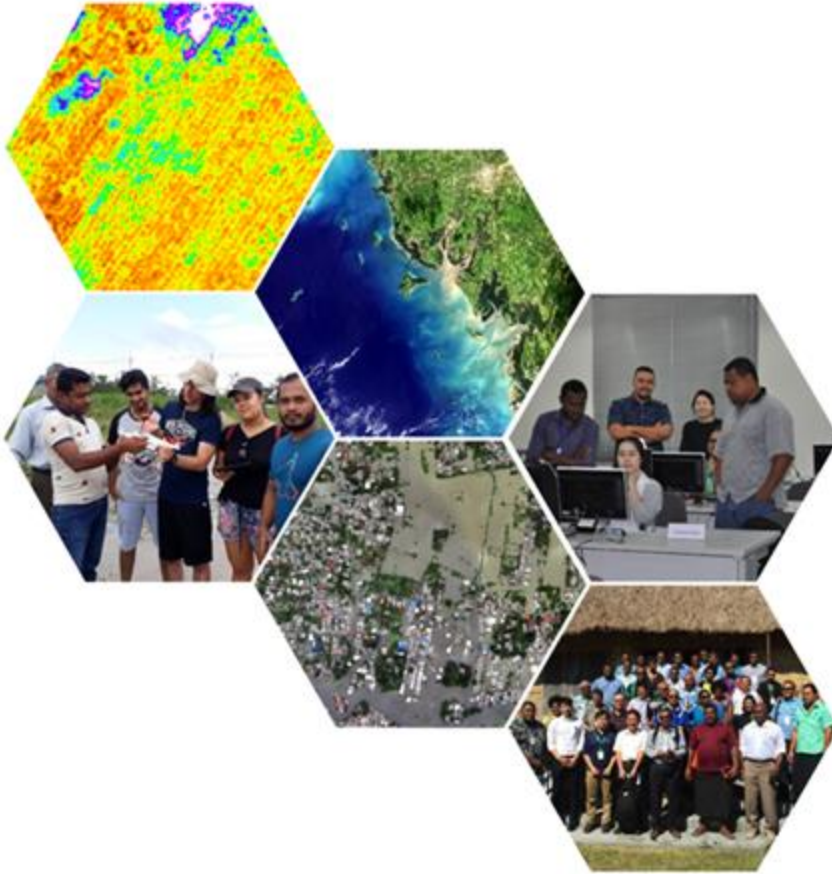# Sentinel-1 Data Handling using SNAP

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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 flood mapping and change detection.

Overview

ALOS-2 Processing Level

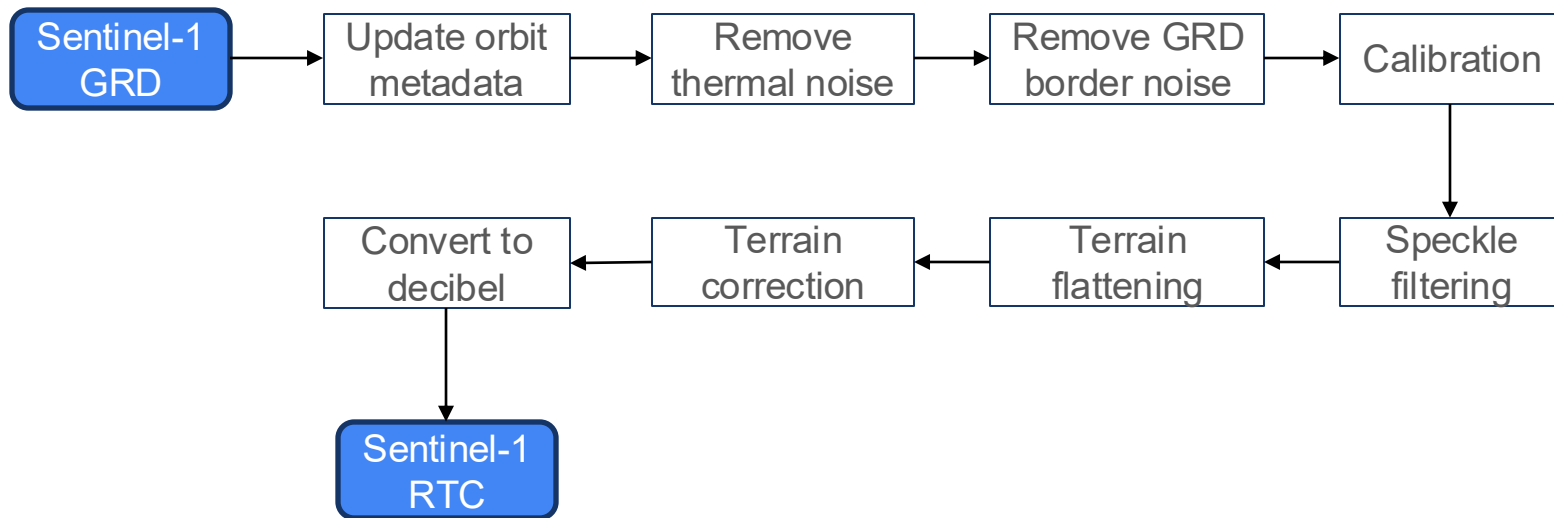| Level	Definition	Format
1.1	• Range and single look azimuth compressed data is represented by complex I and Q channels to preserve the magnitude and phase information. • Range coordinate is in slant range. • In the case of ScanSAR mode, an image file is generated per each scan. • Suitable for InSAR analysis.	CEOS/GeoTIFF
1.5	• Range and multi-look azimuth compressed data is represented by amplitude data. • Range coordinate is converted from slant range to ground range, and map projection is performed. • Image and map are misaligned because it is not orthorectified. Geometric correction is required by a user.	CEOS/GeoTIFF
2.1	• Level 2.1 data is orthorectified from level 1.1 data by using digital elevation model. • Pixel spacing is selectable depending on observation modes. Image coordinate in map projection is geocoded. • Suitable for an easy understanding since the images overlap on the map. During orthorectified processing, images are distorted at higher elevations, which may affect the analysis results.	CEOS/GeoTIFF
3.1	• Image quality corrections (noise reduction and dynamic range compression) are performed to the level 1.5 data. • Image and map are misaligned because it is not orthorectified. Geometric correction is required by a user.	CEOS/GeoTIFF

Overview
Sentinel-1 Processing Level

Level	Definition	Format
0	• Raw, unprocessed data directly from the satellite.	SAFE
1	• Single Look Complex (SLC): Contains the complex signal (amplitude and phase) in slant-range geometry • Ground Range Detected (GRD): Contains detected (magnitude-only) images in ground-range coordinates, after multi-looking and projection.	SAFE
2	• Ocean (OCN): Specifically designed for oceanographic applications, providing geophysical parameters.	SAFE

