# EXERCISE 4 – TUTORIAL

Forestry with Sentinel-1: Single Image Analysis and Time Series to detect forest change using SNAP software

esa
ÚSTAV GEOGRAFIE
Prírodovedecká fakulta UPJŠ v Košiciach
UNIVERZITA
PAVLA JOZEFA ŠAFÁRIKA
V KOŠICIACH

FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

# 1 | Exercise outline

In this exercise, we will:

- Generate Radiometrically Terrain Corrected (RTC) Images from Sentinel-1 GRD products to monitor forest extent, structure and biomass
- Perform statistical analyses using Scatterplots, Histogram Analysis, Profile Plot etc.
- Process SAR data with SNAP using single-date and multi-temporal processing and generate time series analysis of multi-temp dataset
- Emphasize the critical role of SAR in sustainable resource management and forest conservation

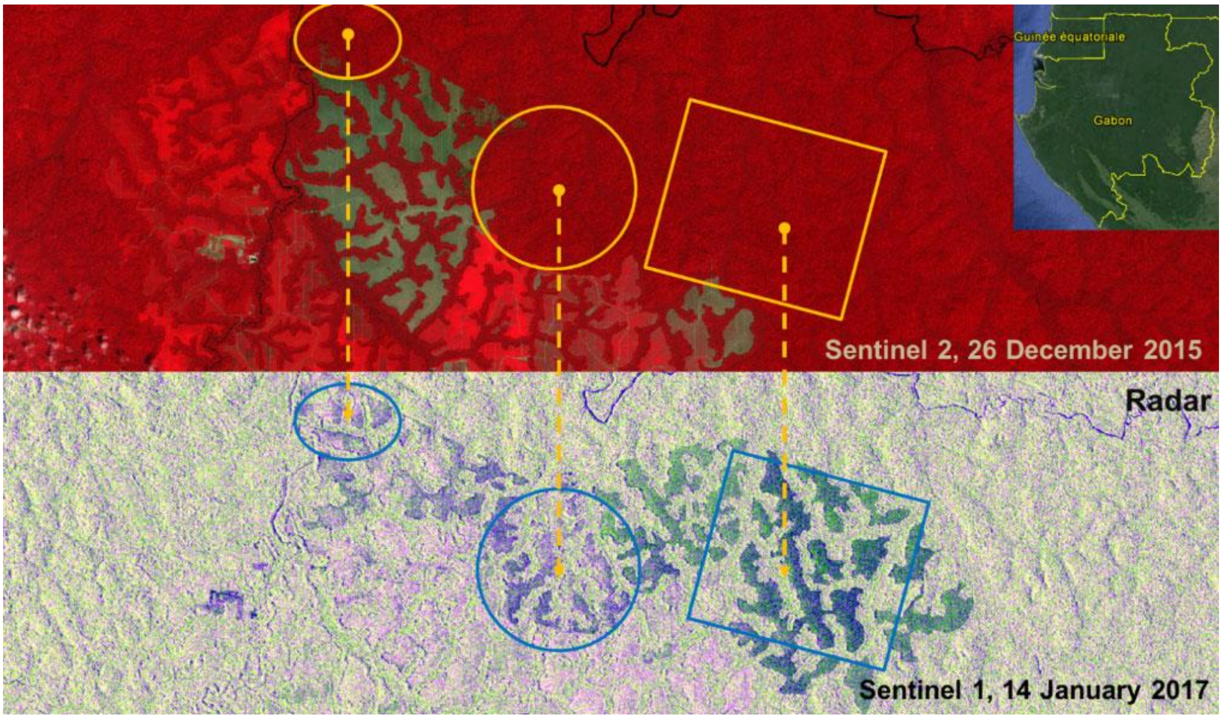
# 2 | Background

## Forestry Mapping with Sentinel-1 data

Sentinel-1 synthetic aperture radar (SAR) data presents a versatile tool for comprehensive forestry mapping and monitoring. By analyzing SAR images acquired at different times, changes in forest cover can be effectively detected, providing insights into deforestation, reforestation, and forest degradation.

Sentinel-1 has a significant potential in sustainable forest management through its ability to detect clear-cut and partial-cut areas, classify forest types, estimate biomass, and identify disturbances. Regarding climate change mitigation, the mapping of forest fire scars using Sentinel-1 data is crucial for understanding a forest's carbon history and accurately estimating carbon emissions.

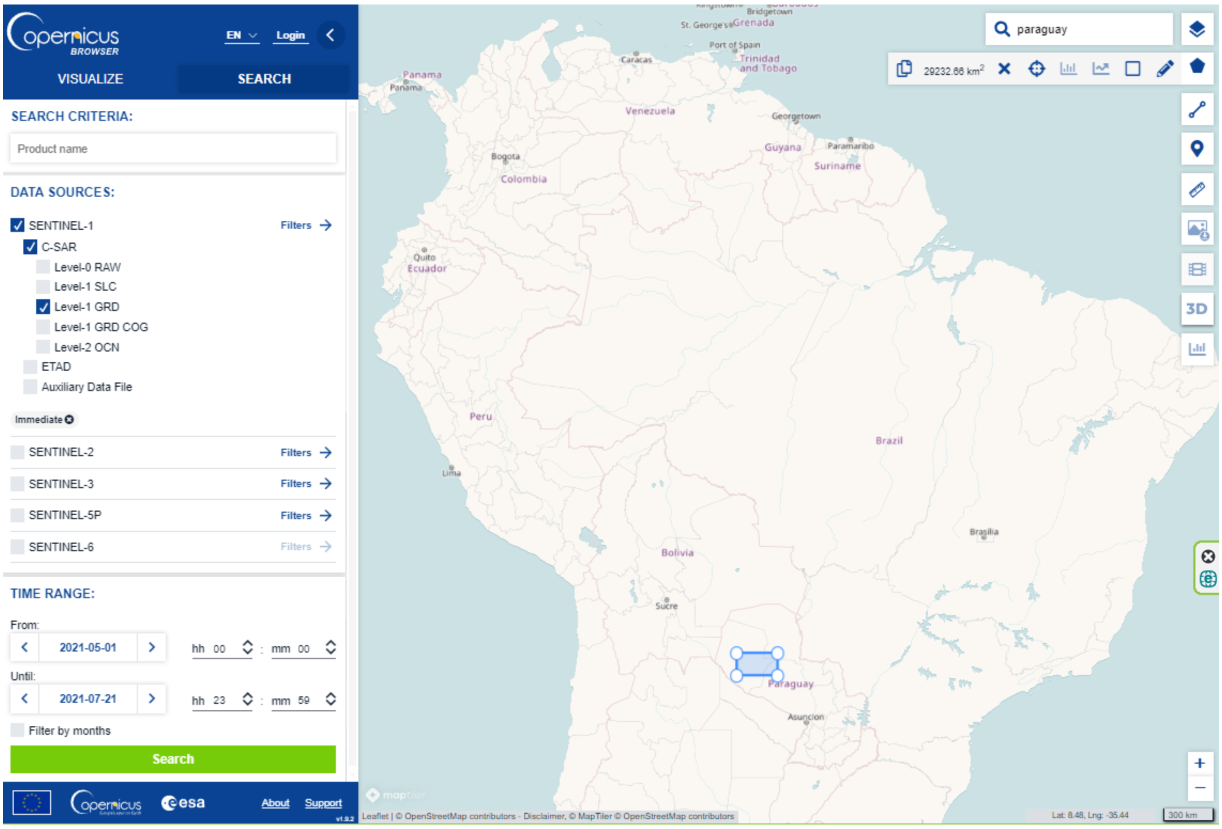
Additionally, SAR data allows for the classification of various forest cover types, aiding in forest management and conservation efforts. Furthermore, SAR data offers valuable information for assessing habitat quality and carbon stocks.




Source: https://sentinels.copernicus.eu/documents/247904/3428726/Sentinel-1-2-rubber-plantation-full.jpg

## 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 GRDH images using dual polarization (VV/VH) acquired in interferometric wide swath mode for the area in Paraguay, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



