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Radar Assignment Course: **Advanced Remote Sensing (651.030)**

CONTENTS

GOAL

The goal of is to apply the techniques learned in the practical session to generate a displacement map using Sentinel-1 SAR datasets for a new study site affected by a geohazard (e.g., landslide, volcanic activity, or even another earthquake). By creating a displacement map, we aim to visualize and quantify ground movement associated with this seismic event, contributing to a better understanding of geohazards and scientific workflows for monitoring them.

STUDY AREA

The chosen geohazard is the devastating earthquakes in south-central Turkey and north-western Syria on February 6, 2023. These earthquakes, centered 37 km west-northwest of Gaziantep, reached a magnitude of 7.8 and caused widespread destruction, including a maximum Mercalli intensity of XII (Extreme) near the epicenter and in Antakya, leading to tragic loss of lives. (Wikipedia, 2023).

WORKFLOW

Step 1: Dataset Search and Download

We utilized Sentinel-1 SAR images acquired before and after the February 6, 2023, earthquakes in Turkey and Syria. These images were sourced from the Copernicus EO Browser. Created a 500m square buffer around the earthquake epicenter and used this to search for the Sentinel 1 SLC dataset as shown below.

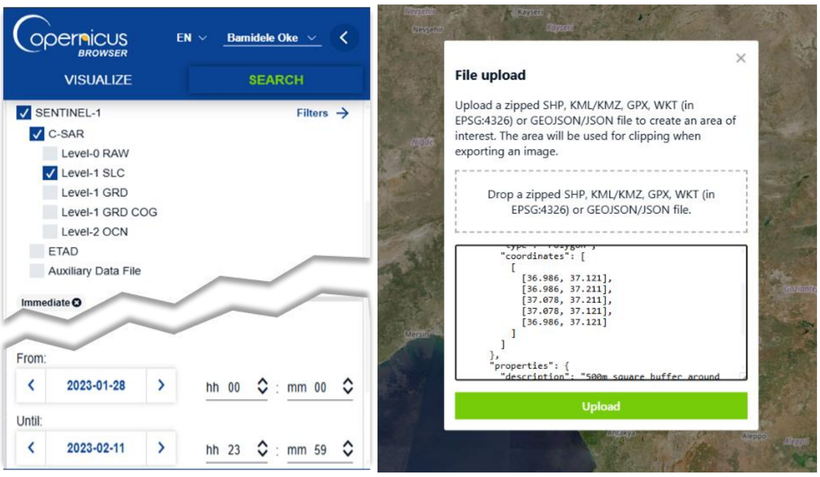


Figure 1 Dataset search in Copernicus browser

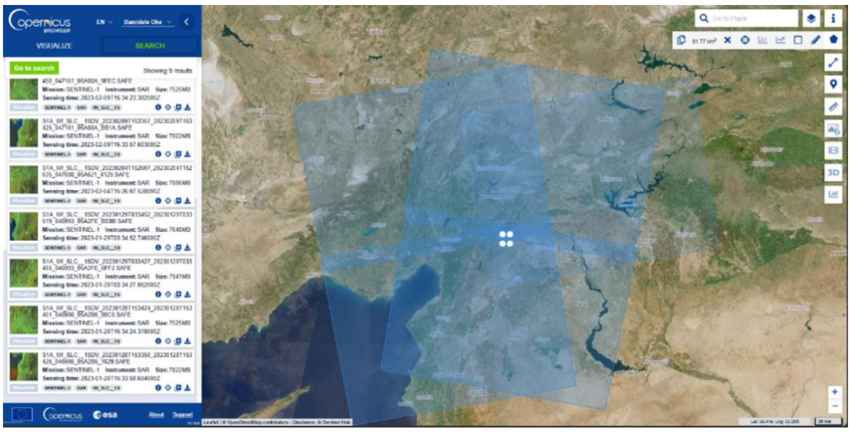


Figure 2 Search Results from Copernicus Browser

Two datasets were selected from the search results as follows. The selection criteria used was the coverage/footprint of the datasets in the event location:

- **Before the event:** S1A_IW_SLC__1SDV_20230129T033452_20230129T033519_046993_05A2FE_BE0B. (January 29, 2023).
- **After the event:** S1A_IW_SLC__1SDV_20230210T033451_20230210T033518_047168_05A8CD_E5B0. (February 10, 2023).

These datasets will be used to analyze the ground deformation caused by the earthquake and subsequently generate the displacement map.

