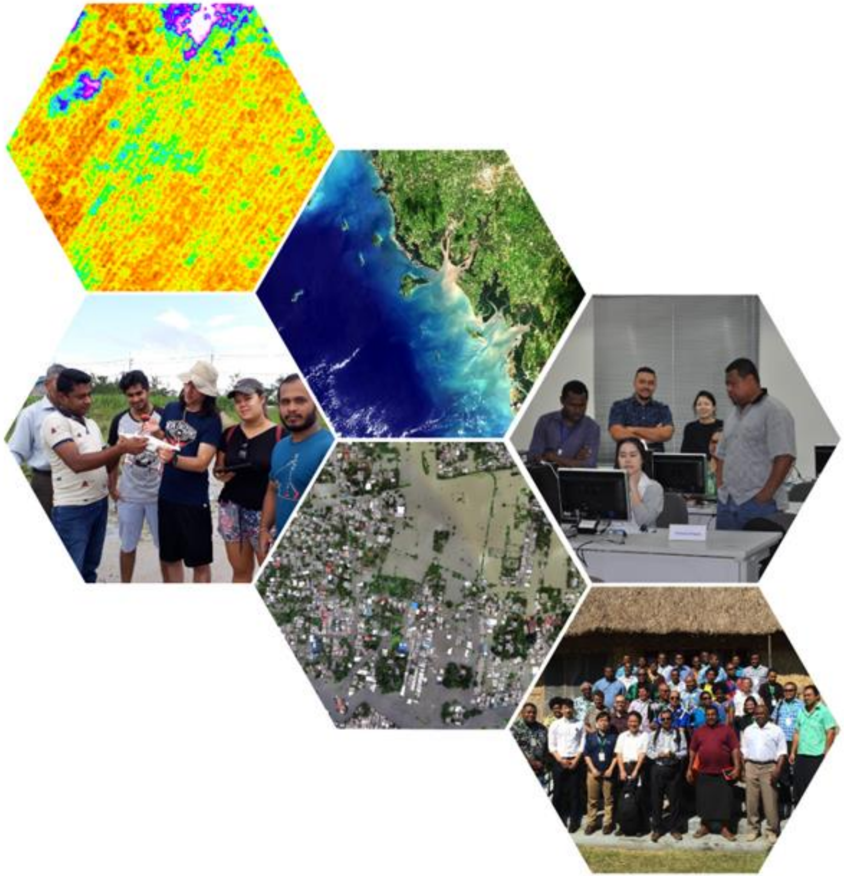

Sentinel-1 Data Handling using SNAP

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Geoinformatics Center - AIT

Overview

Objective

The objective of this exercise is to preprocess Sentinel-1 Ground Range Detected (GRD) imagery to generate Radiometrically Terrain Corrected (RTC) products.

The final RTC product is suitable for quantitative analysis and geospatial applications such as mapping and change detection.

Overview

Data and Software

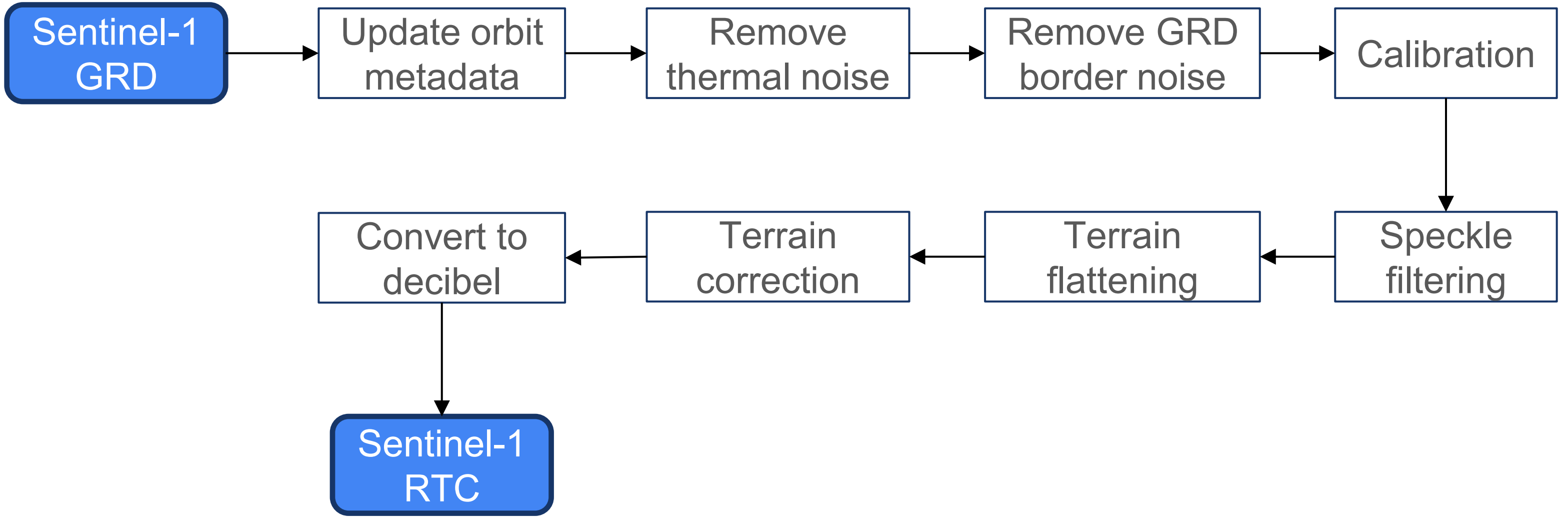
In this exercise, we will use the SNAP software to process a sequence of operations, including orbit metadata update, noise removal, calibration, speckle filtering, terrain flattening, terrain correction, and conversion to decibel scale.

The following data are available:

- Sentinel-1 GRD (Ground Range Detected)
  - File name: S1A_IW_GRDH_1SDV_20250705T001933_20250705T001958_059941_077224_9A87.zip
  - Level-1 Ground Range Detected (GRD) products consist of focused SAR data that has been detected, multi-looked, and projected to ground range using an Earth ellipsoid model.
  - Not terrain-corrected by default.
  - Observation mode: Interferometric Wide (IW).
  - Dual Polarization (VH and VV), Descending
  - Data format: SAFE structure
  - Date: 05 July 2025