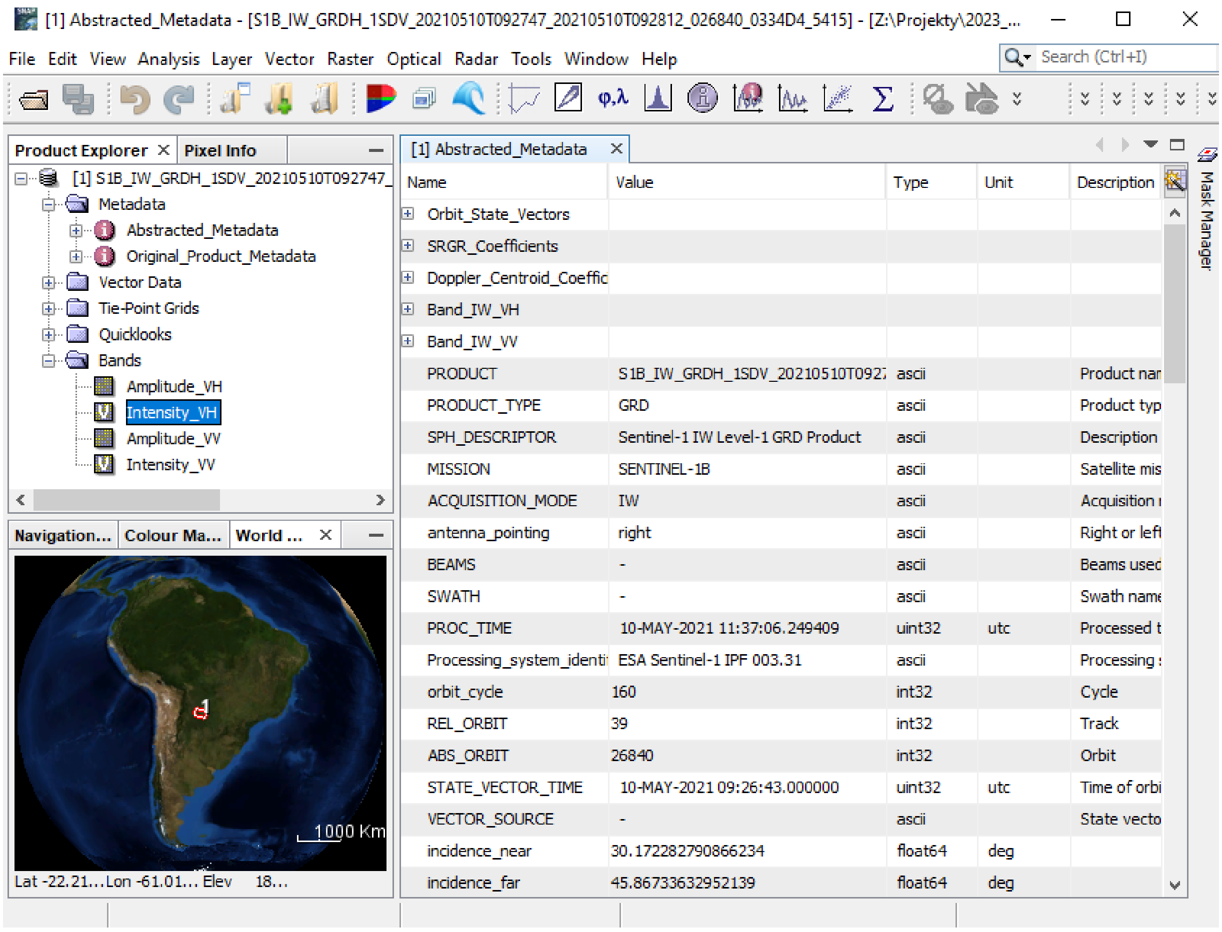

## 2.2. SNAP - Open and explore product

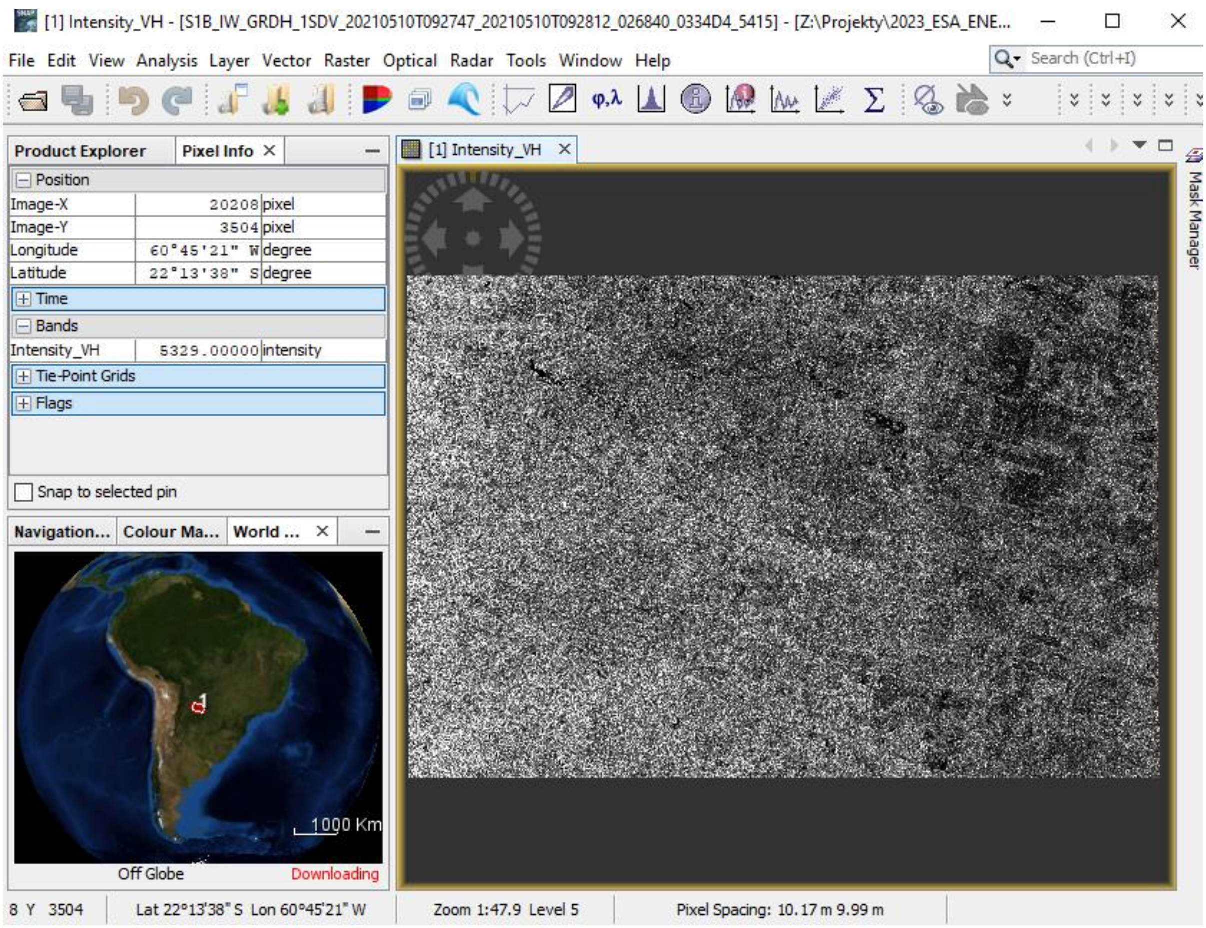
Open SNAP Desktop, click Open Product and open one of the downloaded products by double click on the zipped folders. The opened products will appear in Product Explorer window. The Navigation and World View tabs above the preview window can help you to locate the scene.

S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415.SAFE

To access the information within the product, double-click on it to reveal the directories, open the Metadata folder and double click on Abstracted Metadata.

If you open one of the bands of the image by double clicking the band name, you can see also information on the pixels in the scene by opening the tab Pixel Info (next to Product Explorer) and sliding the mouse over the pixels of interest.


[1] Abstracted_Metadata - [S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415] - [Z:\Projekty\2023_...
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help
Search (Ctrl+I)
Product Explorer
Pixel Info
[1] S1B_IW_GRDH_1SDV_20210510T092747_
Metadata
Abstracted_Metadata
Original_Product_Metadata
Vector Data
Tie-Point Grids
Quicklooks
Bands
Amplitude_VH
Intensity_VH
Amplitude_VV
Intensity_VV
Navigation...
Colour Ma...
World ...
1000 Km
Lat -22.21... Lon -61.01... Elev 18...
[1] Abstracted_Metadata
Name
Value
Type
Unit
Description
Orbit_State_Vectors
SRGR_Coefficients
Doppler_Centroid_Coeffic
Band_IW_VH
Band_IW_VV
PRODUCT
S1B_IW_GRDH_1SDV_20210510T092
asci
Product nar
PRODUCT_TYPE
GRD
ascii
Product typ
SPH_DESCRIPTOR
Sentinel-1 IW Level-1 GRD Product
ascii
Description
MISSION
SENTINEL-1B
ascii
Satellite mis
ACQUISITION_MODE
IW
ascii
Acquisition
antenna_pointing
right
ascii
Right or left
BEAMS
-
ascii
Beams used
SWATH
-
ascii
Swath name
PROC_TIME
10-MAY-2021 11:37:06.249409
uint32
utc
Processed t
Processing_system_identi
ESA Sentinel-1 IPF 003.31
ascii
Processing
orbit_cycle
160
int32
Cycle
REL_ORBIT
39
int32
Track
ABS_ORBIT
26840
int32
Orbit
STATE_VECTOR_TIME
10-MAY-2021 09:26:43.000000
uint32
utc
Time of orbi
VECTOR_SOURCE
-
ascii
State vecto
incidence_near
30.172282790866234
float64
deg
incidence_far
45.86733632952139
float64
deg
Mask Manager


[1] Intensity_VH - [S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415] - [Z:\Projekty\2023_ESA_ENE...
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help
Search (Ctrl+I)
Product Explorer
Pixel Info
Position
Image-X 20208 pixel
Image-Y 3504 pixel
Longitude 60°45'21" W degree
Latitude 22°13'38" S degree
Time
Bands
Intensity_VH 5329.00000 intensity
Tie-Point Grids
Flags
Snap to selected pin
Navigation...
Colour Ma...
World ...
1000 Km
Off Globe
Downloading
[1] Intensity_VH
Mask Manager
8 Y 3504
Lat 22°13'38" S Lon 60°45'21" W
Zoom 1:47.9 Level 5
Pixel Spacing: 10.17 m 9.99 m

## A: SINGLE-DATE ANALYSIS

### Create a subset

There is no need to process the whole image, instead, we can reduce the loaded data 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.

You can define the subset area by either zooming into the region of interest or by defining pixel or geographic coordinates. In this exercise we use the following geographic coordinates, that you can enter manually:

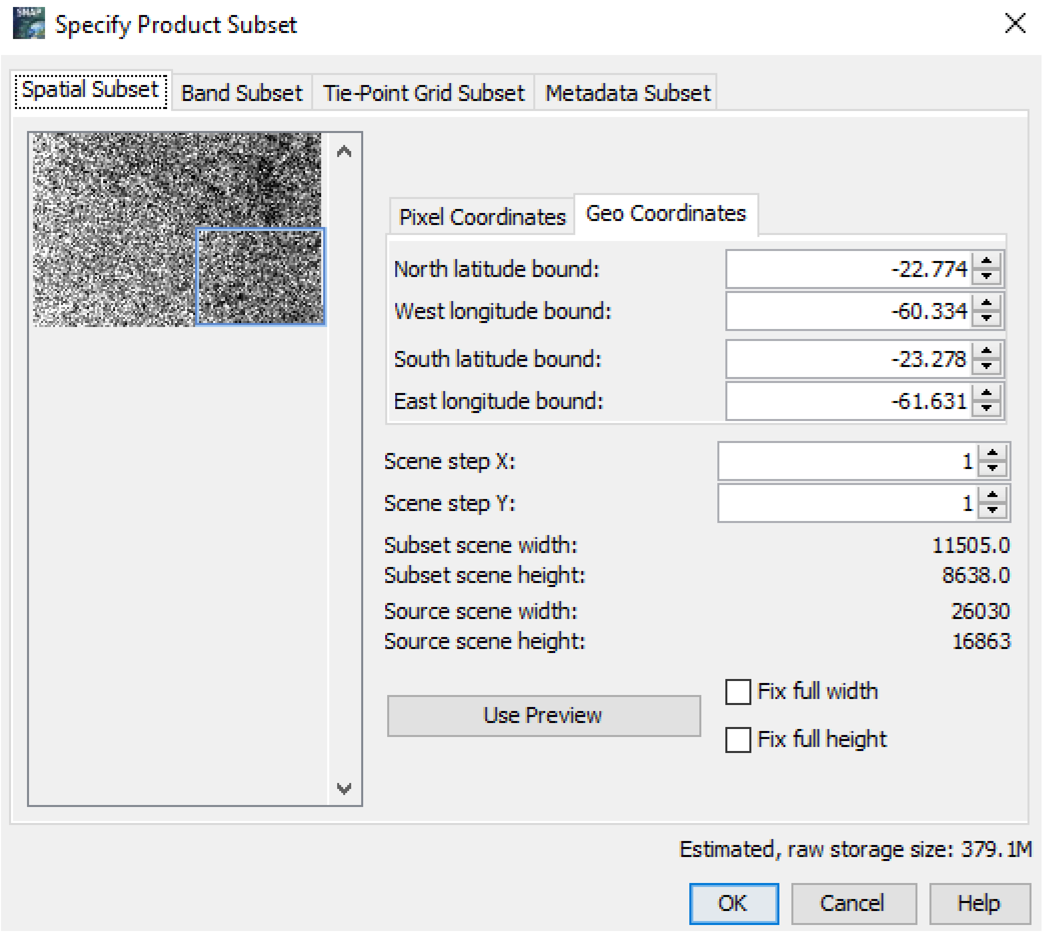
Navigate to Raster – Subset tab

and at Switch to "Geo Coordinates" in Spatial Subset tab

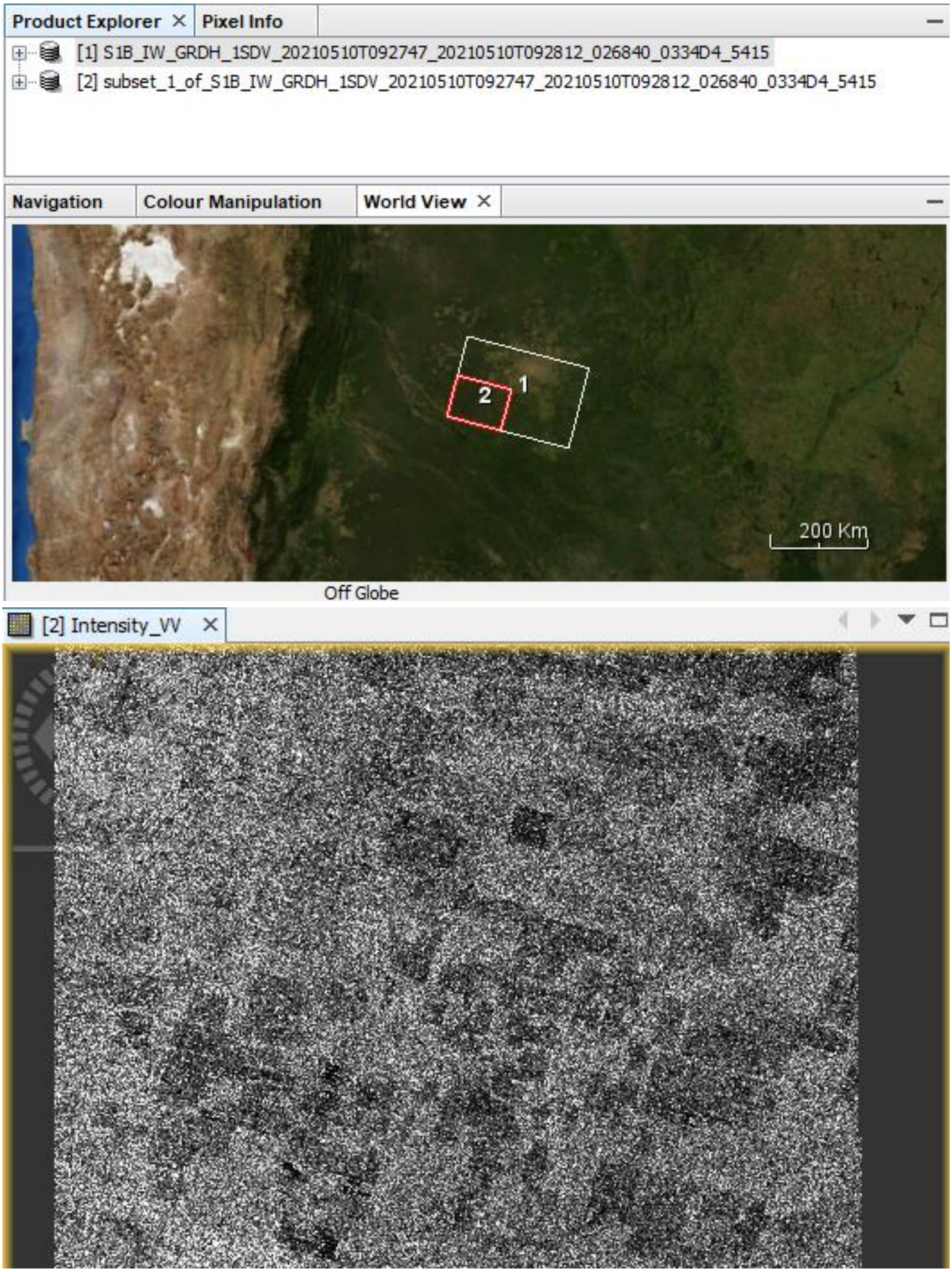
Enter the following numbers:

North latitude bound: -22.774
West longitude bound: -60.334
South latitude bound: -23.278
East longitude bound: -61.631

Confirm with OK.