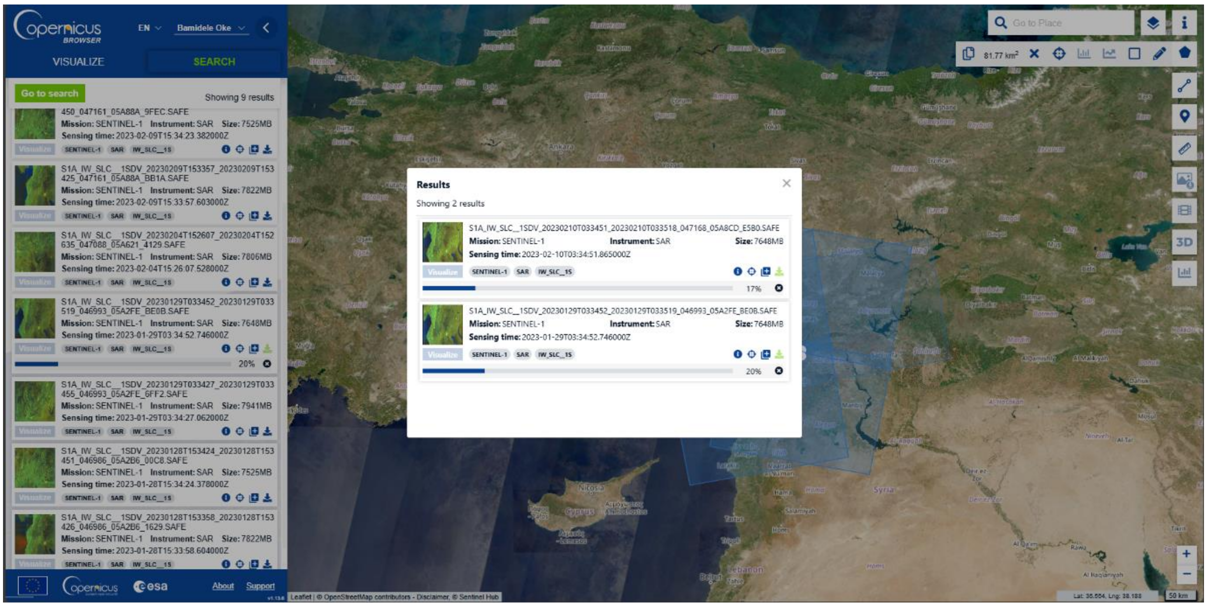


Figure 3 Dataset selection and download from Copernicus Browser

Step 2: Data Preparation and Analysis with SNAP:

For the data preparation and image processing/analysis, we used SNAP (Sentinel Application Platform). Developed by the European Space Agency (ESA). By leveraging the capabilities of SNAP, this analysis will provide valuable insights into the ground deformation patterns associated with the 2023 Turkey-Syria earthquakes, contributing to a better understanding of the seismic event and its impact.

Data Import: we imported Sentinel-1 SLC (Single Look Complex) images acquired before and after the earthquake, which previously downloaded from the Copernicus Browser.

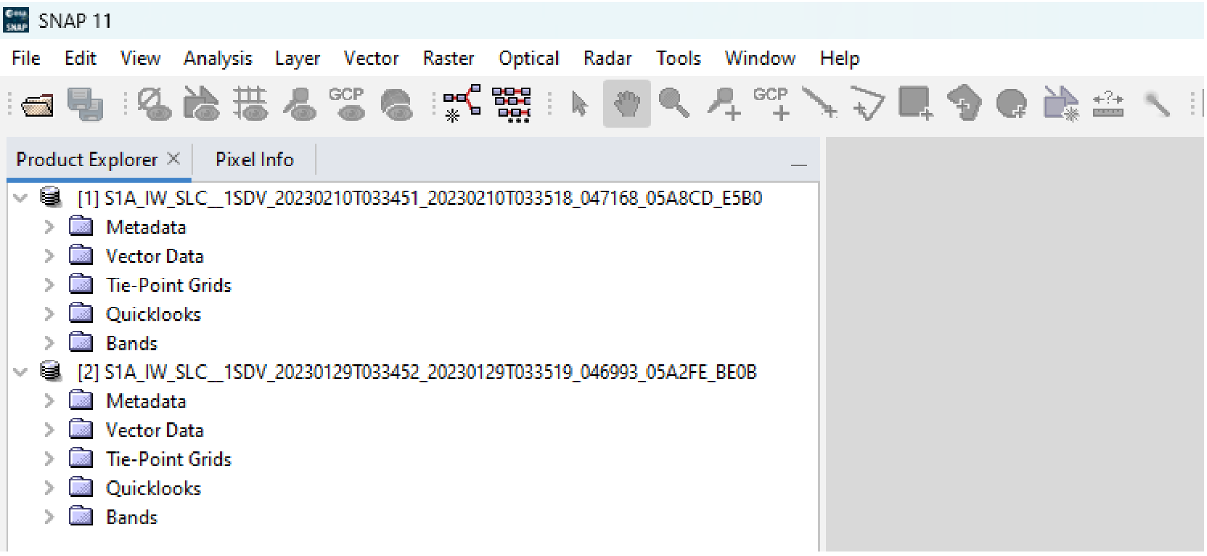


Figure 4 Loading the products into Snap

Sub-swath Selection: To focus on the specific region of interest, we extracted the relevant sub-swaths from each of the full-resolution images. This step reduces data volume and improves processing efficiency and is achieved by running the S-1 TOPS Split tool in Snap.

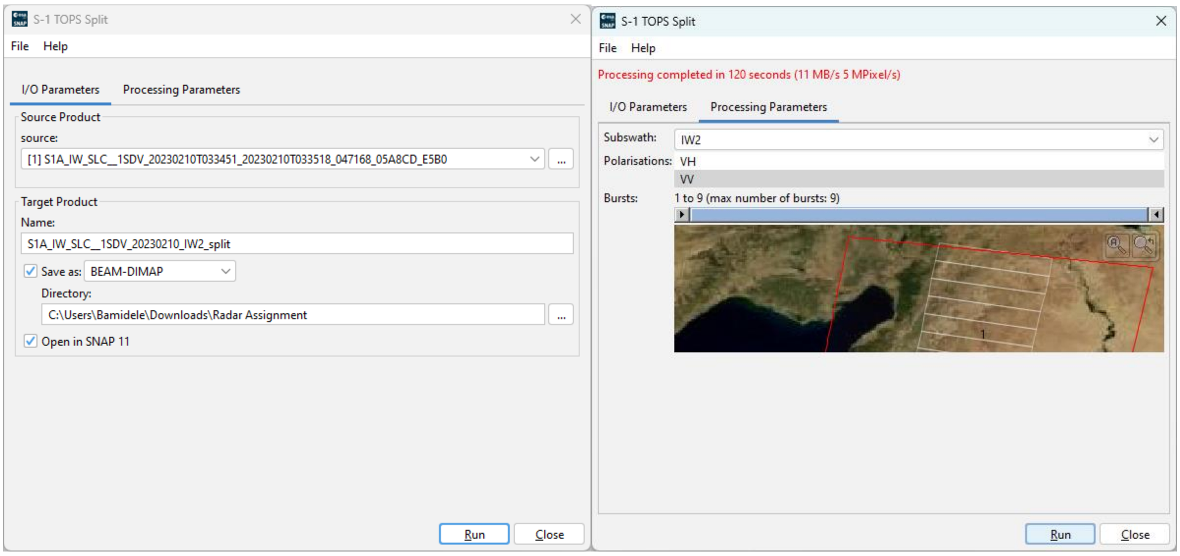


Figure 55 S-1 TOPS Split tool parameters

Orbit File Application: we applied the orbit files to both the "before" and "after" earthquake images. This crucial step corrects for minor positional errors in the satellite's trajectory during image acquisition, ensuring accurate geocoding and subsequent interferometric processing.

