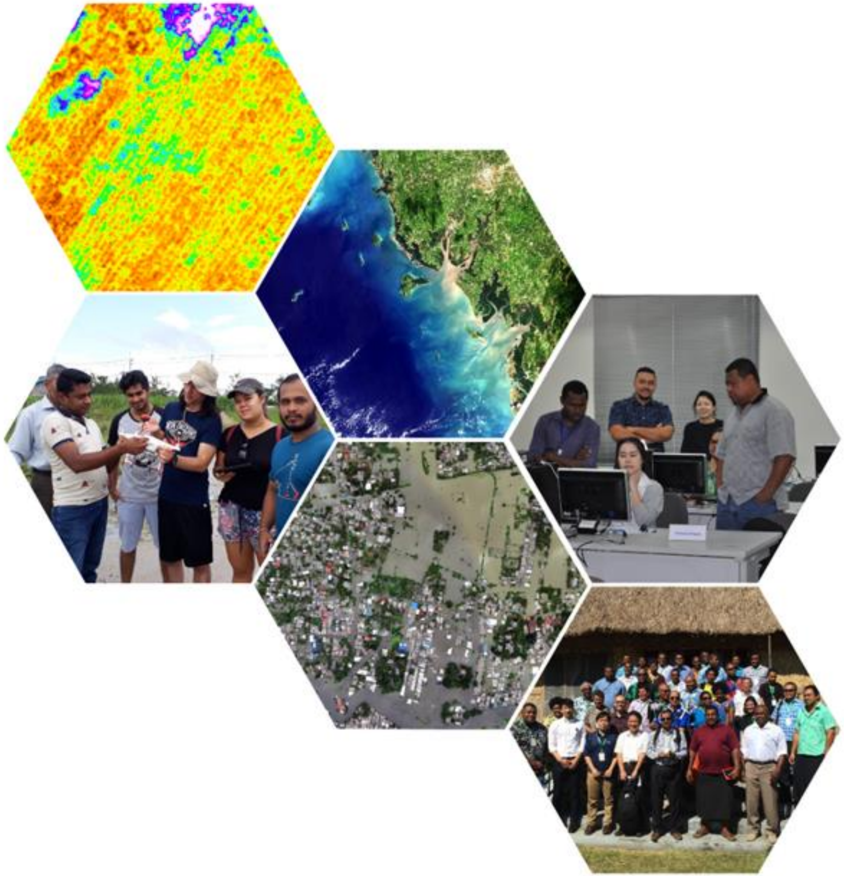


Glacier Velocity Mapping

Geoinformatics Center - AIT

Overview

About Glacier Velocity

Glacier velocity is a vital part of glacier monitoring and understanding of the glacier system dynamics as well as providing valuable insights into changes in climate conditions.

Two methods are commonly used to derive the speed of the ice flow from the satellite data:

1) SAR interferometry;
2) feature/speckle tracking (optical/SAR data) between consecutive acquisitions.

In this tutorial we will use the second method applied to Sentinel-1 data.

Overview

Data and Software

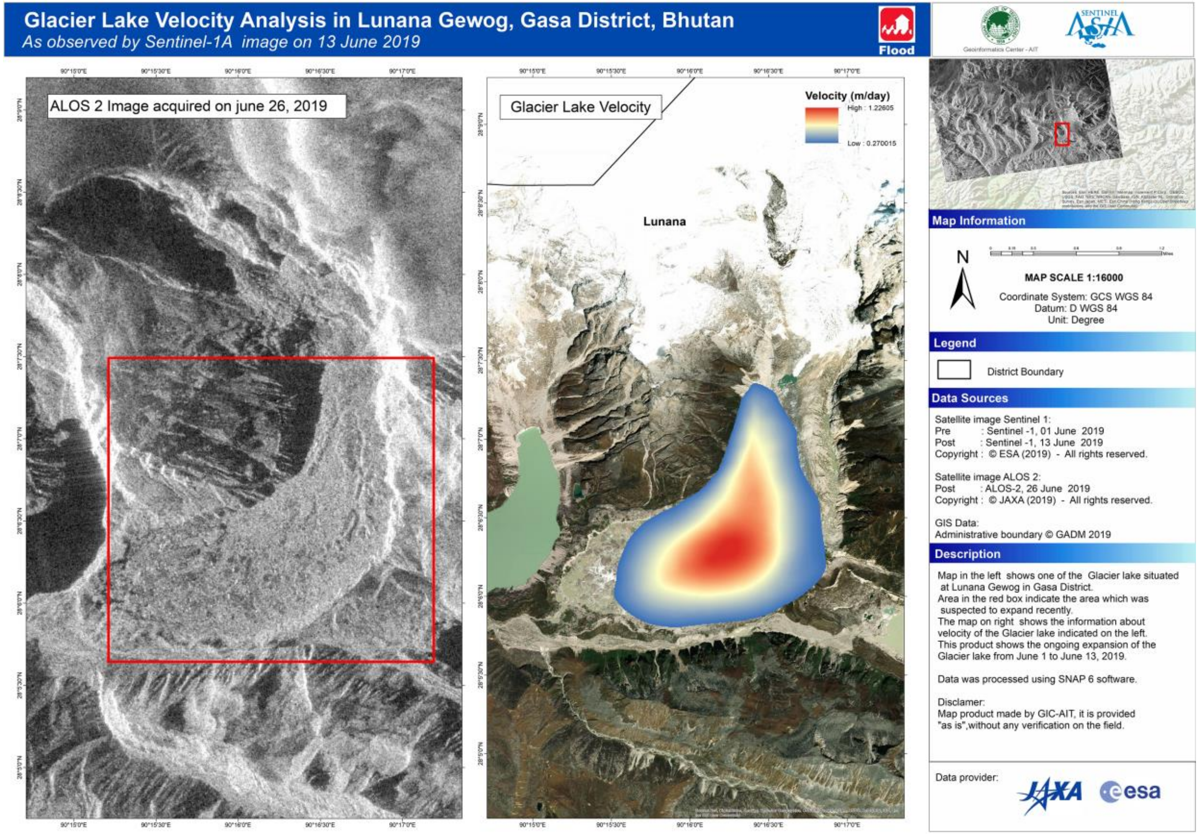
In this exercise, you will work with SNAP software to calculate glacier velocity in Thorthomi Tsho from a pair of Sentinel-1 data. QGIS will also be used to visualize the output.

Data:

- Sentinel-1 GRDH on 01 June 2019: S1A_IW_GRDH_1SDV_20190601T120532_20190601T120557_027486_0319F2_B634.SAFE
- Sentinel-1 GRDH on 13 June 2019: S1A_IW_GRDH_1SDV_20190613T120532_20190613T120557_027661_031F43_196F.SAFE

Overview

Sentinel Asia activation in Bhutan

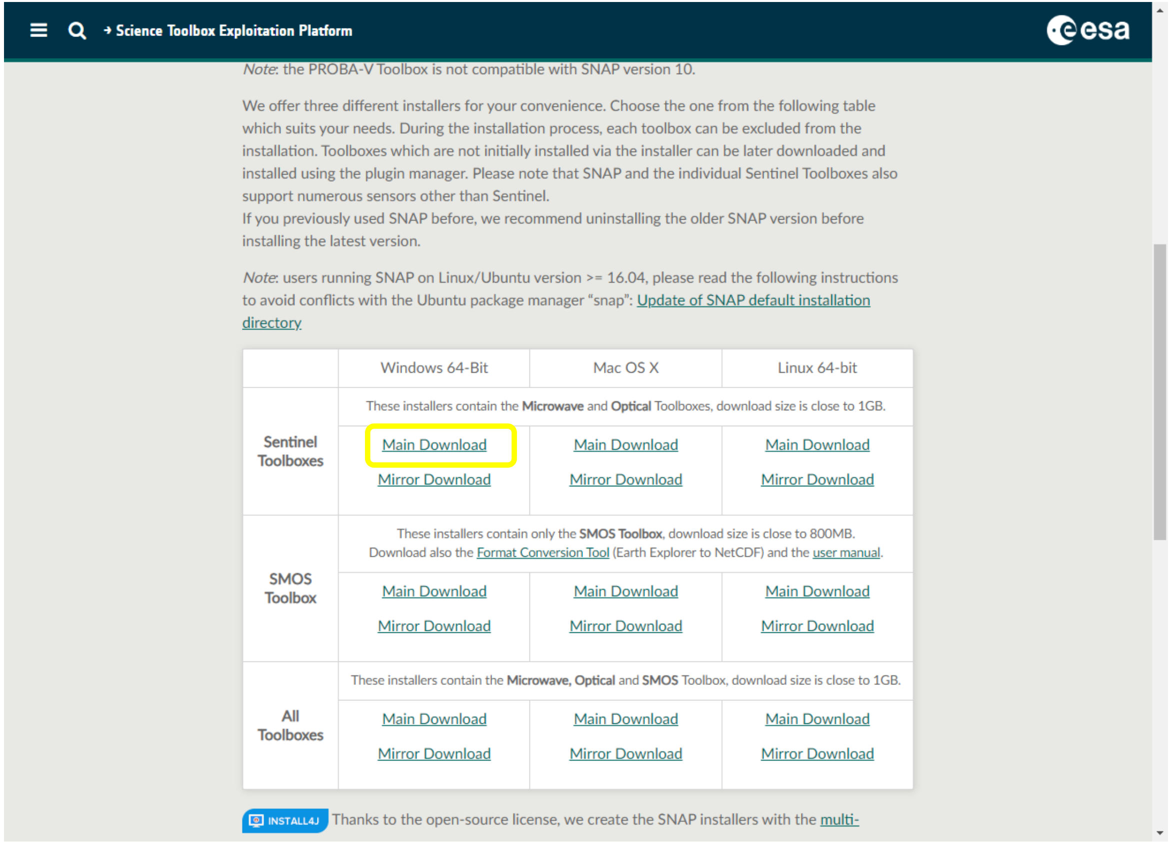


Bhutan Glacier Lake Breach Flood

- Occurrence Date (UTC): 20 June 2019
- SA activation Date(UTC): 22 June 2019
- Requester: Ministry of Home and Cultural Affairs - Bhutan (MOHCA) National Center for Hydrology and Meterology (NCHM)

Overview

SNAP software



Science Toolbox Exploitation Platform

esa

Note: the PROBA-V Toolbox is not compatible with SNAP version 10.

We offer three different installers for your convenience. Choose the one from the following table which suits your needs. During the installation process, each toolbox can be excluded from the installation. Toolboxes which are not initially installed via the installer can be later downloaded and installed using the plugin manager. Please note that SNAP and the individual Sentinel Toolboxes also support numerous sensors other than Sentinel.
If you previously used SNAP before, we recommend uninstalling the older SNAP version before installing the latest version.

Note: users running SNAP on Linux/Ubuntu version >= 16.04, please read the following instructions to avoid conflicts with the Ubuntu package manager “snap”: Update of SNAP default installation directory

	Windows 64-Bit	Mac OS X	Linux 64-bit
Sentinel Toolboxes	These installers contain the **Microwave** and **Optical** Toolboxes, download size is close to 1GB.		
	Main Download Mirror Download	Main Download Mirror Download	Main Download Mirror Download
SMOS Toolbox	These installers contain only the **SMOS Toolbox**, download size is close to 800MB. Download also the Format Conversion Tool (Earth Explorer to NetCDF) and the user manual.		
	Main Download Mirror Download	Main Download Mirror Download	Main Download Mirror Download
All Toolboxes	These installers contain the **Microwave, Optical** and **SMOS** Toolbox, download size is close to 1GB.		
	Main Download Mirror Download	Main Download Mirror Download	Main Download Mirror Download

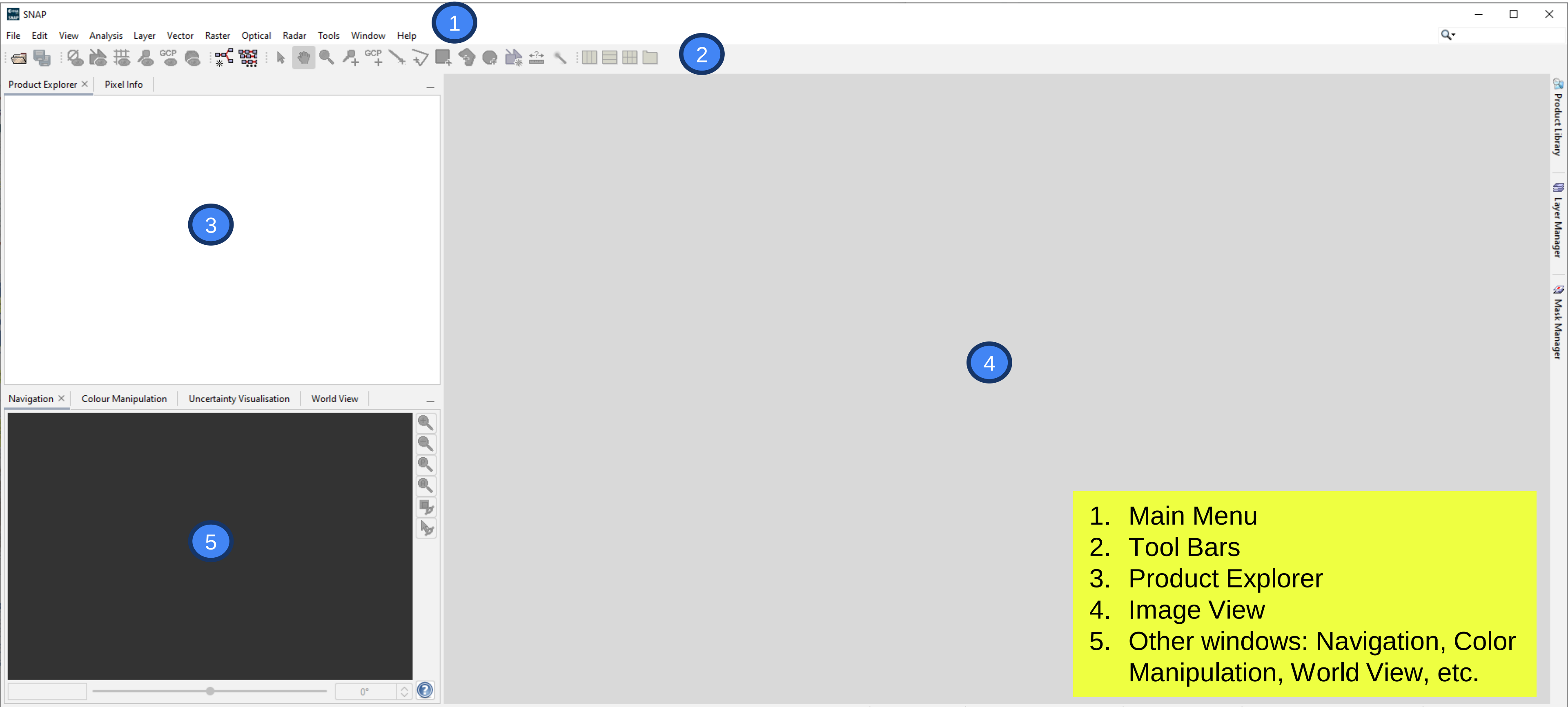
INSTALL4J Thanks to the open-source license, we create the SNAP installers with the multi-

https://step.esa.int/main/download/snap-download/

- The Sentinel Application Platform - or SNAP - in short is a collection of executable tools and Application Programming Interfaces (APIs) which have been developed to facilitate the utilisation, viewing and processing of a variety of remotely sensed data.
- Download the latest SNAP software from ESA. SNAP supports installers for Windows 64-bit, Mac OS X, and Linux 64-bit. **Note**: We’ve downloaded the installer for Windows 64-bit in the training folder.
- Install the software. Use the default configuration.
- Once the installation is finished, update all suggested plugins.

