



EXERCISE 11 – TUTORIAL

Generating high resolution binary and fractional snow maps from Sentinel-2 data using SNAP software

1 | Exercise outline

In this exercise, we will:

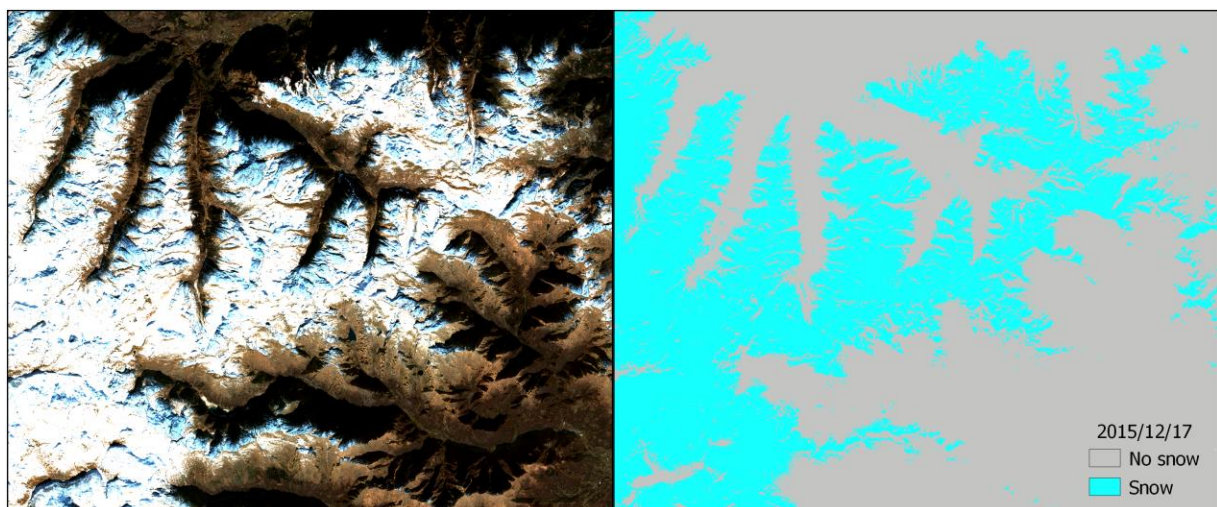
- Explore how data from Sentinel-2 multispectral data are used to detect and measure snow extent
- Learn how to generate and interpret high resolution binary and fractional snow cover products
- Demonstrate real-world examples and applications of these techniques in cryospheric research

2 | Background

Mapping snow and ice using Sentinel-2 data

The routine creation of hemispheric or global snow cover extent data typically relies on medium-resolution optical satellite data, such as Sentinel-3 SLSTR/OLCI, Terra/Aqua MODIS, or NPP VIIRS. To evaluate the accuracy of these products, snow maps derived from high-resolution optical satellite data, such as Sentinel-2 MSI or Landsat 8 OLI, can be utilized.

In this task, you'll produce binary and fractional snow cover datasets using a Sentinel-2 scene captured over the Alps on April 29, 2016. Two approaches, both centered on the Normalized Difference Snow Index (NDSI), will be tested.



