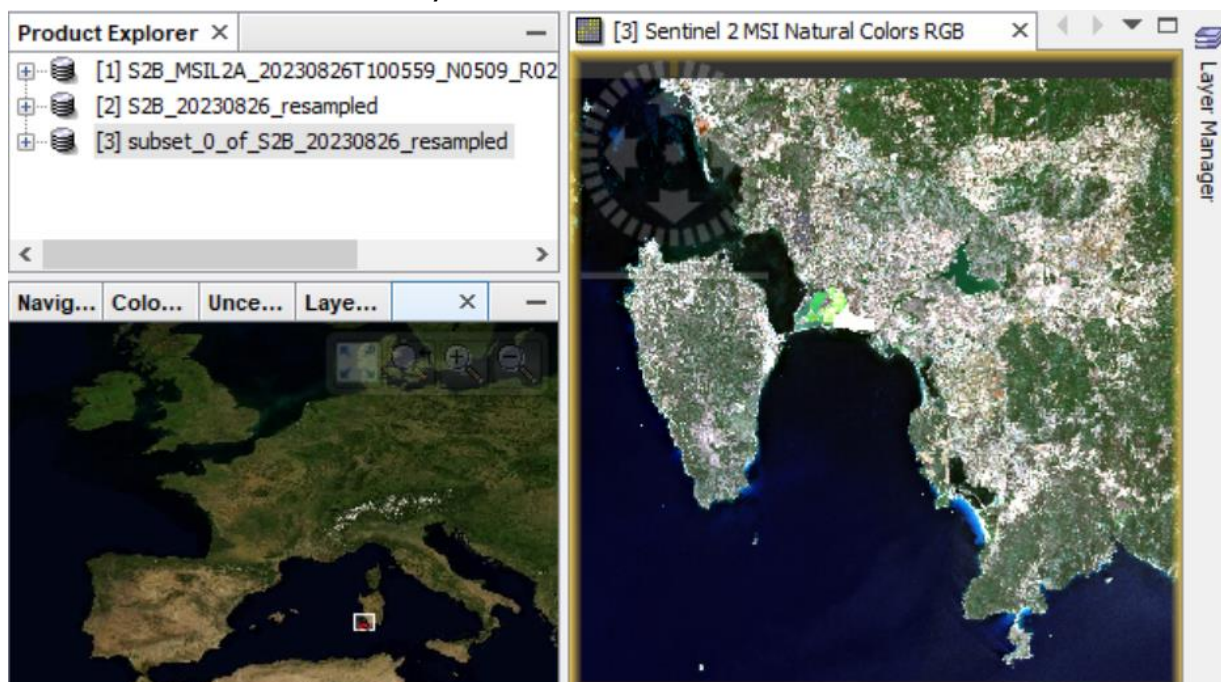
In the **Spatial Subset** tab select the Pixel Coordinates tab, set the following parameters:

Scene start X: 4000
Scene start Y: 6000
Scene end X: 8000
Scene end Y: 10000

In the **Band Subset** tab, choose only the bands that we will need: B2, B3, B4, B5, B8 and click OK:



Right-click on the subset product that will appear at the Product Explorer and click **Open RGB image window** and from the dropdown menu select **Profile: Sentinel 2 MSI Natural Colors** (B4, B3, B2) and click **OK**. Now we can see it contains only the area we selected to create subset.



2.6 Sun Glint Correction

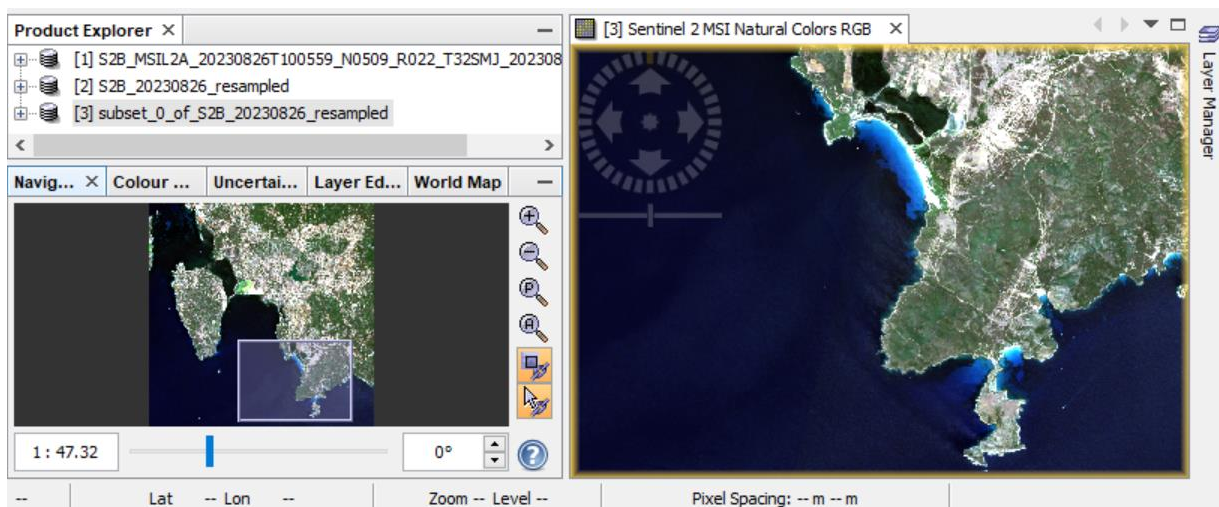
Sun glint is a common phenomenon in satellite images and it essentially refers to the specular reflection of the sun on water surfaces. The water-leaving reflectance can be difficult to observe due to the reflection of direct sunlight on the air-water interface (sunglint) in the direction of the satellite. The viewing geometry of Sentinel-2 satellite makes it vulnerable to sunglint contamination. Sun glint removal is a pre-processing step of multispectral images which is necessary when the amount of sun glint prevents the visibility of the sea bottom, usually in cases of marine habitat mapping.