Data Preparation

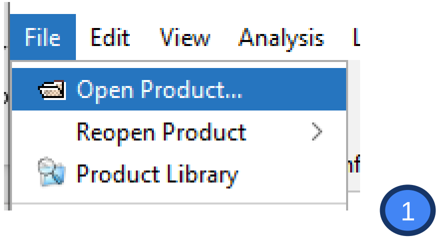
Open SNAP software



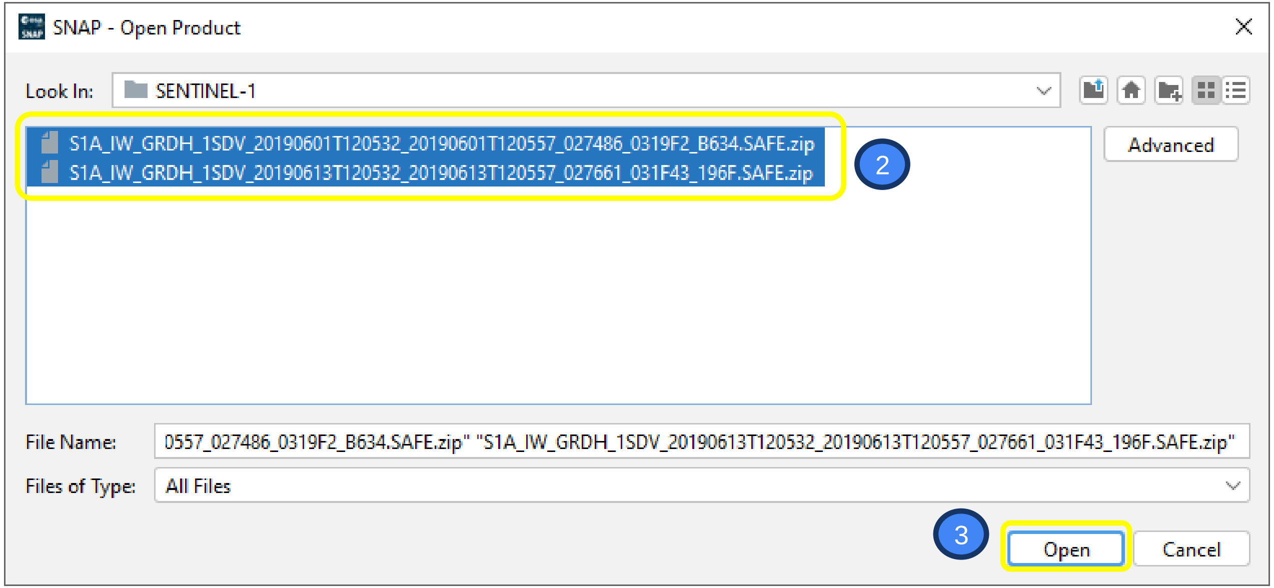
1. Main Menu
2. Tool Bars
3. Product Explorer
4. Image View
5. Other windows: Navigation, Color Manipulation, World View, etc.

Data Preparation

Open Sentinel-1 Data



1. In the Main Menu, go to File → Open Product…

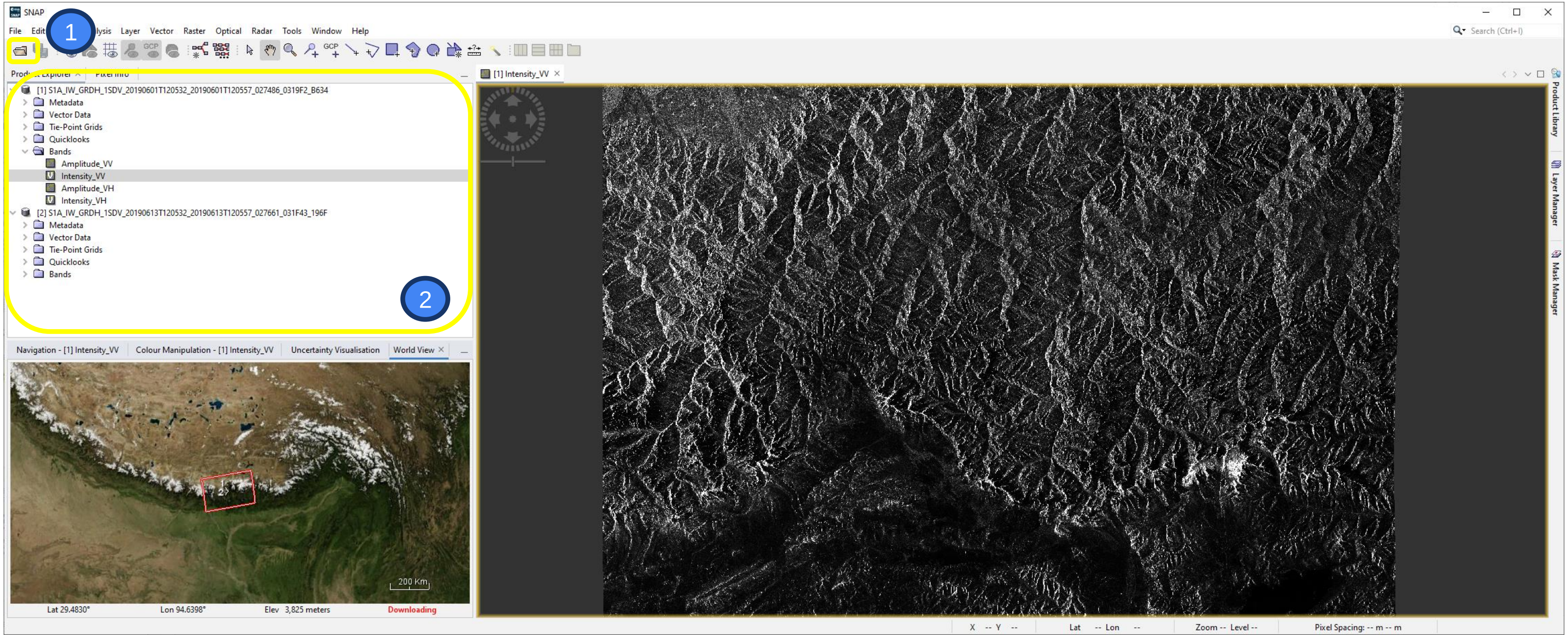


2. Browse to the location of the data. Then select both files of Sentinel-1 data. Each file refers to a different acquisition date.
3. Click Open

Data Preparation

Explore the Sentinel-1 Data

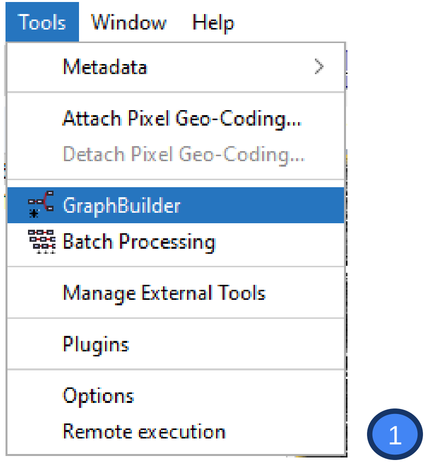
1. Click Open Product and navigate to the data folder. Open both Sentinel-1 data.
2. The opened products will appear in the Product Explorer window. Click > to expand the contents of the product [1], then expand the Bands folder and double-click on the Intensity_VV band to visualize it.



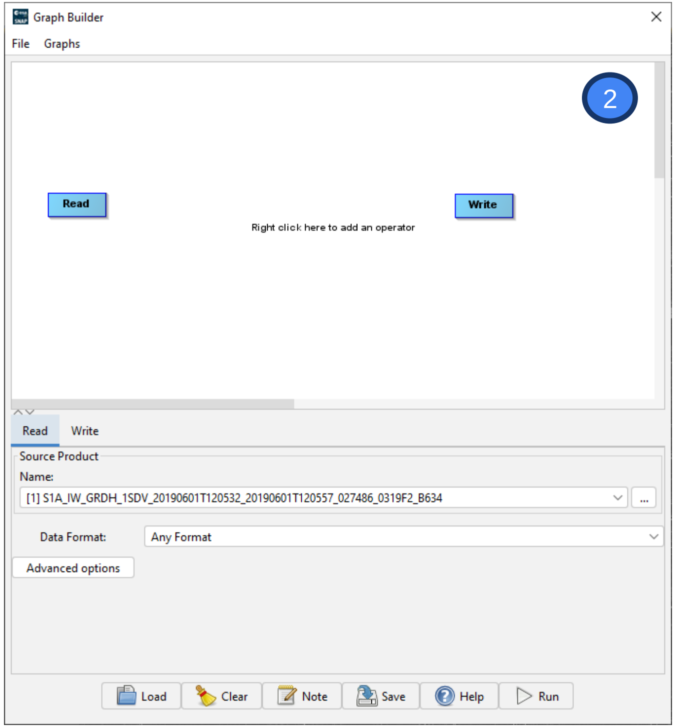
Data Pre-processing

Open Graph Builder

We will use the **Batch Processing** tool available in SNAP to apply all steps to both images in one go (this also saves disk space as only the final product is physically saved).



1. In the Main Menu, go to Tools → GraphBuilder



2. The **Graph Builder** window will show up.

In the beginning, the graph has only two operators: **Read** (to read the input) and **Write** (to write the output). We will create a step-by-step workflow to apply identical pre-processing steps to both of our scenes.

Data Pre-processing

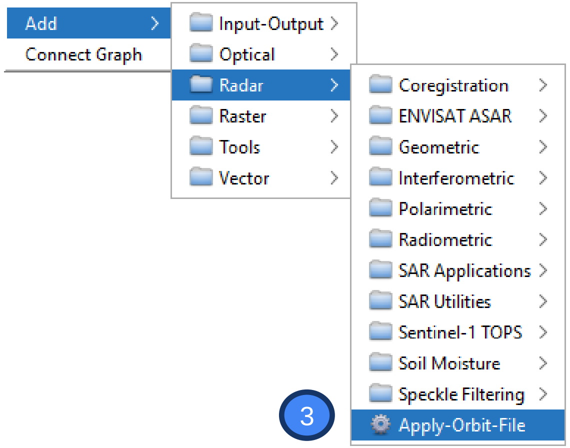
Update the orbit metadata

- The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product.

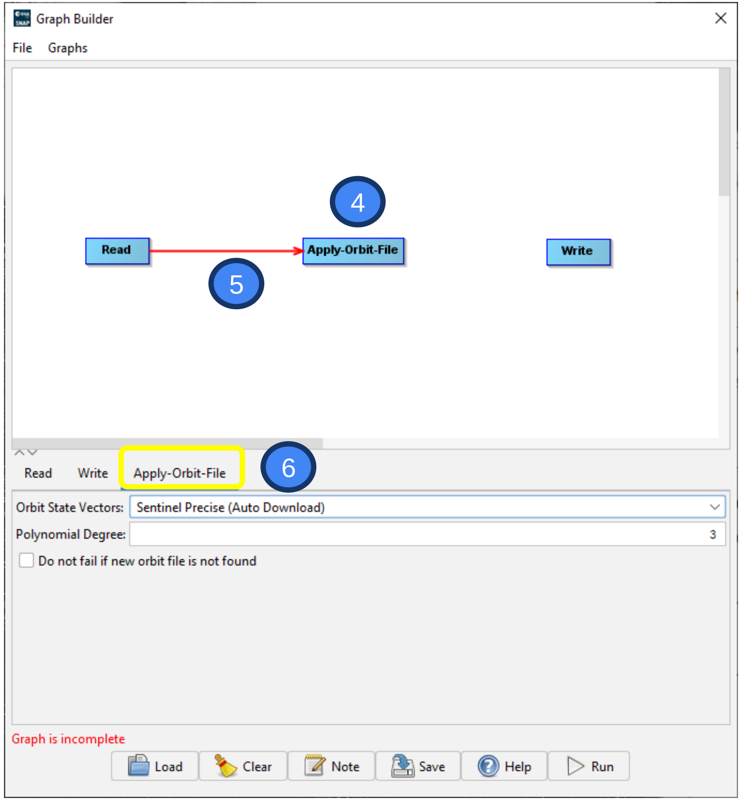
- The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated.

Data Pre-processing

Update the orbit metadata



3. To add the operator right-click the white space between the existing operators and go to Add → Radar → Apply-Orbit-File



4. A new operator rectangle appeared in our graph.
5. Now connect the new **Apply-Orbit-File** operator with the Read operator by clicking to the right side of the Read operator and dragging the red arrow towards the **Apply-Orbit-File** operator.
6. Notice that a new tab also appeared below the graph.

Data Pre-processing

Remove the thermal noise

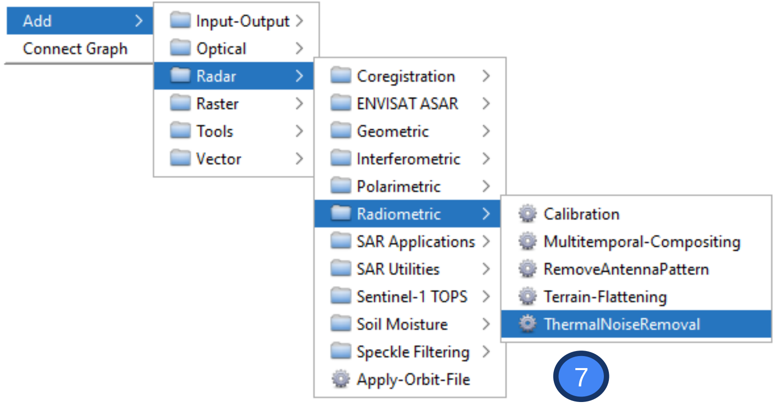
- Thermal noise in SAR imagery is the background energy that is generated by the receiver itself.

- It skews the radar reflectivity to towards higher values and hampers the precision of radar reflectivity estimates.

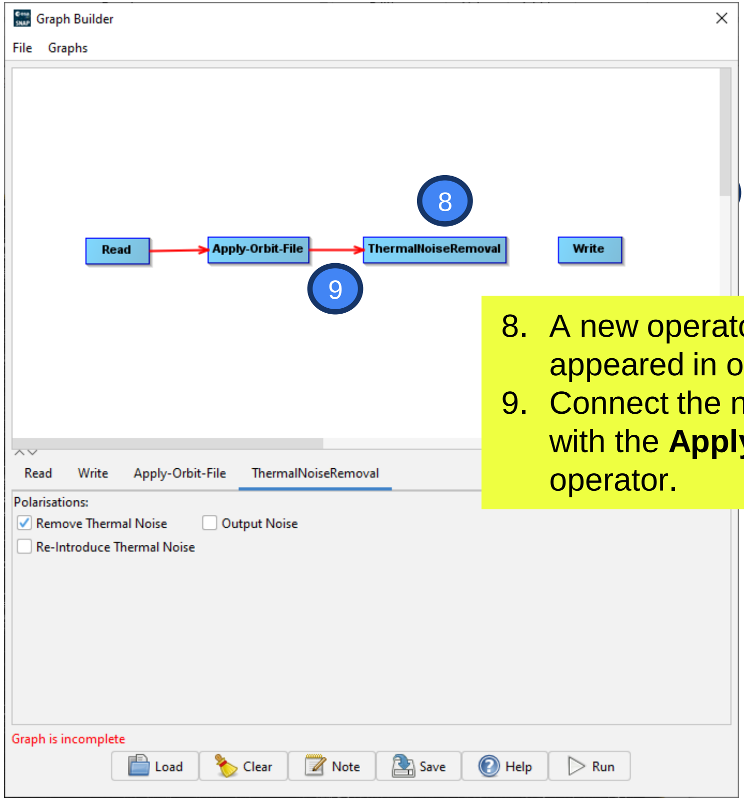
- Level-1 products provide a noise LUT for each measurement dataset, provided in linear power, which can be used to remove the noise from the product.

