

# Damage Proxy Mapping Using Sentinel-1: Coherence Changes

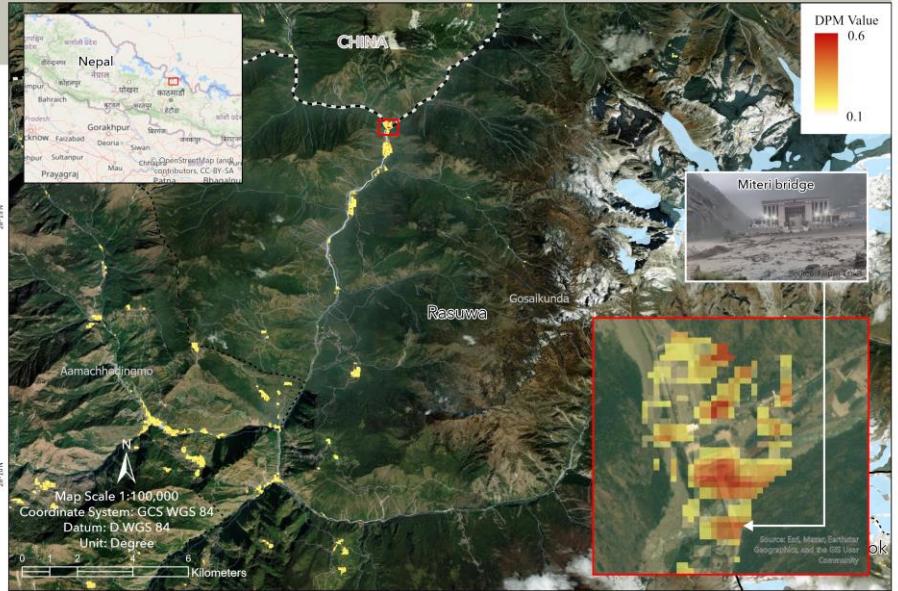
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Geoinformatics Center - AIT

# Overview

## DAMAGE PROXY MAP IN RASUWA DISTRICT, BAGMATI PROVINCE NEPAL

As observed by Sentinel-1 images on 9 July 2025



This map shows the preliminary Damage Proxy Map (DPM) for Rasuwa District, Bagmati Province, Nepal, as of 9 July 2025. According to the initial assessment by the National Disaster Risk Reduction and Management Authority (NDRRA), the disaster was caused by the rupture of a Tibetan glacier lake, resulting in a massive cross-border flood in the region.

## Sentinel Asia activation:

### Flood in Nepal

- Occurrence Date (UTC): 30 June, 2025 and 08 July 2025
- SA activation Date(UTC): 01 July, 2025
- Requester: Department of Hydrology and Meteorology (DHM), Ministry of Energy, Water Resources and Irrigation

# Overview

## Objective

The objective of this exercise is to generate a damage proxy map by analyzing coherence changes derived from pre- and post-event Sentinel-1 SLC (Single Look Complex) data.

This exercise aims to detect areas affected by flooding based on significant coherence loss, supporting rapid disaster response and impact assessment in urban environments.

***Note:** The exercise is adapted from the UN-SPIDER Recommended Practice for Flood Mapping with Sentinel-1 Interferometric Coherence*

# Overview

## Data and Software

In this exercise, we will use SNAP, QGIS, and Google Earth Engine (GEE).

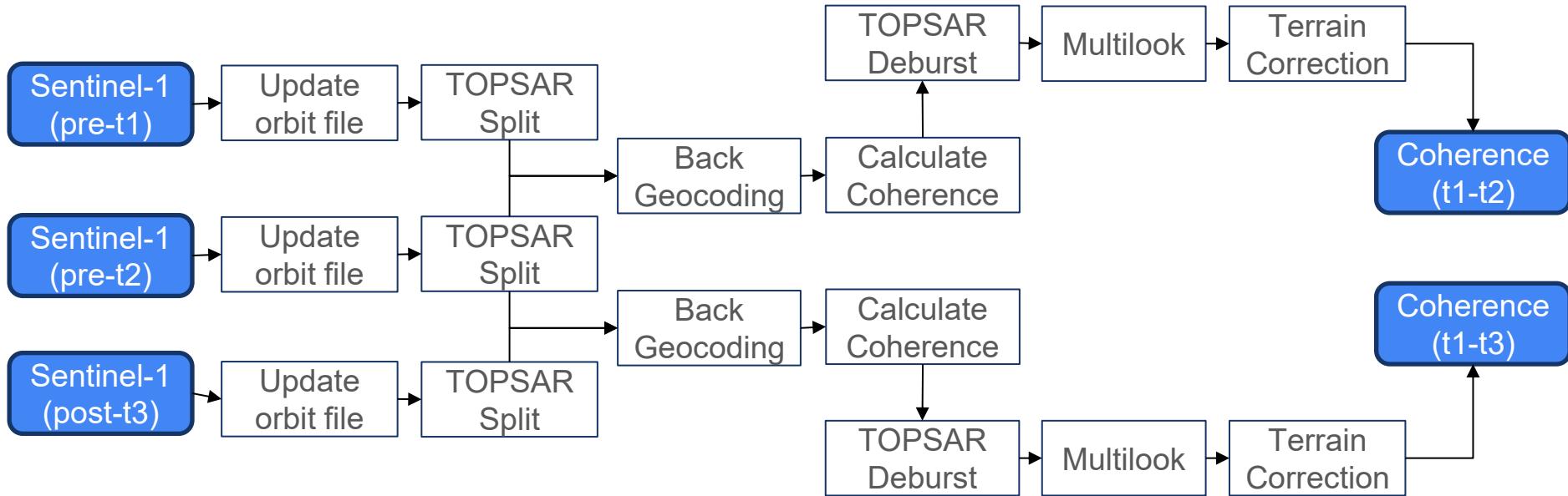
The following data are available:

- **Sentinel-1 SLC (Single Look Complex)**
  - Contain magnitude and phase information represented by complex I and Q numbers. Range coordinate is in slant range.
  - Sentinel-1 Terrain Observation by Progressive Scans SAR (TOPS) captures data in bursts, which are segments of radar echoes acquired by cyclically switching the antenna beam across multiple sub-swaths. Sentinel-1 SLC data are split into bursts per sub-swath.
  - Observation mode: Interferometric Wide (IW).
  - Dual Polarization (VH and VV), Data format: SAFE structure
  - Date: 9 July 2025 (observe), 15 and 27 June 2025 (archive)

