EXERCISE 9 – TUTORIAL

Sentinel-1, Sentinel-2 for Snow and Ice using the SNAP software

1 | Exercise outline

In this exercise, we will:

- Perform our own sea ice classification using created training data and Random forest classificator

- Understand the capabilities and limitations of Synthetic Aperture Radar (SAR) in detecting and monitoring sea ice.

- Discriminate between open water and different types of the sea ice

- Identify areas with varying degrees of ice deformation

- Perform classification using Sentinel-2 data NDSI

2 | Background

Mapping snow and ice using Sentinel-1 and Sentinel-2 data

Sea ice refers to frozen seawater that forms when ocean water freezes due to low temperatures. It typically occurs in polar regions, such as the Arctic and Antarctic, where temperatures drop low enough for the surface of the ocean to freeze. Sea ice can vary in thickness and extent, ranging from thin, seasonal ice that forms and melts each year to thicker, multi-year ice that persists through multiple seasons.
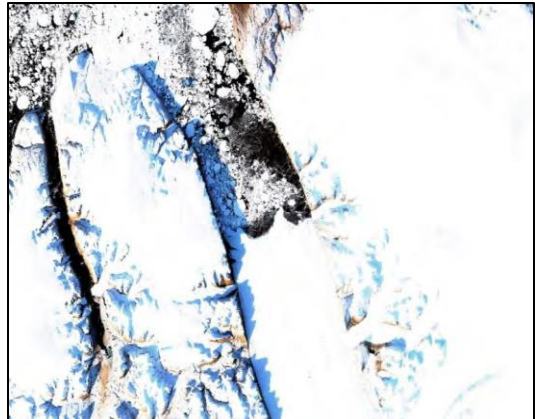
Sea ice plays a crucial role in regulating the Earth's climate, reflecting sunlight back into space and influencing ocean circulation patterns. Additionally, sea ice provides habitat for various species of marine life and serves as a platform for indigenous communities and scientific research.

Sea ice encompasses various types, including first-year ice formed during a single winter season, and multi-year ice, which survives multiple melt seasons and is thicker and more consolidated. Sea ice can also be categorized into additional types such as deformed ice, level ice, young ice, and open water ice:

Deformed Ice: results from the compression and ridging of sea ice due to the movement and collision of ice floes

Level Ice: refers to relatively flat and uniform sea ice surfaces that have not undergone significant deformation or ridging

Young Ice: Young ice is newly formed sea ice that has not yet reached its maximum thickness or strength.

Open Water Ice: describes areas of sea ice where the ice cover has become fragmented or broken, leaving patches of open water exposed.

Sentinel-1 SAR imagery provides all-weather, day-and-night capability, allowing for continuous monitoring of sea ice regardless of atmospheric conditions or sunlight. By analyzing Sentinel-1 SAR images, researchers can monitor changes in sea ice extent, thickness, and movement over time, providing valuable information for climate studies, navigation, and environmental management. Additionally, these data can be used to detect and monitor other features, such as icebergs, ice floes, enhancing our understanding of polar environments and their role in the Earth's climate system.

Sentinel-2 satellite imagery is also valuable for mapping ice due to its high spatial resolution and multispectral capabilities. By capturing detailed images of ice-covered regions, Sentinel-2 facilitates the monitoring of ice extent, ice type classification, glacier movement, and changes in ice dynamics over time.

2.1 Study area and data used

For this exercise, we will use Sentinel-1 GRDH image and Sentinel-2 L2A image over the Straight of Denmark between Greenland and Iceland, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].
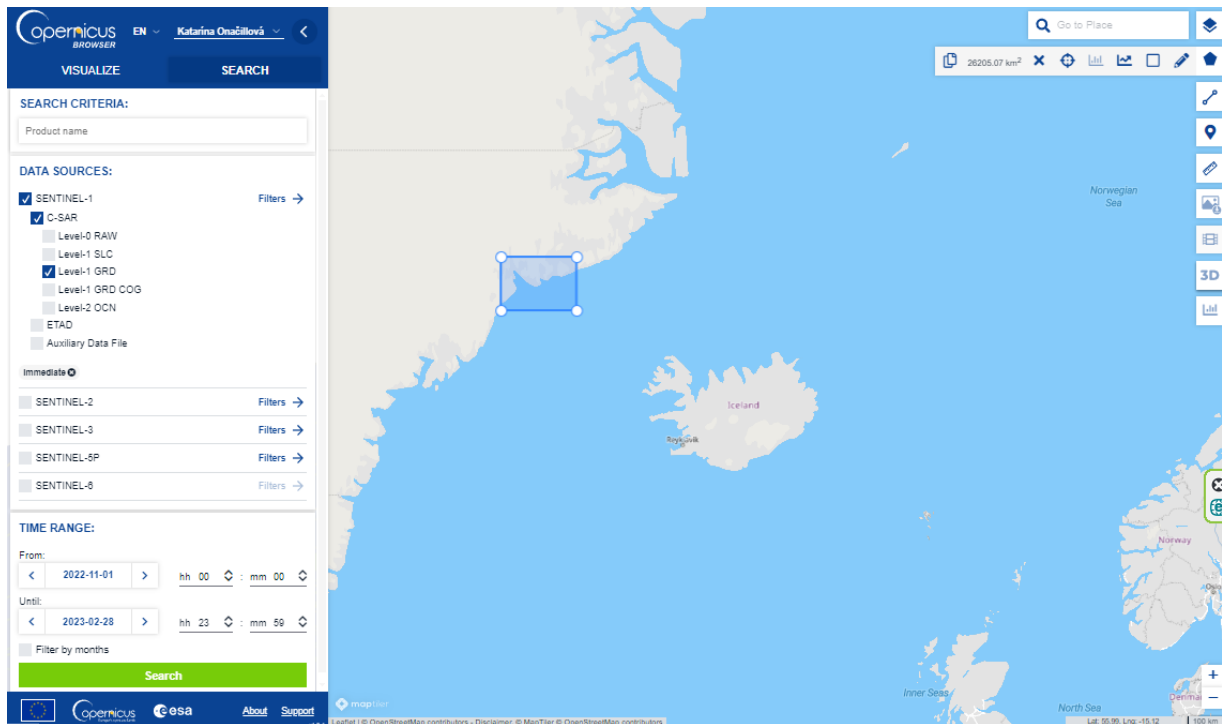

Part A: Sea ice mapping with Sentinel-1

2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open downloaded Sentinel-1 GRDH product by double click on it. The opened product will appear in Product Explorer window. The Worldview window (at the bottom-left corner) shows the coverage of the image opened. Double click on e.g. „Intensity_HH" band within Bands folder to visualize it.