These initial steps are essential for preparing the Sentinel-1 data for subsequent interferometric processing. By carefully selecting the appropriate sub-swaths and applying orbit corrections, we've laid a solid foundation for accurate measurement of ground deformation caused by the earthquake.

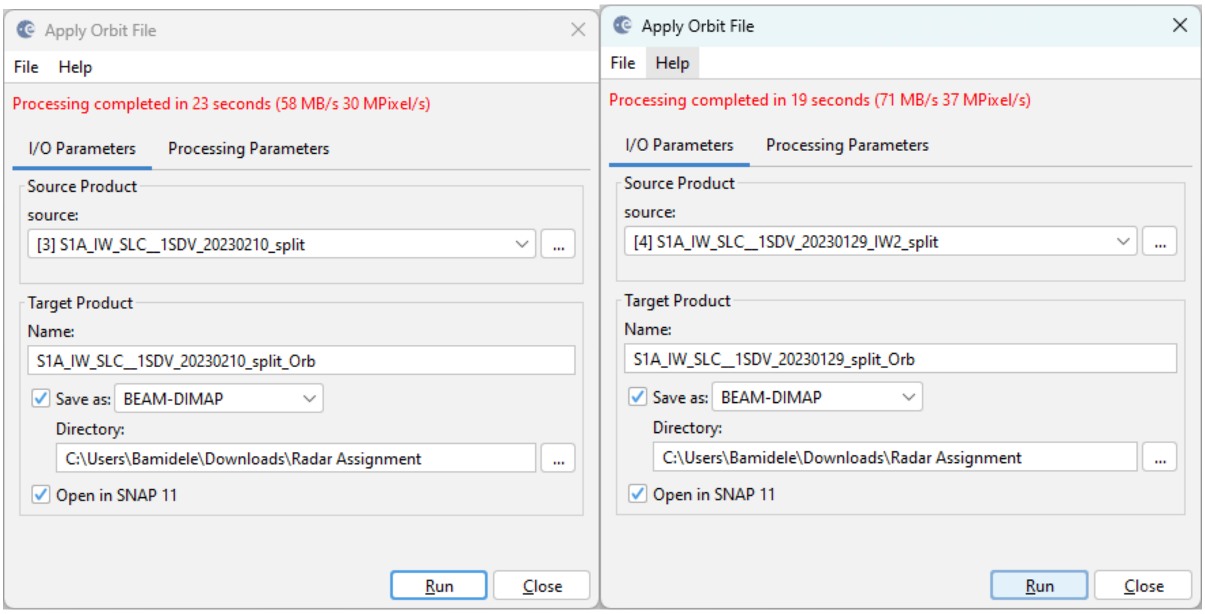


Figure 66 Orbit file application.

Step 3: Generation of Topographic Interferogram:

Coregistration: This is mandatory to align the images using a Digital Elevation Model dataset, in this case, we used the SRTM 3 arc Sec dataset which is automatically downloaded by Snap. The tool to achieve coregistration is the S-1 Back Geocoding tool.

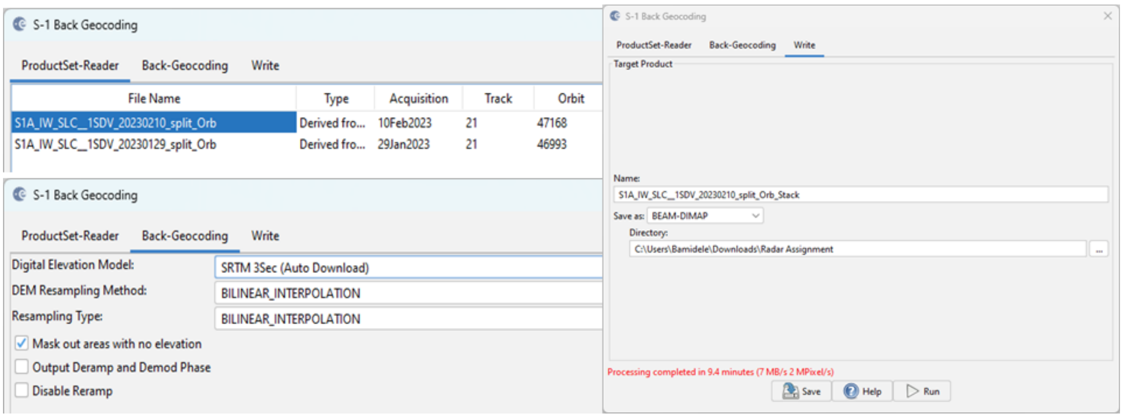


Figure 7 7S-1 Back Geocoding tool parameters.

Interferogram generation and TOPSAR Deburst: The topographic interferogram highlights the differences in phase between two radar images caused primarily by variations in terrain elevation. In the TOPS (Terrain Observation with Progressive Scans) mode, the SAR instrument acquires data by sweeping the radar beam in azimuth (along-track direction) in a sequence of short time segments called bursts. So far, these boundaries appear as lines in the dataset, and we need to remove them.

