EXERCISE 8 – TUTORIAL

Sentinel-1 & Sentinel-2 for Snow and Ice using the SNAP software and EO Browser

ÚSTAV GEOGRAFIE
Prírodovedecká fakulta UPJŠ v Košiciach
UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH
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1 | Exercise outline

In this first exercise for mapping snow and ice, we will:

- Learn the basic steps to calculate glacier velocity using Sentinel-1 data
- Perform preprocessing of data
- Use velocity vector to see direction and speed of glacier flow

2 | Background

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

The Greenland ice sheet ranks as the Earth's second-largest mass of ice. As the climate undergoes changes, there's a notable increase in surface melting of the ice sheet, leading to a greater discharge of freshwater into the ocean. This phenomenon significantly contributes to the global rise in sea levels.

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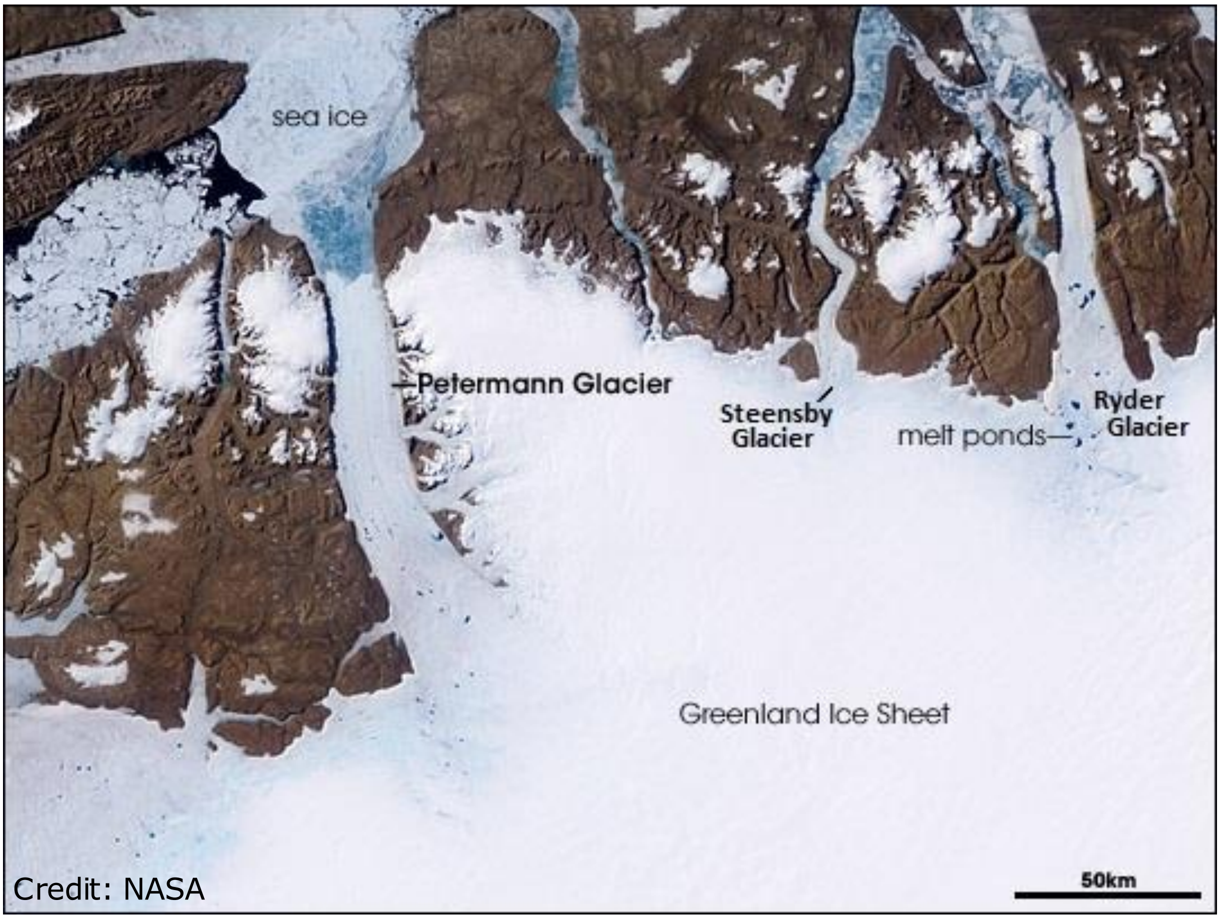
Monitoring glacier velocity is crucial for understanding glacier dynamics and its impact on global sea levels. Satellite data serves as a valuable tool for tracking glacier velocity across expansive areas. Two primary methods are commonly employed to measure ice flow speed using satellite data: SAR interferometry and feature/speckle tracking (utilizing optical or SAR data) between consecutive acquisitions. This tutorial will focus on the latter method, specifically applied to Sentinel-1 data.

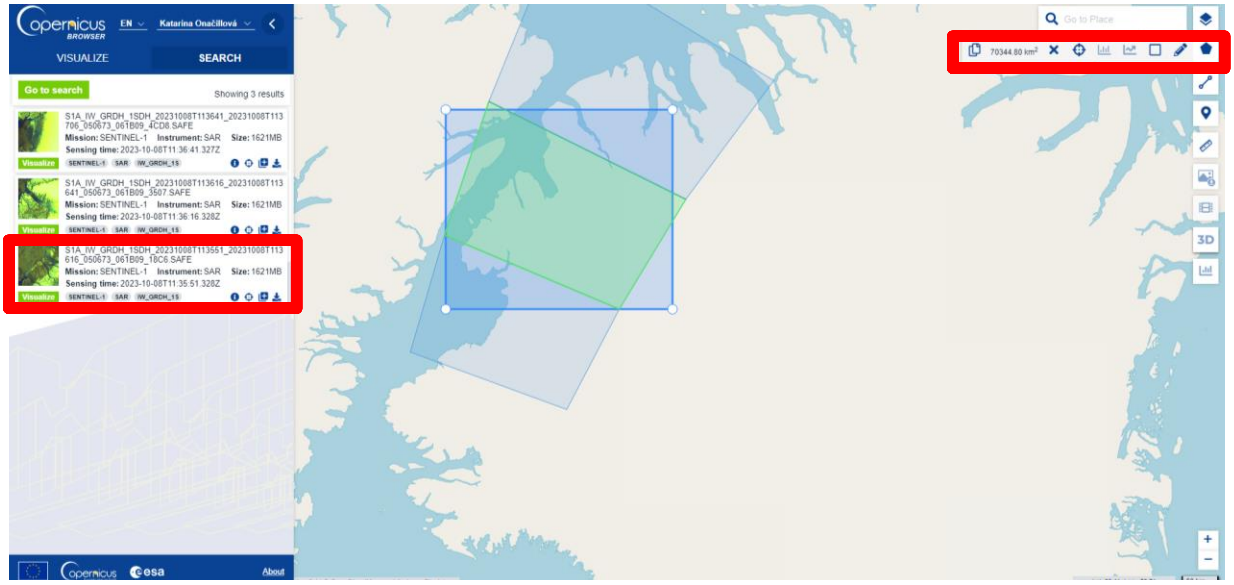
The Petermann Glacier, a substantial tidewater glacier, drains over 4% of the Greenland ice sheet via the 90 km long Petermann Fjord, ultimately terminating in a floating ice tongue spanning an area of approximately 900 km². An estimated 12 billion tonnes of ice are discharged into the ocean annually, with an approximate ice flow speed of 1 km/year.