# Methodology

## Damage Proxy mapping using Sentinel-1 coherence changes

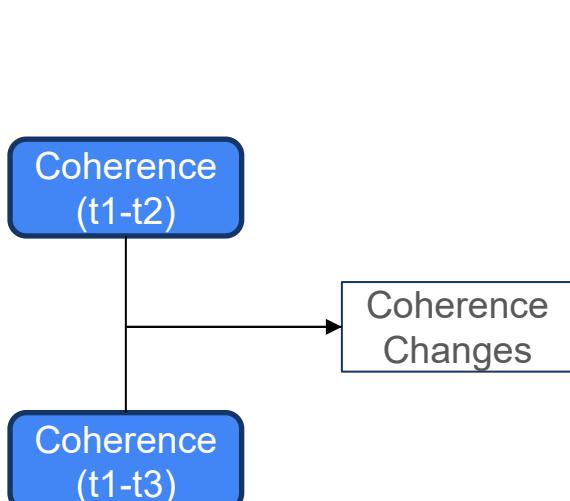
### Processing using SNAP



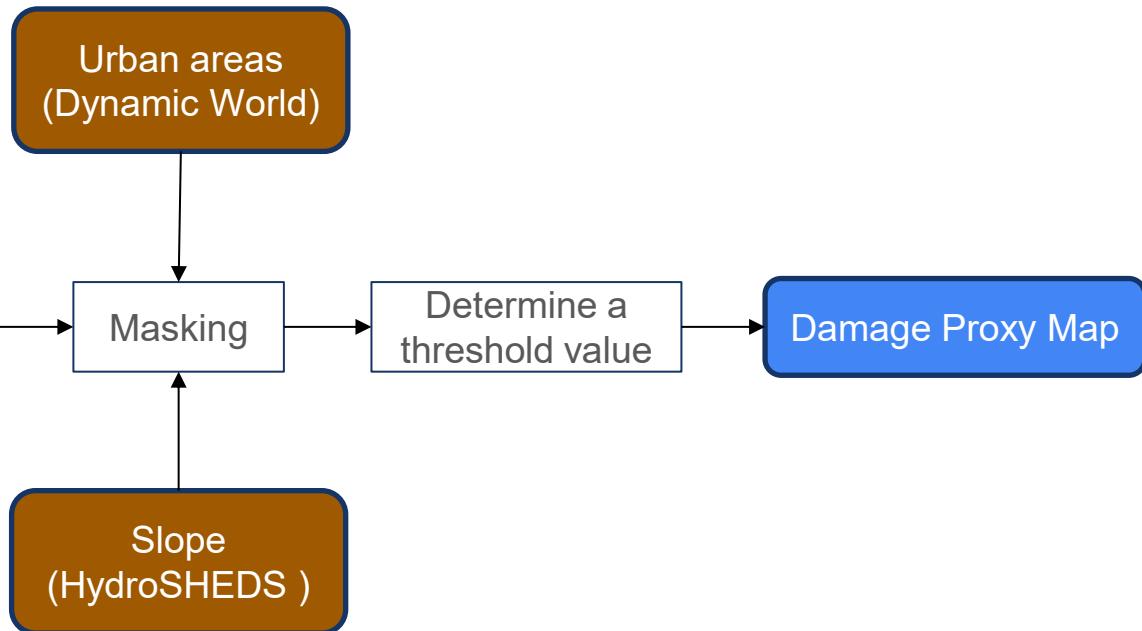
# Methodology

## Damage Proxy mapping using Sentinel-1 coherence changes

### Processing using QGIS

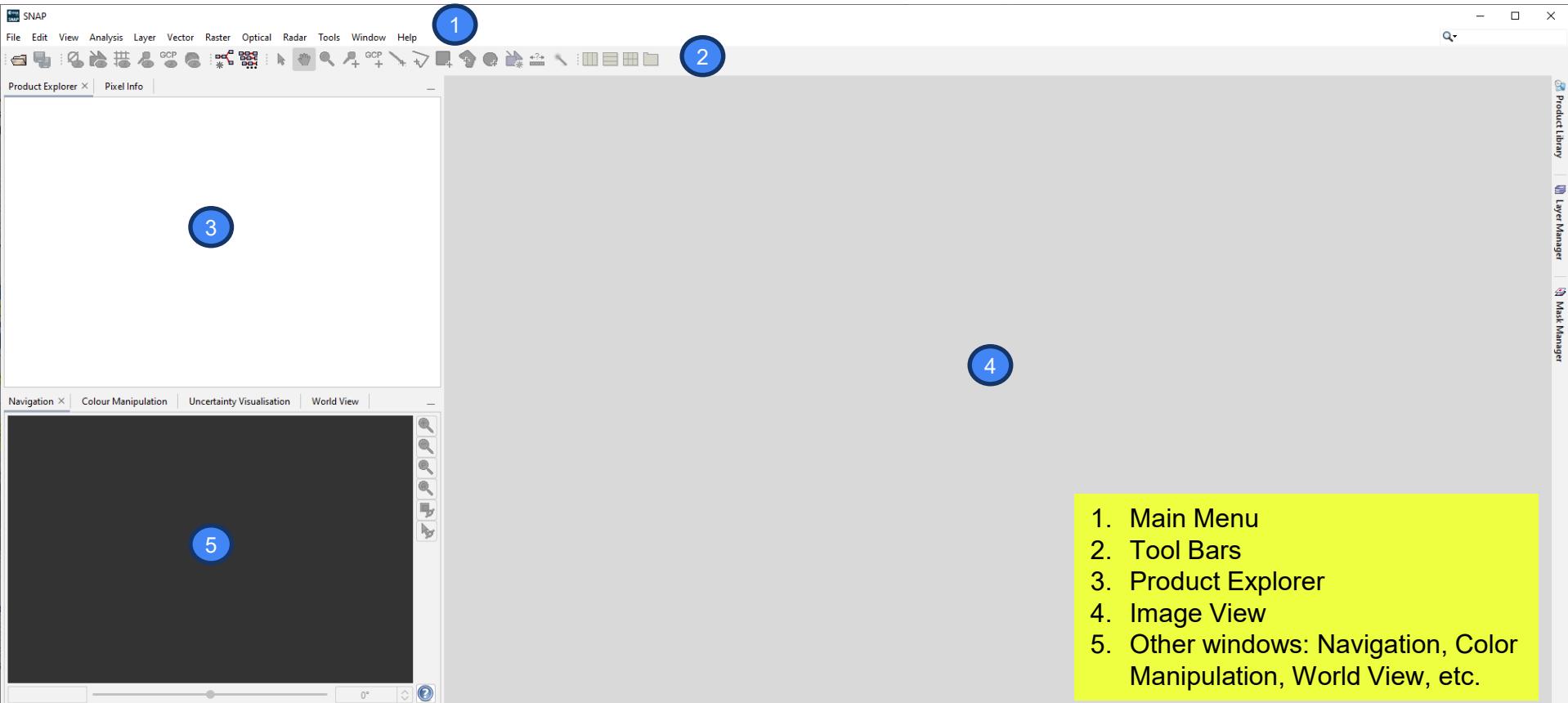


### Processing using Google Earth Engine (GEE)



# Data Exploration in SNAP

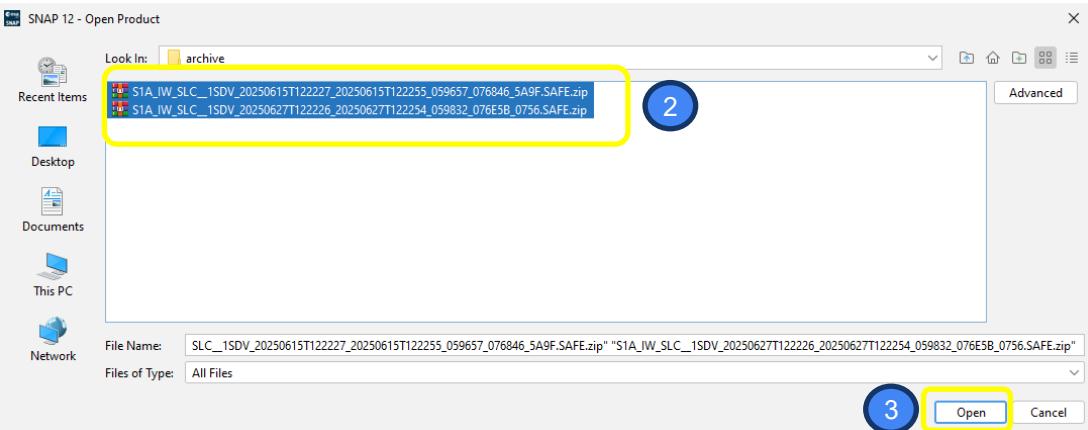
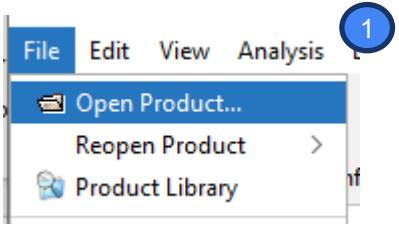
Open the SNAP software



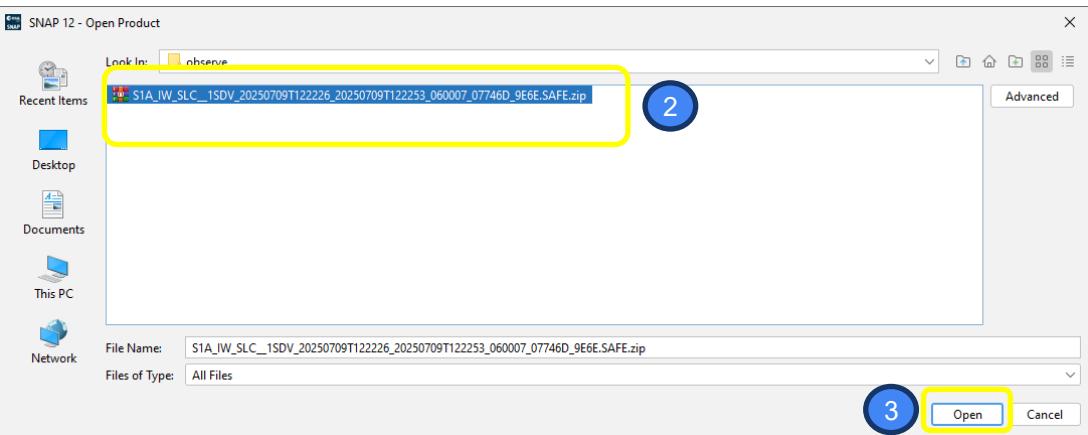
1. Main Menu
2. Tool Bars
3. Product Explorer
4. Image View
5. Other windows: Navigation, Color Manipulation, World View, etc.

# Data Exploration in SNAP

## Open Sentinel-1 Data

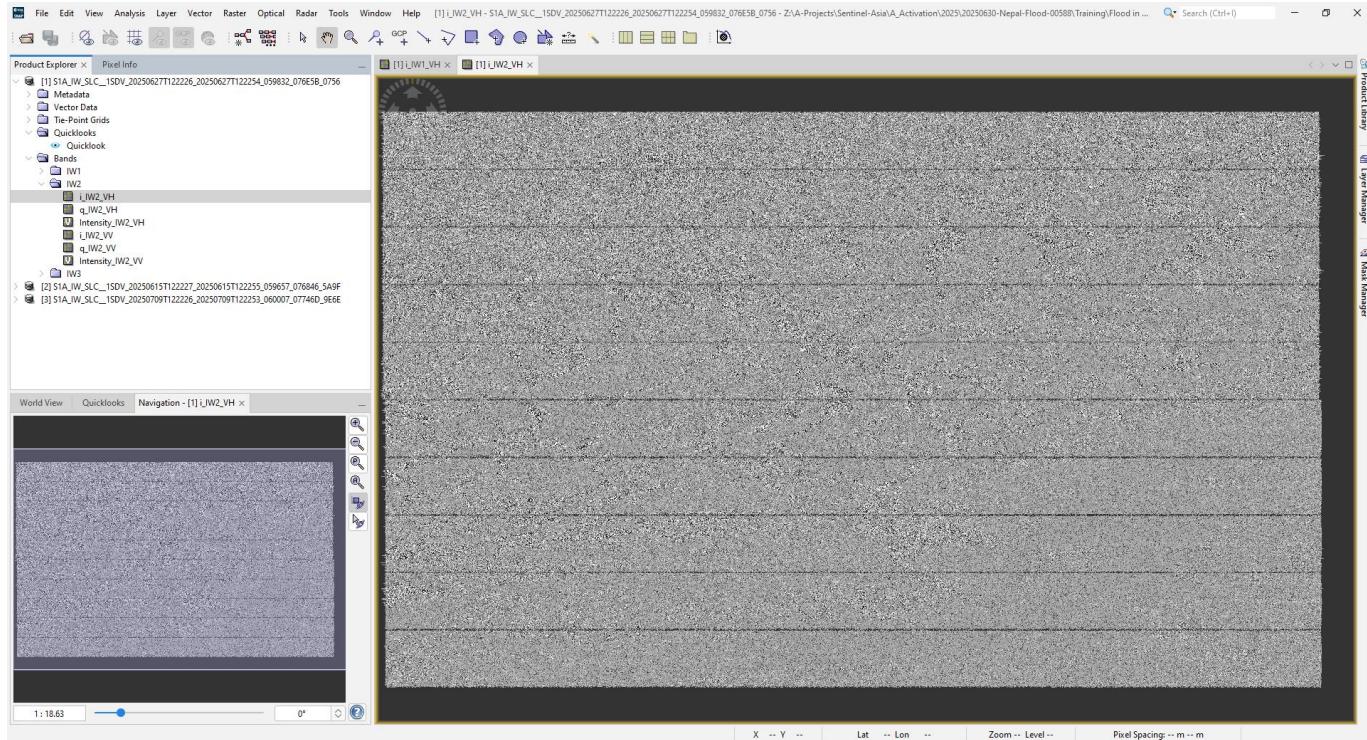


1. In the Main Menu, go to [File](#) → [Open Product...](#)
2. Browse to the location of the data. Then select all Sentinel-1 data in both archive and observe folders. Each file refers to a different acquisition date.
3. Click [Open](#)



# Data Exploration in SNAP

## Explore the Sentinel-1 Data



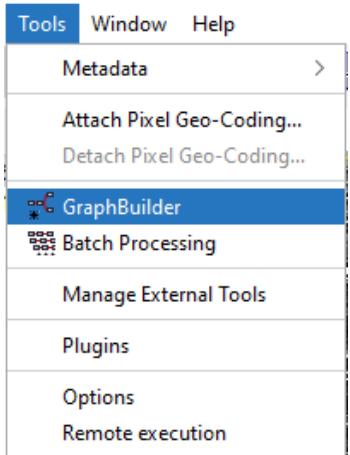
The opened products will appear in the Product Explorer window.

1. Click > to expand the contents of the product [1], then expand the Bands folder. You can see three sub-swaths (IW1, IW2, IW3). Expand one of the folder and you will see the complex data and intensity for each VH and VV polarizations.
2. Double-click on the `i_IW1_VH`, `q_IW1_VH` (complex data), and `Intensity_IW1_VH` band to visualize it.