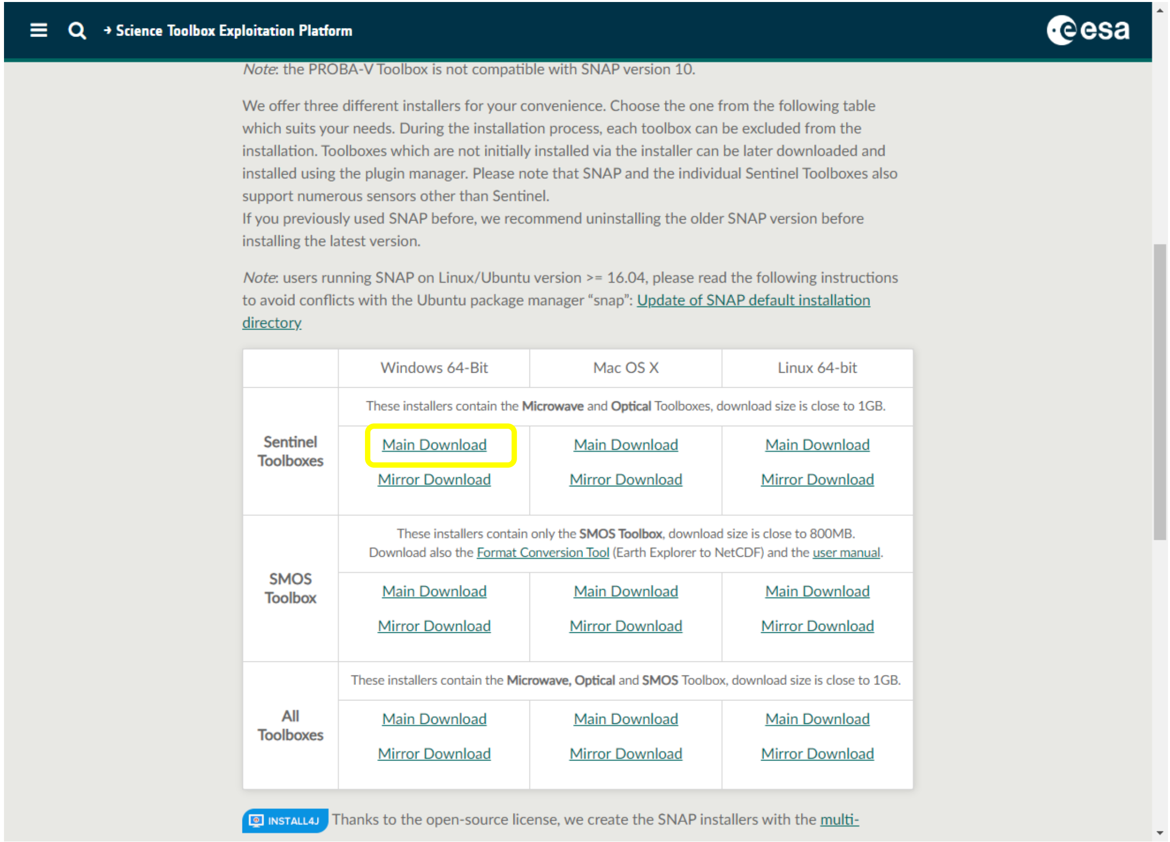
Methodology
Sentinel-1 RTC Workflow

Processing using SNAP



SNAP (Sentinel Application Platform)

Download the 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

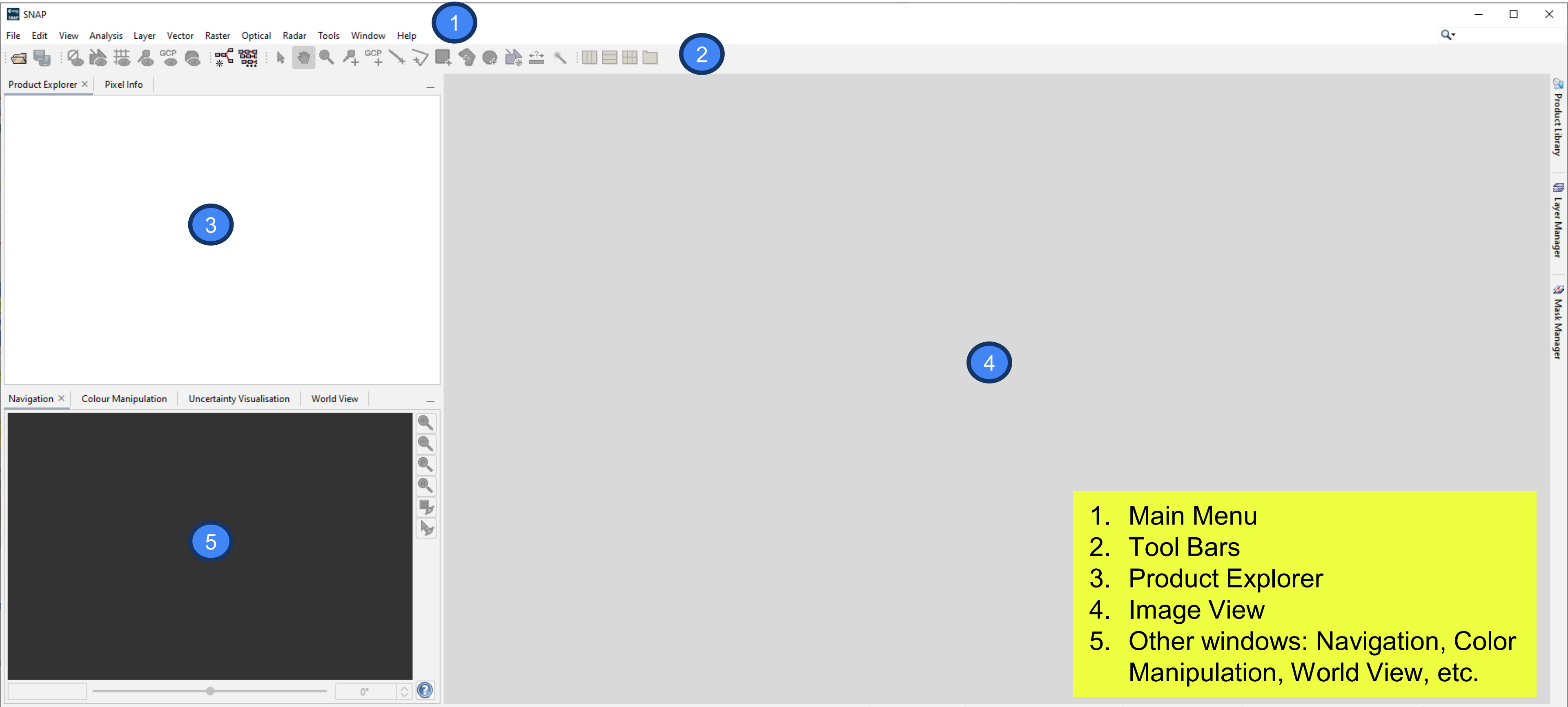
INSTALL4J Thanks to the open-source license, we create the SNAP installers with the multi-

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 Exploration in SNAP

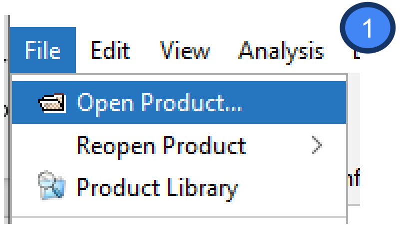
Open SNAP software

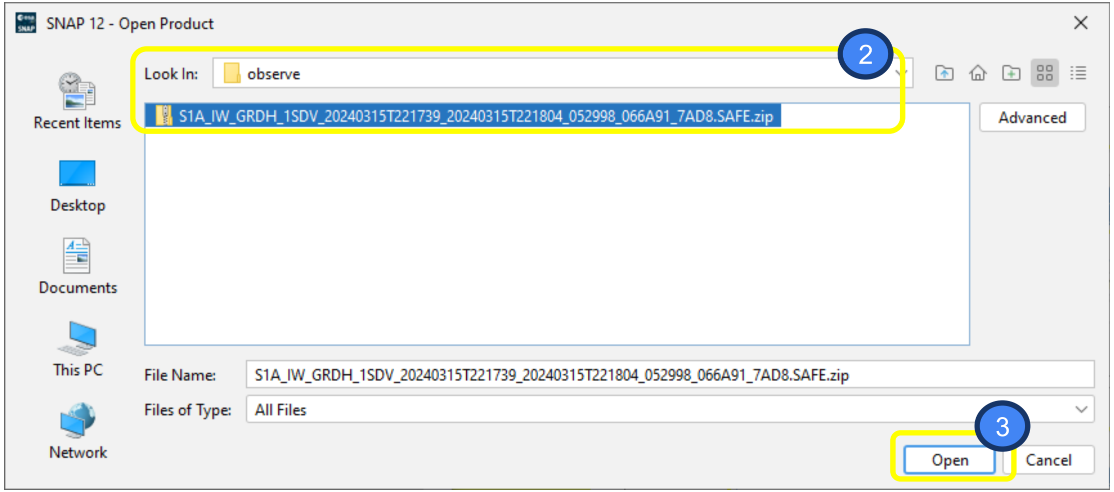


1. Main Menu
2. Tool Bars
3. Product Explorer
4. Image View
5. Other windows: Navigation, Color Manipulation, World View, etc.

