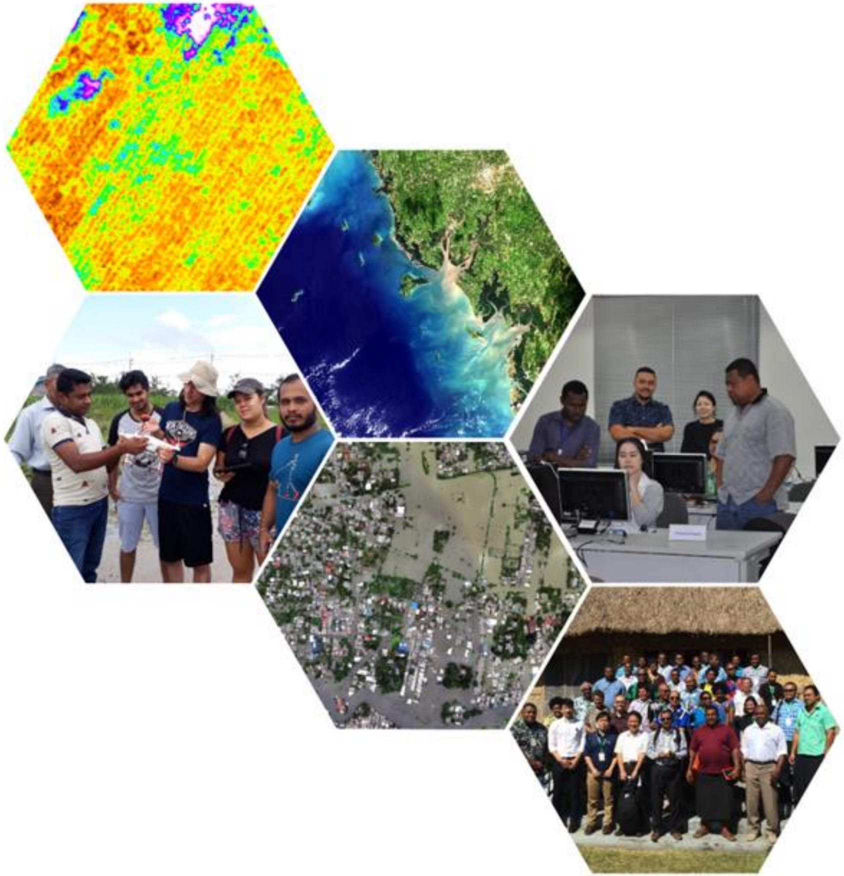
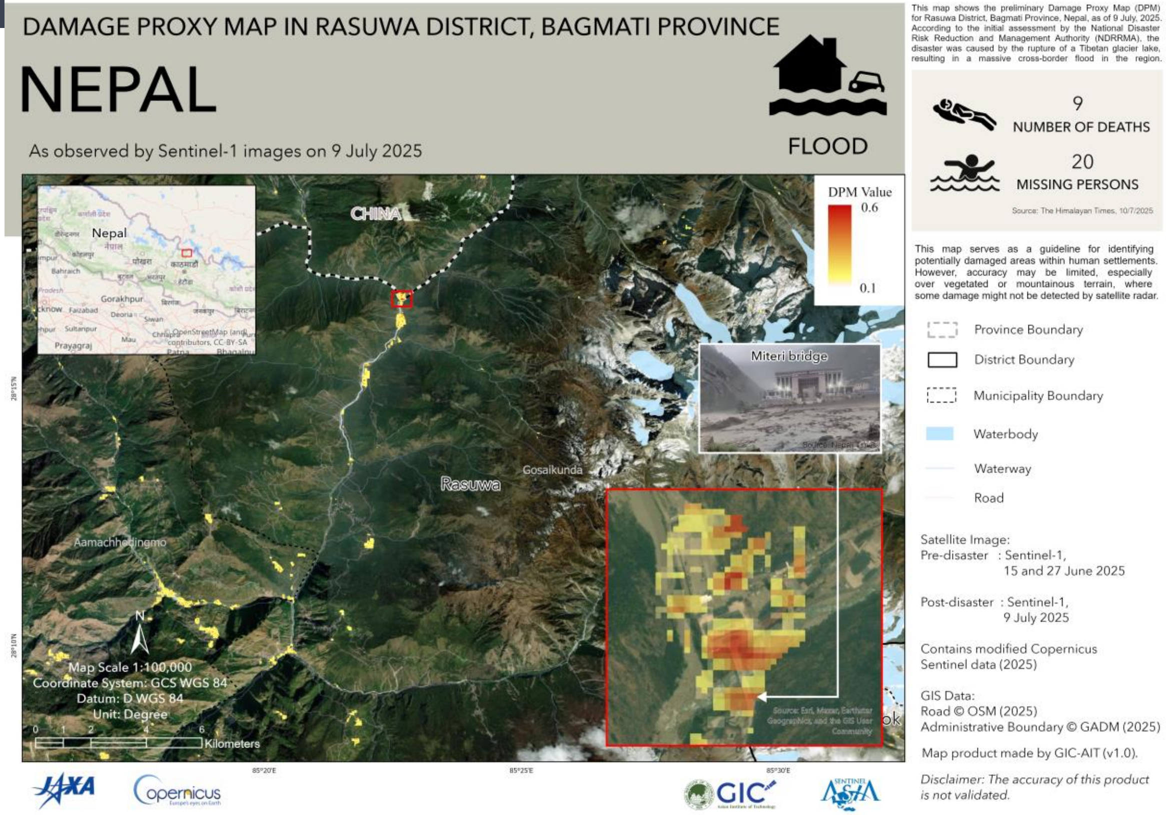


Damage Proxy Mapping Using Sentinel-1: Coherence Changes

syams@ait.asia
Geoinformatics Center - AIT

Overview



(https://sentinel-asia.org/EO/2025/article20250630NP.html)

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).

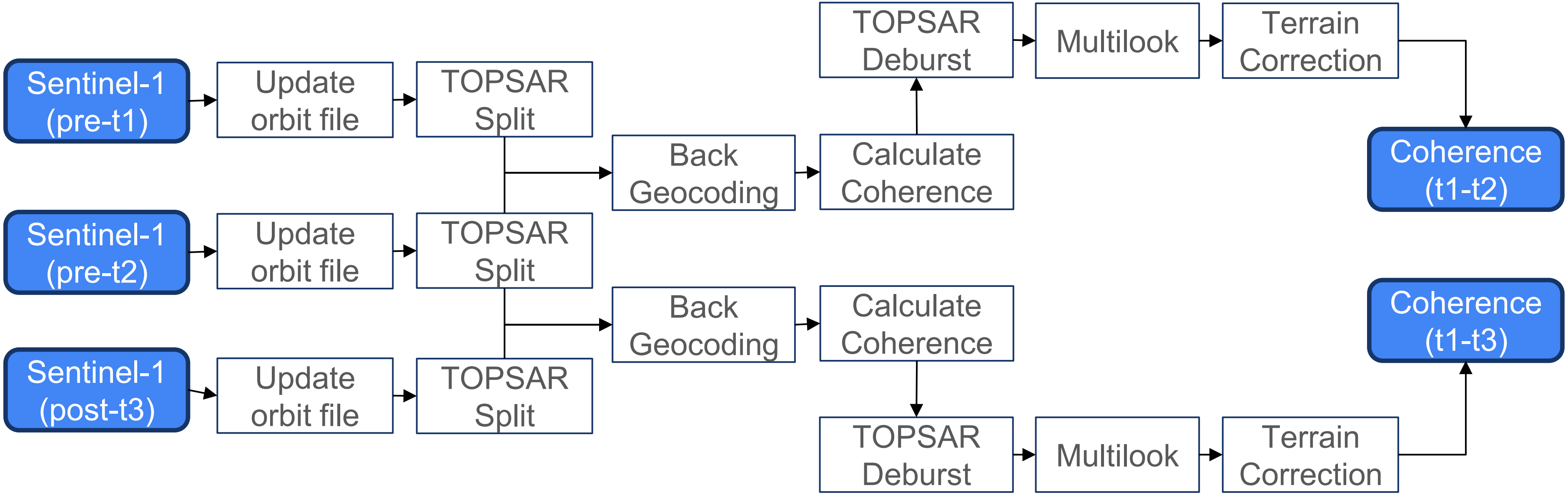
The following data are available:

- 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

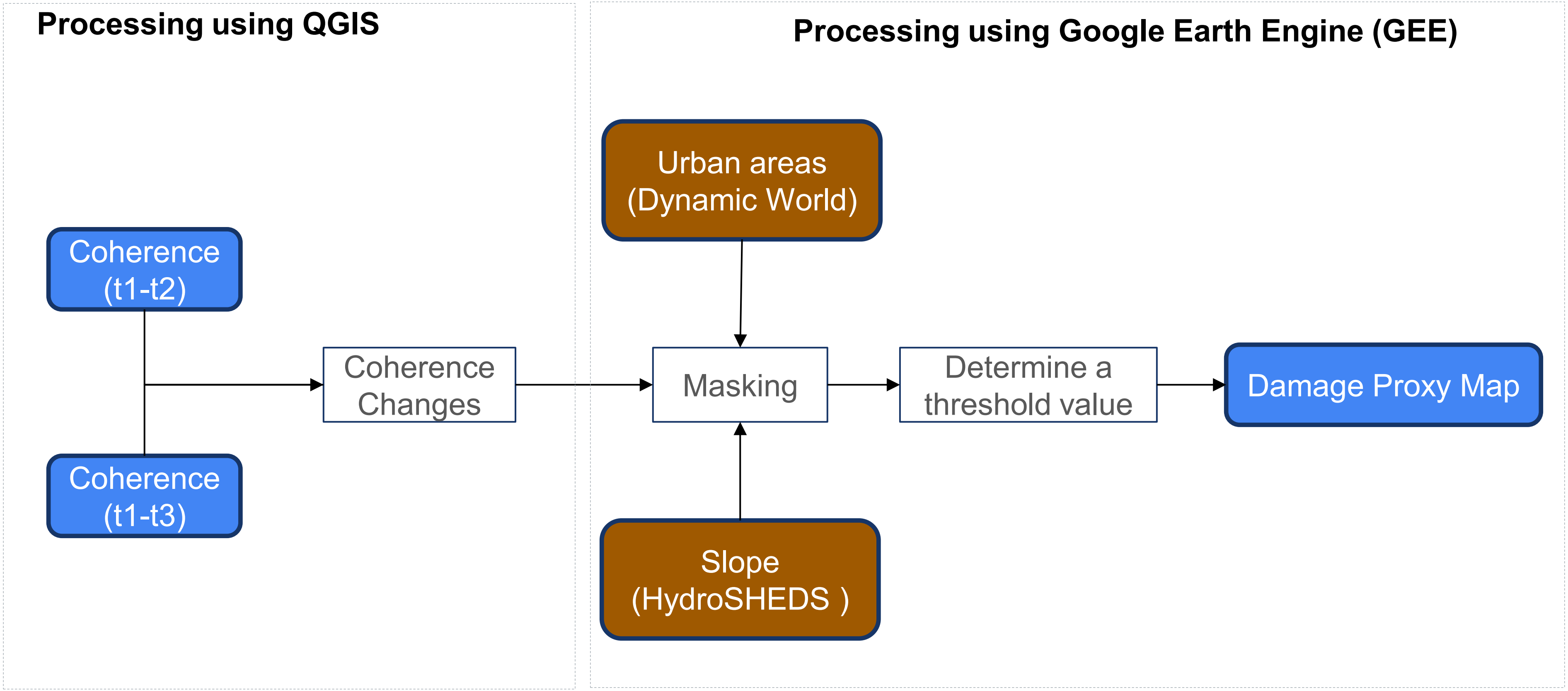
Damage Proxy mapping using Sentinel-1 coherence changes

