Experiment No. 6: Mine subsidence modeling using Spaceborne SAR interferometry technique

1. **Aim of Experiment:** To prepare subsidence map using Spaceborne SAR interferometry technique

2. **Data and Resources used:**
    - Sentinel-1A satellite Data
    - SNAP of ESA

3. **Differential SAR Interferometry (DInSAR)**

DInSAR technique utilizes the phase information of a single interferometric pair which is formed by two slant range single look complex (SSLC) SAR images acquired in repeat pass over the same area of interest. Further, these two images are allowed for multiplicative interferometry to form interferogram and subsequently simulated topographic phase is subtracted to get differential interferogram, which consists of phase of interest (displacement) and other unwanted phases. Figure (i) showing schematic diagram of space-borne differential interferometric SAR configuration

Most simplified differential interferometric phase can be written as:

$$\Delta\phi_{diff-\,int} = \Delta\phi_{int} - \phi_{simu-topo} = \phi_{disp} \tag{1}$$

Whereas, a detailed can be written as: $\Delta\phi_{diff-\,int} = \Delta\phi_{int} - \phi_{simu-topo}$

$$= \phi_{disp} + \phi_{RTE} + \Delta\phi_{atm} + \Delta\phi_{orbit} + \phi_{noise} + 2.n.\pi \tag{2}$$

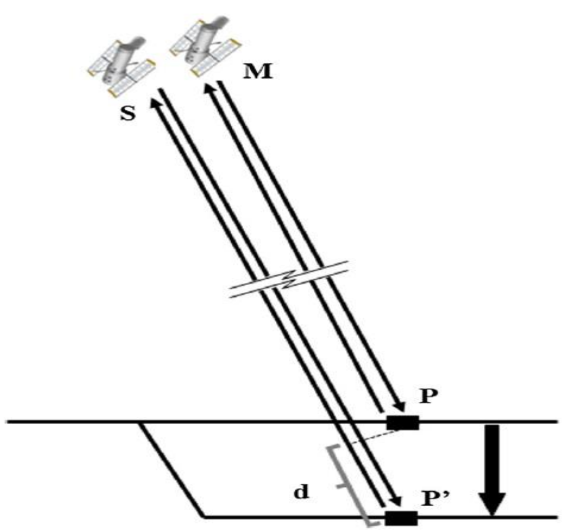

Figure (i): schematic diagram showing space-borne differential interferometric SAR configuration

4. Process Flow

Flowchart for subsidence/displacement map preparation using ESA SNAP is shown in Figure (ii)