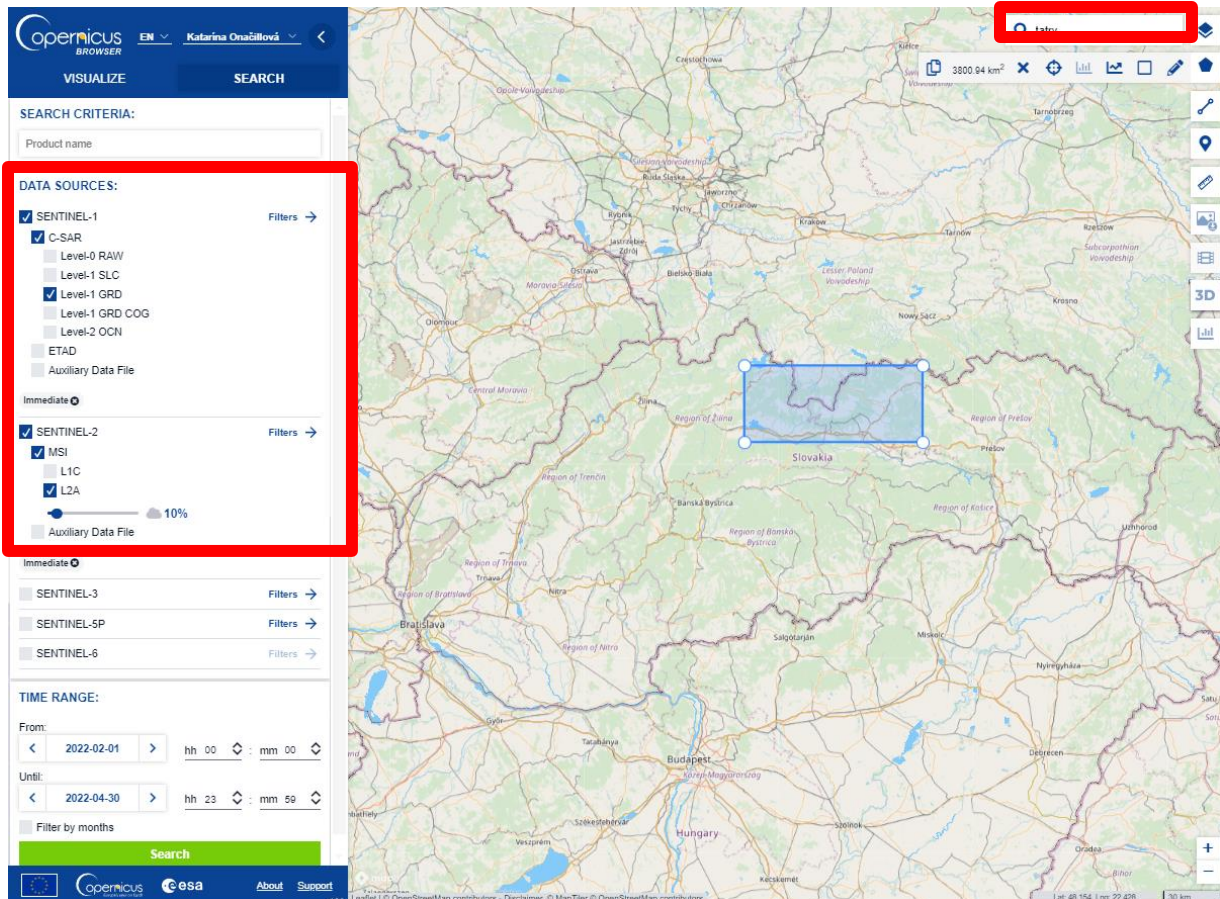
Snow cover extent map

In this Copernicus Sentinel-2 image of 17 December 2015, we can see an example of a snow cover extent map from Sentinel-2 tile T32TLR during the winter season.

Source: Contains modified Copernicus Sentinel data (2015)/processed by e-shape

2.1 Study area and data used

For this exercise, we will use Sentinel-1 and Sentinel-2B images of the High Tatras area in Slovakia, with its expanse of national parks with its typical flora and rocky mountains covered, especially in winter season with snow and ice. For the first part of the exercise, we will use the Tile Number *34UDV* downloaded for 25 March 2022 from the Dataspace Copernicus Open Access Hub [[@https://dataspace.copernicus.eu/](https://dataspace.copernicus.eu/)].



S2B_MSIL2A_20220325T094029_N0400_R036_T34UDV_20220325T132010.SAFE

2.2 Part A: Generate high resolution binary and fractional snow maps from Sentinel-2 data over the Alps

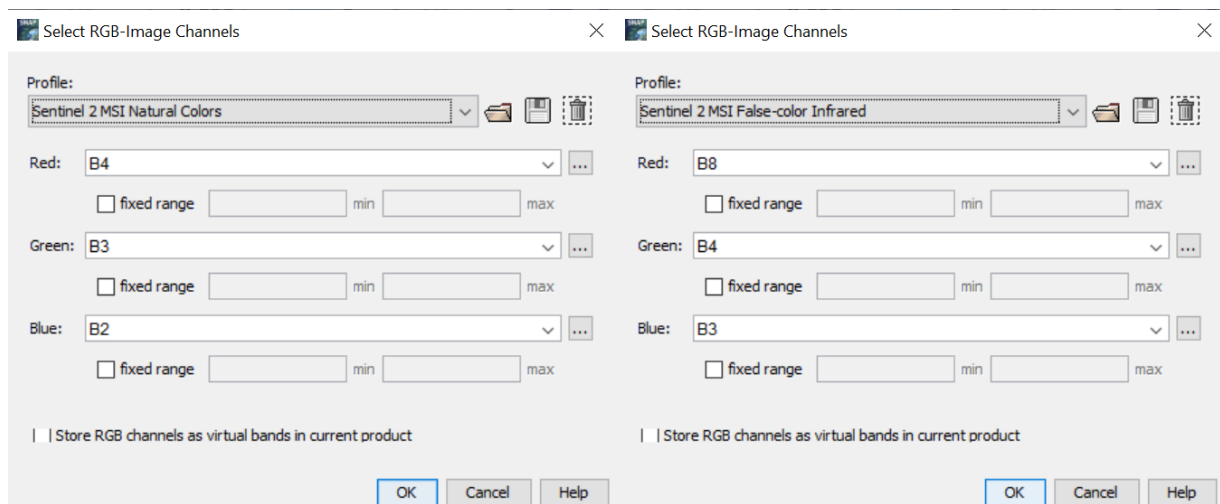
SNAP - Open and explore product

Open SNAP Desktop and import the Sentinel-2 data set Sentinel-2: File Import Optical Sensors Sentinel-2 S2 MSI L2A. Navigate to the S2 directory in the input data directory and select the XML file. The opened products will appear in Product Explorer window.