Credit: NASA

2.1 Study area and data used

For this exercise, we will use two Sentinel-1 images of the same area in northern Greenland, downloaded for year 2023 from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].

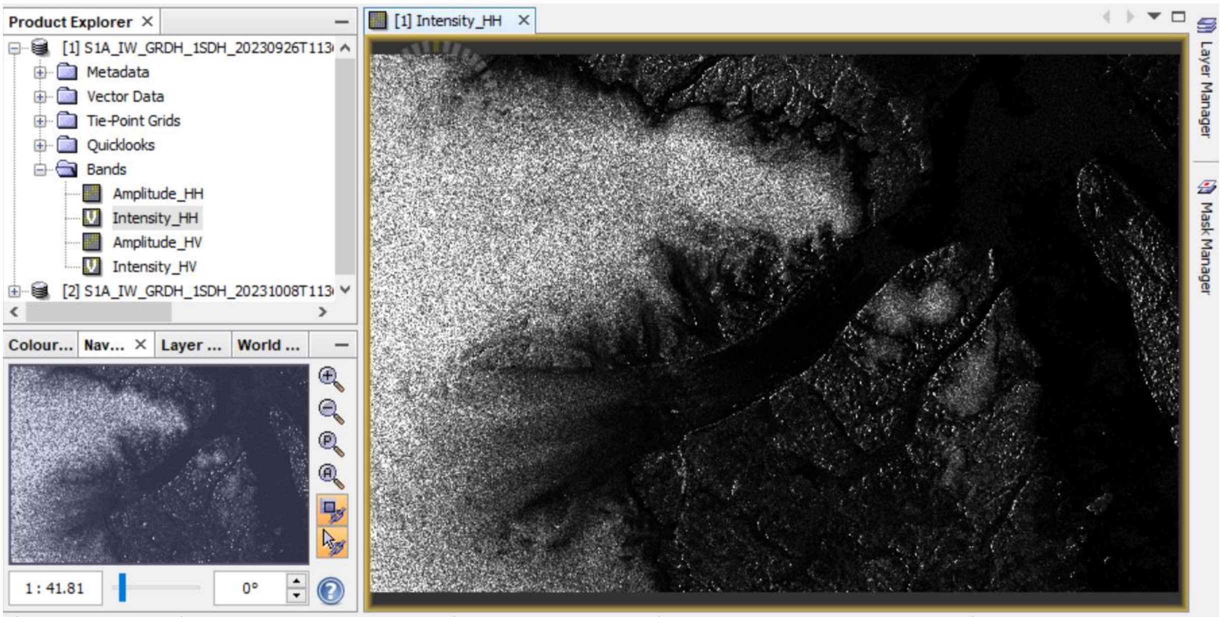


2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open 2 Sentinel-1 GRDH downloaded products with HH and HV polarizations acquired on 26 September and 8 October 2023 by double click on the zipped folders. The opened products will appear in Product Explorer window:

S1A_IW_GRDH_1SDH_20230926T113616_20230926T113641_050498_061508_2030.zip
S1A_IW_GRDH_1SDH_20231008T113616_20231008T113641_050673_061B09_3507.zip

Click + to expand the contents of product [1] from 26 September 2023, then expand Bands folder and double click on Intensity_HH band to visualize it.



The scene appears to be "mirrored" due to the fact that it was captured during a descending pass, with the satellite moving from north to south and looking towards the right (in this case, west). As a result, the view displays pixels in the order of data acquisition, as the image has not yet been projected into cartographic coordinates.

3.1 Pre-processing

We need to apply identical pre-processing steps to both of our scenes:

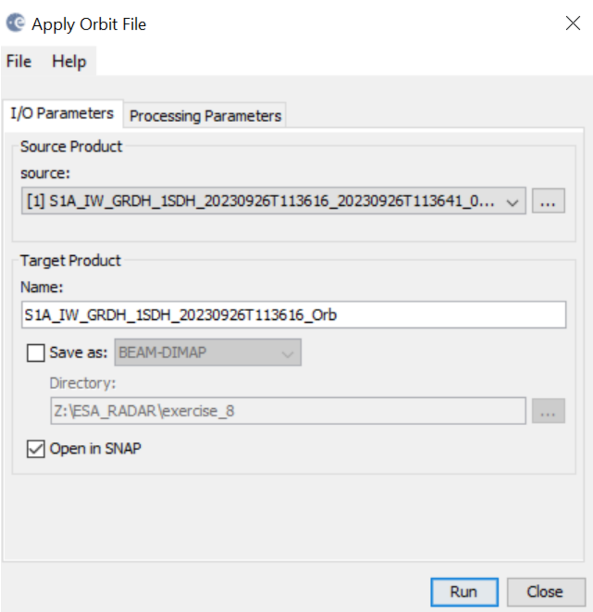
Apply orbit file

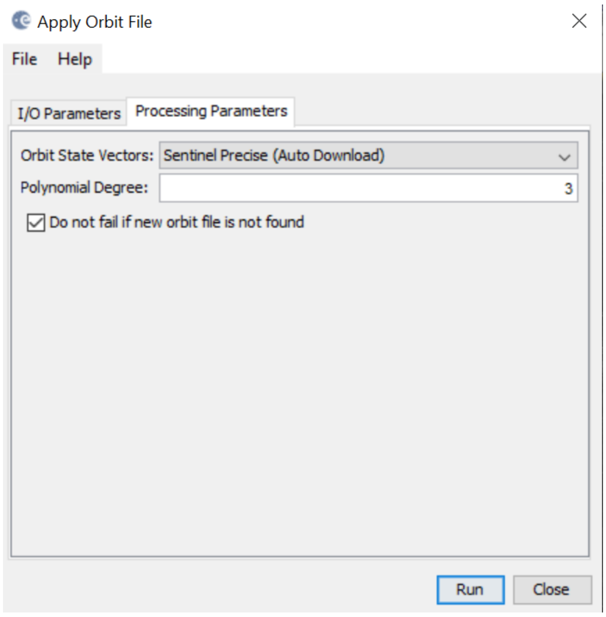
Navigate to Main Menu – Radar – Apply orbit file

In the I/O Parameters tab, select the first product and name the target product. 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"

Repeat for the second image.