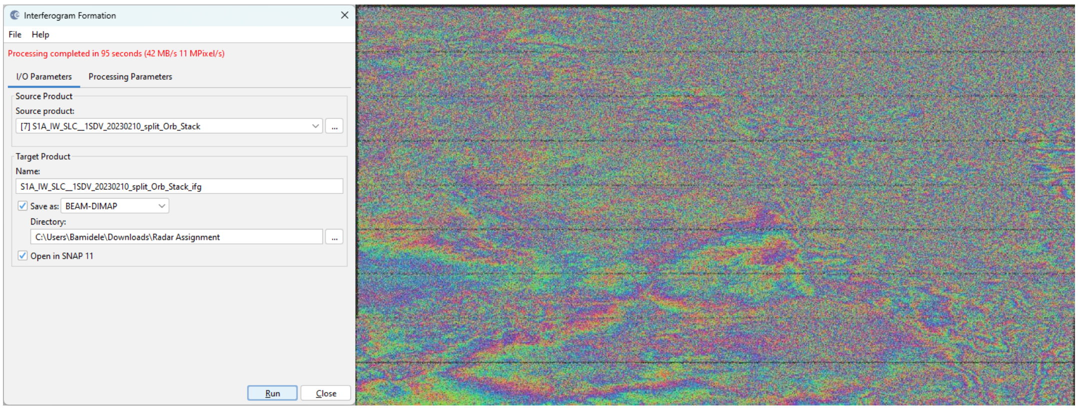


Figure 88 Phase interferogram generated with burst boundaries (black lines in the image)

The TOPS Deburst tool is then run after generating the interferogram to remove the burst boundaries.

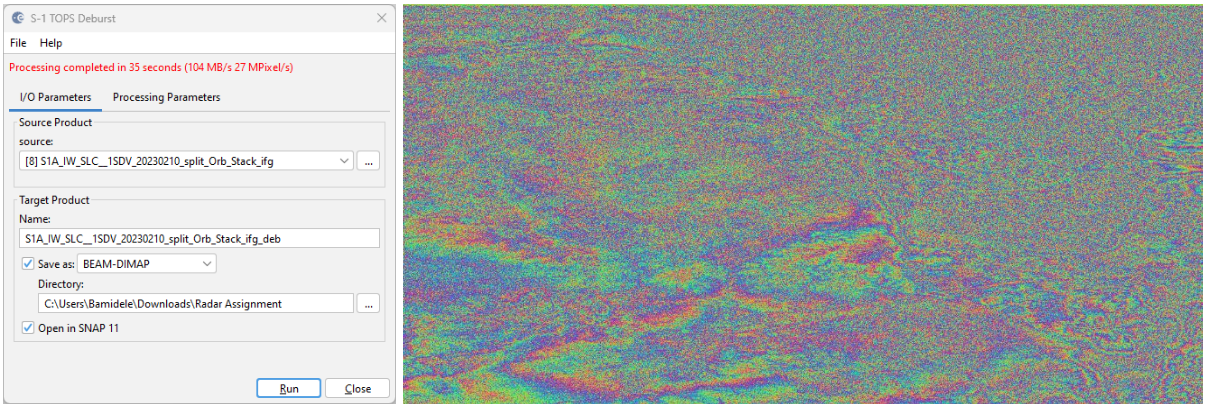


Figure 9 S9-1 TOPS Deburst tool has removed the burst boundaries from the image

Step 4: Generation of Differential Interferogram

Topographic Phase Removal: Because we have combined radar images from 2 satellite phases to form the interferogram, the resulting phase difference can be influenced by several factors including topography, displacement, noise, etc. This step is aimed at isolating the phase contributions caused by ground deformation or displacement by removing the influence of terrain elevation from the interferogram.