Data Pre-processing

Remove the thermal noise



7. Right-clicking the white space somewhere and go to to Add → Radar → Radiometric → ThermalNoiseRemoval



8. A new operator rectangle appeared in our graph.
9. Connect the new operator with the **Apply-Orbit-File** operator.

Data Pre-processing

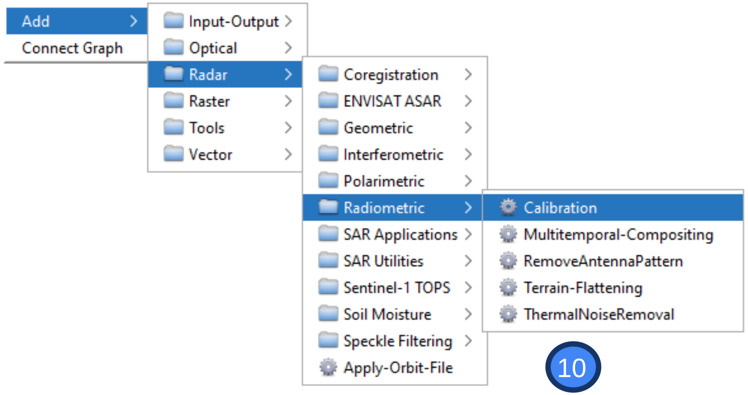
Calibration

- Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains.

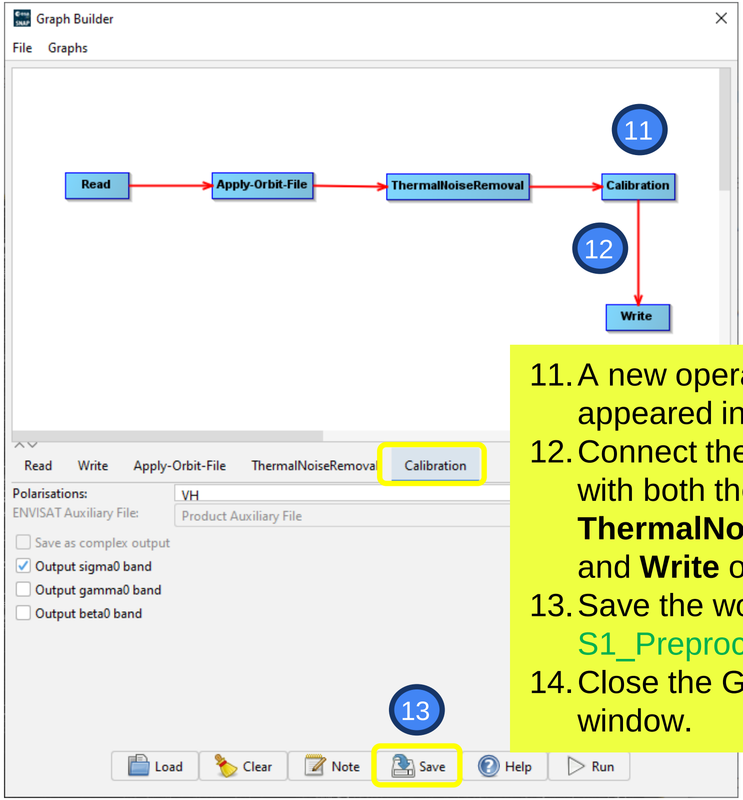
- The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison of SAR images acquired with different sensors or acquired from the same sensor but at different times, in different modes, or processed by different processors.

Data Pre-processing

Calibration



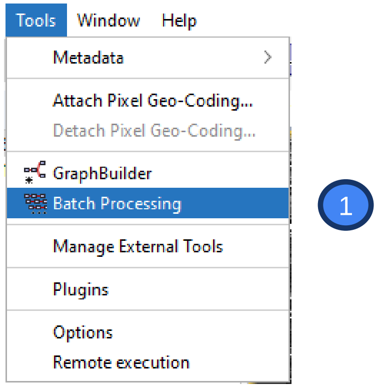
10. Right-clicking the white space somewhere and go to Add → Radar → Radiometric → Calibration



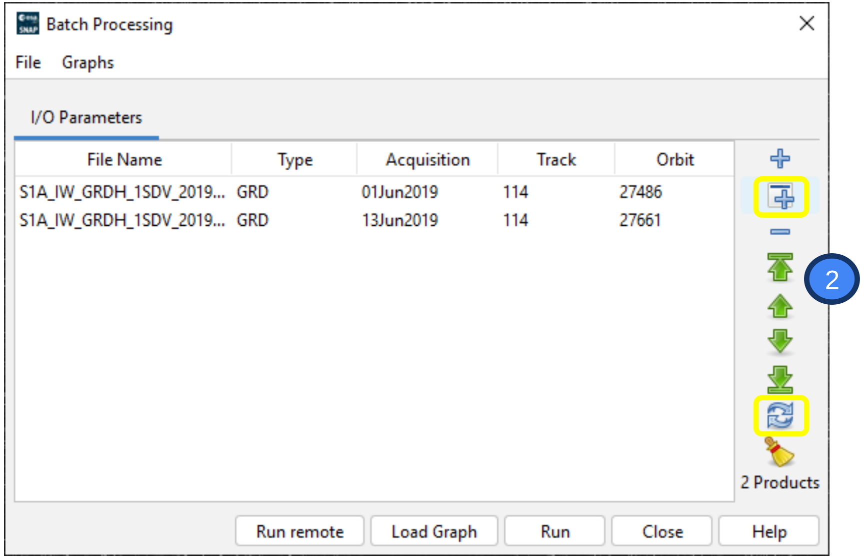
11. A new operator rectangle appeared in our graph.
12. Connect the new operator with both the **ThermalNoiseRemoval** and **Write** operators.
13. Save the workflow to S1_Preprocessing.xml
14. Close the Graph Builder window.

Data Pre-processing

Batch processing



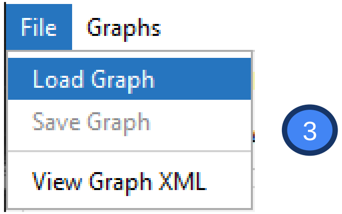
1. In the Product Explorer window, select (highlight) the product [1] (1 June 2019). Open the Batch Processing tool (Tools → Batch Processing).



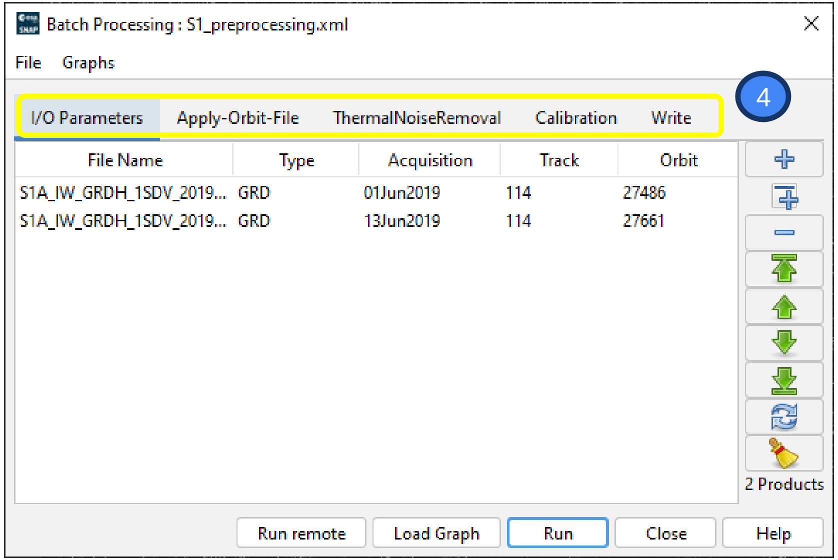
2. We will add both opened products by clicking **Add Opened** in the upper right (the second icon from the top) and then clicking **Refresh** (the second icon from the bottom).

Data Pre-processing

Batch processing



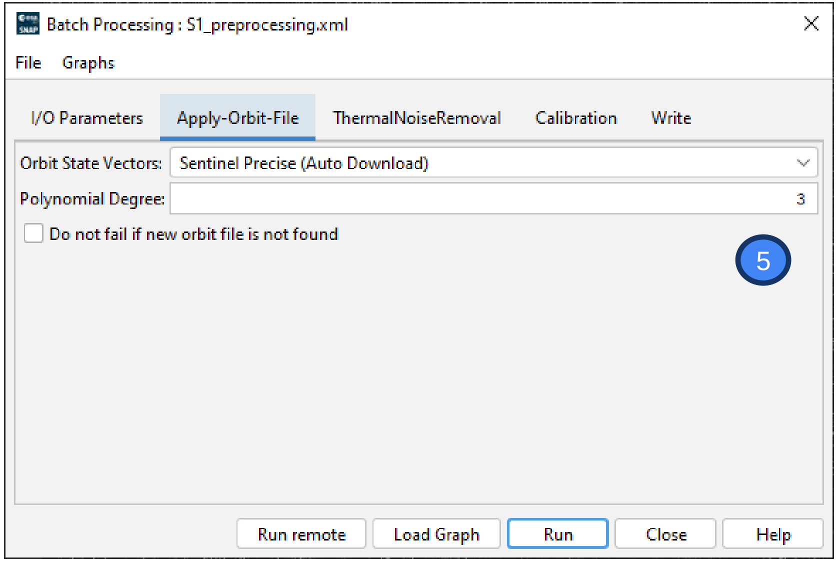
3. In the **Batch Processing** window, click File → Load Graph and navigate to our saved graph (S1_Preprocessing.xml) and open it.

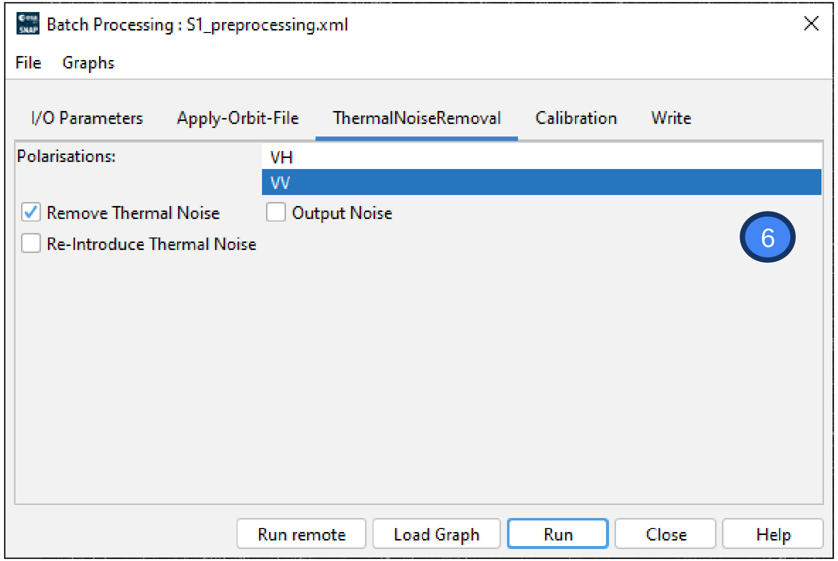


4. We see that new tabs have appeared at the top of the **Batch Processing** window corresponding to our operators. We will change the parameter of each operator in the next steps.

Data Pre-processing

Batch processing



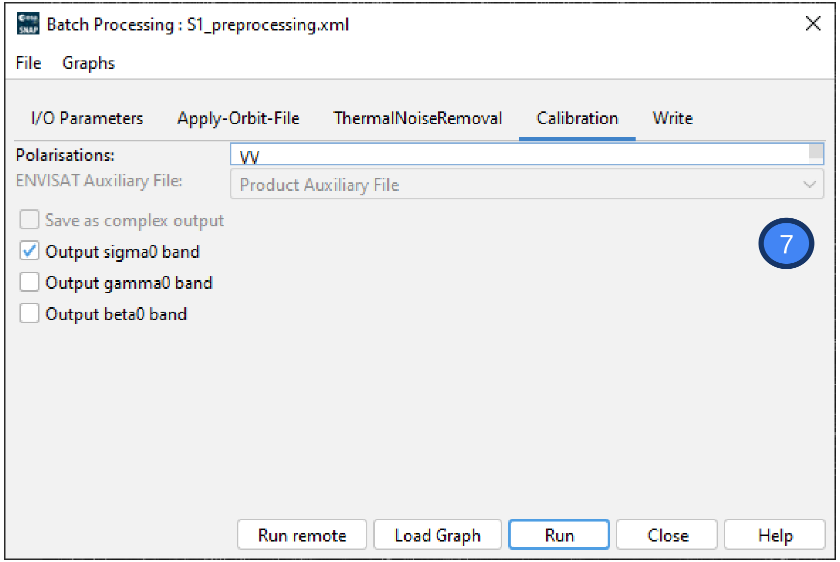


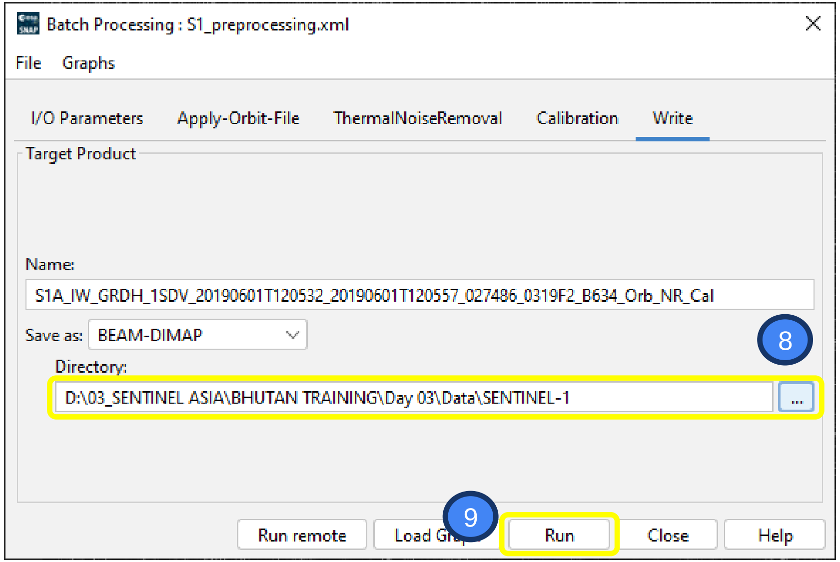
5. In the Apply-Orbit-File tab, accept the default settings.

6. In the ThermalNoiseRemoval tab select VV polarization and make sure that the “Remove Thermal Noise” option is selected.

Data Pre-processing

Batch processing



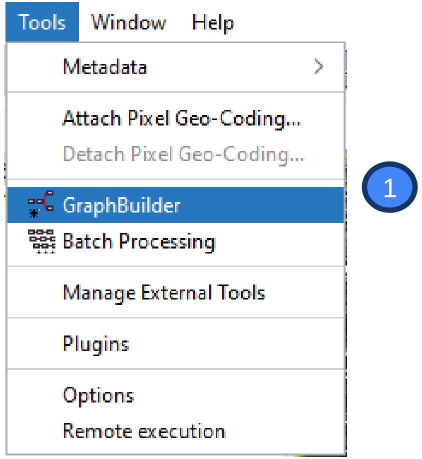


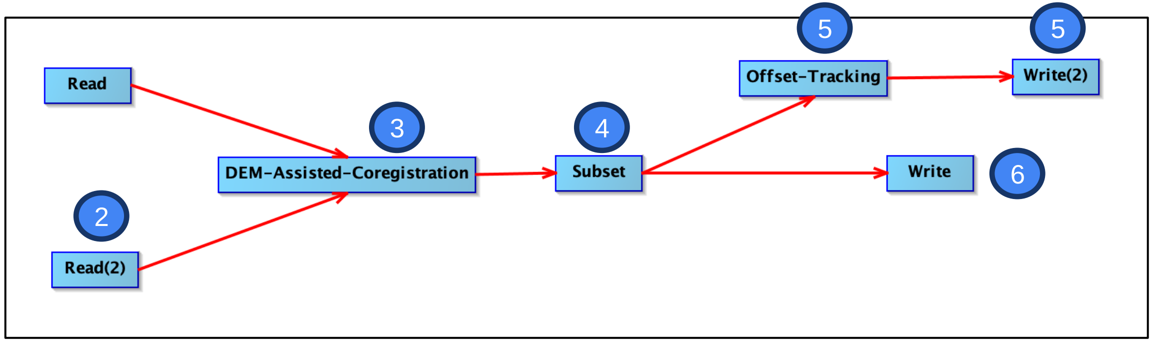
7. In the Calibration tab, accept all default settings.
8. In the Write tab, define your output directory.
9. Click Run. It will take a few seconds or minutes to complete the process.