Processing using SNAP



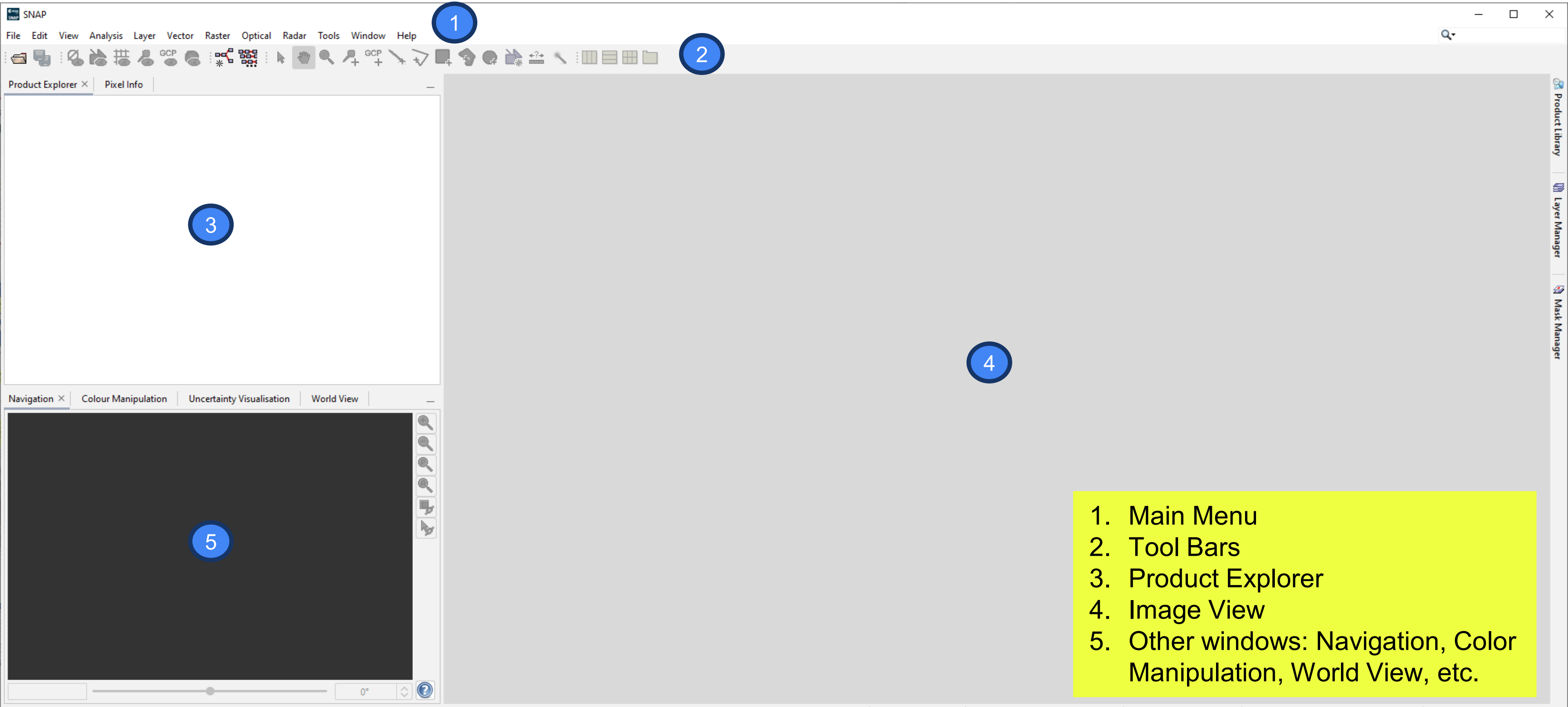
Methodology

Damage Proxy mapping using Sentinel-1 coherence changes



Data Exploration in SNAP

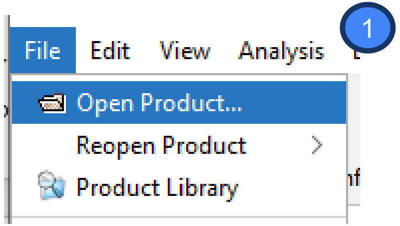
Open the SNAP software

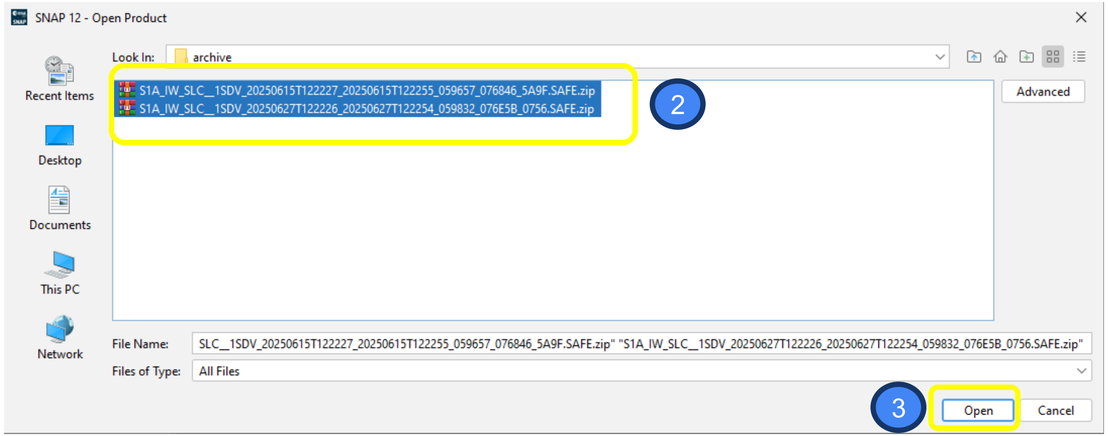


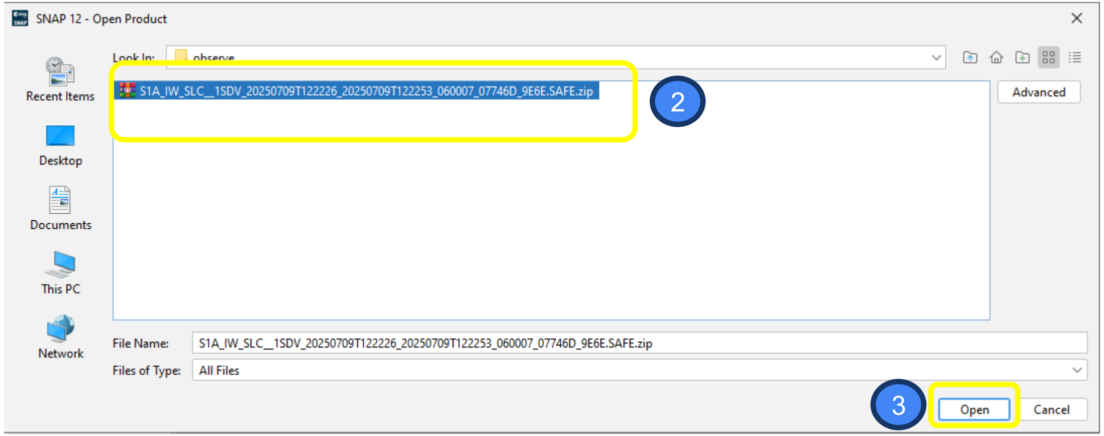
1. Main Menu
2. Tool Bars
3. Product Explorer
4. Image View
5. Other windows: Navigation, Color Manipulation, World View, etc.

Data Exploration in SNAP

Open Sentinel-1 Data



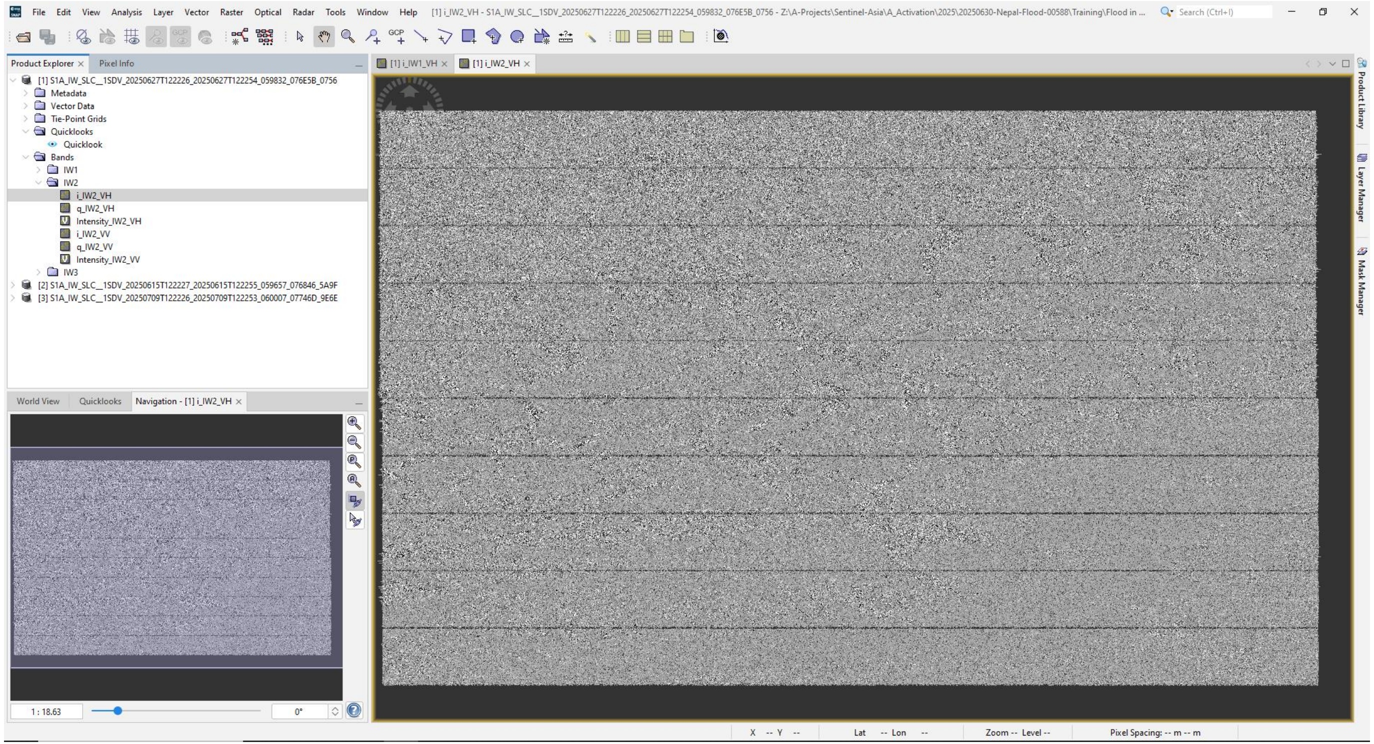




1. In the Main Menu, go to File → Open Product…
2. Browse to the location of the data. Then select all Sentinel-1 data in both archive and observe folders. Each file refers to a different acquisition date.
3. Click Open