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)
  - 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: 15 March 2024

Methodology
Sentinel-1 RTC Workflow

Processing using SNAP

SNAP (Sentinel Application Platform)
Download the software

- 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.
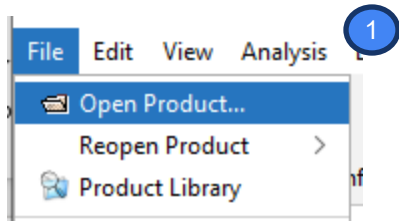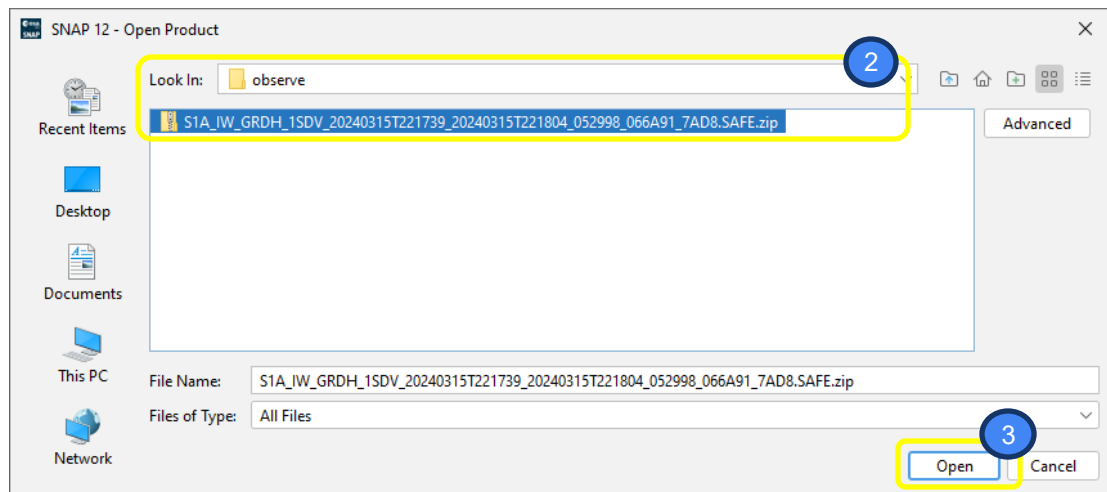
Data Exploration in SNAP
Open SNAP software
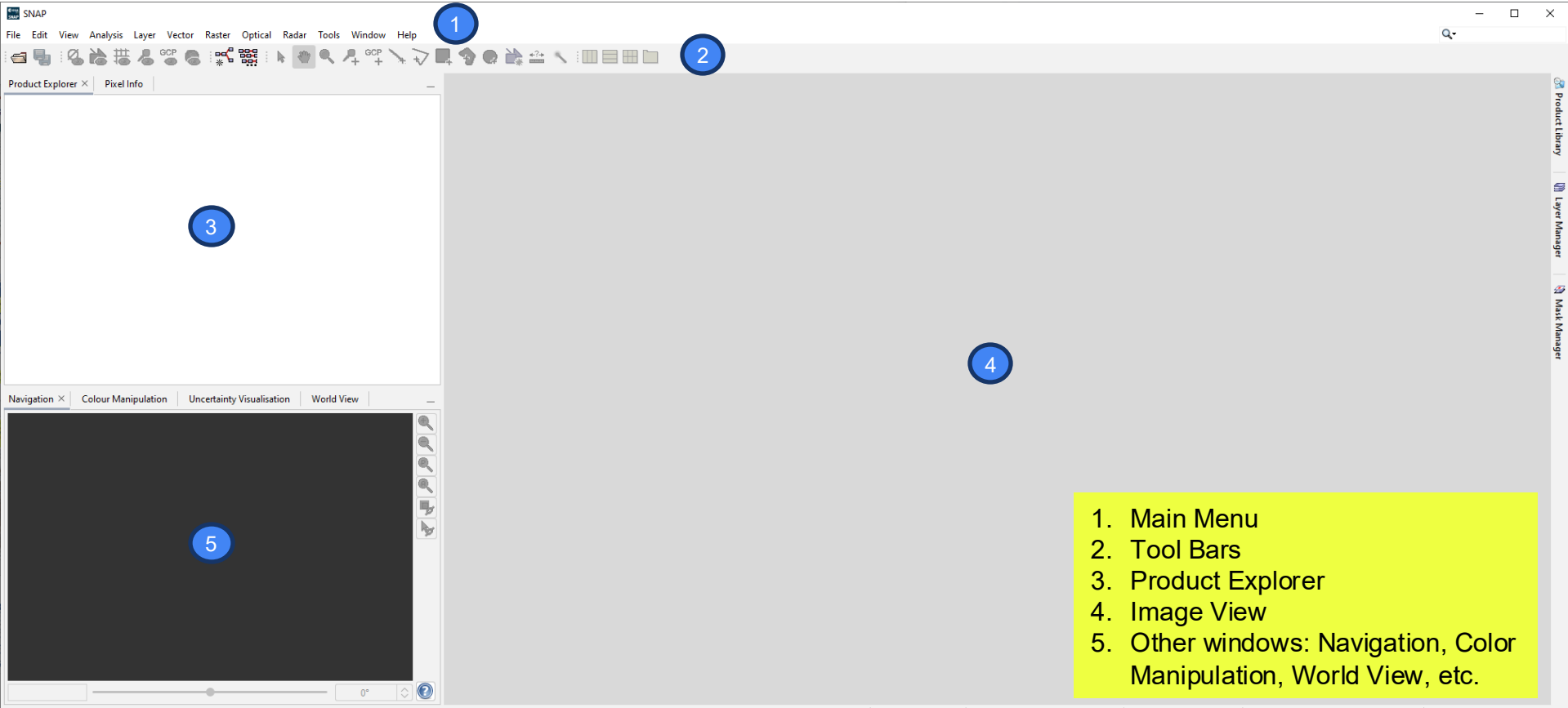
1. Main Menu
2. Tool Bars
3. Product Explorer
4. Image View
5. Other windows: Navigation, Color Manipulation, World View, etc.