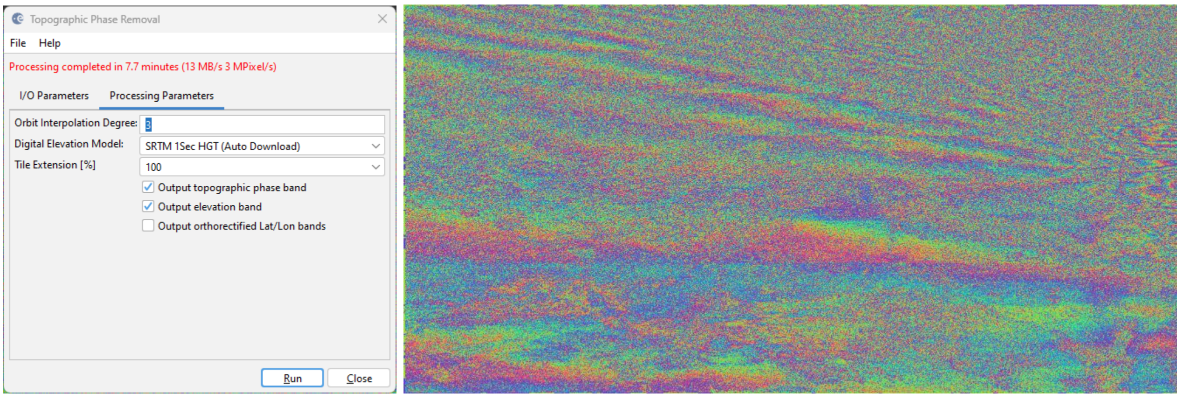


Figure: 10 10Result after Topographic phase removal

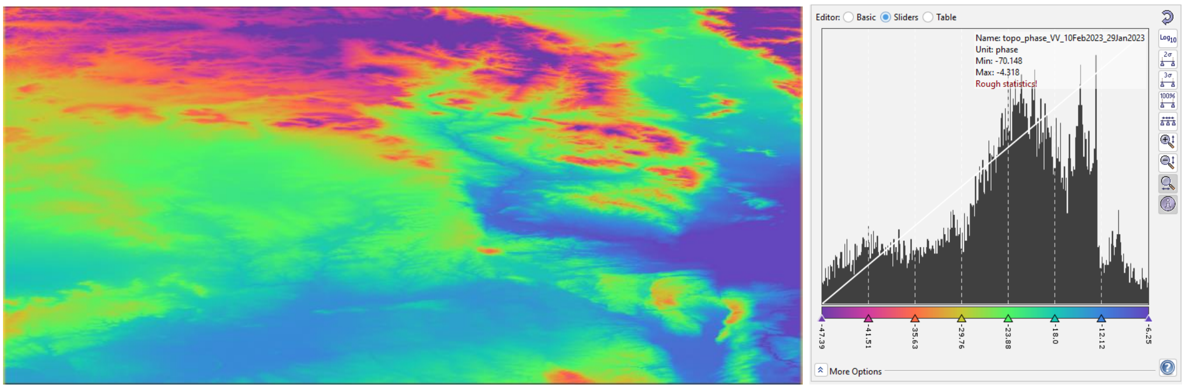


Figure: 11 11Topographic Phase isolated from the interferogram.

Multilooking: This reduces noise but more importantly it can be used to get square pixels. This will improve the visual interpretability of the differential interferogram.

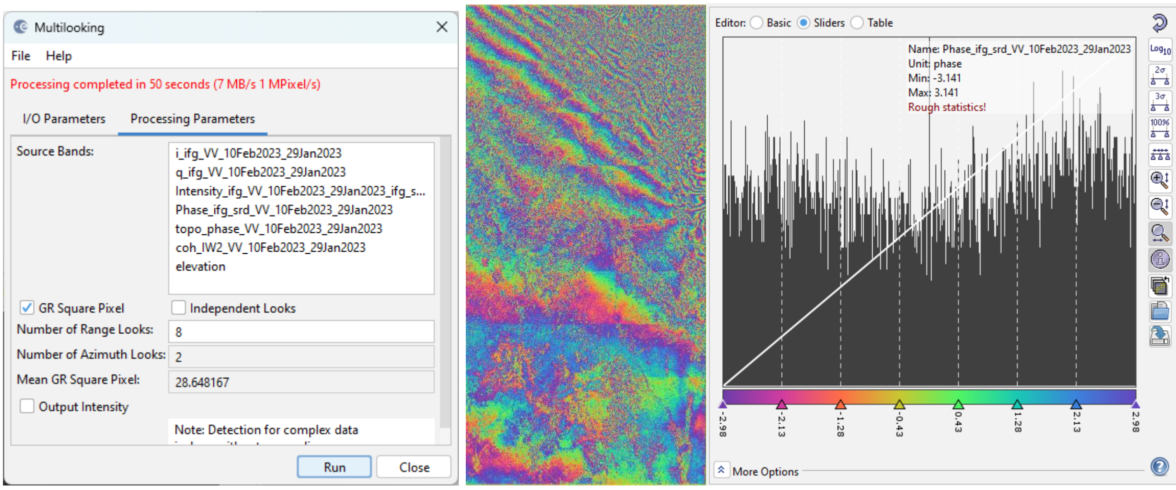


Figure: 12 12Result of Multilooking process.

Goldstein Phase Filtering: This step will improve phase quality by reducing noise, in order to ensure accurate unwrapping and displacement calculation.

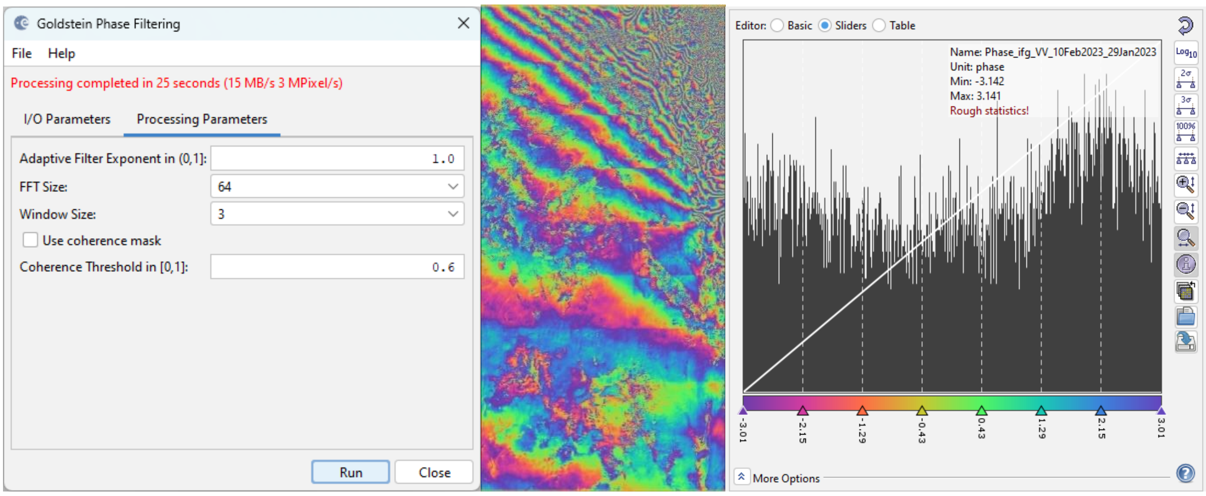


Figure 13 Result13 after applying the Goldstein Phase Filtering.

Step 5: Generation of displacement map

Snaphu installation: To obtain continuous measurements of ground displacement from the wrapped phase data, we installed snaphu by downloading and extracting the content into the snap installation folder and performed the following steps after restarting snap to detect the new plugin. In addition, the Snaphu path is added to the Windows Environment Path variable.