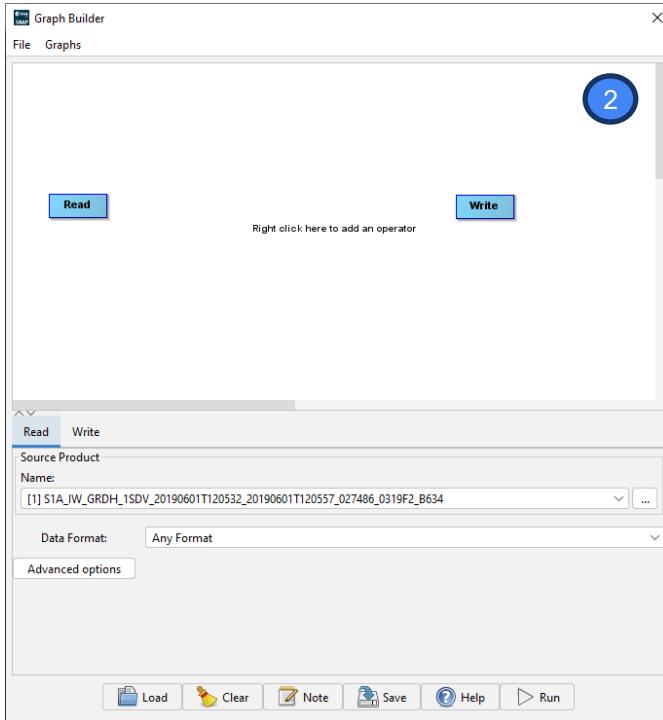
# Data Processing in SNAP

## 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.

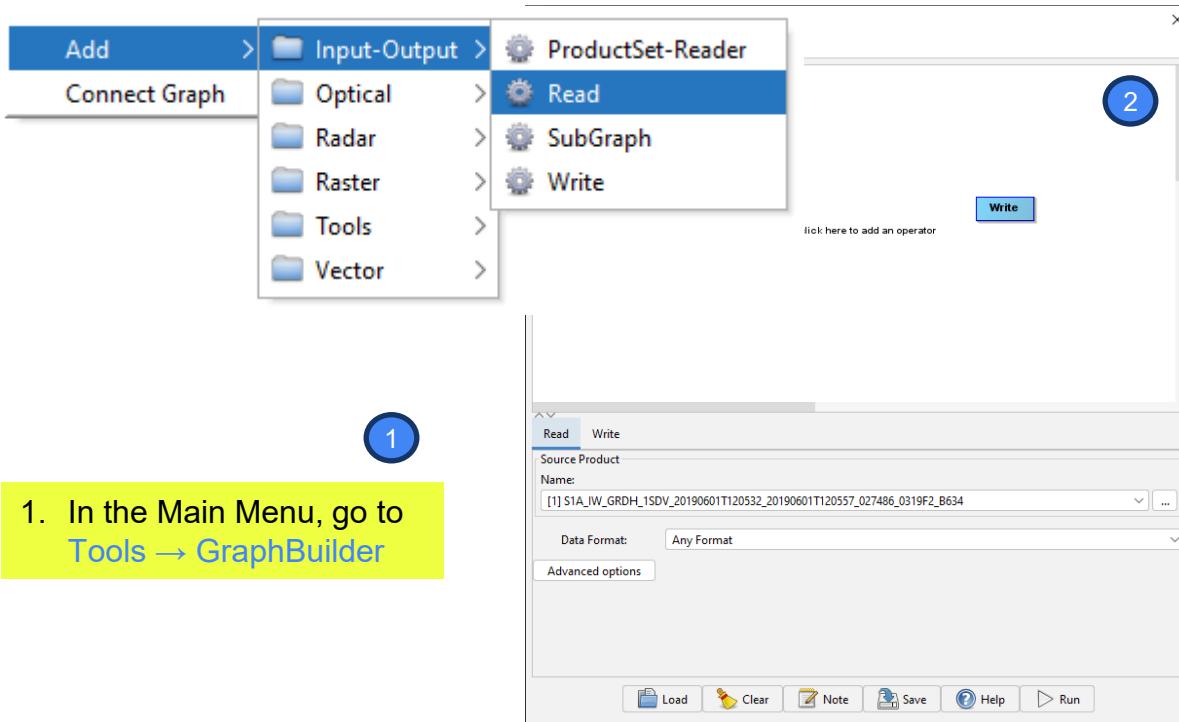
In the beginning, the graph has only two operators: **Read** (to read the input) and **Write** (to write the output). We will create a step-by-step workflow to apply identical pre-processing steps to both of our scenes.

You can delete the **Write** operator for now (Right-click on the operator and select **Delete**).

# Data Processing in SNAP

## Prepare Read operators

We will create two more Read operators in addition to the default one because we have three input data.



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

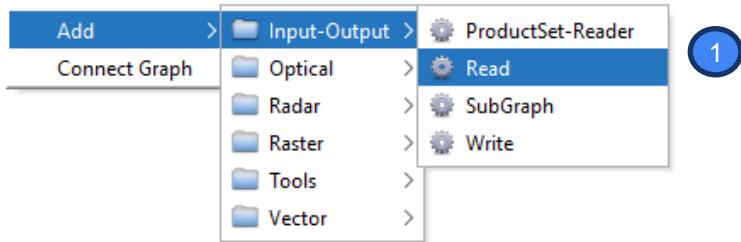
2. The **Graph Builder** window will show up.

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.

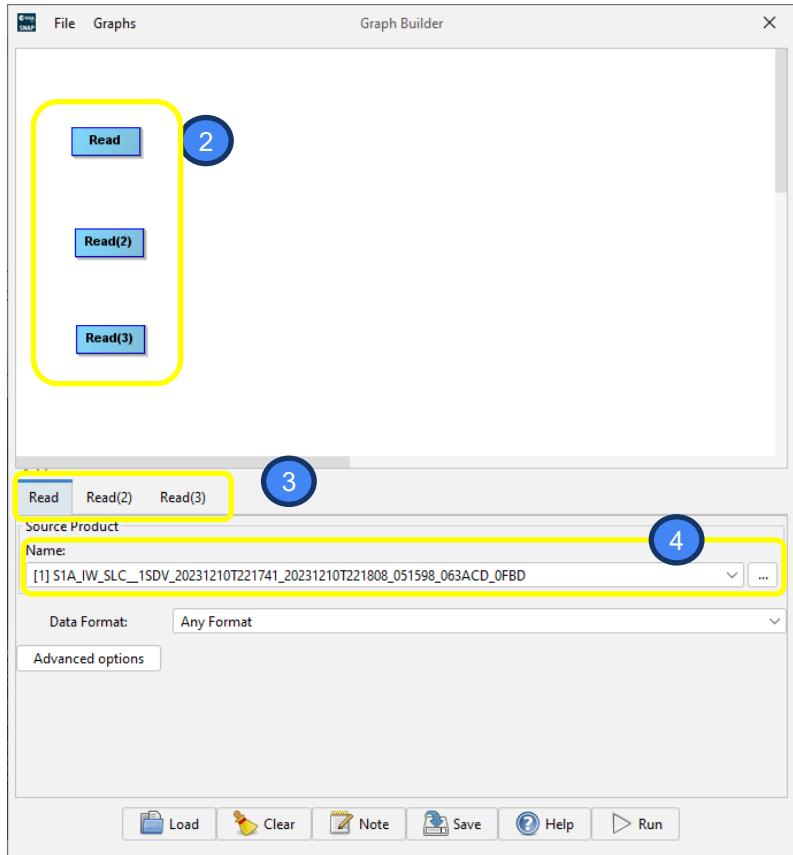
You can delete the **Write** operator for now (Right-click on the operator and select **Delete**).

# Data Processing in SNAP

## Prepare Read operators



1. To add the operator right-click the white space between the existing operators and go to **Add** → **Input-Output** → **Read**
2. A new **Read** operator rectangle appeared in our graph. Add one more **Read** operator.
3. Notice that a new tab also appeared below the graph.
4. In each **Read** tabs, select the scenes in the right order.
  - **Read** = Pre-event 1 (20250615)
  - **Read(2)** = Pre-event 2 (20250627)
  - **Read(3)** = Post-event (20250709)



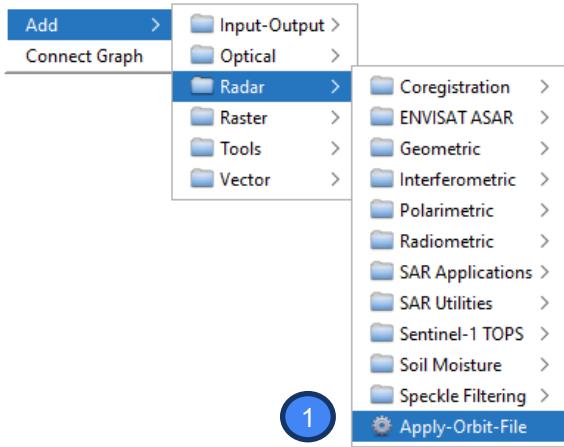
# Data Processing in SNAP

## Update the orbit metadata

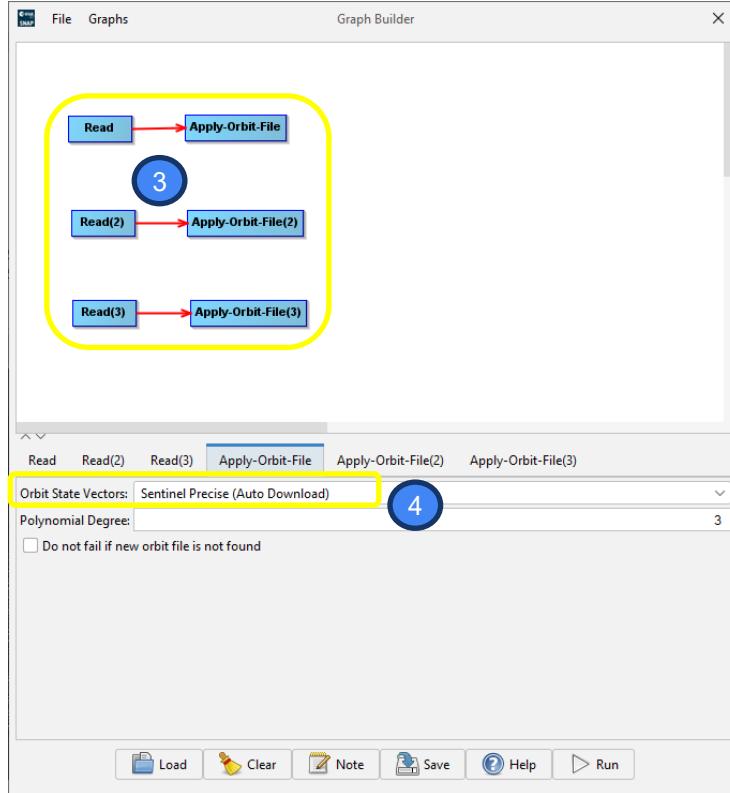
- The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product.
- The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated.

# Data Processing in SNAP

## Update the orbit metadata



1. Right-click the white space between the existing operators and go to **Add** → **Radar** → **Apply-Orbit-File**.



3. 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. Do the same to all.
4. Check that the new tabs appear below the graph. Choose **Sentinel Precise (Auto Download)**.