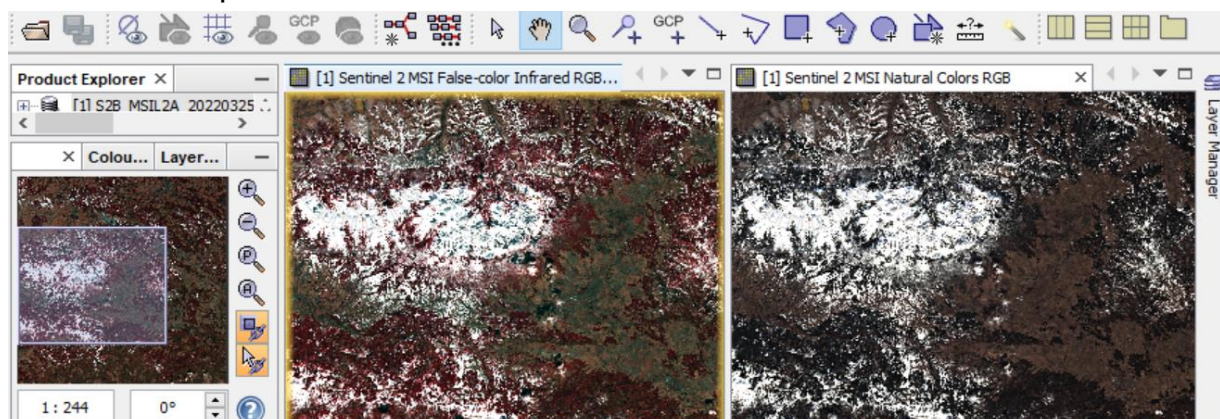
S2B_MSIL2A_20220325T094029_N0400_R036_T34UDV_20220325T132010.SAFE.zip

Get a first overview of the snow and cloud conditions on the 25 March 2022 over Tatra's region using true- and false colour composite previews:

1. Select the product in the Product Explorer window.
2. Display product using e.g. True and False color composition: Right click on the product - Open RGB Image Window.
3. In the pop-up window select 'Sentinel 2 MSI Natural colors (Red: B4; Green: B3; Blue: B2)'.
4. Then, choose another color composition, e.g. 'Sentinel 2 MSI False-color Infrared (Red: B8; Green: B4; Blue: B3)'.

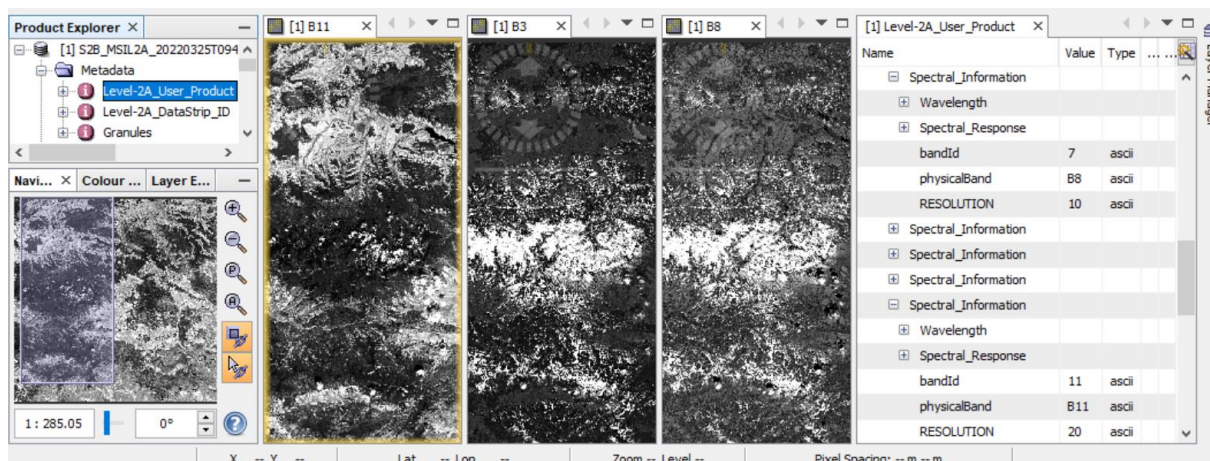


5. In the Navigation window, zoom in to the snow region
6. Tile Windows, e.g. Horizontally
7. Get an impression on the overall snow conditions on 25 March 2022



Get familiar also with the basic information associated to the Sentinel-2 data set:

Open the file structure of the Sentinel-2 scene by double left click on the product (or click on the +). Click on the menu Metadata, double click on Level-2A_User_Product and find the spectral information for the bands needed for the snow mapping approaches (B3, B8, B11): band numbers, resolution (pixel size).



Resample

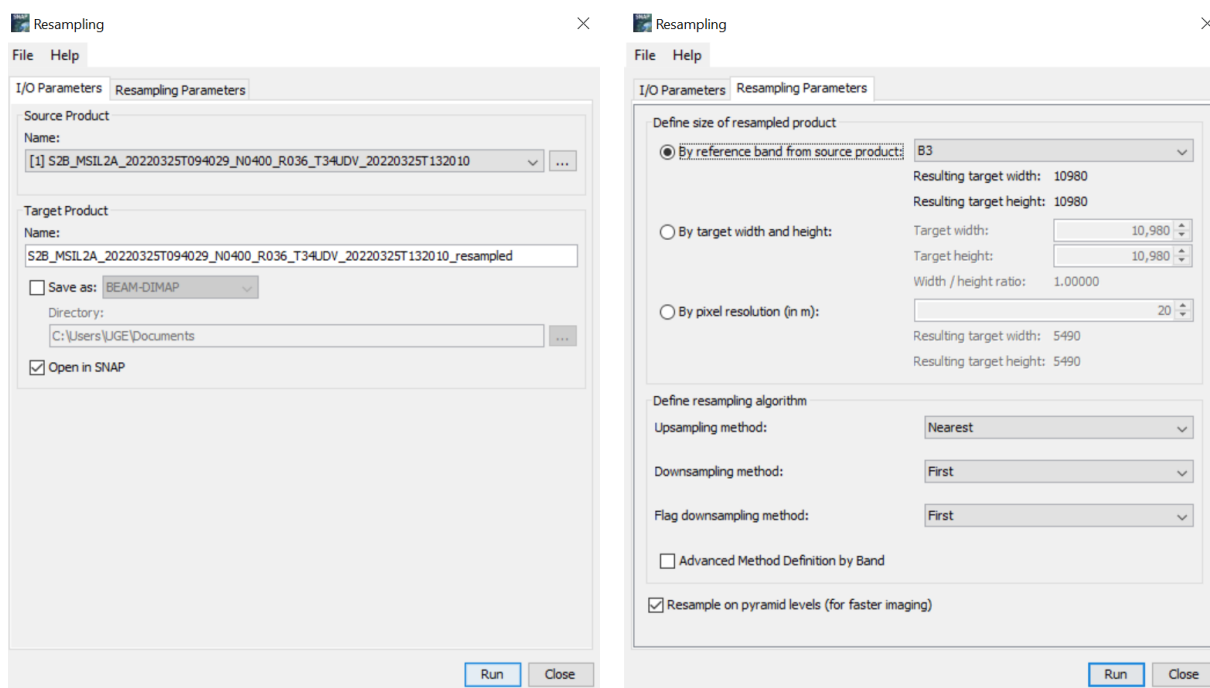
Resample the bands to the pixel size of the VIS bands:

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. B3 with 10 m resolution to resample all the bands to 10 m as output spatial resolution.



Create subset

Click on the resampled product in the Product Explorer, go to the main SNAP menu and select Raster - Subset...:

Create a subset with the following settings:

Spatial subset:

Scene start X: 0,

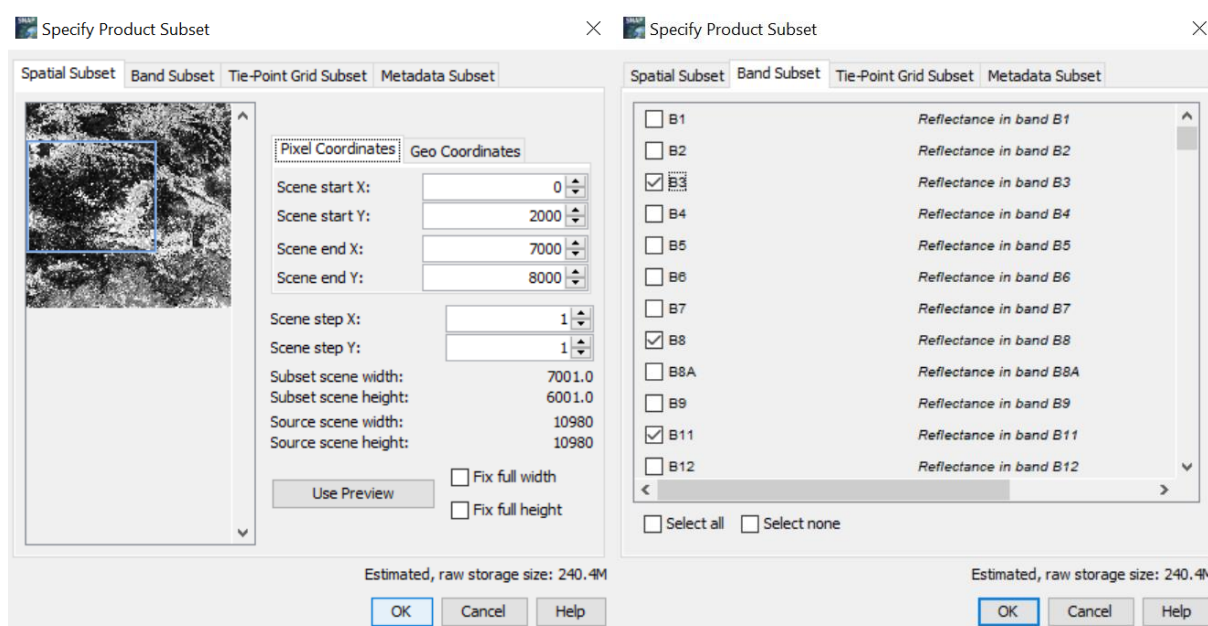
Scene start Y: 2000,

Scene end X: 7000,

Scene end Y: 8000

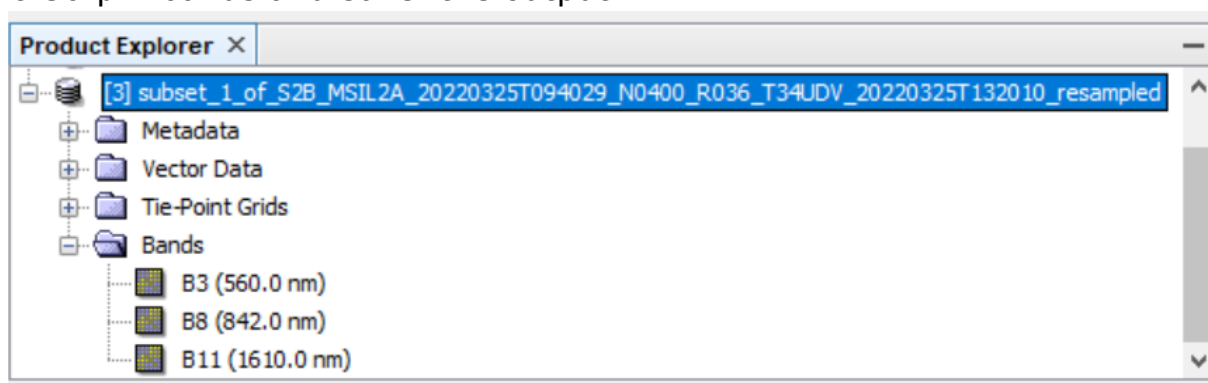
Band subset: B3, B8, B11

And click OK



In the main SNAP menu, select Raster - Band Maths (unlock the box "Virtual")

From the created subsets, calculate the NDSI using the 1.6 μm and the 0.56 μm bands and save the output.