There are several available sun glint removal methods for high resolution images and coastal applications. In this exercise we will apply the deglint methodology using SNAP plugin Sen2Coral.

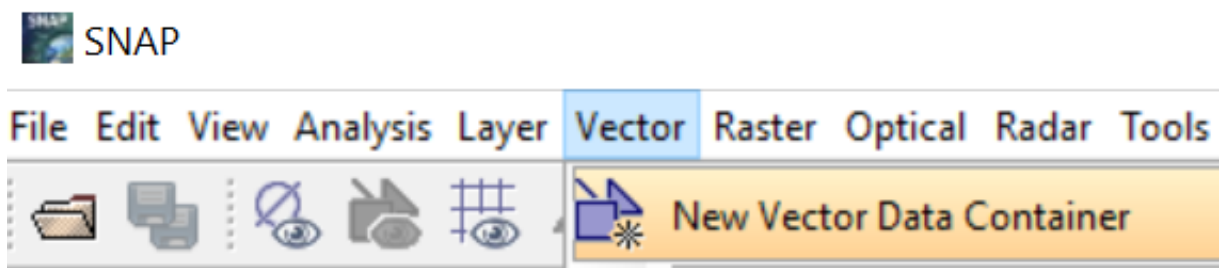
To apply the correction we have to use one or more image samples of sun glinted regions to scale the relationship between the NIR signal and sun glint.

Right-click on the last subset product and click Open RGB image window and from the dropdown menu select Profile: Sentinel 2 MSI Natural Colors (B4, B3, B2) and click OK.

As you can see in the image, there are bright areas on the deep water – sunglint



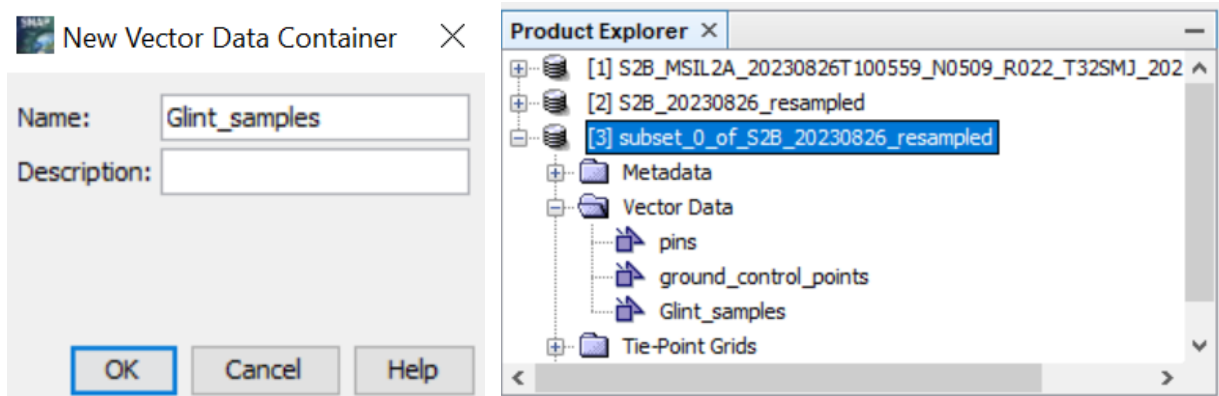
Now, we will create samples from those pixels as well as glint-free pixels. Go to Vector – New Vector Data Container



Set the parameters for new vector layer:

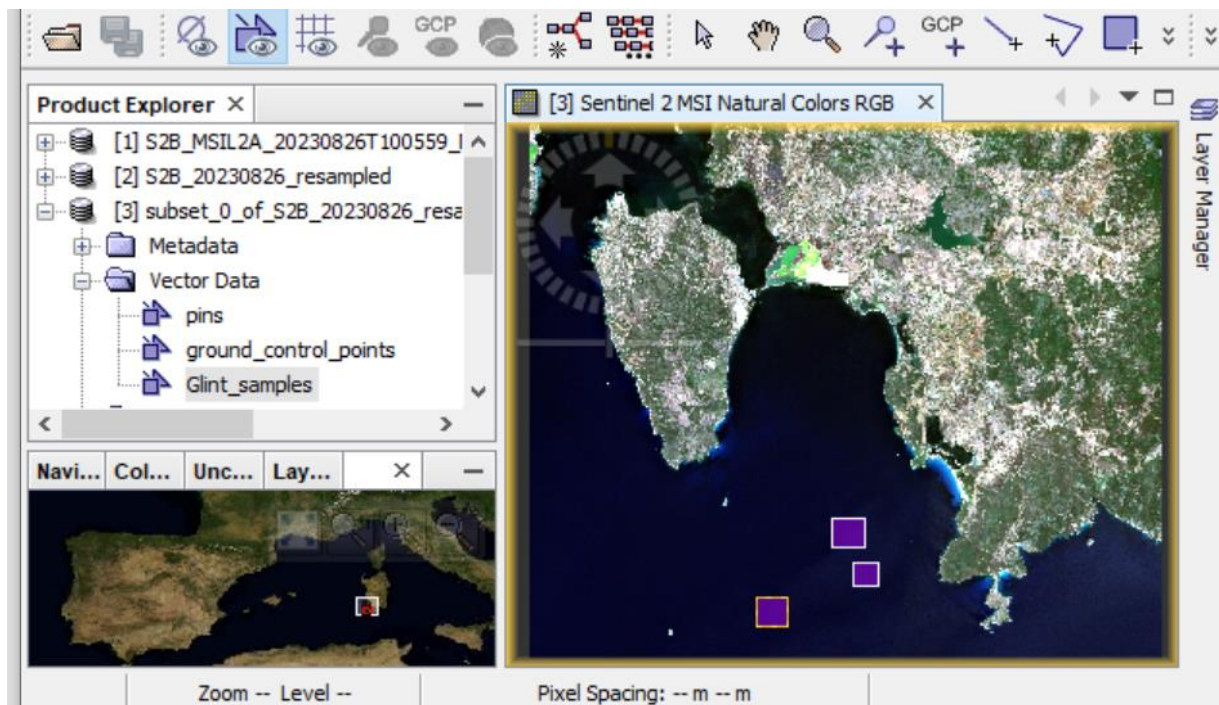
Name: Glint samples

And click OK.



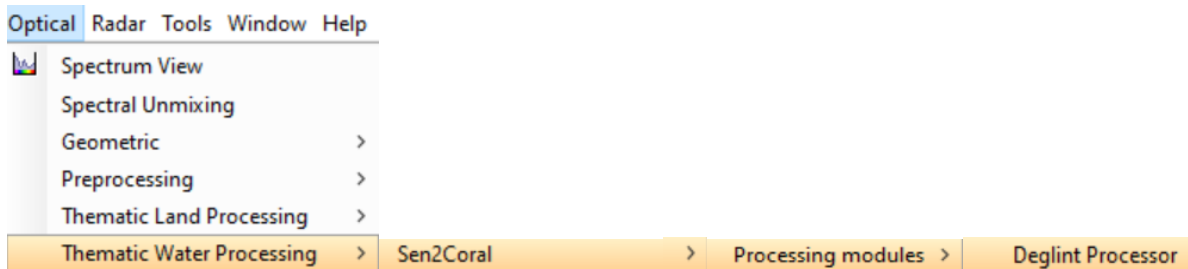
The new vector data container layer „Glint_samples“ has been added in the Vectors folder of our subset product in the Product Explorer Window.

Let's create some glint samples. For that, you can use RGB composition as well as one of the bands, e.g. band 8 (try to play with histogram to better see the sunglint areas) Click on the Rectangle drawing tool icon in the Menu bar and draw the samples (at least 4) that includes sunglint and also glint-free pixels.



After that, we will use Deglint processor tool. (Note: if the product involves Tie-pont grids folder with some data, delete it first)

Navigate to Optical – Thematic Water Processing – Sen2Coral – Processing modules – Deglint processor



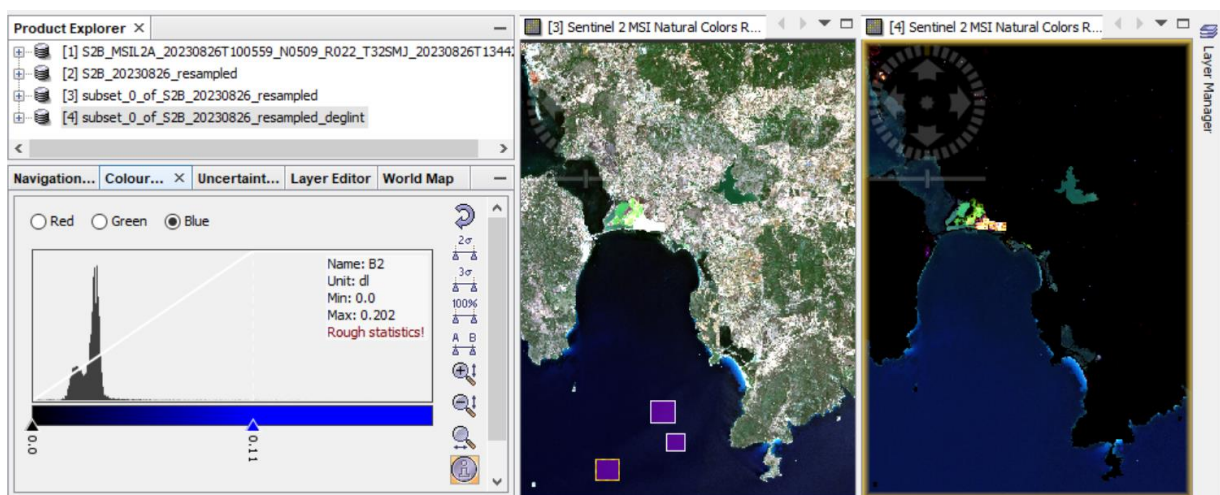
In the I/O Parameters tab, select the last subset product. In the Processing Parameters set the following parameters:

Sun Glint Areas: Glint_samples

Source Bands: select B2, B3, B4, B5

Reference Bands: select B8

After that, new product with „deglint“ at the end is created in which land areas are also masked automatically. You can open an RGB image if you want before and after applying the sunglint correction and compare them.

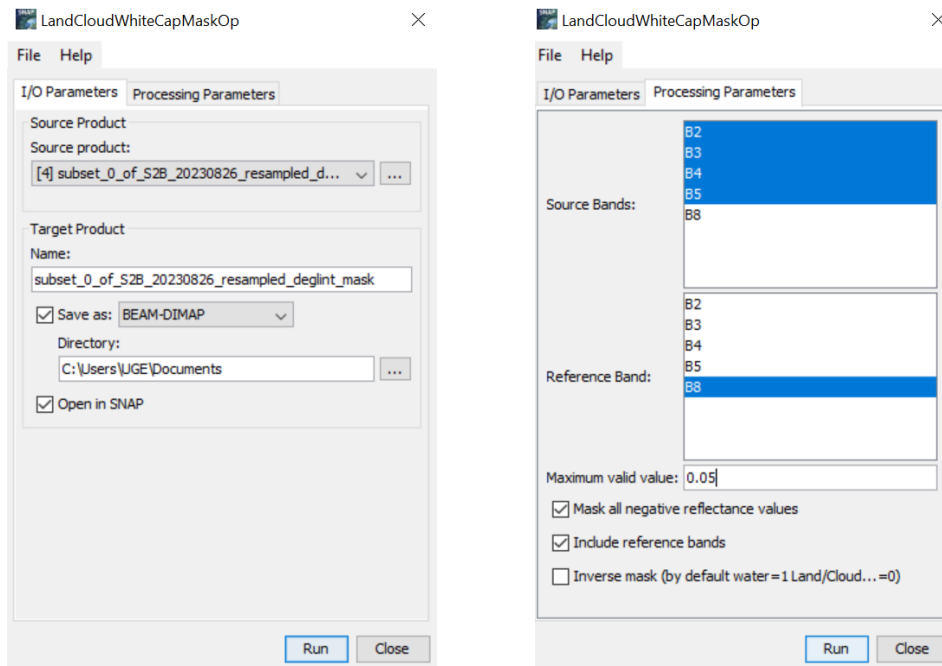


2.7 Dark-Object Atmospheric Correction

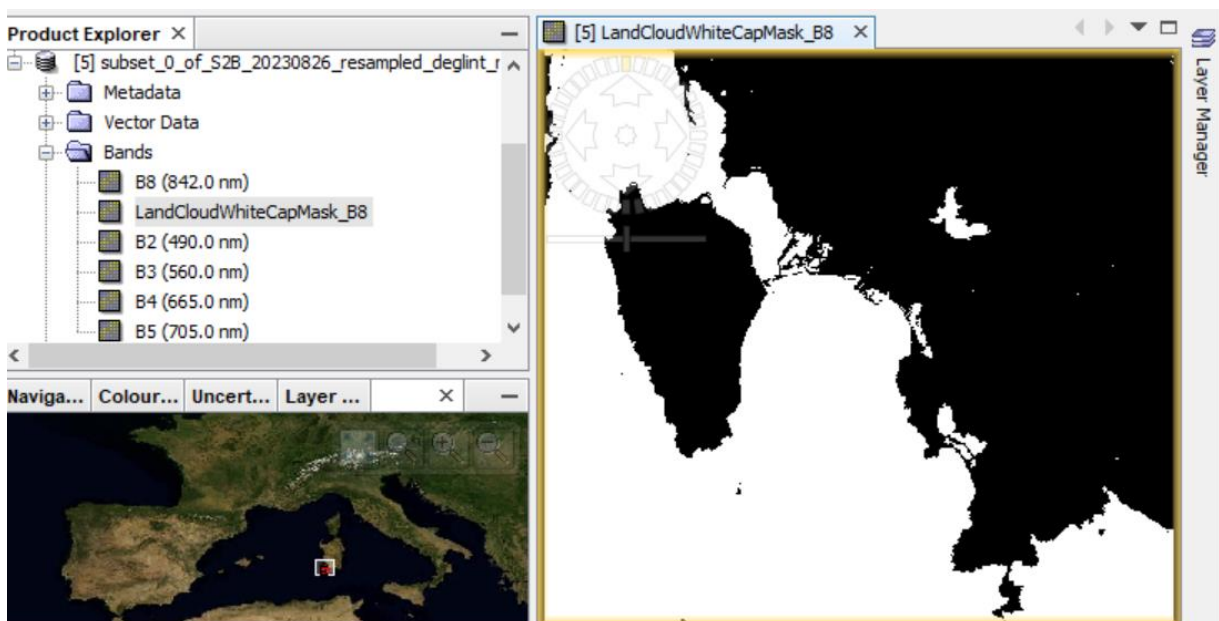
Dark Object Subtraction (DOS) is a practical method for atmospheric correction, assuming that dark objects reflect atmospheric scattering. By subtracting the atmospheric offset, calculated as the histogram's cut-off point at the lower end, from each pixel in a band, this method effectively corrects for atmospheric interference. Optically-deep water, with an anticipated zero reflectance, is considered the most suitable dark target for this purpose (Chavez, 1998).