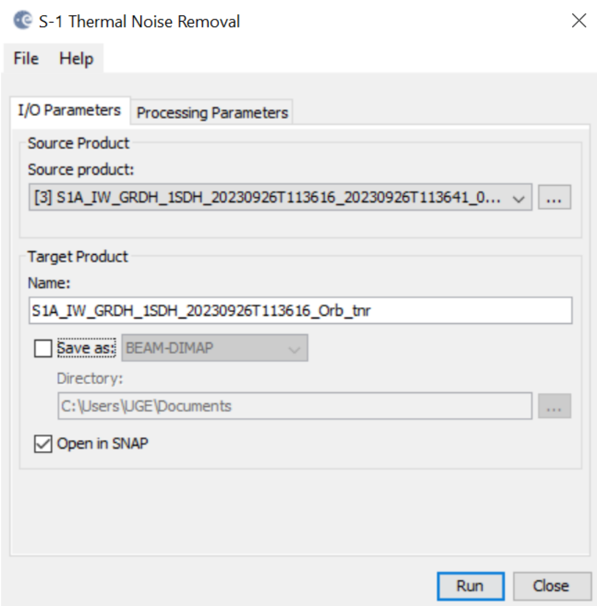
Thermal noise removal

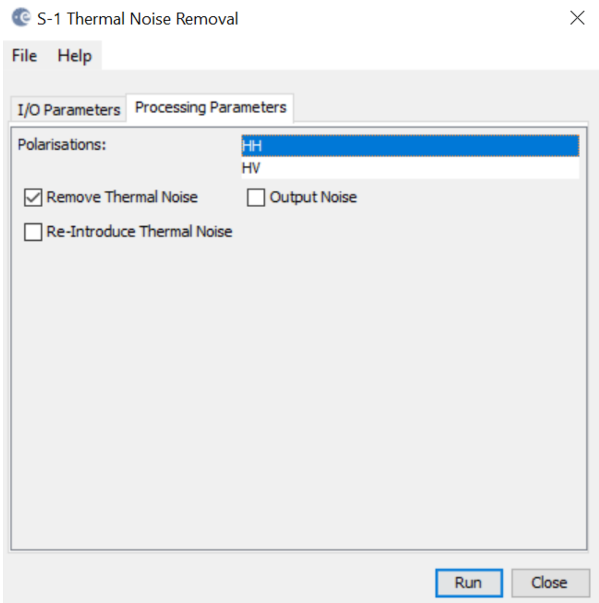
Navigate to Main Menu – Radar – Radiometric – S-1 Thermal Noise Removal

In the I/O Parameters tab, select the product with applied orbit file and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters you can select only HH polarization (or it is possible within the next step calibration) and make sure that the "Remove Thermal Noise" option is selected.

Repeat for the second image.





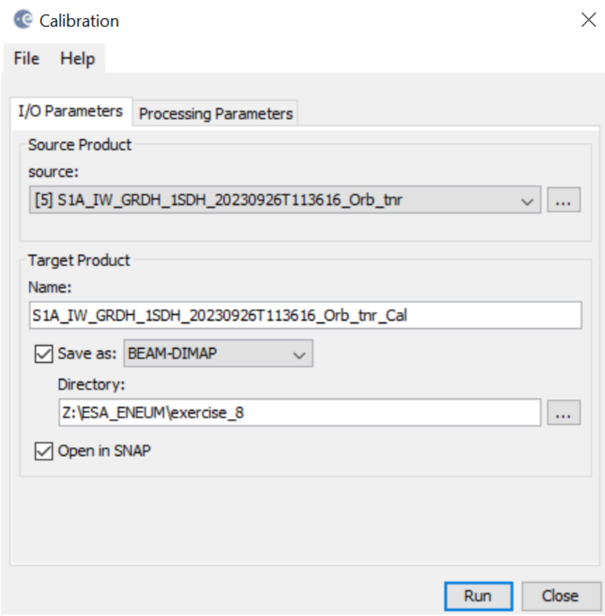
Calibration

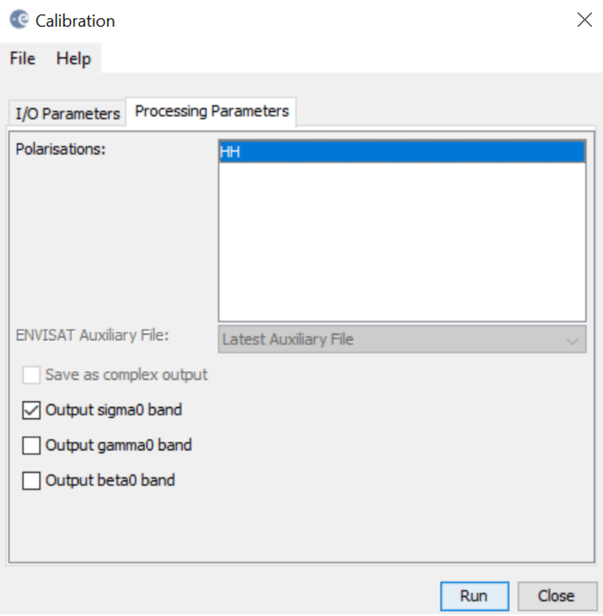
Navigate to Main Menu – Radar – Radiometric – Calibrate

In the I/O Parameters tab, select the product with thermal noise removal and name the target product. In the case of this final product of preprocessing, please, save it to your folder for this exercise