S1A_IW_GRDH_1SDH_20230217T193310_20230217T193335_047280_05AC96_9AFD.SAFE.zip
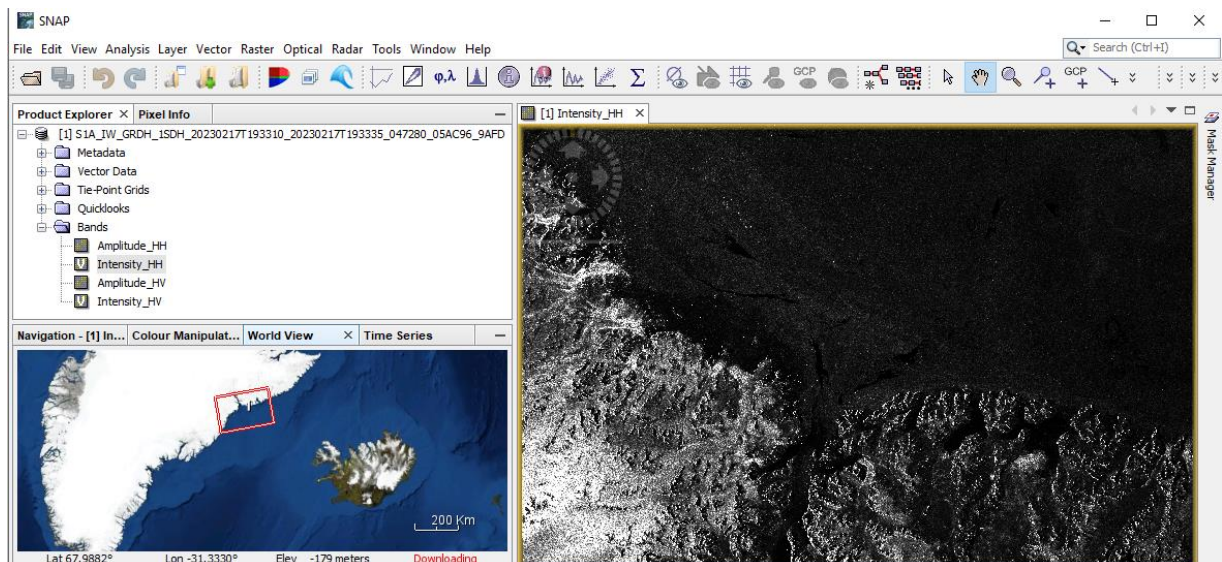
2.3 Pre-processing

We need to apply identical pre-processing steps to our scene:

Apply orbit file

Navigate to Main Menu > Radar > Apply orbit file

In the I/O Parameters tab, select the opened product. By default, the output target is set to the same directory and appends „Orb" to the filename. There is no need to save the output as BEAM-DIMAP (we will save the time this way).

In the Processing Parameters accept the default settings and select the option „Do not fail if new orbit file not found"
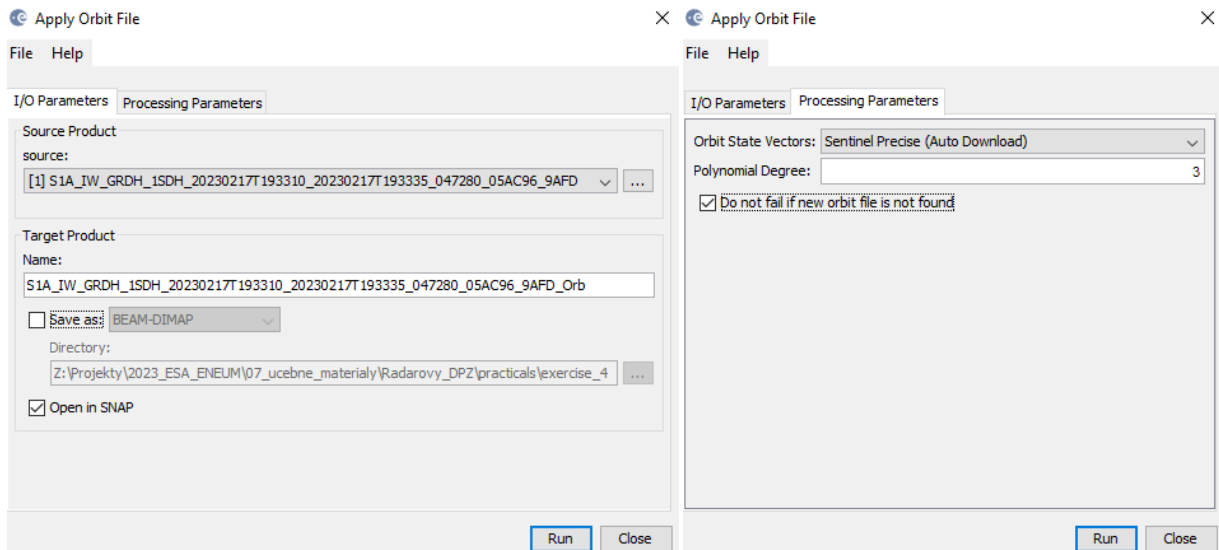

Thermal noise removal

Navigate to Main Menu – Radar > Radiometric > S-1 Thermal Noise Removal

In the I/O Parameters tab, select the product with applied orbit file. By default, the output target is set to the same directory and appends „tnr" to the filename. There is no need to save the output as BEAM-DIMAP.