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
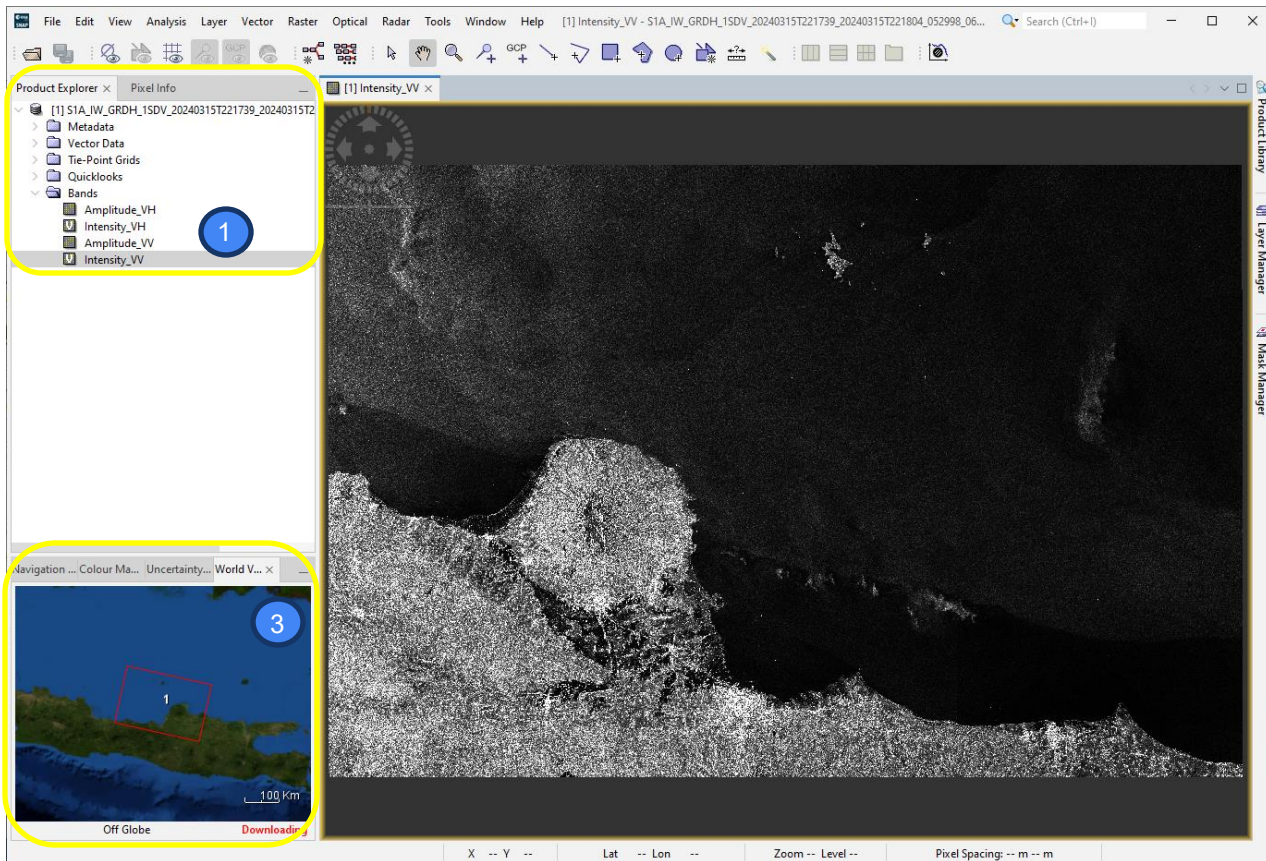
The opened products will appear in the Product Explorer window.

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
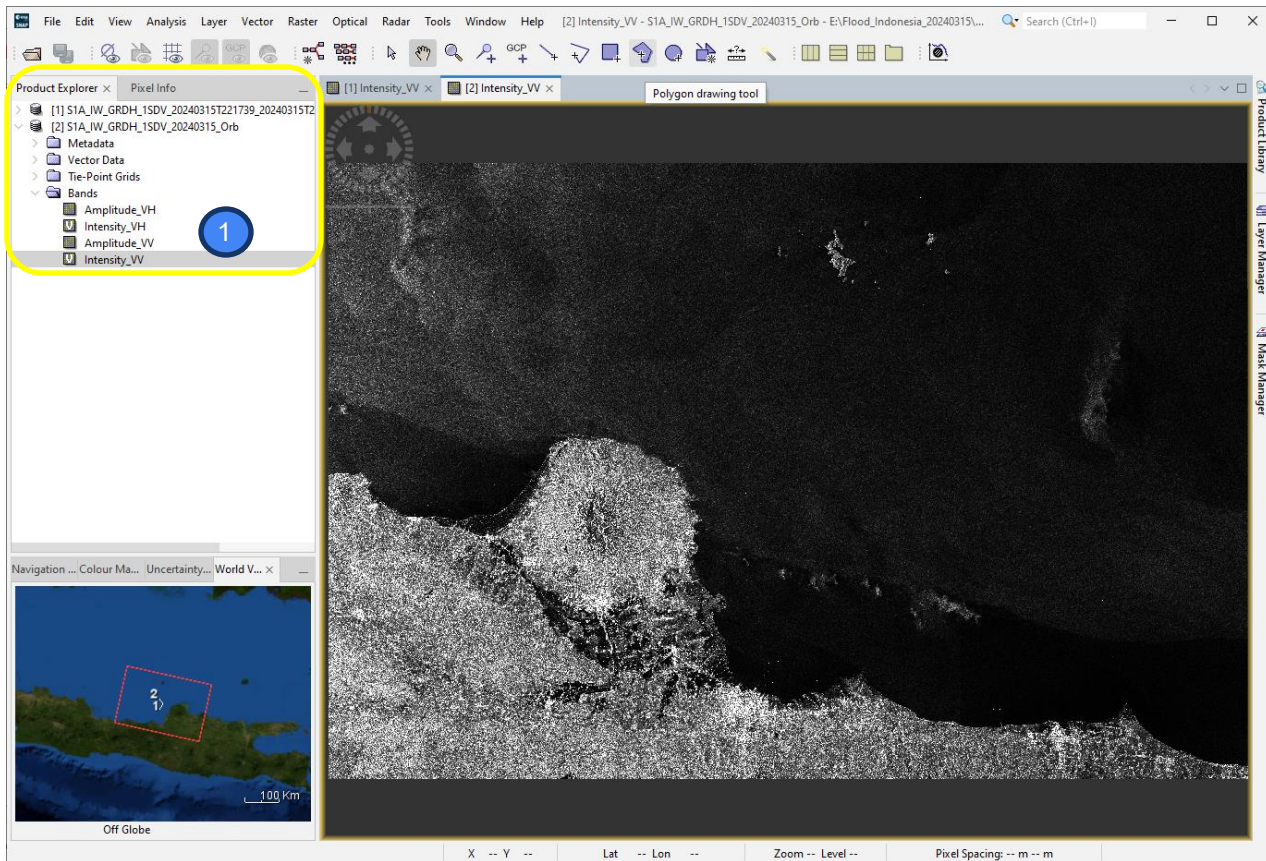3. Save and change the output directory. Use the standard SNAP I/O format, BEAM-DIMAP
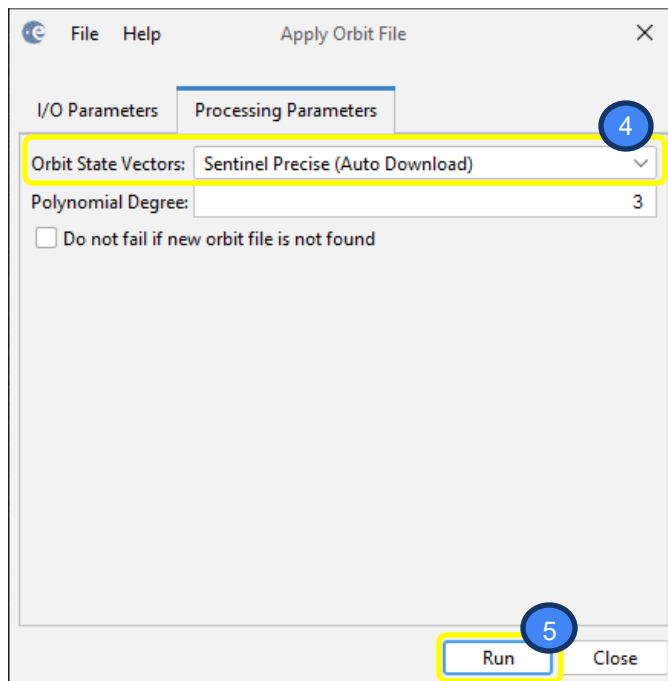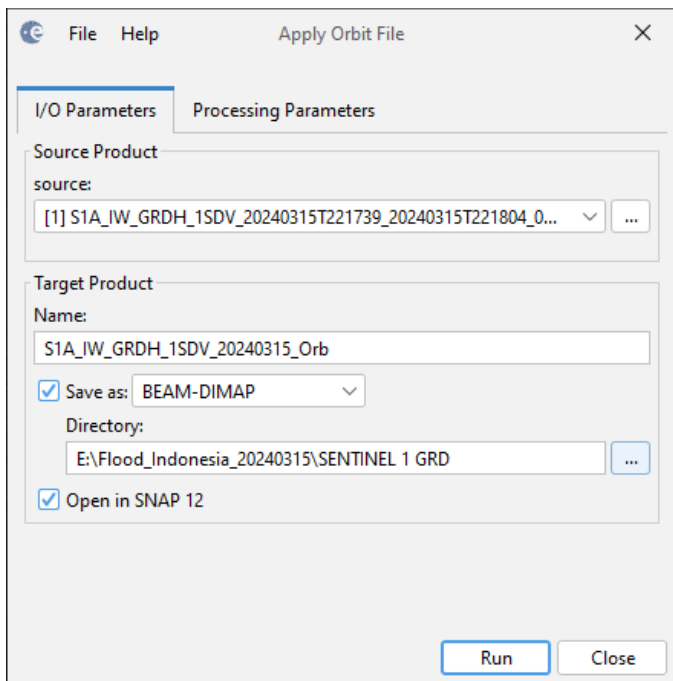
4. Go to the **Processing Parameters** tab. Select the default Sentinel Precise (Auto Download)
5. Run this operator.
6. Check the output image appearance