Data Exploration in SNAP

Open Sentinel-1 Data

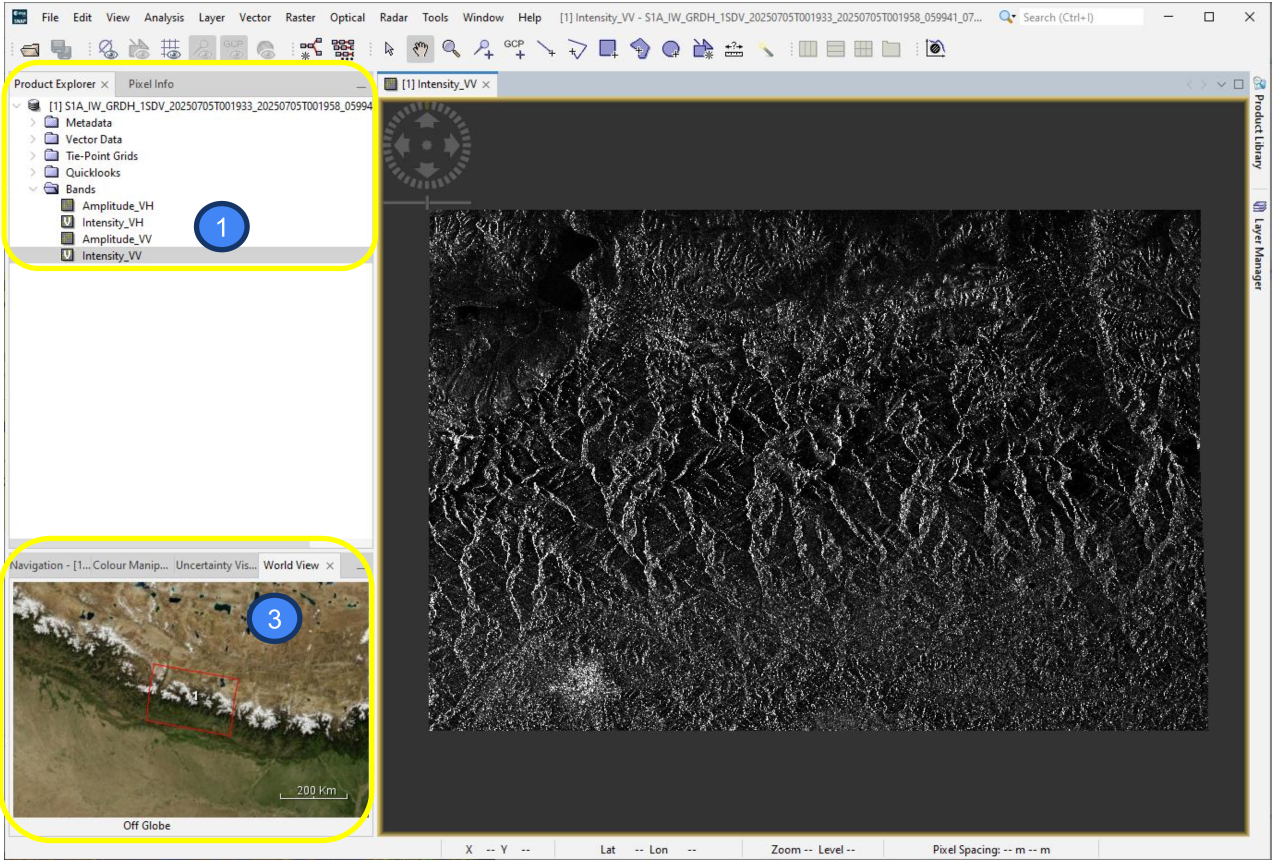




1. In the Main Menu, go to File → Open Product…
2. Browse to the location of the data and select the Sentinel-1 data.
3. Click Open

Data Exploration in SNAP

Explore the Sentinel-1 Data



The opened products will appear in the Product Explorer window.

1. 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.
2. Check also the metadata folder and others.
3. Click the **World View** tab at the bottom left to make sure the images are in the correct area.

Data Processing

Update the orbit metadata

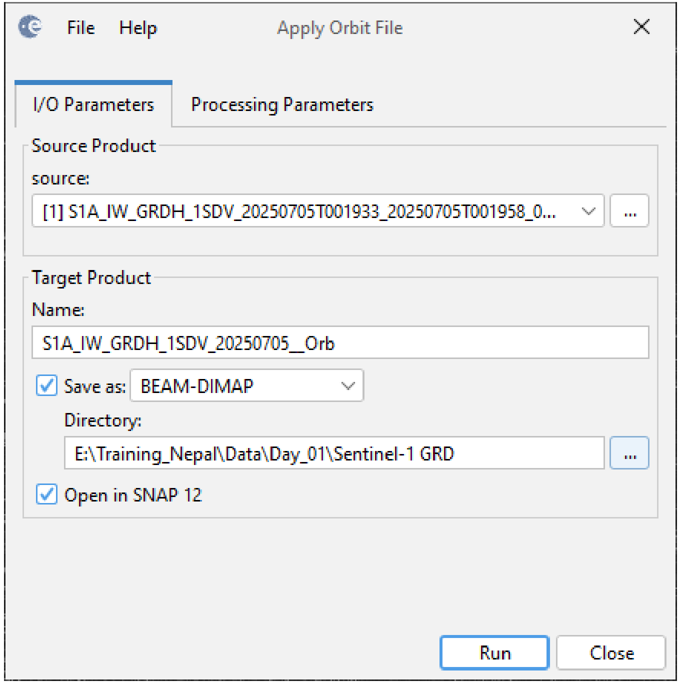
- The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product.

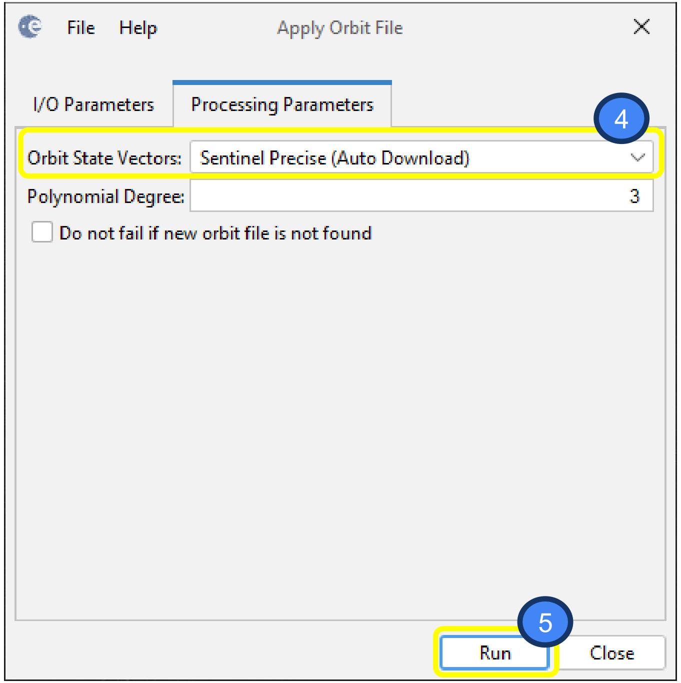
- The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated.