In the Processing Parameters keep both HH and HV polarisations and make sure that the "Remove Thermal Noise" option is selected.
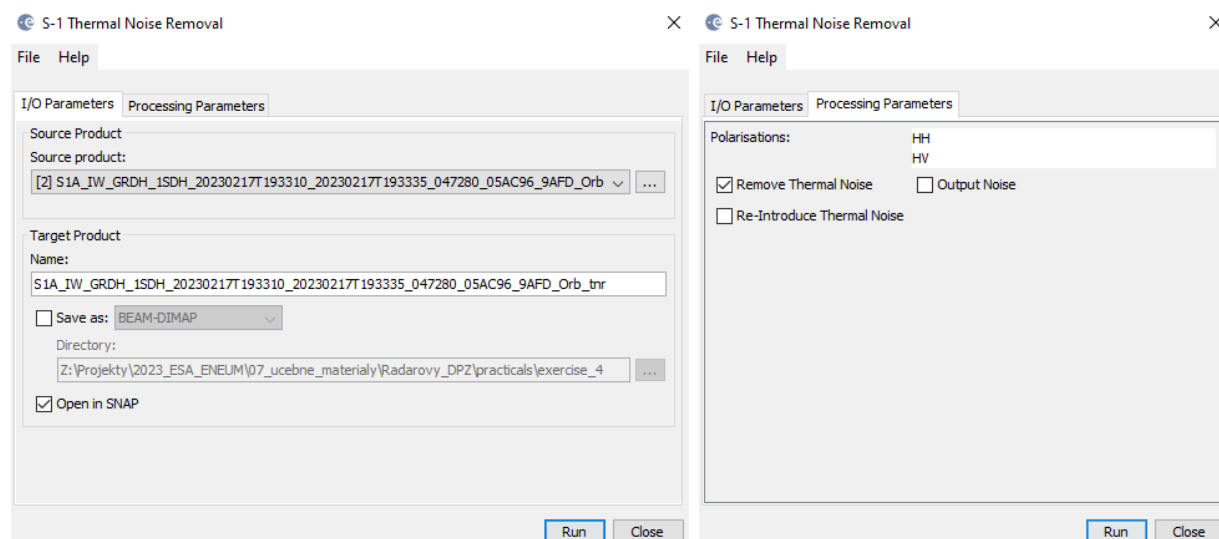
The image should then look something like this (view e.g. Intensity_HH):
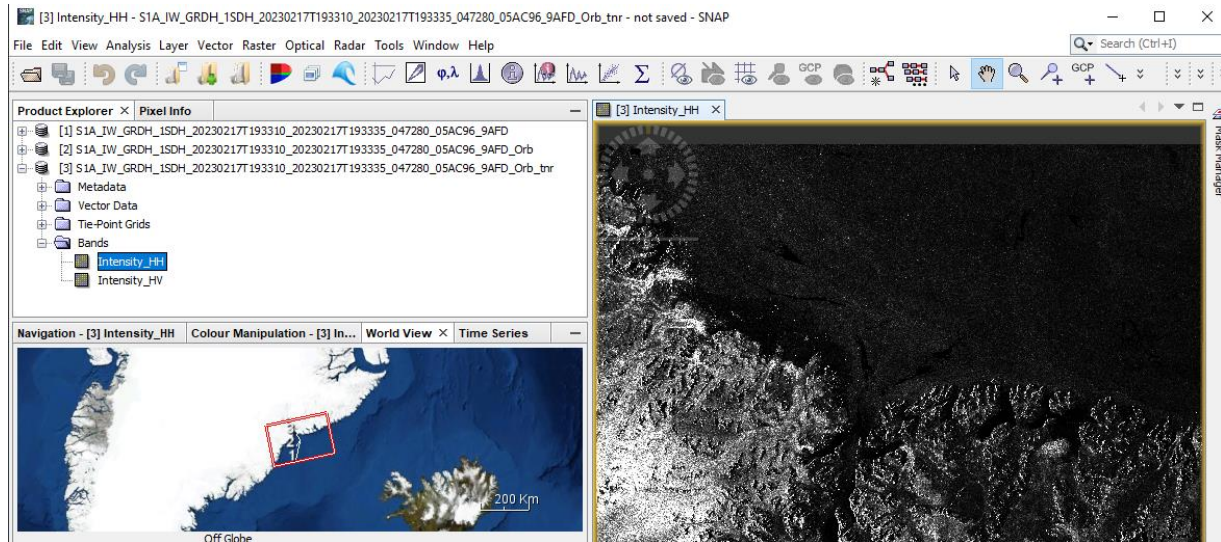

Create subset

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size – creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

Select the last product with applied Thermal noise removal.
Go to the Subset tab and at "Pixel Coordinates" set:

Scene start X: 5500
Scene start Y: 3000
Scene end X: 17300
Scene end Y: 15100

Now, the image is prepared for classification. Open the final product, e.g. Intensity_HH to see the output image.
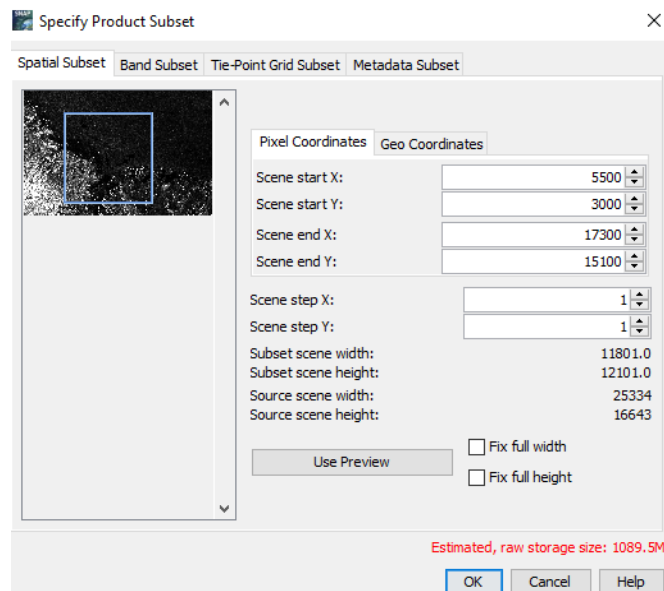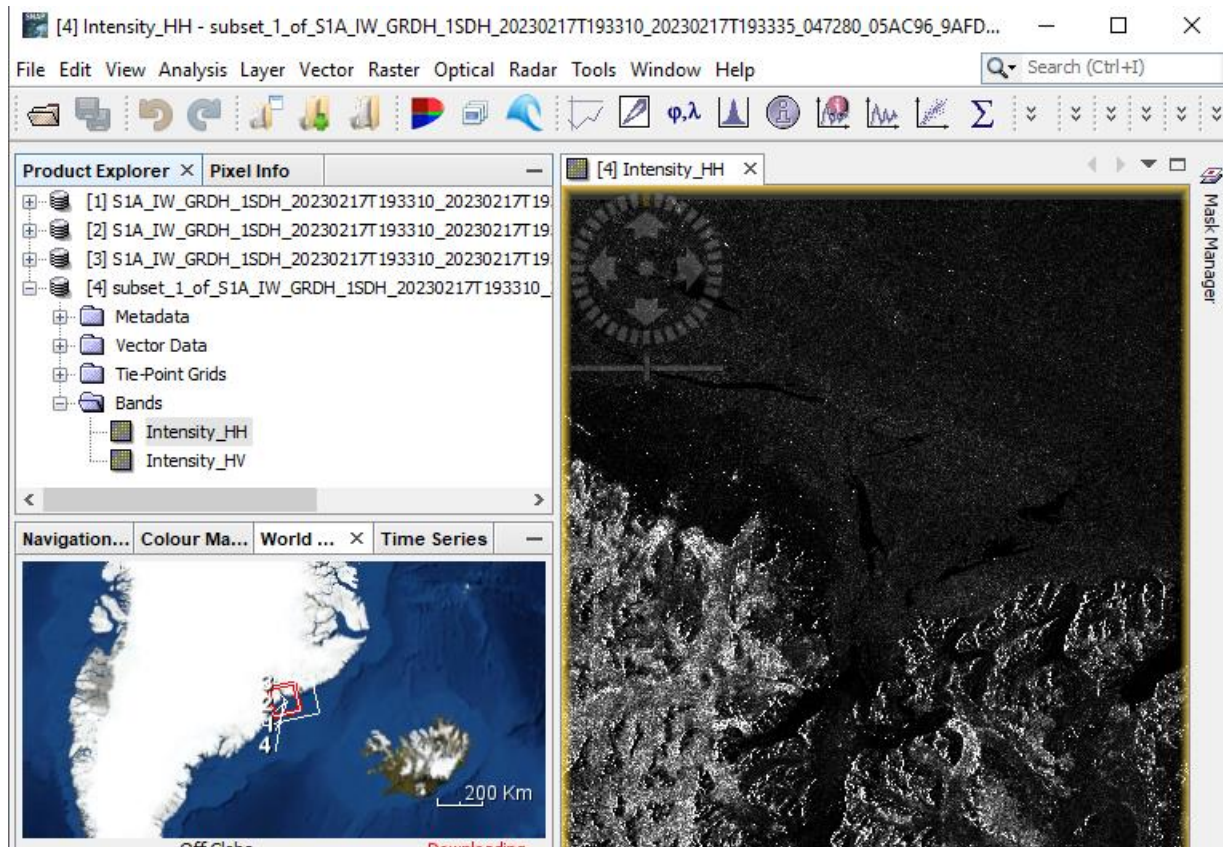
2.4 Image classification