Process *completed in 6 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
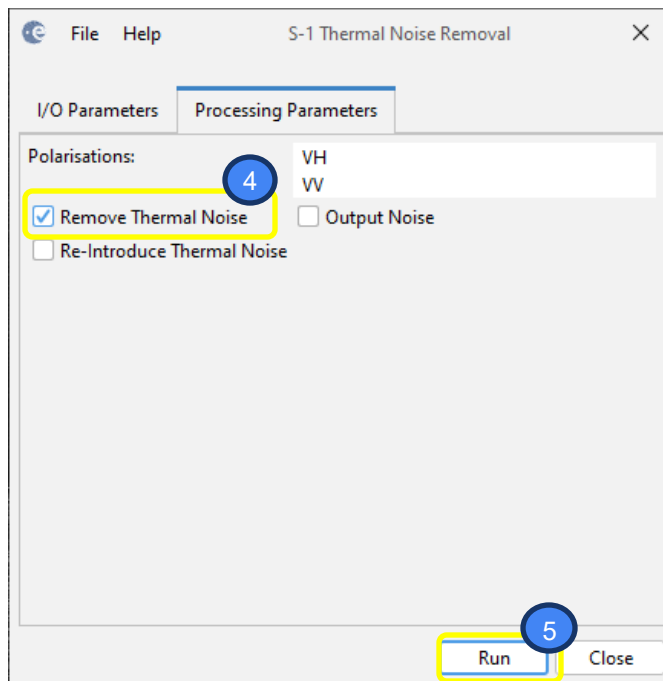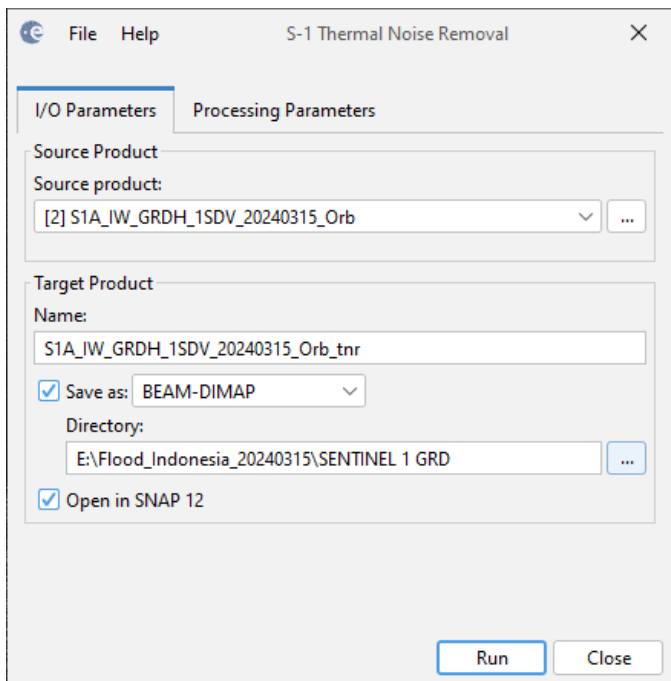## Remove the thermal noise