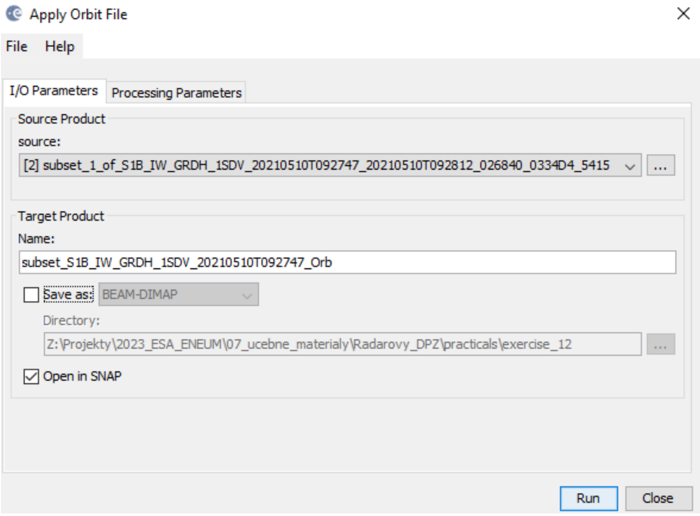
The new subset will appear in your Product Explorer window. You can open one of its bands by double-click on the selected band if you expand Bands folder within the product.

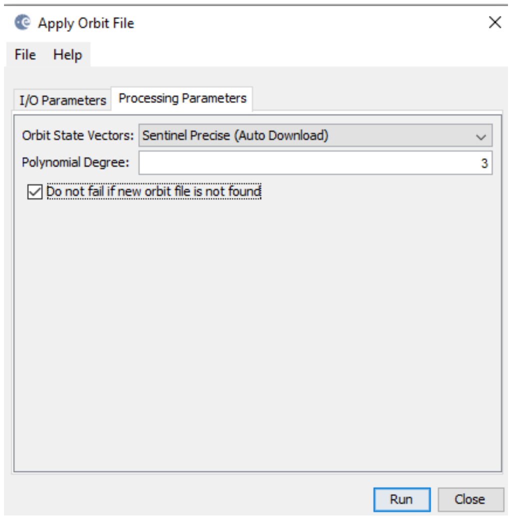


## Apply orbit file

- Navigate to Main Menu – Radar – Apply orbit file
- In the I/O Parameters tab, select the subset product and name the target product. There is no need to save the output as BEAM-DIMAP
- In the Processing Parameters accept the default settings and select the option „Do not fail if new orbit file not found“

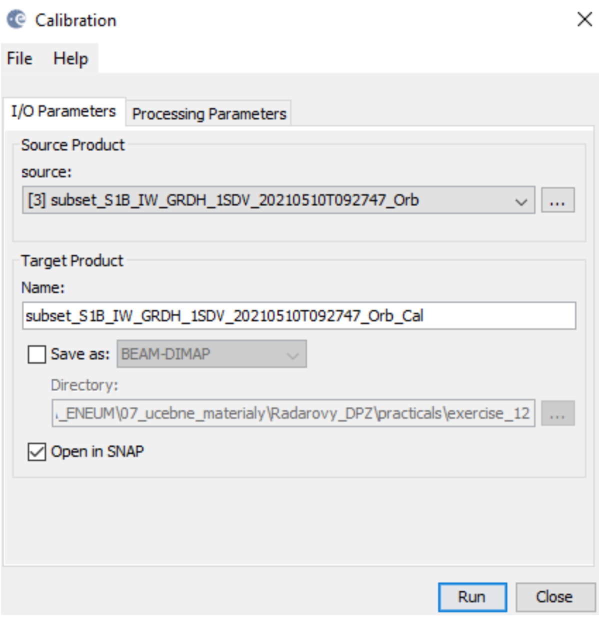
Note: If precise orbits are not yet available for your product, restituted orbits can be selected which may not be as accurate as the Precise orbits but will be better than the predicted orbits available within the product.

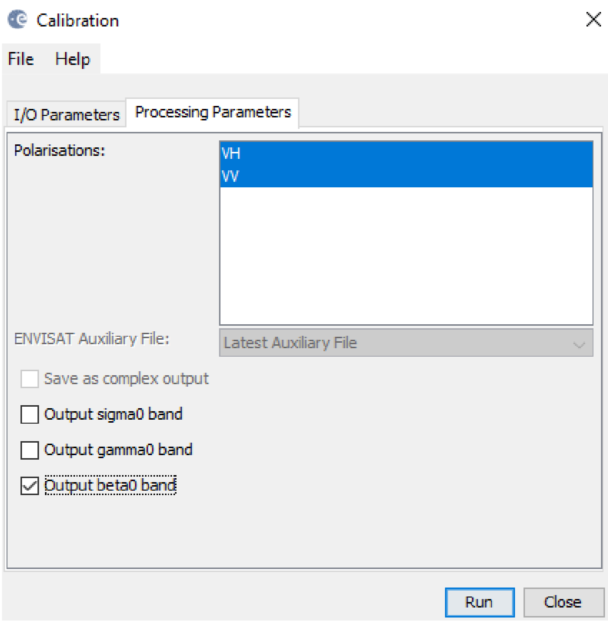



## Apply radiometric correction

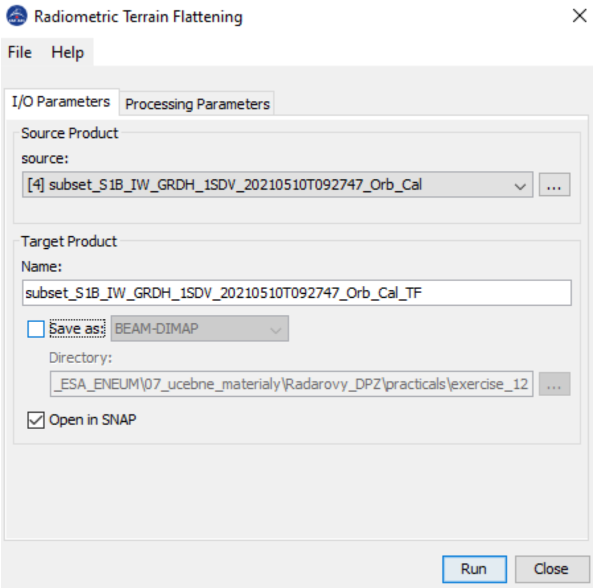
- Go to Radar > Radiometric > Calibrate and select the result product from previous step
- Under the Processing Parameters tab select both polarizations and select the **Output beta0** band option. The radiometric correction is necessary to remove any image-dependent radiometric bias.

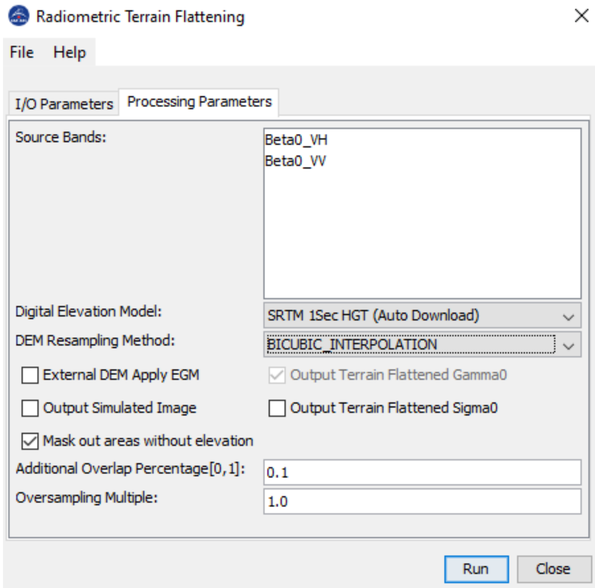


## Radiometric Terrain Flattening

- Flatten Terrain
- Go to Radar > Radiometric > Radiometric Terrain Flattening
- Under Processing Parameters select SRTM 1Sec HGT (Auto Download)
- For DEM Resampling Method, use Bicubic_interpolation



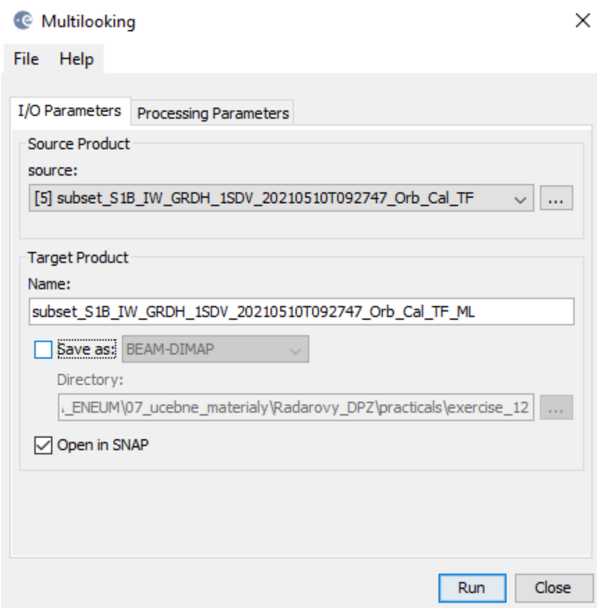



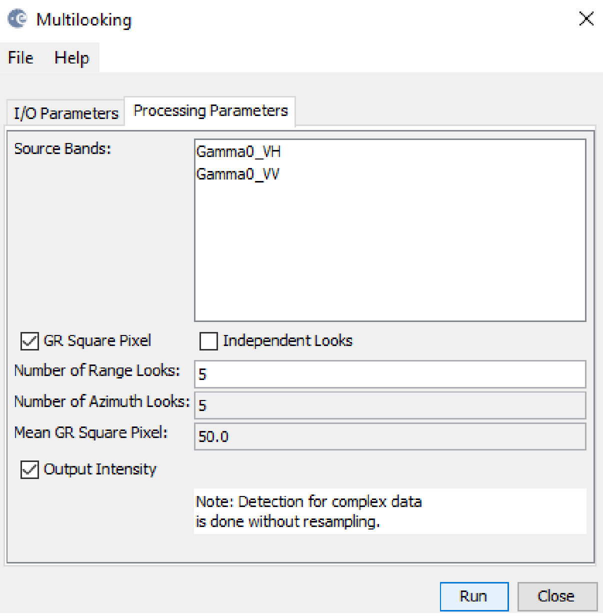

The output of this process will be transformed Beta0 into Gamma0

## *Multilooking*

Go to Radar > Multilooking:

In "Processing Parameters" multilook the image by a factor 5x5 - change "Number of Range Looks" and "Number of Azimuth Looks" both to 5. If the "GR Square pixel" option is enabled, an equal number of looks will be applied in both the azimuth and range directions.