You should have 2 new products in the Product Explorer window. Close the Batch Processing window.

Data Processing

Open Graph Builder: Coregistration and Offset Tracking



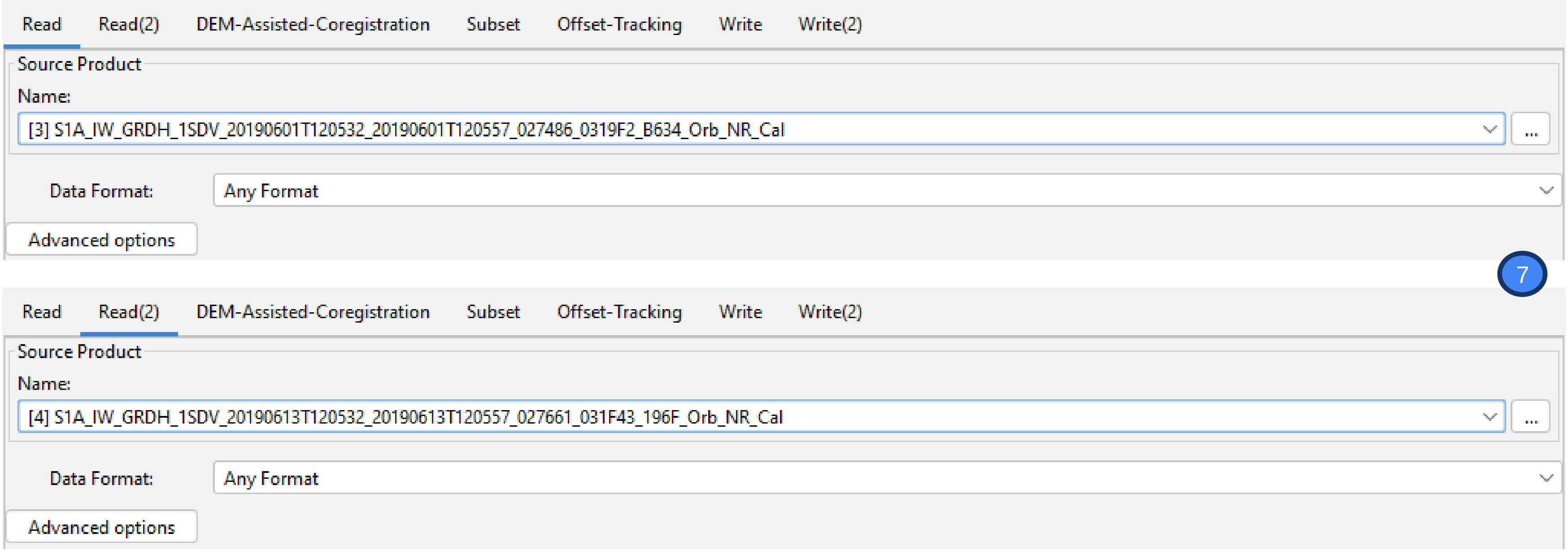


1. In the Main Menu, go to Tools → GraphBuilder

2. First, we need to delete the **Write** operator. Right click on it and select "Delete". Then we need to add a second **Read** operator. Right-click in the white space and go to Add → Input-Output → Read.
3. We will add the **DEM-Assisted Coregistration** operator by going to Add → Radar → Coregistration → DEM-Assisted-Coregistration and connect both **Read** operators to it.
4. Next, we will add the **Subset** operator (Add → Raster → Geometric → Subset) and connect the **DEM-Assisted-Coregistration** operator to it.
5. Since we want to continue to Offset Tracking and save this subset separately as well, we will add the **Offset-Tracking** operator (Add → Radar → SAR Applications → Offset-Tracking) and the **Write** operator (Add → Input-Output → Write). Connect the **Subset** operator to both **Offset-Tracking** and **Write** operator.
6. Lastly, we will add another **Write** operator (Add → Input-Output → Write) and connect the **Offset-Tracking** operator to it in order to save the final product

Data Processing

Read Data



7. First, let’s go to the first **Read** tab and make sure that the pre-processed product [3] from 1-Jun 2019 is selected as the Source product. Then go to the **Read(2)** tab and set the pre-processed product [4] from 13 Jun 2019 as the Source product.

Data Processing

DEM-assisted coregistration

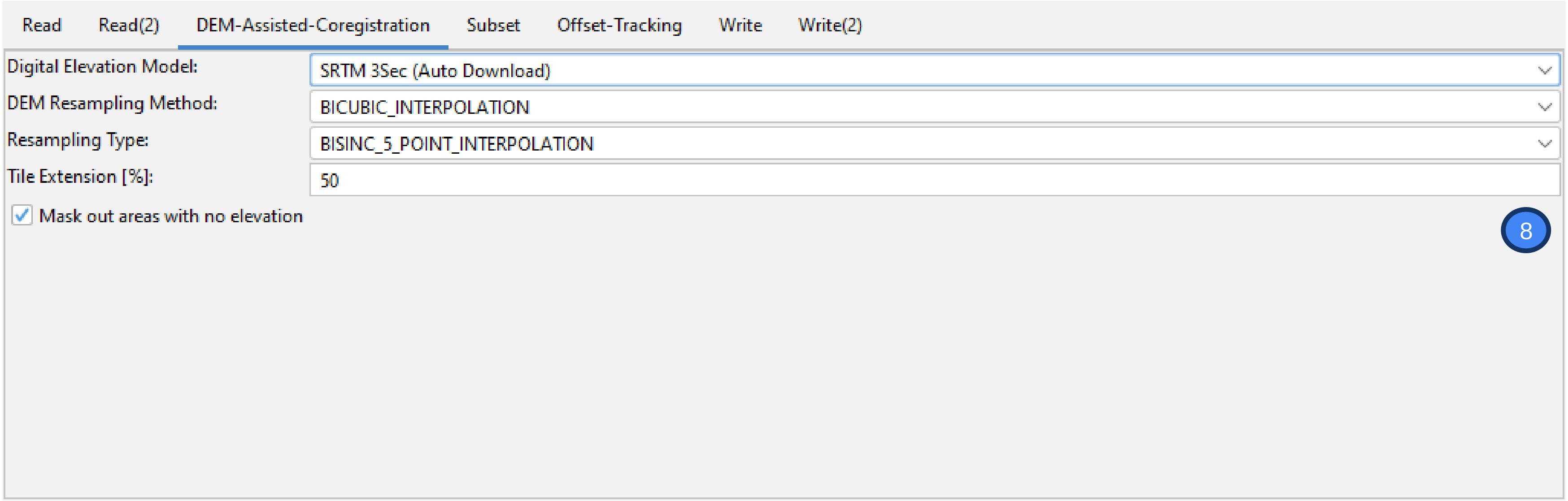
- Image coregistration is the process of geometrically aligning two or more images so that corresponding pixels represent identical area on earth surface.

- It is possible to coregister two or more products using only orbit state vectors, however for the purpose of offset tracking we need more precise coregistration.

- Therefore, we use additional information provided by digital elevation model (DEM).

Data Processing

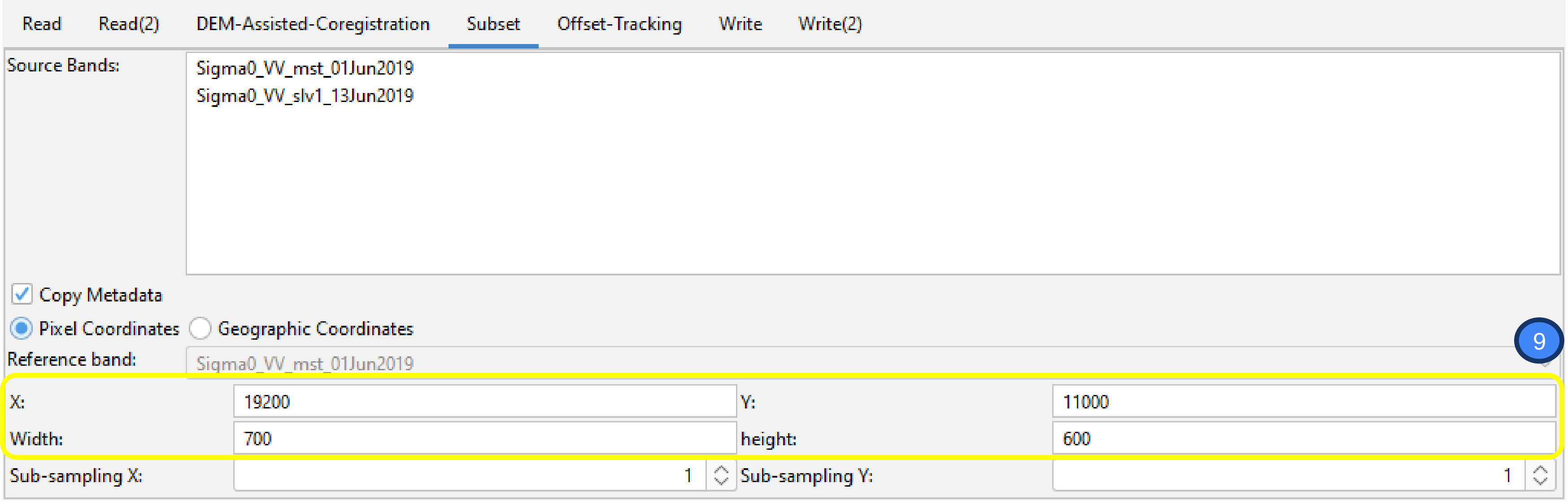
DEM-assisted coregistration



8. Go to the **DEM-Assisted-Coregistration** tab and set “Digital Elevation Model”: SRTM 3Sec (Auto Download)

Data Processing

Subset image



Since our Area of Interest (AOI) is quite small and there is no need to process the whole image, we start with sub-setting the scene to a more manageable size. This will reduce the processing time in further steps and is recommended when the analysis is focused only on a specific area and not on the complete scene.

9. Go to the **Subset** tab and at “Pixel Coordinates” set:

   X = 19200 Y = 11000
   Width = 700 Height = 600

Data Processing

Offset tracking

- Offset Tracking is used to estimate the motion of a feature between two acquisitions through cross-correlation on selected Ground Control Point (GCP) in coregistered images (master and slave) in both slant-range and azimuth direction.

- The movement velocity is then computed based on the offsets estimated by the cross-correlation.

- The velocities computed on the GCP grid are interpolated to create velocity map. It is a method frequently used for glacier motion estimation.

Data Processing

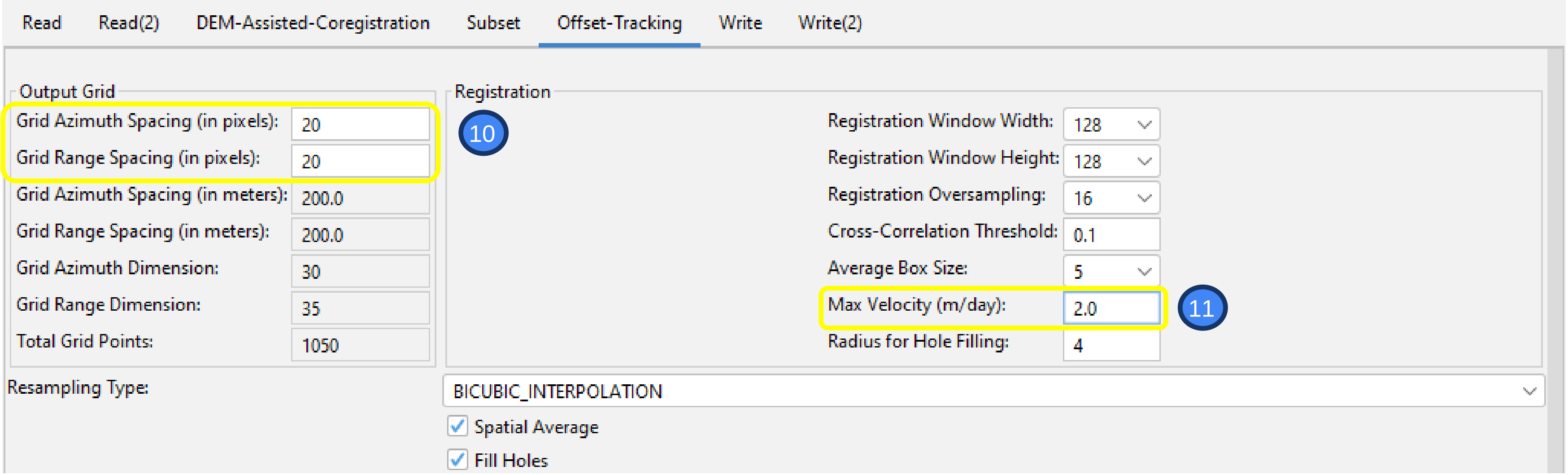
Offset tracking

The Offset Tracking is performed in the following sub-steps (ESA Snap):

- For each point in the user-specified GCP grid in the master image, compute the corresponding pixel position in slave image using normalized cross-correlation.
- If the computed offset between master and slave GCP positions exceeds the maximum offset (computed from user-specified maximum velocity), then the GCP point is marked as outlier.
- Perform local average for the offset on valid GCP points.
- Fill holes caused by the outliers. The offset at the missing point will be replaced by a new offset computed by local weighted average.
- Compute the velocities for all points on the GCP grid from their offsets.
- Finally, compute velocities for all pixels in the master image from the velocities on GCP grid by interpolation (the final product has same pixel size as the input data).