- 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 32 seconds*
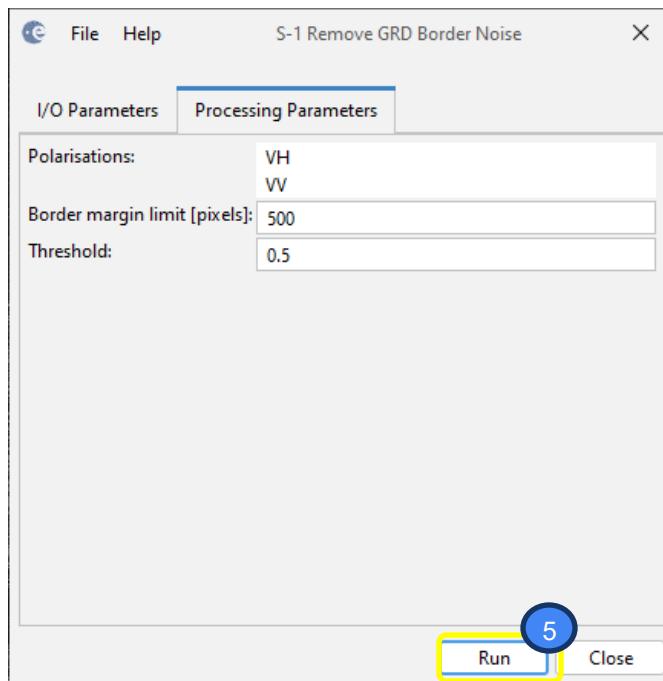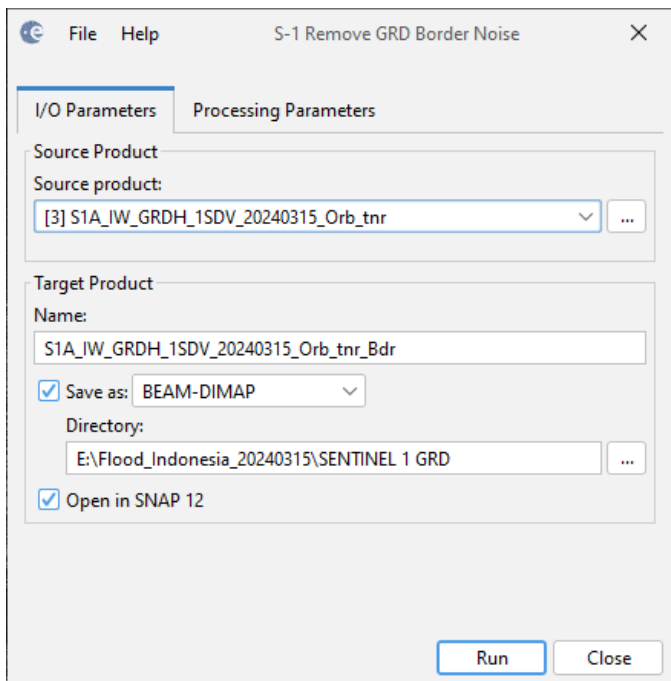
Data Processing
Remove GRD border noise

- 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 2 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

https://elisecolin.medium.com/what-are-the-physical-quantities-in-a-sar-image-c788a8265abd
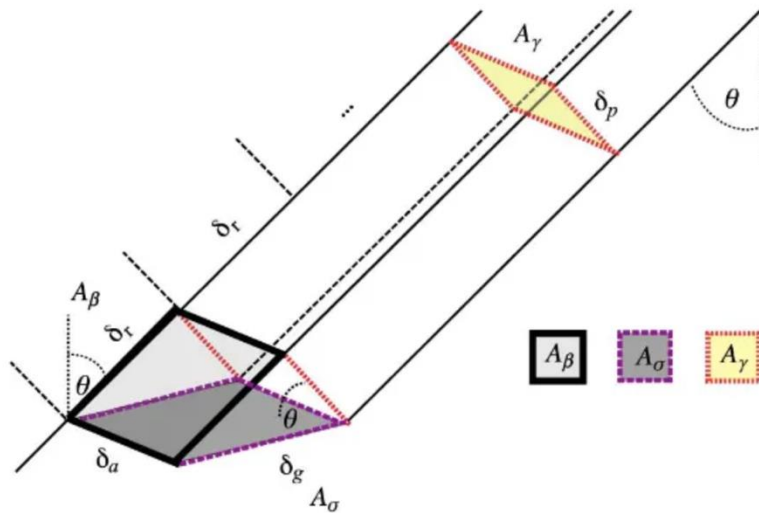
Backscatter coefficient is defined as the ratio of the radar echo power returned by a unit area of the target to the incident wave power per unit area, normalized by the ground area of that unit. It is often expressed in decibels (dB) for convenience

σ^o **(sigma-nought)**, is a normalized measure of the radar echo power returned by a unit area of the target's surface

β^o **(or beta-nought)** is the ratio of the radar echo power returned by a unit area perpendicular to the radar beam to the incident wave power. Unlike σ^o, β^o does not take into account the ground geometry but focuses on a surface perpendicular to the radar beam, $A\beta$.

γ^o **(or 'gamma-nought')** is the ratio of the radar echo power returned by a unit area on the ground to the incident wave power, corrected for the radar's incidence angle.

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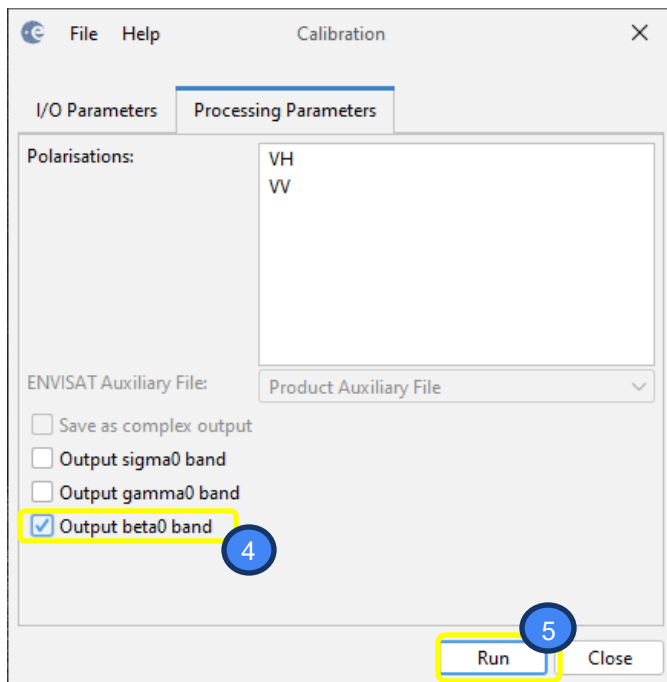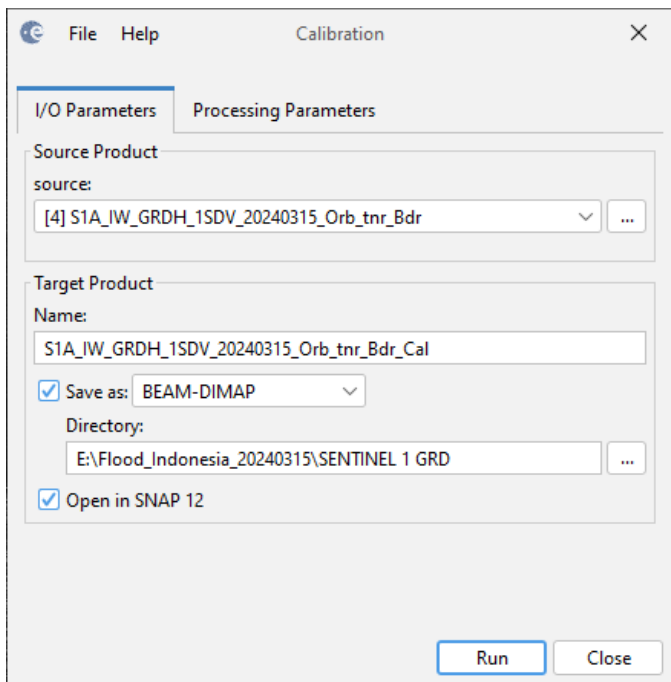
4. Go to the **Processing Parameters** tab. Select the "Output beta0 band" option. The beta0 is required for another processing step (Terrain Flattening).
5. Run this operator.
6. Check the output image appearance.