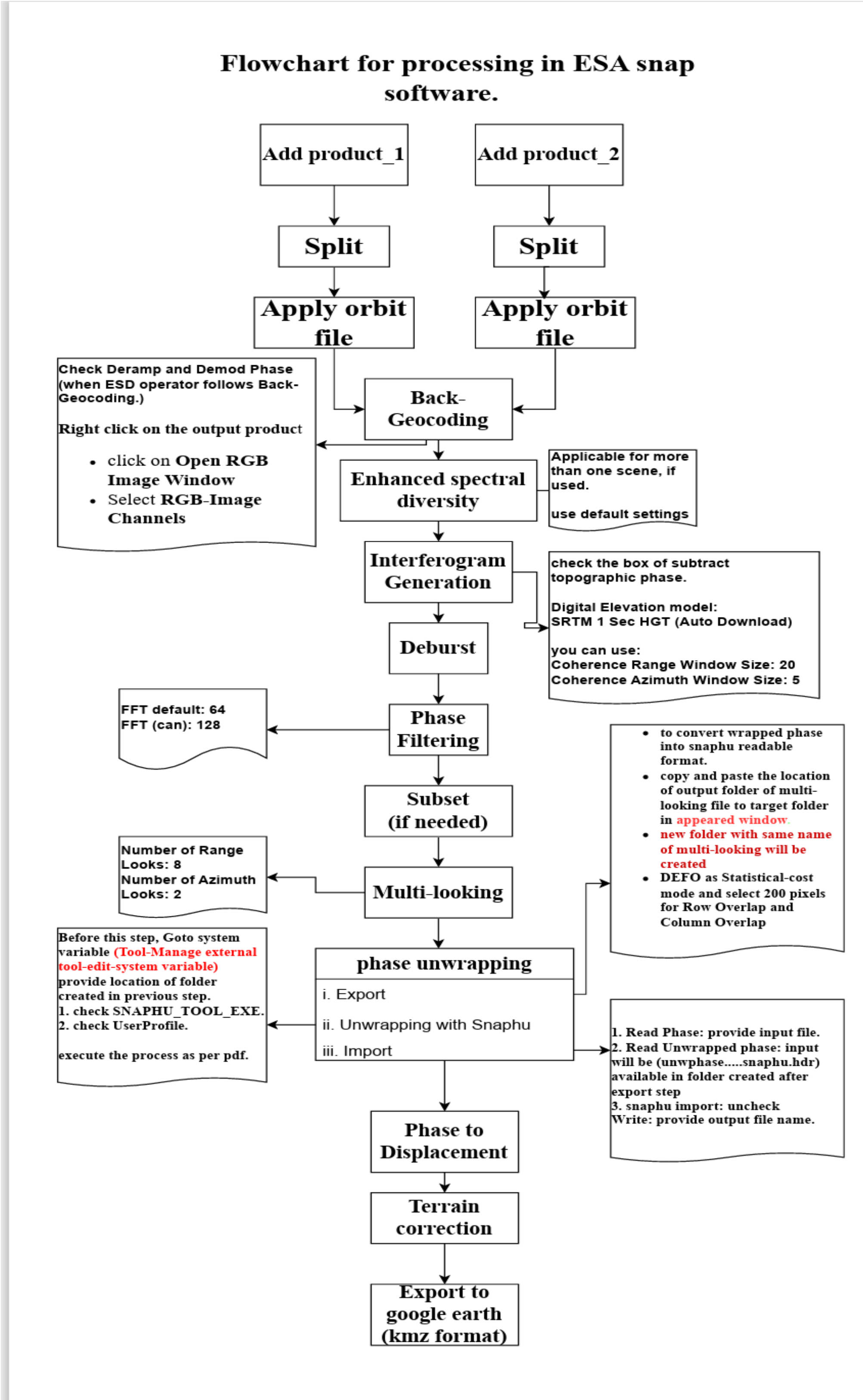

Figure (ii): Flowchart for subsidence/displacement map preparation using ESA SNAP

5. **Stepwise-processing of Interferometric data (S1A) dated (07/01/2017-19/01/2027) in SNAP.**

Open snap software by double clicking the icon of snap  on the desktop screen.