Today we will perform a random forest classification. For this we will create some training data by identifying polygons containing the different ice types:
– Deformed Ice
– Level Ice
– Young Ice
– Open Water

Select the last subset product by clicking on it. Navigate to Vector > New Vector Data Container.
Create four new data containers – separate for each type of ice mentioned above.
Start with creating the data container for, e.g. deformed_ice" and repeat this step for other three types.
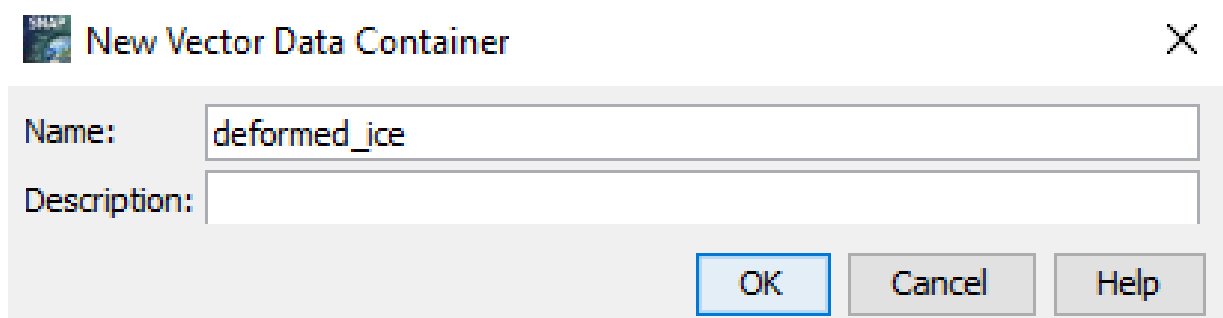
The newly created four vector data containers for each ice type should appear under "Vector Data" in the Product Explorer.
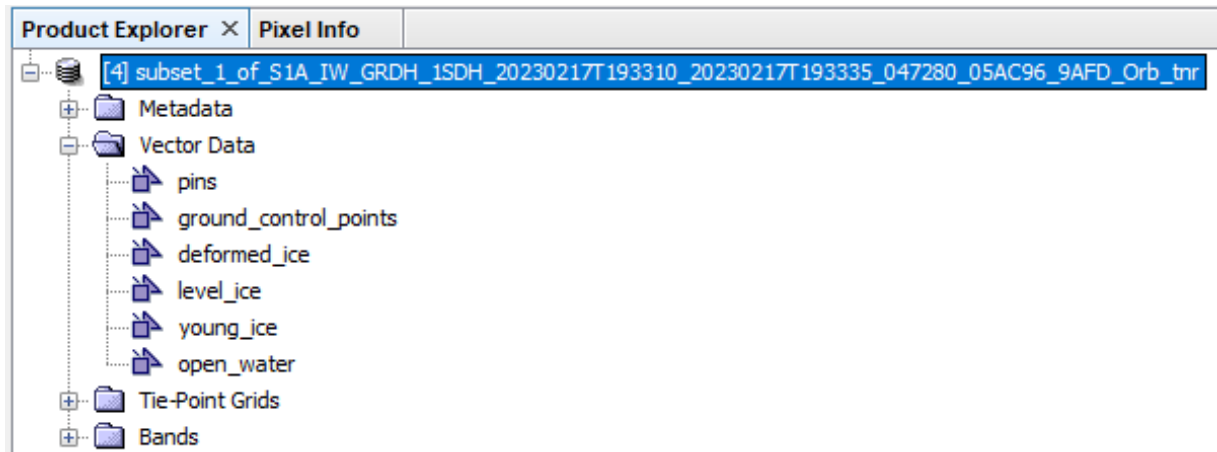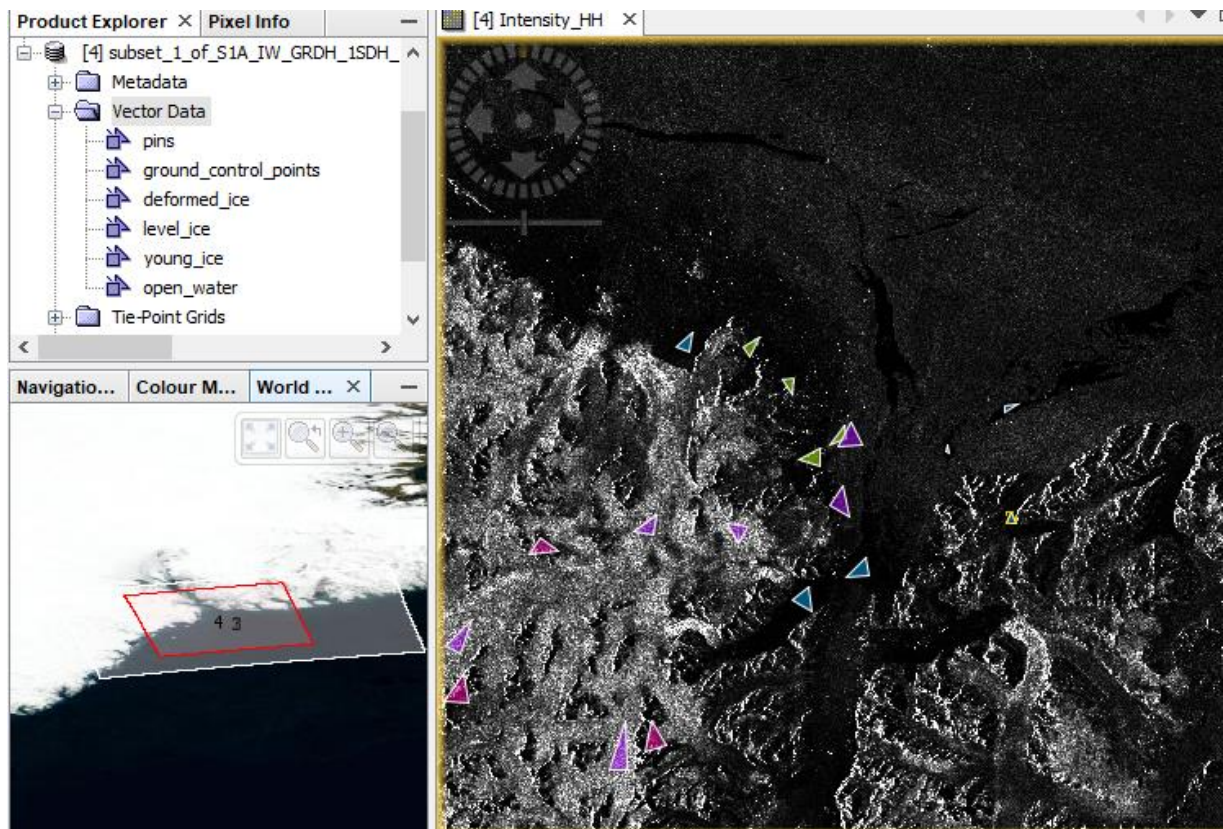