Data Exploration in SNAP

Explore the Sentinel-1 Data



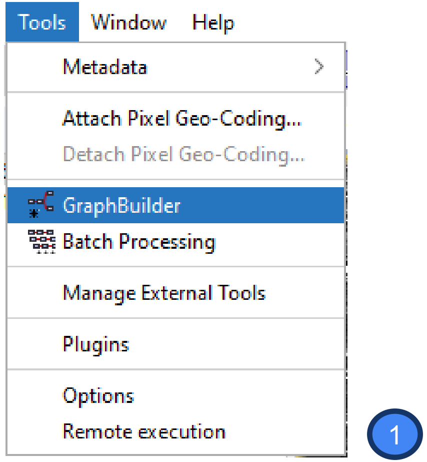
The opened products will appear in the Product Explorer window.

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.

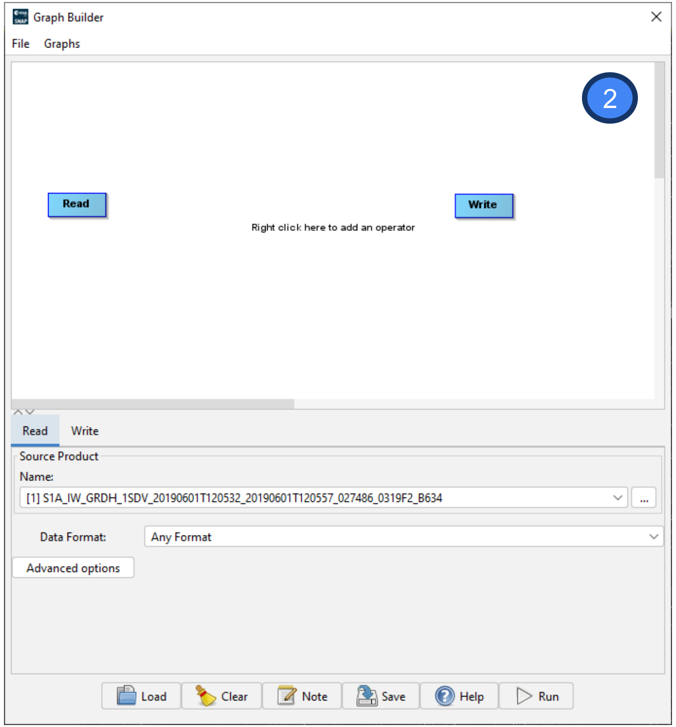
Data Processing in SNAP

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.

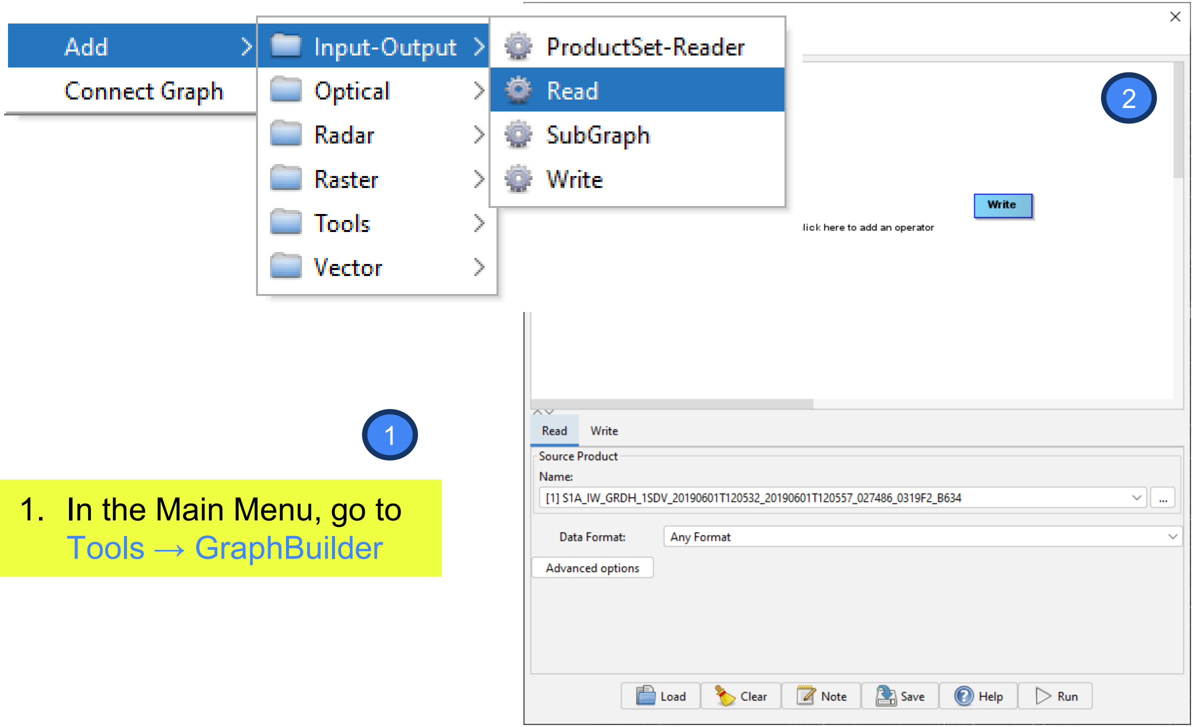
In the beginning, the graph has only two operators: **Read** (to read the input) and **Write** (to write the output). We will create a step-by-step workflow to apply identical pre-processing steps to both of our scenes.

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

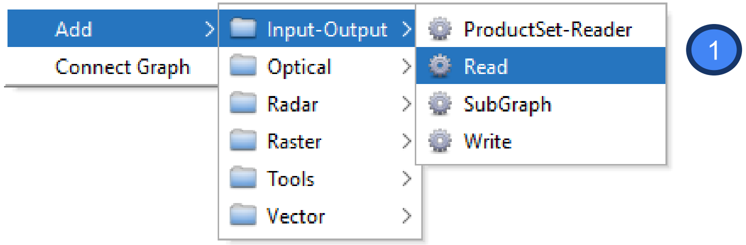
2. The **Graph Builder** window will show up.

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.

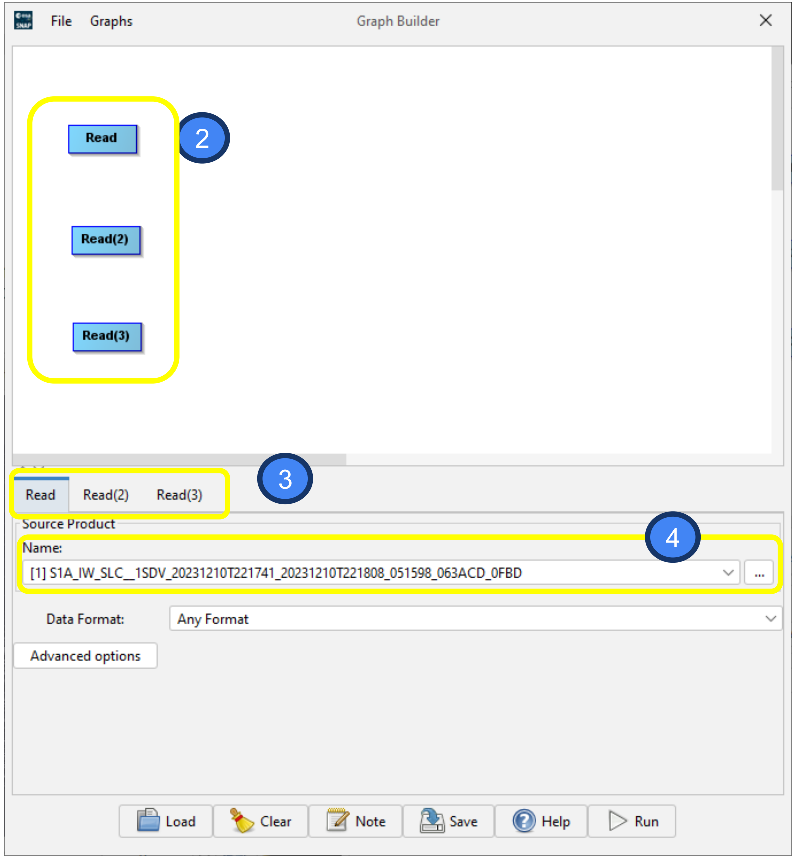
You can delete the **Write** operator for now (Right-click on the operator and select Delete).

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

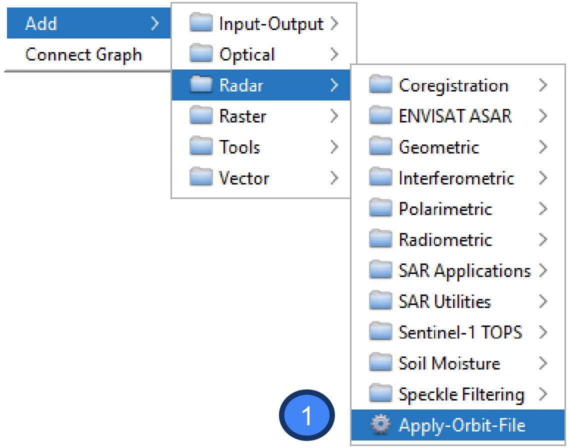
Update the orbit metadata

- 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.