Now, let's mask the clouds.

Navigate to Optical – Thematic Water Processing – Sen2Coral – Processing modules – LandCloudWhiteCapMaskOpt

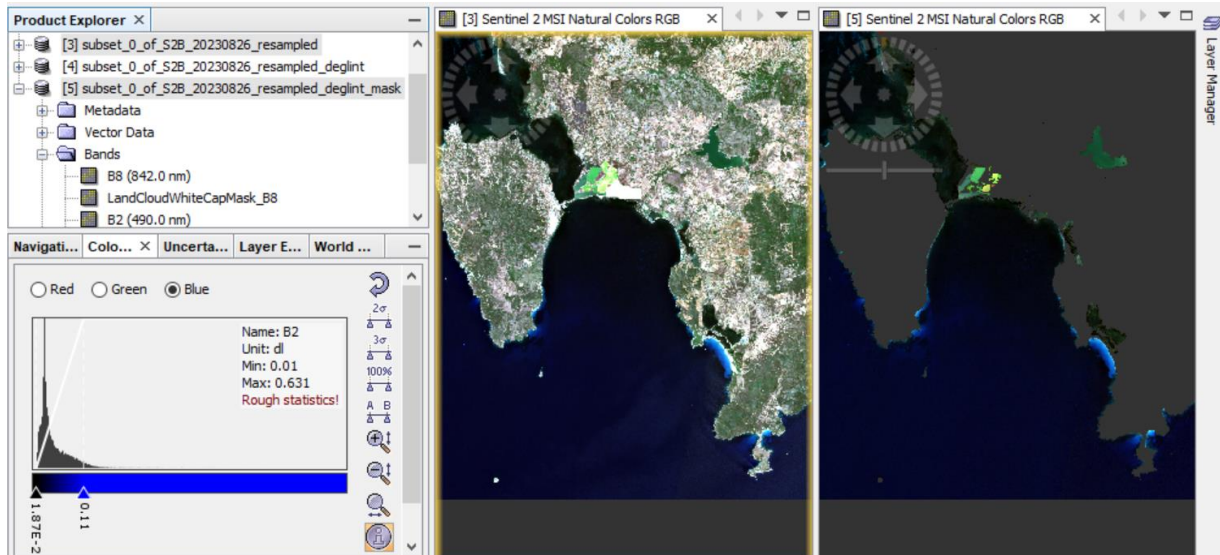


Now, we have create the new product. If we open the folder Bands for this new product in the Product Explorer, we will see that new layer was created. Double click to see it.



Now, open the RGB composition for the last product and RGB composition of the original resampled product without any correction. Tile Windows Horizontally and set the histogram for RGB of the last product similar to the histogram of the original resampled product without any correction.

We can see that residuals (clouds, sunglint) have been corrected correctly.