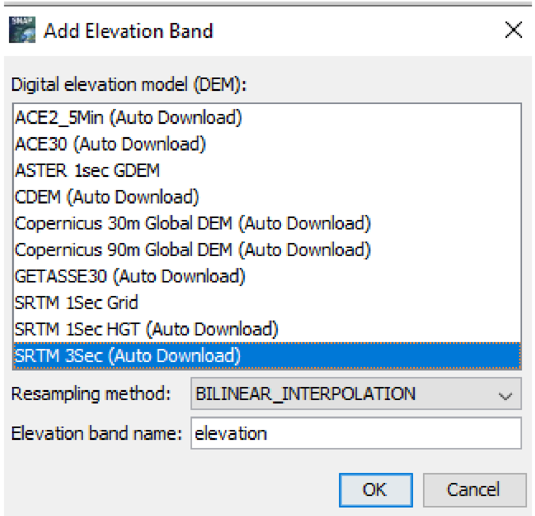


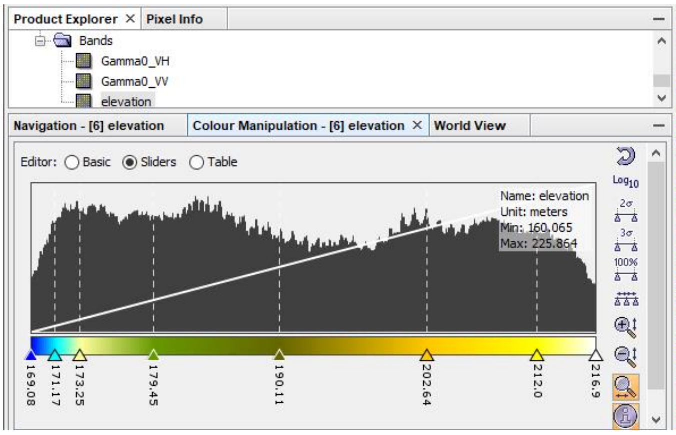



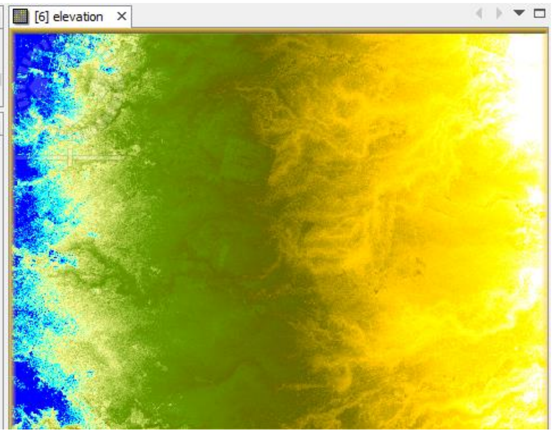
## Create elevation band

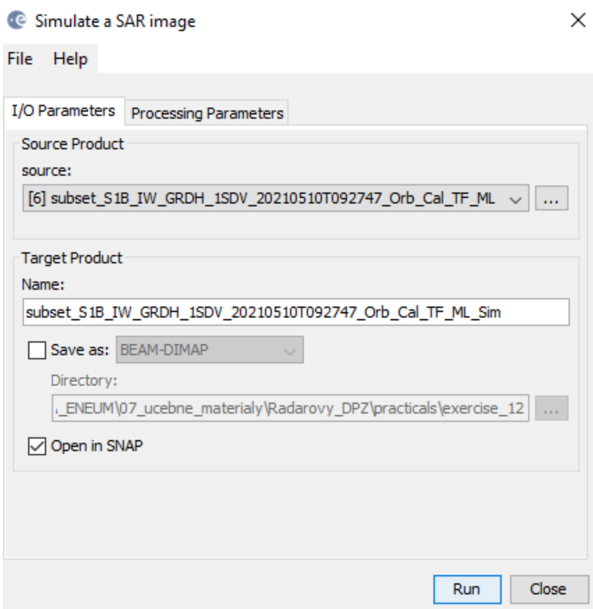
Go to Raster > DEM Tools > > Add Elevation Band:

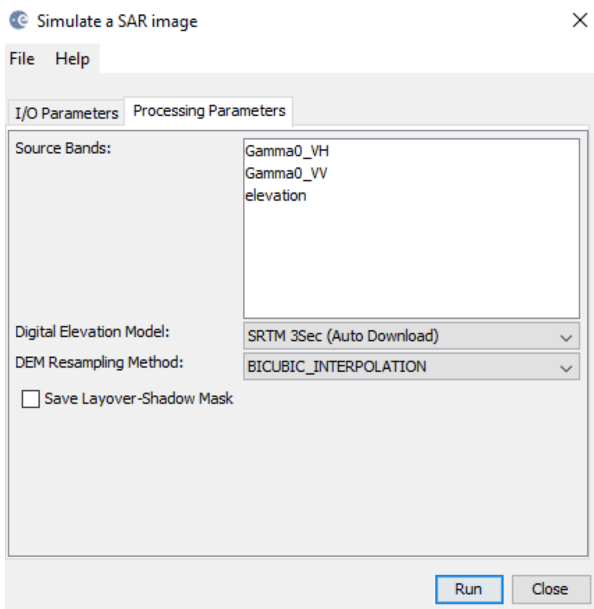
- Select the appropriate elevation band to add to the image, e.g. SRTM 3 sec (AutoDownload)
- After having added the elevation band, go to Radar > Geometric > Terrain Correction > SAR Simulation and run the SAR simulation.



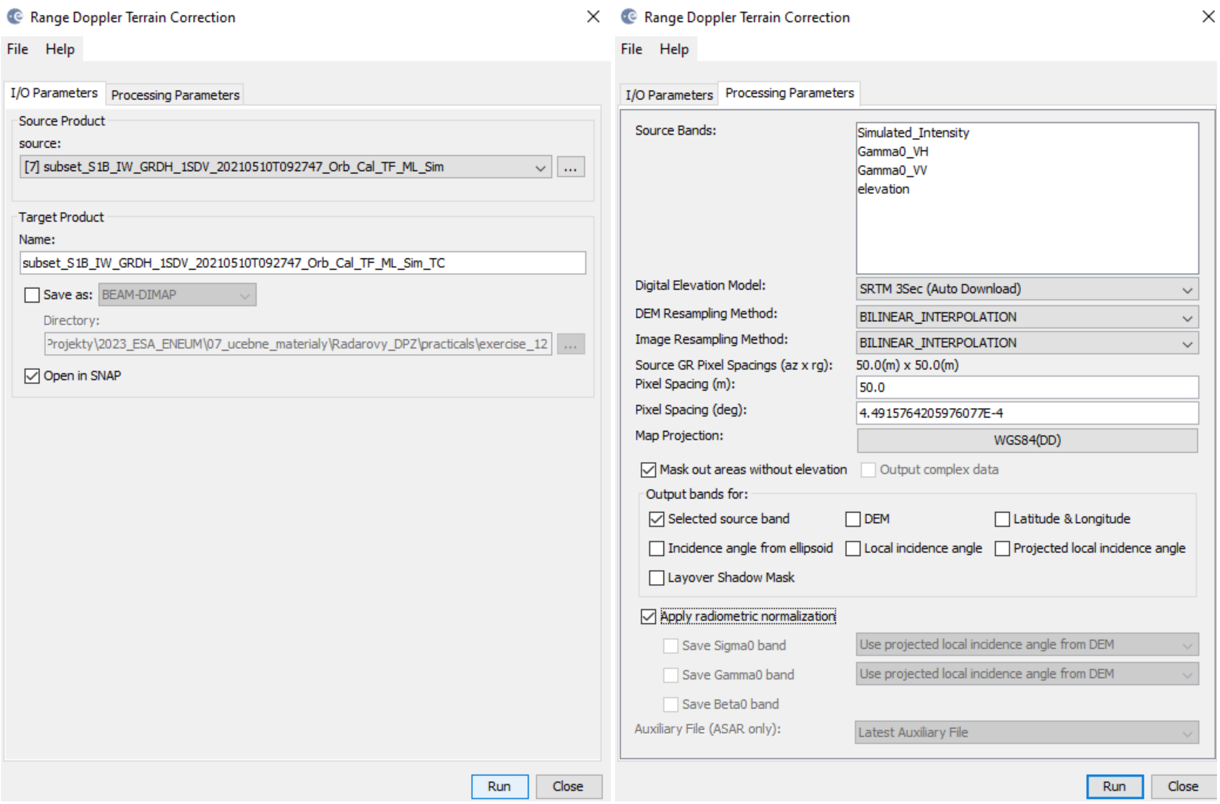




## Terrain Correction

Go to Radar > Geometric > Terrain Correction > Range-Doppler Terrain Correction

- In the I/O Parameters select the last simulated product
- Under Processing Parameters tab select:
  - Digital Elevation Model: SRTM 3Sec (Auto Download)
- - DEM Resampling Method: Bilinear Interpolation
  - Check the "Mask out areas without elevation" box
  - Check the "Apply radiometric normalisation" box




## Convert gamma0 to dB

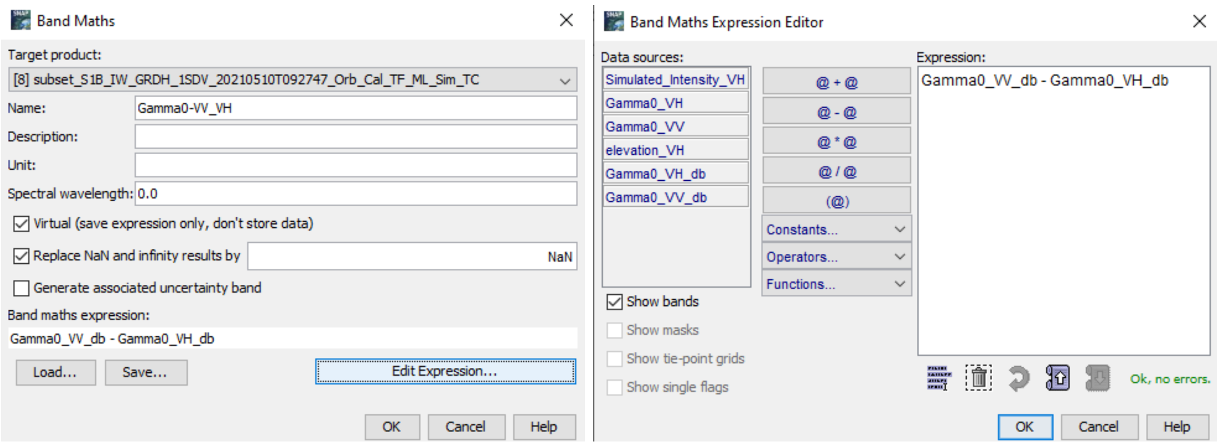
In the Product Explorer select first the Gamma0_VH band, then go to Raster > Data Conversion > Linear to/from dB and repeat with the Gamma0_VV band.

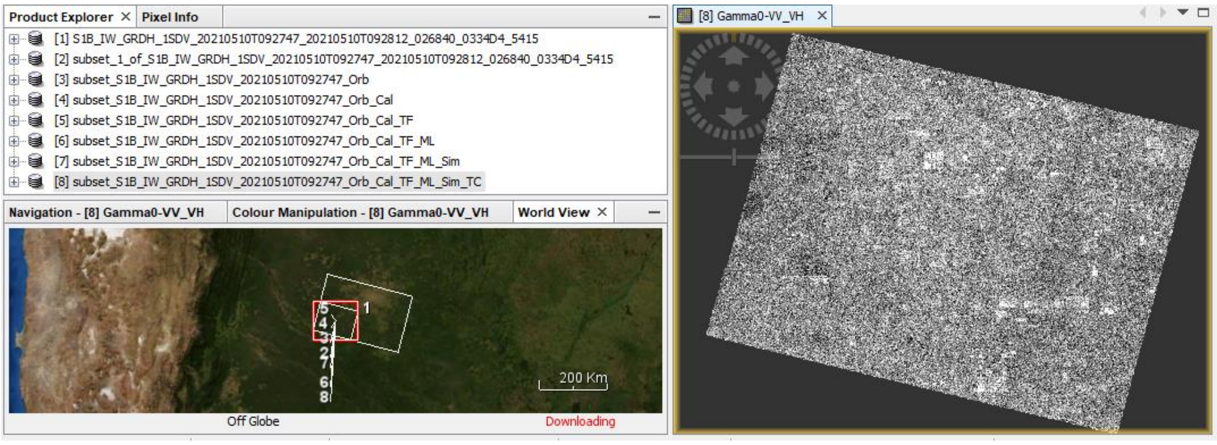
This will create two Virtual bands (with a V icon). Right click on each > Convert Band to transform them.