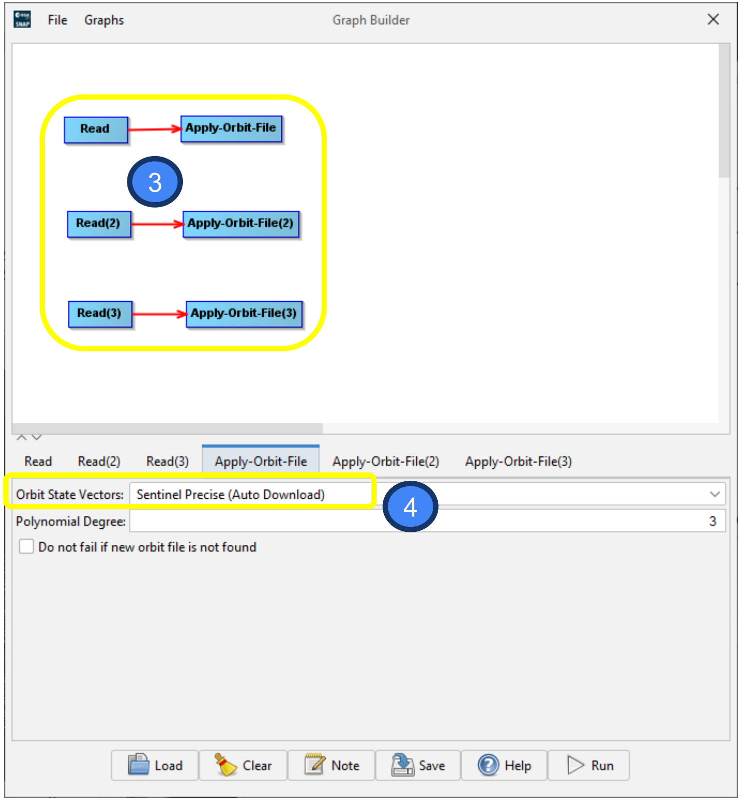
- The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated.

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).

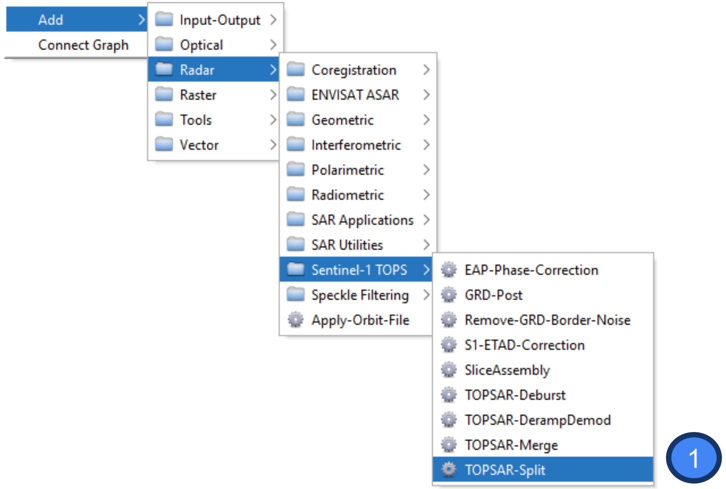
Data Processing in SNAP

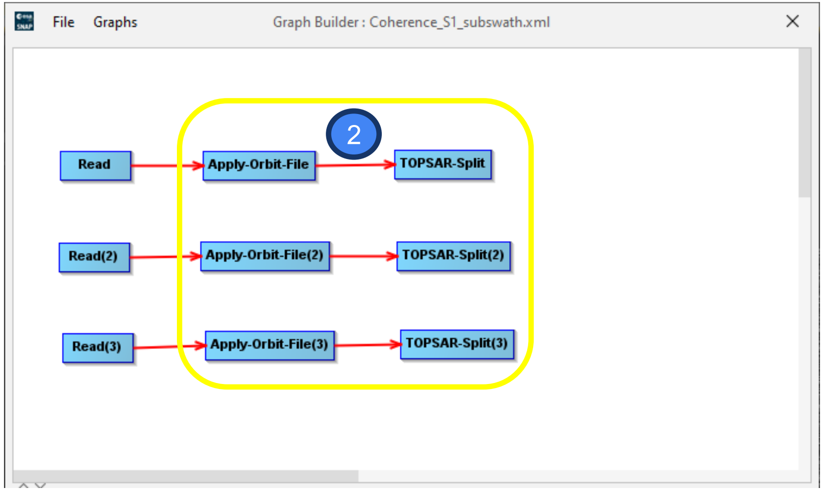
TOPSAR Split

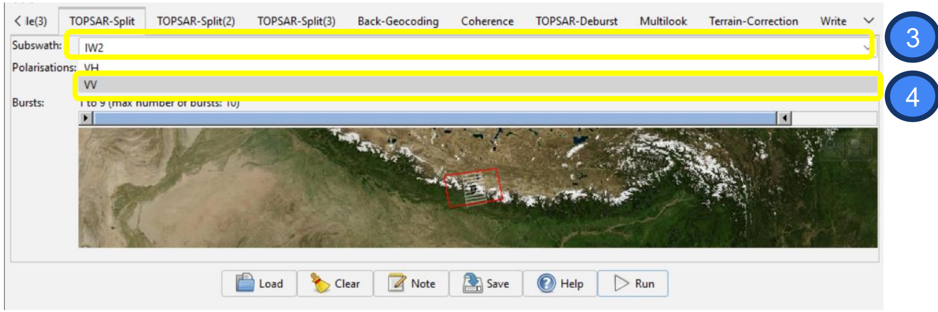
- Sentinel-1 SLC images in Interferometric Wide (IW) mode typically consist of 3 sub-swaths (IW1, IW2, IW3) — each composed of multiple bursts.
- The TOPSAR Split operator provides a convenient way to split each sub-swath with selected bursts into a separate product.
- The user may select the desired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

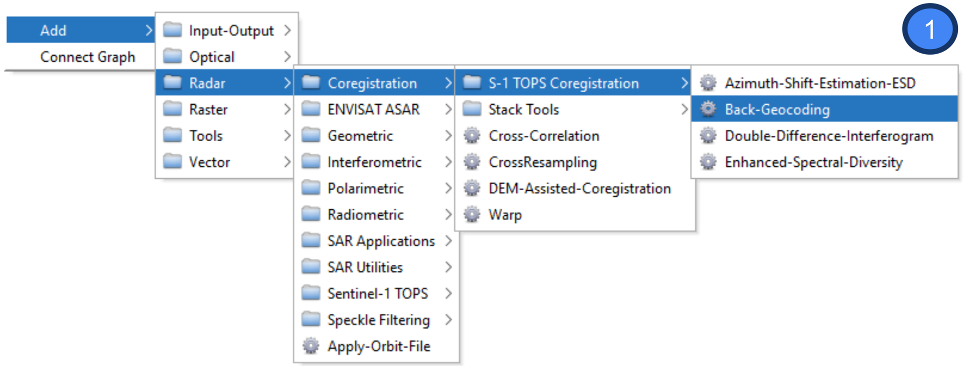
Back Geocoding

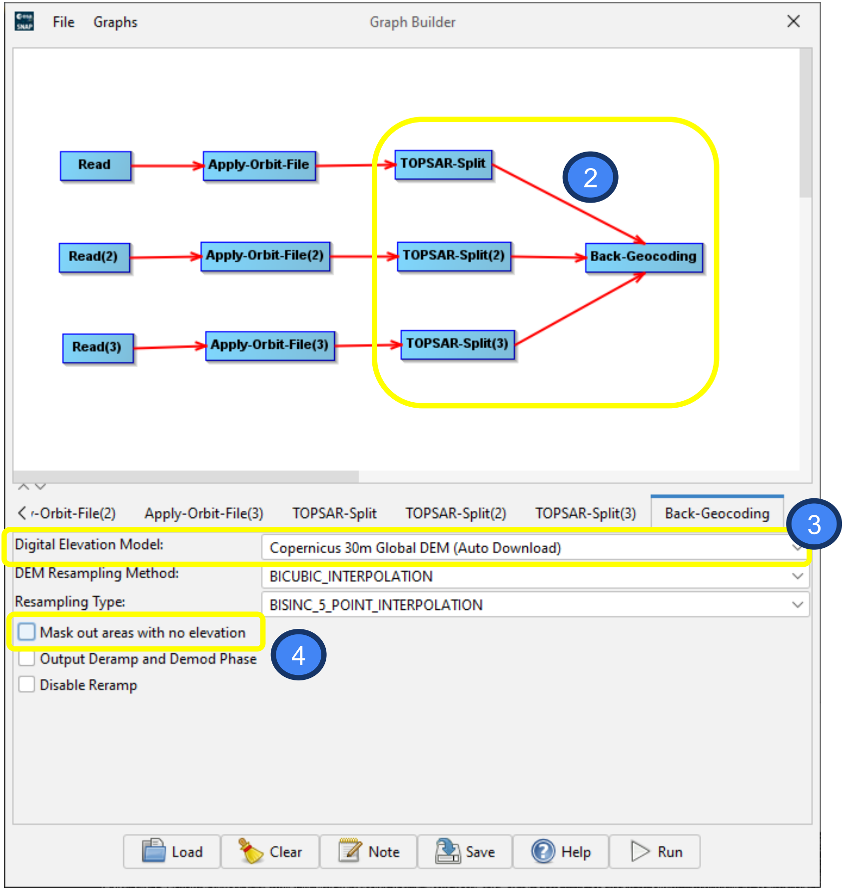
- Due to satellite movement, orbital drift, and acquisition differences, reference and secondary SLC images need to be geometrically matched.

- 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

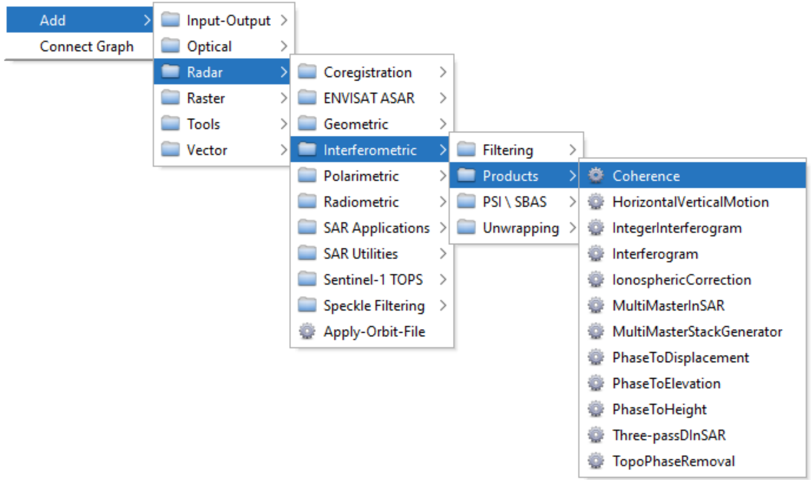
Coherence Estimation

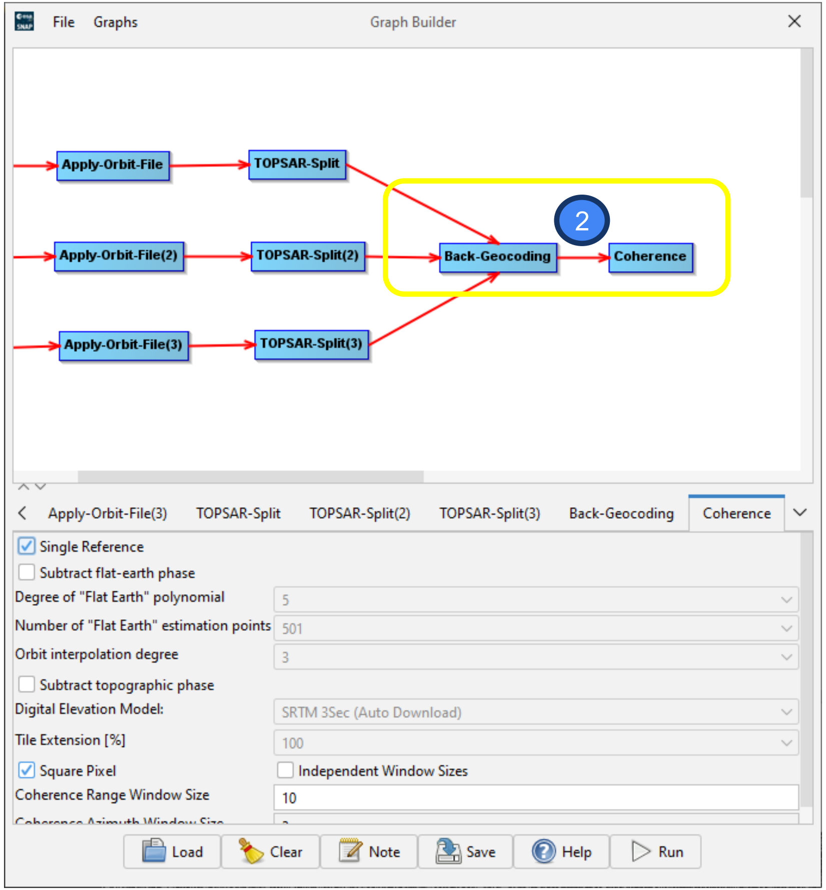
- Coherence is a measure of the similarity in radar signal phase and amplitude between two SAR images acquired at different times, for the same location.