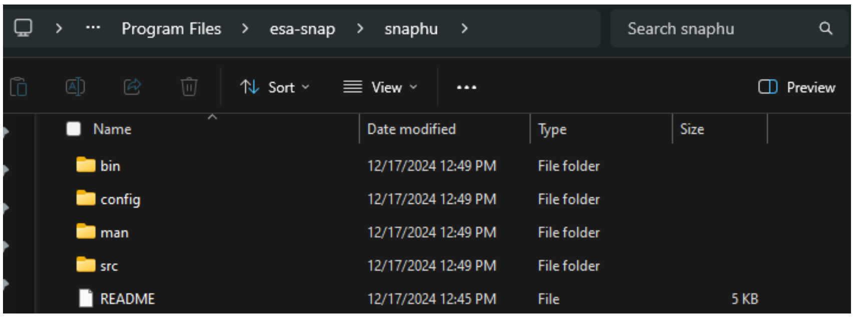


Figure 14 14Snaphu extracted to the snap installation folder

Snaphu Export: We used the "Snaphu Export" tool in Snap to prepare the data in a format compatible with the plugin. This involves configuring the export settings and specifying the output folder.

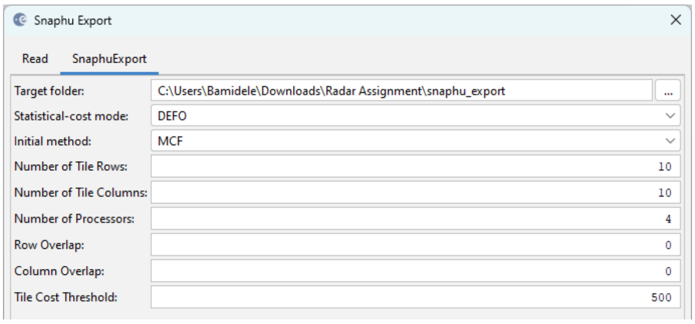


Figure 15 Running15 the Snaphu Export tool in Snap

Execute Snaphu: We executed the Snaphu software from the command prompt to unwrap the phase using the exported files. This is possible because Snaphu has been added to the Path variable making it available to the Window's command line as an executable. Before executing Snaphu, we also updated the *snaphu.conf* file and added the correct name for the Coherence file. This file is among the files generated by running the Snaphu Export tool.