## Compute difference image from gamma0 [dB]: VV-VH

Open Raster > Band Maths:
Name it "Gamma0-VV_VH". Click on 'Edit Expression' and enter the expression Gamma0_VV_dB – Gamma0_VH_dB

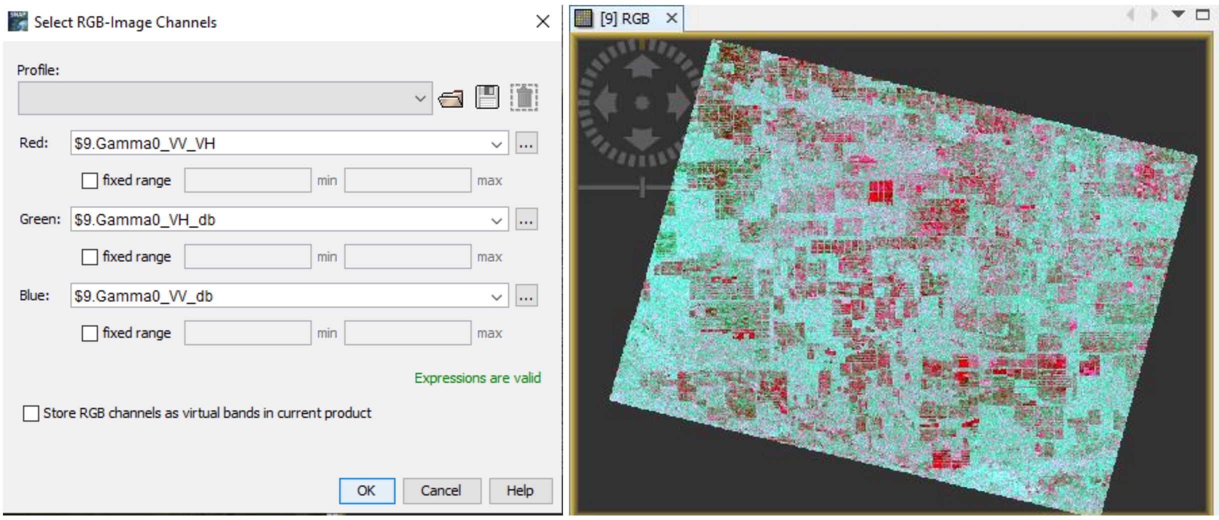
Convert virtual raster




## Display as RGB view

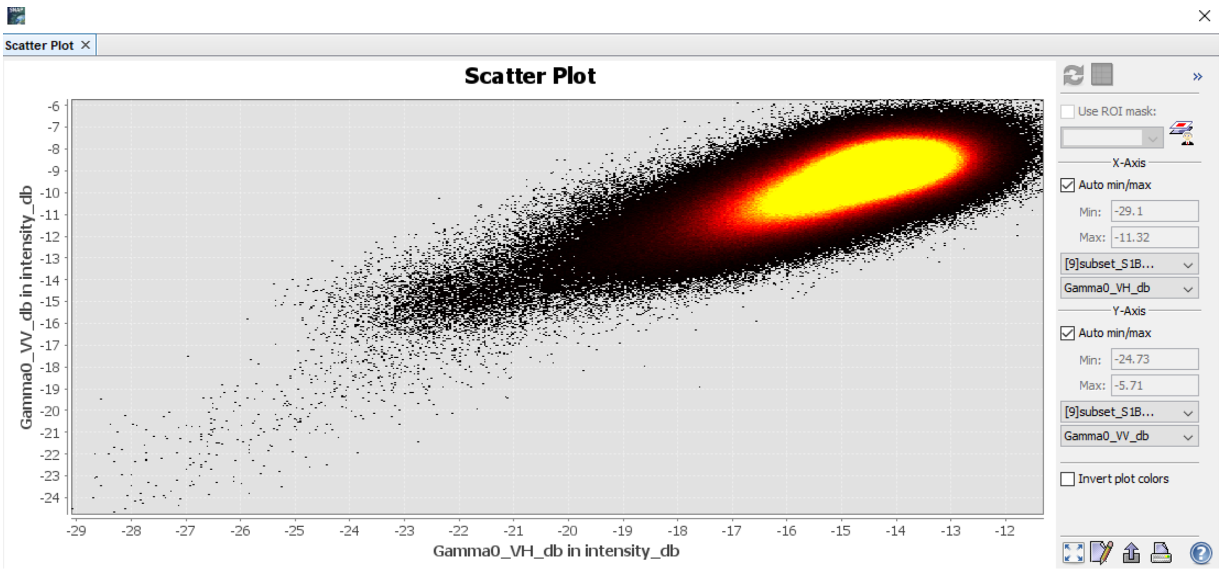
Go to Window > Open RGB Image Window (or right-click on the last product in the Product Explorer and Open RGB window) and select:
Red: the difference band „Gamma0_VV_VH"
Green: „Gamma0_VH_db"
Blue: „Gamma0_VV_db"



## Statistical analysis

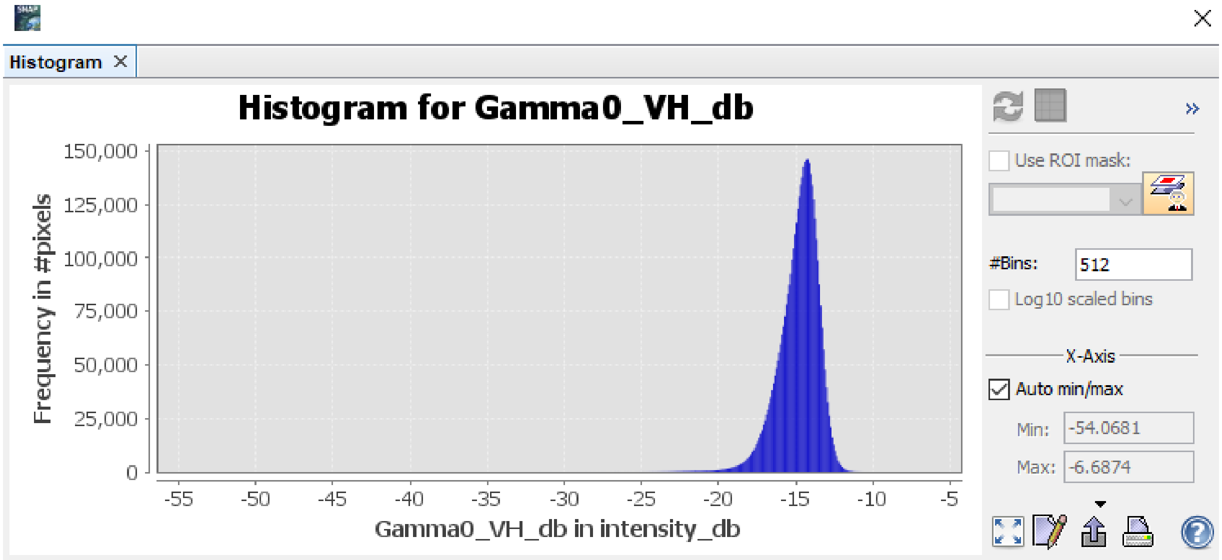
*Scatterplot*

Open Analysis > Scatter Plot and in the right panel select the Gamma0_VH_dB as X-axis input and Gamma0_VV_dB as Y-axis input, then click the Refresh View button.



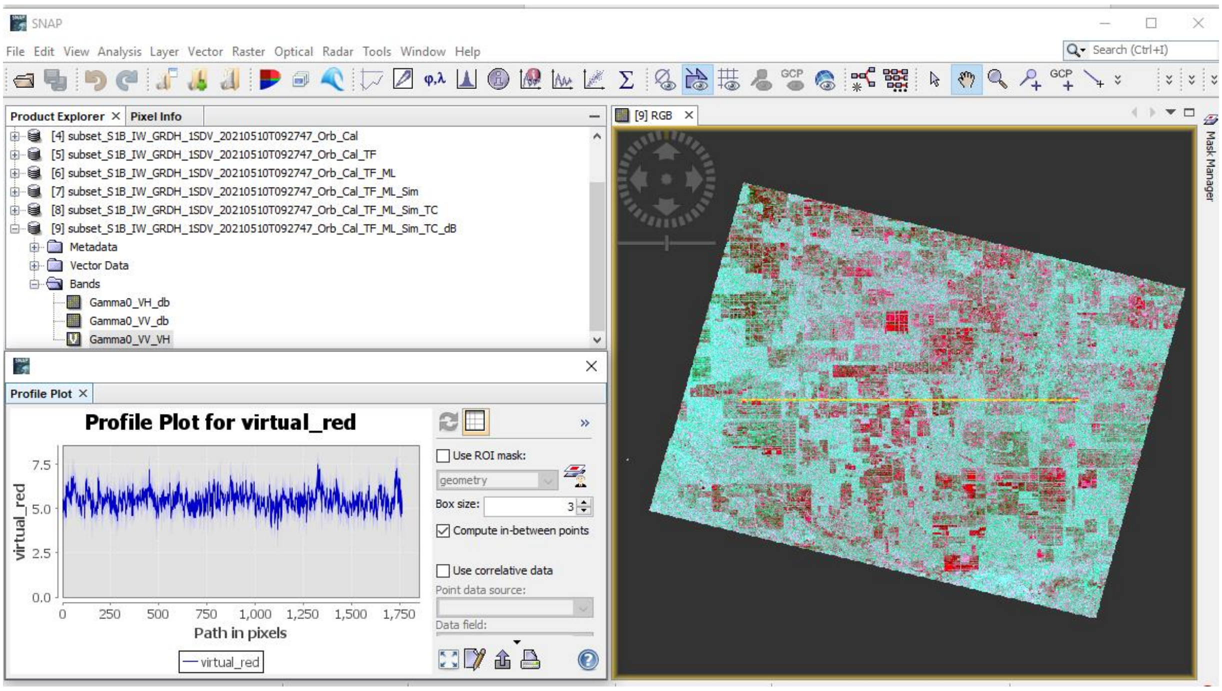

*Histogram*

Select e.g. the Gamma0_VH_dB band and open Analysis > Histogram. Click the Refresh View button.



*Profile Plot*

Select the Gamma0_VV_VH band. In the toolbar select the Polygon or the Line tool and draw a shape on your region of interest. Open Analysis > Profile Plot. This operation can be done for any of the other bands.



## B: MULTITEMPORAL ANALYSIS

Load both Sentinel-1 products by navigating to File - Open Product.