1. Add *product to product explorer windows* (minimum two products needed for processing)

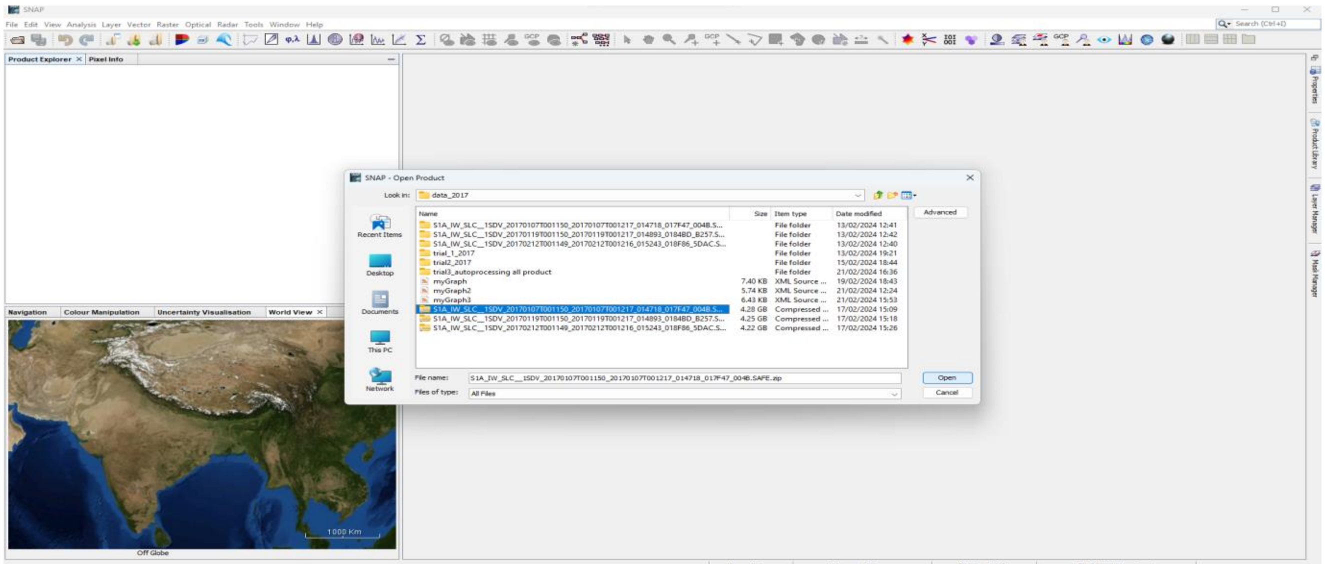

Fig 1: open product

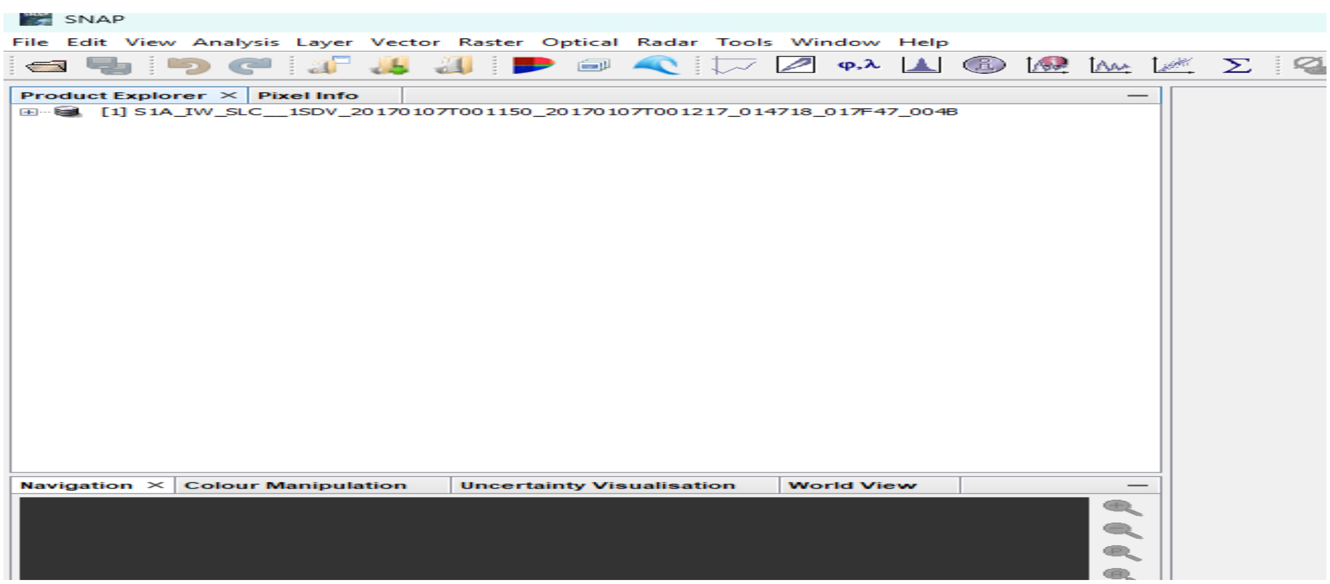

Fig 2: Product explorer windows.

2. **Product split (for both products)**: Goto *Radar* → *sentinel 1-Tops*→ *S1-Tops split*.