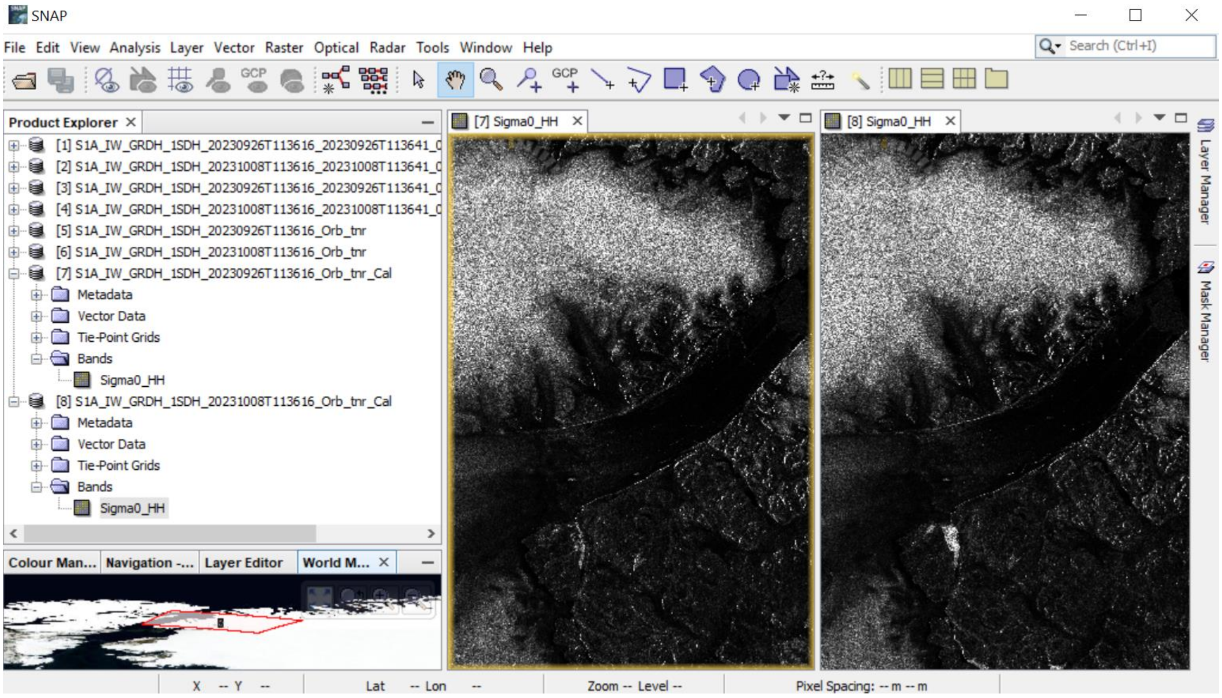
In the Processing Parameters you can select only HH polarization and accept all default settings and then click Run

Repeat for the second image. The saving might take some time.





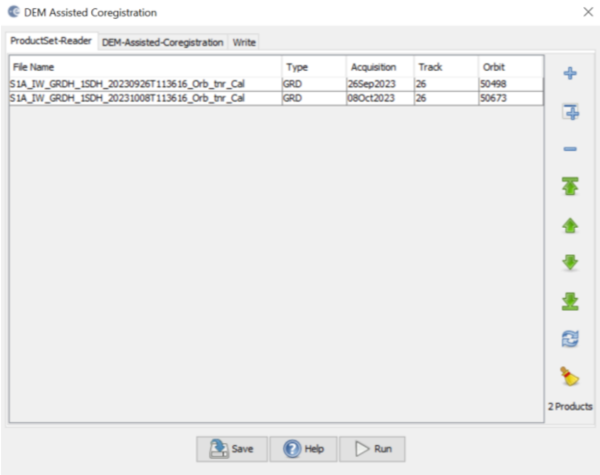
If you finish all preprocessing steps, you should have eight products in the Product Explorer. Open the Bands folder of the last two products, double click on Sigma_HH for both of the products and Tile them Horizontally. You can see little differences between these two acquisition dates.
Let´s corregistrate these images and track the offset.

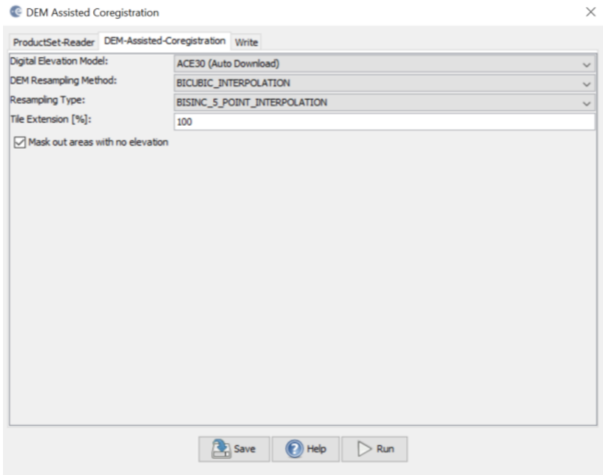


3.2 Coregistration

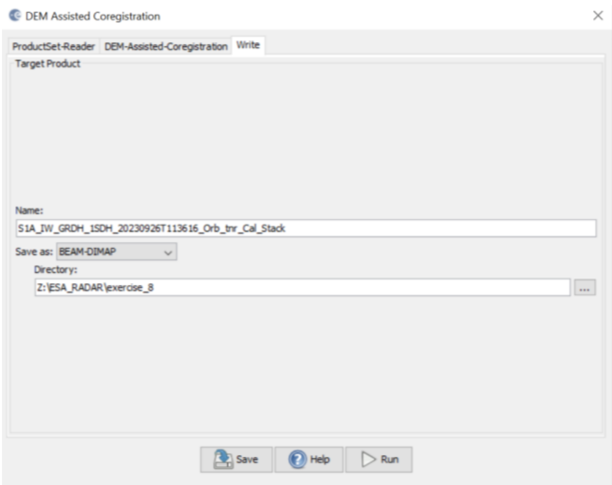
Image coregistration is the process that involves aligning two or more images geometrically, ensuring that corresponding pixels depict the same area on the Earth's surface. While orbit state vectors alone can suffice to coregister images, for precise offset tracking, additional data from a digital elevation model (DEM) is necessary to enhance coregistration accuracy.