Now let´s start creating training polygons for these different containers on ice type using the Polygon drawing tool:

Open both HH and HV polarisations to better identify different types of ice.by double clicking on them.

Then, click on the icon Tile Horizontally (or navigate to the main menu - Window and select this option).
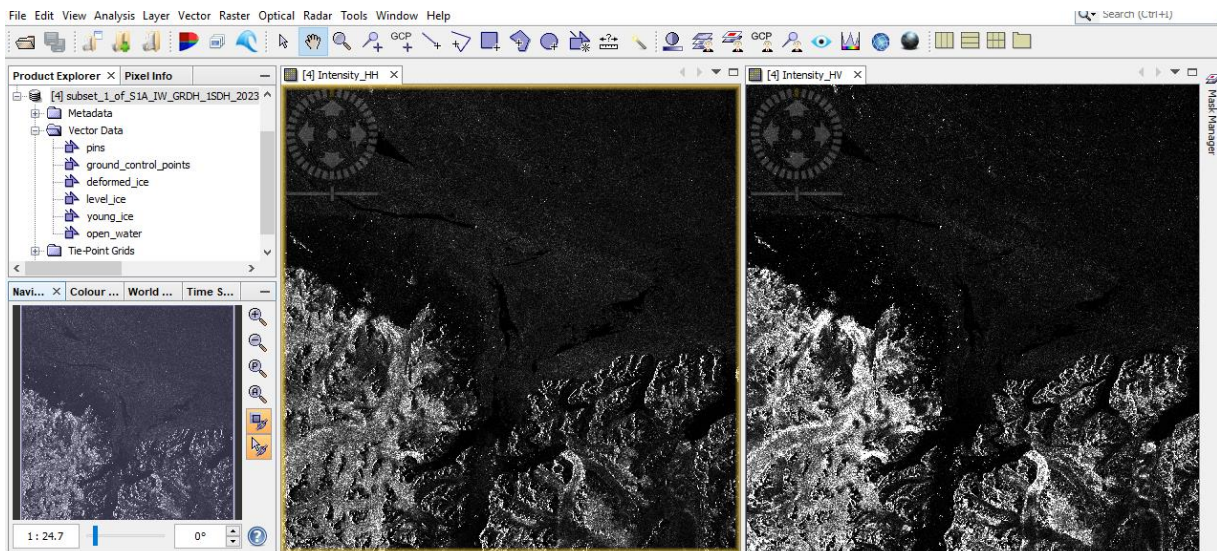
Deformed (Pink), Level (Violet), Young ice (Green) and Open water (Blue) Sea Ice Polygons. Save the final product with your created vector data containers to your folder.

Random Forest image classification

Navigate to Raster > Classification > Supervised classification > Random Forest Classifier


- In the ProductSetReader tab select the saved product with your training data.

- In the Random-Forest-Clasiffier select the classes/training vectors (all our sea ice polygon vector containers) and feature bands (select both Intensity_HH and Intenisty_HV polaristaions) that you'd like to include into image classification.

- In the Write tab by default, the output target is set to the same directory and appends „RF" to the filename.

- Click RUN.
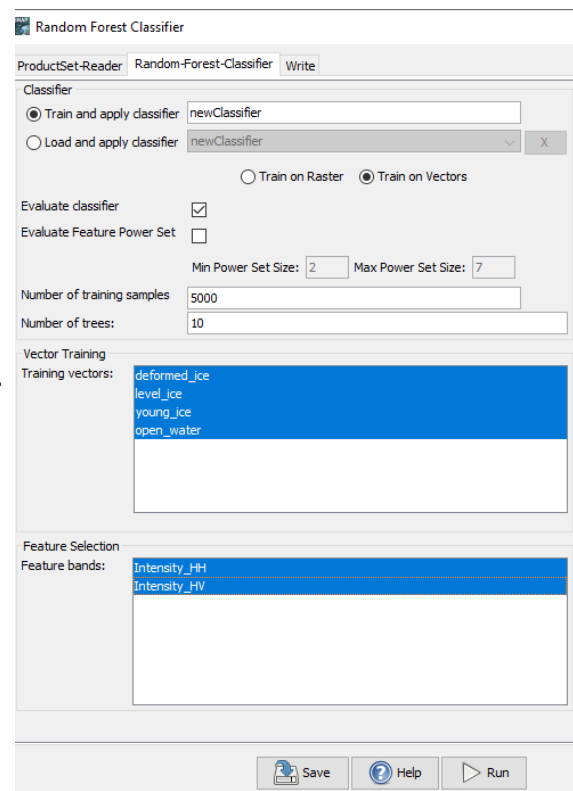
2.5 Post-processing

The final product should now appear in the ProductExplorer. Visualize this output classified image and classes by double-click on the layer „LabeledClasses" under Bands folder in the Product Explorer.

