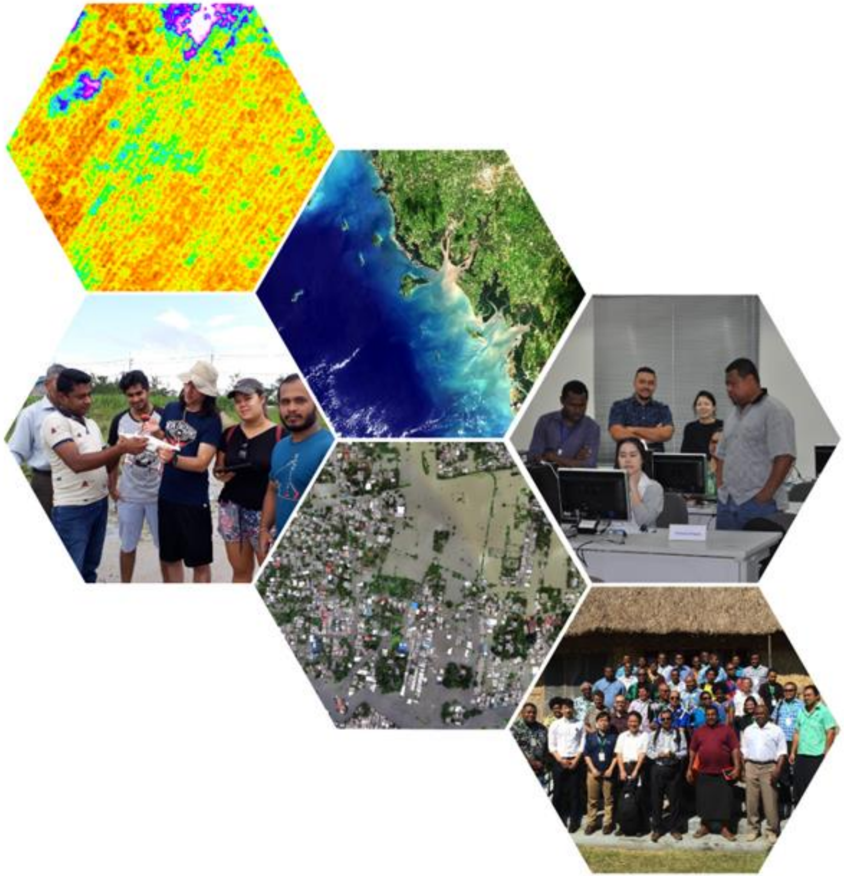

Flood Mapping using ALOS-2: Backscatter Thresholding

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Overview

Flood in Central Java, Indonesia on March 2024

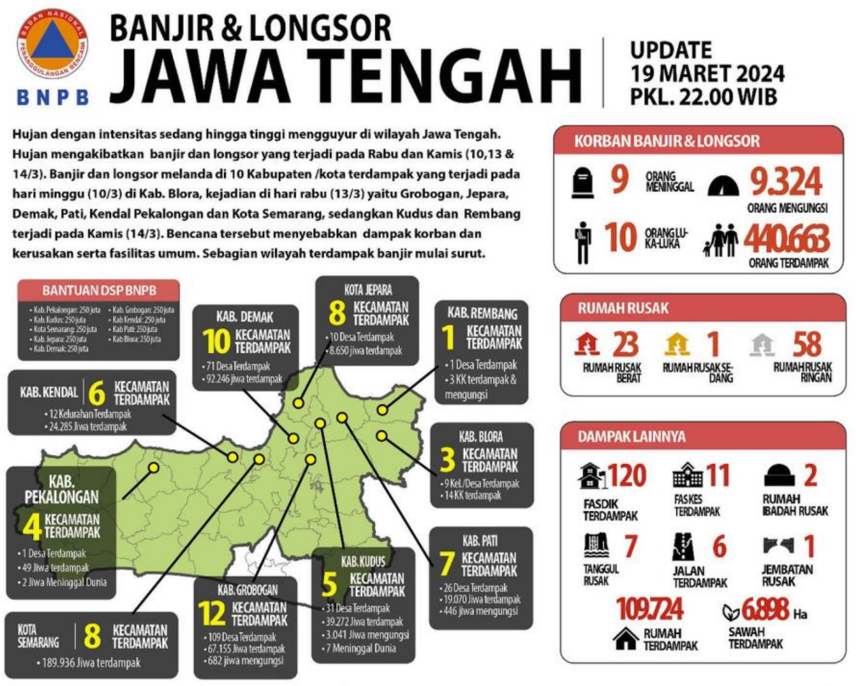
- Extreme weather and heavy rainfall caused floods and flash floods in Central Java, which overwhelmed river systems and hydrological infrastructure (dam failures) across the northern coast region.
- In some areas, heavy rainfall has started since February and continues until mid to the end of March.
- Affected areas include Kota Semarang, Kota Jepara, Pekalongan, Kendal, Demak, Rembang, Blora, Pati, Kudus, and Grobogan (*BPBD Jateng)*.
- Damages to public infrastructure and hundreds of thousands of residents were affected by the floods.

Kecamatan Karanganyar, Kebupaten Demak, Jawa Tengah, Sunday (17/3/2024)

- Sentinel Asia was activated on 20 March 2024 at the request of the National Research and Innovation Agency (BRIN).
- Archive and crisis images were obtained from multiple sources, including ALOS-2 from the Japan Aerospace Exploration Agency (JAXA), FORMOSAT-5 from the Taiwan Space Agency (TASA), TelEOS-1 from the Centre for Remote Imaging Sensing and Processing (CRISP), and Resourcesat-2 from the Indian Space Research Organization (ISRO).

Overview

Flood in Central Java, Indonesia on March 2024



Overview

Objective

The objective of this exercise is to generate a flood map from ALOS-2 SAR data by performing a complete processing workflow consisting of data pre-processing, flood classification using a threshold-based binary method, and post-processing refinement techniques.

The final product aims to produce accurate flood boundary delineation for emergency response purposes.

Overview

Data and Software

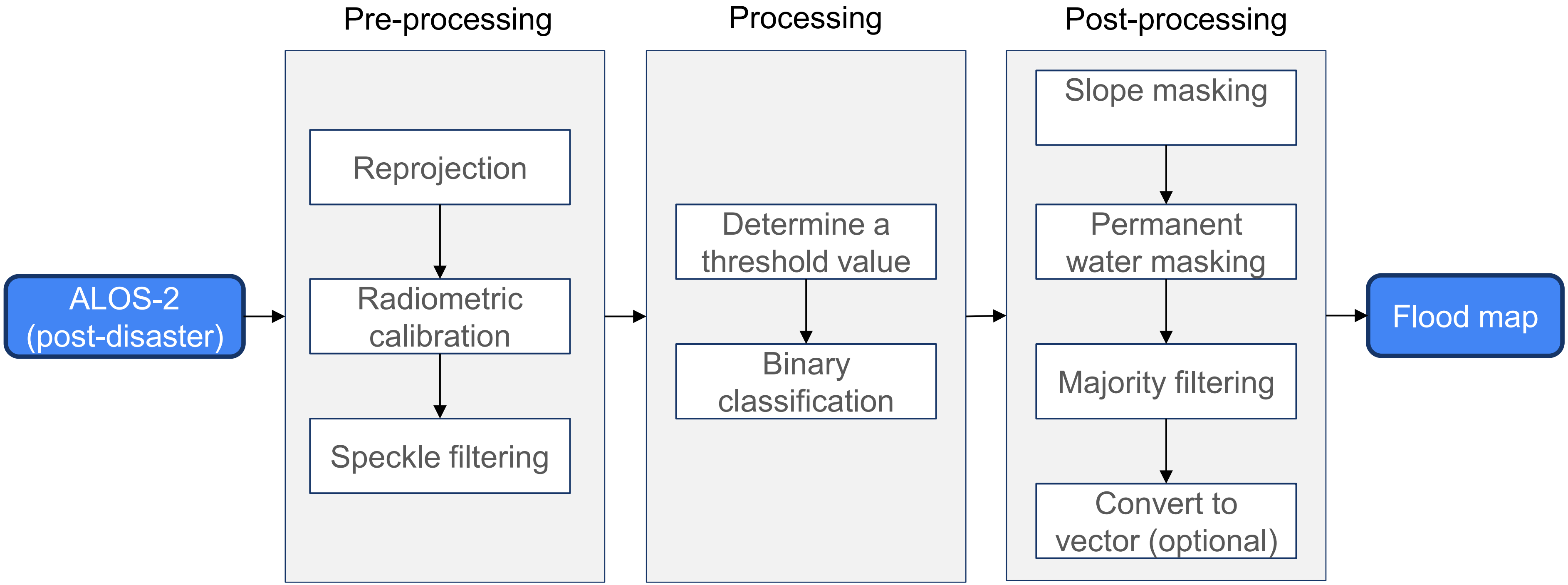
In this exercise, we will use QGIS software.