Data Processing

Update the orbit metadata

1. In the SNAP Main Menu, select Radar → Apply Orbit File
2. Go to the **I/O Parameters** tab, select the [1] layer
3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP



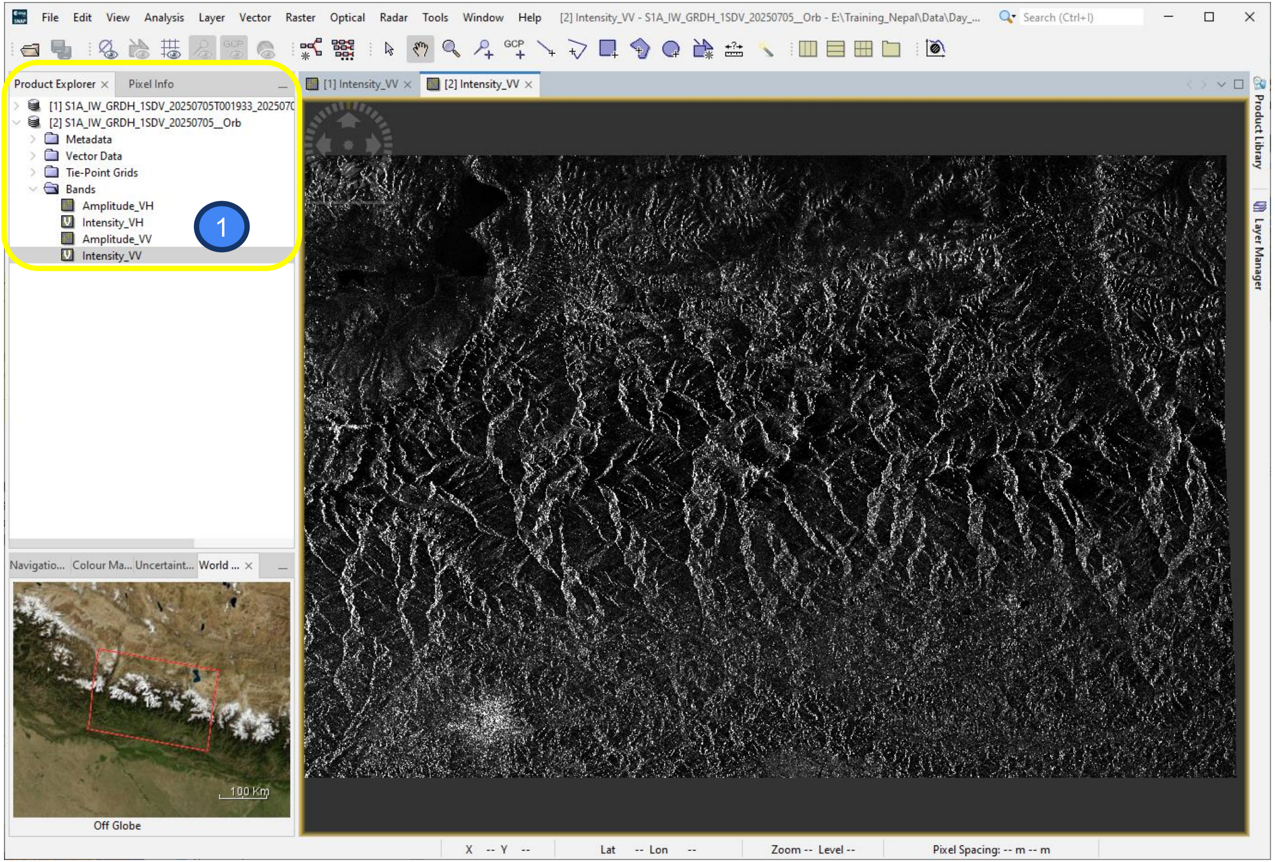


4. Go to the **Processing Parameters** tab. Select the default Sentinel Precise (Auto Download)
5. Run this operator.
6. Check the output image appearance

Process *completed in 9 seconds*

Data Processing

Update the orbit metadata



A new layer appears in the Product Explorer window.

1. Click > to expand the contents of the product [2], then expand the Bands folder and double-click on the Intensity_VV band to visualize it.

The image appearance stays visually unchanged, but its **orbit state vector data (OSVs)** — satellite position and velocity information — is updated.

Data Processing

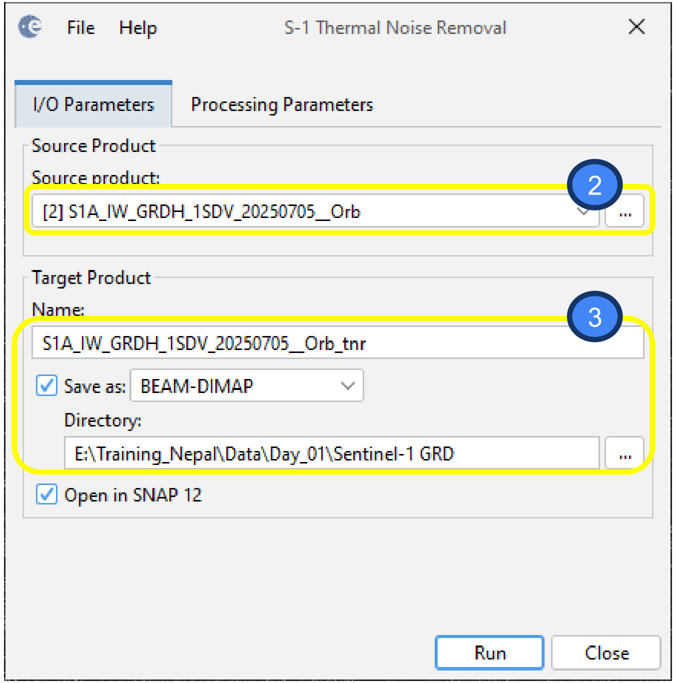
Remove the thermal noise

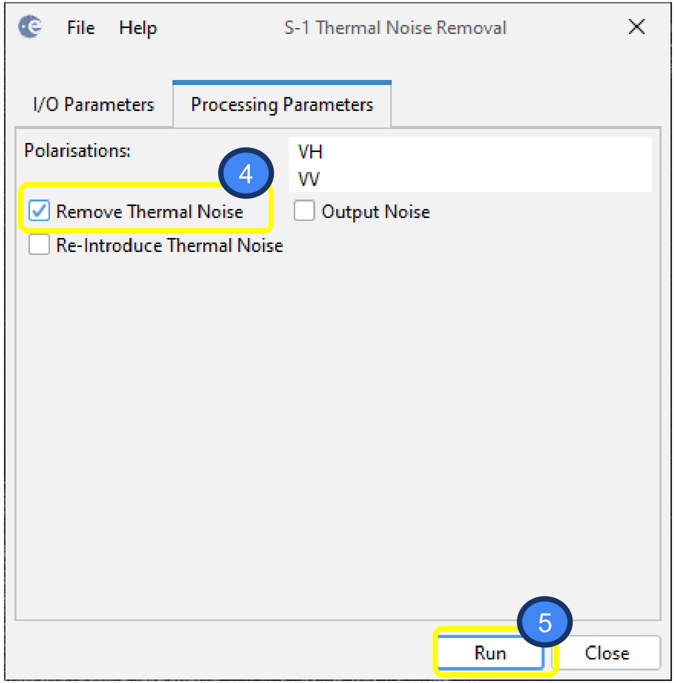
- Thermal noise in SAR imagery is the background energy that is generated by the receiver itself.
- It skews the radar reflectivity to towards higher values and hampers the precision of radar reflectivity estimates.
- Level-1 products provide a noise LUT for each measurement dataset, provided in linear power, which can be used to remove the noise from the product.

Data Processing

Remove the thermal noise

1. In the SNAP Main Menu, select Radar → Radiometric → S-1 Thermal Noise Removal
2. Go to the **I/O Parameters** tab, select the [2] layer
3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP.





4. Go to the **Processing Parameters** tab. Make sure to check the Remove Thermal Noise option.
5. Run this operator.
6. Check the output image appearance.

Process *completed in 53 seconds*

Data Processing

Remove GRD border noise

- The Sentinel-1 GRD (ground range detected) Level-1 product has noise artifacts at the image borders, which are quite consistent at both the left and right sides of the satellite's cross-track and at the start and end of the data take-along track.