Navigate to Colour Maniulation tab to change the colours of individual sea ice classes and exlore the frequency of these classes through the classified image and table.
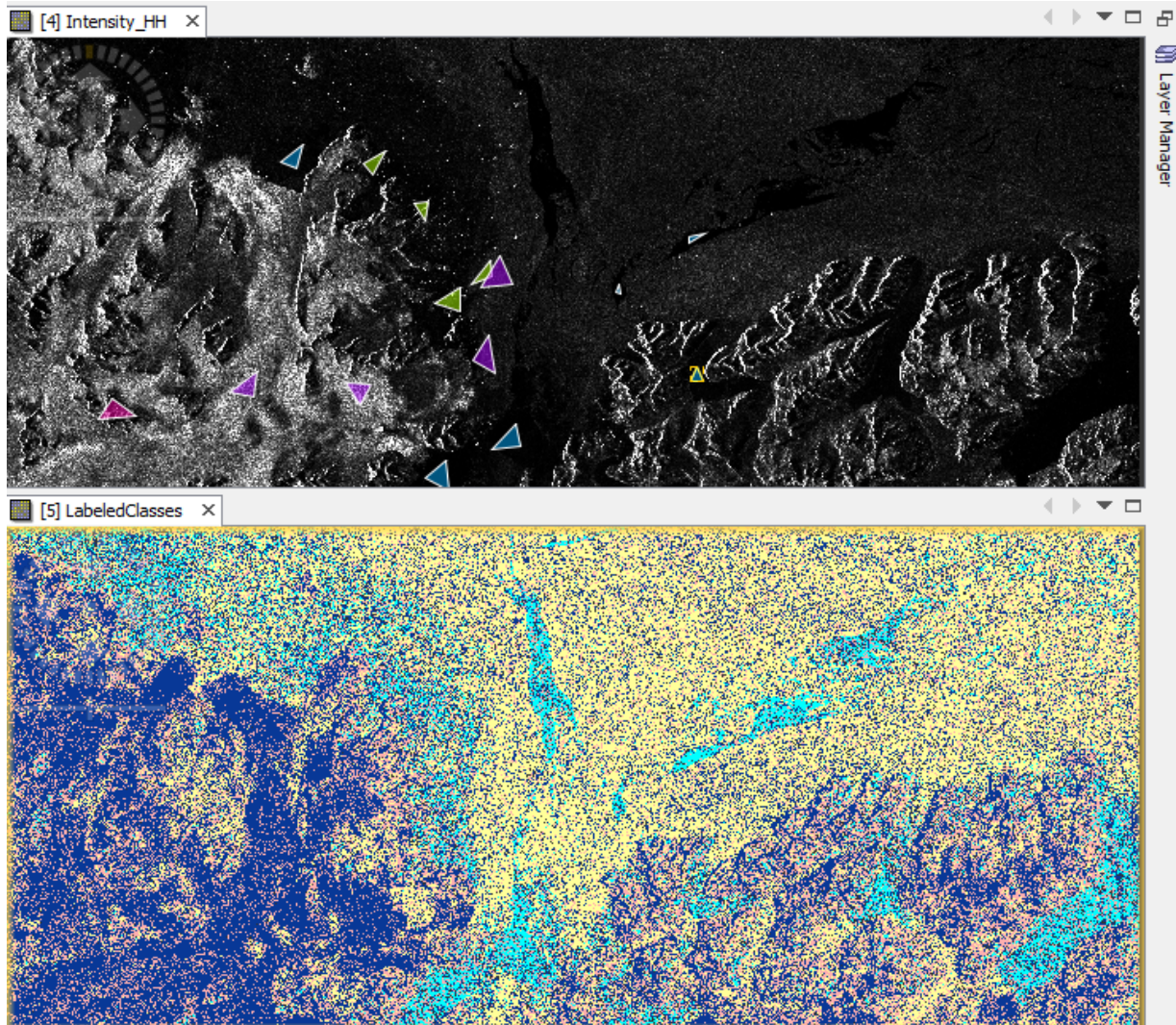
Label	Colour	Value	Frequency	Description
no data		-1	0.000%	no data
deformed_ice		0	19.440%	
level_ice		1	42.332%	
young_ice		2	33.787%	
open_water		3	4.442%	

Part B: Sea ice mapping with Sentinel-2
2.6 SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open downloaded Sentinel-2 by double-clik on the metadata „MTL.txt" inside the unzipped folder (or click on Import Product). The opened product will appear in Product Explorer window.

S2A_MSIL2A_20230221T140211_N0509_R010_T25WER_20230221T185001.SAFE.zip

Select (by clicking on it) the product in the Product Explorer window. The Worldview window (at the bottom-left corner) shows the coverage of the image opened.

Now, let´s visualize the image using True colour composition:

• Right click on the product.

• Open RGB Image Window.

• In the pop-up window select 'Sentinel 2 MSI Natural colors' (Red: B4; Green: B3; Blue: B2)

Now, let´s visualize the image using False colour composition:
• Right click on the product.
• Open RGB Image Window.
• In the pop-up window select 'Sentinel 2 MSI False Colour-Infrared' (Red: B8; Green: B4; Blue: B3)

Now, let´s visualize the image using another False colour composition:
• Right click on the product.
• Open RGB Image Window.
• In the pop-up window select 'Sentinel 2 MSI Atmospheric-Penetration' (Red: B12; Green: B11; Blue: B8A)