Data Processing

Offset tracking



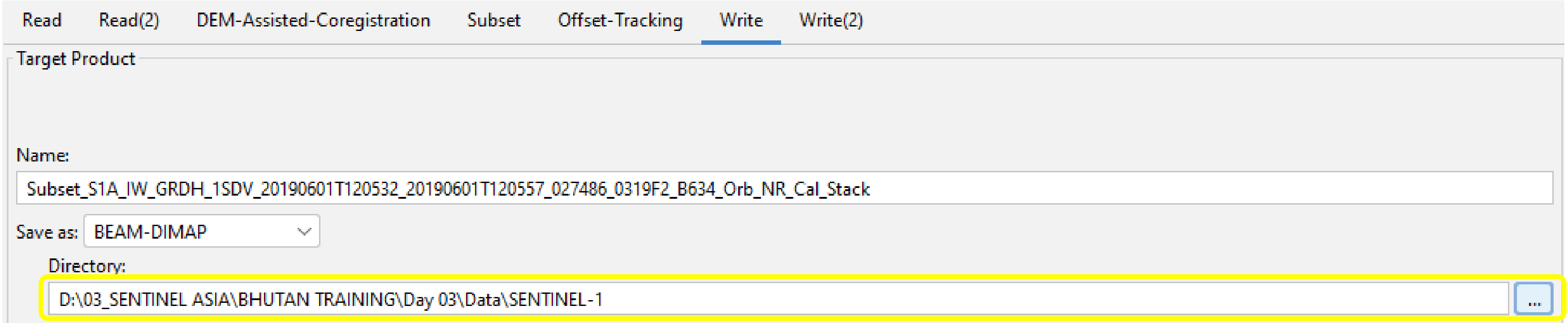
10. In the **Offset-Tracking** tab, we need to set several parameters. First, we need to set the GCP grid spacing in pixels in range and azimuth directions (determines the resolution/level of detail of our velocity product).
    Grid Azimuth Spacing (in pixels): 20
    Grid Range Spacing (in pixels): 20

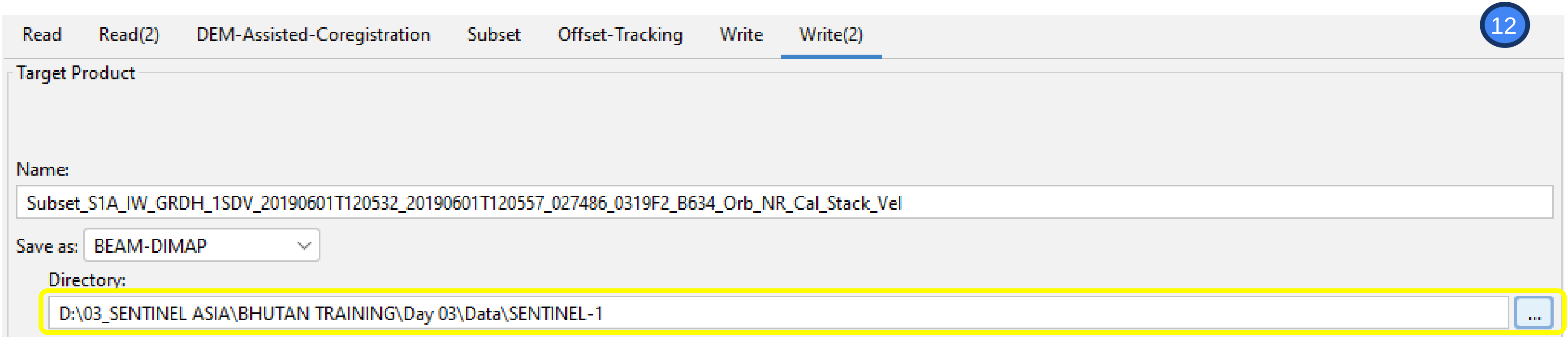
11. Next, we need to set the Registration Window dimensions; the size of the registration window depends on the maximum velocity of the glacier (from the literature of historical data) and the period between the data acquisitions.
    Max Velocity (m/day): 2.0

Data Processing

Write output

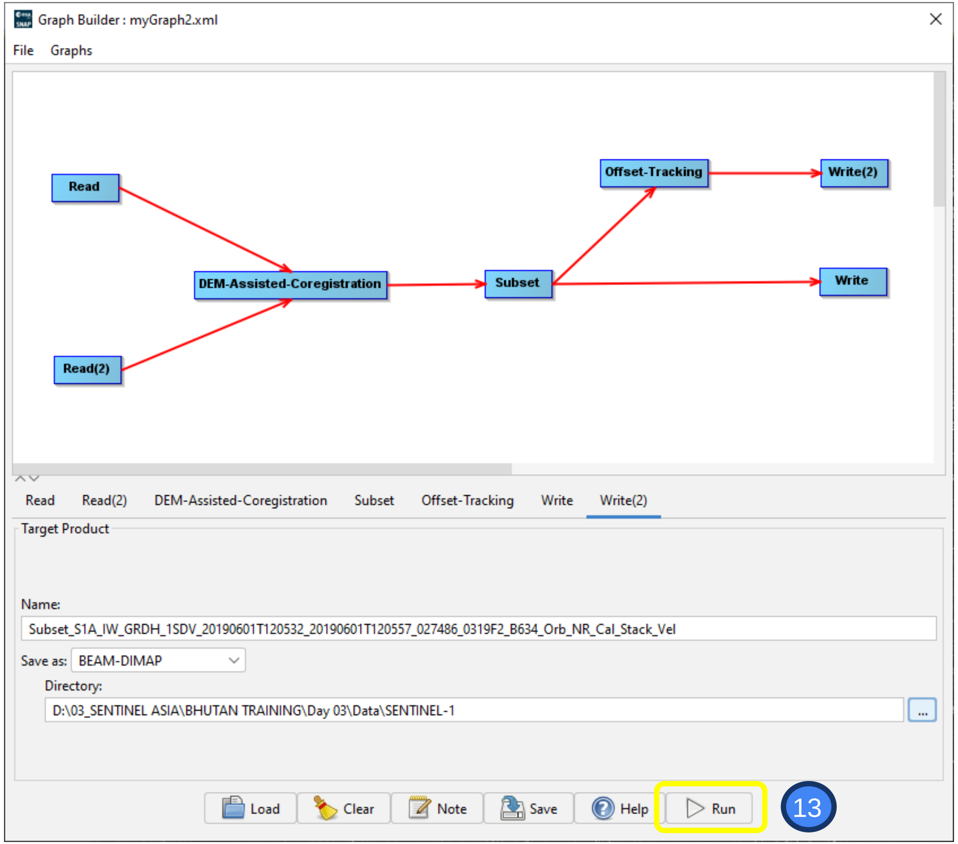
12. In both the Write and Write(2) tabs, define your output directory.





Data Processing

Run the Graph Builder



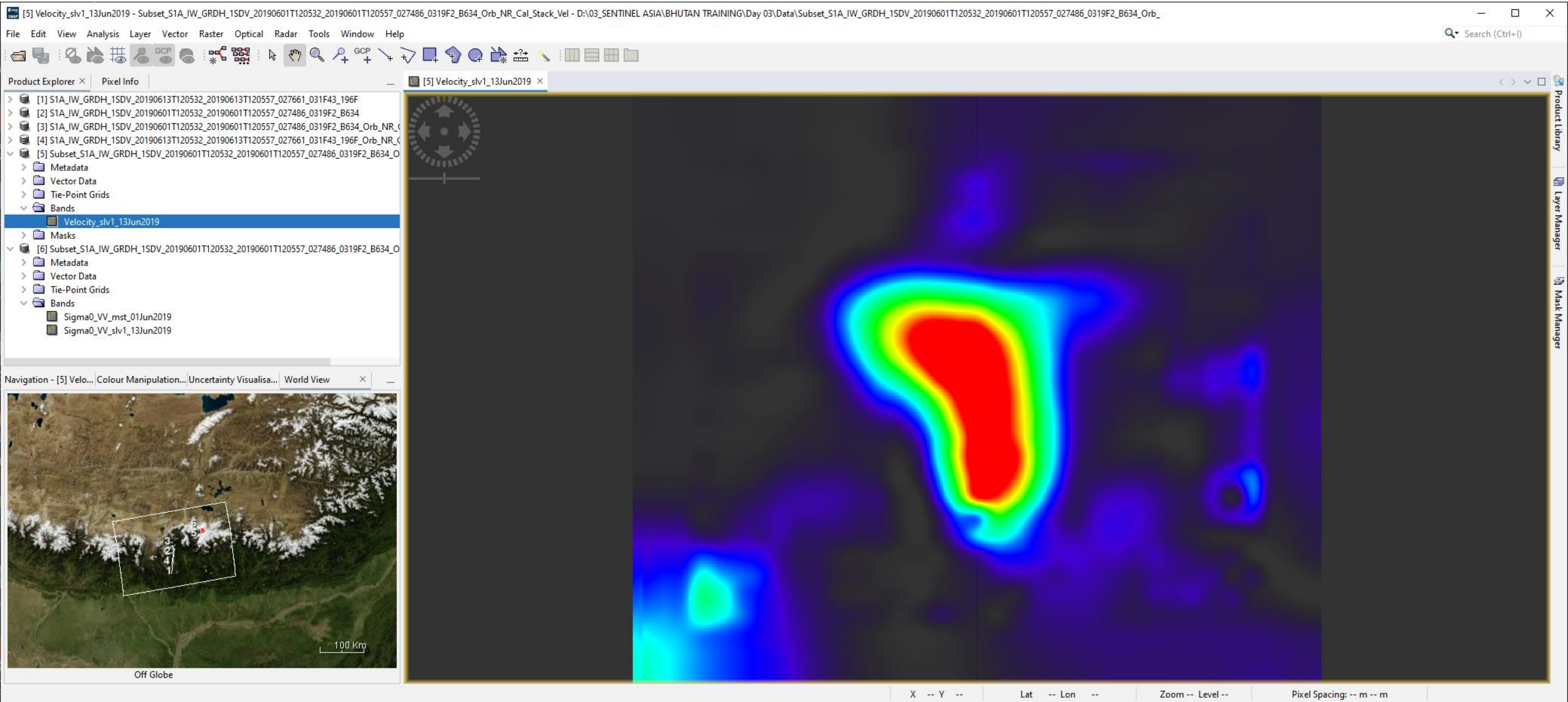
13. Now that all settings are completed. Run the Graph Builder.

Note:
Depending on the version of SNAP that you have, there might be a recurring bug that prevents the Graph Builder from running. In such a case, we've prepared a Graph_offsetTracking_backup.xml file as a workaround.

You must load the .xml file in the Graph Builder and continue to work from there. You may still have to add some operators and modify the parameters as necessary.

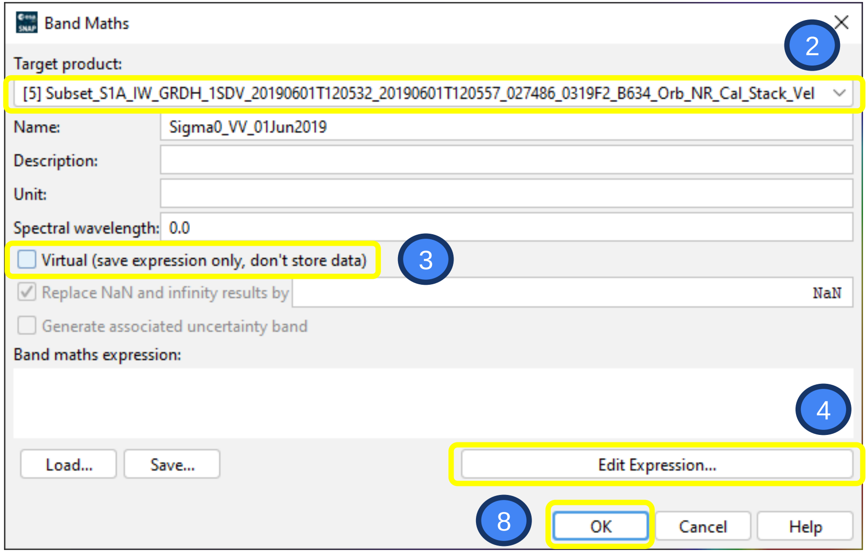
Data Processing

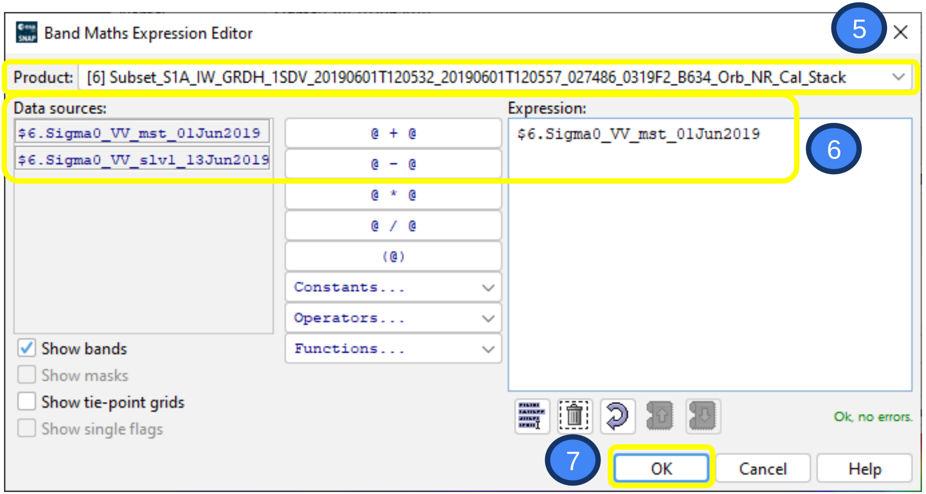
Visualize output: velocity



Data Processing

Stack the products



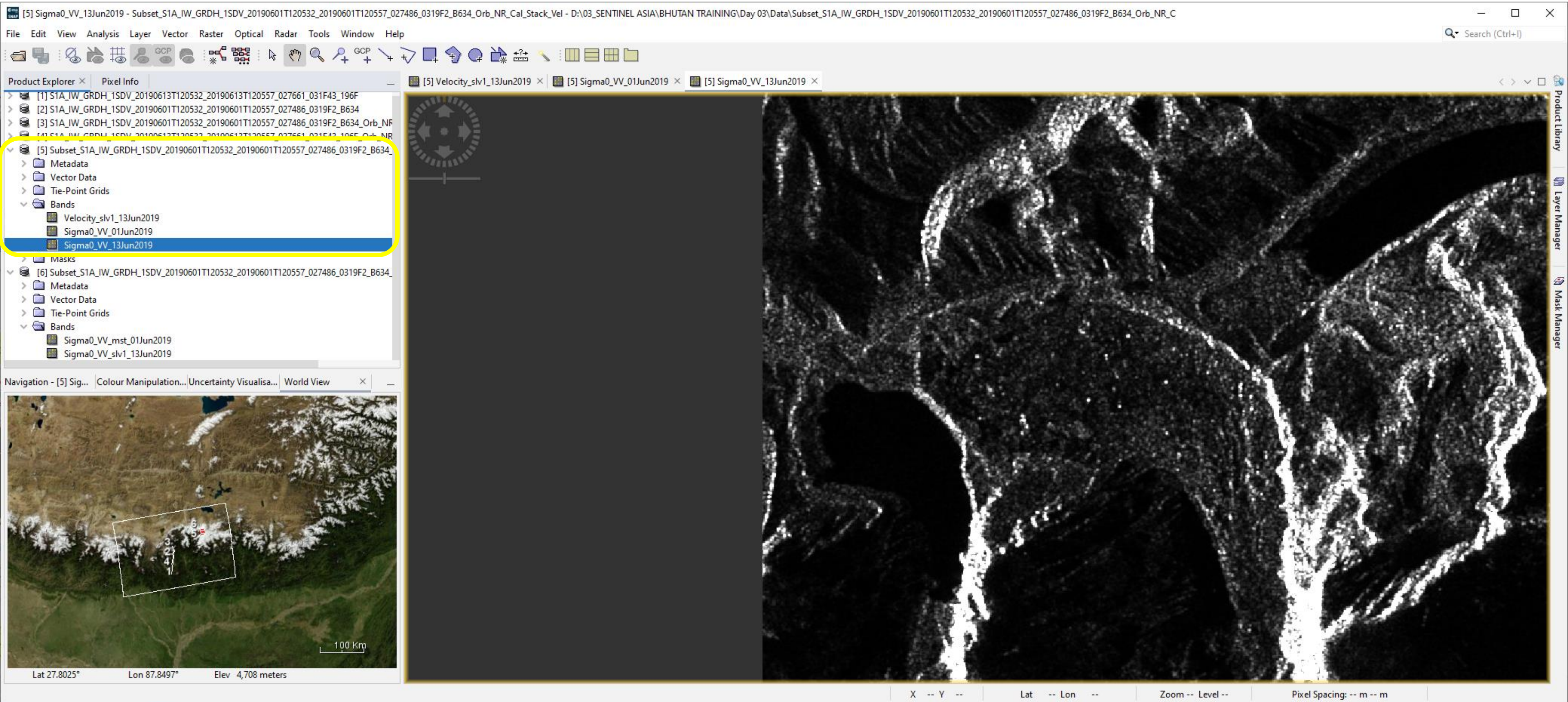


1. Right-click product [5] and open BandMath dialog.
2. Set "Name" to Sigma0_VV_01Jun2019
3. Deselect the Virtual (save expression only, don't store data) option because we want to store the data.