The following data are available:

- ALOS-2 Level 2.1
  - Geometrically corrected (orthorectified) data using the digital elevation data from Level 1.1.
  - Observation mode: Stripmap, Dual Polarization (HH and HV)
  - Spatial resolution: 6.25m, Data format: GeoTIFF
  - Date: 24 March 2024 (observe), 31 December 2023 (archive)
- Ancillary data
  - Copernicus 30m DEM
  - OSM permanent water data

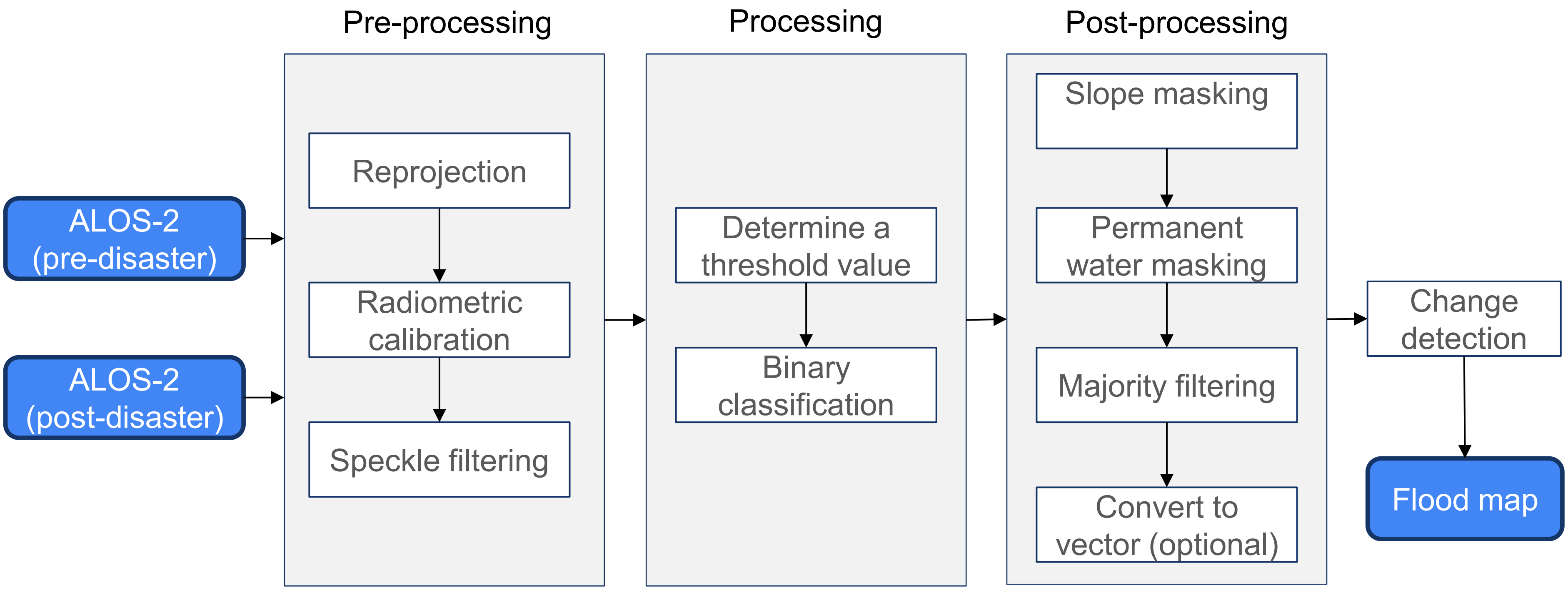
Methodology

Flood mapping using ALOS-2 data (single post-disaster data)



Methodology

Flood mapping using ALOS-2 data (pre- and post-disaster data)



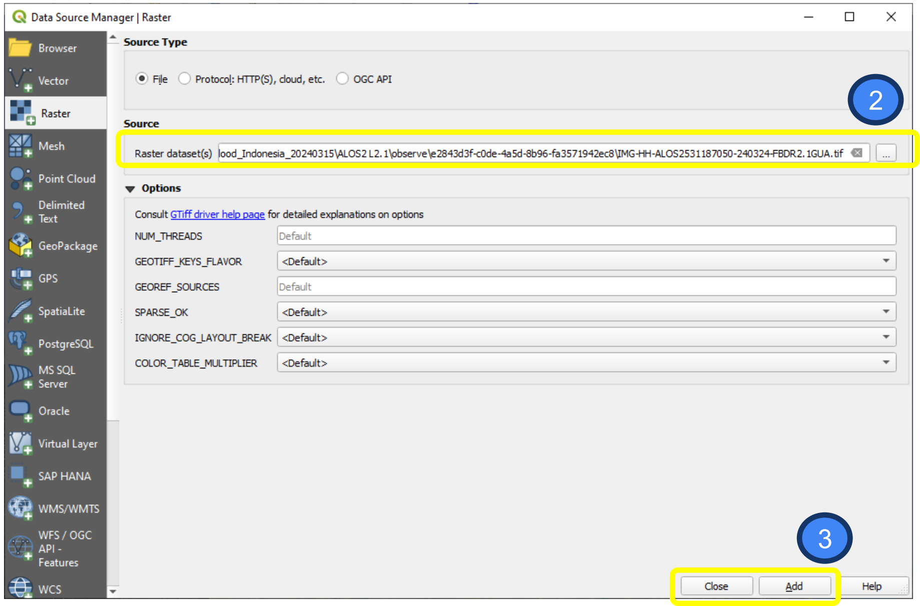
Data Pre-processing

Follow Along: Open ALOS-2 data (24 March 2024)

1. In the Menu Bar, click on Layer → Add Layer → Add Raster Layer.

2. In Data Source, click on the Browse button … and navigate to the file IMG-HH-ALOS2531187050-240324-FBDR2.1GUA.tif in the ALOS-2 L2.1 archive data folder.

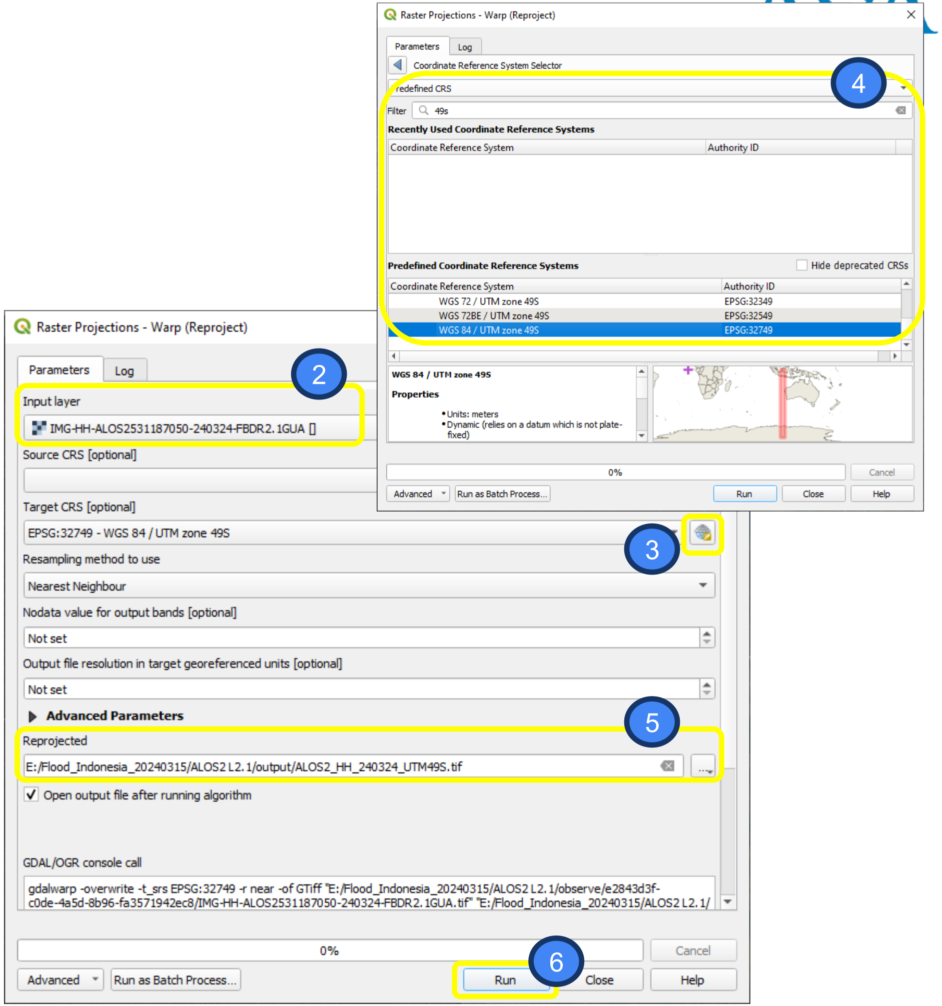
3. With this file selected, click Add, then Close. The data you specified will now load.