Tile Windows, e.g. Horizontally, to explore the Sentinel-2 image features.
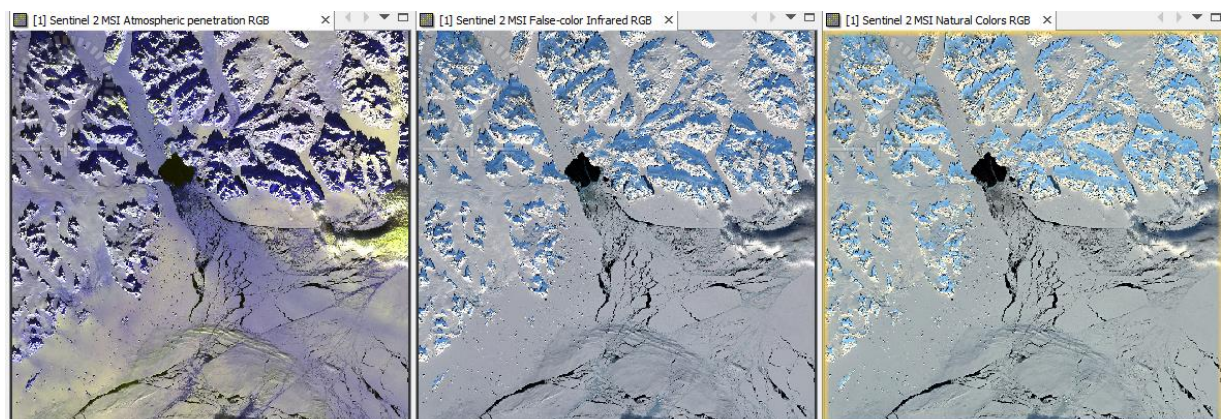
2.7 Resample

Resample the bands to the pixel size of the VIS bands:
In the main SNAP menu, select Raster > Geometric > Resampling
In the I/O Parameters tab, the source product is set to our only product in the SNAP, change the name of the target resampled product if needed
Do not save the output product - disable the box "Save as:" (if selected).
In the Processing Parameters tab, use e.g. B2 with 10 m resolution to resample all the bands to 10 m as output spatial resolution.
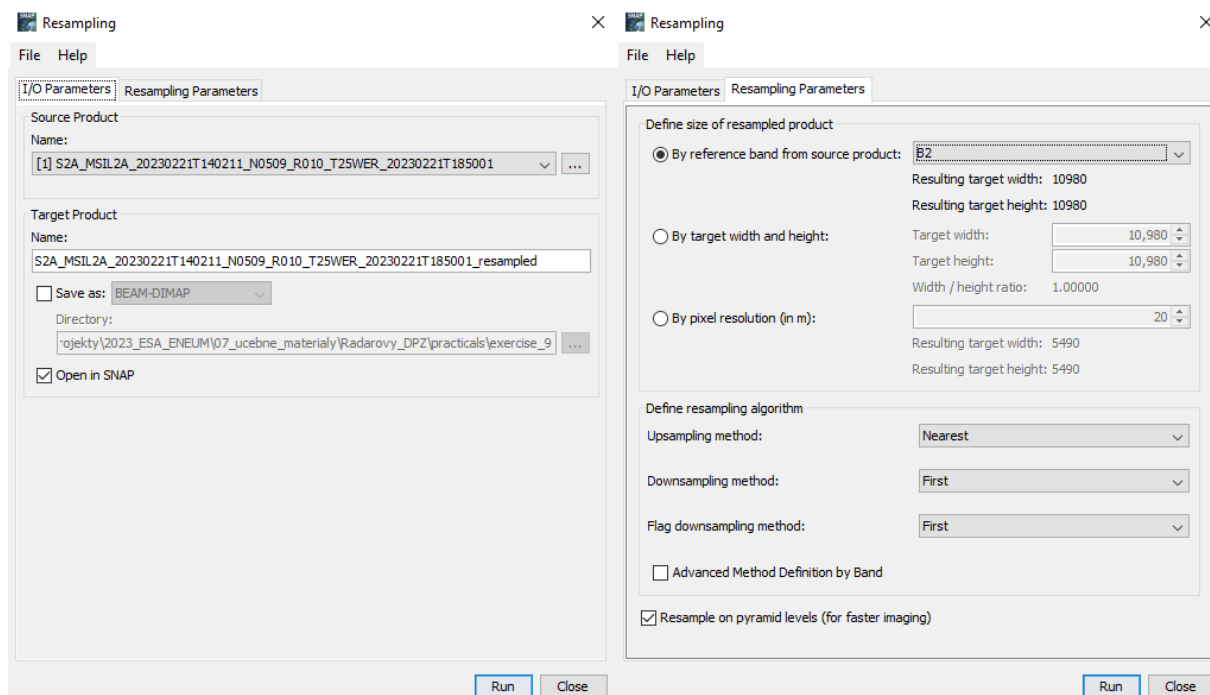
2.8 Normalized Difference Snow Index

Next, we will calculate Normalized Difference Snow Index (NDSI) in SNAP.

The Sentinel-2 NDSI is a ratio of two bands: one in the VIR (Band 3) and one in the SWIR (Band 11). Values above 0.4 are usually snow. The Sentinel-2 NSDI can be used to differentiate between cloud and snow cover as snow absorbs in the short-wave infrared light, but reflects the visible light, whereas cloud is generally reflective in both wavelengths. Most potential cloudy pixels have NDSI values in a range between -0.1 and +0.2.

To calculate NDSI, select the last subset product, navigate to the main SNAP menu and select Raster - Band Maths (deselect the box "Virtual").

SNAP menu and select Raster - Band Maths (deselect the box "Virtual").
Click on Edit Expression to calculate the NDSI using the equation below
and click OK:

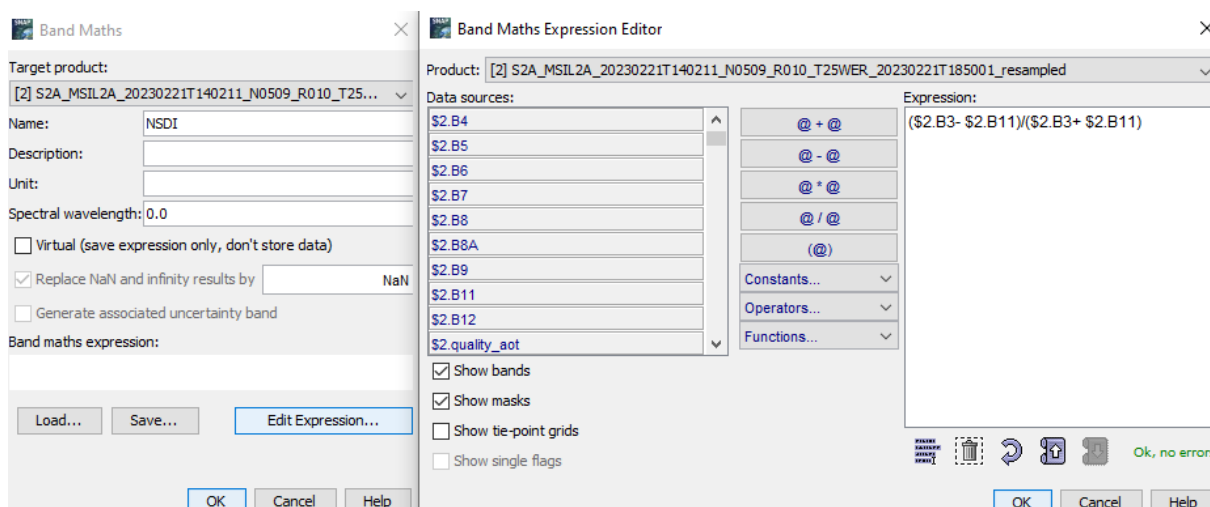$$\rho(VIS) - \rho(SWIR) / \rho(VIS) + \rho(SWIR)$$