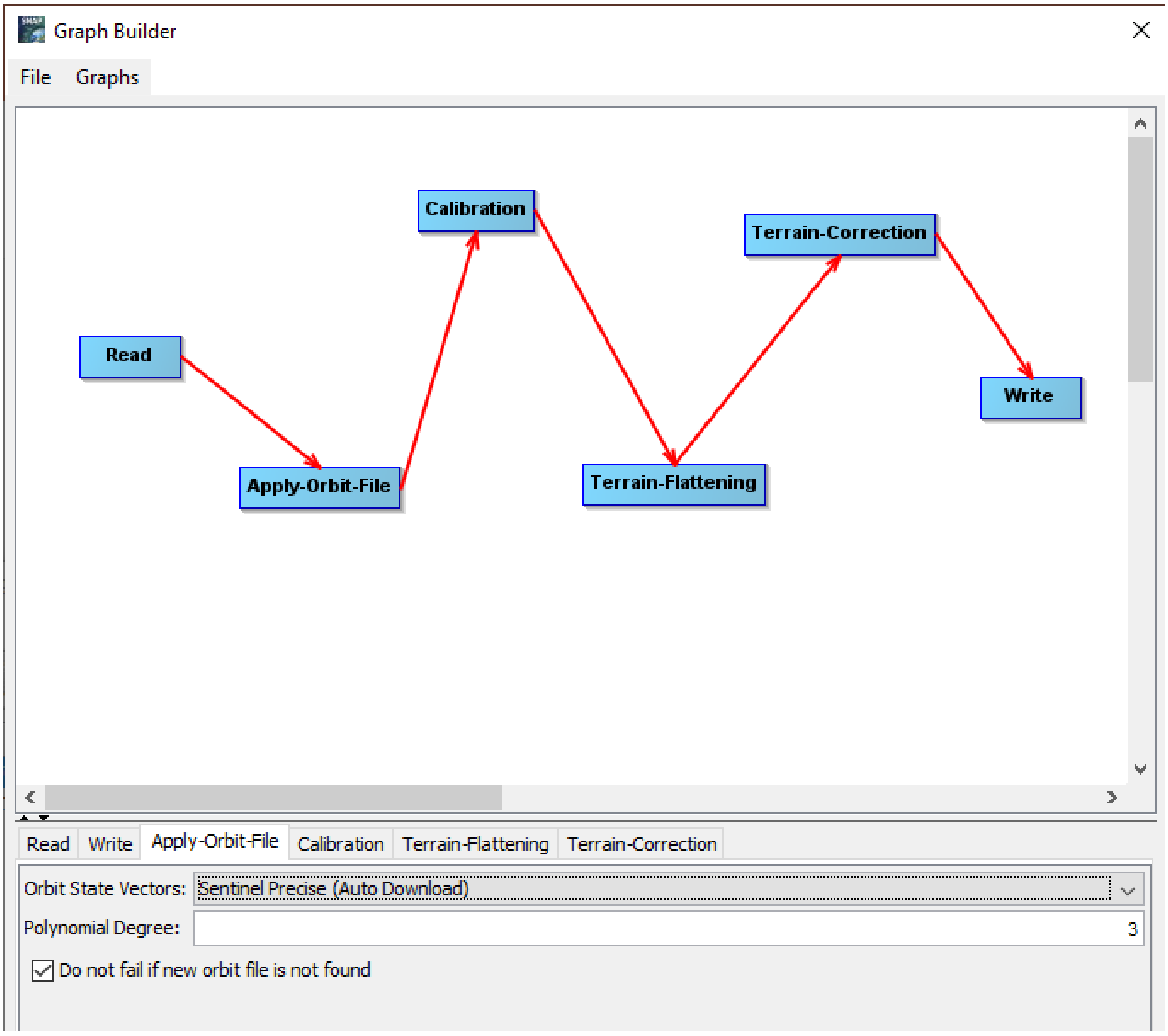
### Build a pre-processing graph

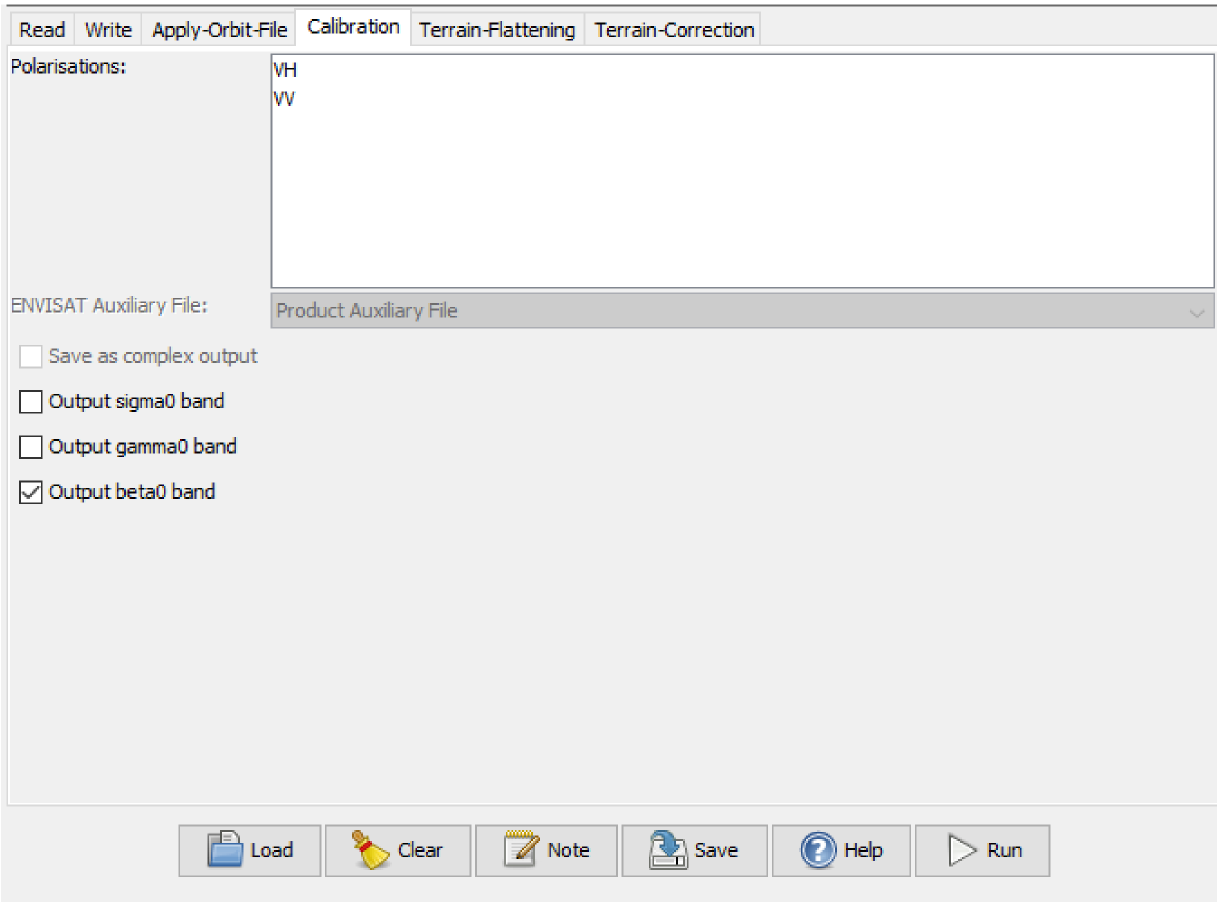
Use the graph builder tool to create workflow for data processing:

Go to Tools>GraphBuilder
Right click and add, in the order below, each of the preprocessing steps:

The first tool is Read
Add>Radar>Apply-Orbit-File and keep pre-defined parameters. Check „Do not fail if new orbit file is not found"
Add>Radar>Radiometric>Calibration and select Output beta0 band
Add>Radar>Radiometric>Terrain Flattening will add terrain flattening
Add>Radar>Geometric> Terrain Correction>Terrain Correction
The last tool is Write

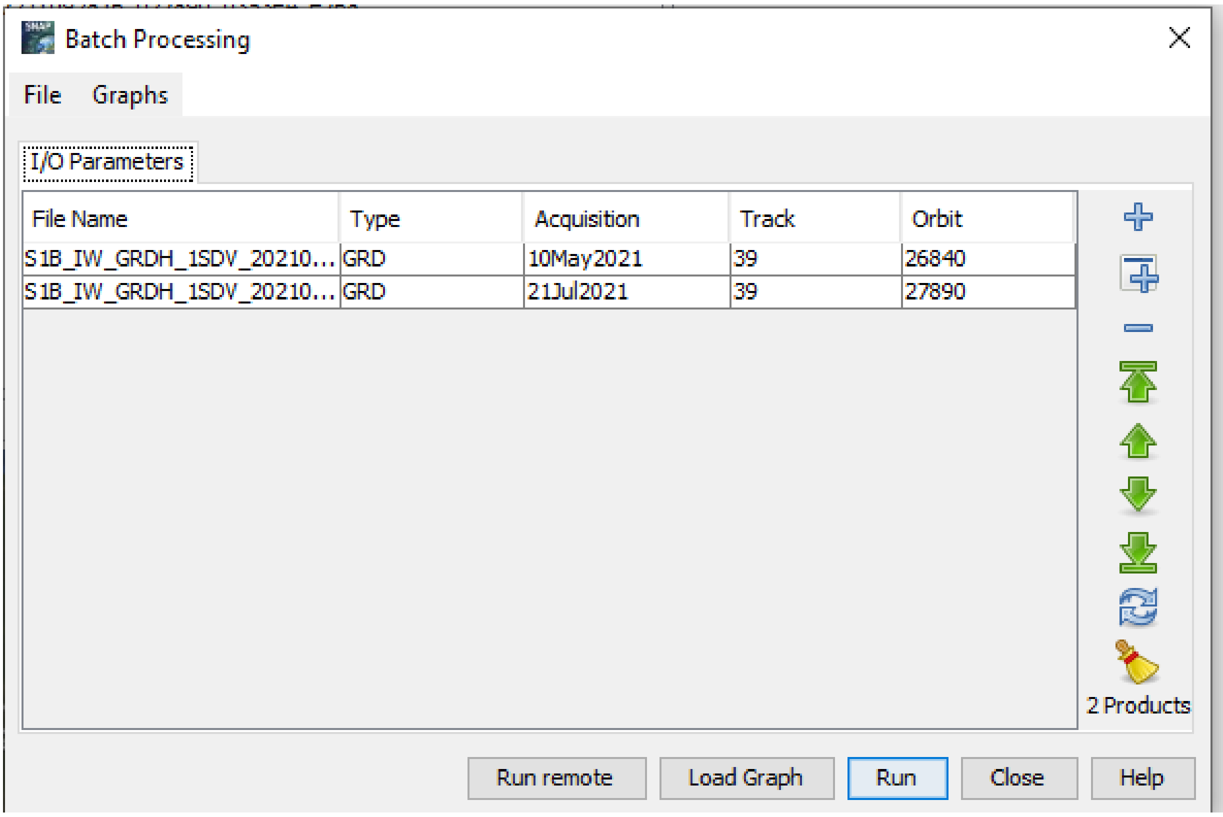
Click on each tool, and connect them by dragging the red arrows from one tool to the next, respecting the order above
Then got to File>Save Graph to save the workflow as a XML file.