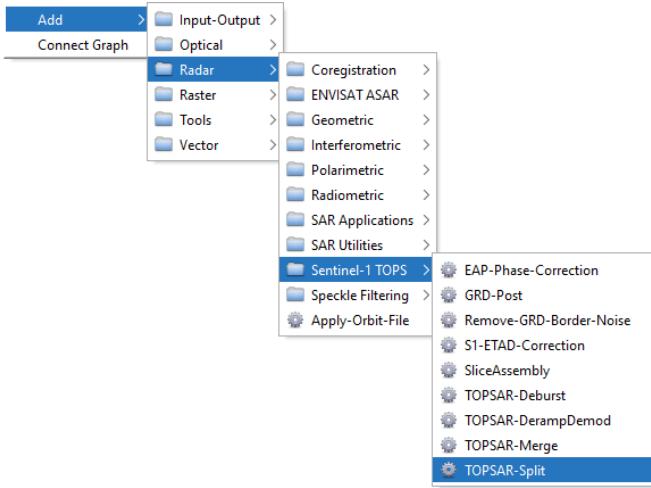
# Data Processing in SNAP

## TOPSAR Split

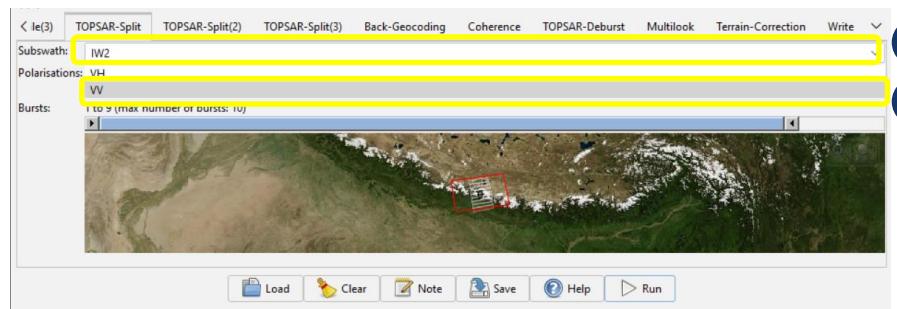
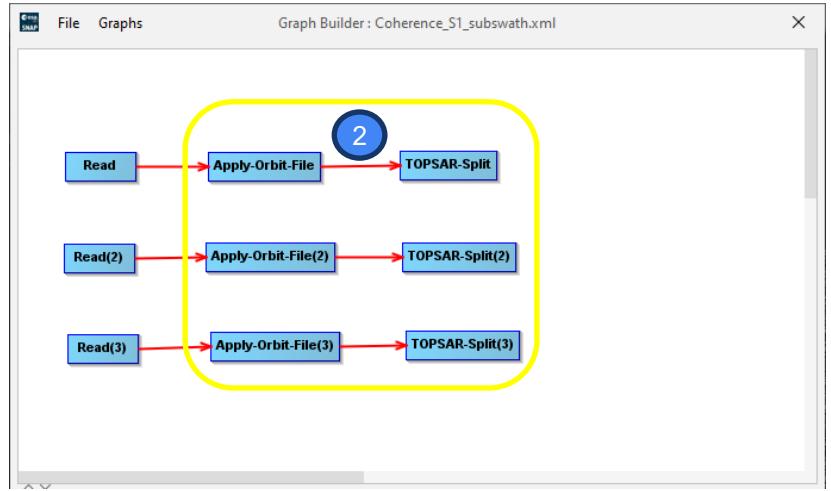
- Sentinel-1 SLC images in Interferometric Wide (IW) mode typically consist of 3 sub-swaths (IW1, IW2, IW3) — each composed of multiple bursts.
- The TOPSAR Split operator provides a convenient way to split each sub-swath with selected bursts into a separate product.
- The user may select the desired sub-swath with desired bursts and polarizations.

# Data Processing in SNAP

## TOPSAR Split



1. Right-click the white space between the existing operators and go to **Add** → **Radar** → **Sentinel-1 TOPS** → **TOPSAR-Split**.
2. Connect the new operator with the **Apply-Orbit-File** operators.
3. Select the Subswath: **IW2** because this subswath cover our study area
4. Select **VV** polarization.



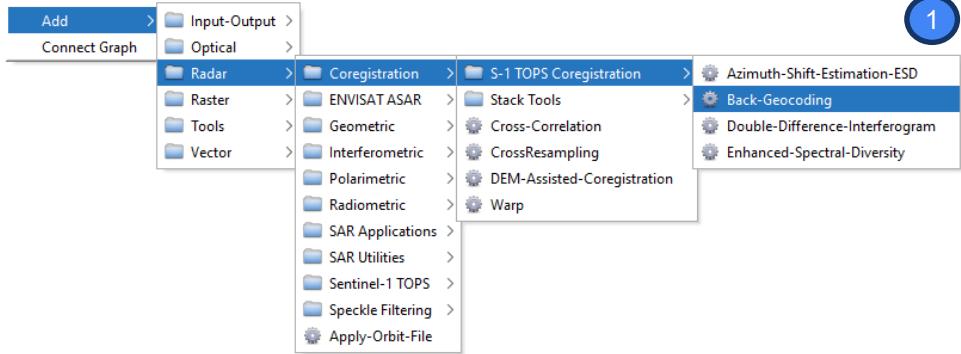
# Data Processing in SNAP

## Back Geocoding

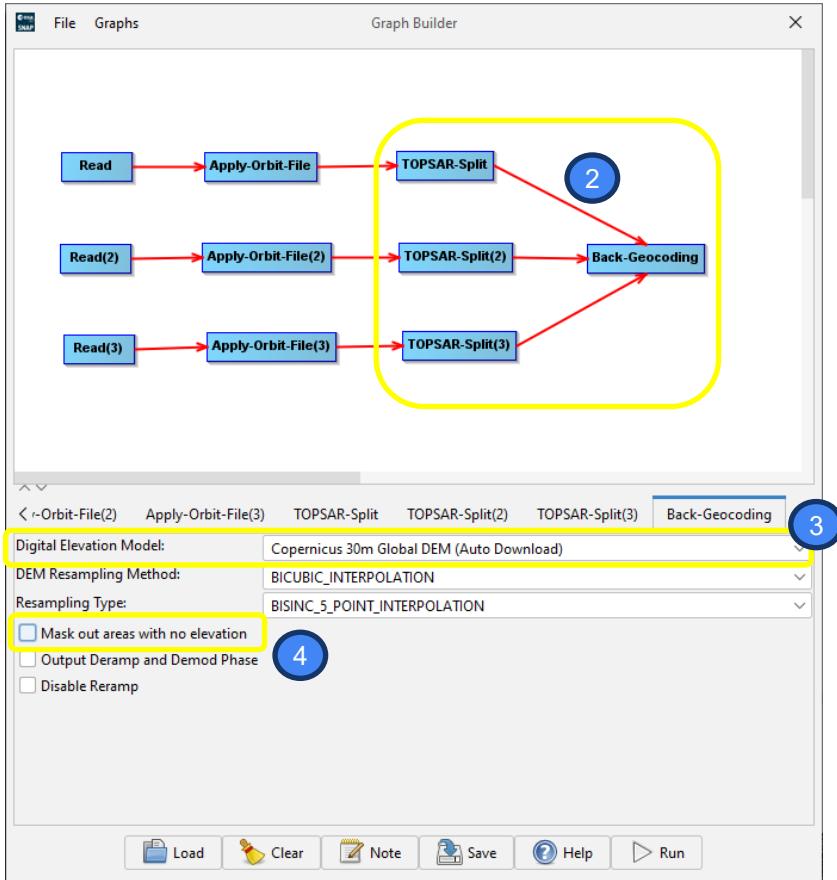
- Due to satellite movement, orbital drift, and acquisition differences, reference and secondary SLC images need to be geometrically matched.
- This operator co-registers two S-1 SLC split products (reference and secondary) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM).

# Data Processing in SNAP

## Back Geocoding



1. Right-click the white space between the existing operators and go to **Add** → **Radar** → **Coregistration** → **S1-TOPS Coregistration** → **Back Geocoding**
2. Connect the new operator with all TOPSAR-Split operators.
3. Select DEM: **Copernicus 30m**.
4. Uncheck “**Mask out areas with no elevation**”. It is recommended to avoid artefacts along the coast in the co-registered images.



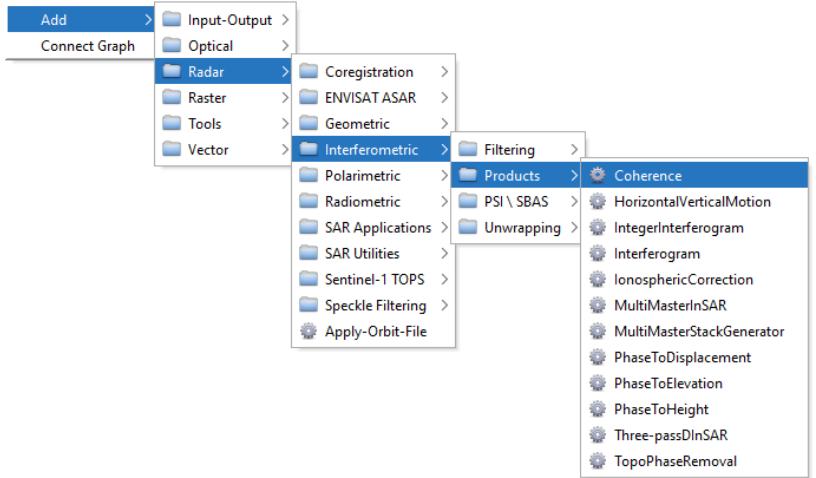
# Data Processing in SNAP

## Coherence Estimation

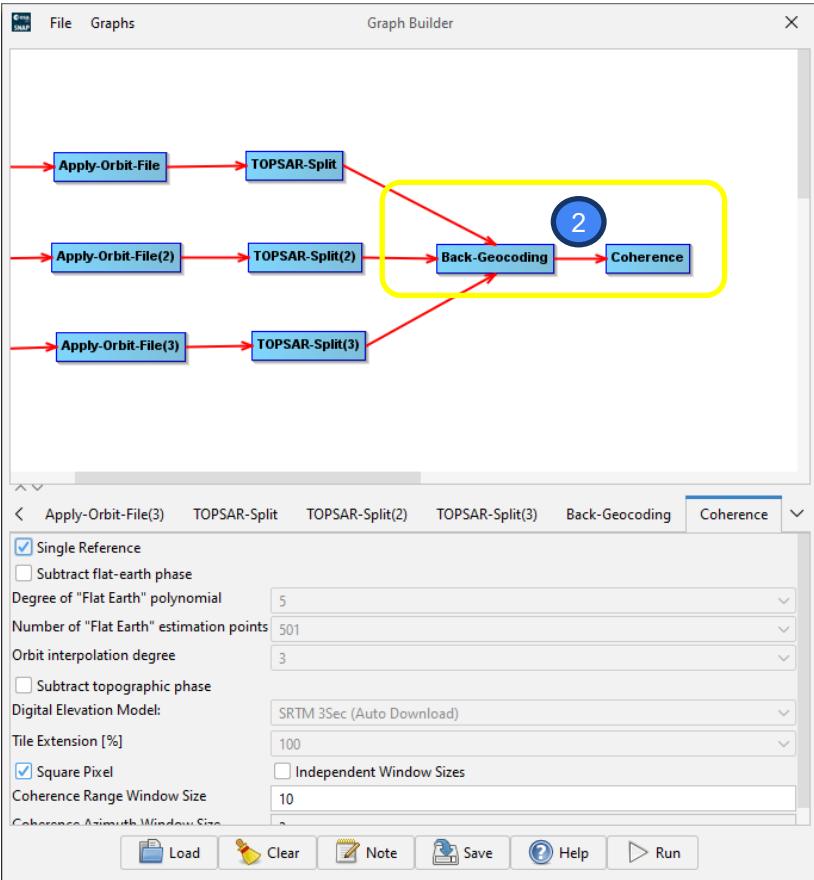
- Coherence is a measure of the similarity in radar signal phase and amplitude between two SAR images acquired at different times, for the same location.
- The Coherence Estimation operator in SNAP calculates the interferometric coherence between a pair of co-registered Sentinel-1 SLC images (reference and secondary).