- 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

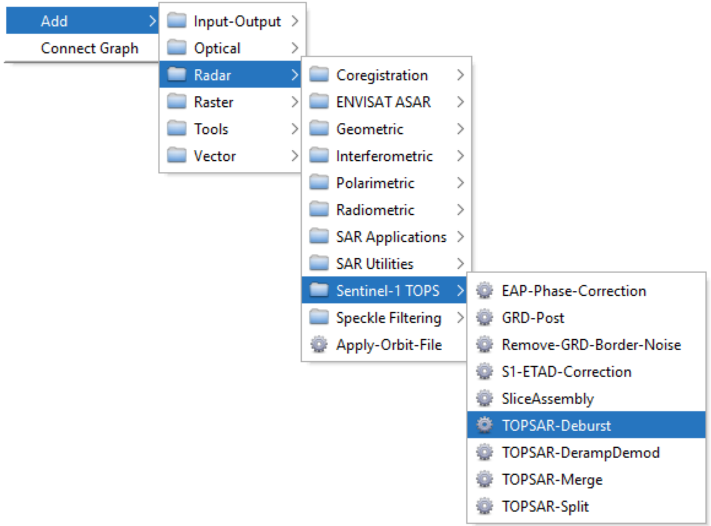
TOPSAR Deburst

- Each sub-swath consists of a series of adjacent but slightly overlapping bursts, which can cause visible discontinuities (burst gaps) in the interferogram.

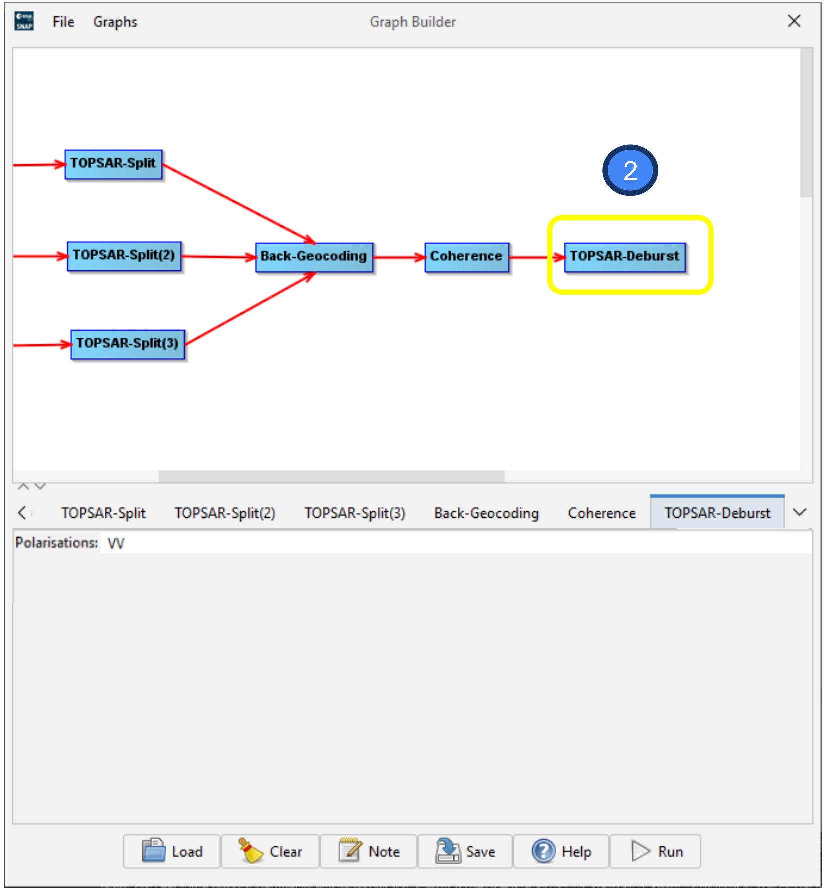
- Debursting removes those discontinuities and stitches the bursts together to create a continuous, seamless image for each sub-swath.

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

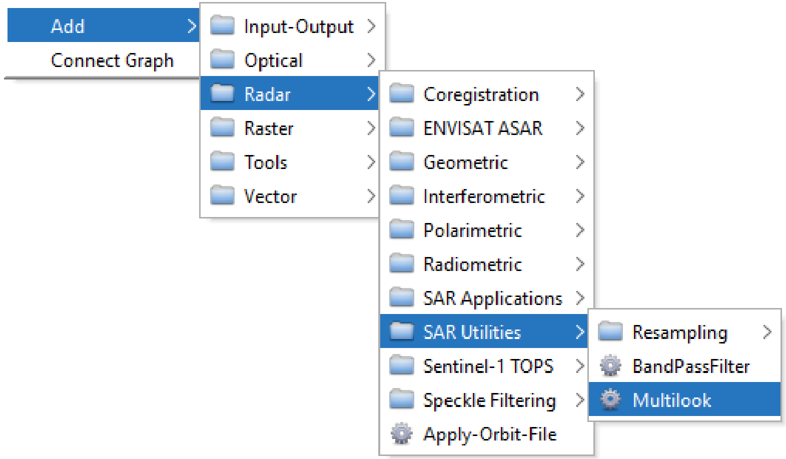
- Multilook is a SAR image processing technique used to reduce speckle noise and improve the visual appearance and radiometric quality of SAR images by averaging neighboring pixels in range and azimuth directions.

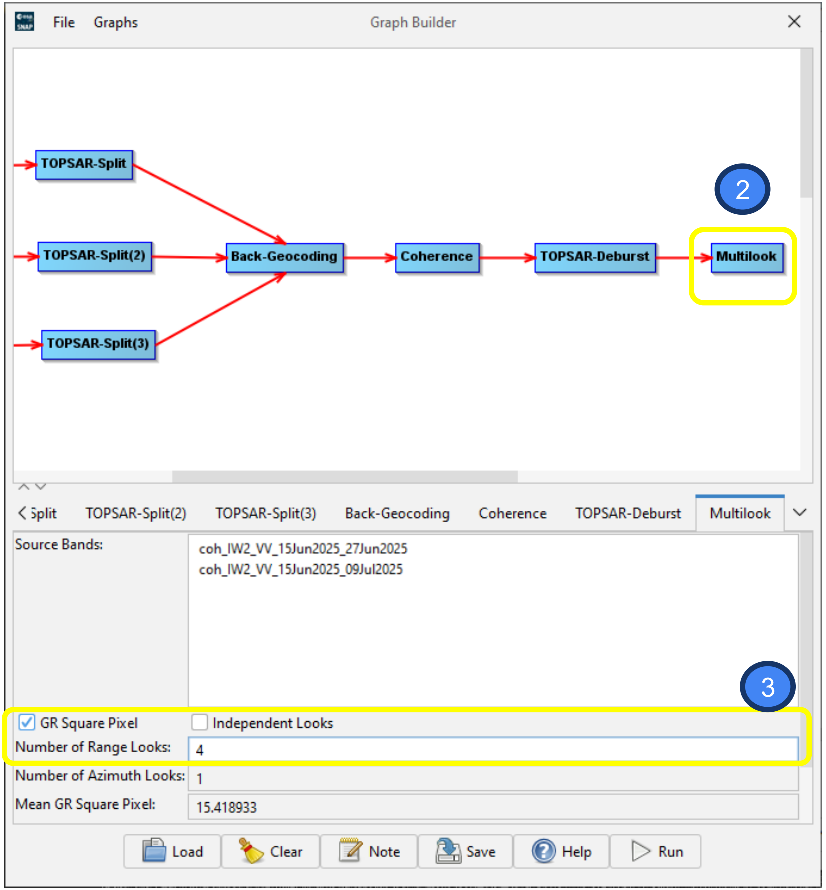
- It can be produced by space-domain averaging of a single look image or by a frequency-domain method using the sub-spectral band width.

- 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.