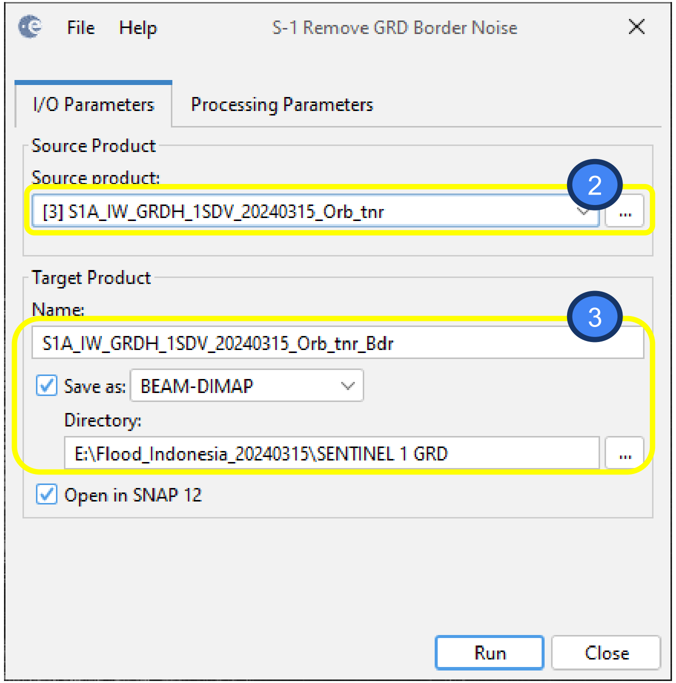
- The Sentinel-1 border noise troubles the creation of a clean and consistent time series of backscatter.

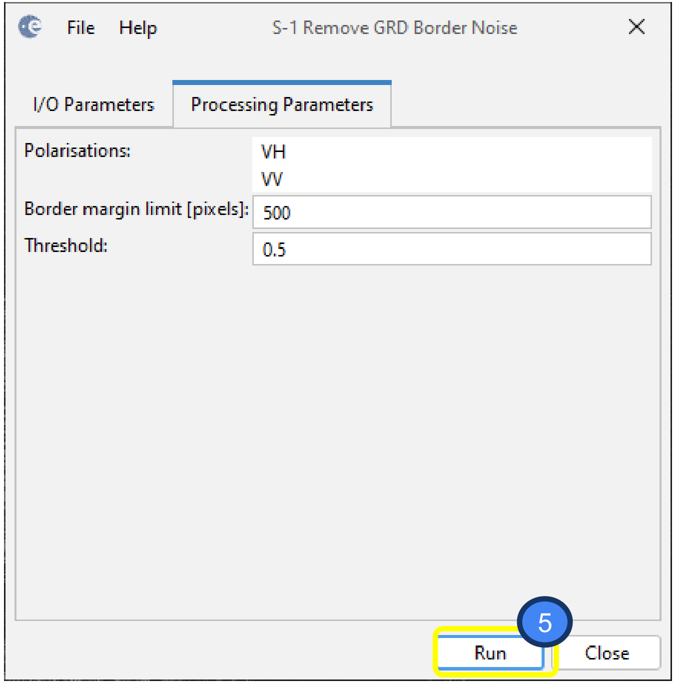
- These processing steps are mainly the azimuth and /range compression and the sampling start time changes handling that is necessary to compensate for the change of earth curvature.

Data Processing

Remove GRD border noise

1. In the SNAP Main Menu, select Radar → Sentinel-1 TOPS → S-1 Remove GRD Border Noise
2. Go to the **I/O Parameters** tab, select the [3] layer
3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP.





4. Go to the **Processing Parameters** tab. Keep the default option.
5. Run this operator.
6. Check the output image appearance.

Process *completed in 5 minutes*

Data Processing

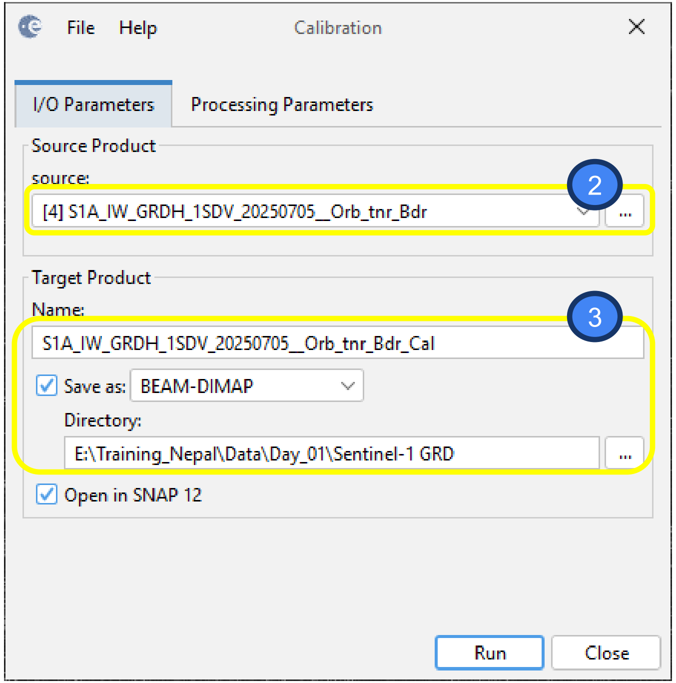
Calibration

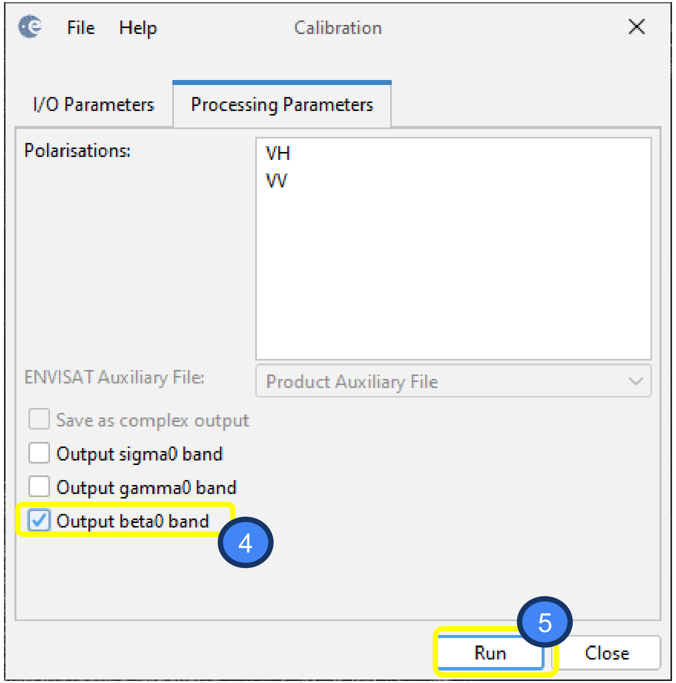
- Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains.
- The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison 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 Processing

Calibration

1. In the SNAP Main Menu, select Radar → Radiomteric → Calibrate
2. Go to the **I/O Parameters** tab, select the [4] layer
3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP.





4. Go to the **Processing Parameters** tab. Select the ”Output beta0 band” option. The beta0 is required for another processing step (Terrain Flattening).
5. Run this operator.
6. Check the output image appearance.

Process *completed in 6 minutes*

Data Processing
Speckle filter

- SAR images have inherent salt and pepper-like texturing called speckles, which degrade the quality of the image and make the interpretation of features more difficult.