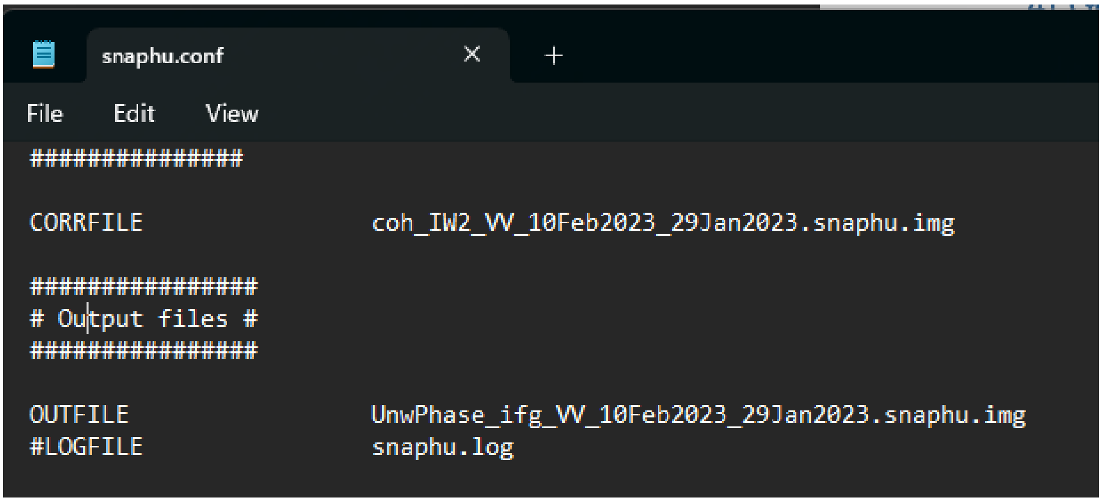


Figure 16 Updating16 the CORRFILE parameter in snaphu.conf

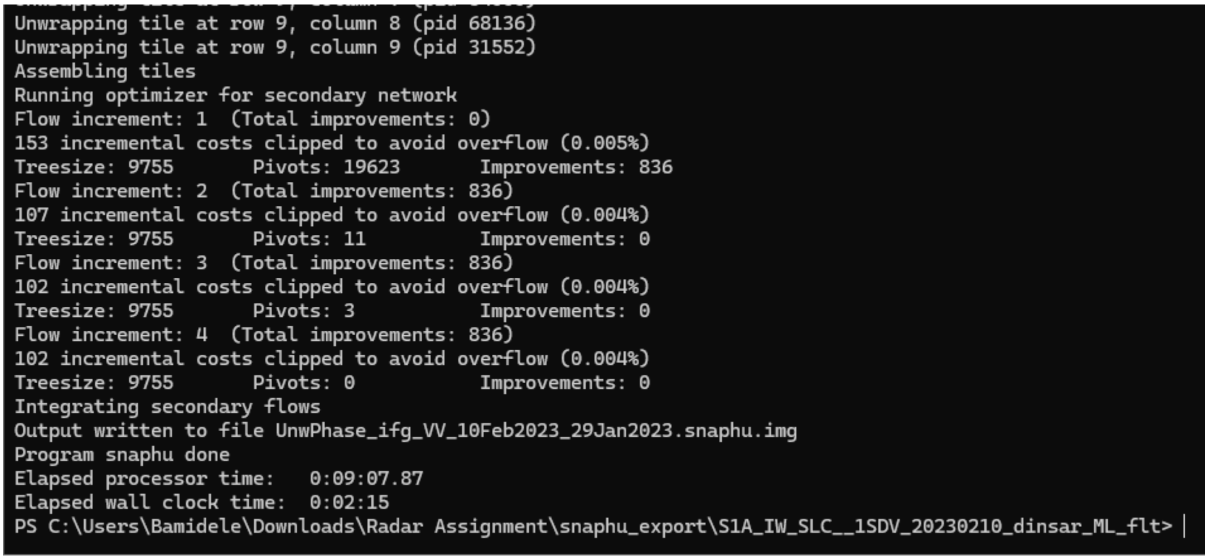
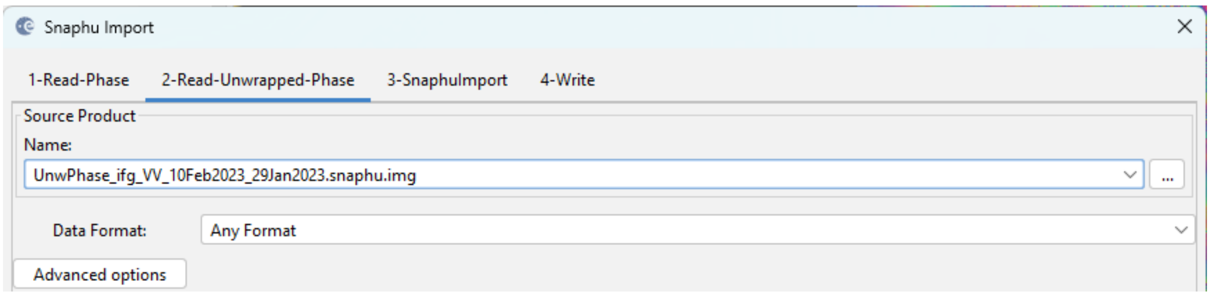
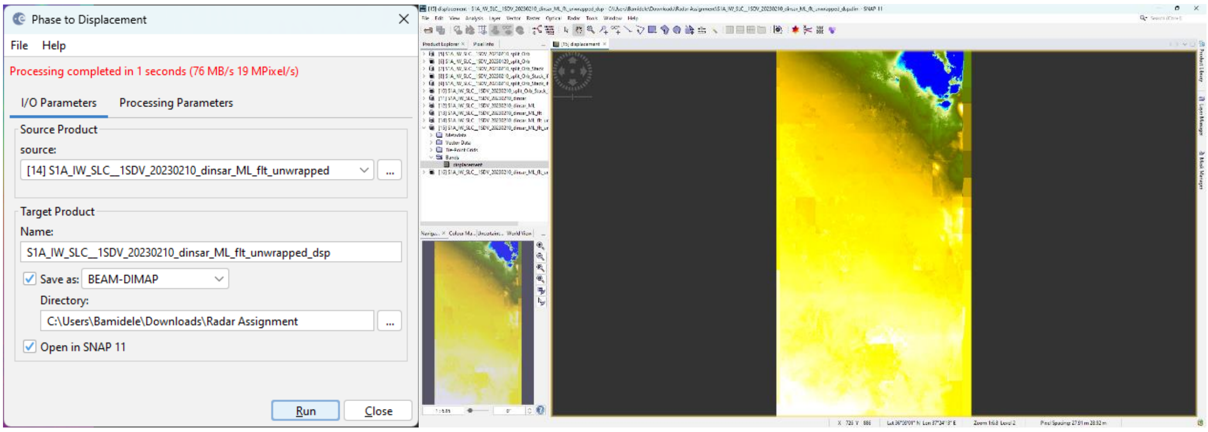


Figure 17 Executing17 Snaphu in Command prompt.

Snaphu Import: After Snaphu completed the unwrapping process, we imported the results back into Snap.



Displacement map generation: Using the *Phase to Displacement* tool, we converted the unwrapped phase values into actual ground displacement measurements. This step provides the information we need to analyze ground movement.



Terrain Correction: Finally, we applied terrain correction to the displacement map. This crucial step accounts for the influence of topography on the radar measurements, ensuring that the displacement values are accurately georeferenced and free from distortions caused by elevation variations. We used a the SRTM 1Sec HGT DEM again for this step and specified the desired output projection for the displacement map.

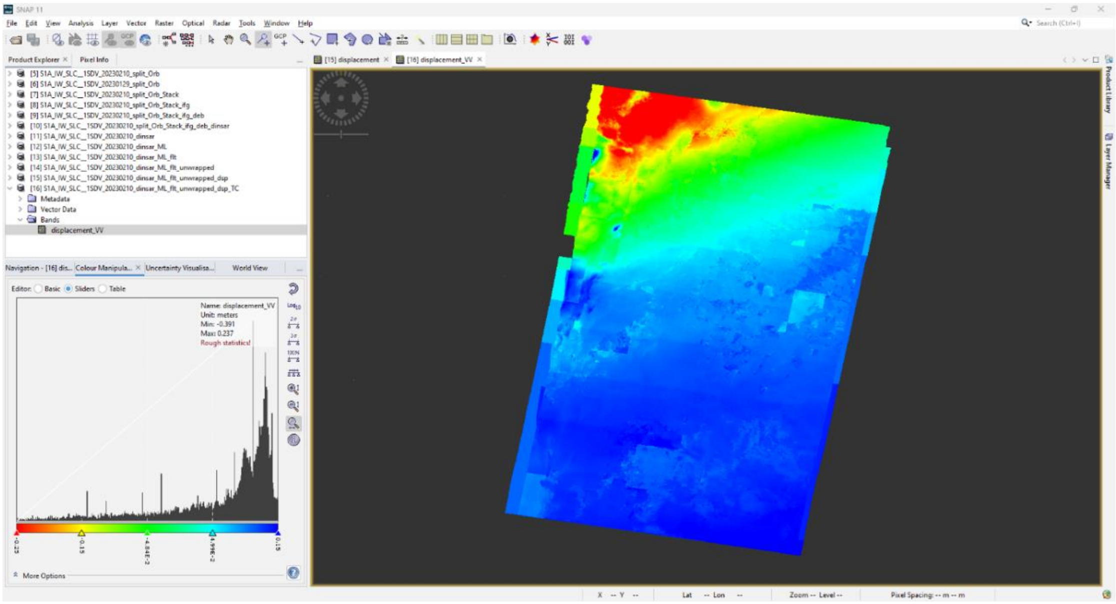


Figure 18 Displacement map after range terrain correction with a DEM.