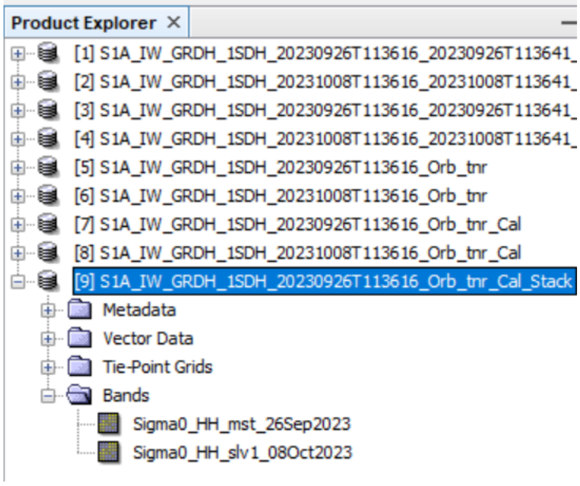
Navigate to Main Menu – Radar – Coregistration – DEM-Assisted Coregistration
In the ProductSet-Reader tab, select/leave only the last two preprocessed products and name the target product
In DEM-Assisted-Coregistration tab set:
“Digital Elevation Model”: ACE30 (Auto Download)
DEM Resampling method: BICUBIC_INTERPOLATION
Resampling Type: BISINC_5_POINT_INTERPOLATION





In Write tab name the output product and select the directory to save it. Then, click on RUN. This process may take some time. The resulting product will include two HH polarizations - "mst" = master (the main/first image used for co-registration) and "slv" = slave image.

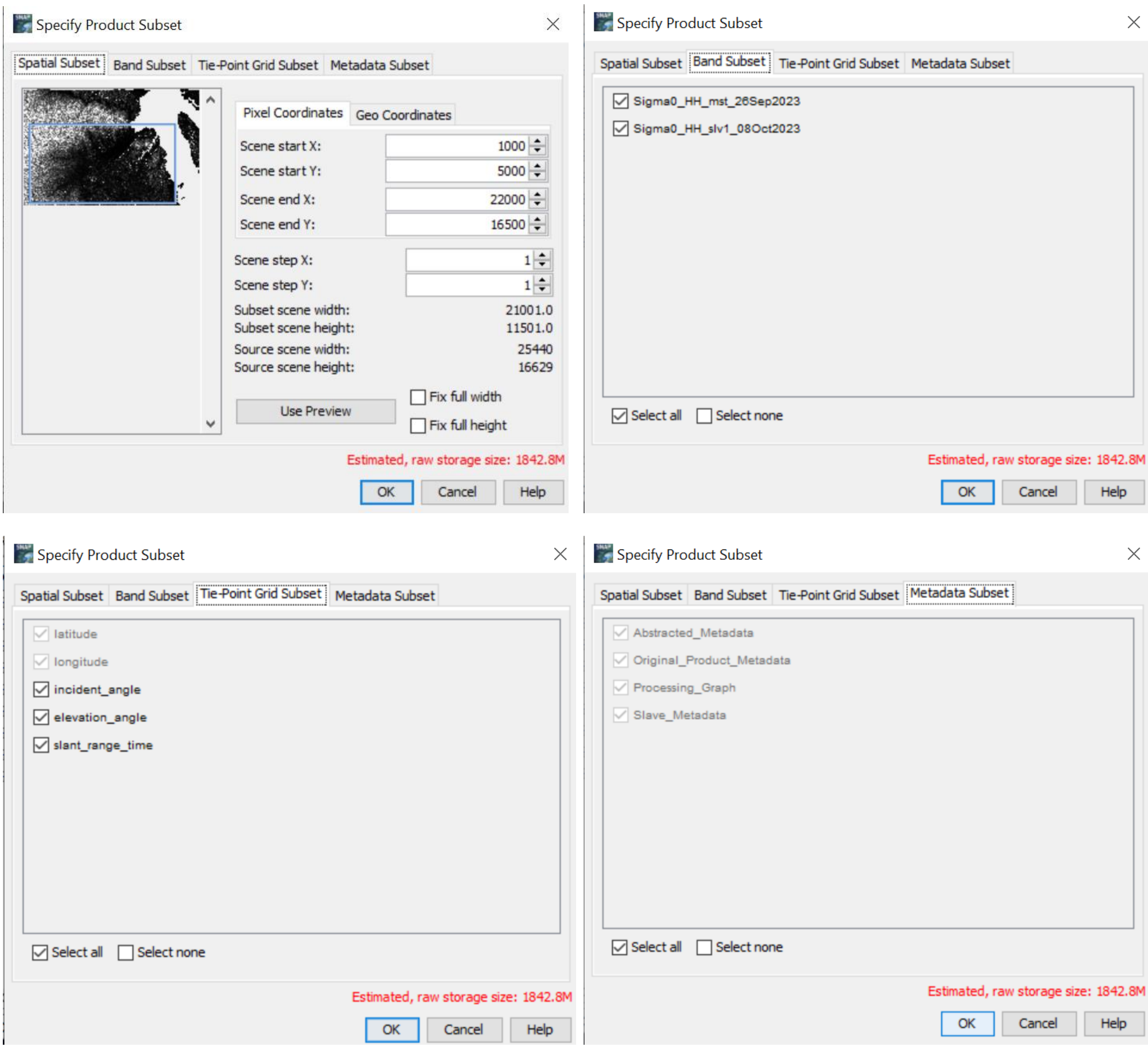




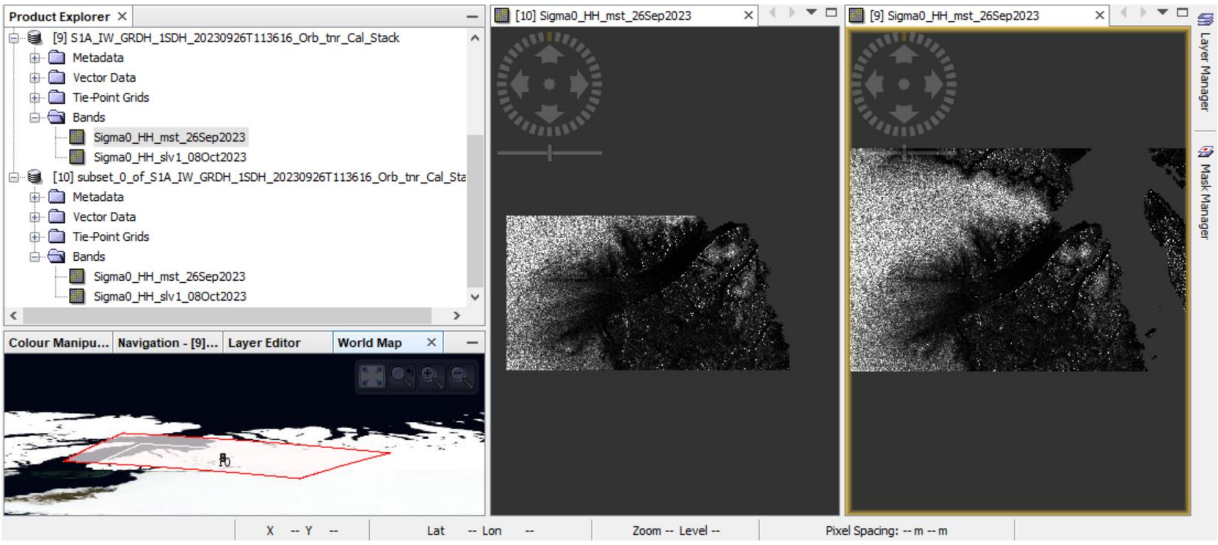
3.1 Create subset

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.