4. Click on the Edit Expression.
5. Set Product to: [6].
6. In Data Sources, click on $6.Sigma0_VV_mst_01Jun2019 band.
7. Click OK in both windows. Repeat the process to add also the second band.

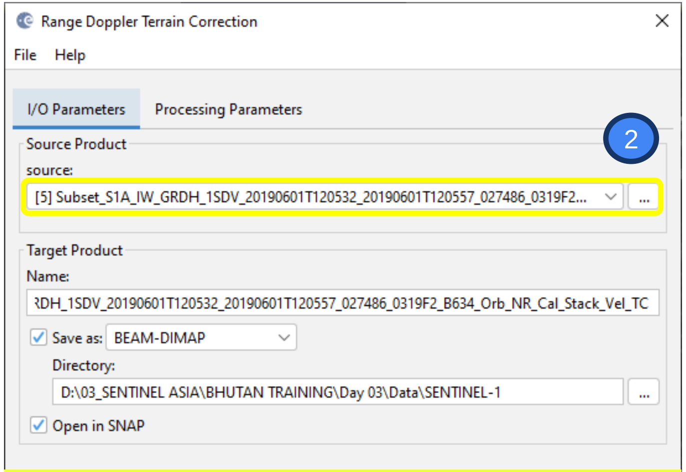
Data Processing

Stack the products (output)

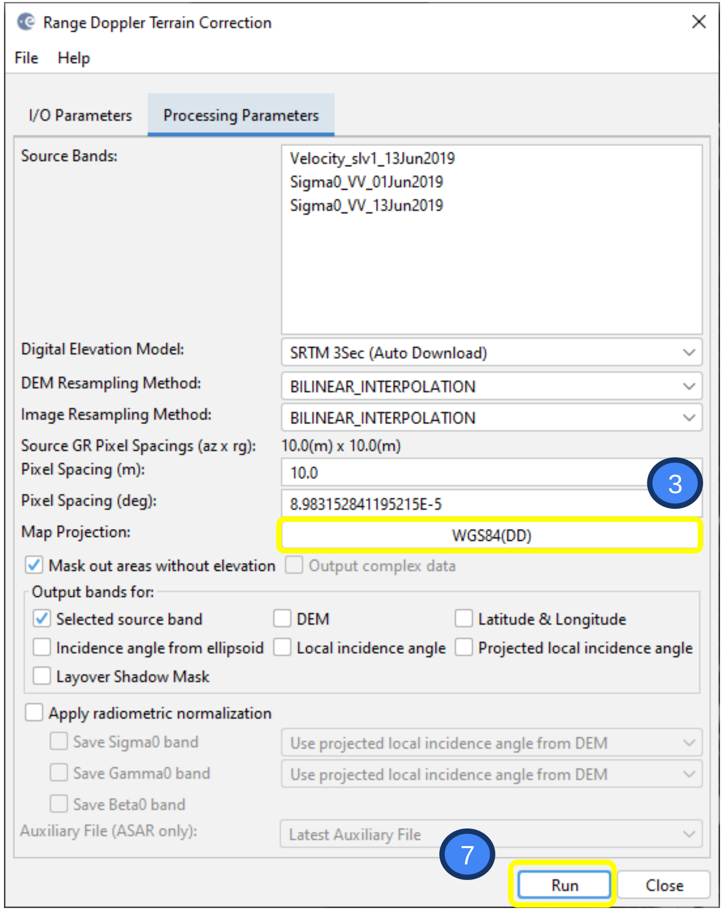


Data Processing

Terrain correction



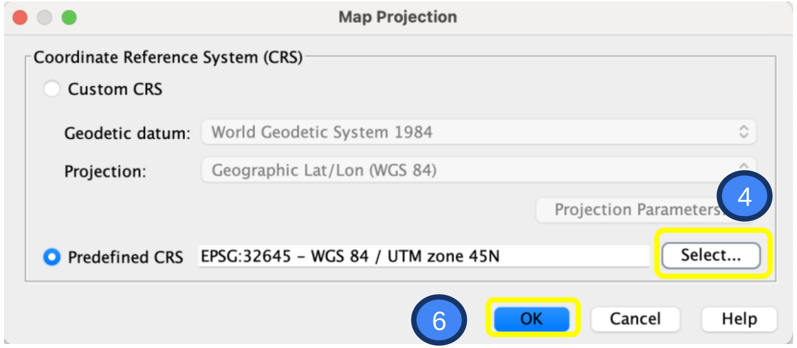
1. Click Radar → Geometric → Terrain Correction → Range-Doppler Terrain Correction
2. In the I/O Parameters tab set as “Source Product” the product [5] (velocity product). Keep the default.

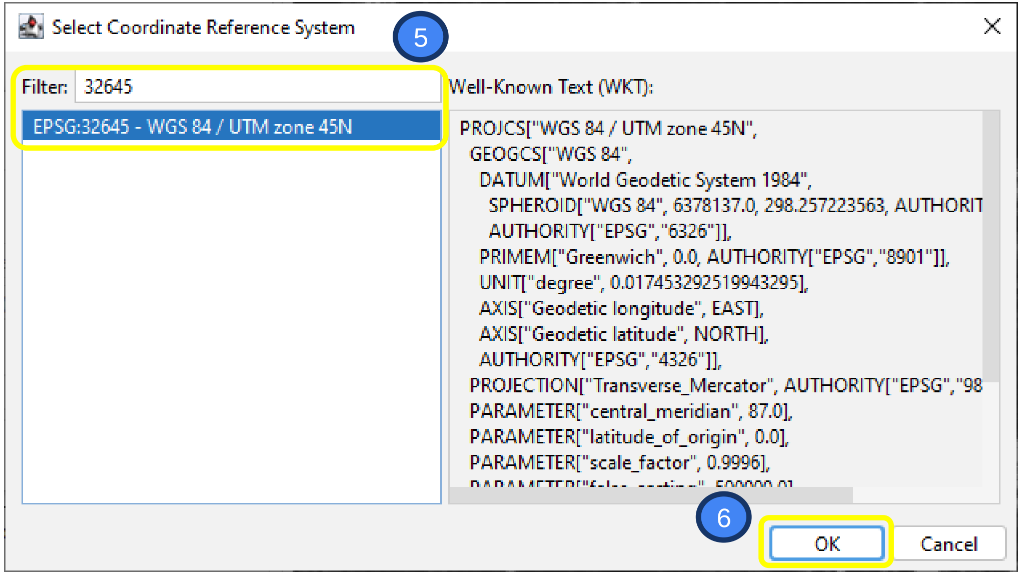


3. In the **Processing Parameters** tab set: Click on Map Projection.

Data Processing

Terrain correction

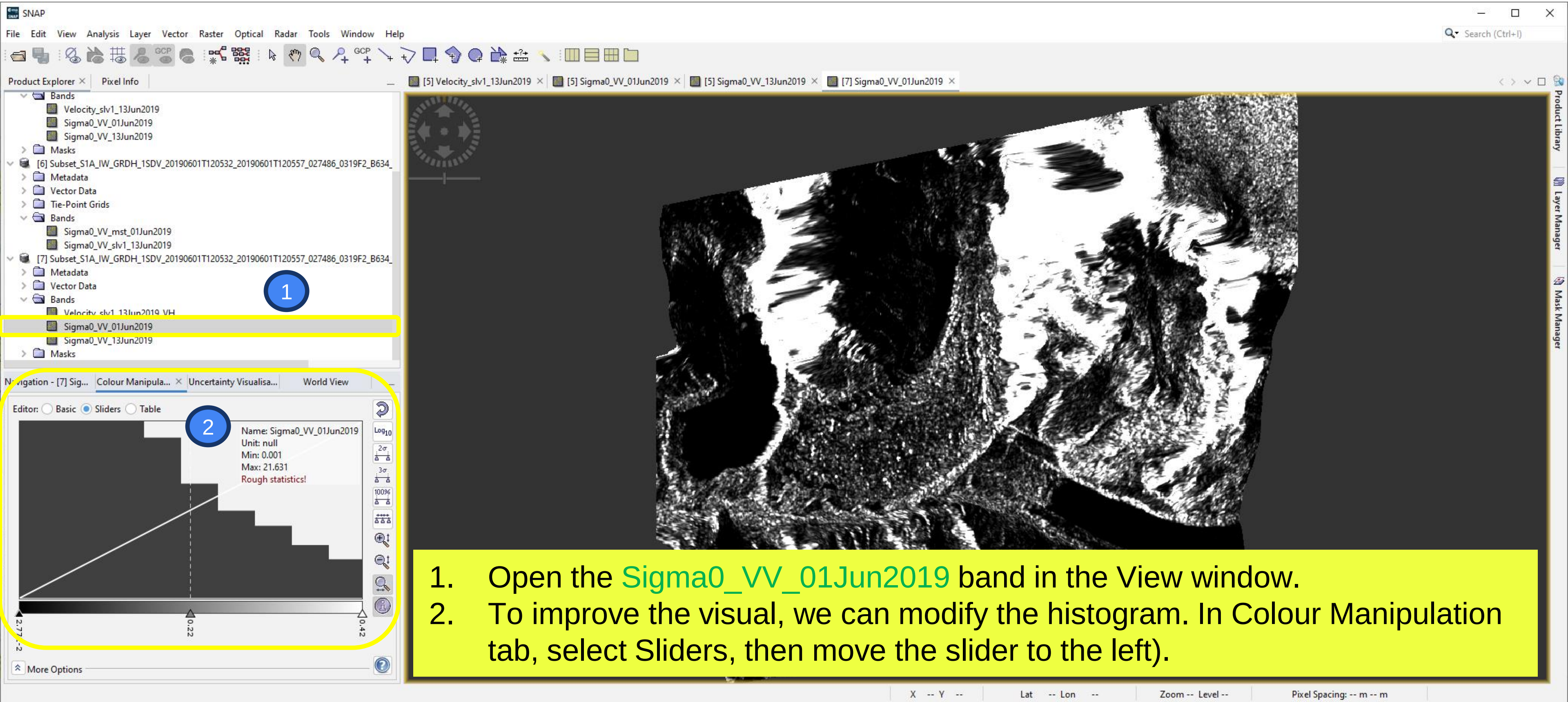




4. In the Map Projection, choose Predefined CRS and click on “Select”.
5. In “Filter” search for 32645 (EPSG: 32645 – WGS84 / UTM Zone 45N)
6. Click OK to both windows.
7. Click Run in **Range Dopler Terrain Correction** window.

Data Processing

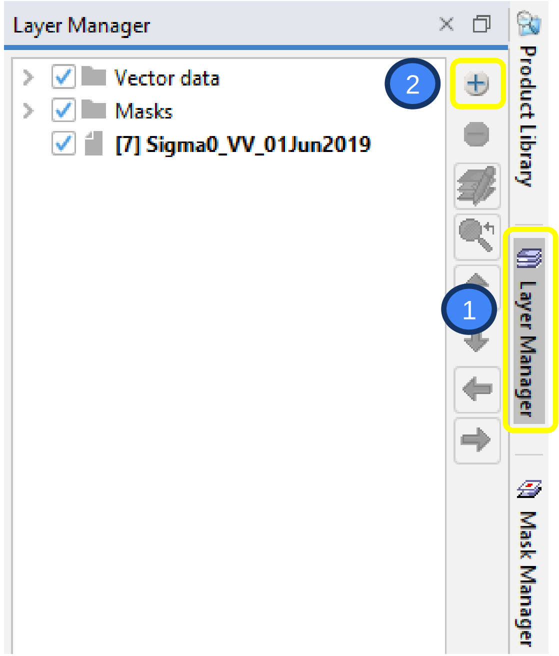
Visualize output: color manipulation

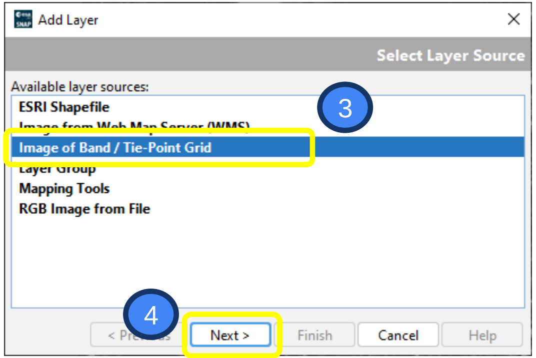


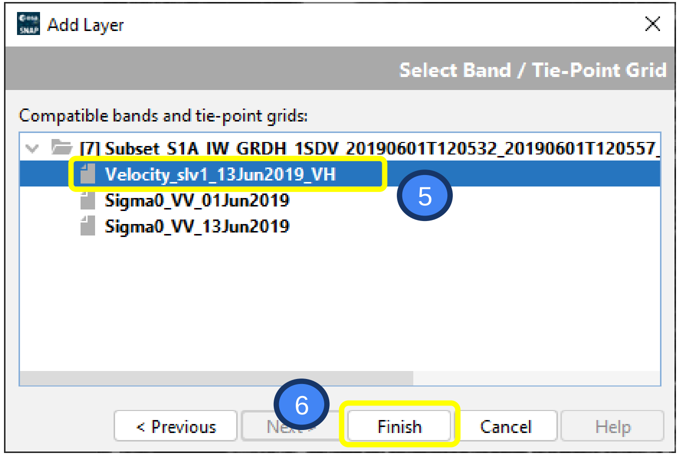
1. Open the Sigma0_VV_01Jun2019 band in the View window.
2. To improve the visual, we can modify the histogram. In Colour Manipulation tab, select Sliders, then move the slider to the left).