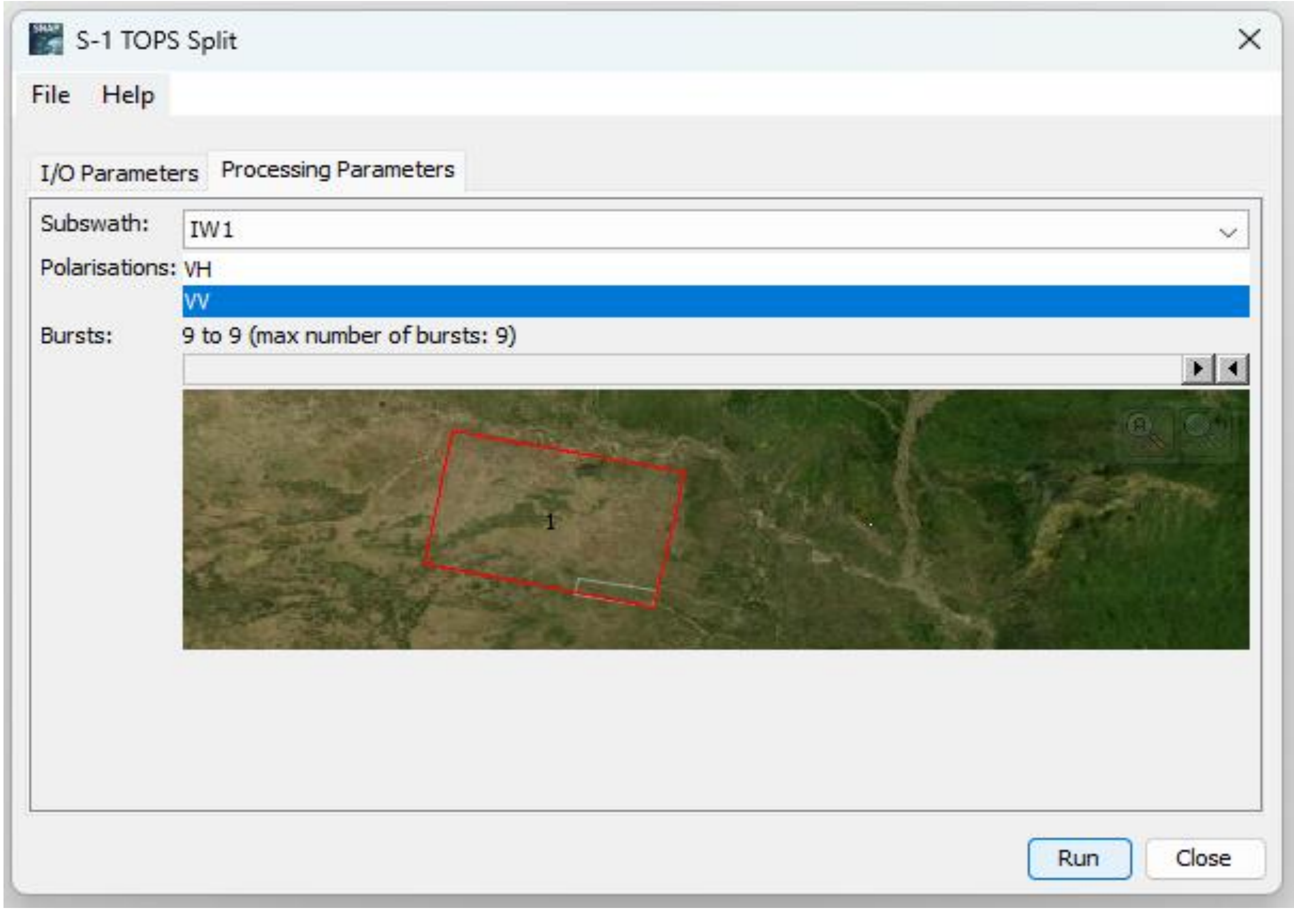

Fig 3: split.

3. **Apply orbit file (for both products)** : Goto *Radar* → click on *Apply orbit file.*

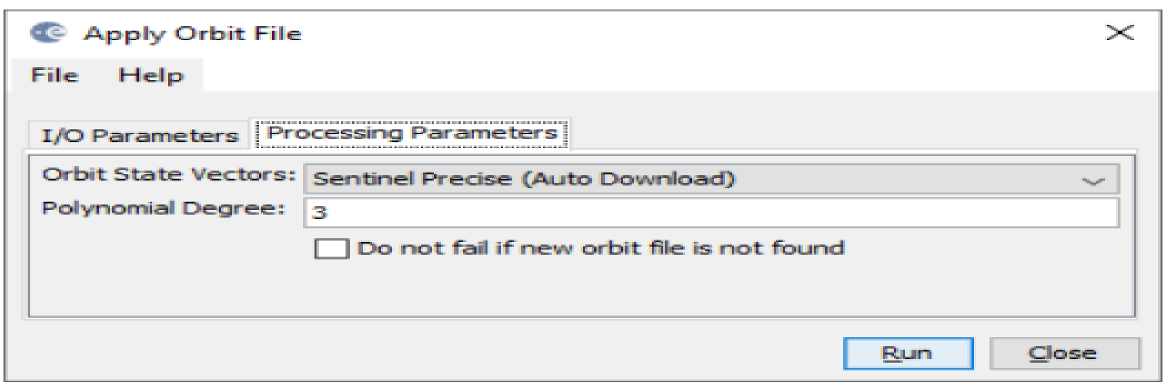

Fig 4: apply orbit file.