Data Pre-processing

Follow Along: Reprojection

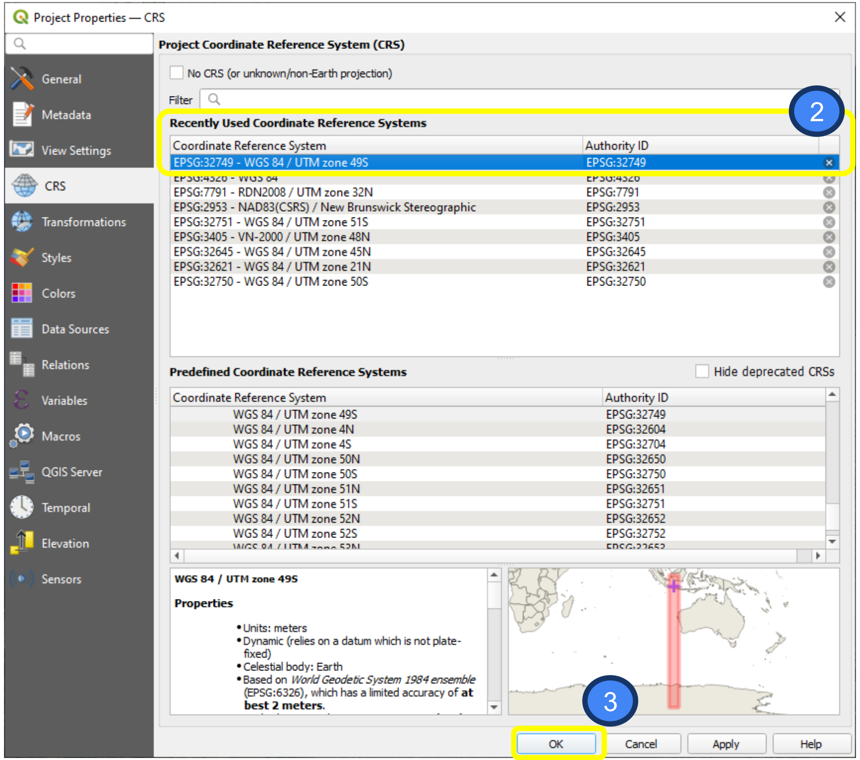
1. In the Menu Bar, click on Raster → Projection → Warp (Reproject).
2. In the Input Layer, select IMG-HH-ALOS2531187050-240324-FBDR2.1GUA
3. In the Target CRS (optional), click 
4. Select Predefined CRS, then EPSG:32749 – WGS84 / UTM Zone 49S.
5. Save the result to ALOS2_HH_240324_UTM49S.tif
6. Click Run.



Data Pre-processing

Follow Along: Change the project CRS

1. In the Menu Bar, click Project → Properties.
2. Select EPSG:32749 – WGS84 / UTM Zone 49S
3. Click OK.



Data Pre-processing

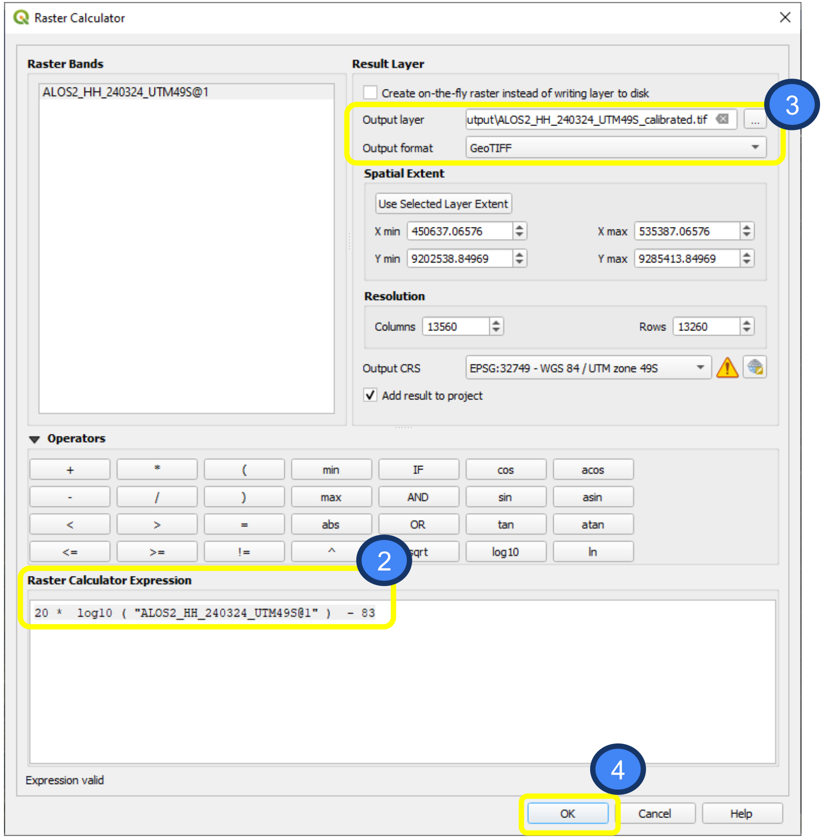
Follow Along: Radiometric calibration

Digital number in the ALOS-2 JAXA product is converted to backscattering coefficient (sigma naught, sigma zero) using the following equations:

$$\sigma^0_{Q16} = 10 \cdot \log_{10}\langle DN^2 \rangle + CF_1$$

(for L1.5, L2.1)

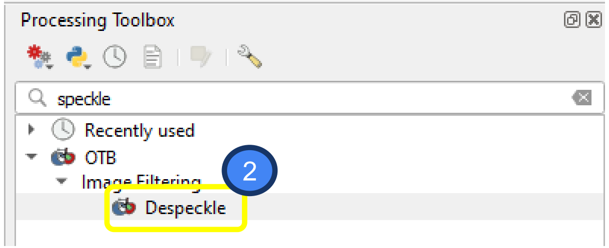
1. In the Menu Bar, click on Raster → Raster Calculator.
2. In the Raster Calculation Expression write:
   20 * log10 ("ALOS2_HH_240324_UTM49S@1") - 83
3. Save the result to ALOS2_HH_240324_UTM49S_calibrated.tif
4. Click OK.

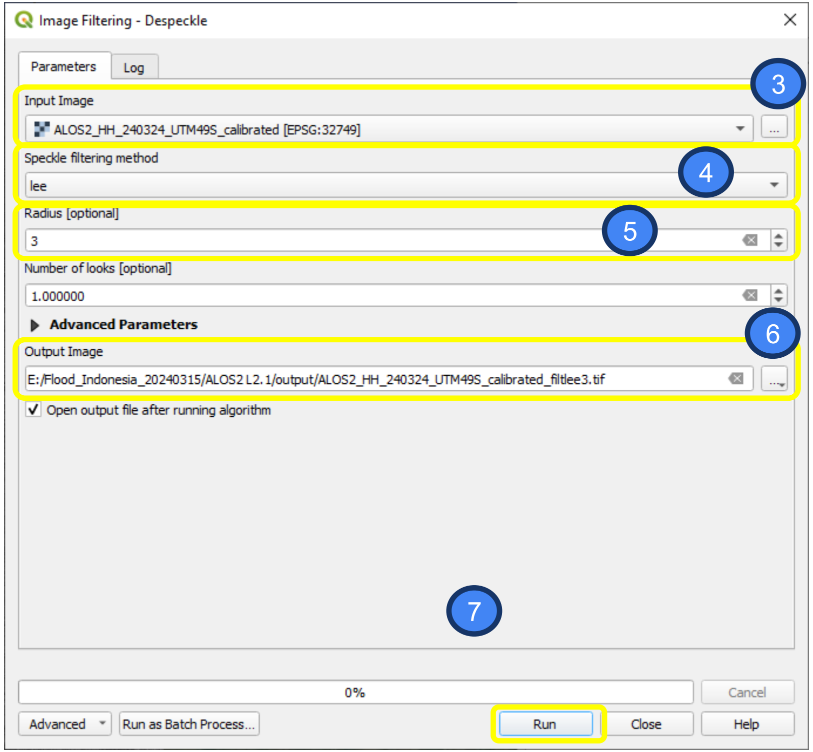


Data Pre-processing

Follow Along: Speckle filtering

1. In the Menu Bar, click Processing → Toolbox.
2. Search for OTB → Image filtering → Despeckle
3. In the Input Layer, select ALOS2_HH_240324_UTM49S_calibrated
4. In the Speckle filtering method, select lee.
5. In the Radius (optional), write 3. The unit of radius is pixel.
6. Save the result to ALOS2_HH_240324_UTM49S_calibrated_filtlee3.tif
7. Click Run.





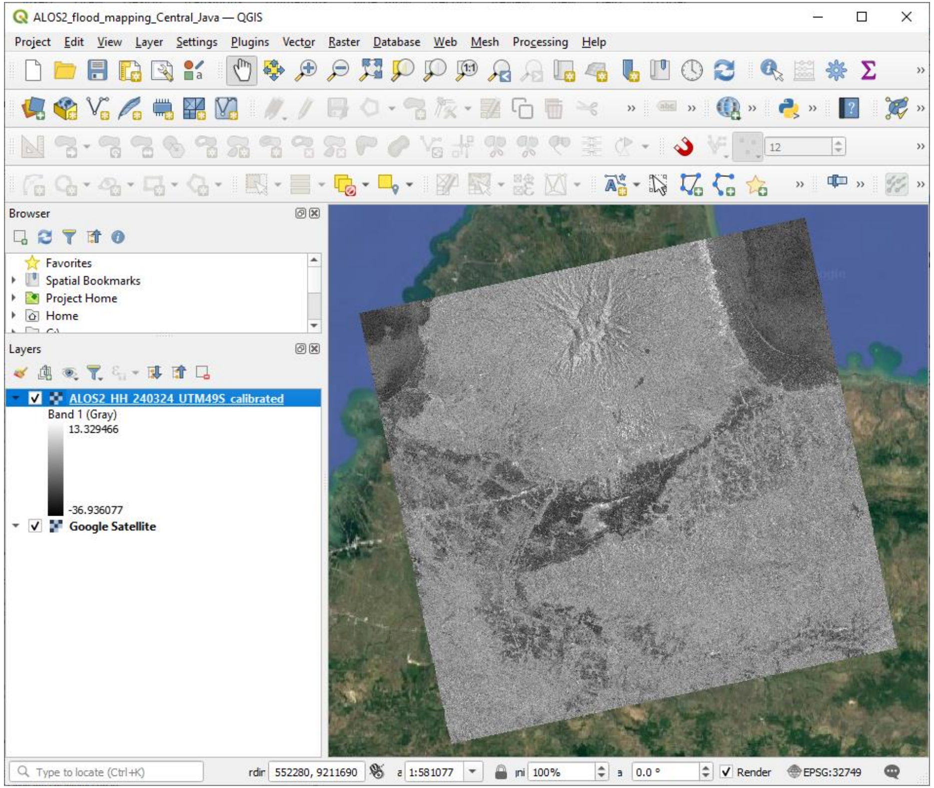
Data Pre-processing

Follow Along: Save your work!