Data Processing

Visualize output: overlaying



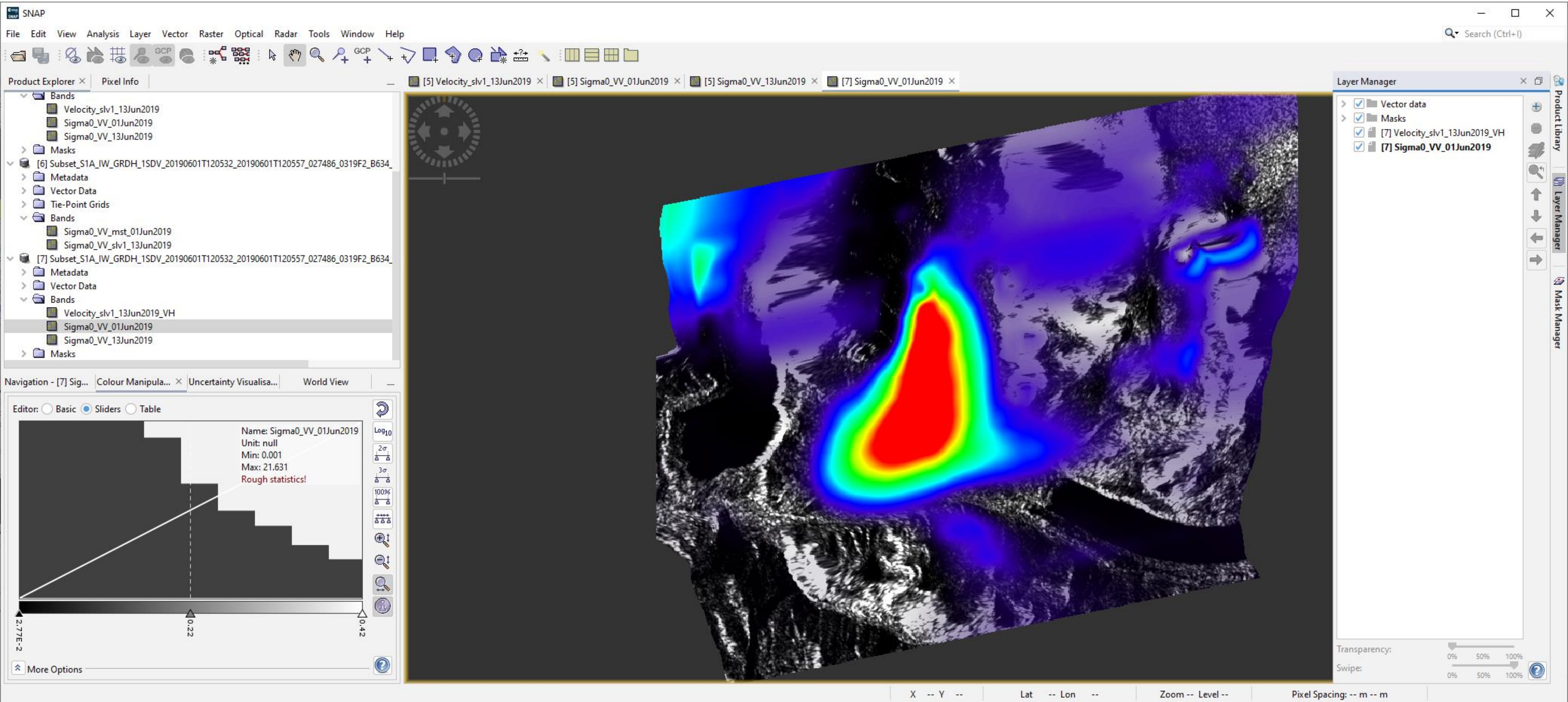




1. Go to the **Layer Manager** in the top right corner.
2. Click on ⊕ to add an overlay layer.
3. Select Image of Band / Tie-Point Grid.
4. Click Next.
5. Select the Velocity_slv1_13Jun2019_VH.
6. Click Finish.

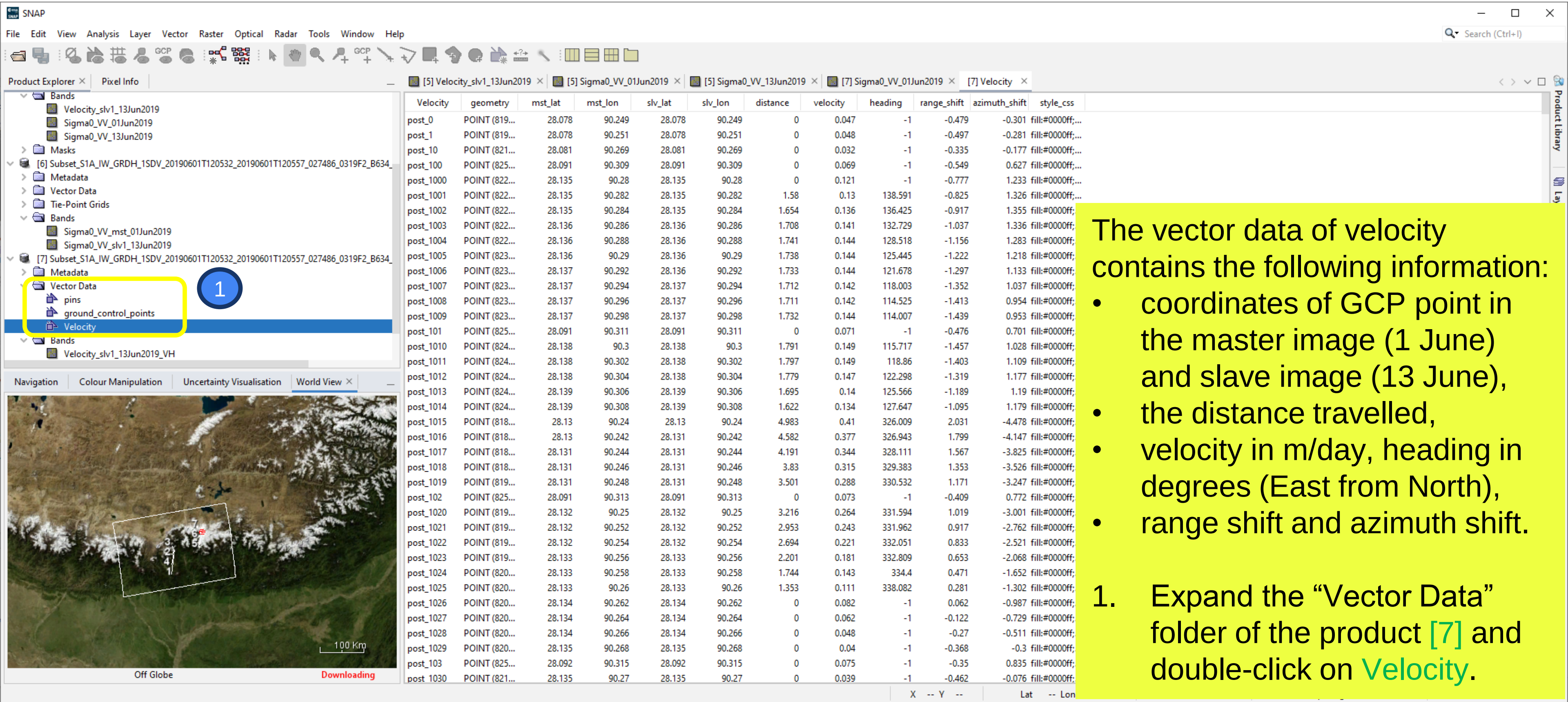
Data Processing

Visualize output: overlaying



Data Processing

Visualize output: table of velocity (vector data)



Velocity	geometry	mst_lat	mst_lon	slv_lat	slv_lon	distance	velocity	heading	range_shift	azimuth_shift	style_css
post_0	POINT (819...	28.078	90.249	28.078	90.249	0	0.047	-1	-0.479	-0.301	fill:#0000ff;...
post_1	POINT (819...	28.078	90.251	28.078	90.251	0	0.048	-1	-0.497	-0.281	fill:#0000ff;...
post_10	POINT (821...	28.081	90.269	28.081	90.269	0	0.032	-1	-0.335	-0.177	fill:#0000ff;...
post_100	POINT (825...	28.091	90.309	28.091	90.309	0	0.069	-1	-0.549	0.627	fill:#0000ff;...
post_1000	POINT (822...	28.135	90.28	28.135	90.28	0	0.121	-1	-0.777	1.233	fill:#0000ff;...
post_1001	POINT (822...	28.135	90.282	28.135	90.282	1.58	0.13	138.591	-0.825	1.326	fill:#0000ff;...
post_1002	POINT (822...	28.135	90.284	28.135	90.284	1.654	0.136	136.425	-0.917	1.355	fill:#0000ff;
post_1003	POINT (822...	28.136	90.286	28.136	90.286	1.708	0.141	132.729	-1.037	1.336	fill:#0000ff;
post_1004	POINT (822...	28.136	90.288	28.136	90.288	1.741	0.144	128.518	-1.156	1.283	fill:#0000ff;
post_1005	POINT (823...	28.136	90.29	28.136	90.29	1.738	0.144	125.445	-1.222	1.218	fill:#0000ff;
post_1006	POINT (823...	28.137	90.292	28.136	90.292	1.733	0.144	121.678	-1.297	1.133	fill:#0000ff;
post_1007	POINT (823...	28.137	90.294	28.137	90.294	1.712	0.142	118.003	-1.352	1.037	fill:#0000ff;
post_1008	POINT (823...	28.137	90.296	28.137	90.296	1.711	0.142	114.525	-1.413	0.954	fill:#0000ff;
post_1009	POINT (823...	28.137	90.298	28.137	90.298	1.732	0.144	114.007	-1.439	0.953	fill:#0000ff;
post_101	POINT (825...	28.091	90.311	28.091	90.311	0	0.071	-1	-0.476	0.701	fill:#0000ff;
post_1010	POINT (824...	28.138	90.3	28.138	90.3	1.791	0.149	115.717	-1.457	1.028	fill:#0000ff;
post_1011	POINT (824...	28.138	90.302	28.138	90.302	1.797	0.149	118.86	-1.403	1.109	fill:#0000ff;
post_1012	POINT (824...	28.138	90.304	28.138	90.304	1.779	0.147	122.298	-1.319	1.177	fill:#0000ff;
post_1013	POINT (824...	28.139	90.306	28.139	90.306	1.695	0.14	125.566	-1.189	1.19	fill:#0000ff;
post_1014	POINT (824...	28.139	90.308	28.139	90.308	1.622	0.134	127.647	-1.095	1.179	fill:#0000ff;
post_1015	POINT (818...	28.13	90.24	28.13	90.24	4.983	0.41	326.009	2.031	-4.478	fill:#0000ff;
post_1016	POINT (818...	28.13	90.242	28.131	90.242	4.582	0.377	326.943	1.799	-4.147	fill:#0000ff;
post_1017	POINT (818...	28.131	90.244	28.131	90.244	4.191	0.344	328.111	1.567	-3.825	fill:#0000ff;
post_1018	POINT (818...	28.131	90.246	28.131	90.246	3.83	0.315	329.383	1.353	-3.526	fill:#0000ff;
post_1019	POINT (819...	28.131	90.248	28.131	90.248	3.501	0.288	330.532	1.171	-3.247	fill:#0000ff;
post_102	POINT (825...	28.091	90.313	28.091	90.313	0	0.073	-1	-0.409	0.772	fill:#0000ff;
post_1020	POINT (819...	28.132	90.25	28.132	90.25	3.216	0.264	331.594	1.019	-3.001	fill:#0000ff;
post_1021	POINT (819...	28.132	90.252	28.132	90.252	2.953	0.243	331.962	0.917	-2.762	fill:#0000ff;
post_1022	POINT (819...	28.132	90.254	28.132	90.254	2.694	0.221	332.051	0.833	-2.521	fill:#0000ff;
post_1023	POINT (819...	28.133	90.256	28.133	90.256	2.201	0.181	332.809	0.653	-2.068	fill:#0000ff;
post_1024	POINT (820...	28.133	90.258	28.133	90.258	1.744	0.143	334.4	0.471	-1.652	fill:#0000ff;
post_1025	POINT (820...	28.133	90.26	28.133	90.26	1.353	0.111	338.082	0.281	-1.302	fill:#0000ff;
post_1026	POINT (820...	28.134	90.262	28.134	90.262	0	0.082	-1	0.062	-0.987	fill:#0000ff;
post_1027	POINT (820...	28.134	90.264	28.134	90.264	0	0.062	-1	-0.122	-0.729	fill:#0000ff;
post_1028	POINT (820...	28.134	90.266	28.134	90.266	0	0.048	-1	-0.27	-0.511	fill:#0000ff;
post_1029	POINT (820...	28.135	90.268	28.135	90.268	0	0.04	-1	-0.368	-0.3	fill:#0000ff;
post_103	POINT (825...	28.092	90.315	28.092	90.315	0	0.075	-1	-0.35	0.835	fill:#0000ff;
post_1030	POINT (821...	28.135	90.27	28.135	90.27	0	0.039	-1	-0.462	-0.076	fill:#0000ff;

The vector data of velocity contains the following information:

- coordinates of GCP point in the master image (1 June) and slave image (13 June),
- the distance travelled,
- velocity in m/day, heading in degrees (East from North),
- range shift and azimuth shift.

1. Expand the “Vector Data” folder of the product [7] and double-click on Velocity.

Data Visualization in QGIS

Open .csv file

1. Open **QGIS Desktop** software

2. In the Menu Bar, click on Layer → Add Layer → Add Delimited Text Layer.

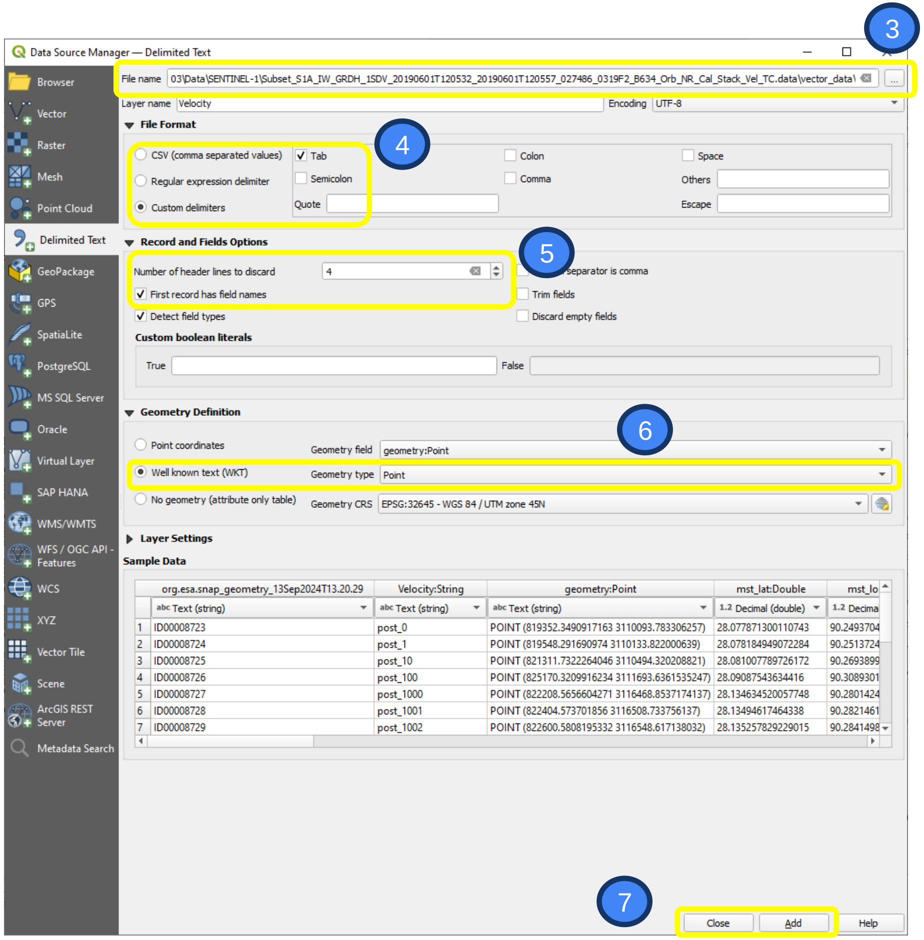
3. In Data Source, click on the Browse [...] button and navigate to the vector file ...\Subset_S1A_IW_GRDH_1SDV_20190601T120532_20190601T120557_027486_0319F2_B634_Orb_NR_Cal_Stack_Vel_TC.data\vector_data\Velocity.csv in the data folder.

4. In File format, select Custom delimiter, checklist Tab, and uncheck all other delimiters.

5. In Record and Field options, set the Number of header lines to discard to "3" and make sure to checklist the "First record has field names" option.