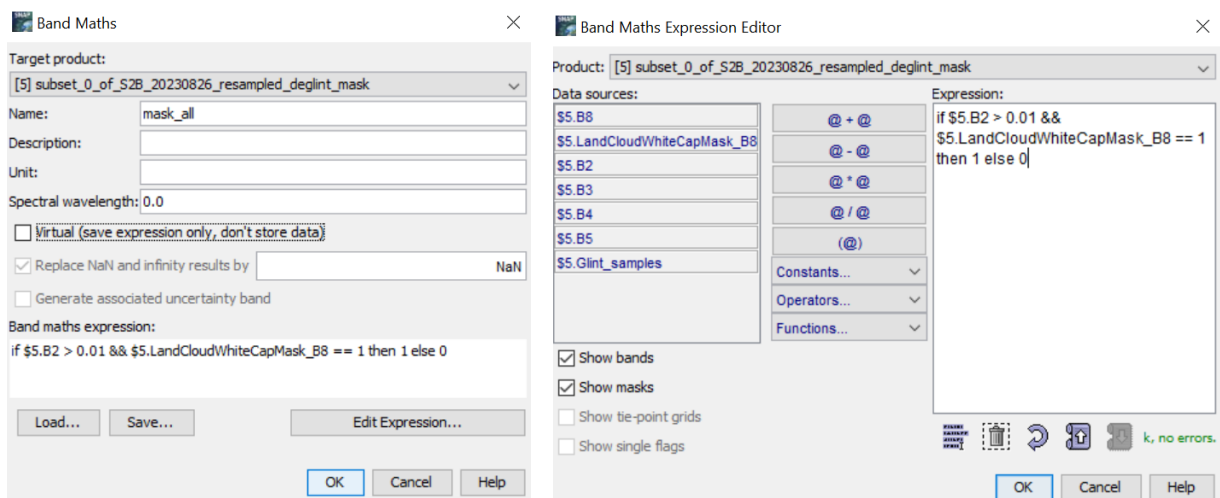


However, if we visualise e.g. B2, we can see that there are still some clouds that need to be removed. We will create the final mask which will contain all the invalid features.

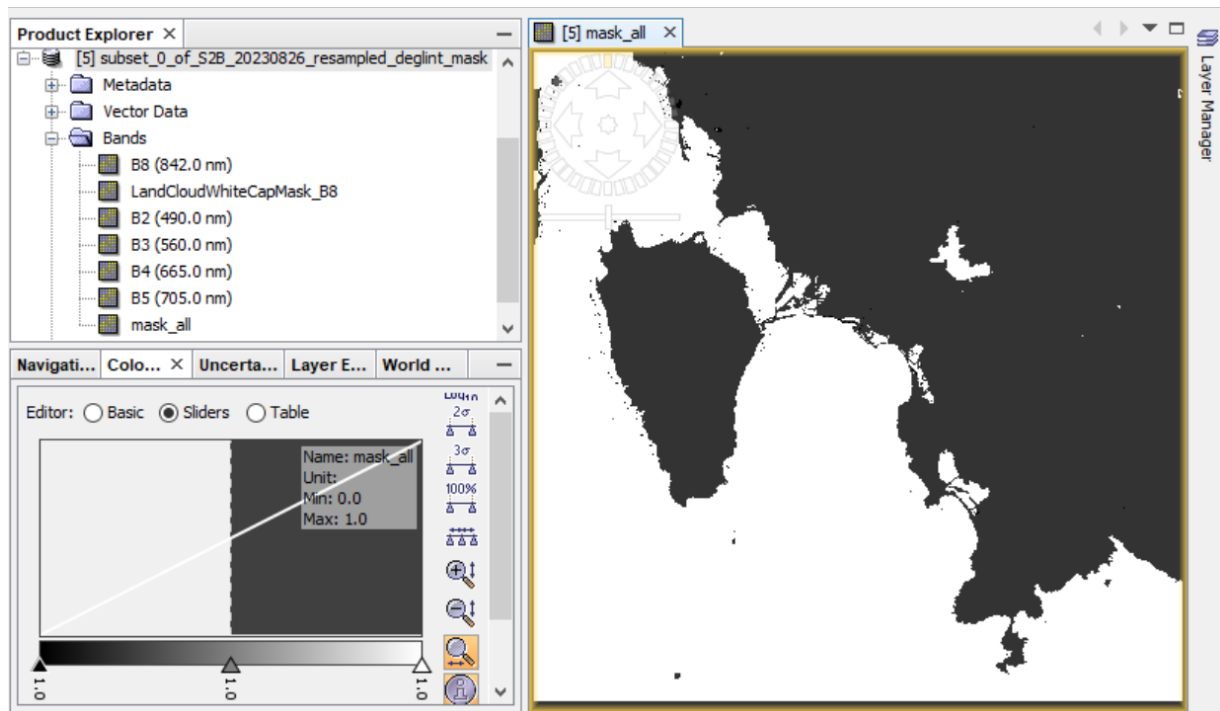
Right click on the product – Band Maths:

Name: mask_all

Deselect Virtual and click on Edit Expression



The final mask will appear in the new Window.