# Data Processing in SNAP

## Coherence Estimation



1. Right-click the white space between the existing operators and go to **Add** → **Radar** → **Interferometric** → **Products** → **Coherence**
2. Connect the new operator with Back-Geocoding operator.
3. Keep the default settings.



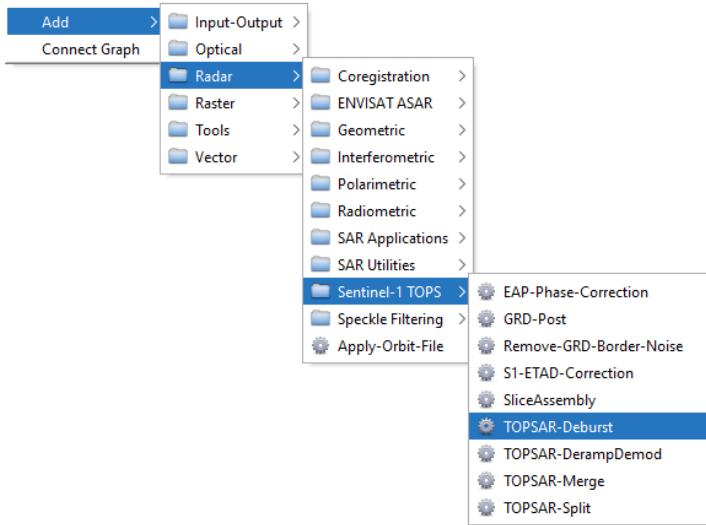
# Data Processing in SNAP

## TOPSAR Deburst

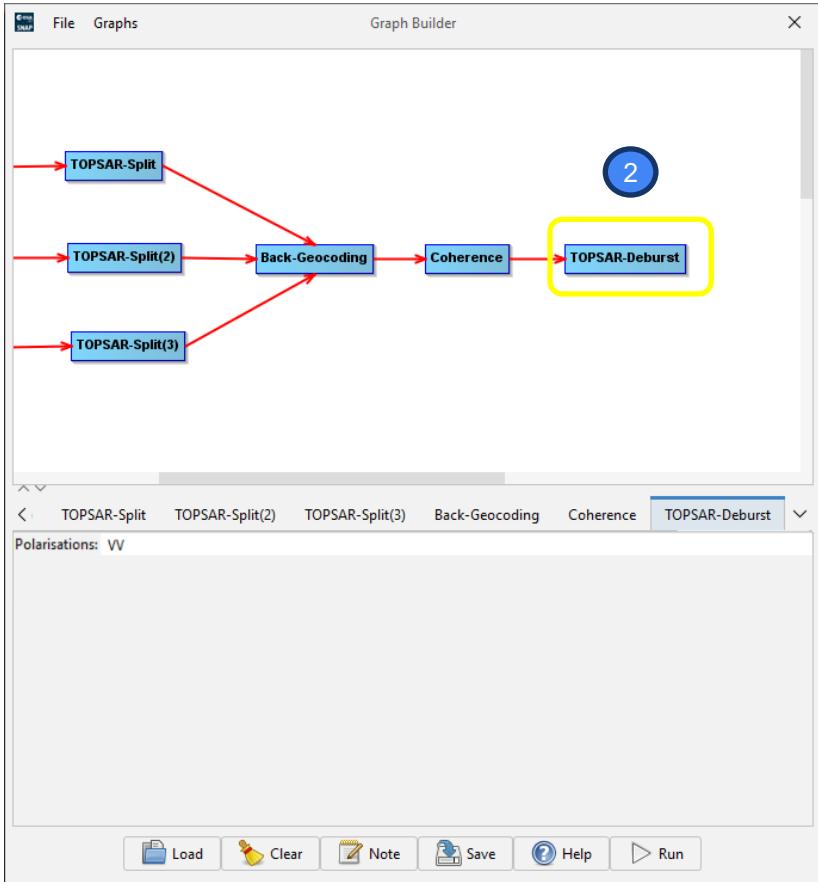
- Each sub-swath consists of a series of adjacent but slightly overlapping bursts, which can cause visible discontinuities (burst gaps) in the interferogram.
- Debursting removes those discontinuities and stitches the bursts together to create a continuous, seamless image for each sub-swath.

# Data Processing in SNAP

## TOPSAR Deburst



1. Right-click the white space between the existing operators and go to [Add](#) → [Radar](#) → [Sentinel-1 TOPS](#) → [TOPSAR-Deburst](#)
2. Connect the new operator with the Coherence operator.
3. Keep the default settings.



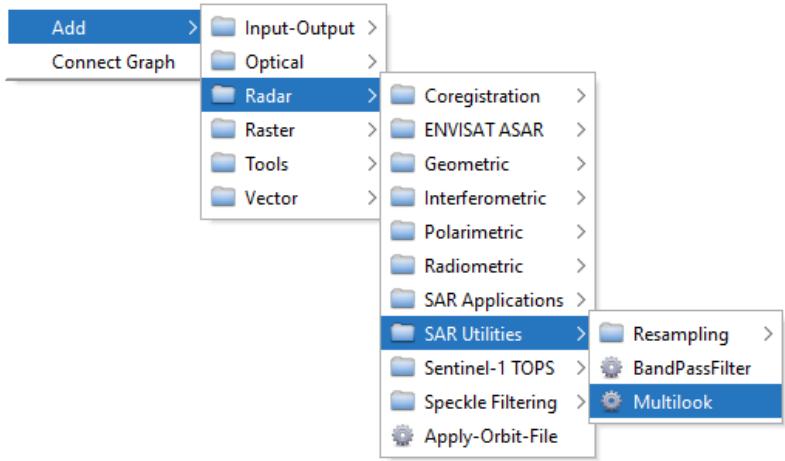
# Data Processing in SNAP

## Multilook

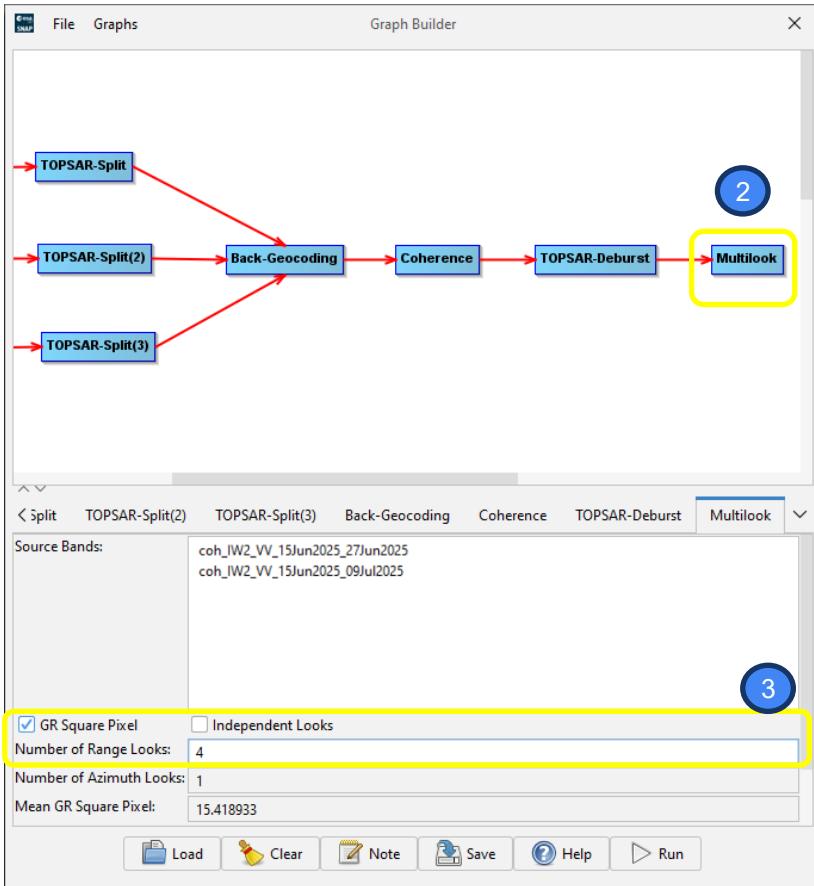
- Multilook is a SAR image processing technique used to reduce speckle noise and improve the visual appearance and radiometric quality of SAR images by averaging neighboring pixels in range and azimuth directions.
- It can be produced by space-domain averaging of a single look image or by a frequency-domain method using the sub-spectral band width.
- Additionally, multi-look processing can be used to reduce the image pixel size.

# Data Processing in SNAP

## Multilook



1. Right-click the white space between the existing operators and go to [Add](#) → [Radar](#) → [SAR Utilities](#) → [Multilook](#)
2. Connect the new operator with the TOPSAR-Deburst operator.
3. Specify the Number of Range Looks: **4**. If you check the GR Square Pixel option, the range and azimuth spacings are approximately the same in the multilooked image.



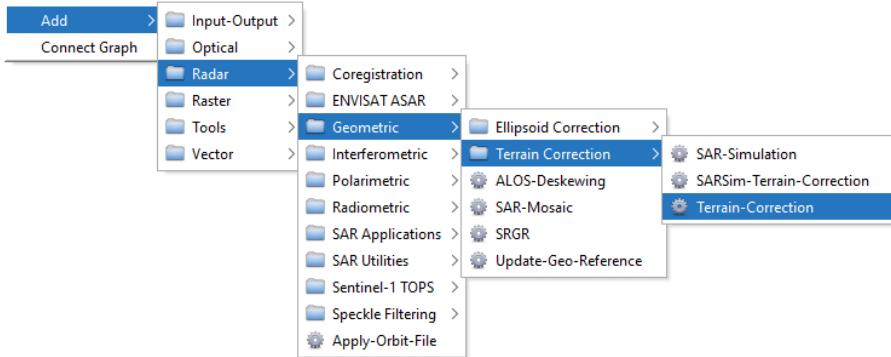
# Data Processing in SNAP

## Terrain Correction

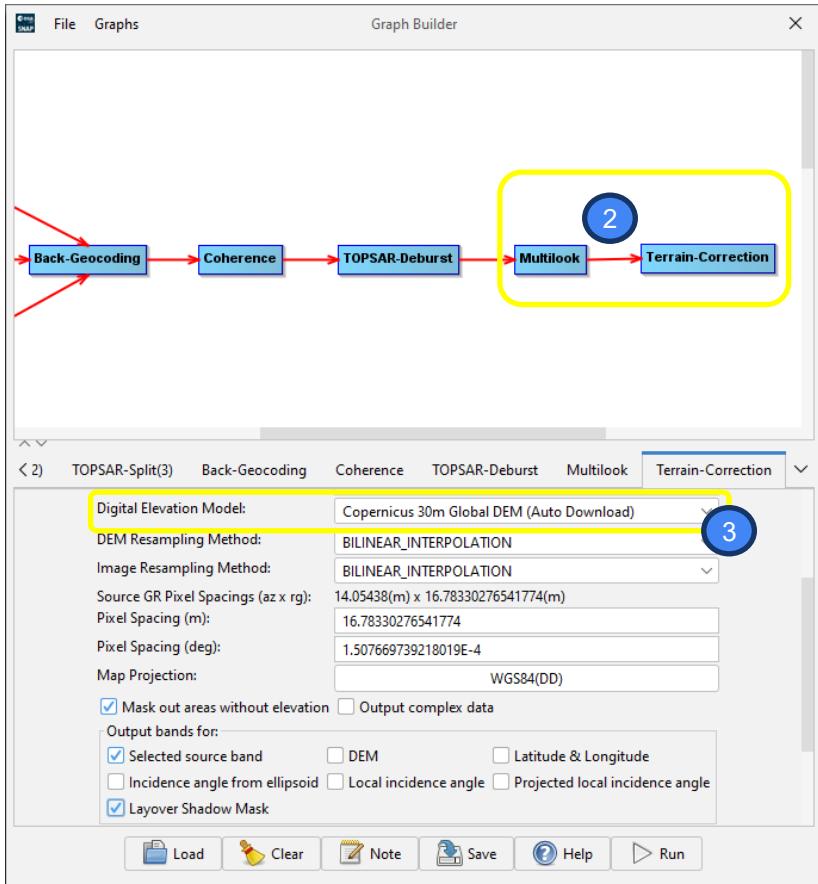
- Due to topographical variations of a scene and the tilt of the satellite sensor, distances can be distorted in the SAR images.
- Image data not directly at the sensor's Nadir location will have some distortion.
- Terrain corrections are intended to compensate for these distortions so that the geometric 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 in SNAP