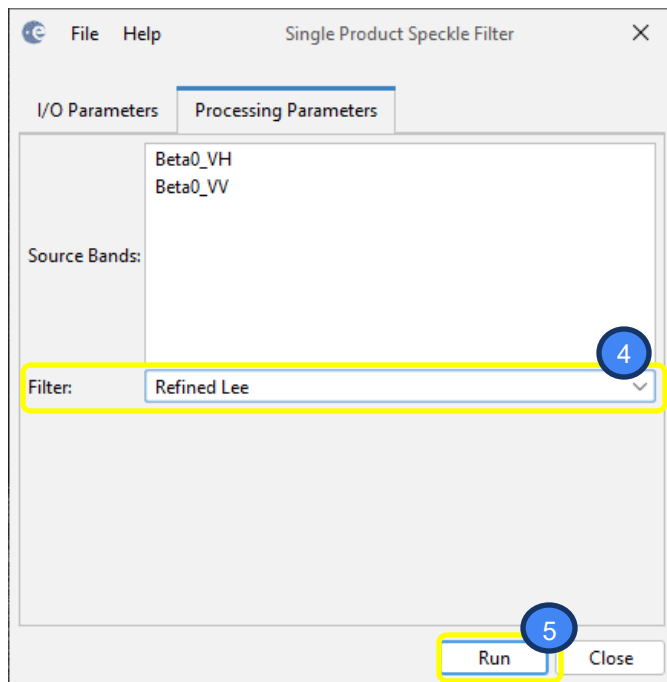Process *completed in 21 seconds*
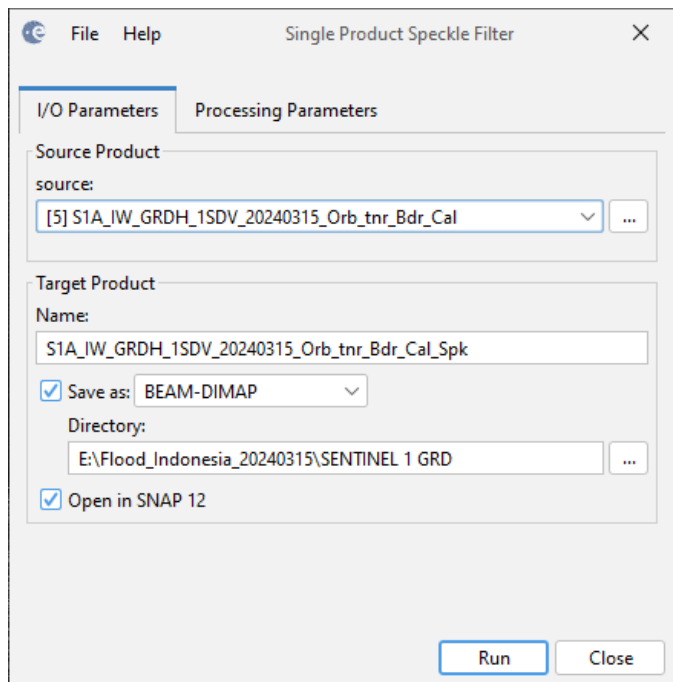
Data Processing
Speckle filter

- 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.

Left dialog — I/O Parameters:

File Help   Single Product Speckle Filter   ✕

I/O Parameters | Processing Parameters

Source Product
source:
[5] S1A_IW_GRDH_1SDV_20240315_Orb_tnr_Bdr_Cal

Target Product
Name:
S1A_IW_GRDH_1SDV_20240315_Orb_tnr_Bdr_Cal_Spk
☑ Save as: BEAM-DIMAP
Directory:
E:\Flood_Indonesia_20240315\SENTINEL 1 GRD
☑ Open in SNAP 12

Run   Close

Right dialog — Processing Parameters:

File Help   Single Product Speckle Filter   ✕

I/O Parameters | Processing Parameters

Source Bands:
Beta0_VH
Beta0_VV

Filter: Refined Lee

Run   Close

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.
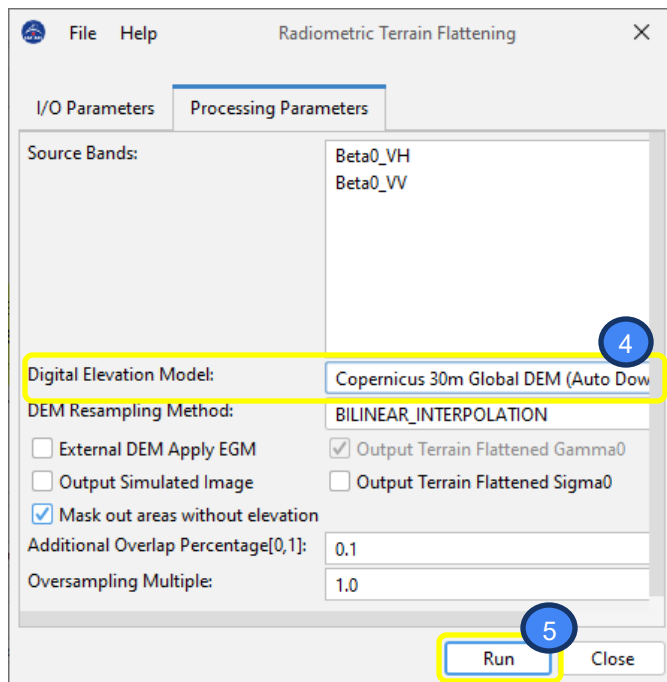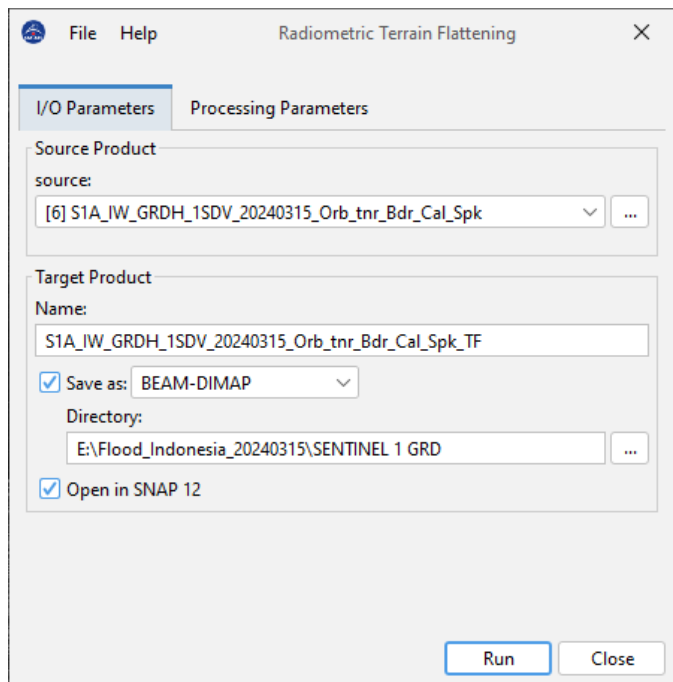
Process *completed in 94 seconds*