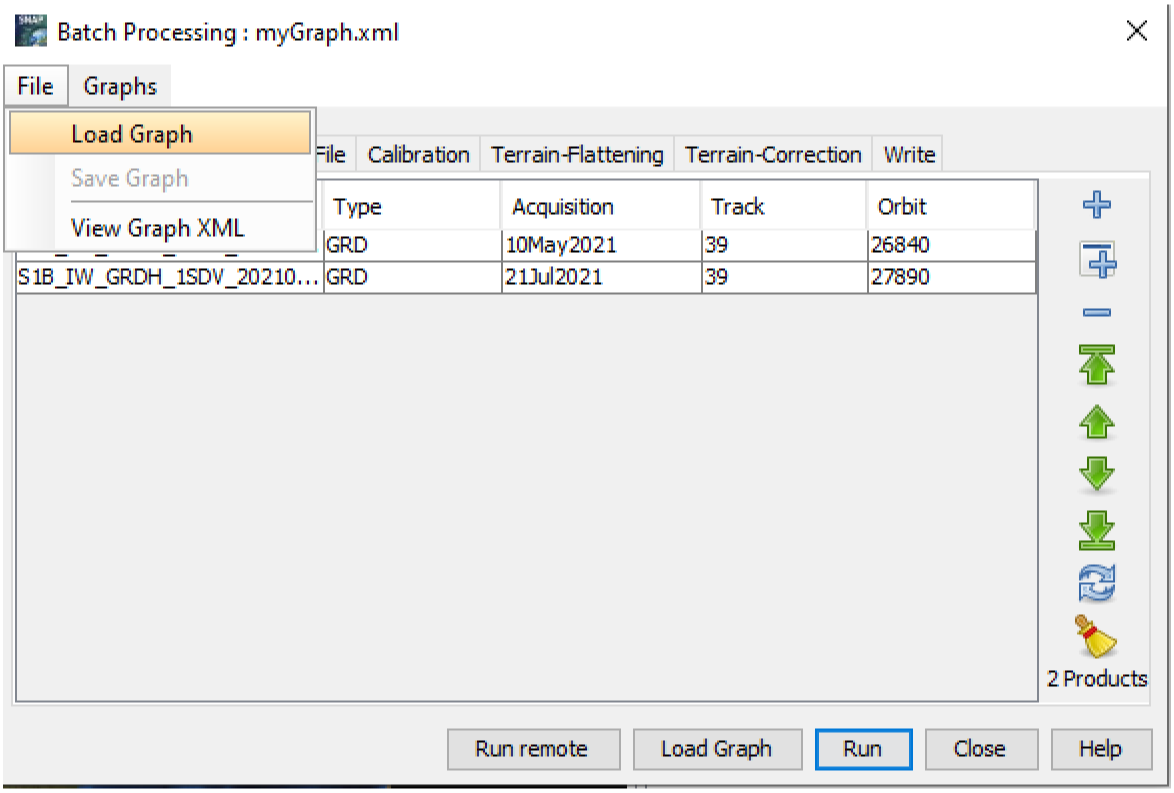


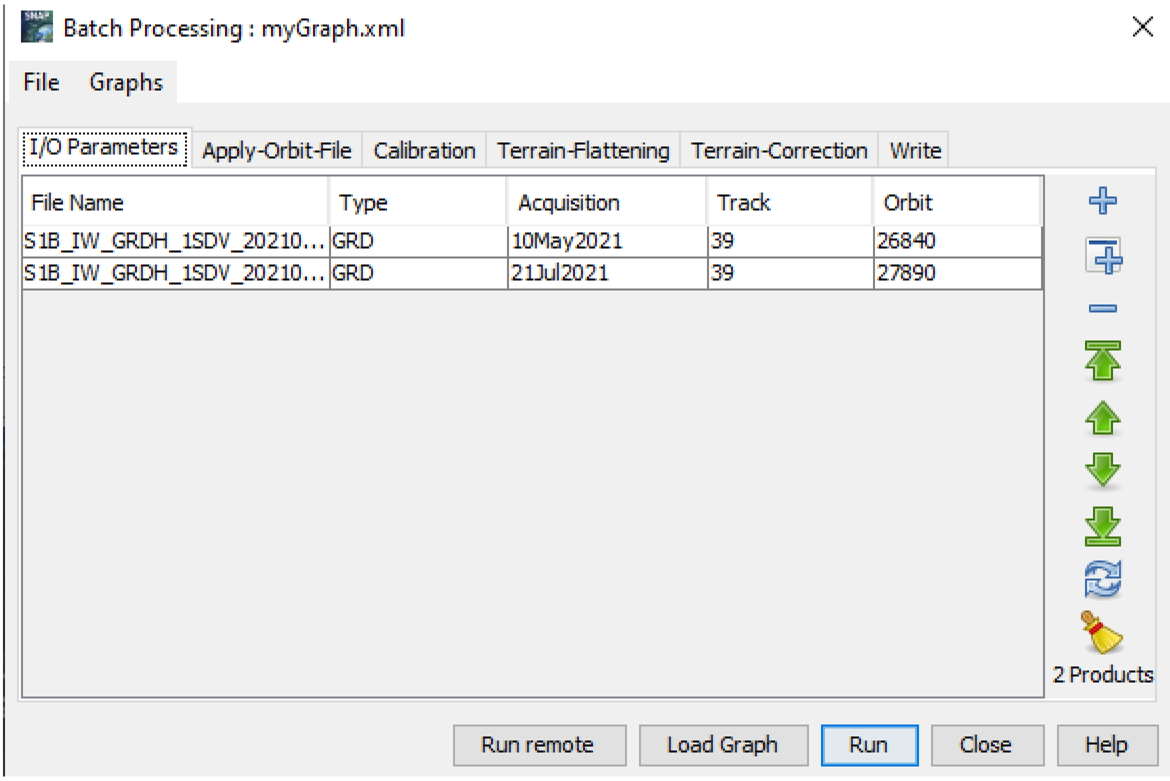

## Batch processing

Navigate to Tools > Batch Processing:
Using the Add opened symbol select the files you want to process.



Using the Load Graph button, load the .xml-file you just saved

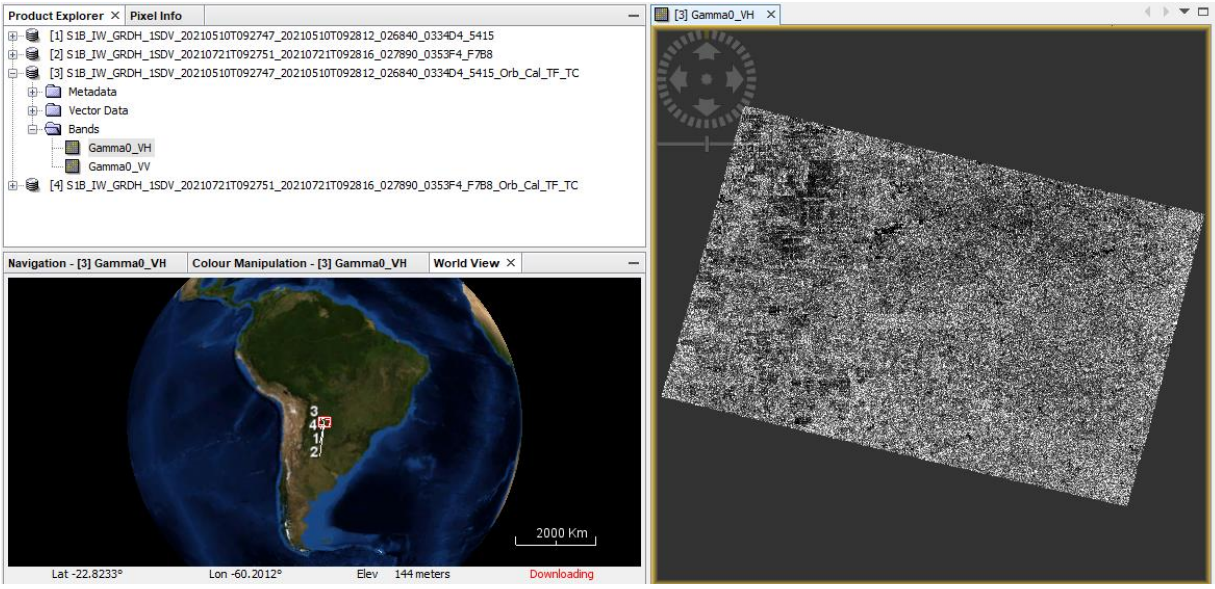



Adjust the output folder, click Run.

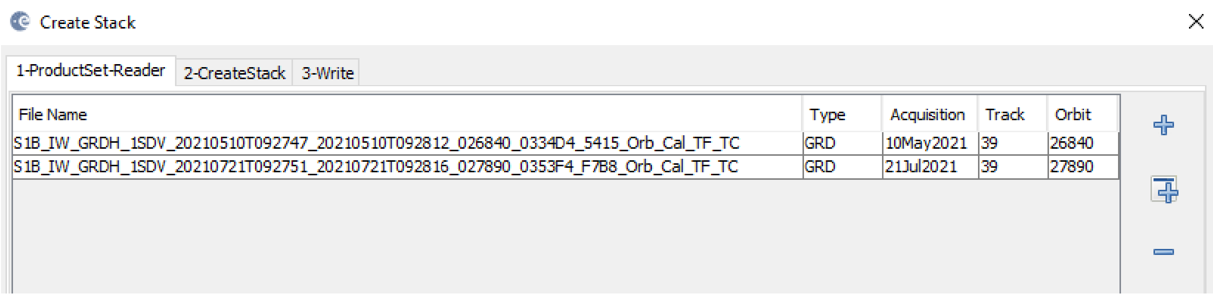
Note: this step might take several minutes/hours to run.

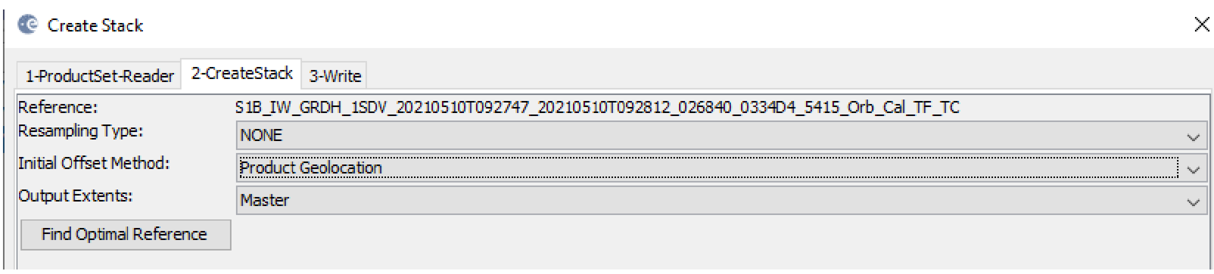
View the output product, e.g. by doulble-click on Gamma0_VH terrain corrected band.

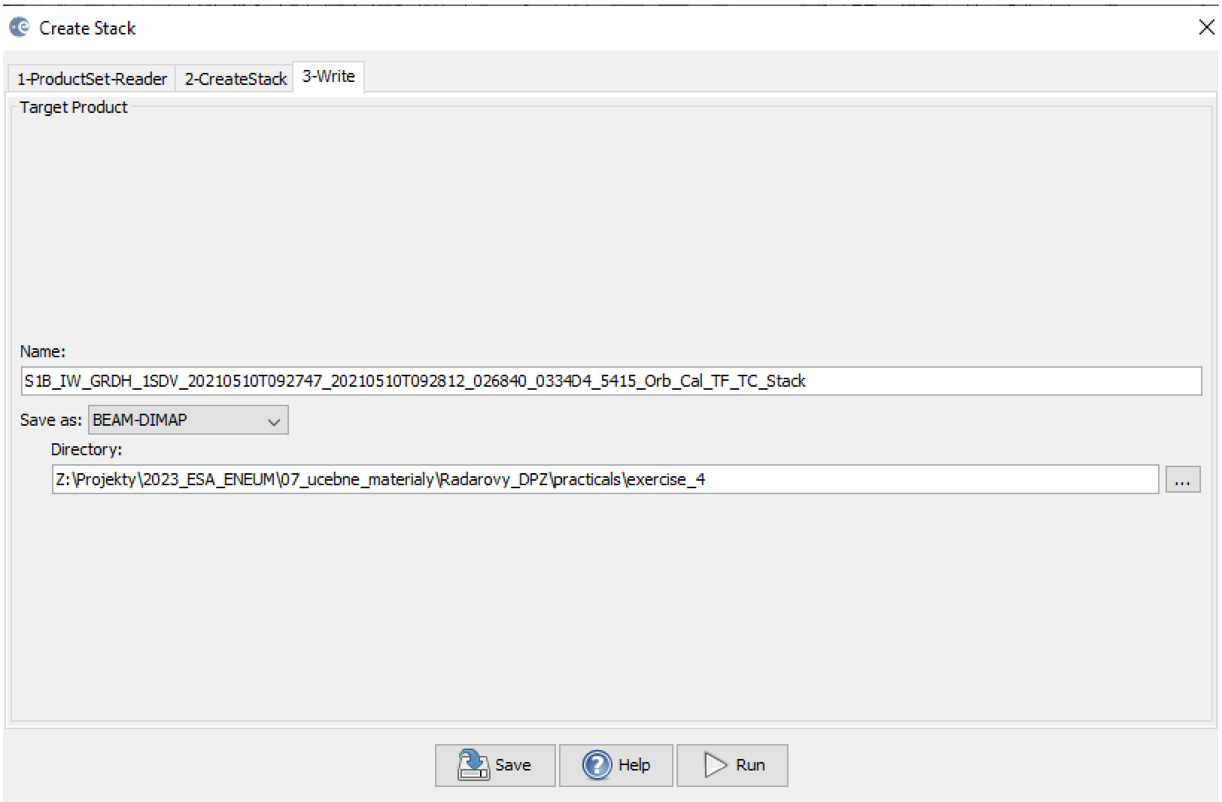



## Create stack

Go to Radar > Coregistration > Stack Tools > Create Stack
In the CreateStack tab, select Product Geolocation as Initial Offset Method
In the Write tab, adjust the stack name if needed, adjust the output folder and click Run. This step will might take few minutes.