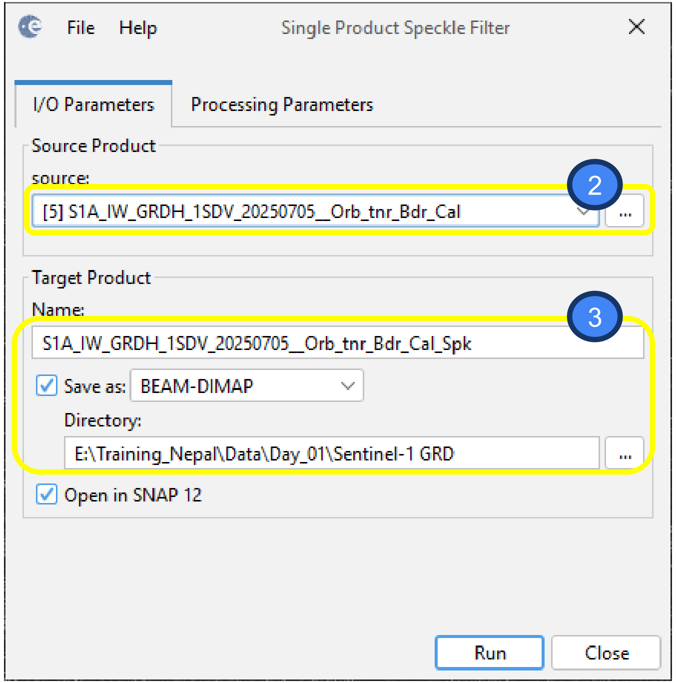
- Speckles are caused by random constructive and destructive interference of the de-phased but coherent return waves scattered by the elementary scatterers within each resolution cell.

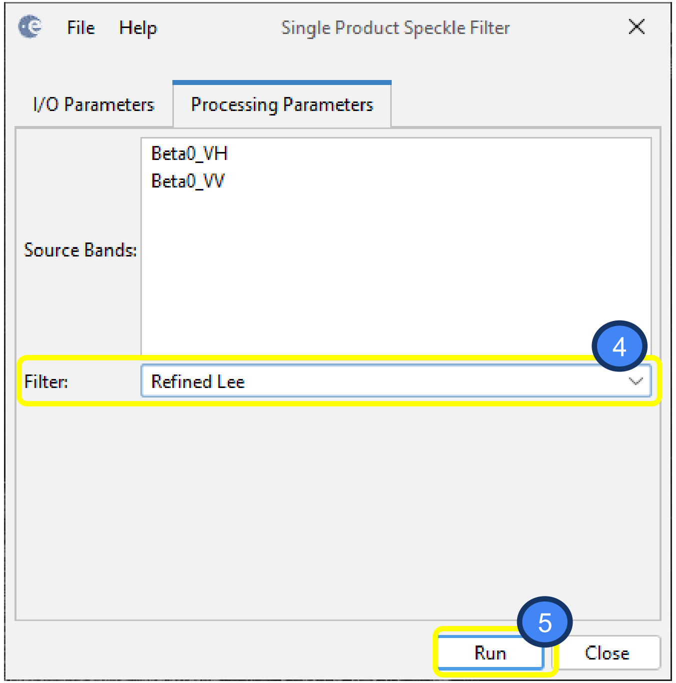
- Speckle noise reduction can be applied either by spatial filtering or multilook processing. The operator supports several speckle filters for handling speckle noise of different distributions (Gaussian, multiplicative or Gamma), including Boxcar (mean), Median, Frost, Lee, Refined Lee, Gamma-MAP, Lee Sigma, IDAN.

Data Processing

Speckle filter

1. In the SNAP Main Menu, select Radar → Speckle Filtering → Single Product Speckle Filter
2. Go to the **I/O Parameters** tab, select the [5] layer
3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP.





4. Go to the **Processing Parameters** tab. Select the "Refined Lee" filter option. You can also try other available filters if you'd like.
5. Run this operator.
6. Check the output image appearance.

Process *completed in 8 minutes*

Data Processing

Terrain flattening

- Terrain variations affect not only the position of a target on the Earth's surface, but also the brightness of the radar return. Without treatment, the radiometric biases caused by terrain variations are introduced into the coherency and covariance matrices.

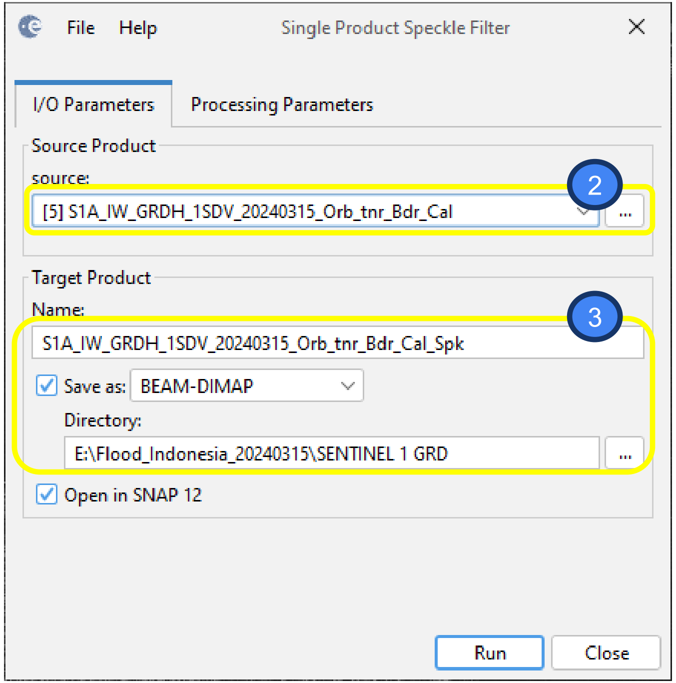
- This operator removes the radiometric variability associated with topography using the Radiometric Terrain Correction algorithm.

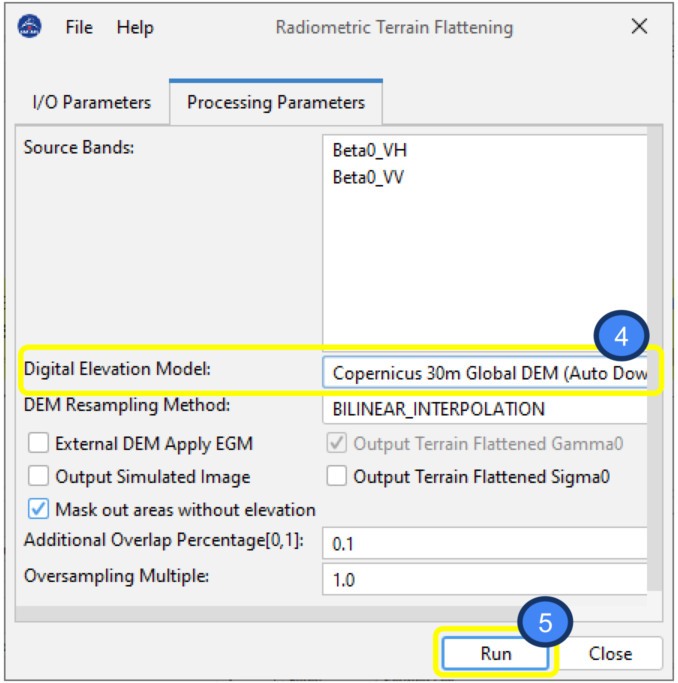
- In the RTC algorithm, the radiometric effect is simulated using a digital elevation model (DEM) of the imaged area. It is therefore required that the DEM resolution must be higher than the image resolution. In case that the DEM resolution is lower than the image resolution, users have two options: 1) Oversample the DEM to higher resolution, 2) Multilook the source image to lower resolution

- The input to this operator should be calibrated beta0. The output of this operator is terrain flattened gamma0.

Data Processing
Terrain flattening

1. In the SNAP Main Menu, select Radar → Radiometric → Radiometric Terrain Flattening
2. Go to the **I/O Parameters** tab, select the [6] layer
3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP.





4. Go to the **Processing Parameters** tab. Select the "Copernicus 30m Global DEM" option.
5. Run this operator.
6. Check the output image appearance.

Process *completed in 14 minutes.*

Data Processing
Terrain correction

- Due to topographical variations of a scene and the tilt of the satellite sensor, distances can be distorted in the SAR images.

- Image data not directly at the sensor’s Nadir location will have some distortion.