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 3m Global DEM" option.
5. Run this operator.
6. Check the output image appearance.
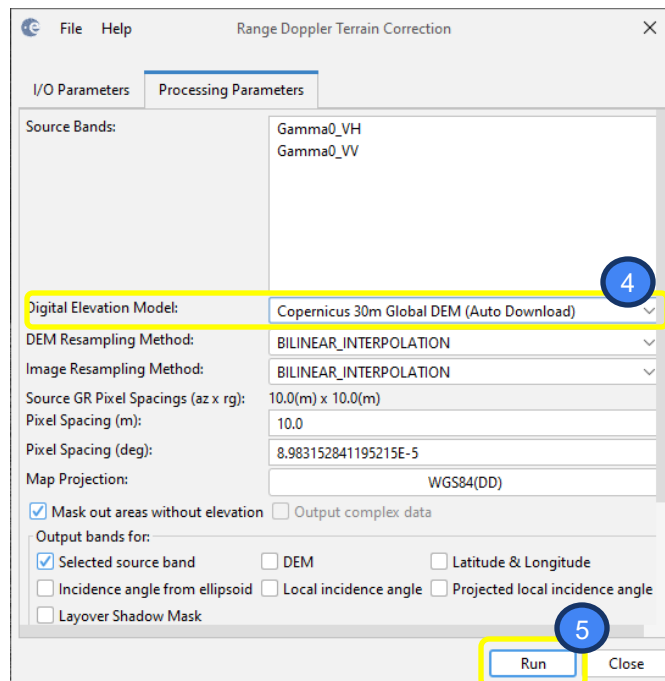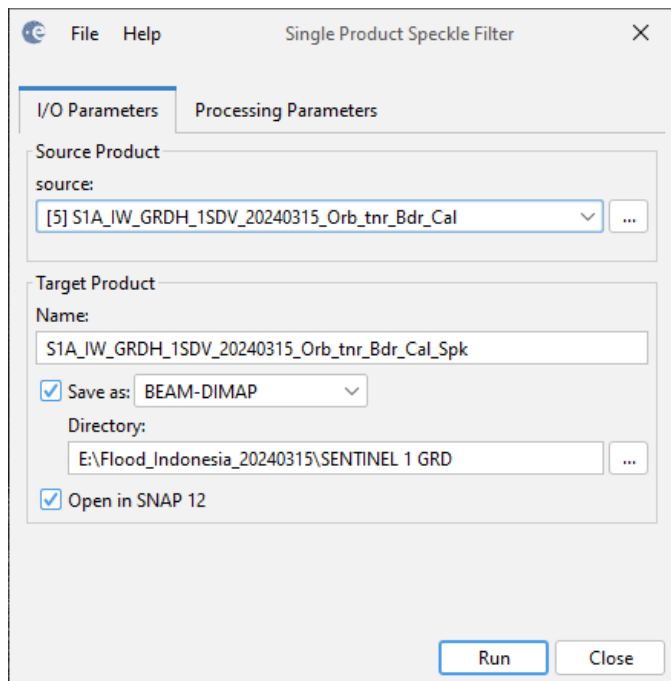
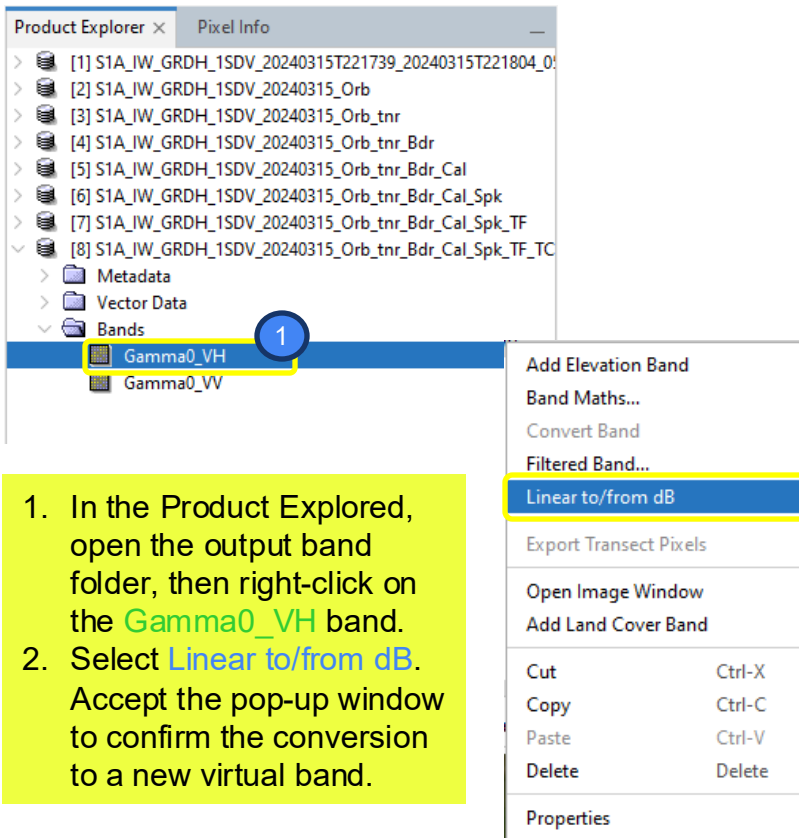Process *completed in 114 seconds*

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 3m Global DEM" option.
5. Run this operator.
6. Check the output image appearance.