You can open the calibrated image and observe the object on the image. Can you visually identify any inundated areas here?

Now would be a good time to save your work.

1. In the Menu Bar, click on Project → Save As
2. Save the map in the working folder: ALOS2_flood_mapping_Central_Java.qgs

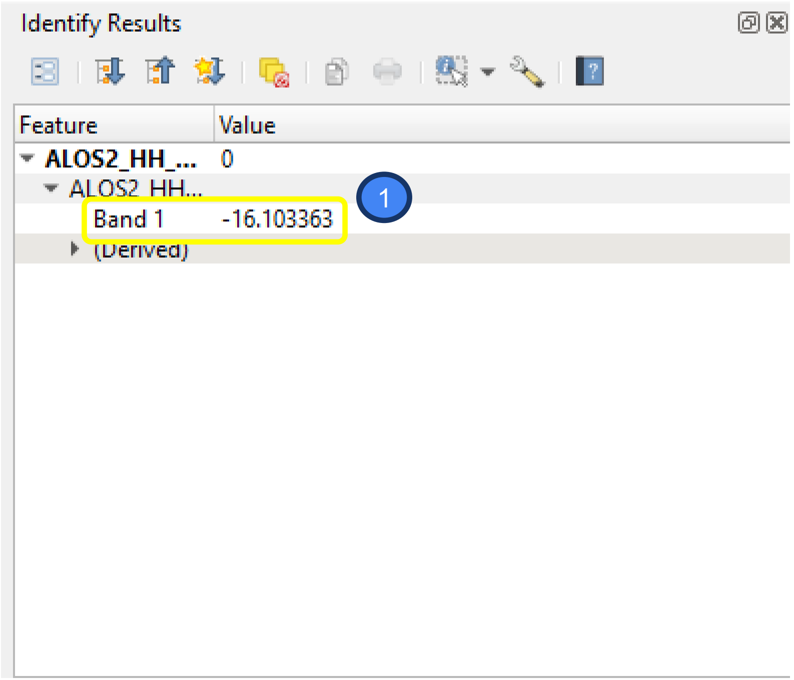


Determine a Threshold Value

Follow Along: (Option 1) Manual visual observation

You can determine threshold values by a manual visual observation. Flooded areas often appear as dark regions in SAR images because open water surfaces cause specular reflection, resulting in lower backscatter returns. Examine the image and incrementally adjusts the threshold value while seeking a value that best separates flooded and non-flooded areas.

1. Use Identify Features  tool to inspect the backscatter value. Click on a specific pixel on the image to find out the value.



Determine a Threshold Value

Follow Along: (Option 2) Histogram analysis

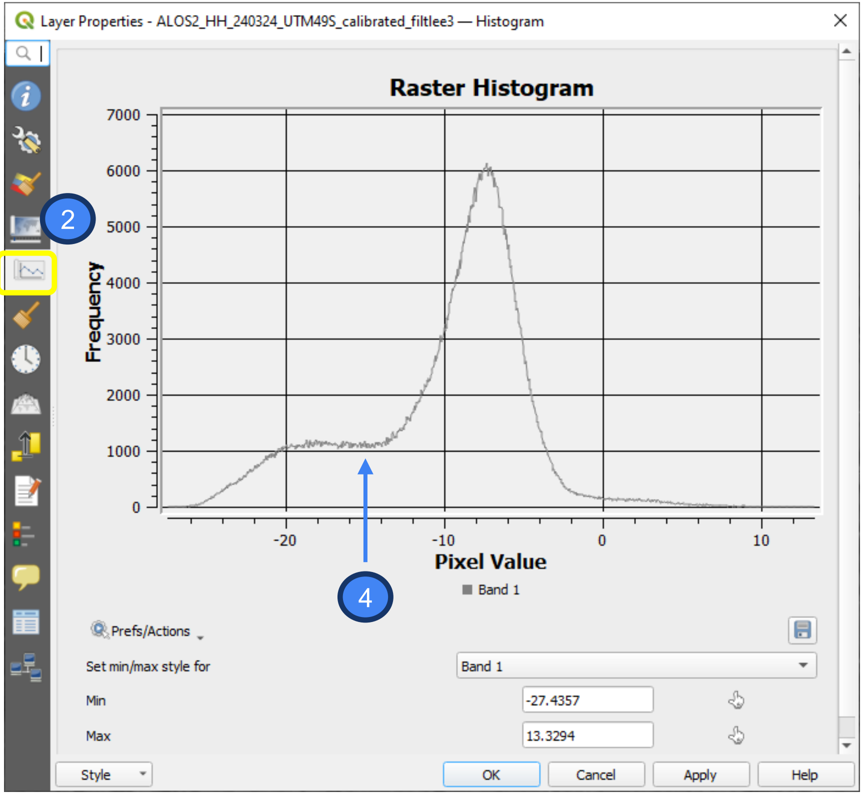
Determine the threshold based on the histogram of the whole filtered image.

1. Right-click on the ALOS2_HH_240324_UTM49S_calibrated_filtlee3 layer in the Layers list and select the menu item Properties in the menu that appears.

2. Select the Histogram tab 

3. In the Raster Histogram window, click Compute Histogram [Compute Histogram] button.

4. A histogram is calculated. Ideally, we look for bimodal histograms, where water and land have two distinct peaks in the backscatter value distribution.



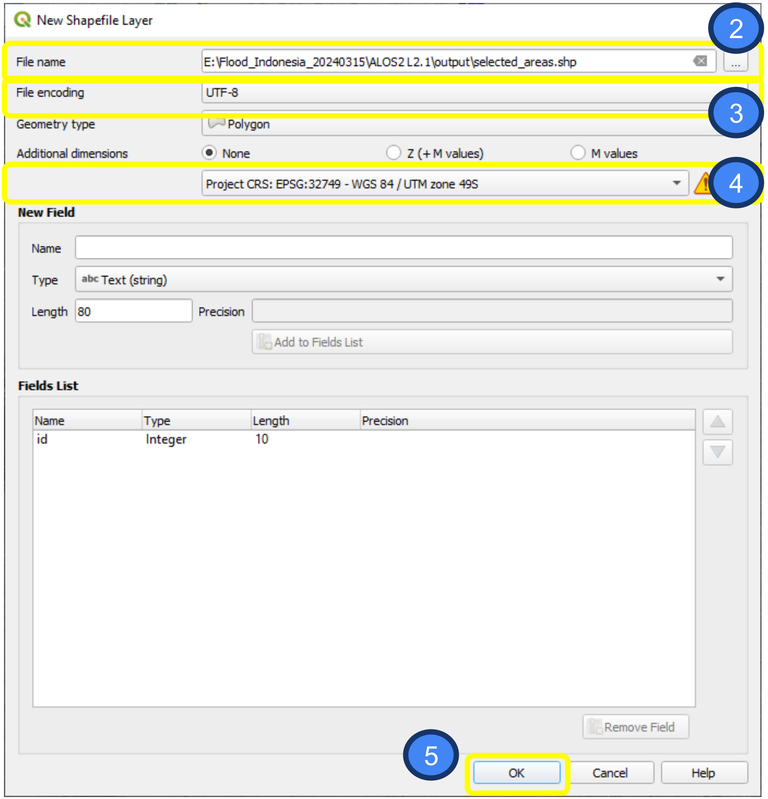
Determine a Threshold Value

Follow Along: (Option 2) Histogram analysis

Since the threshold between two peaks was difficult to get for the whole image histogram, we will determine the threshold based on the histogram of the selected areas.

First, we have to create a polygon shapefile with the selected areas:

1. In the Menu Bar, click on Layer → Create Layer → New Shapefile Layer.
2. In File name, save the results as selected_areas.shp.
3. In Geometry type, select Polygon.
4. In Projection system, select EPSG:32749 – WGS84 / UTM Zone 49S
5. OK.



Determine a Threshold Value

Follow Along: (Option 2) Histogram analysis

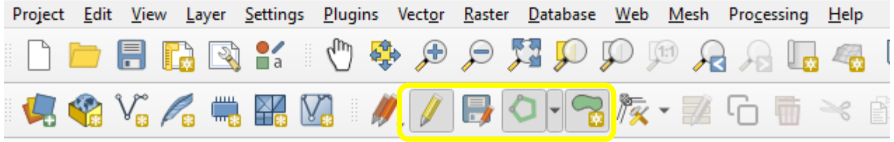
Go to editing mode to start digitizing:

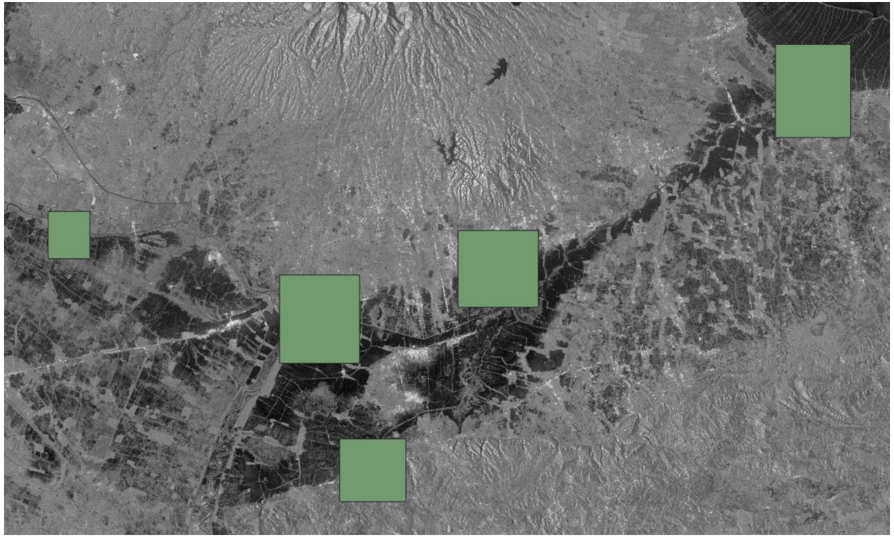
1. Your new empty vector layer will appear in the Layers panel. In the Tool Bar, click on Toggle Editing to start digitizing.