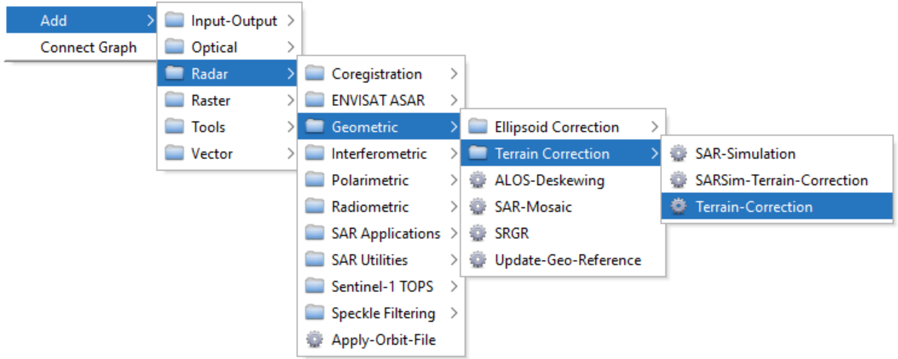
Data Processing in SNAP

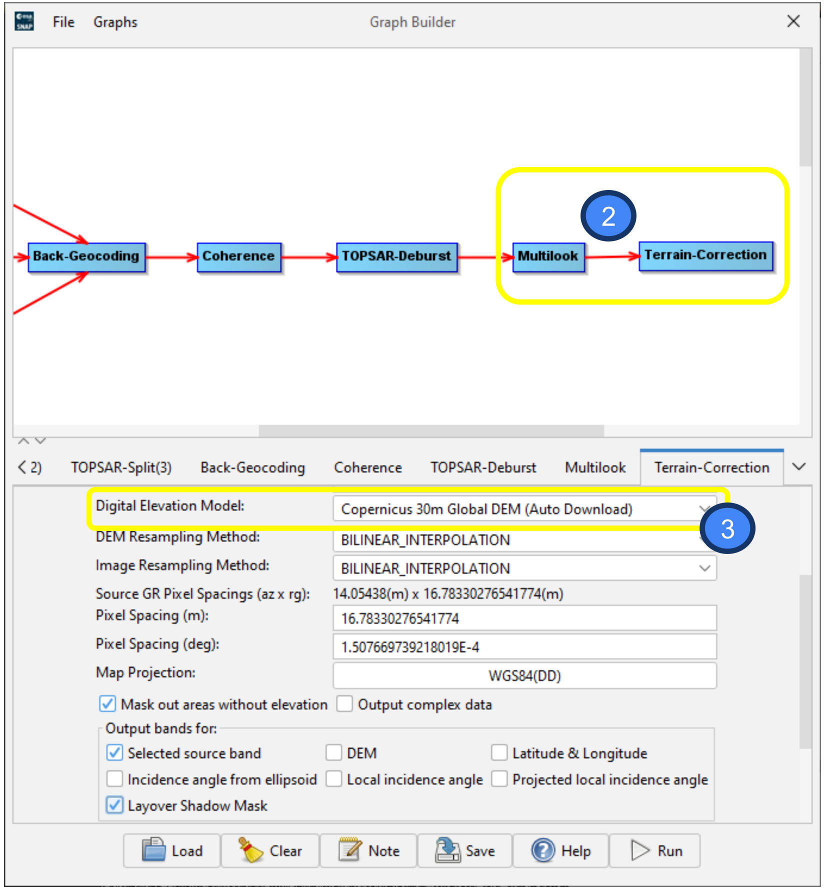
Terrain Correction

- 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

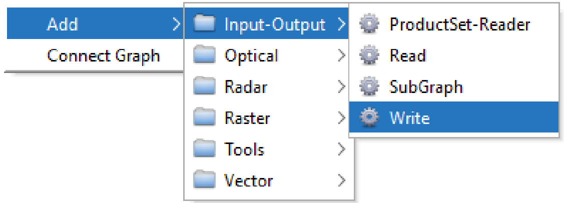




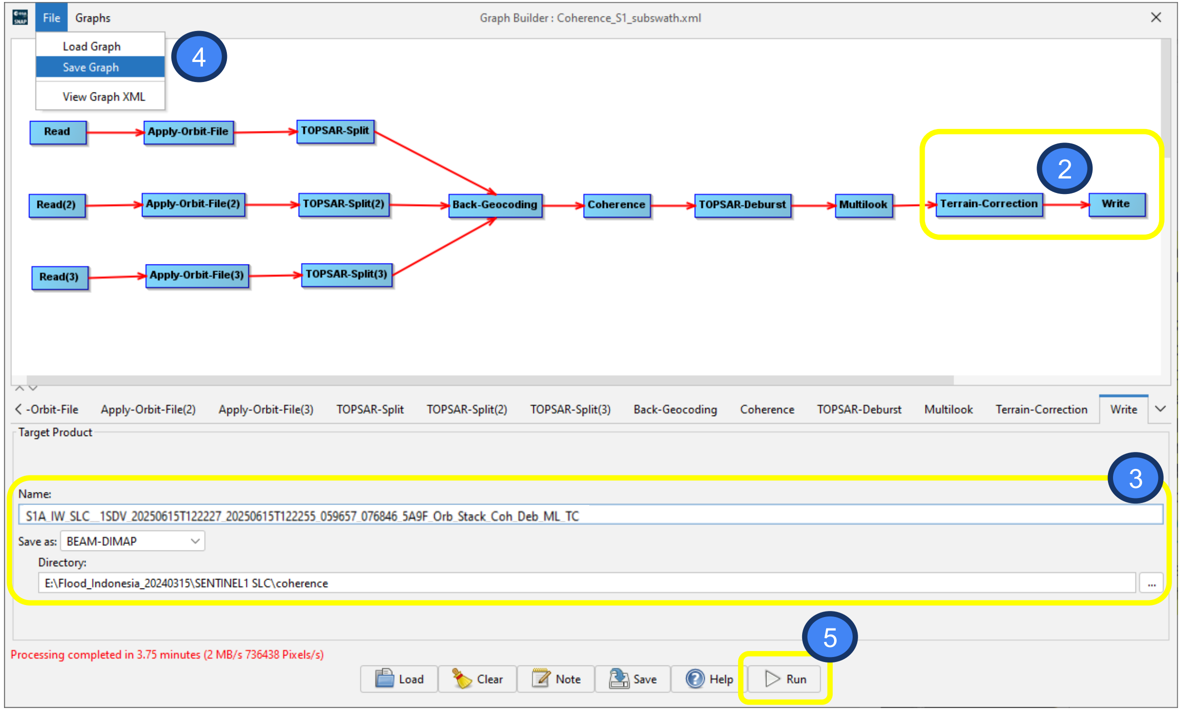
1. Right-click the white space between the existing operators and go to Add → Radar → Geometric → Terrain Correction → Terrain-Correction
2. Connect the new operator with the Multilook operator.
3. Select DEM: Copernicus 30m.

Data Processing in SNAP

Terrain Correction



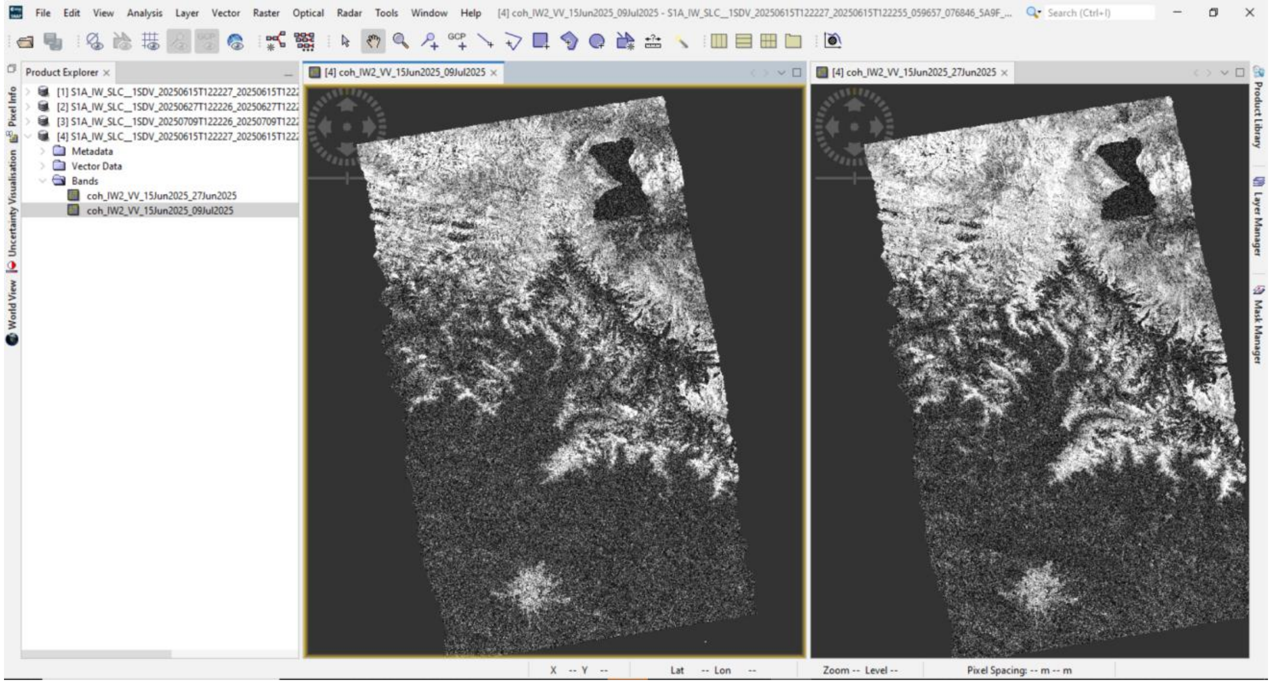
1. Let's complete the graph with the output. Right-click the white space between the existing operators and go to Add → Input-Output → Write
2. Connect the new operator with the Terrain-Correction operator.
3. Save and change the output directory: S1A_IW_SLC__1SDV_20250615T122227_20250615T122255_059657_076846_5A9F_Orb_Stack_Coh_Deb_ML_TC
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.