ρ = Top of atmosphere reflectance
VIS = Visible band (0.56 µm)
SWIR = Short-Wave Infrared Band (1.6 µm)

Replace the bands in the equation with the corresponding bands for
Sentinel 2:

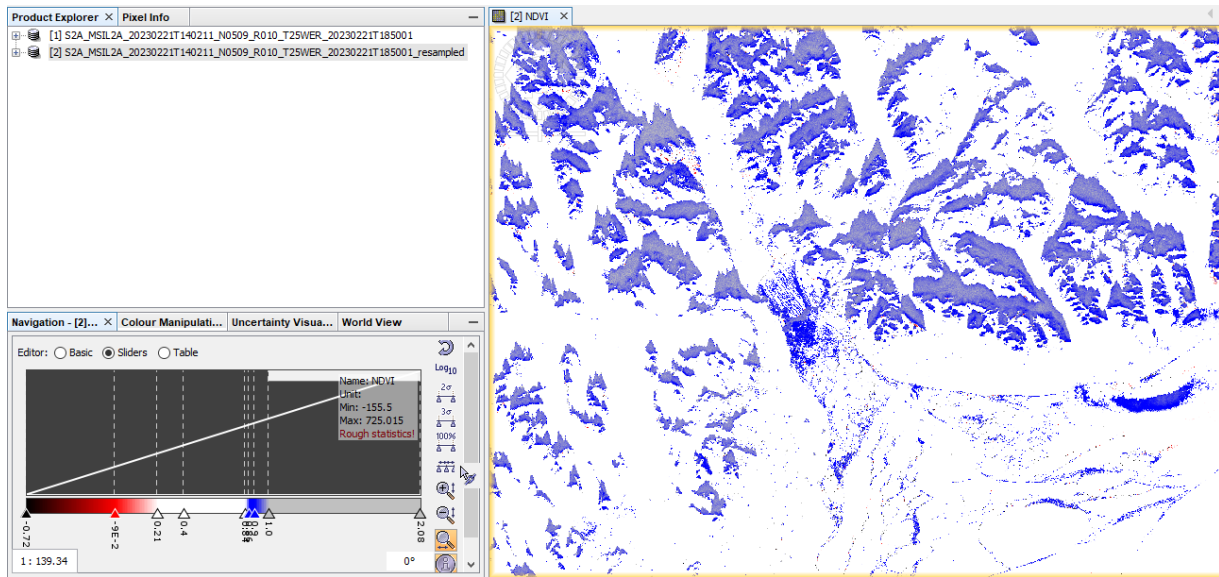$$\rho(B3) - \rho(B11) / \rho(B3) + \rho(B11)$$

Open the output product in the Product Explorer by double click on the
new raster NDSI within Bands folder.
Go to Color Manipulation tab and go to Table – set the thresholds of
slider to three values – minimum value, up to 0.4 (usually pixels with no
snow), higher than 0.4 (usually snow pixels) and maximum value.
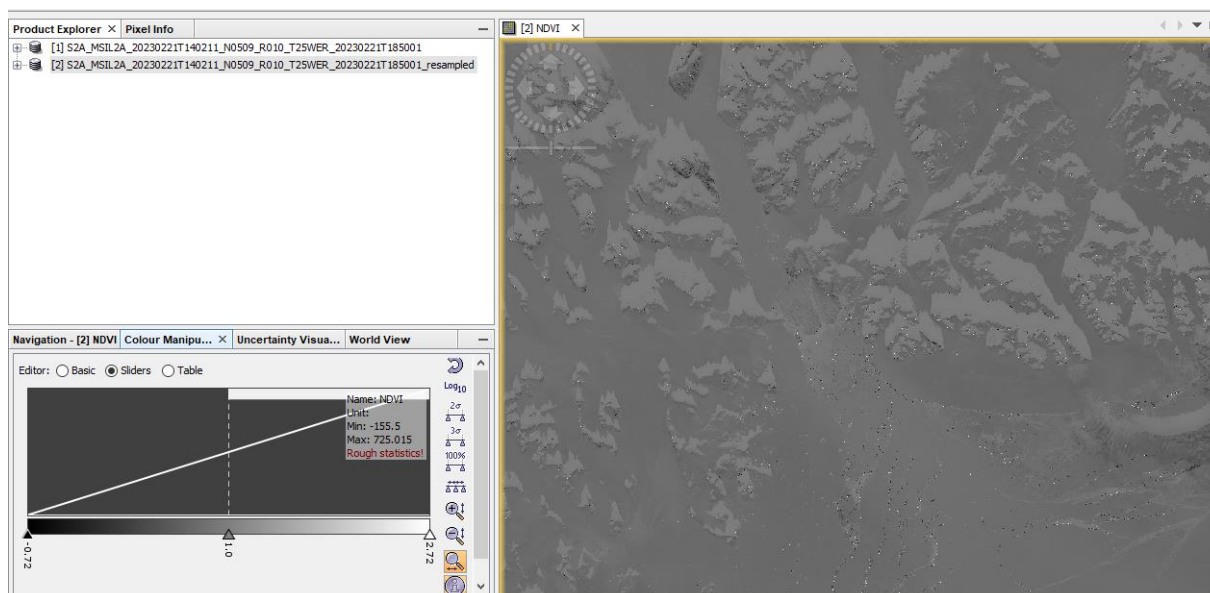
Explore the image: values above 0.4 are usually snow pixels (shades of grey for the lowest probability of snow and shades of white for the highest probability of snow). The Sentinel-2 NSDI can be also used to differentiate between cloud and snow cover as snow absorbs in the short-wave infrared light, but reflects the visible light, whereas cloud is generally reflective in both wavelengths.

Most potential doudy pixels have NDSI values in a range between -0.1 and +0.2. Add 4 new sliders and change their colour to e.g. red to highlight these values of potentially cloudy pixels.