2. In the Tool Bar, click on to add polygon. Click to place each vertex on the image. Right-click to finish the shape. Leave attribute values empty. Create several polygons that include water and non-water pixels.

3. After digitizing, click Save Layer Edits on the toolbar.

4. Click on Toggle Editing again to finish digitizing.



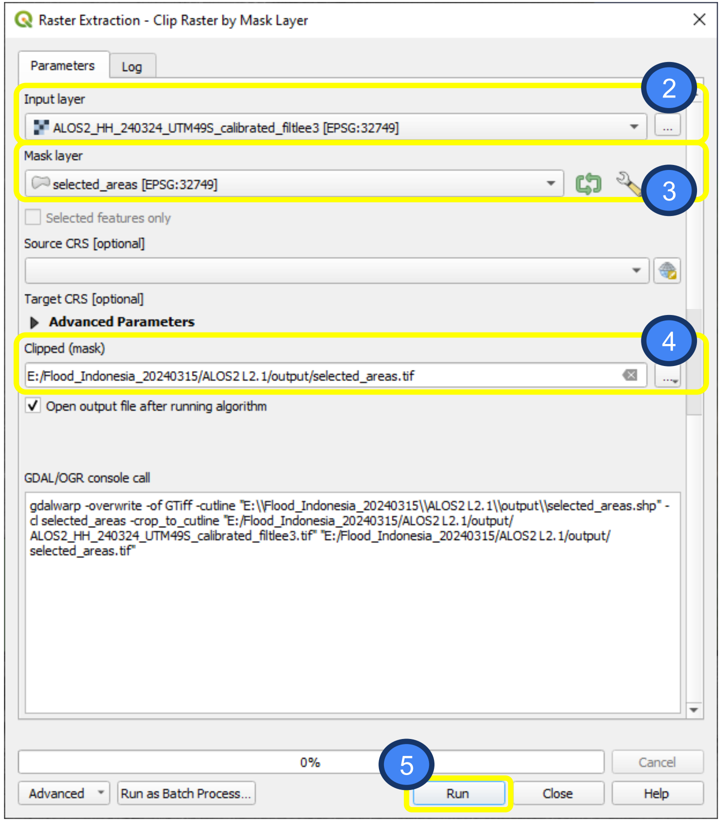


Determine a Threshold Value

Follow Along: (Option 2) Histogram analysis

Next, we will clip the image based on the created polygons:

1. In the Menu Bar, click on Raster → Extraction → Clip Raster by Mask Layer.
2. In the Input Layer, select ALOS2_HH_240324_UTM49S_calibrated_filtlee3
3. In the Mask Layer, select selected_areas.
4. Save the result to selected_areas.tif.
5. Click Run.

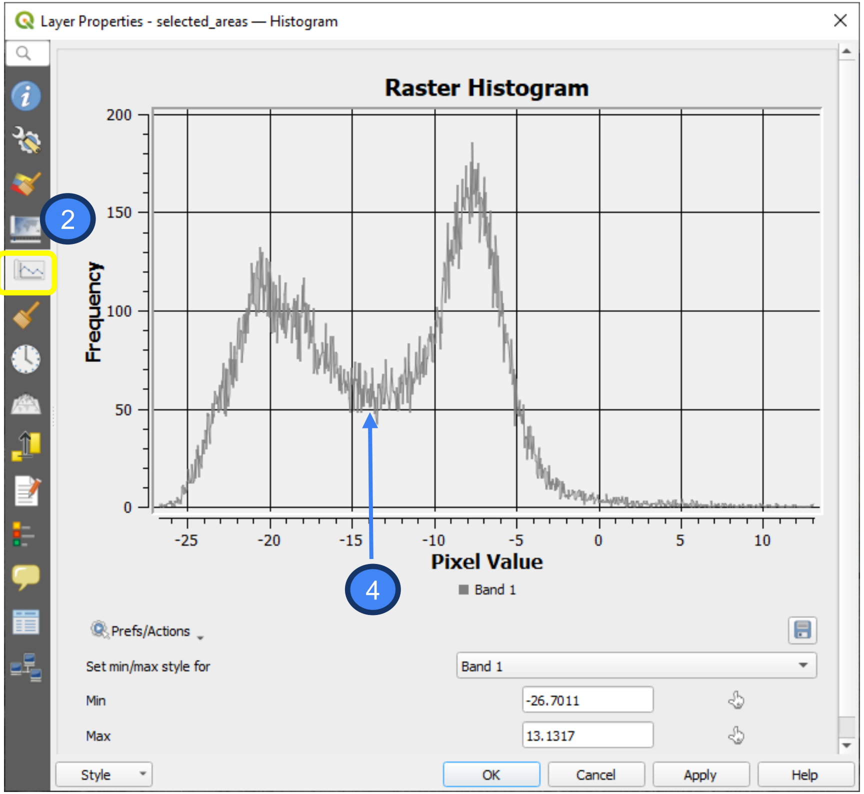


Determine a Threshold Value

Follow Along: (Option 2) Histogram analysis

Compute the histogram for the clipped image.

1. Right-click on the selected areas layer in the Layers list and select the menu item Properties in the menu that appears.
2. Select the Histogram tab
3. In the Raster Histogram window, click Compute Histogram [Compute Histogram] button.
4. A histogram is calculated. Notice there are two histogram peaks now: the lower value refers to water pixels, while the higher value refers to non-water pixels.
5. Determine the threshold by identifying the pixel value between water and non-water: ~-14 dB.