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 0.42 are usually snow. The Sentinel-2 NDSI 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"). Click on Edit Expression to calculate the NDSI using the equation below and click OK:

$$\rho(\text{VIS}) - \rho(\text{SWIR}) / \rho(\text{VIS}) + \rho(\text{SWIR})$$

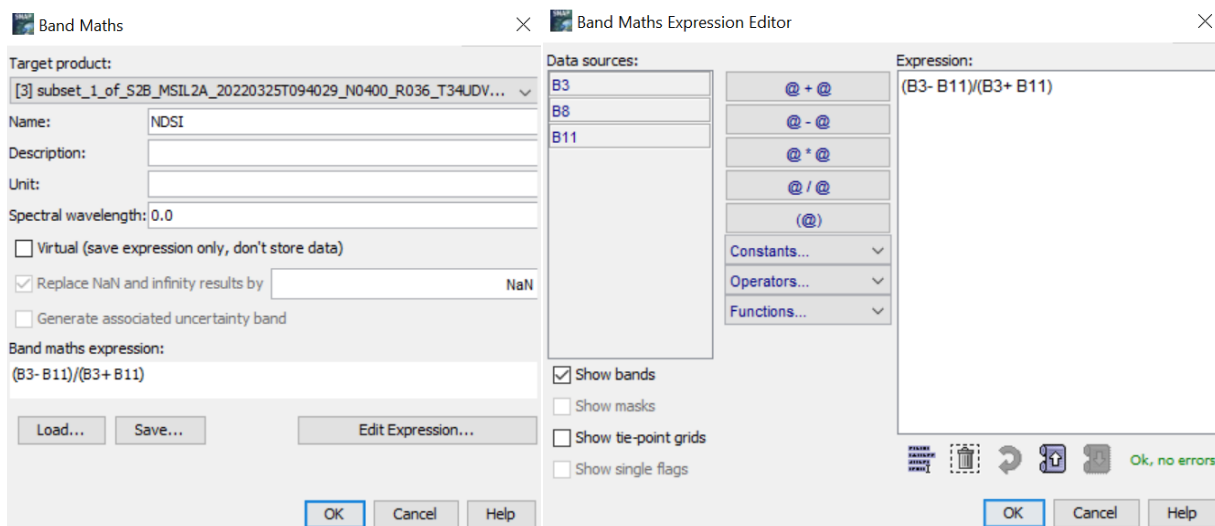
ρ = Top of atmosphere reflectance

VIS = Visible band (0.56 μm)

SWIR = Short-Wave Infrared Band (1.6 μm)

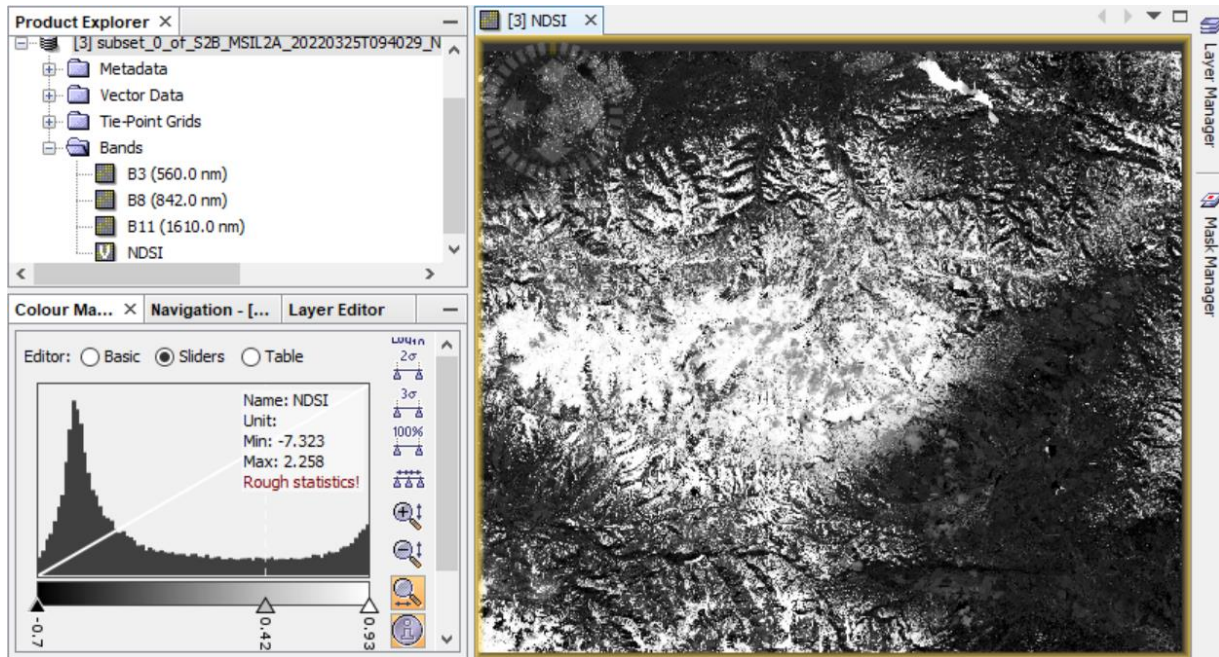
Replace the bands in the equation with the corresponding bands for Sentinel 2:

$$\rho(\text{B3}) - \rho(\text{B11}) / \rho(\text{B3}) + \rho(\text{B11})$$



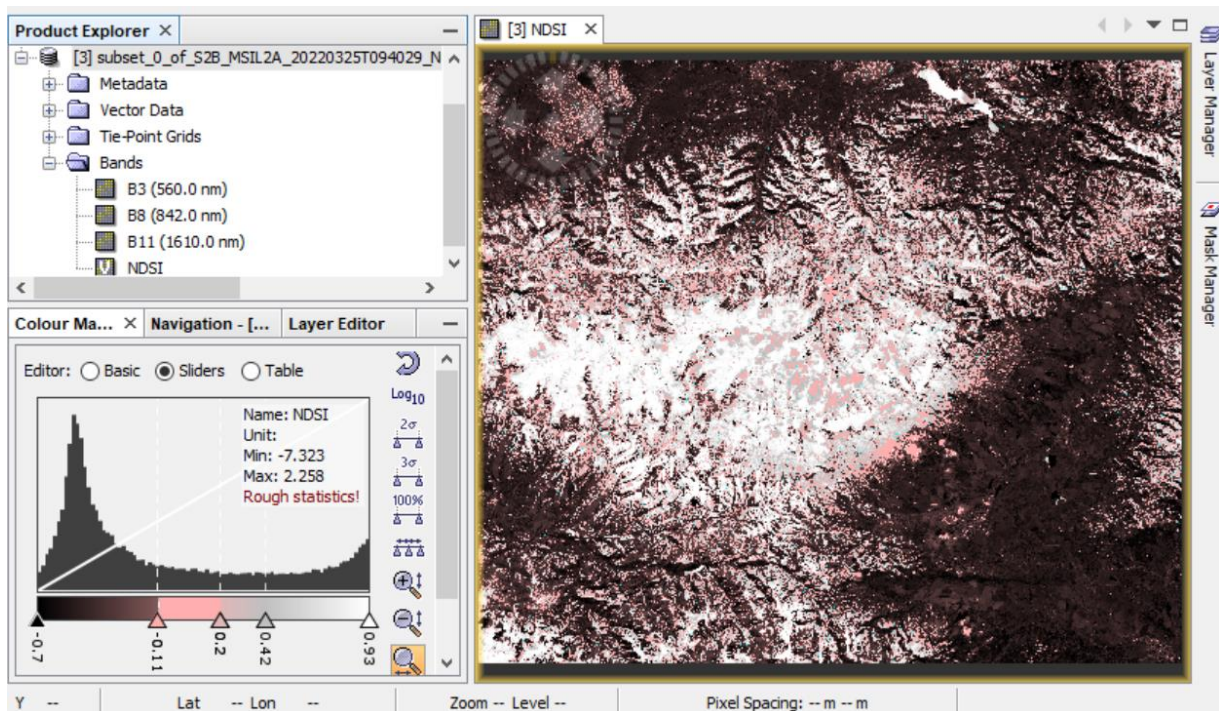
Open the output product in the Product Explorer by double click on the new raster NDSI within Bands folder.

Go to Color Manipulation tab and go to Table – set the thresholds of slider to three values – minimum value, up to 0.42 (usually pixels with no snow), higher than 0.42 (usually snow pixels) and maximum value.



Explore the image: values above 0.42 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 NDSI 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 cloudy 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.



Binary snow classification (snow / no snow)

Applying thresholds on the NDSI and a Near Infrared band (NIR, e.g. 0.842 μm) it is possible to derive binary snow classification.

The method utilized in this task has been adjusted and made simpler based on the approach employed in the Theia Snow collection (Gascoin et al. 2019). We apply a cautious threshold to NDSI. Certain murky waters may exhibit comparably high NDSI values, thus, we incorporate an extra condition concerning red reflectance to prevent erroneous snow identification in such regions. A pixel free from clouds is classified as snow under these conditions:

$$(NDSI < n1) \text{ AND } (pred < r1)$$

Where $n1$ and $r1$ are the selected thresholds, during the first pass they are set conservatively high to avoid false detections. If the above expression is not fulfilled, then the pixel is marked as "no snow"

Minimum value of NDSI for the pass 1 snow test - $n1$ 0.4

Minimum value of the red band (B8) for the pass 1 snow test - $r1$ 0.11

After substitution with corresponding Sentinel-2 bands, the equation is:

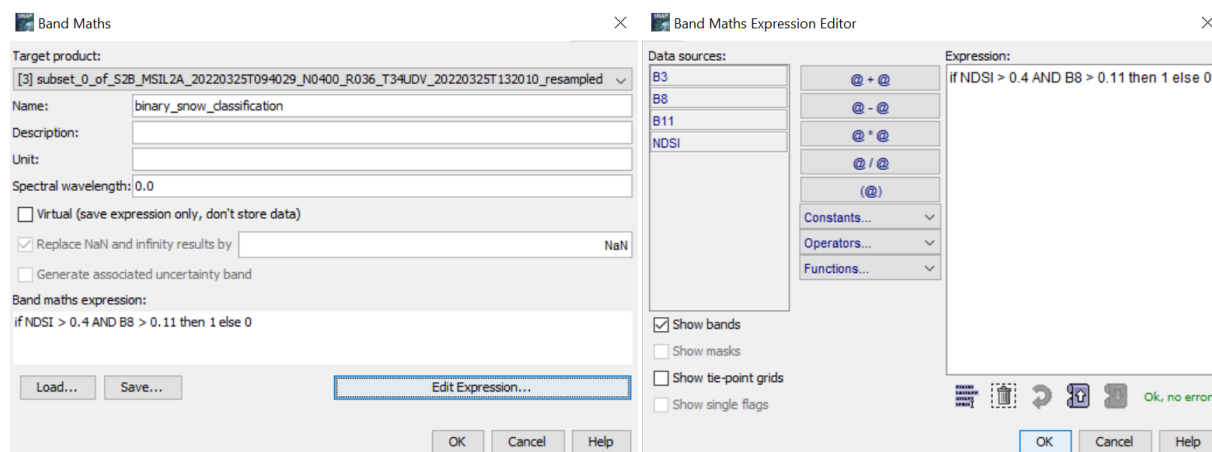
$$\text{Expression: if NDSI} > 0.4 \text{ AND B8} > 0.11 \text{ then 1 else 0}$$

Now, navigate to Main Menu: Raster – Band Maths

Unlock the band "Virtual",

Define output layer name: `binary_snow_classification`

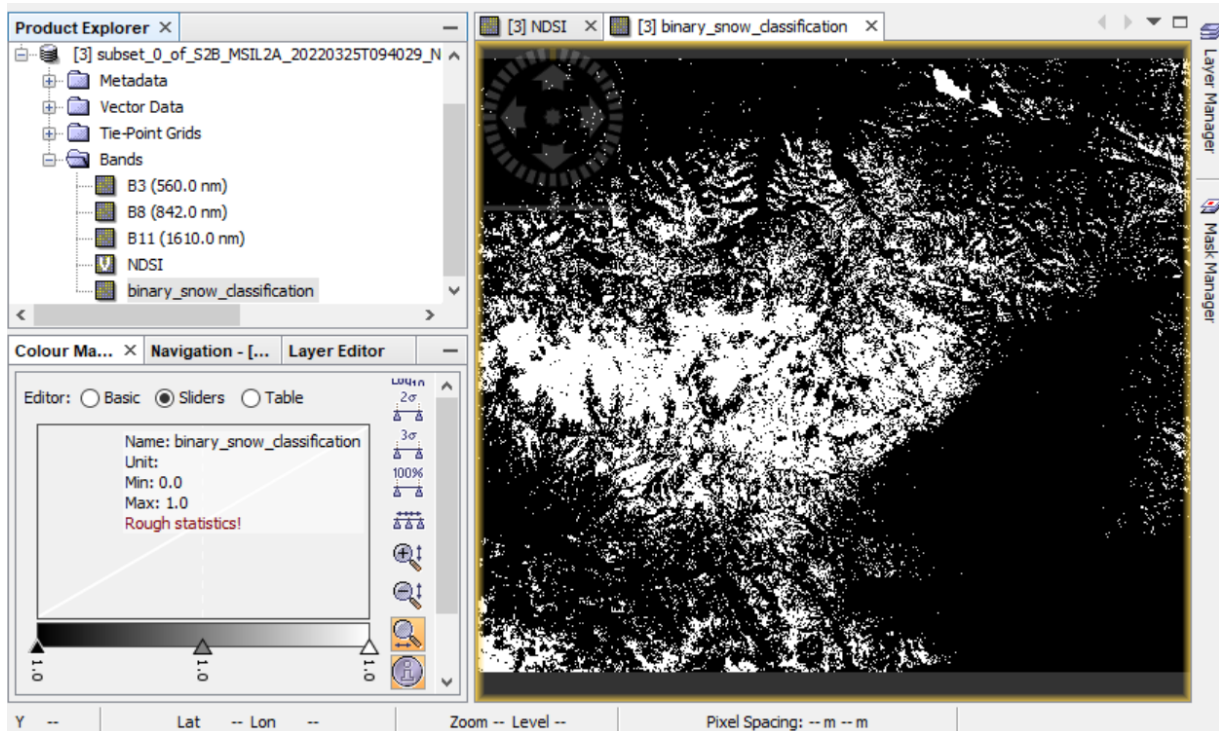
and Edit Expression: `if NDSI > 0.4 AND B8 > 0.11 then 1 else 0`



Open the output product in the Product Explorer by double click on the new raster „`binary_snow_classification`“ within Bands folder.

Go to Color Manipulation tab and go to Table – set the thresholds of slider to three values – minimum value, up to 0.42 (usually pixels with no snow), higher than 0.42 (usually snow pixels) and maximum value.