Go to the Subset tab and at "Pixel Coordinates" set:
Scene start X: 1000
Scene start Y: 5000
Scene end X: 22000
Scene end Y: 16500



Open the subset image and compare it with previous product image of the entire area. Double click on HH polarization rasters in Bands folder to open them. Tile them e.g. Horizontally to compare them.



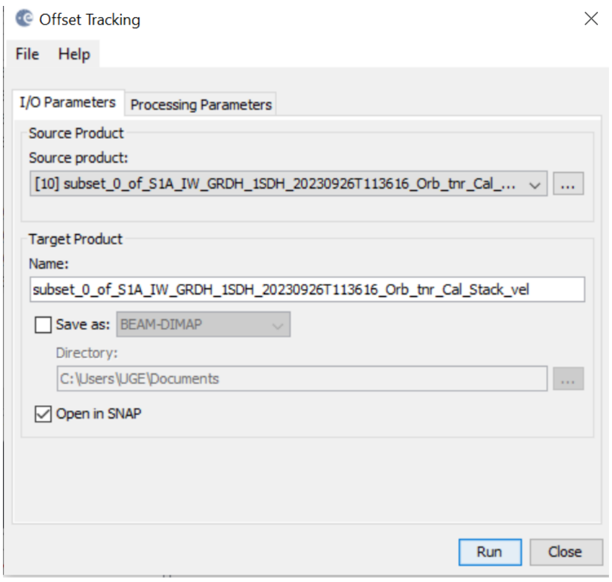
Offset Tracking

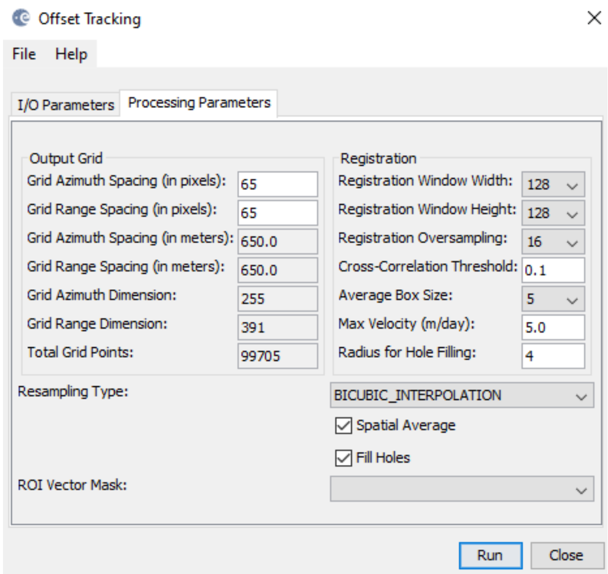
Offset Tracking is employed to determine the movement of a feature between two acquisitions by conducting cross-correlation on designated Ground Control Points (GCP) within coregistered images (master and slave) in both slant-range and azimuth directions. The velocity of movement is subsequently calculated using the offsets derived from the cross-correlation (refer to NOTE 5). The velocities calculated on the GCP grid are then interpolated to generate a velocity map. This method is commonly utilized for estimating glacier motion.

To conduct Offset-Tracking, we must configure various parameters. Initially, we establish the spacing of the Ground Control Point (GCP) grid in pixels in the range and azimuth directions. We opt for a spacing of 60 pixels (equivalent to 600 meters) in both directions, striking a balance between detail and smoothness in our output. It's worth noting that higher resolutions entail longer processing times.

Subsequently, we address the dimensions of the Registration Window. The size of this window hinges on the maximum velocity of the glacier, gleaned from literature or historical data, and the time span between data acquisitions. Given that our images were captured 13 days apart and the maximum speed of the Petermann Glacier is approximately 5 meters per day, the surface of the glacier could potentially shift by a maximum of 60 meters. Consequently, we maintain the default setting of 128 pixels (equivalent to 1280 by 1280 meters). Additionally, to mitigate false high values, we specify the known maximum glacier velocity as 5 meters per day. Therefore, we need to establish:

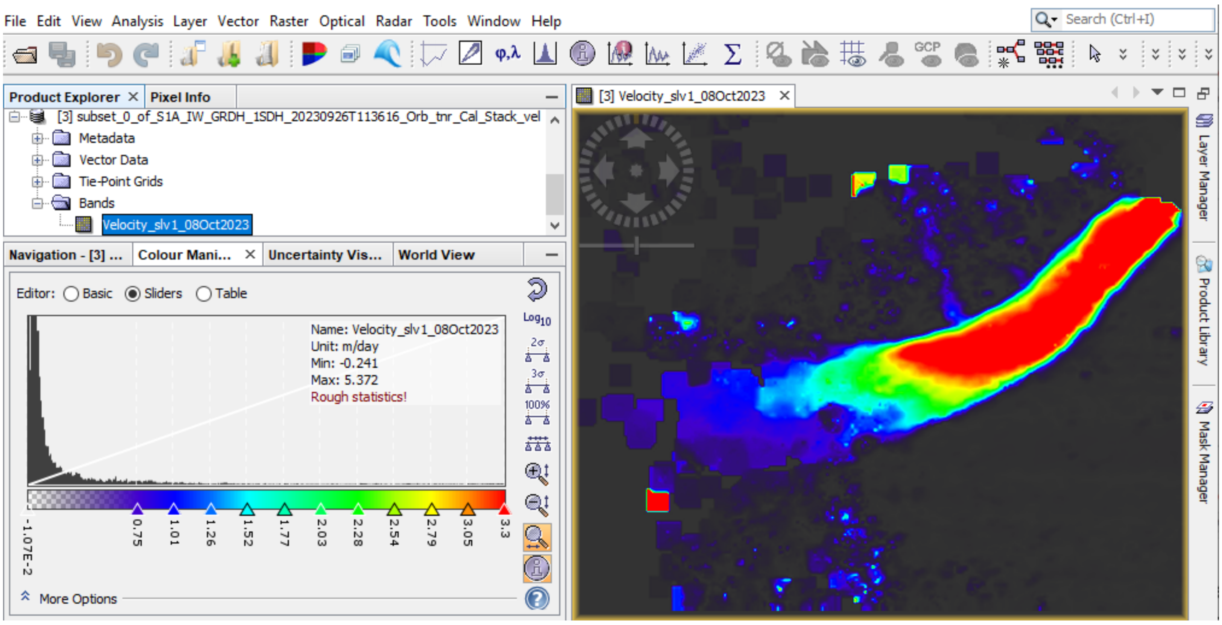
Grid Azimuth Spacing (in pixels): 65
Grid Range Spacing (in pixels): 65
Max Velocity (m/day): 5.0