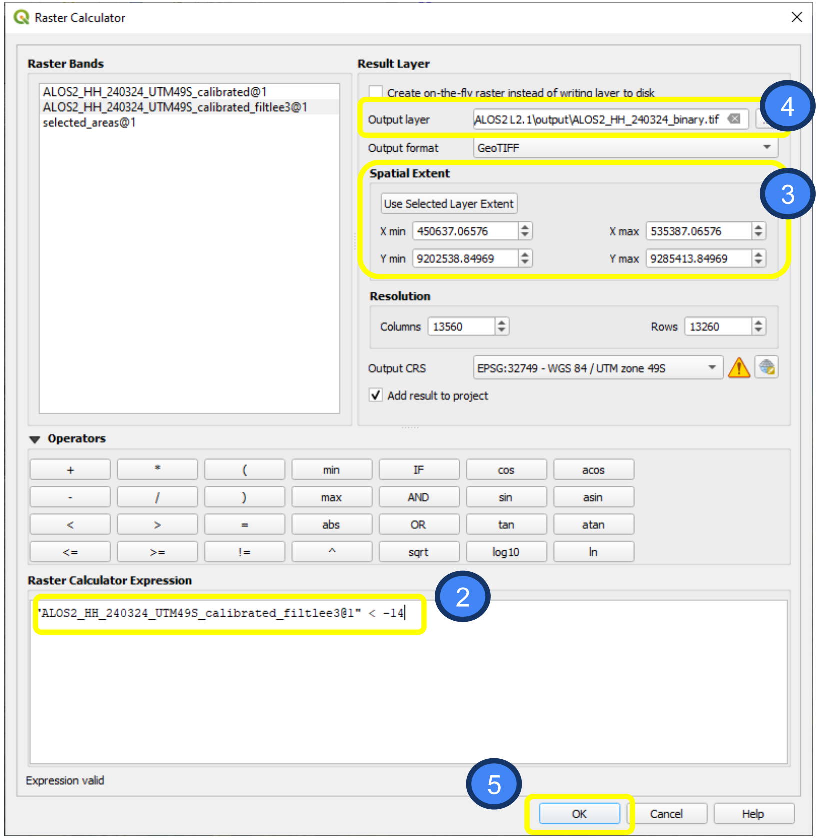


Binary Classification

Follow Along: Create a binary map based on the threshold value

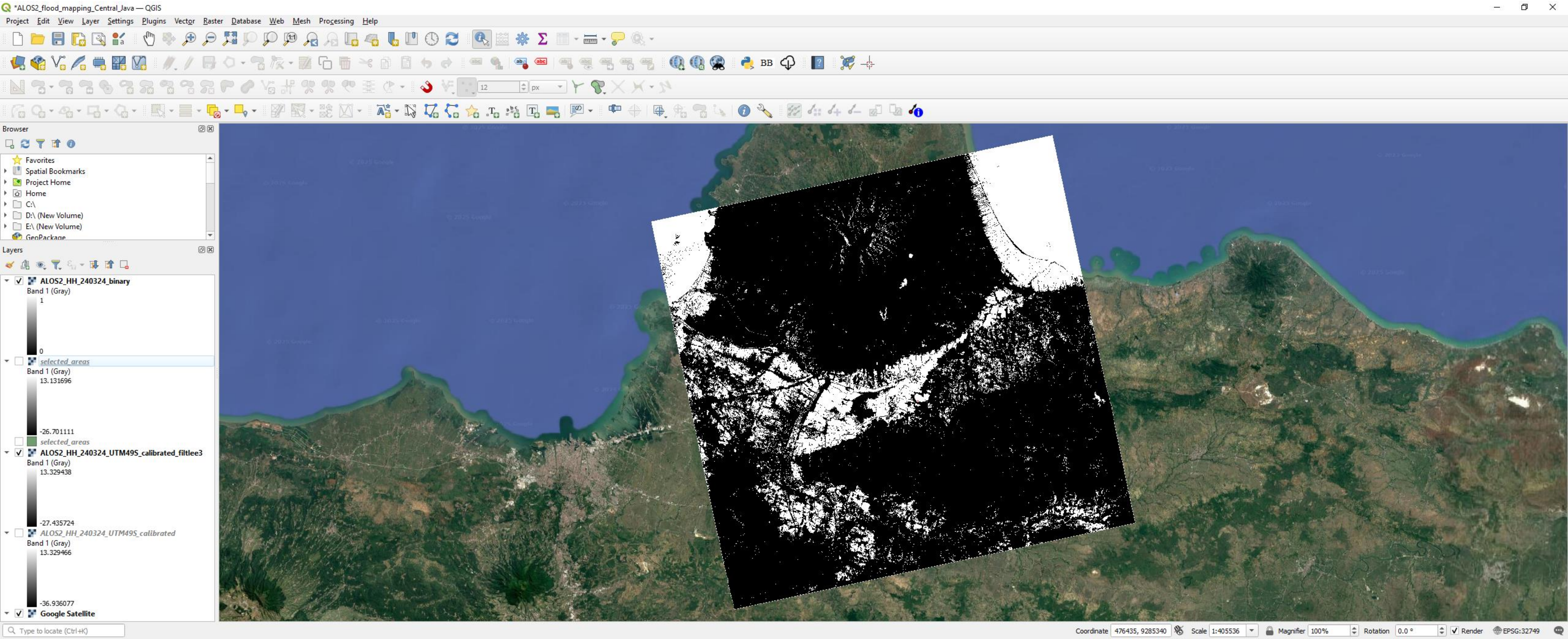
We will use the threshold value from the second option's result: -14 dB.

1. Click on Raster → Raster Calculator.
2. In the Raster Calculation Expression write: " "ALOS2_HH_240324_UTM49S_calibrated_filtlee3@1" < -14
3. In the Spatial Extent, define the extent based on the image.
4. Save the result to "ALOS2_HH_240324_binary.tif
5. Click OK.



Binary Classification

Visualization



Post-processing

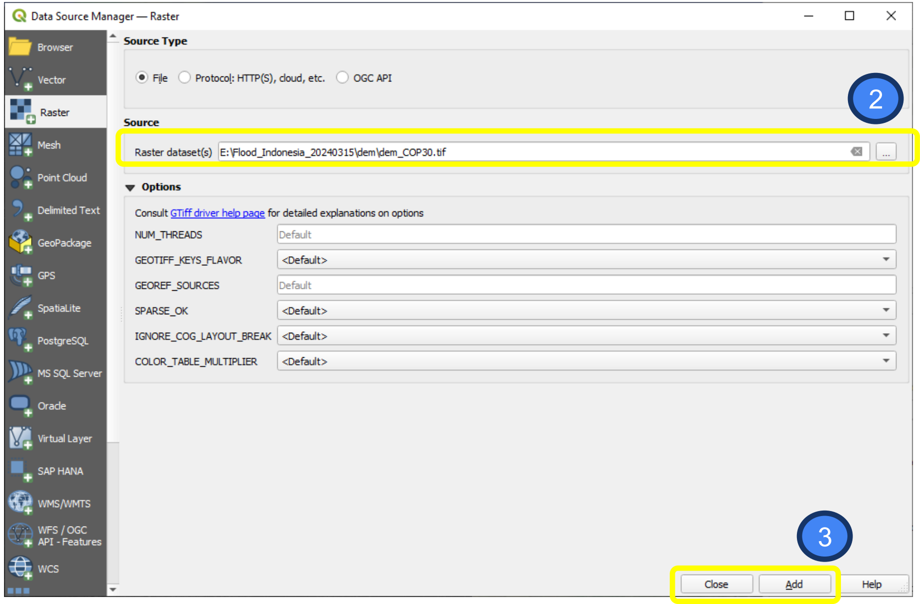
Follow Along: Eliminate pixels found in slope > 5 deg.

First, let's open DEM for the area, 30m Copernicus extracted from OpenTopography.

1. In the Menu Bar, click on Layer → Add Layer → Add Raster Layer.

2. In Data Source, click on the Browse button ... and navigate to the file dem_COP30.tif in the ancillary data folder.

3. With this file selected, click Add, then Close. The data you specified will now load.



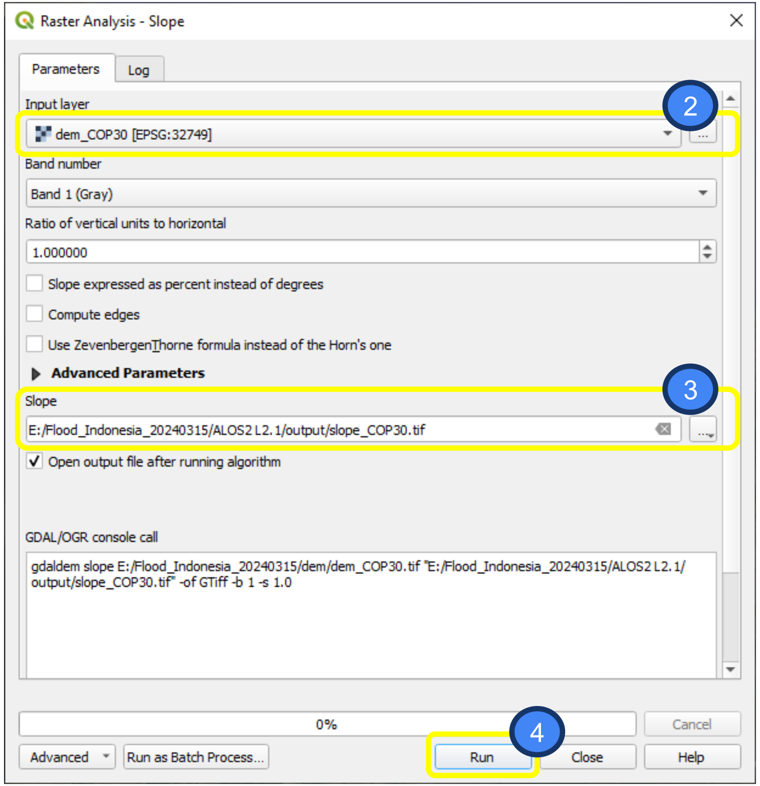
Post-processing

Follow Along: Eliminate pixels found in slope > 5 deg.

Now, we are ready to remove misclassified pixels in the regions of steep slopes.

First, let's calculate the slope from the DEM:

1. Calculate Slope: Raster → Analysis → Slope.
2. In the Input Layer, select dem_COP30
3. Save the result to slope_COP30.tif
4. Click Run.

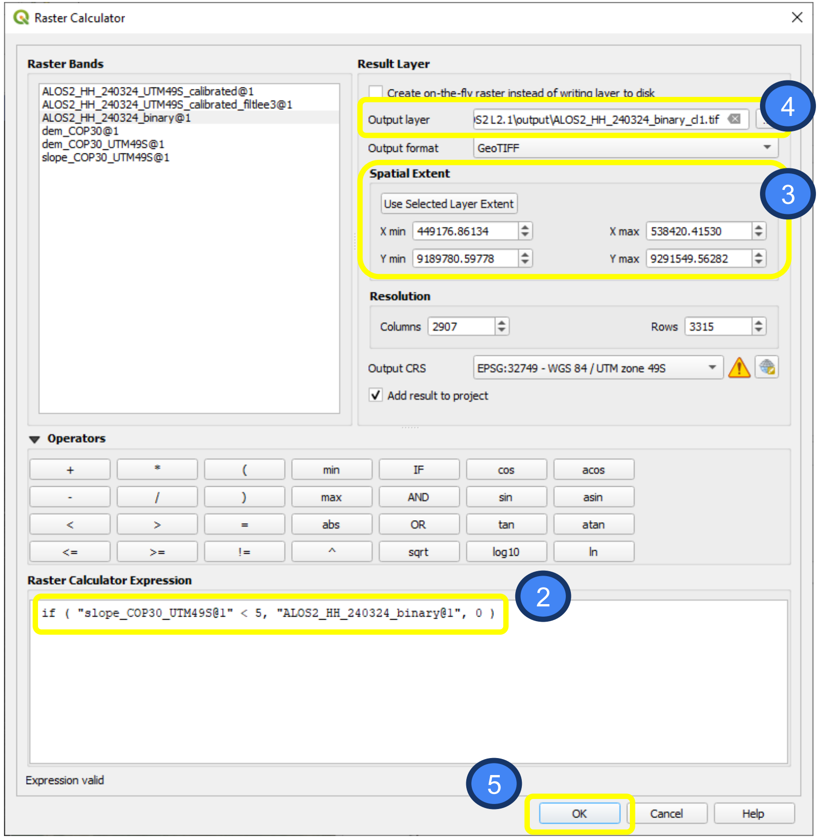


Post-processing

Follow Along: Eliminate pixels found in slope > 5 deg.