2.8 Empirical Bathymetry

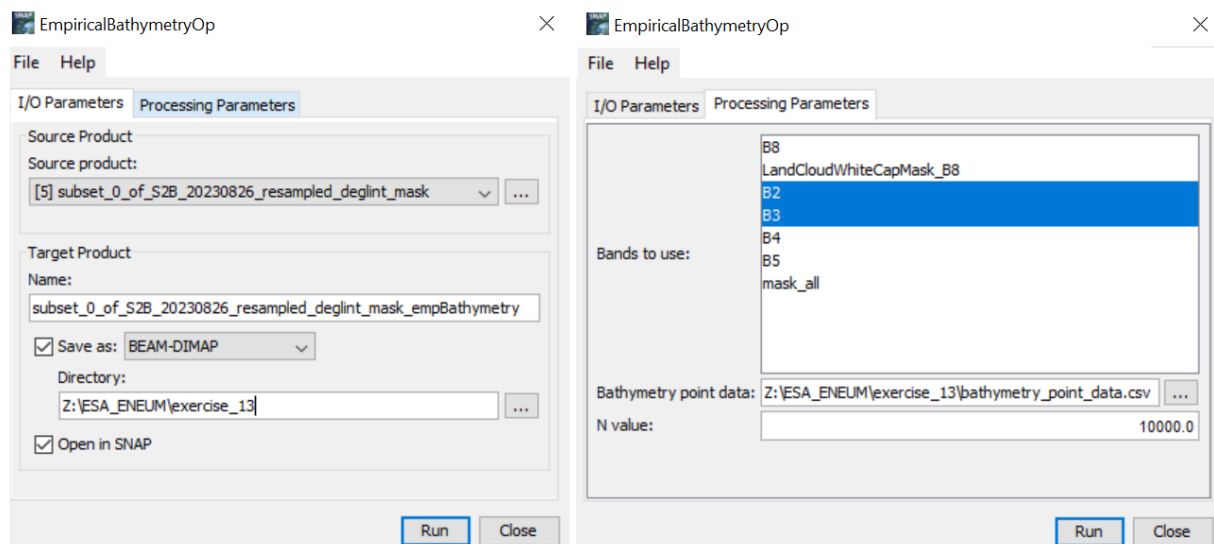
Navigate to Optical – Thematic Water Processing – Sen2Coral – Processing modules – EmpiricalBathymetry processor

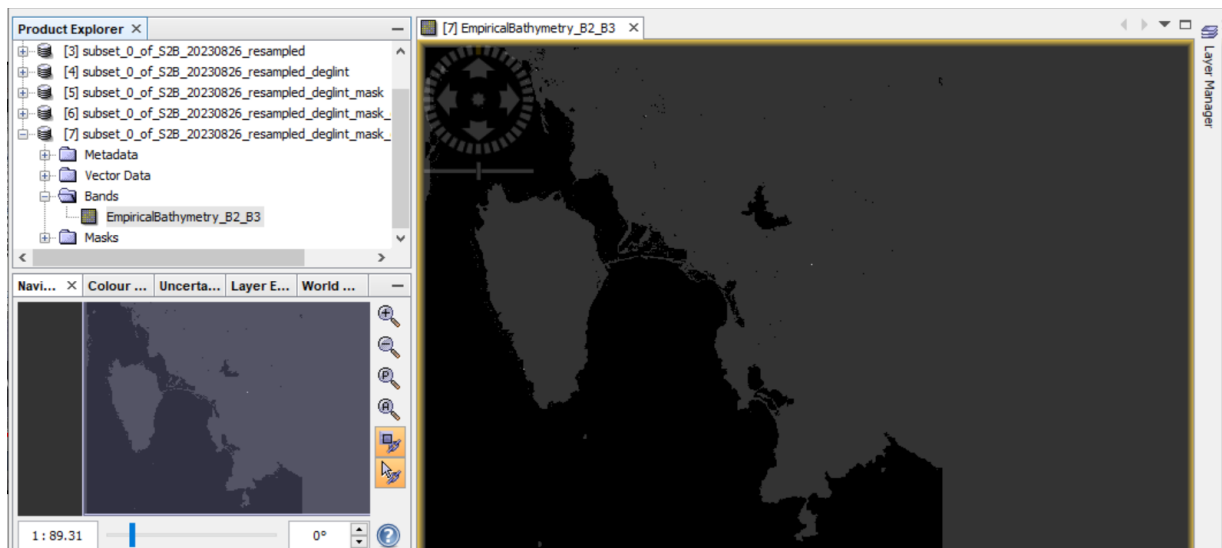
In the I/O Parameters tab select the resampled and sun-glinted mask

In the Processing Parameters choose bands B2 and B3 to estimate the bathymetry that give us the best trade-off between the water penetration depth and the spatial resolution

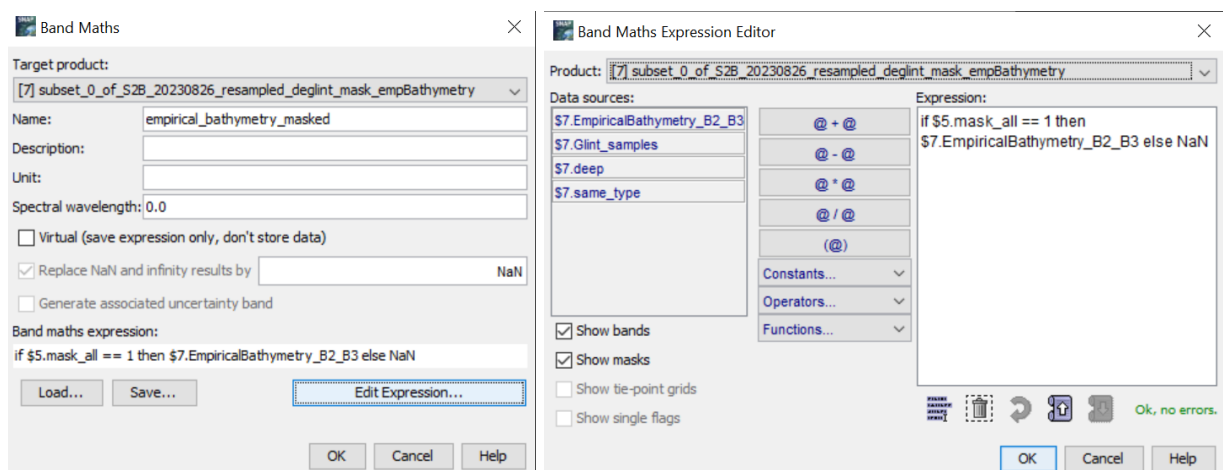
Then, choose the .csv file containing the set of bathymetry point data (latitude, longitude, depth) – these data have been derived using Coastal Relief Model Mosaic from <https://www.ncei.noaa.gov/maps/grid-extract/>