Process *completed in 97 seconds*

Data Processing
Terrain correction
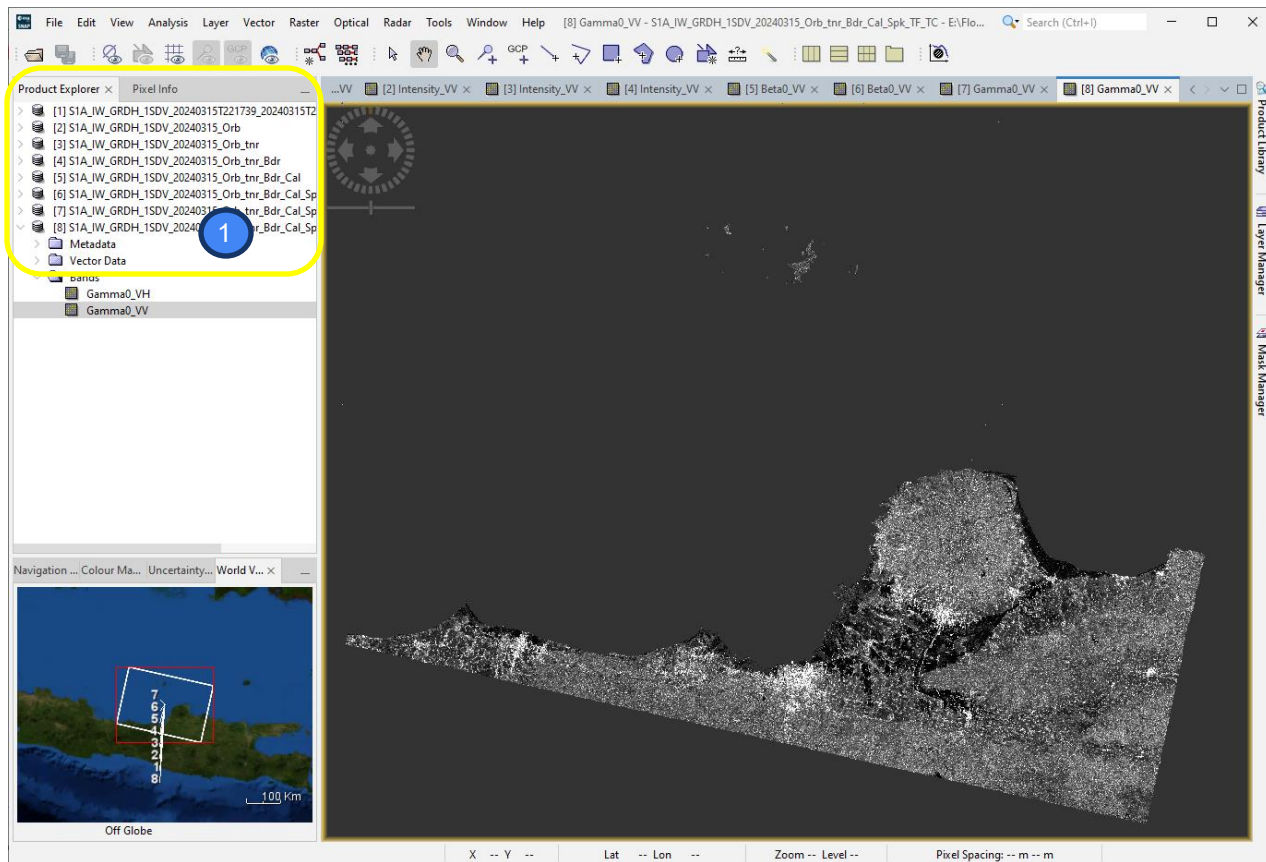
A new layer appears in the Product Explorer window.

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
Save the output to GeoTIFF
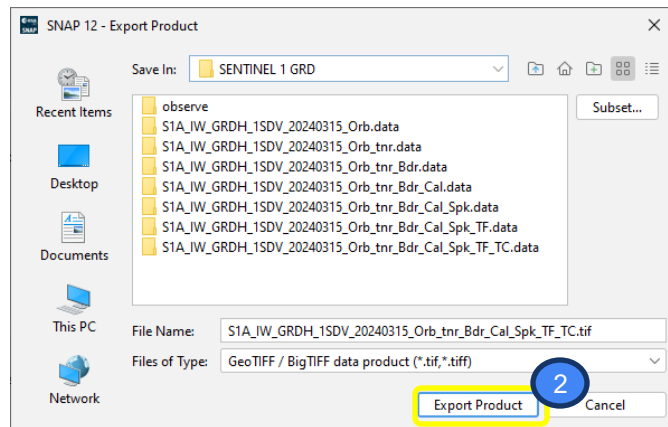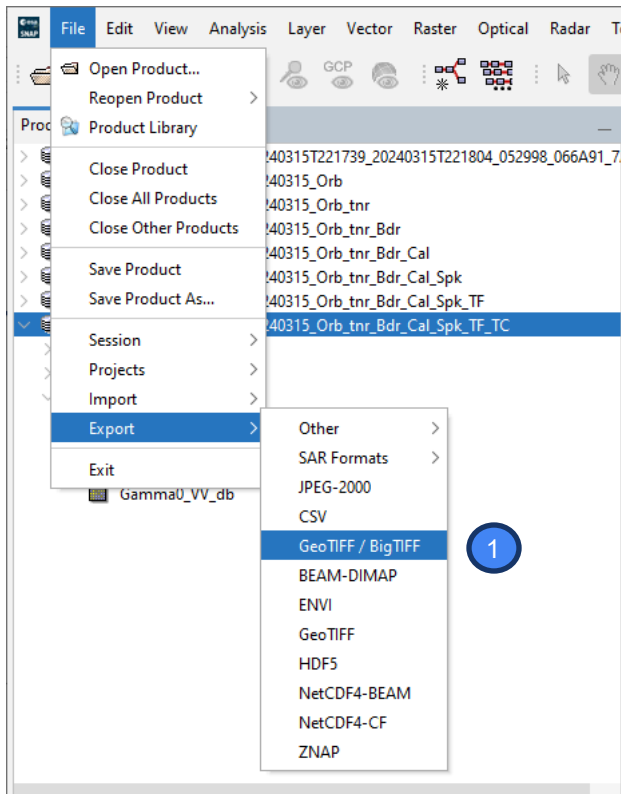
1. While the output layer is selected, go to File → Export → GeoTIFF/BigTIFF.
2. Click Export Product to save the output.

THANK YOU

Geoinformatics Center, Asian Institute of Technology