Use Raster Calculator to remove regions with a slope above 5 degrees.

1. Click on Raster → Raster Calculator.
2. In the Raster Calculation Expression write:
   if ("slope_COP30@1" < 5, "ALOS2_HH_240324_binary@1", 0)
3. In the Spatial Extent, define the extent based on the image.
4. Save the result to ALOS2_HH_240324_binary_cl1.tif
5. Click OK.



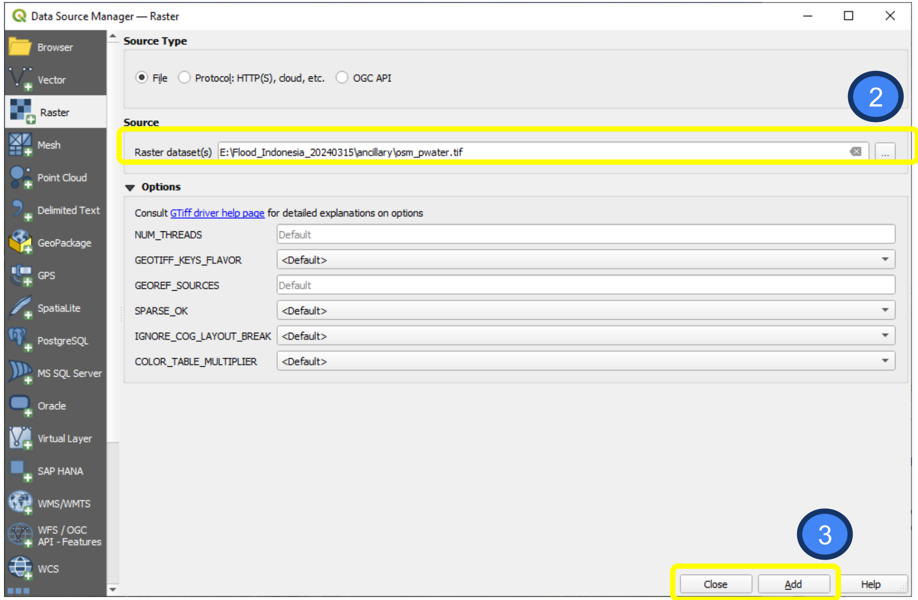
Post-processing

Follow Along: Eliminate permanent water areas

First, let's open permanent water data for the area, extracted from OSM.

1. In the Menu Bar, click on Layer → Add Layer → Add Raster Layer.
2. In Data Source, click on the Browse button 

and navigate to the file osm_pwater.tif in the ancillary data folder.
3. With this file selected, click Add, then Close. The data you specified will now load.

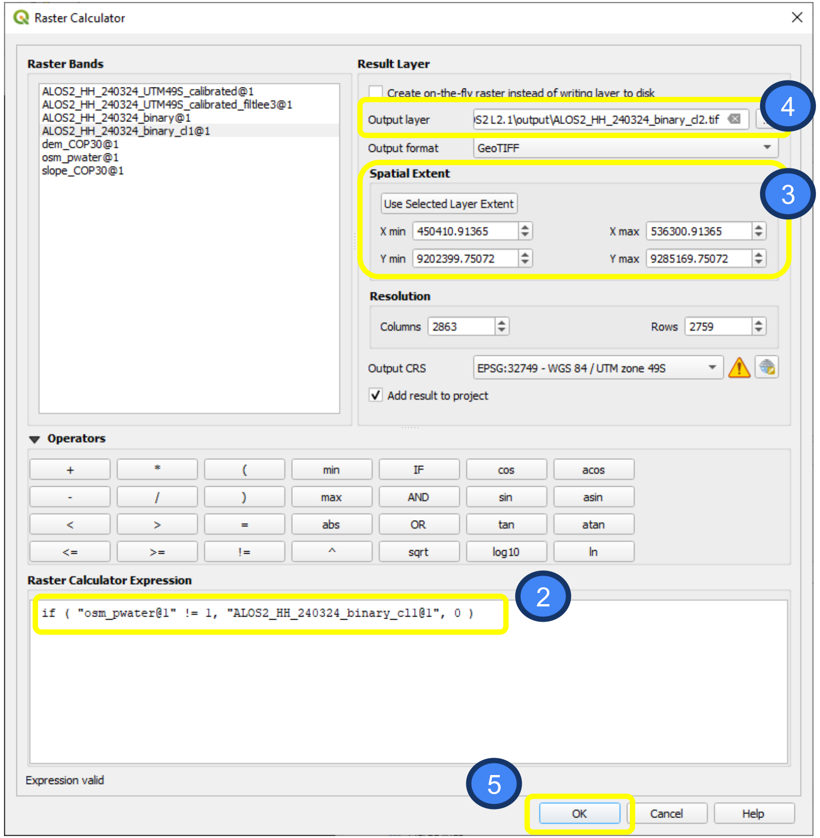


Post-processing

Follow Along: Eliminate permanent water areas

Use Raster Calculator to eliminate permanent water areas.

1. Click on Raster → Raster Calculator.
2. In the Raster Calculation Expression write:
   if ("osm_pwater@1" != 1, "ALOS2_HH_240324_binary_cl1@1“, 0)
3. In the Spatial Extent, define the extent based on the image.
4. Save the result to ALOS2_HH_240324_binary_cl2.tif
5. Click OK.

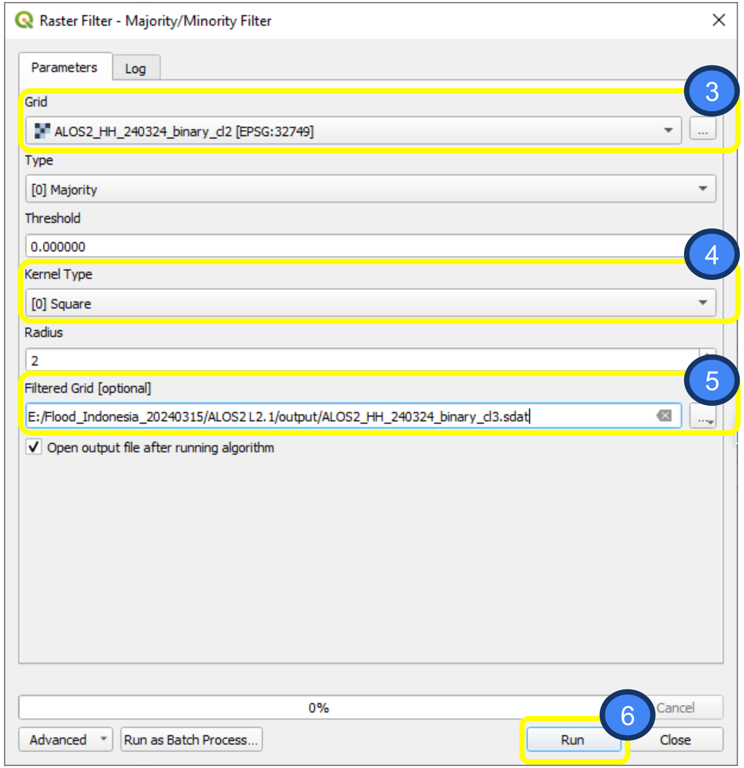


Post-Processing

Follow Along: Remove isolated pixels

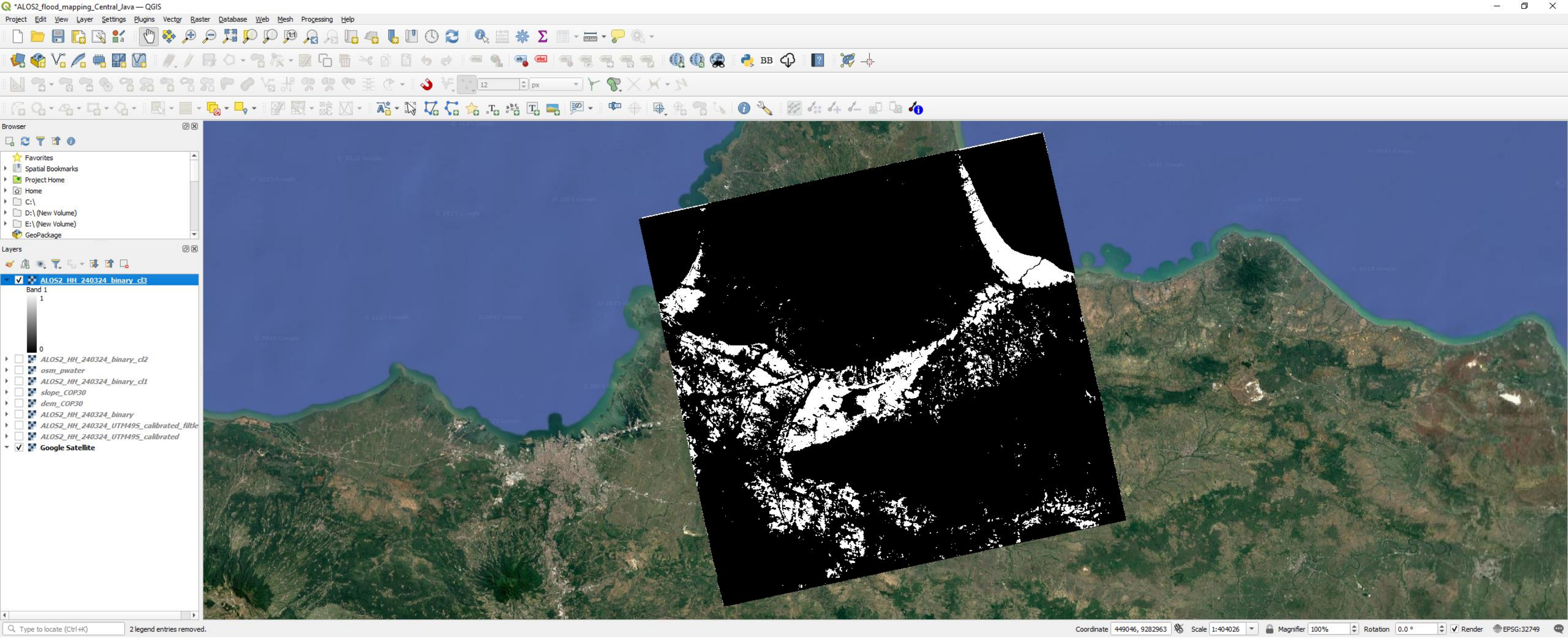
We will remove small, isolated misclassified pixels or noise in the binary map using a majority filter.