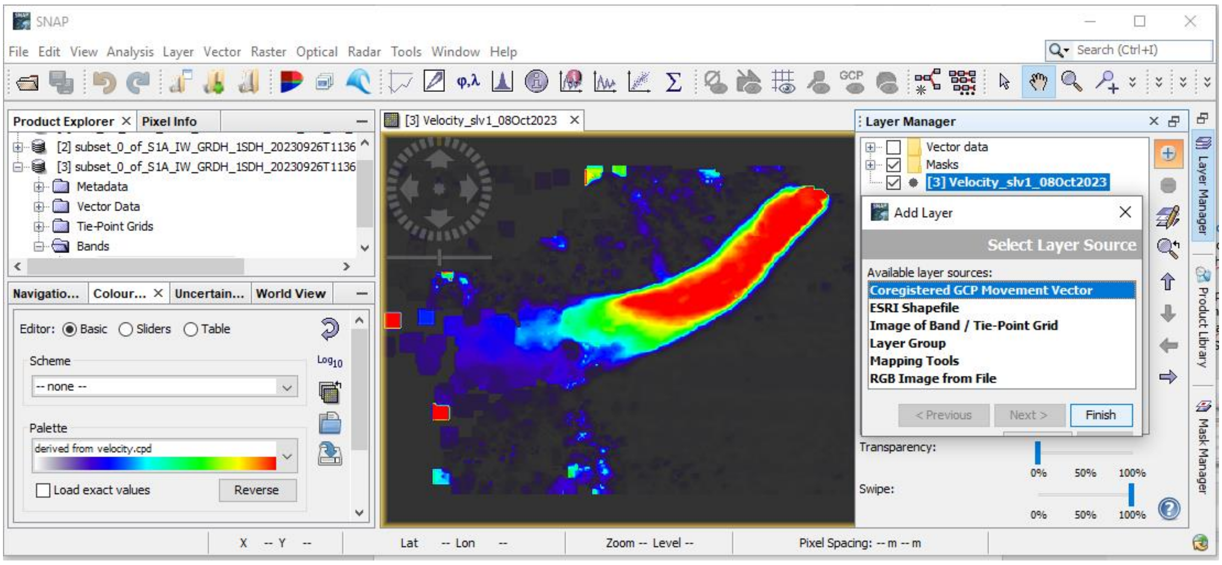
Offset Tracking

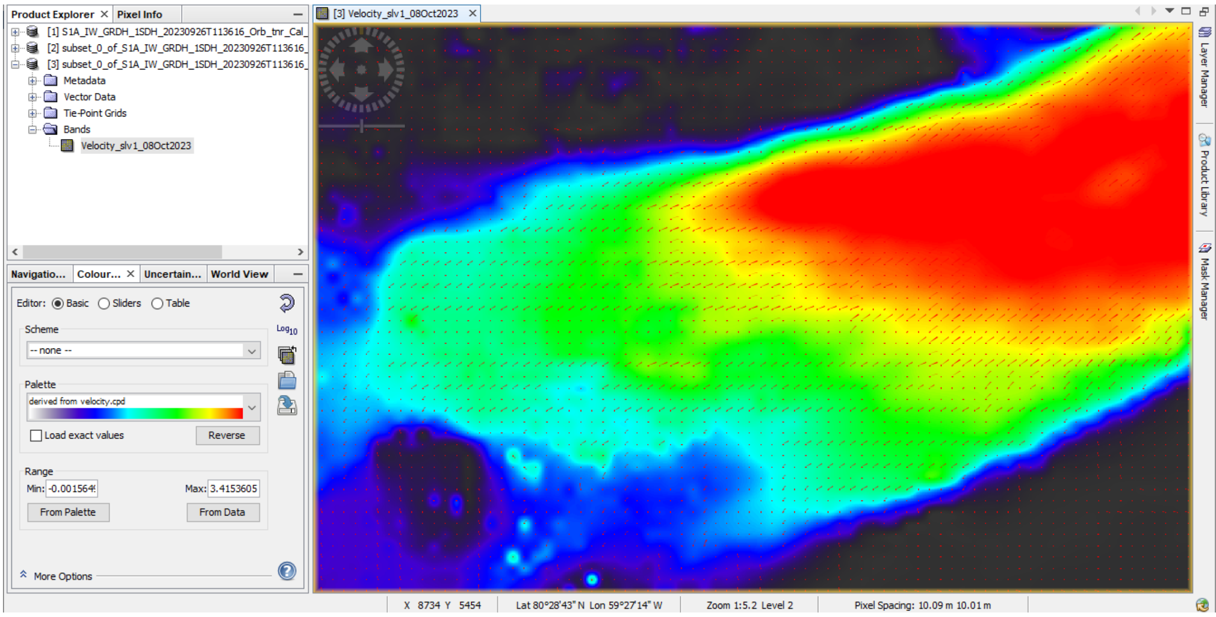
Once the processing finishes, a new product emerges in the Product Explorer window. Extend the velocity product and click twice on the Velocity_slv1_08Oct2023 band to unveil it in the View window.
Open Colour Manipulation tab – select sliders and explore velocity values in m/day in this area.



Add velocity vector to see direction and speed

Navigate to Layer > Layer Manager
From the Layer Manager window, deselect Vector data to remove the grid
Click on the "+" button to open the Add Layer window
In the Add Layer window, click Coregistered GCP Movement Vector and click on Finish. You will see the velocity vectors displayed on the GCP grid showing direction and speed.