## Terrain Correction

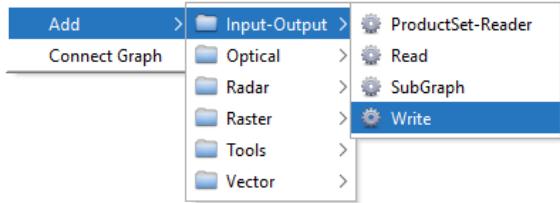


1. Right-click the white space between the existing operators and go to [Add](#) → [Radar](#) → [Geometric](#) → [Terrain Correction](#) → [Terrain-Correction](#)
2. Connect the new operator with the Multilook operator.
3. Select DEM: [Copernicus 30m](#).

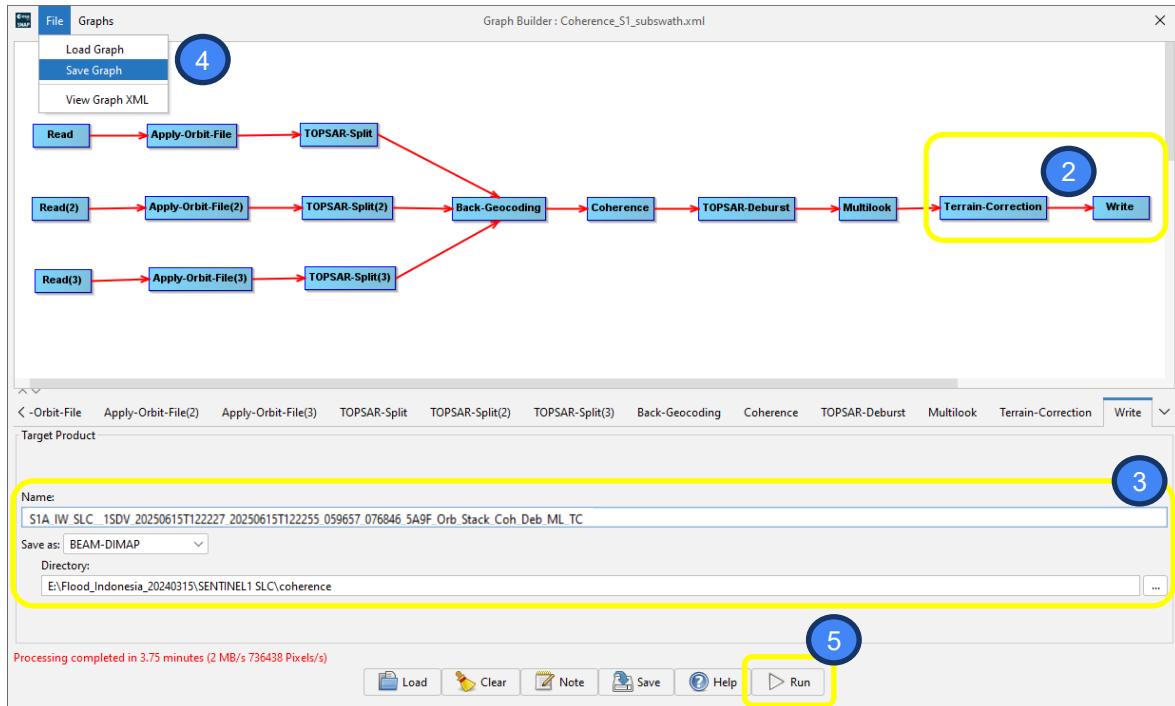


# Data Processing in SNAP

## Terrain Correction



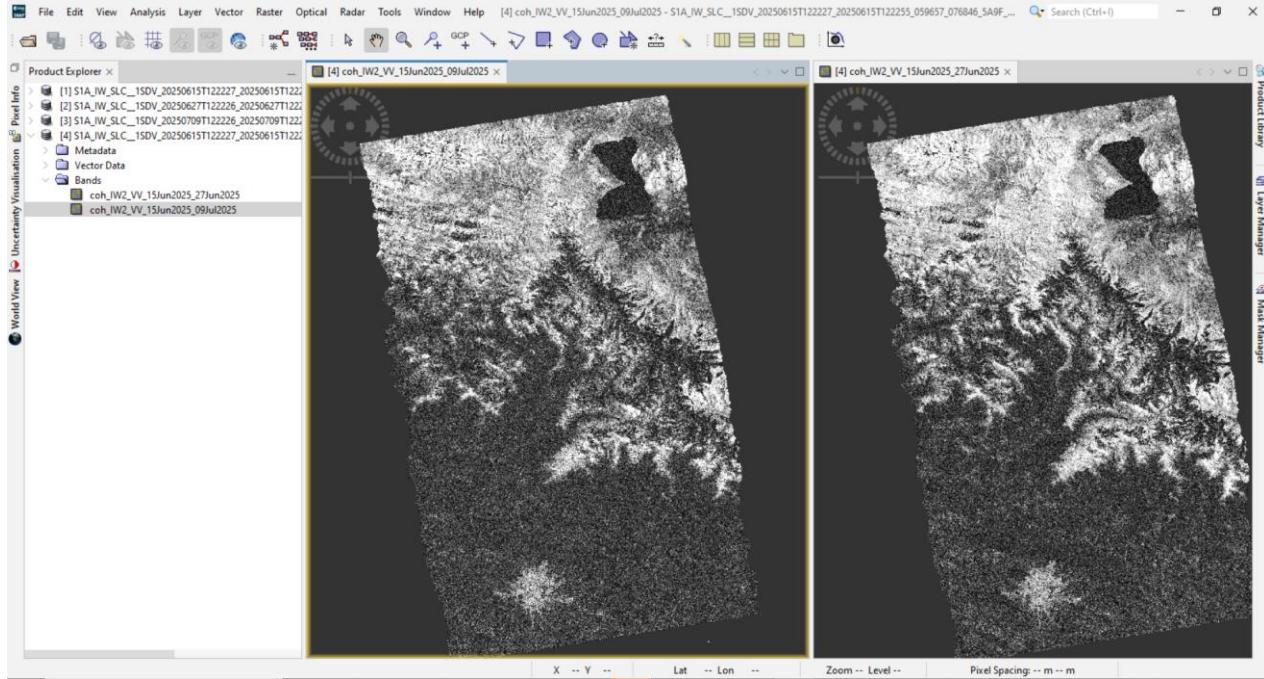
1. Let's complete the graph with the output. Right-click the white space between the existing operators and go to [Add → Input-Output → Write](#)
2. Connect the new operator with the Terrain-Correction operator.
3. Save and change the output directory:  
`S1A_IW_SLC_1SDV_20250615T122227_20250615T122255_059657_076846_5A9F_Orb_Stack_Coh_Deb_ML_TC`
4. Save the graph, go to [File → Save Graph](#) in the Graph Builder Main Menu: `Coherence_Snap.xml`
5. Now that all settings are completed. [Run](#) the Graph.



Here, the processing completed in **~3-4 minutes** (depending on your PC/laptop)

# Data Processing in SNAP

## Output: Coherence



The coherence products will appear in the Product Explorer window.

1. Click > to expand the contents of the product [1], then expand the Bands folder. You can see the coherence of pre-event (t1-t2) and post-event (t1-t3). Make sure the combinations are correct.
2. Double-click on both coherence bands to visualize them.

Note: If you have time, you can run the Graph again to process coherence for sub-swath IW1 and IW3.

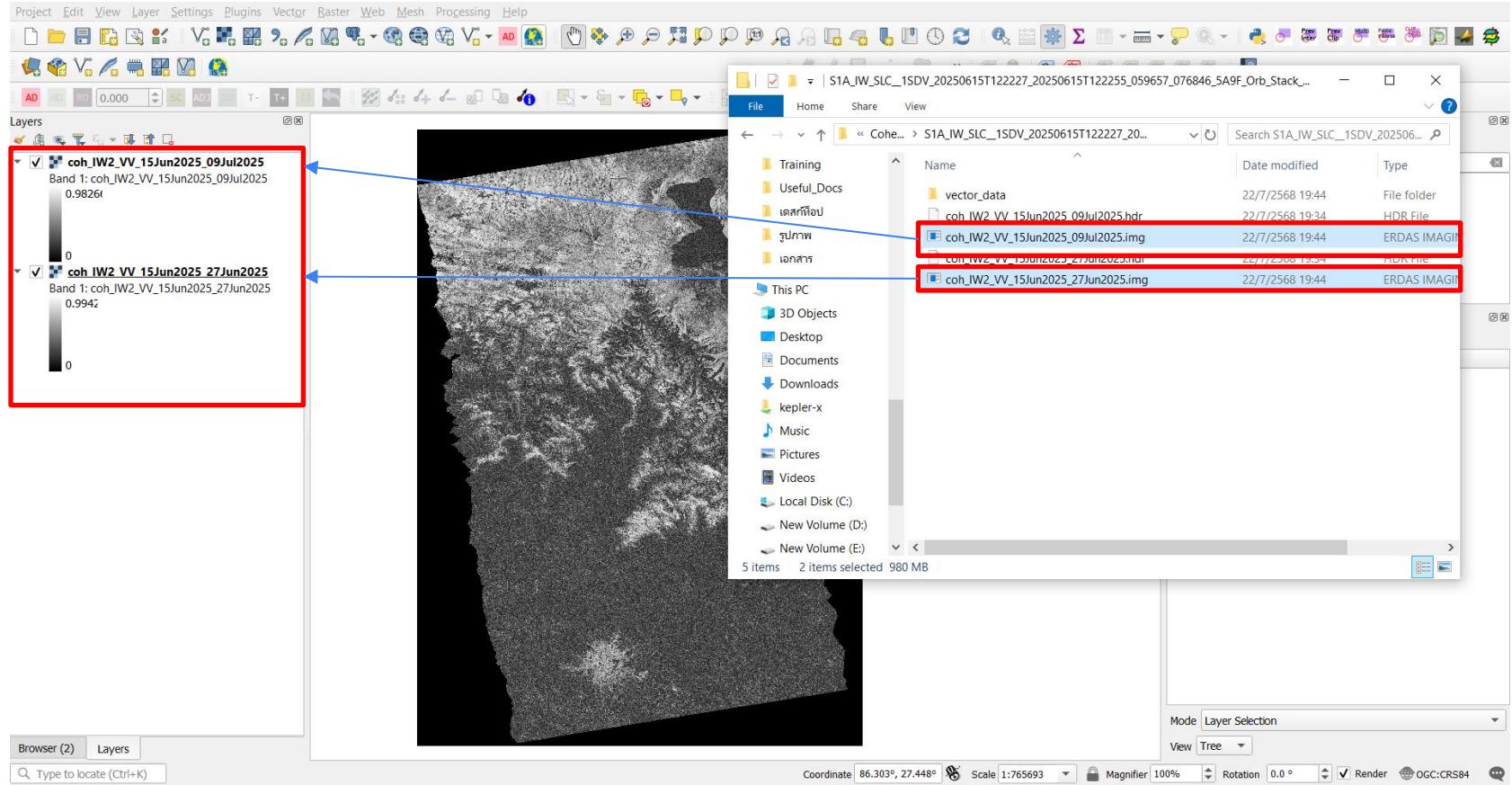
# Coherence Changes Calculation

To quantify the impact of the July 08, 2025, event on coherence. This involves comparing the coherence calculated from post-event (t1-t3) with a pre-event baseline coherence (which would be the coherence calculated from pre-event (t1-t2). This highlights the actual change caused by the event.