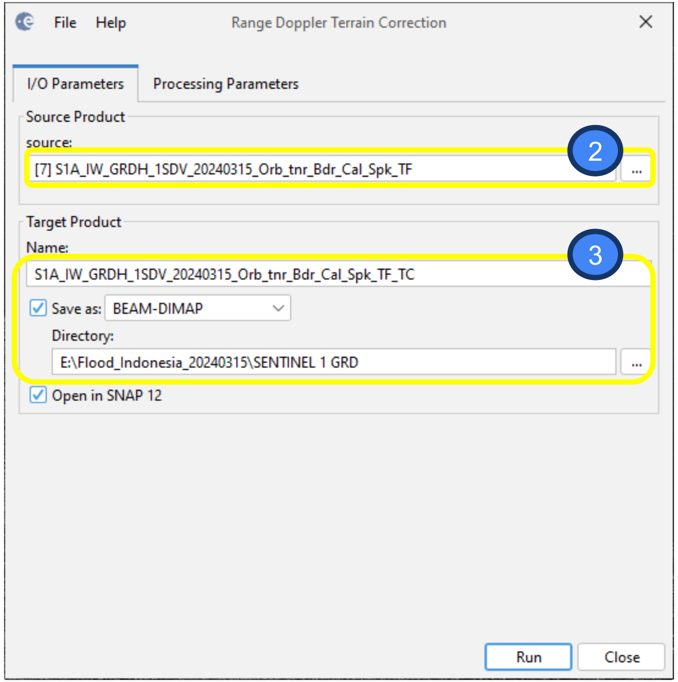
- Terrain corrections are intended to compensate for these distortions so that the geometric representation of the image will be as close as possible to the real world.

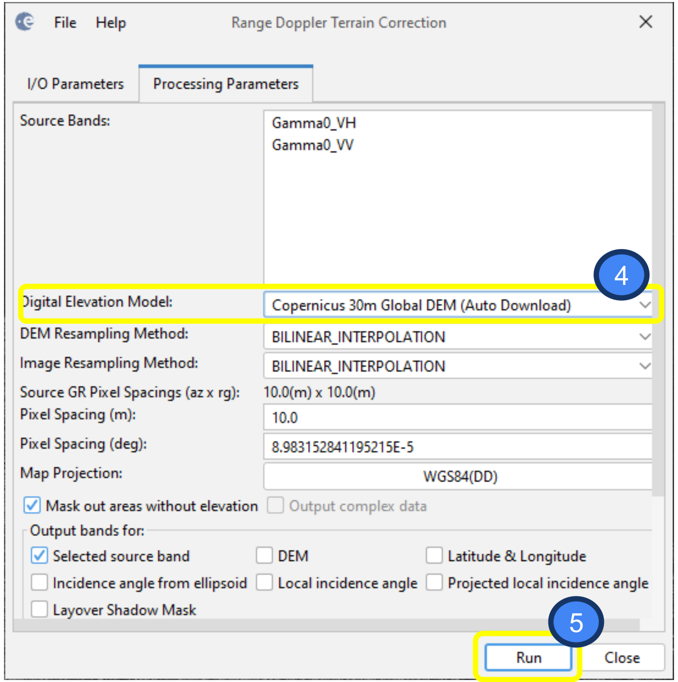
- The Range Doppler Terrain Correction Operator implements the Range Doppler orthorectification method for geocoding SAR images from a single 2D raster radar geometry.

Data Processing

Terrain correction

1. In the SNAP Main Menu, select Radar → Geometric → Terrain Correction → Range-Doppler Terrain Correction
2. Go to the **I/O Parameters** tab, select the [7] layer
3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP.



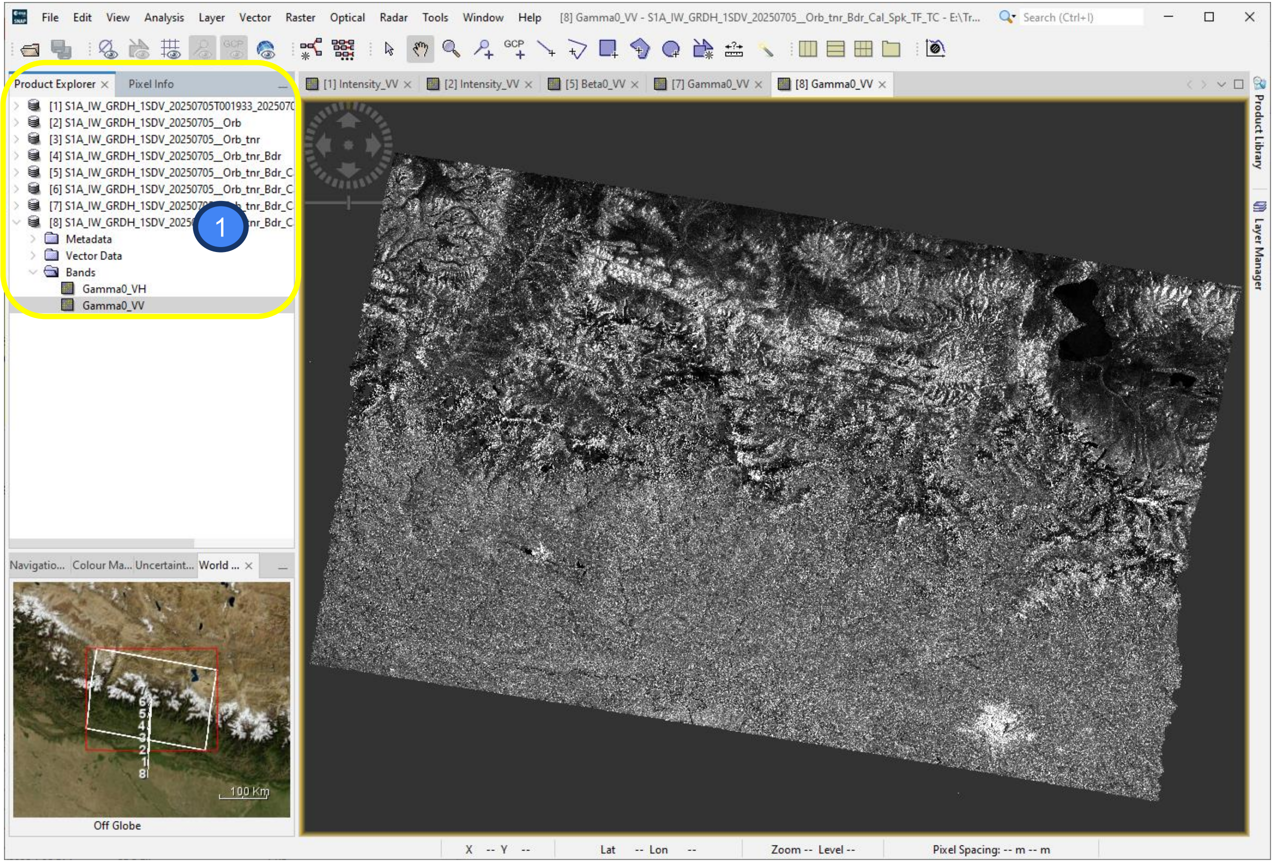


4. Go to the **Processing Parameters** tab. Select the "Copernicus 30m Global DEM" option.
5. Run this operator.
6. Check the output image appearance.

Process *completed in 21 minutes*

Data Processing

Terrain correction



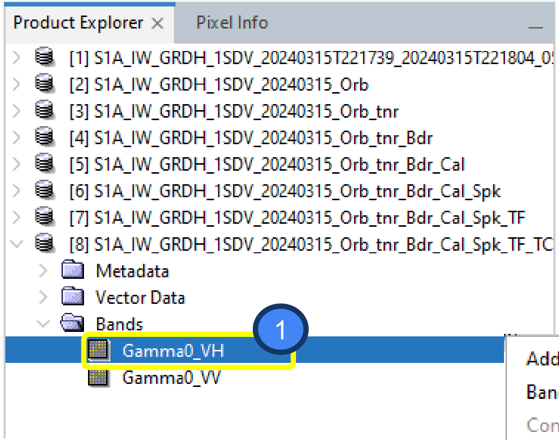
A new layer appears in the Product Explorer window.