4. **Product Back-Geocoding** : *Radar → Co-registration → S1Tops Coregistration→ S1 Back-geocoding.*

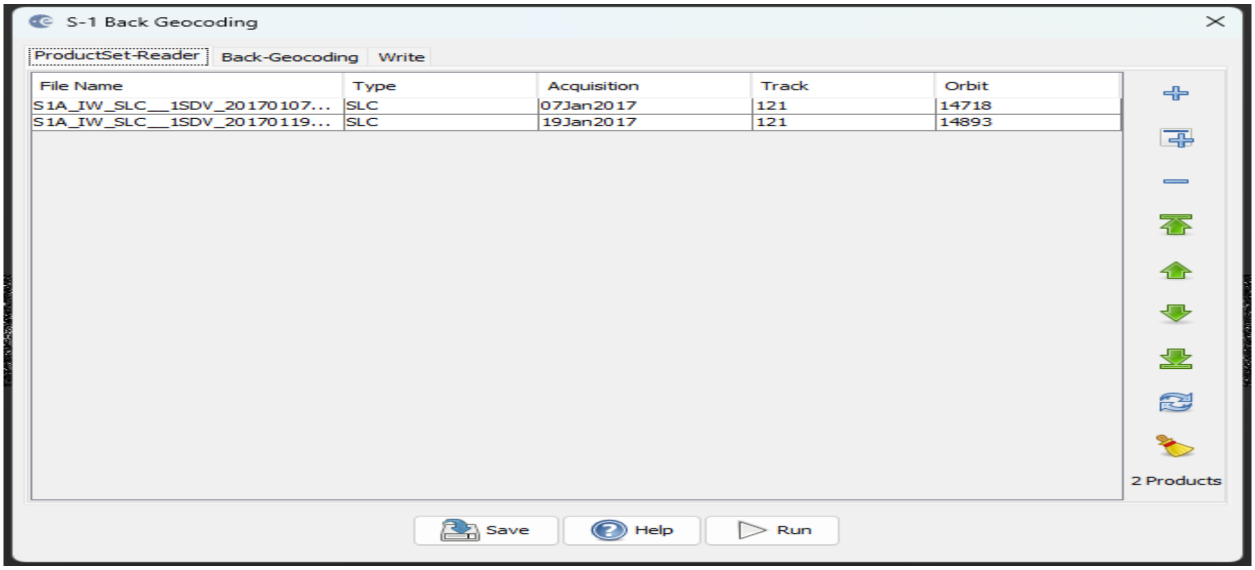

Fig 5: Back Geocoding step_1

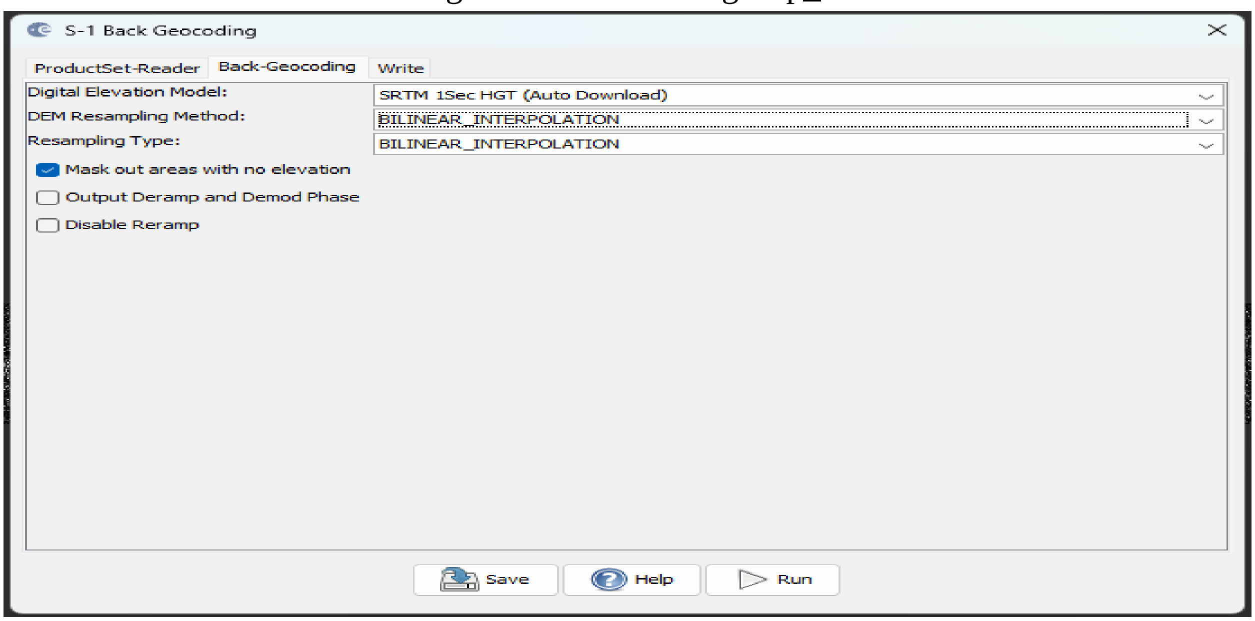

Fig 6: Back-geocoding step 2.

Note:

i. after back-geocoding right click on product in product explorer windows, click on open RGB image windows

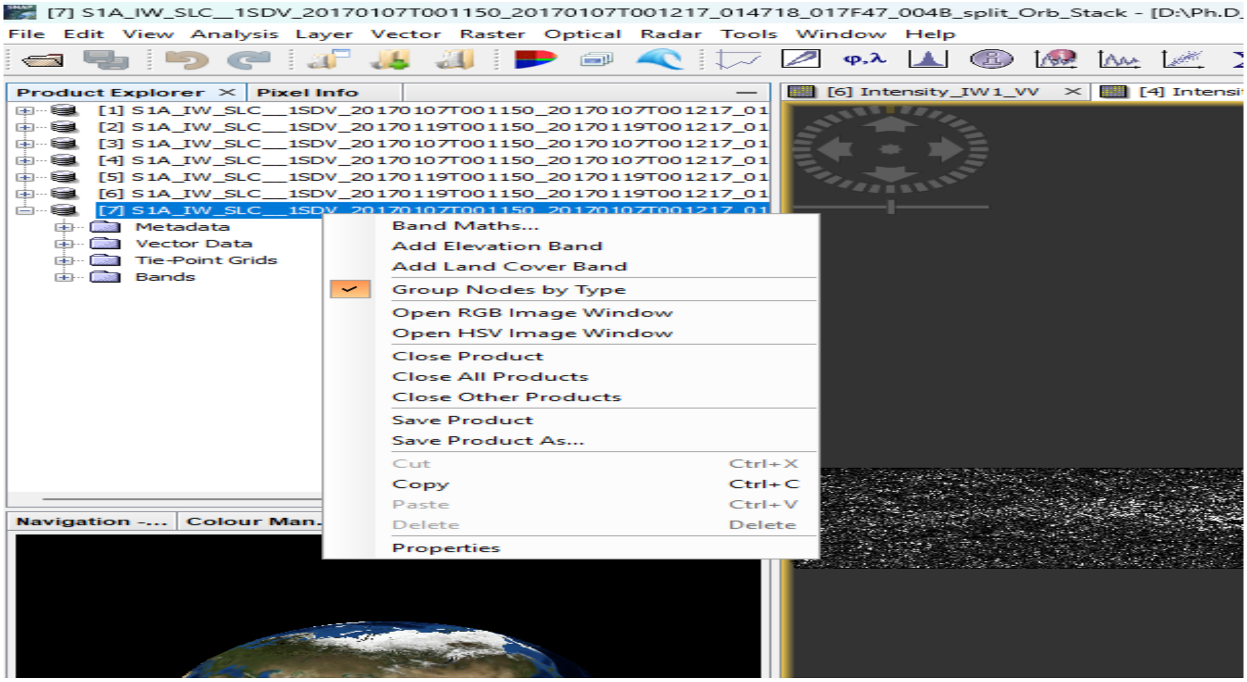

Fig 7: After back_geocoding 1

ii. Choose intensity master VV for red and green band and intensity slave VV for blue band.