1. In the Menu Bar, click Processing → Toolbox.
2. Search for SAGA Next Gen → Raster filter → Major/minority filter
3. In the Grid input, select ALOS2_HH_240324_binary_cl2.
4. Change Kernel Type to Square and keep other parameters as default. You may want to test with different threshold and radius.
5. Save the result to ALOS2_HH_240324_binary_cl3.sdat
6. Click Run



Post-Processing

Visualization

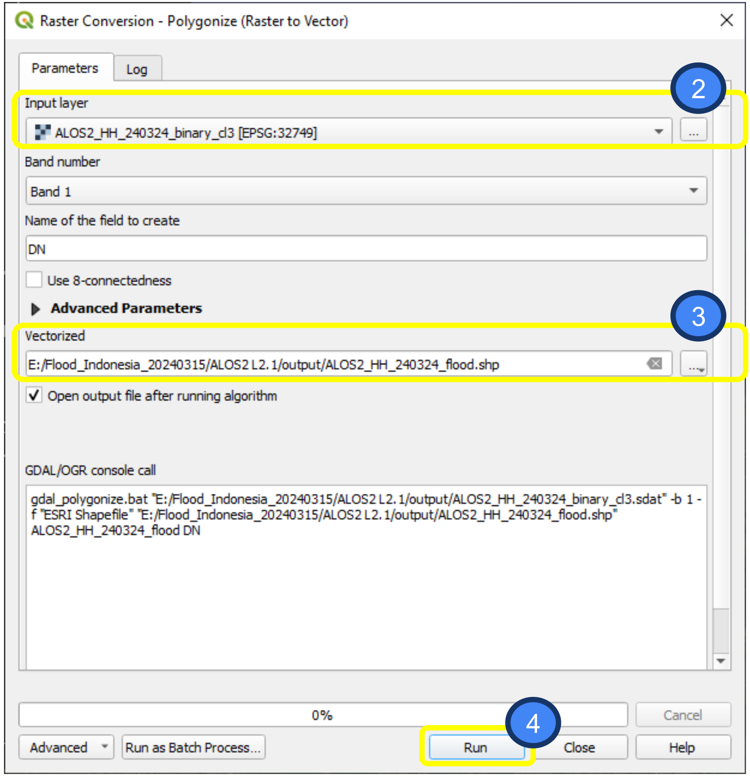


Post-Processing

Follow Along: Vectorize flood pixels

We will convert the flood raster to polygons.

1. Click on Raster → Conversion → Polygonize (Raster to Vector)…
2. In the Input Layer, select ALOS2_HH_240324_binary_cl3
3. Save the Vectorized result to ALOS2_HH_240324_flood.shp
4. Click Run.

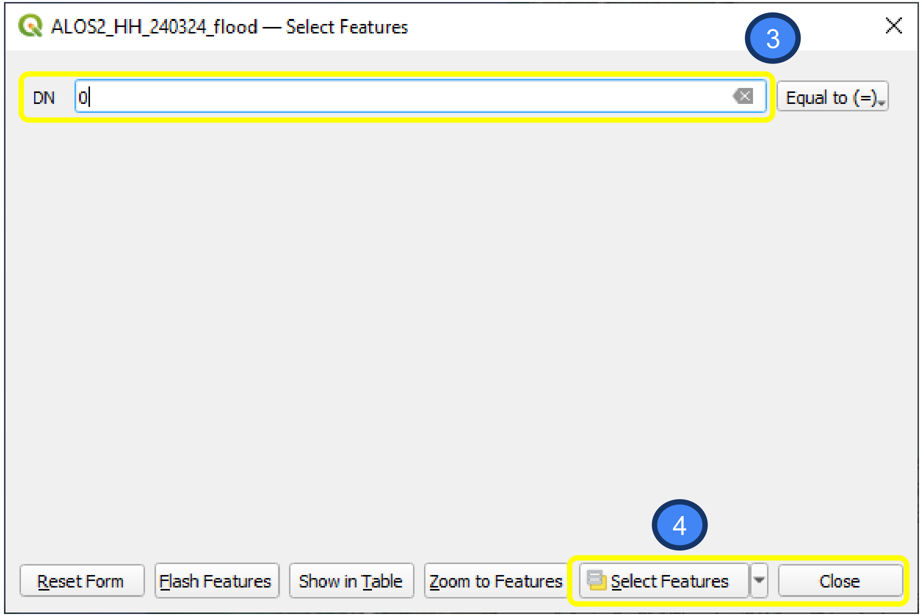


Post-processing

Follow Along: Remove non-water polygons

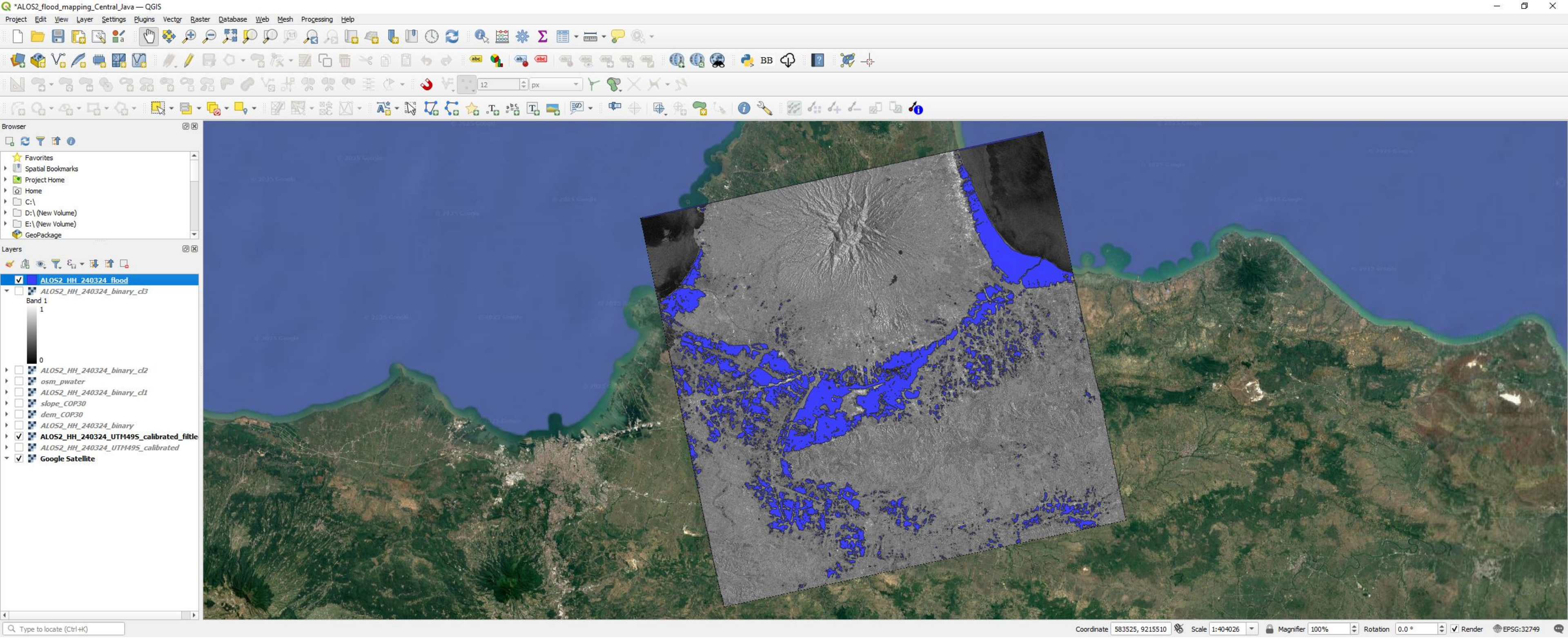
Let's remove non-water polygons.

1. In Toolbars, activate the editing mode by clicking the Toggle Editing button.
2. In Toolbars, click Select Features by Value button or click F3.
3. In the DN value, write 0.
4. Click Select Features, then Close.
5. In Toolbars, click Delete Selected button to delete non-water polygons.
6. Click Toggle Editing button again to stop the editing, then select Save.



Post-processing

Final visualization



THANK YOU

Geoinformatics Center, Asian Institute of Technology