The resulting "coherence change" map is your primary tool for damage assessment. Areas showing a significant drop in coherence in this final map are strong indicators of damage or significant surface alteration directly related to the event, as stable features would have lost their consistent radar scattering properties.

# Data Processing in QGIS

## Input Coherence results in QGIS

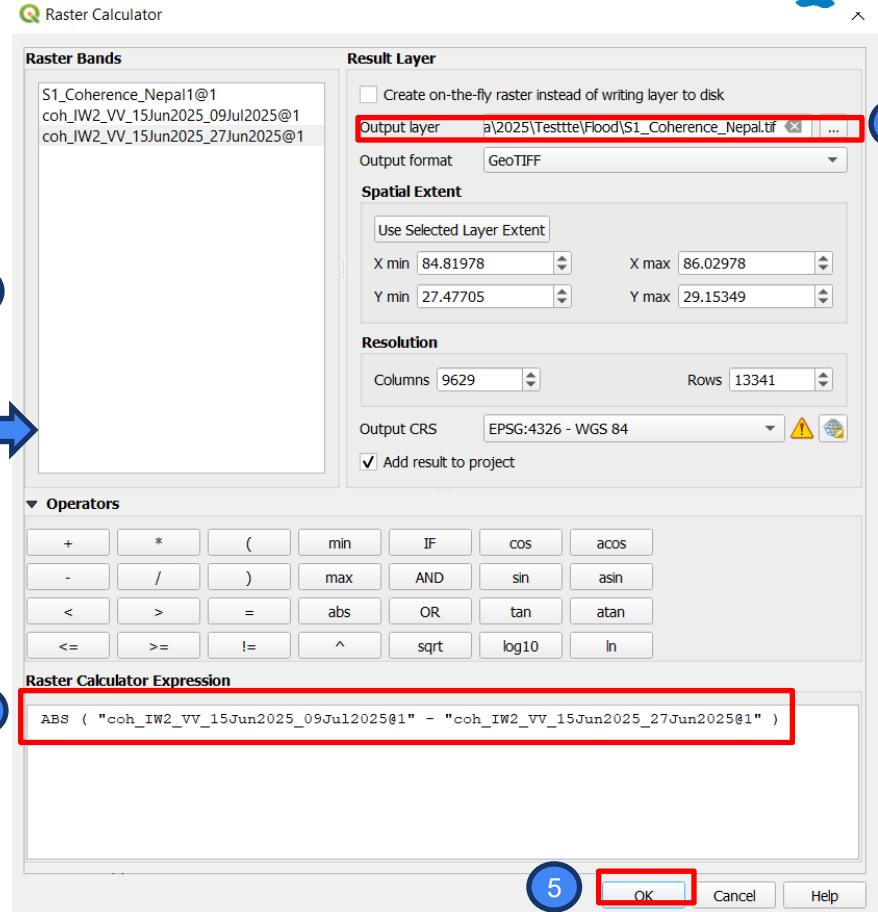
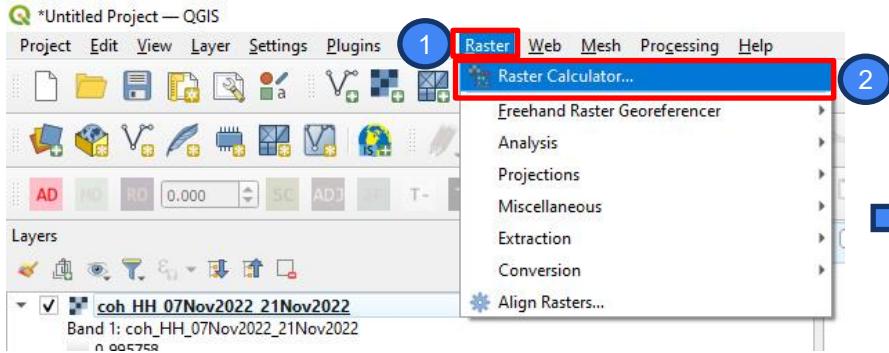


# Data Processing in QGIS

## Coherence Changes Calculation

- Using Raster Calculator tool in QGIS

Goto Raster > Raster Calculator

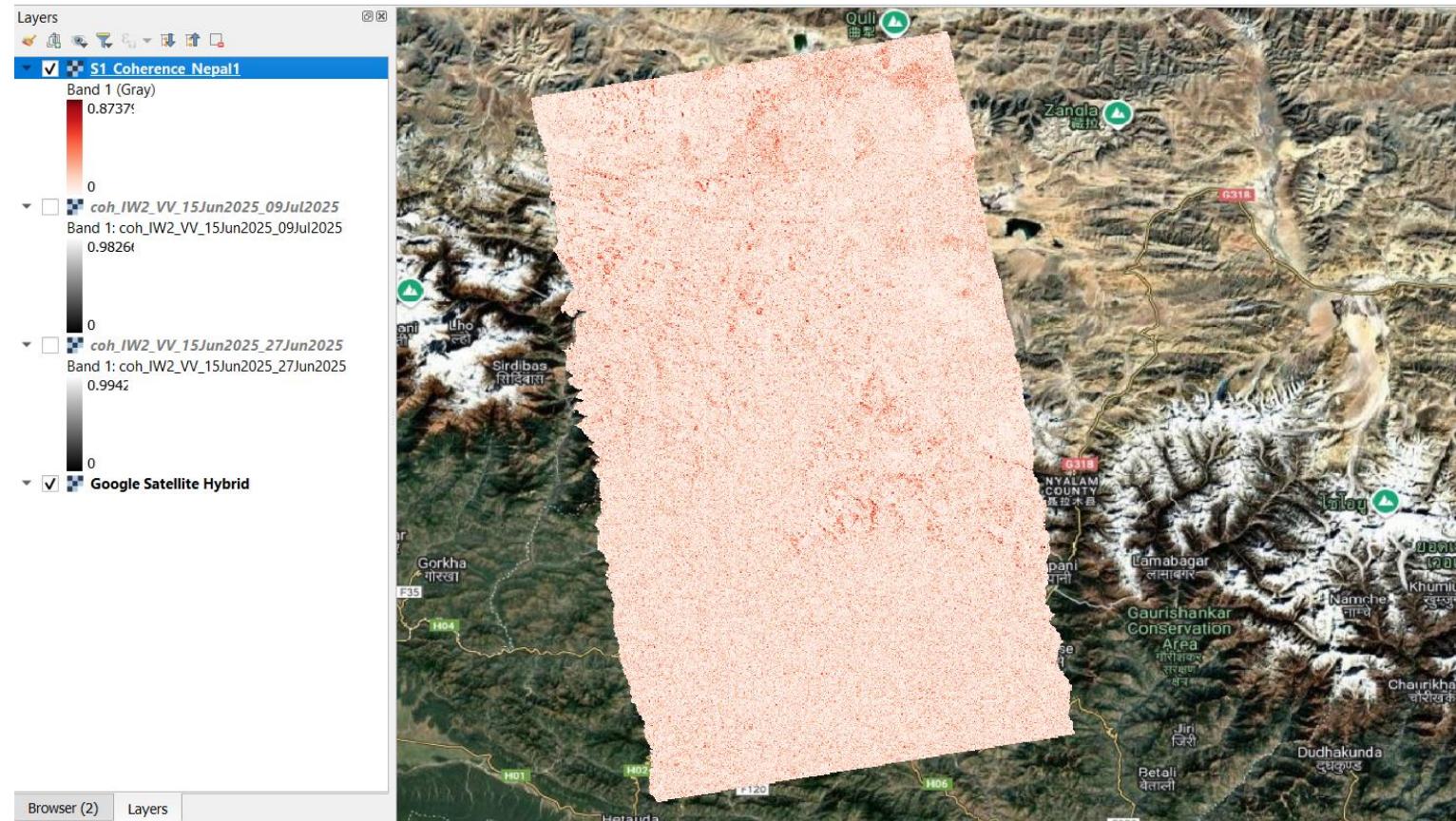


Equation:

$ABS ( "coh\_IW2\_VV\_15Jun2025\_09Jul2025@1" - "coh\_IW2\_VV\_15Jun2025\_27Jun2025@1" )$

# Data Processing in QGIS

## Output: Coherence Changes



# Data Processing in Google Earth Engine (GEE)

Load the coherence changes product to the GEE assets



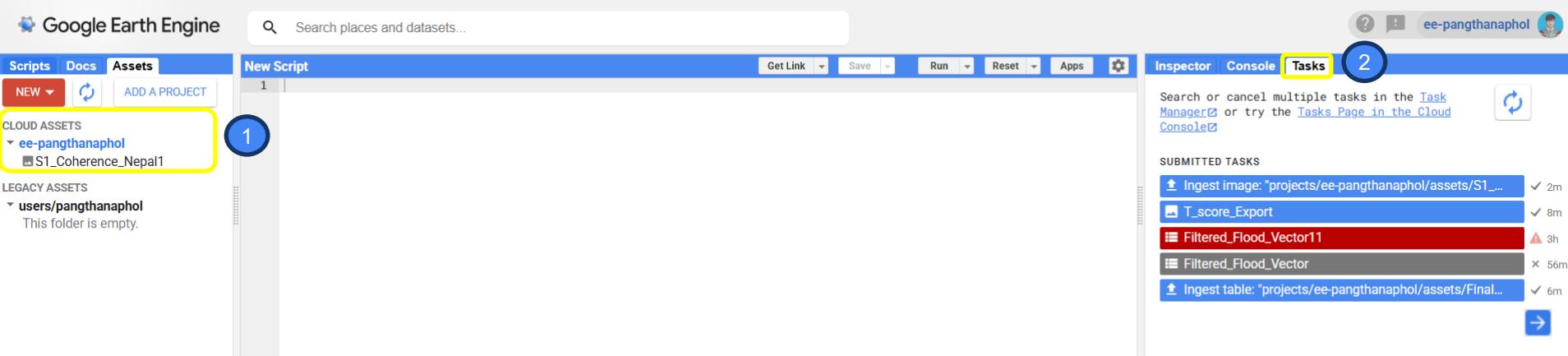
The screenshot shows the Google Earth Engine interface. On the left, the 'Assets' tab is selected, with a 'NEW' button highlighted by a red box and a blue circle labeled '1'. The 'Image Upload' section is also highlighted with a yellow box and a blue circle labeled '2'. The central area shows a 'New Script' editor with a single line of code '1'. The 'Inspector' tab is active, showing the user 'ee-syams1'. The right side of the interface shows a map of the United States with various locations labeled. At the bottom, there are standard Google Earth Engine controls for zooming and orientation.