6. In the Geometry definition, select "Well known text (WKT)" and set the Geometry type to "Point".

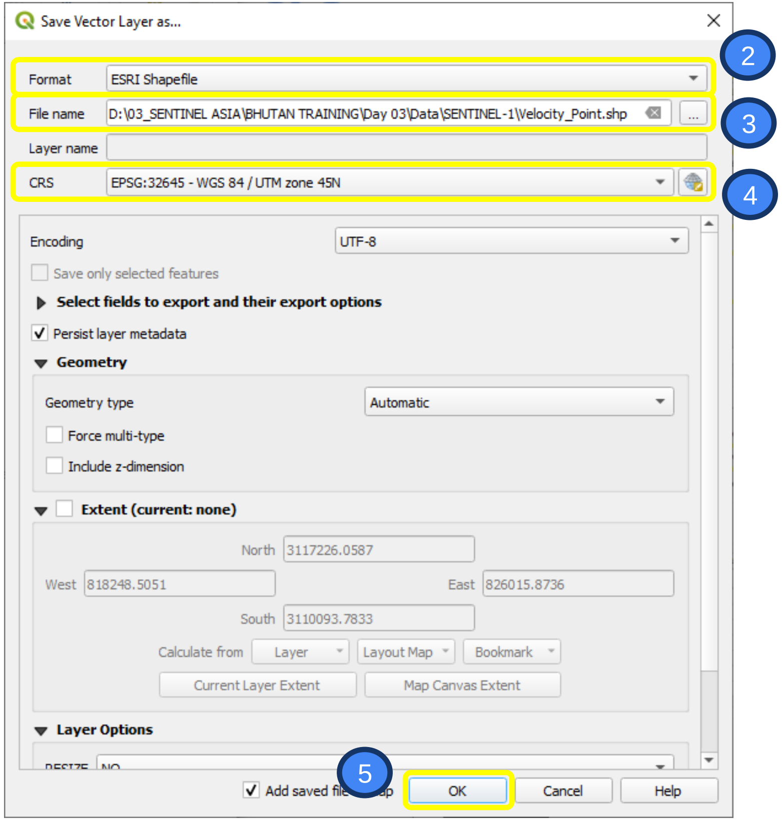
7. With this file selected, click Add, then Close. The data you specified will now load.



Data Visualization in QGIS

Convert .csv file to shapefile

1. Right-click on the opened Velocity layer, then click Save Vector Layer as
2. In Format, select ESRI Shapefile.
3. Save the Vectorized result to Velocity_Point.shp
4. In CRS, make sure to select EPSG: 32645 – WGS84 / UTM Zone 45N.
5. Click OK.



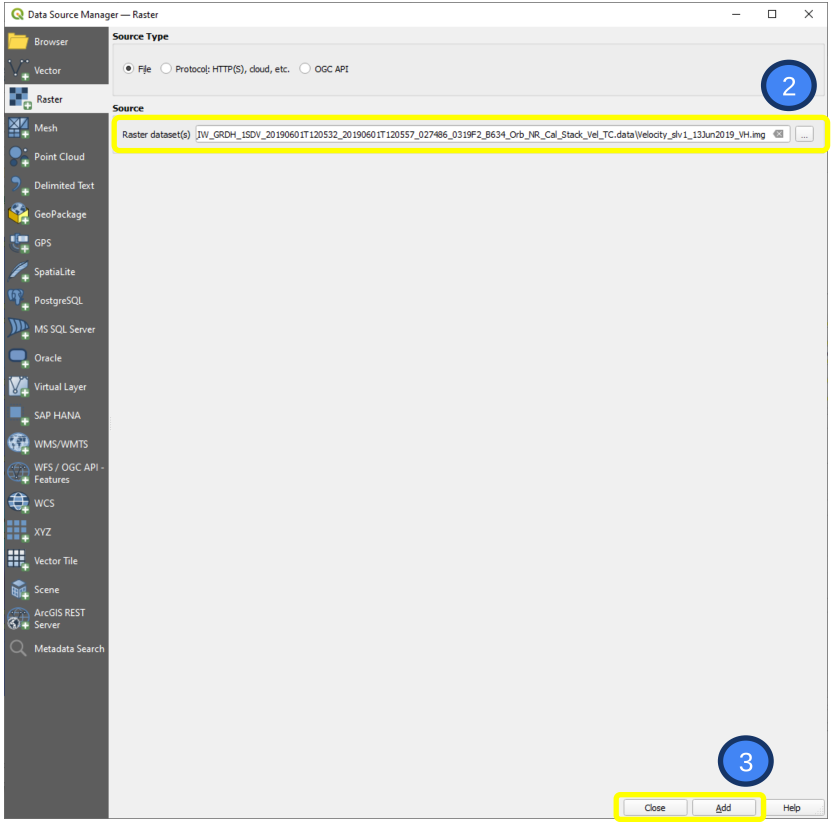
Data Visualization in QGIS

Open velocity raster data

1. In the Menu Bar, click on Layer → Add Layer → Add Raster Layer.

2. In Data Source, click on the Browse button and navigate to the file \Subset_S1A_IW_GRDH_1SDV_20190601T120532_20190601T120557_027486_0319F2_B634_Orb_NR_Cal_Stack_Vel_TC.data\Velocity_slv1_13Jun2019_VH.img in the data folder.

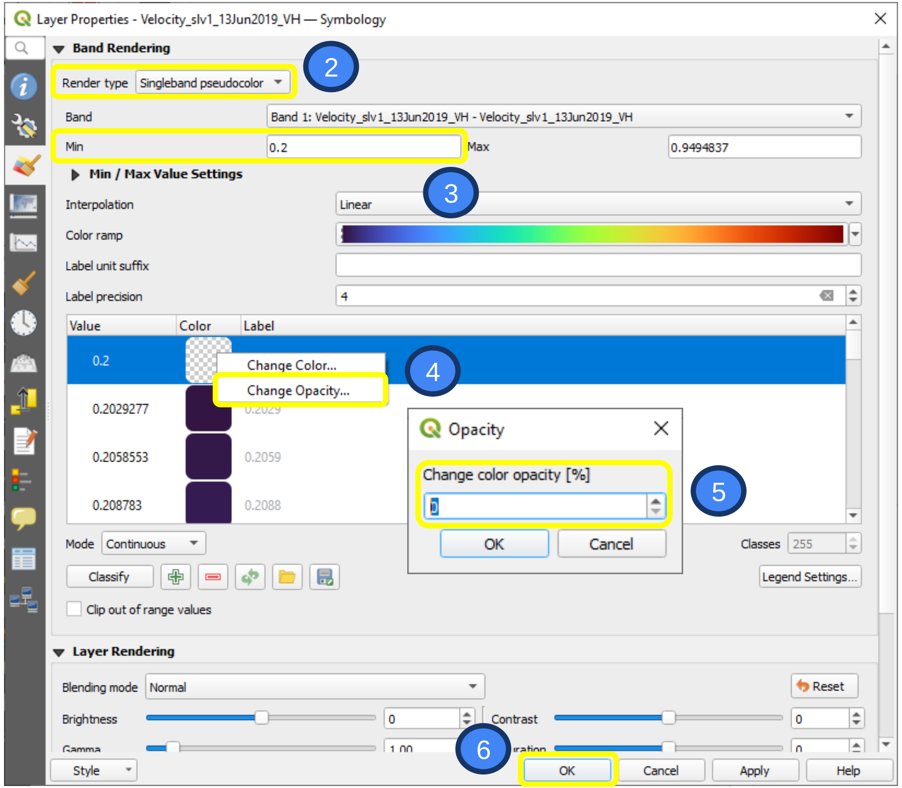
3. With this file selected, click Add, then Close. The data you specified will now load.



Data Visualization in QGIS

Change the appearance of the velocity raster layer

1. Right-click on the opened Velocity_slv1_13Jun2019_VH raster layer, then click Properties.
2. In Render type, change to Singleband pseudocolor.
3. Let's change the Min value to 0.2.
4. Right-click the Color for the Min value, then select Change Opacity...
5. To make it transparent, change the color opacity to 0.
6. Click OK



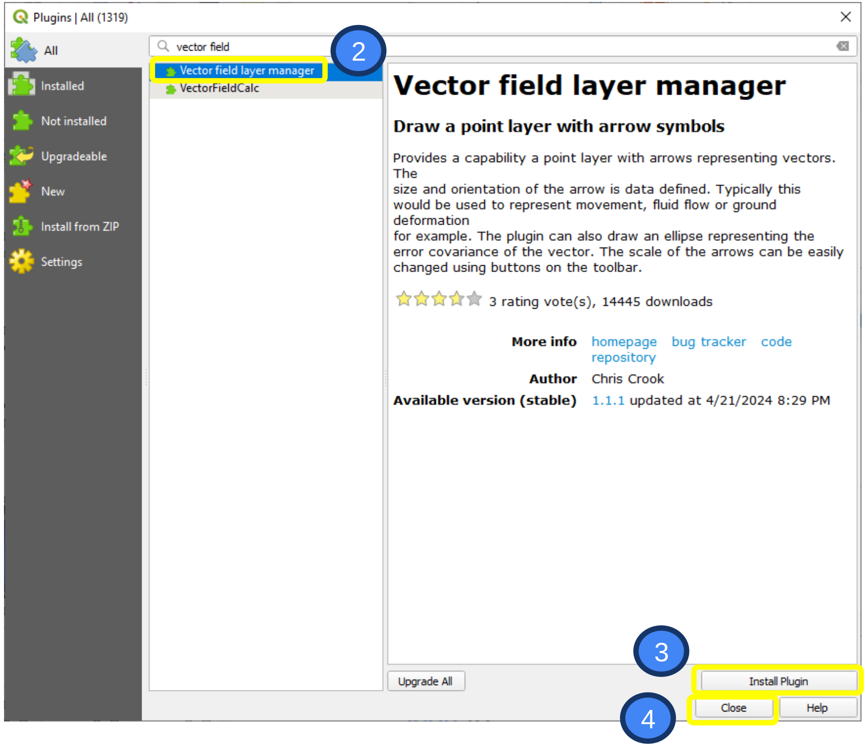
Data Visualization in QGIS

Install a plugin: Vector field layer manager

To visualize the velocity vector fields, we need to install the Vector field layer manager plug-in.

1. In the Menu Bar, click on Plugins → Manage and Install Plugins.
2. In the dialog that opens, find the Vector field layer manager plugin.
3. Click Install Plugin.
4. Click Close.

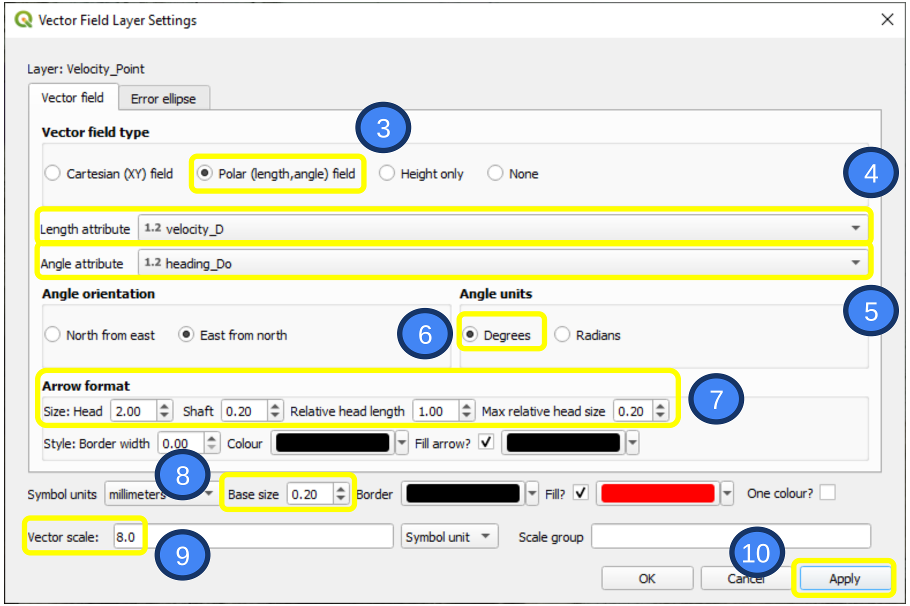
Your new plugin  is installed.



Data Visualization in QGIS

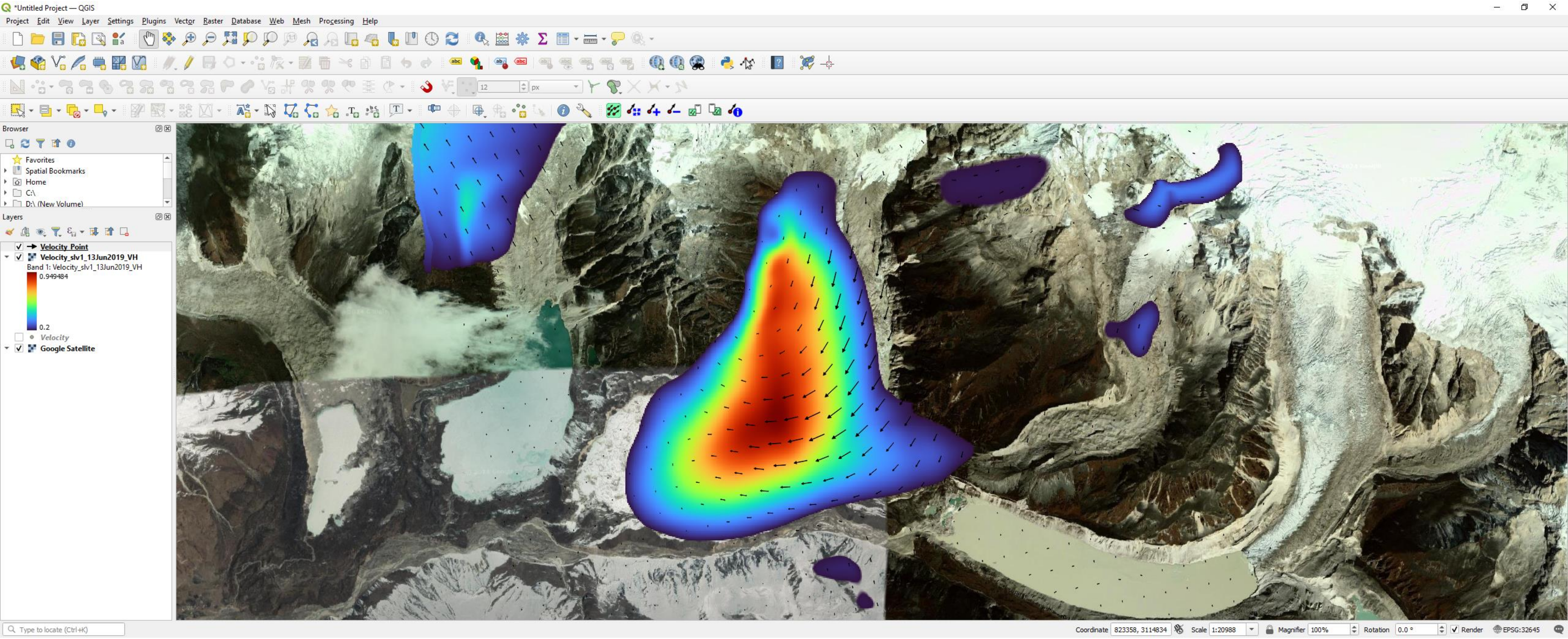
Setup the velocity vector field

1. In Layer List, select Velocity_Point layer to activate the Vector field layer manager plugin.
2. In Toolbar, click 
3. In the Vector field, select Polar (length, angle) field.
4. In the Length attribute, select velocity_D.
5. In the Angle attribute, select Heading_Do.
6. In the Angle units, change to Degrees.
7. In the Arrow format, set the following
    - Head: 2.00
    - Shaft: 0.20
    - Relative head length: 1.00
    - Max relative head size: 0.20
8. In the Base size, set to 0.20
9. In the Vector scale, set to 8.0
10. Click Apply.



Data Visualization in QGIS

Install a plugin: Vector field layer manager



Sources

- Serco Italia SPA (2018). Glacier Velocity with Sentinel-1– Peterman Glacier, Greenland (version 1.2). Retrieved from RUS Lectures.

- How to Create Glacier Velocity Maps with Sentinel-1 Toolbox: https://asf.alaska.edu/how-to/data-recipes/how-to-create-glacier-velocity-maps-with-sentinel-1-toolbox/

THANK YOU

Geoinformatics Center, Asian Institute of Technology