We can observe that pixels have been divided into two categories: with snow (white pixels) and without snow (black pixels)

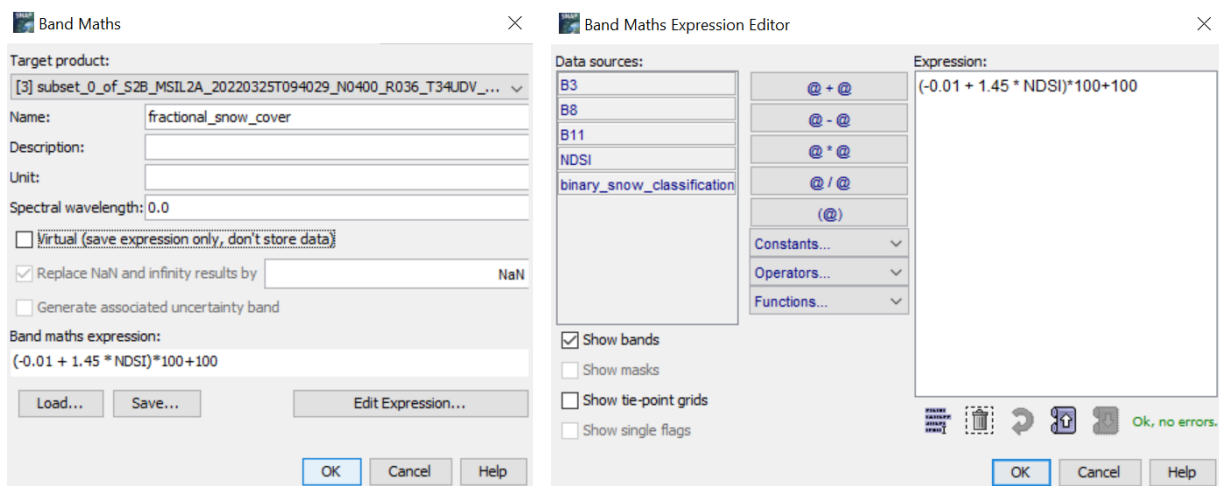


Fractional snow cover

In the second part of the task, we will try to detect fractional snow cover (FSC, 0 % - 100% snow) according to the approach of Salomonson and Appel (2004, 2006), which was originally developed for MODIS data:

$$FSC = (-0.01 + 1.45 * NDSI) * 100 + 100$$

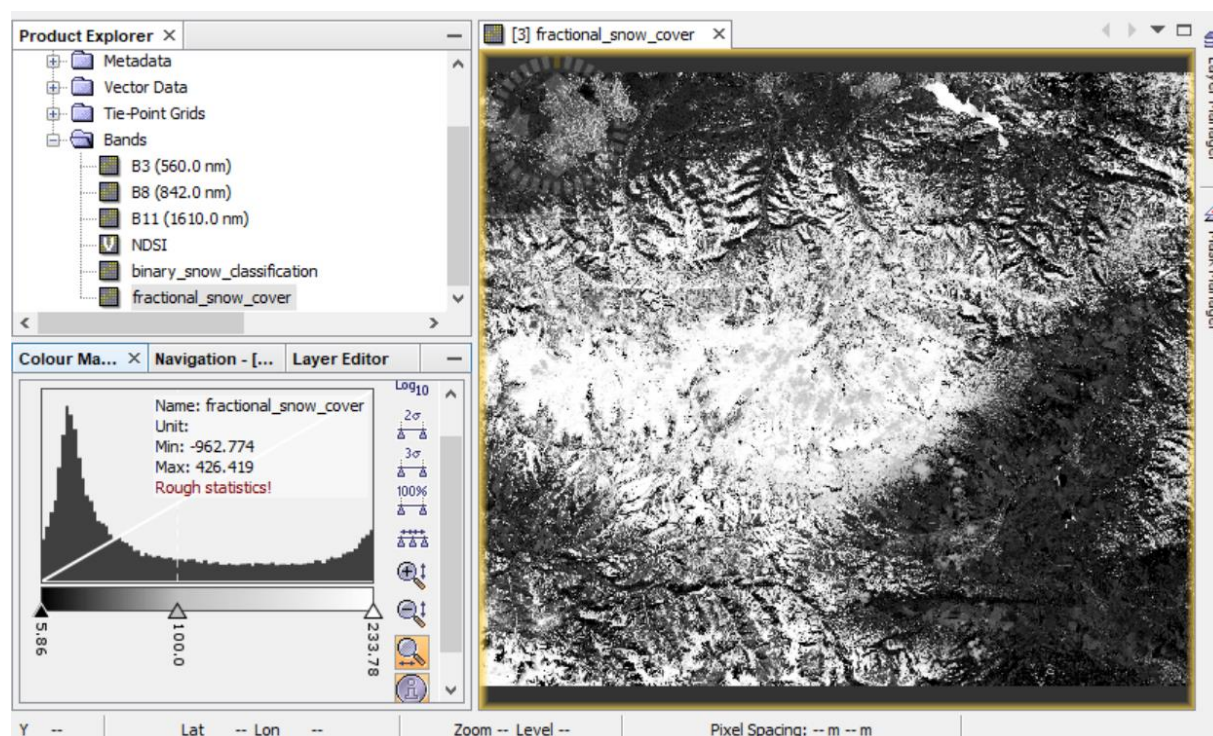
Now, navigate again to Main Menu: Raster – Band Maths
 Unlock the band "Virtual",
 Define output layer name: fractional_snow_cover
 and Edit Expression: $(-0.01 + 1.45 * NDSI) * 100 + 100$



In forested areas, this approach aims on detecting the viewable snow, i.e. the snow on top of the forest canopy. Let's check the results.

Open the output product in the Product Explorer by double click on the new raster „fractional_snow_cover“ within Bands folder.

Go to Color Manipulation tab and set value range between 100 (snow free) and 200 (100 % snow covered):



THANK YOU FOR FOLLOWING THE EXERCISE!