N value: 10000.0 (default)



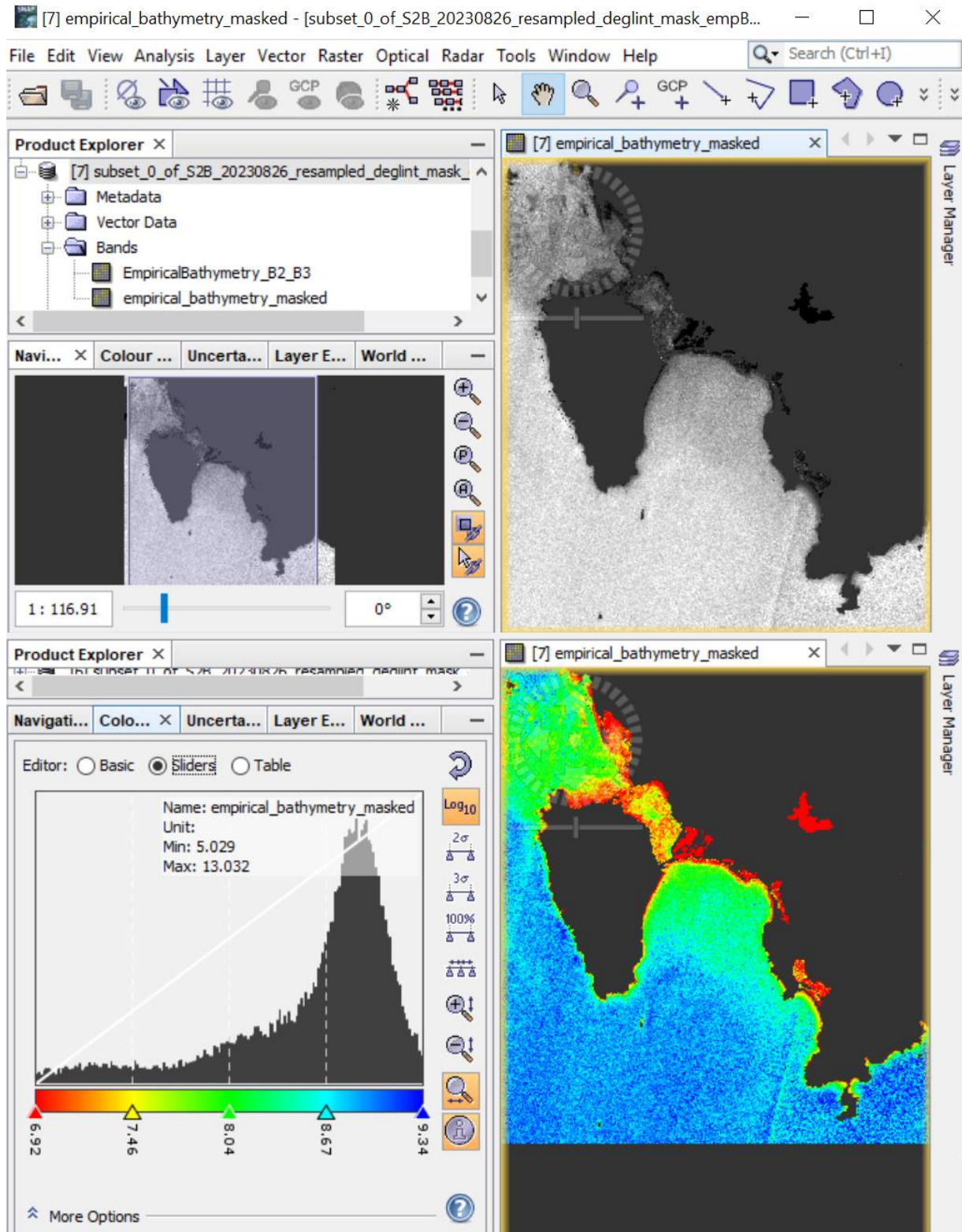


Now, we will mask the bathymetric product with the final mask
 Right click on the bathymetric product – go to Band Math
 Unselect virtual raster
 Go to Edit Expression and type in the following expression like in the image



In the Product Explorer Window, the new product is created. Double click on its band to visualize it.

Go to the Colour Manipulation tab and select the colour palette. Set the range according the data. Explore the values of the final output on bathymetry in this area



THANK YOU FOR FOLLOWING THE EXERCISE!