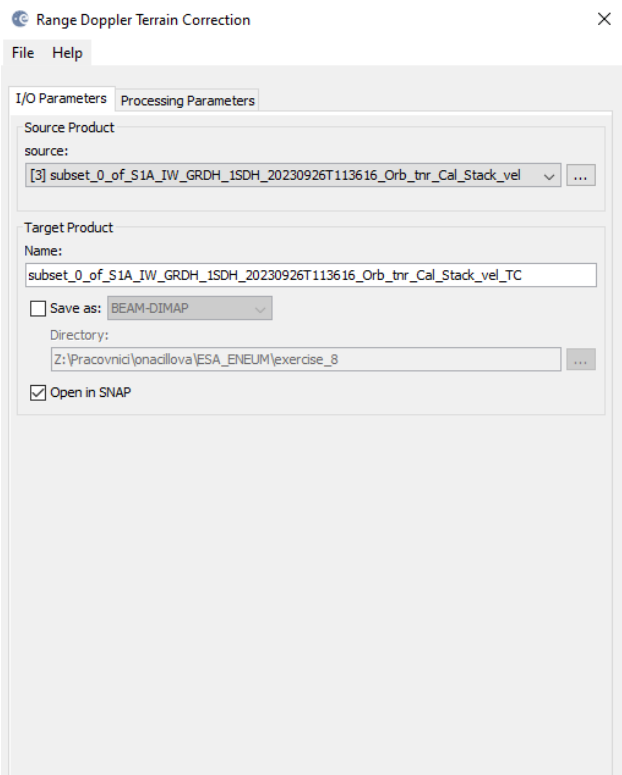
Peterman Glacier velocity vectors. Contains modifed Copernicus Sentinel data 2023

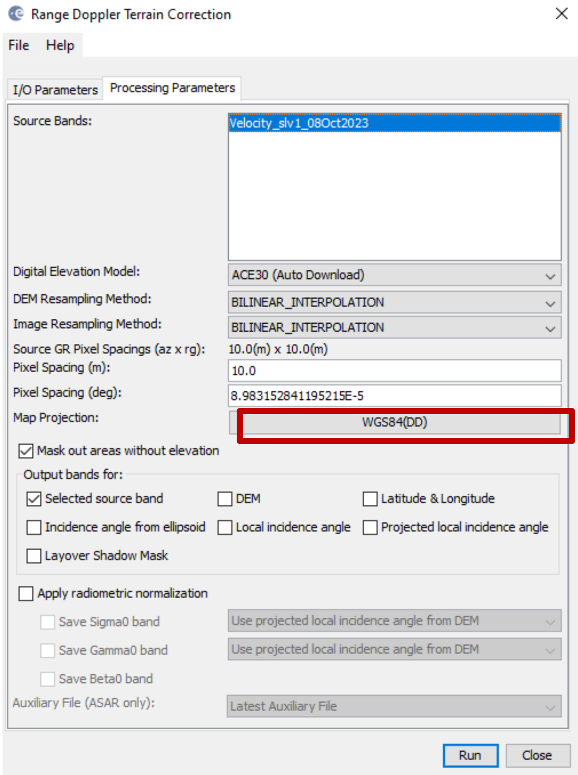
Terrain correction

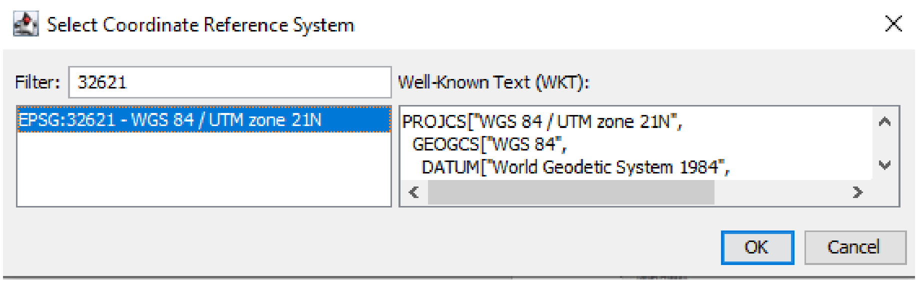
Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. We need to apply Terrain Correction to compensate for the distortions and reproject the scene to geographic projection.

- Navigate to Main Menu: Radar - Geometric - Terrain Correction - Range-Doppler Terrain Correction
- In the I/O Parameters tab set as "Source Product" the velocity product.
- In "Target Product", keep the default name and set the Directory
- In the Processing Parameters tab set:
- Digital Elevation Model: ACE30 (Auto Download)
- Map Projection: Click on the tab next to Map projection (WGS84(DD) – select Predefined CRS and click on "Select". In "Filter" search for 32621 (EPSG: 32621 – WGS84 / UTM Zone 21N) and when you find it click OK to both windows.

Keep defaults values for the other parameters. Click Run. Approximate processing time: 2.5 minutes.



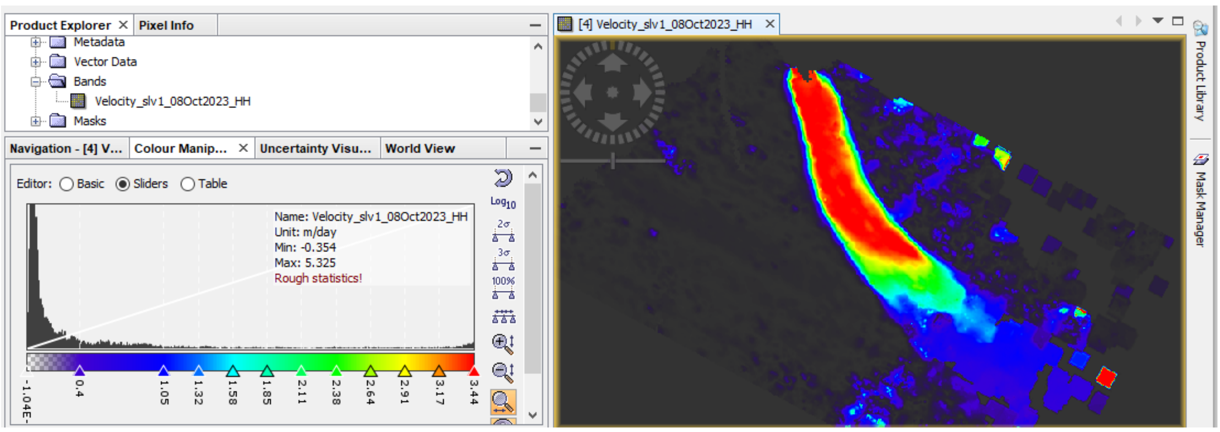




Visualize

Close Range Doppler Terrain Correction window. Let's open the terrain corrected velocity. Expand the new georeferenced product and open the Velocity_slv1_08Oct2023_HH band by double click on it in View window.

We can stretch the histogram a little in the Colour Manipulation tab (move the white slider on the right, to approx. 0.45).



THANK YOU FOR FOLLOWING THE EXERCISE!