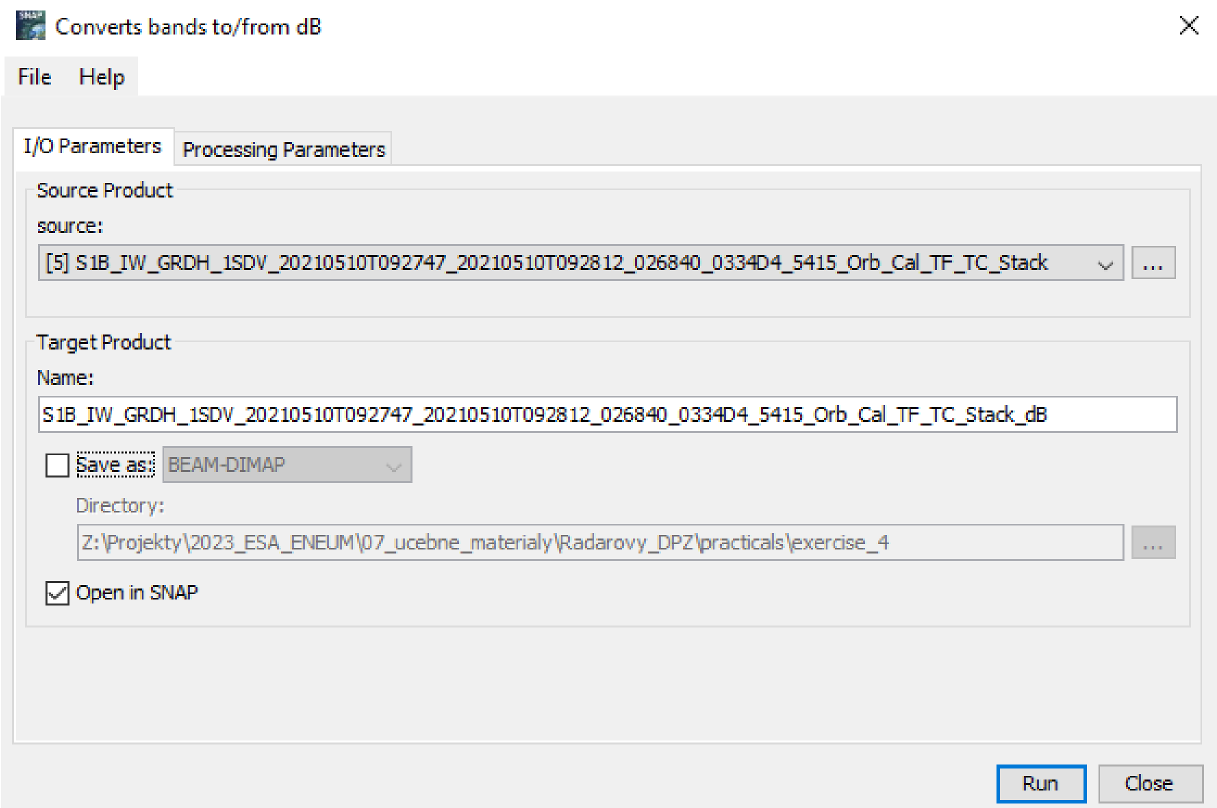




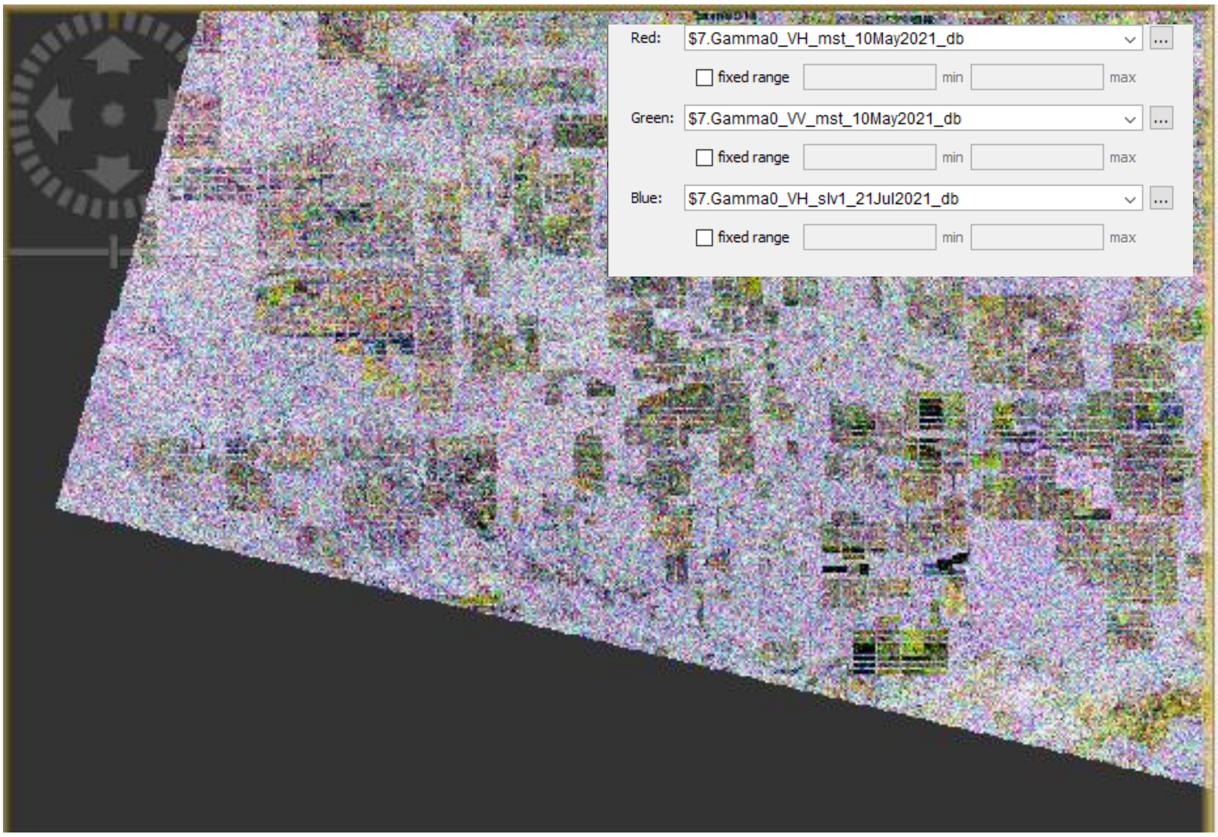

## Convert bands to dB

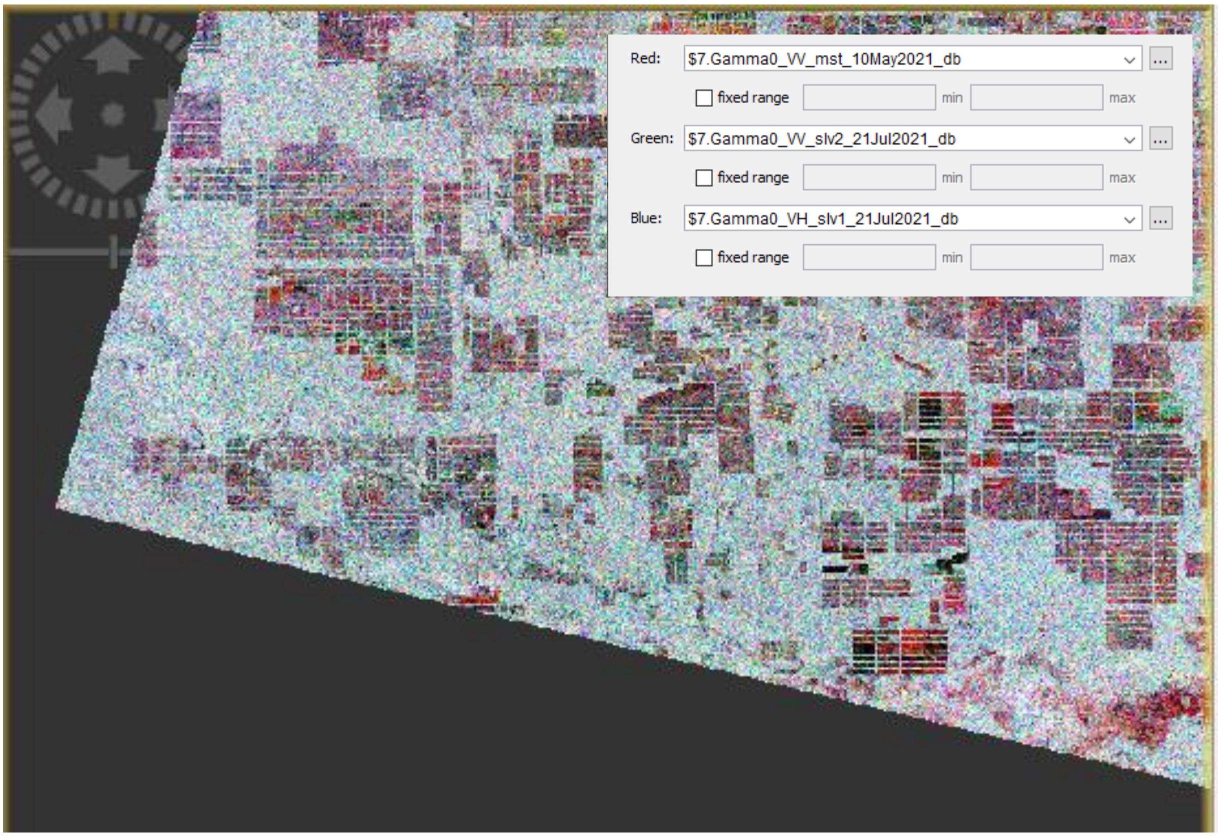
In the Product Explorer select the processed Gamma0_VH band, then go to Raster > Data Conversion > Linear to/from dB and repeat with the Gamma0_VV band.



## Display an RGB

Right-click on the last product – Open RGB Image Window and select different band combinations to see the change of backscatter between different acquisitions. Explore values over forest area and fields.

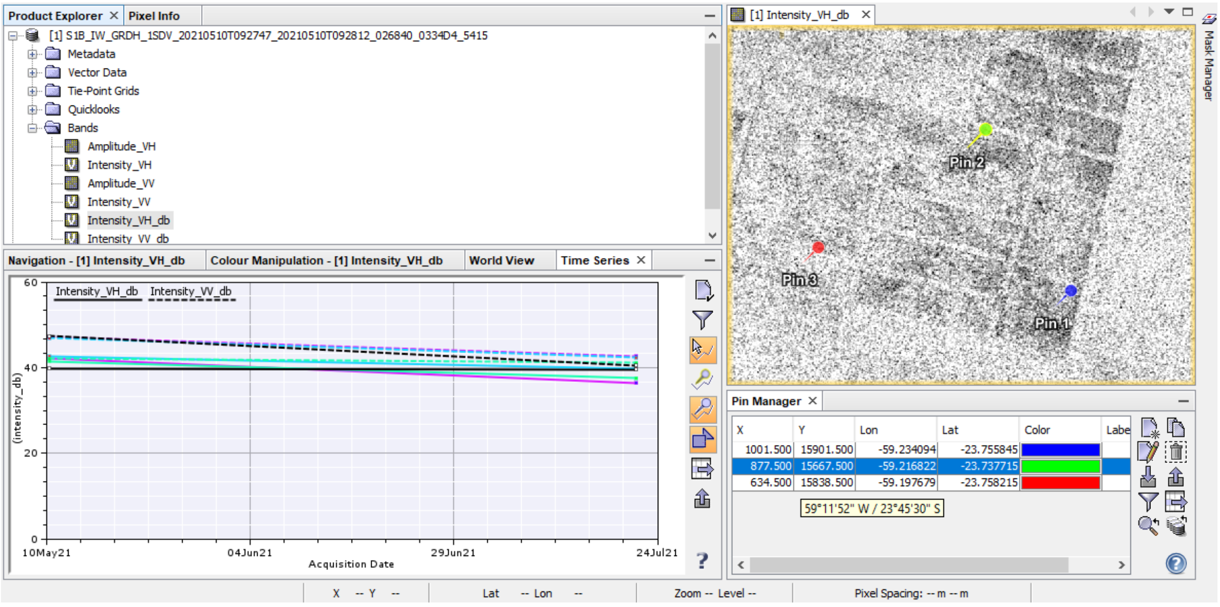


## Time Series Analysis (using single scenes, not a stack)

Tool cannot use a stack, it needs single images instead

Navigate to View > Tool Windows > Radar > Time Series to open the Time Series tab at the bottom left of your SNAP window.
Click on Settings (top right of Time Series tab) and add individual (pre-processed) images. Click Apply.
Using the time series tab, hover your mouse over the area to see the behaviour of single pixels over or use Pin Manager to see the behaviour of the selected Pins.




Explore values to identify forest area and fields.

For more information, see the lecture: [4. SAR remote sensing for forestry]

THANK YOU FOR FOLLOWING THE EXERCISE!