Results Analysis: The displacement map shows that the downward displacement is approximately -44cm. These are the red regions and there were several depressions. We proceeded to export the displacement map as GeoTIFF and imported it to ArcGIS Pro to overlay the earthquake epicenter and also make the map more informative. In the map below it is obvious that the areas with most displacements are close to the earthquake epicenter. The collage displayed here also shows pictures from the event and this is quite relatable when compared with the -44cm that is observed.

Figure 19 Collage19 of 2023 Turkey–Syria earthquake (Wikipedia, 2023)

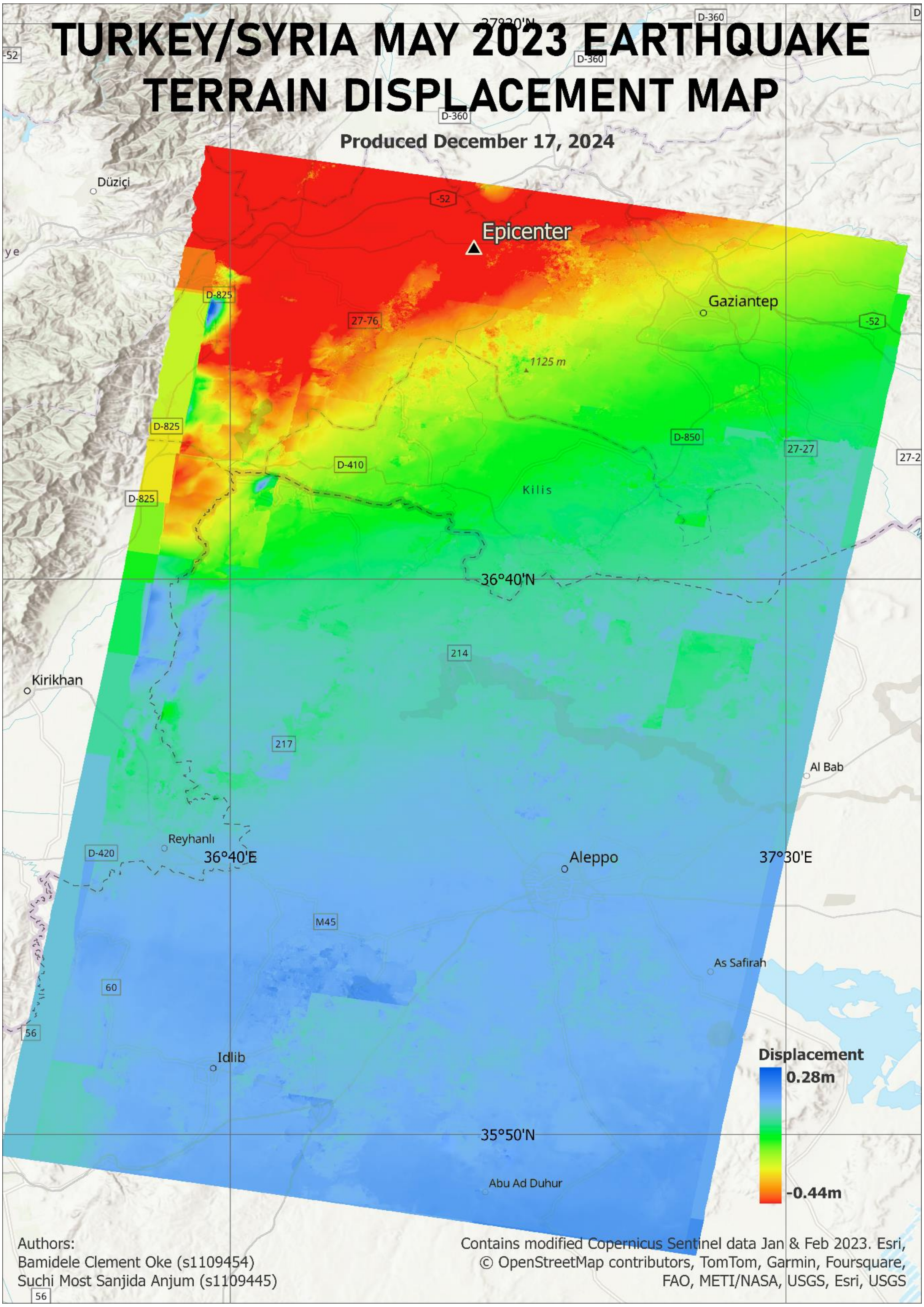


Figure 2020 Final Displacement Map

References:

Hadj-Rabah, K. (2024, December). Class exercise manual: Radio detection and ranging - Practical - Generation of a displacement map.

Wikipedia contributors. (n.d.). *2023 Turkey–Syria earthquakes*. Wikipedia. Retrieved December 19, 2024, from https://en.wikipedia.org/wiki/2023_Turkey%E2%80%93Syria_earthquakes

Wikipedia contributors. (n.d.). *Collage of 2023 Turkey–Syria earthquake*. Wikipedia. Retrieved December 19, 2024, from https://en.wikipedia.org/wiki/2023_Turkey%E2%80%93Syria_earthquakes#/media/File:Collage_of_2023_Turkey%E2%80%93Syria_earthquake.jpg