The screenshot shows the 'Upload a new image asset' dialog box. The 'Source files' section is highlighted with a yellow box and a blue circle labeled '3'. The 'Asset ID' field contains 'S1\_Coherence\_Nepal1.tif'. The 'Properties' section shows 'Asset Name' as 'S1\_Coherence\_Nepal1'. The 'Advanced options' section includes 'Pyramiding policy' set to 'MEAN' and 'Masking mode' set to 'None'. At the bottom right, a blue button labeled 'UPLOAD' is highlighted with a yellow box and a blue circle labeled '4'.

1. Login to your GEE account.
2. Go to the [Assets](#) tab, then click [NEW](#) and [GeoTIFF](#).
3. Click [SELECT](#) and upload the [GeoTIFF](#) coherence product from QGIS.
4. Click [UPLOAD](#).

# Data Processing in Google Earth Engine (GEE)

## Import the coherence product to the GEE script window



1. Once uploading is complete, it will be available as **Cloud Assets**. You may have to click restart to see the product on the **Assets** tab.
2. Check the **Tasks** tab to check the uploading status.

# Data Processing in Google Earth Engine (GEE)

## Copy the script and Run

The screenshot shows the Google Earth Engine (GEE) interface. On the left, there's a sidebar with 'Scripts', 'Docs', and 'Assets' tabs, and buttons for 'NEW', 'ADD A PROJECT', 'CLOUD ASSETS' (containing 'ee-pangthanaphol' and 'S1\_Coherence\_Nepal1'), and 'LEGACY ASSETS' (containing 'users/pangthanaphol' with a note 'This folder is empty'). The main area is a 'New Script' editor with the following code:

```
1 // 1. Define AOI using bounding box coordinates
2 var aoi = ee.Geometry.Rectangle([85.299951, 28.177378, 85.398319, 28.296120]);
3
4 // 2. Load Coherence image from Assets
5 var coherence = ee.Image('projects/ee-pangthanaphol/assets/S1_Coherence_Nepal1');
6
7 // 3. Load Urban areas from Dynamic World
8 var urban = ee.ImageCollection('GOOGLE/DYNAMICWORLD/V1')
9   .select('built')
10  .mean()
11  .gt(0.1) // Only keep clearly urban areas
12  .clip(aoi);
13
14 // 4. Load DEM and create slope mask
15 var DEM = ee.Image('WRF/HydroSHEDS/03VDEM');
16 var terrain = ee.Algorithms.Terrain(DEM);
17 var slope = terrain.select('slope');
18 var slopeMask = slope.lt(20); // Mask out areas with slope >= 20 degrees
19
20 // 5. Combine the urban mask and slope mask
21 var combinedMask = urban.updateMask(slopeMask);
22
23 // 6. Apply combined mask to the Coherence image
24 var masked = coherence
25   .clip(aoi)
26   .updateMask(combinedMask);
27
28 // 7. Visualization
29 Map.centerObject(aoi, 12);
30 Map.addLayer(masked, {min: 0, max: 1, palette: ['yellow', 'red']}, 'Coherence Masked: Urban + Low Slope');
31
32 // Optional: display AOI
33 Map.addLayer(aoi, {color: 'blue'}, 'AOI');
34
35 // 8. Export the result to Google Drive
36 Export.image.toDrive({
37   image: masked,
38   description: 'coherence_masked_urban_slope',
39   folder: 'GEE_Export',
40   fileNamePrefix: 'coherence_mask_urban_slope',
41   region: aoi,
42   scale: 10,
43   maxPixels: 1e13
44});
```

The interface has a toolbar with 'Get Link', 'Save', 'Run' (highlighted with a yellow box and a blue circle with '3'), 'Reset', 'Apps', and a gear icon. A search bar at the top says 'Search places and datasets...'. The code is annotated with numbered steps:

1. Copy the prepared script to the Script window.
2. Update the file path of your image.
3. Run the script.

# Data Processing in Google Earth Engine (GEE)

## Output: Coherence Changes (Mask Slope and Urban areas)

Search places and datasets...

```
1 // 1. Define AOI using bounding box coordinates
2 var aoi = ee.Geometry.Rectangle([85.299951, 28.177378, 85.398319, 28.296120]);
3
4 // 2. Load Coherence image from Assets
5 var coherence = ee.Image("projects/ee-pangthanaphol/assets/S1_Coherence_Nepal1");
6
7 // 3. Load Urban areas from Dynamic World
8 var urban = ee.ImageCollection('GOOGLE/DYNAMICWORLD/V1')
9 .select('built')
10 .mean()
```

Inspector   Console   Tasks

Search or cancel multiple tasks in the Task Manager or try the Tasks Page in the Cloud Console

UNSUBMITTED TASKS

coherence\_masked\_urban\_slope RUN

Download

The image shows the Google Earth Engine (GEE) interface. On the left, a script editor contains code for defining an Analysis Of Interest (AOI) using a bounding box, loading a coherence image from a project asset, and loading urban areas from the Dynamic World collection. On the right, an 'Inspector' panel shows the task 'coherence\_masked\_urban\_slope' with a 'RUN' button highlighted by a yellow box. Below the script editor is a satellite map of a mountainous region in Nepal, with a yellow oval highlighting a specific area. The map labels include 'CHINA', 'NEPAL', 'Gatlang', 'BANGKU', 'Thuman', 'TIMURE', 'Khangjim', 'Chilime', 'Bridhim', 'Syapru Besi', 'Sherpagaon', 'MANCHET', 'RASUA', 'RESUO', 'Gompa', 'KYANJIN GOMPA', 'KYANGJIN KHARKA', 'Langlang', and 'THANGSYAP'. The bottom of the interface includes standard GEE navigation and information buttons.

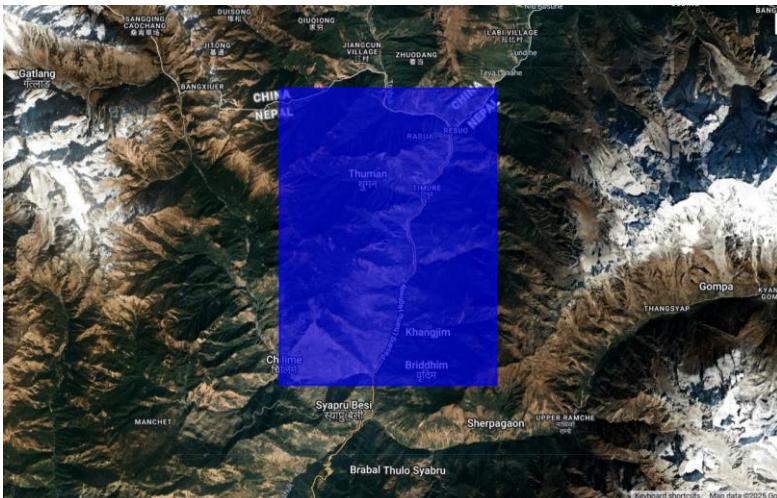
# Data Processing in Google Earth Engine (GEE)

## Script description

- Defines a rectangular AOI in Nepal using bounding box
- Coordinates: [85.299951, 28.177378, 85.398319, 28.296120]
- Used to clip all subsequent data layers

```
// 1. Define AOI using bounding box coordinates
```

```
var aoi = ee.Geometry.Rectangle([85.299951, 28.177378, 85.398319, 28.296120]);
```

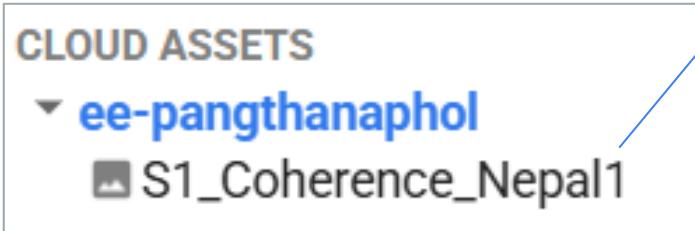


# Data Processing in Google Earth Engine (GEE)

## Script description

- Loads preprocessed Sentinel-1 Coherence image from Assets
- Coherence indicates surface change or stability between SAR acquisitions

```
// 2. Load Coherence image from Assets
var coherence = ee.Image("projects/ee-pangthanaphol/assets/S1_Coherence_Nepal1");
```



# Data Processing in Google Earth Engine (GEE)

## Script description



- Uses Dynamic World dataset ('built' band)
- Takes temporal mean and thresholds >10% urban probability
- Clips to AOI

```
// 3. Load Urban areas from Dynamic World
var urban = ee.ImageCollection('GOOGLE/DYNAMICWORLD/V1')
  .select('built')
  .mean()
  .gt(0.1) // Only keep clearly urban areas
  .clip(aoi);
```

# Data Processing in Google Earth Engine (GEE)



## Script description

- Loads DEM from HydroSHEDS
- Computes slope using Terrain algorithm
- Masks out areas with slope  $\geq 20^\circ$

```
// 4. Load DEM and create slope mask
var DEM = ee.Image('WWF/HydroSHEDS/03VFDEM');
var terrain = ee.Algorithms.Terrain(DEM);
var slope = terrain.select('slope');
var slopeMask = slope.lt(20); // Mask out areas with slope >= 20 degrees
```

# Data Processing in Google Earth Engine (GEE)



## Script description

- Applies slope mask to urban area layer
- Keeps only urban areas on low-slope land
- Clips the coherence image to AOI
- Applies the combined urban + slope mask
- Output: Coherence in urban + low-slope areas only

```
// 5. Combine the urban mask and slope mask
var combinedMask = urban.updateMask(slopeMask);

// 6. Apply combined mask to the Coherence image
var masked = coherence
  .clip(aoi)
  .updateMask(combinedMask);
```

# Data Processing in Google Earth Engine (GEE)

## Script description



- Centers map on AOI
- Displays coherence in yellow-red palette
- Shows AOI outline in blue

```
// 7. Visualization
Map.centerObject(aoi, 12);
Map.addLayer(masked, {min: 0, max: 1, palette: ['yellow', 'red']}, 'Coherence Masked: Urban + Low Slope');

// Optional: display AOI
Map.addLayer(aoi, {color: 'blue'}, 'AOI');
```

# Data Processing in Google Earth Engine (GEE)



## Script description

- Exports final image as 'coherence\_mask\_urban\_slope'
- Output to folder: GEE\_Export
- Scale: 10m/pixel, region: AOI, format: GeoTIFF

```
// 8. Export the result to Google Drive
Export.image.toDrive({
  image: masked,
  description: 'coherence_masked_urban_slope',
  folder: 'GEE_Export',
  fileNamePrefix: 'coherence_mask_urban_slope',
  region: aoi,
  scale: 10,
  maxPixels: 1e13
});
```

Inspector   Console   Tasks

Search or cancel multiple tasks in the [Task Manager](#) or try the [Tasks Page in the Cloud Console](#)

### UNSUBMITTED TASKS

coherence\_masked\_urban\_slope

RUN

# THANK YOU

Geoinformatics Center, Asian Institute of Technology