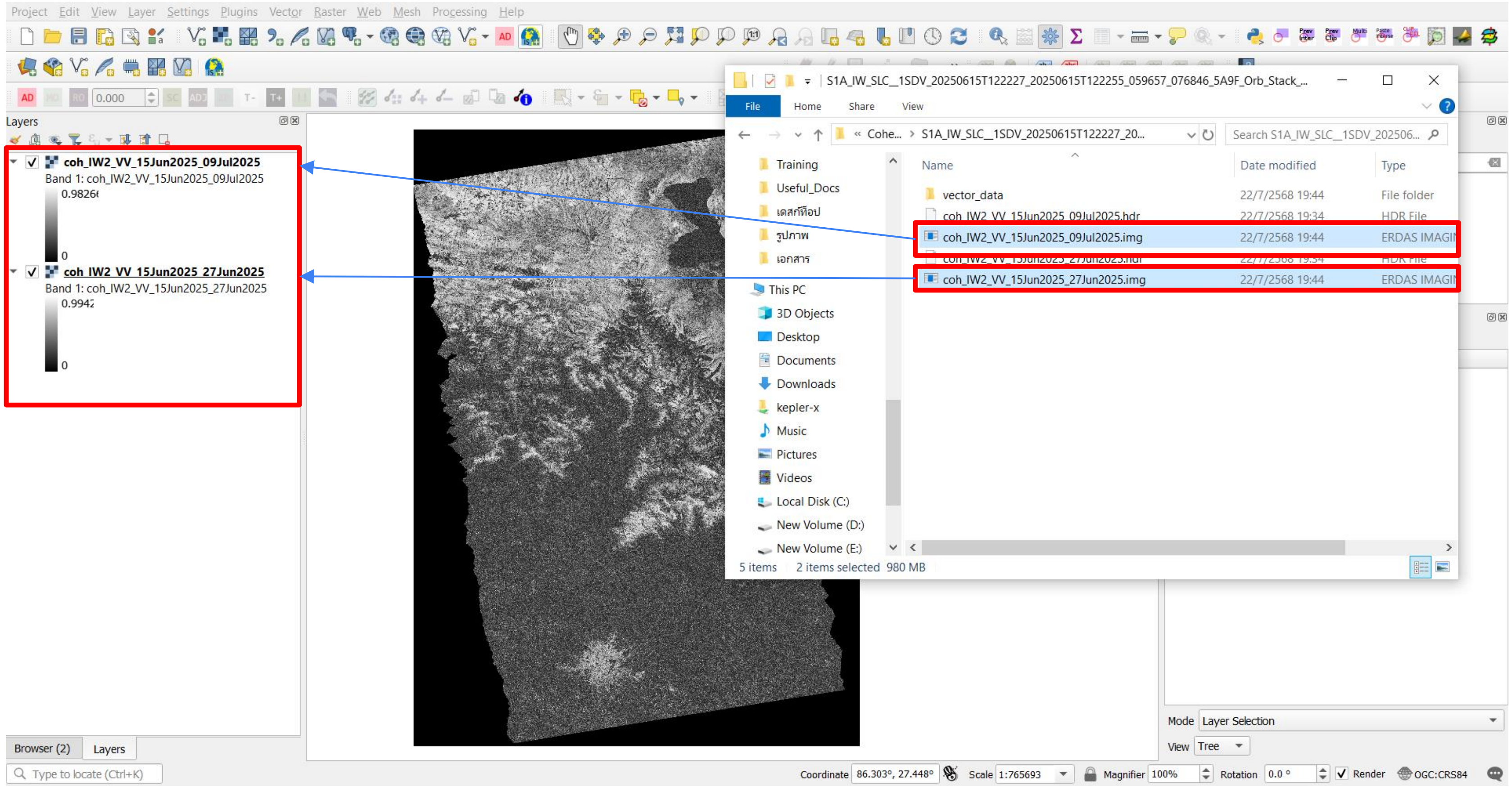
Coherence Changes Calculation

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

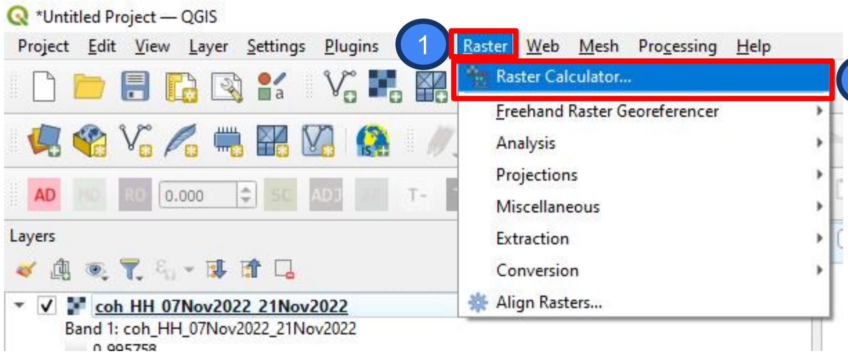


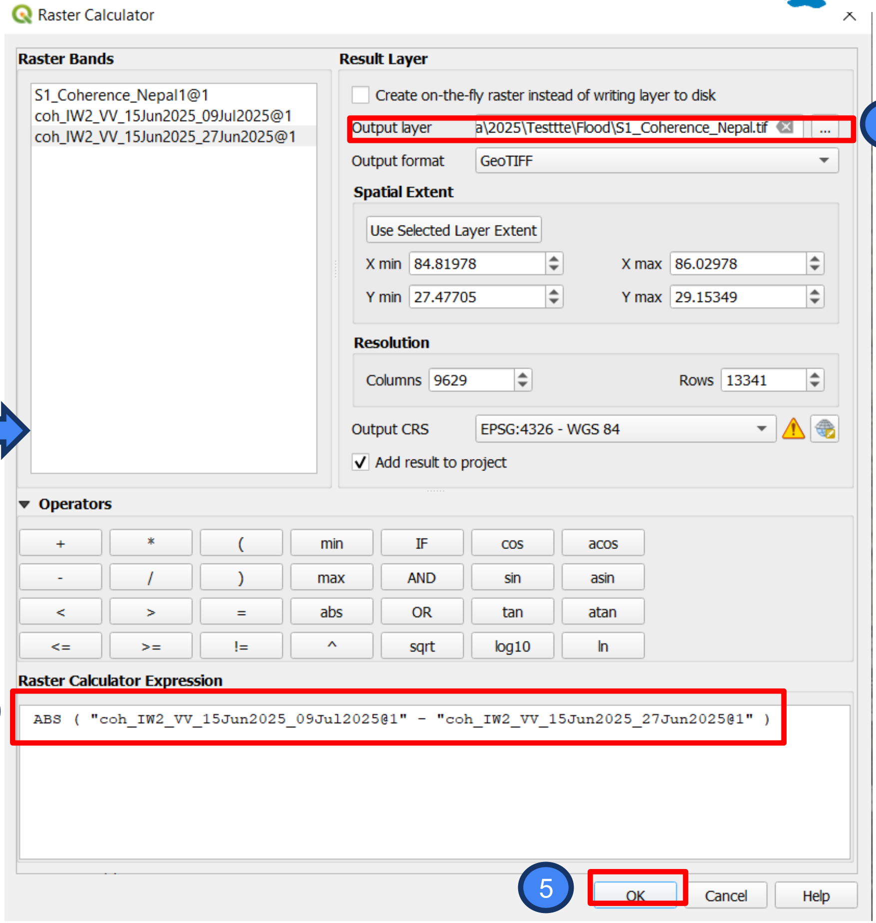
Data Processing in QGIS

Coherence Changes Calculation

- Using Raster Calculator tool in QGIS

Goto Raster > Raster Calculator



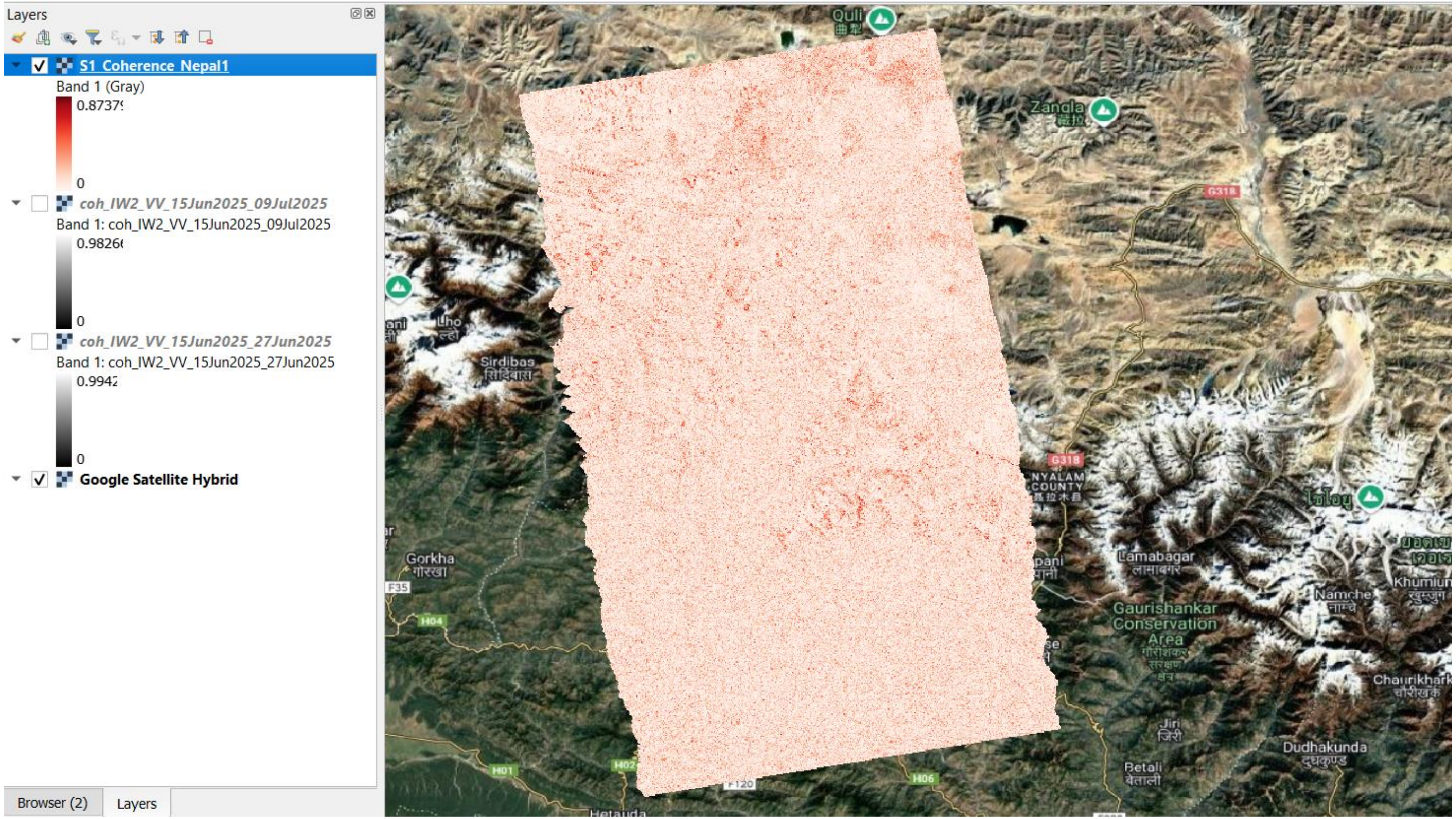


Equation:

ABS ("coh_IW2_VV_15Jun2025_09Jul2025@1" - "coh_IW2_VV_15Jun2025_27Jun2025@1")