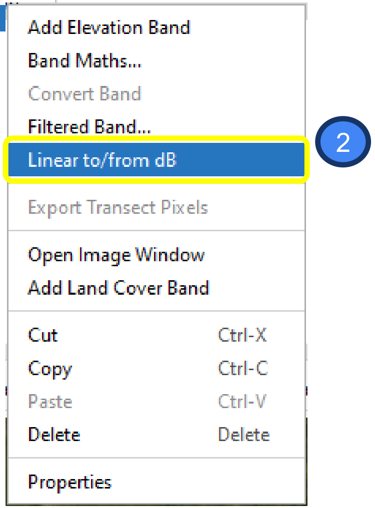
1. Click > to expand the contents of the product [8], then expand the Bands folder and double-click on the Gamma0_VV band to visualize it.

The image is terrain-corrected, map-projected backscatter bands. Pixel coordinates correspond accurately to lat/lon or UTM positions.

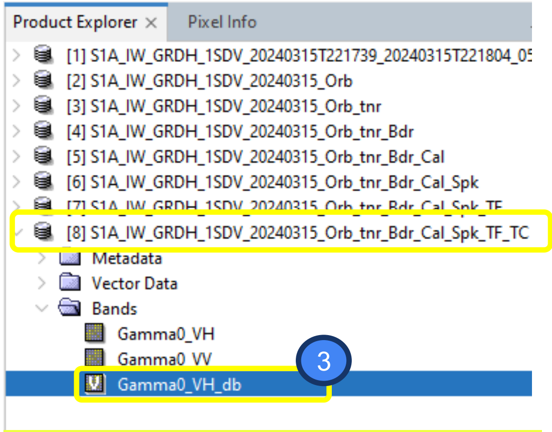
Data Processing

Convert to decibel

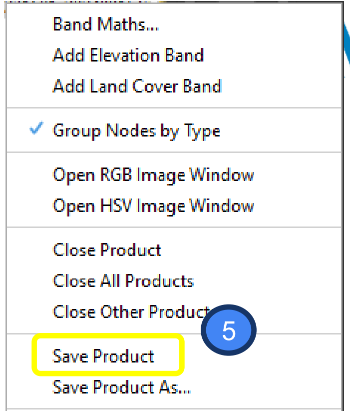


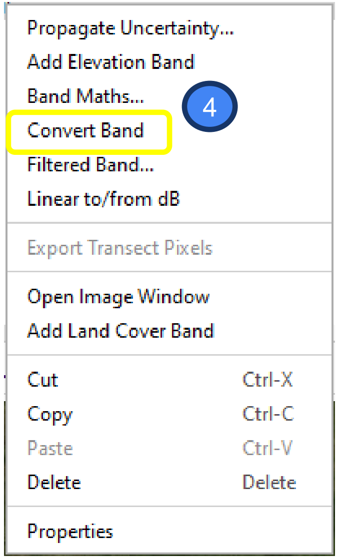


1. In the Product Explored, open the output band folder, then right-click on the Gamma0_VH band.
2. Select Linear to/from dB. Accept the pop-up window to confirm the conversion to a new virtual band.



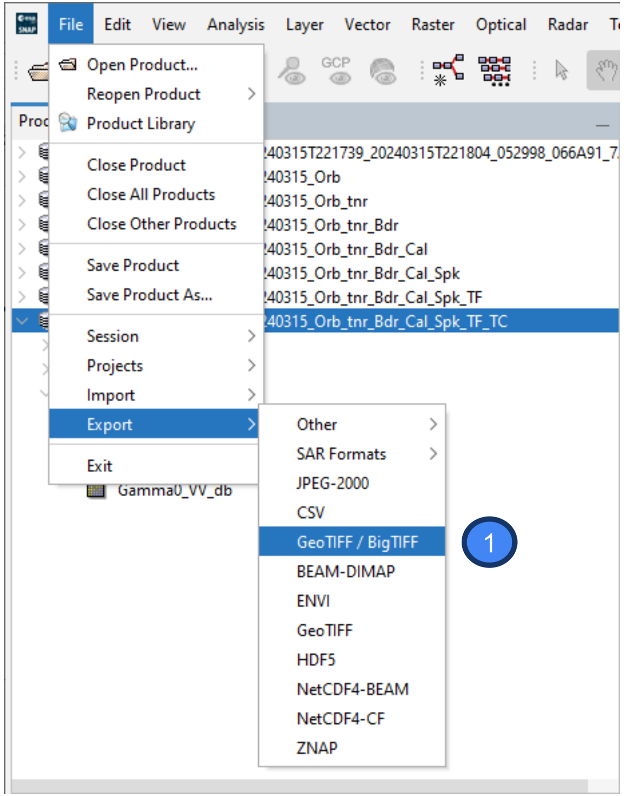
3. The converted Gamma0_VH_db band will be saved in the band folder.
4. Right-click on this new band, then select Convert Band to convert the virtual band to image.
5. Do the same for VV polarization
6. Right-click on the [8] folder, and select Save Product

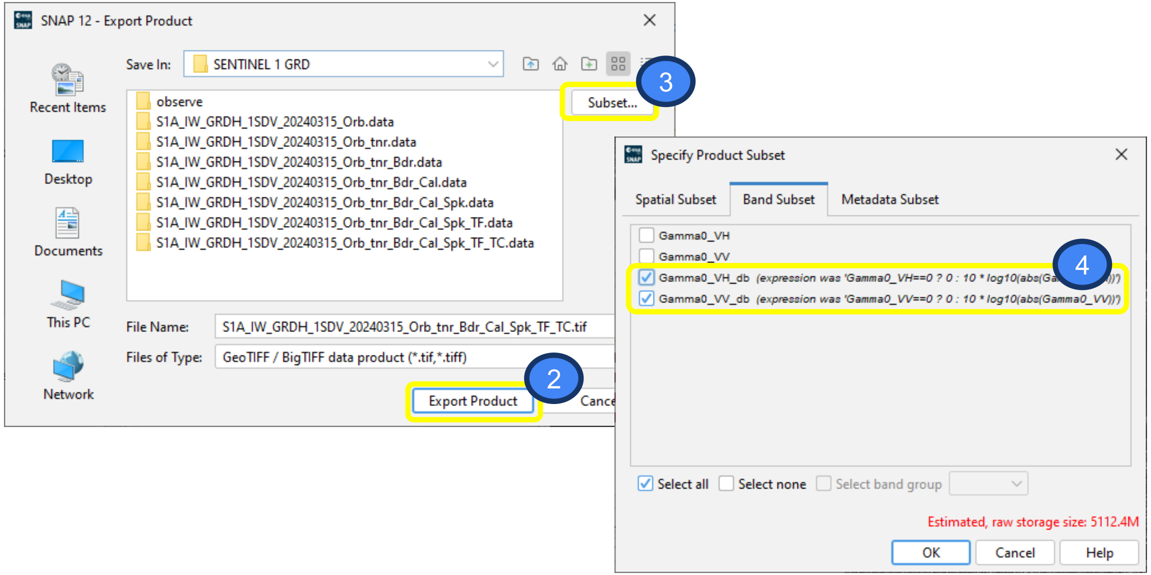




Data Processing

Optional: Save the output to GeoTIFF





1. While the output layer is selected, go to File → Export → GeoTIFF/BigTIFF.
2. Click Subset to specify the product to be exported.
3. Go to Band Subset, select the decibel products. Click OK.
4. Click Export Product to save the output.

THANK YOU

Geoinformatics Center, Asian Institute of Technology