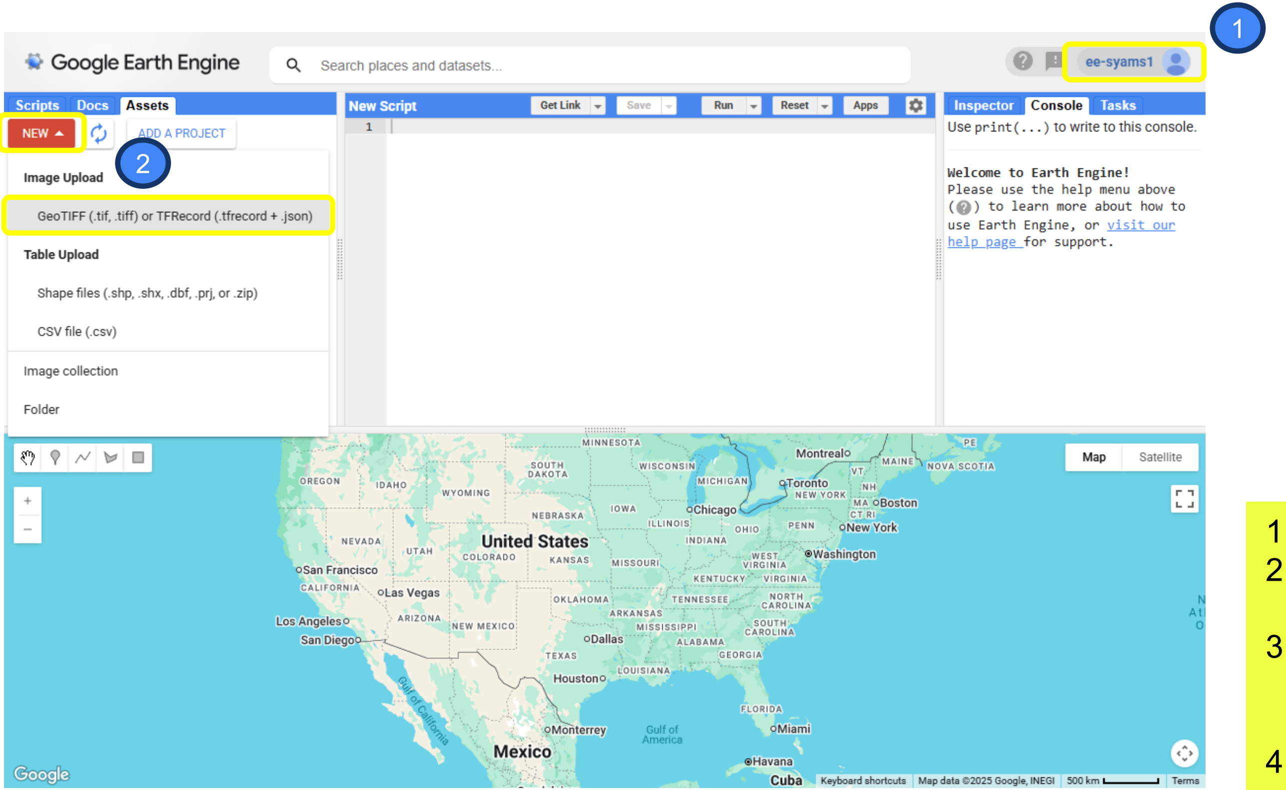
Data Processing in QGIS

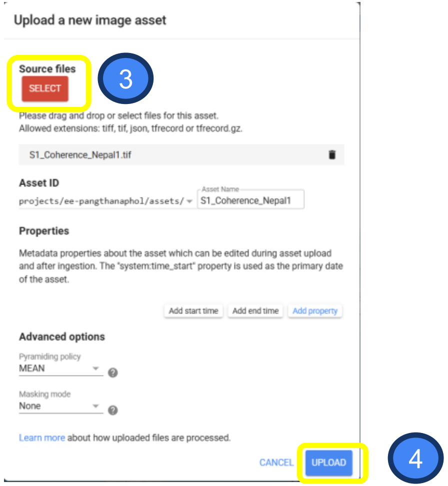
Output: Coherence Changes



Data Processing in Google Earth Engine (GEE)

Load the coherence changes product to the GEE assets

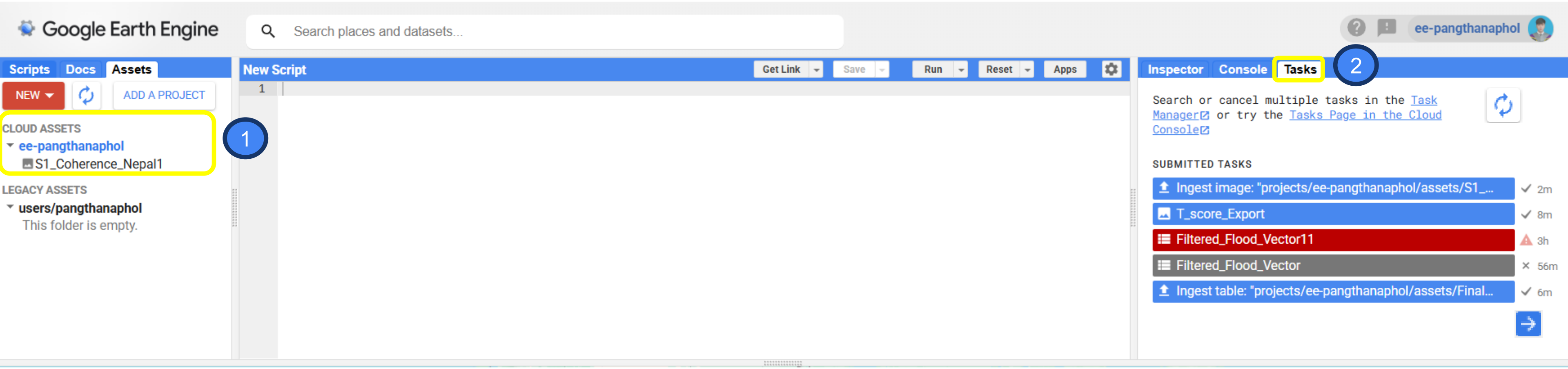




1. Login to your GEE account.
2. Go to the Assets tab, then click NEW and GeoTIFF.
3. Click SELECT and upload the GeoTIFF coherence product from QGIS.
4. Click UPLOAD.

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

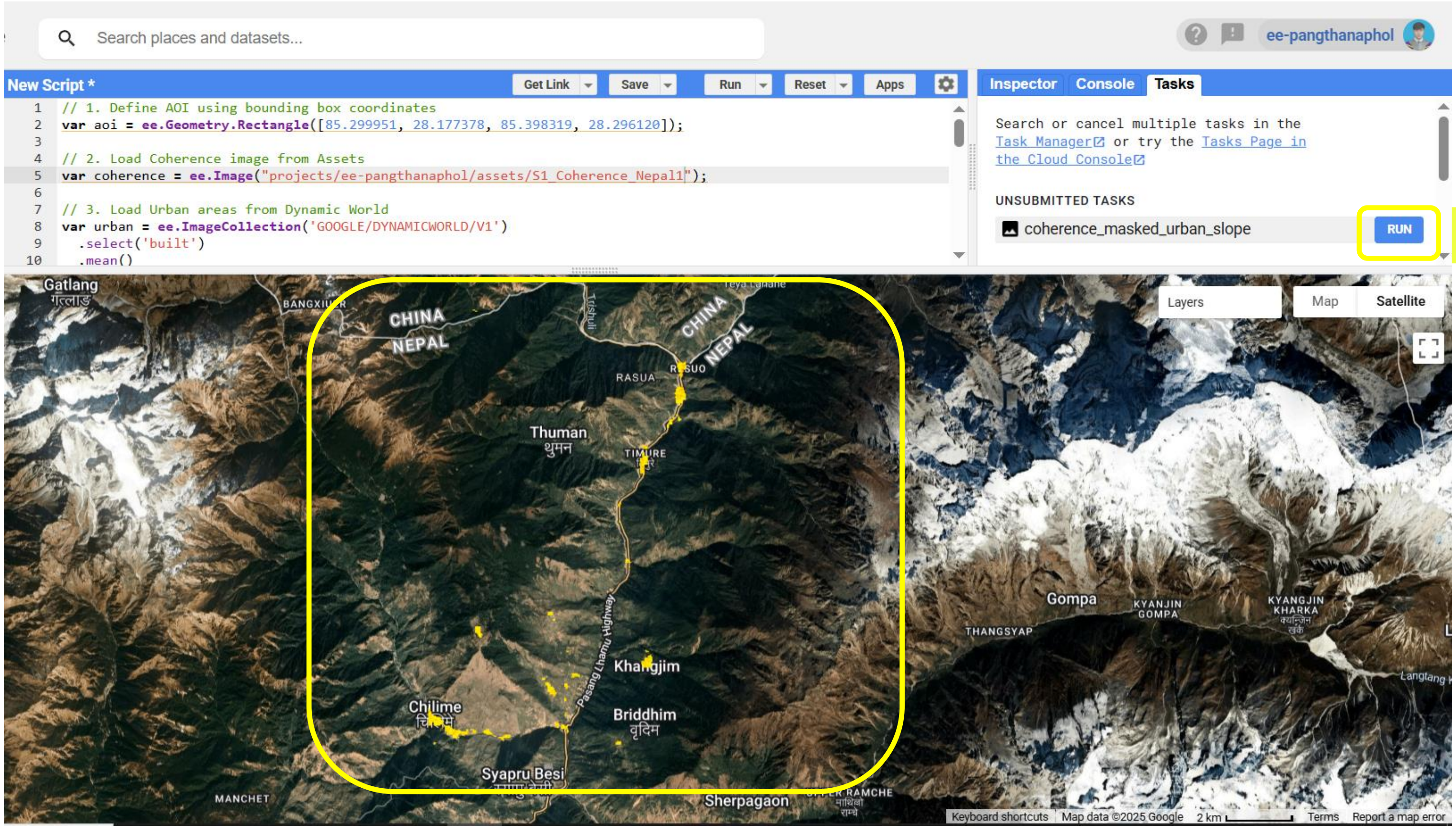
3. Run the script.

2. Update the file path of your image.

1. Copy the prepared script to the Script window.

Data Processing in Google Earth Engine (GEE)

Output: Coherence Changes (Mask Slope and Urban areas)



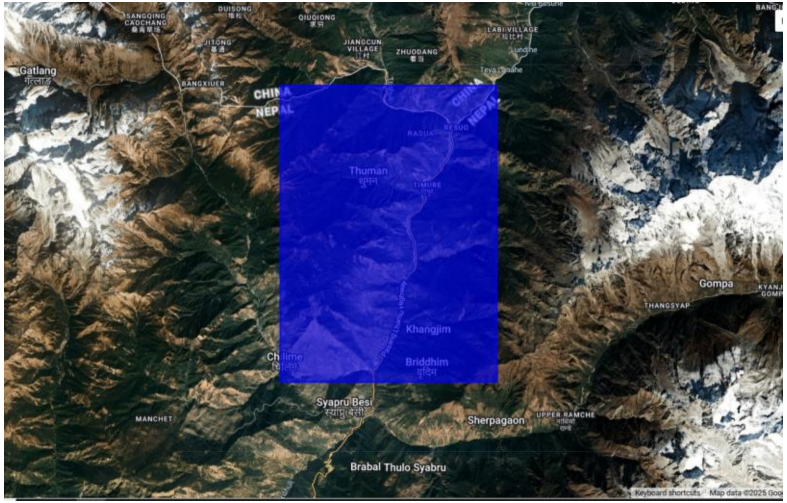
Download

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 ≥ 20°

```
// 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

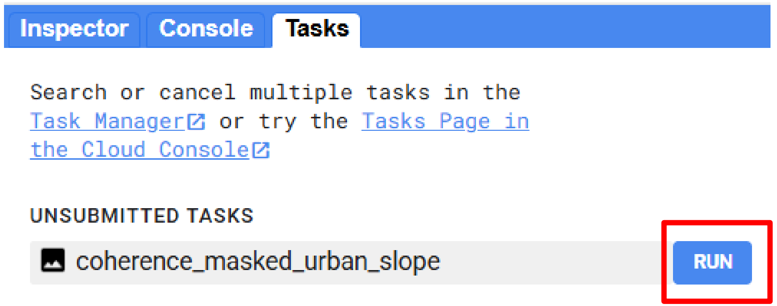
```
// 7. Visualization
Map.centerObject(aoi, 12);
Map.addLayer(masked, {min: 0, max: 1, palette: ['yellow', 'red']}, 'Coherence Masked: Urban + Low Slope');

// 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
});
```



THANK YOU

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