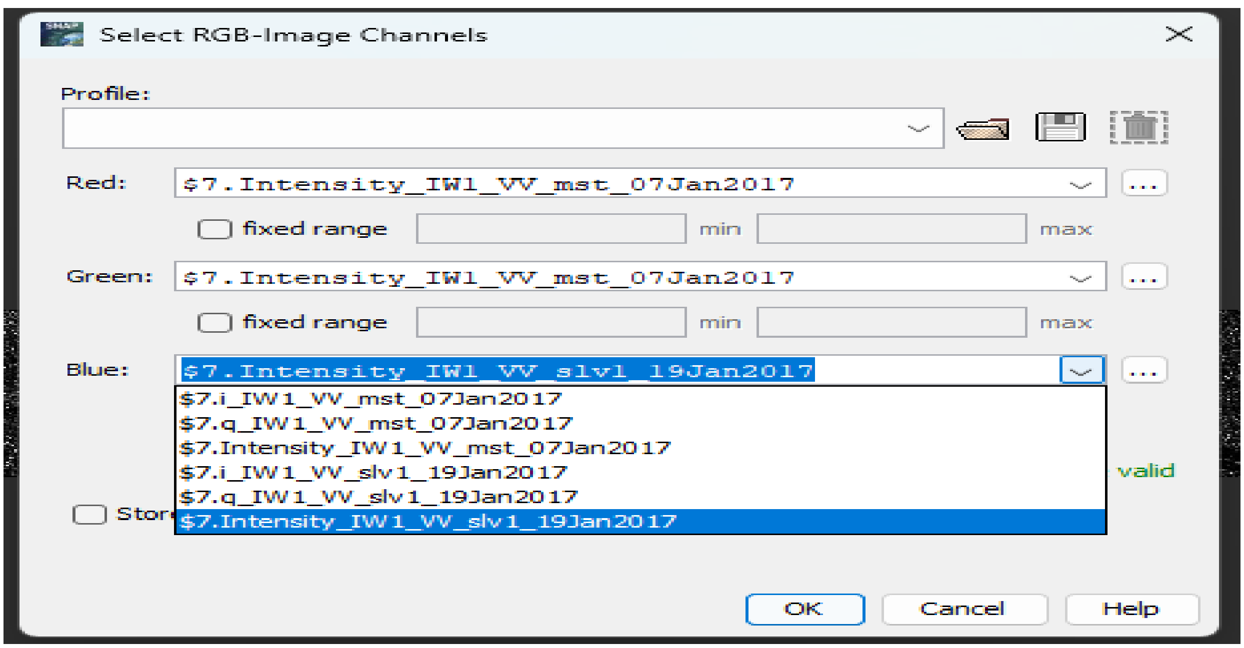

Fig 8: After back_geocoding 2

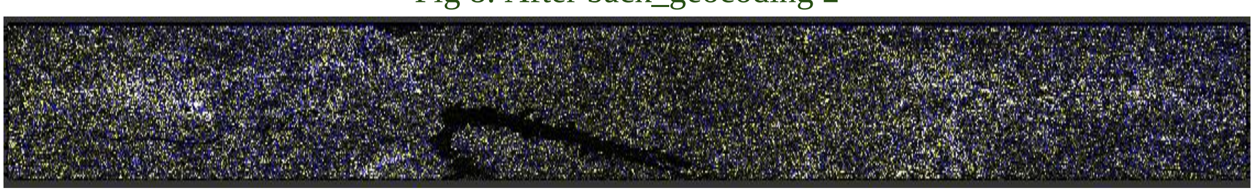

Fig 9: coregistration in an RGB image

5. **Enhanced spectral diversity (**done for more than one scene **)**: *Radar → Co-registration → S1Tops Coregistration→ S1 Enhanced spectral diversity*.

Note: ESD not used, as we used only one scene.

6. **Interferogram Generation** : *Radar → Interferometric → Product → interferogram generation.*

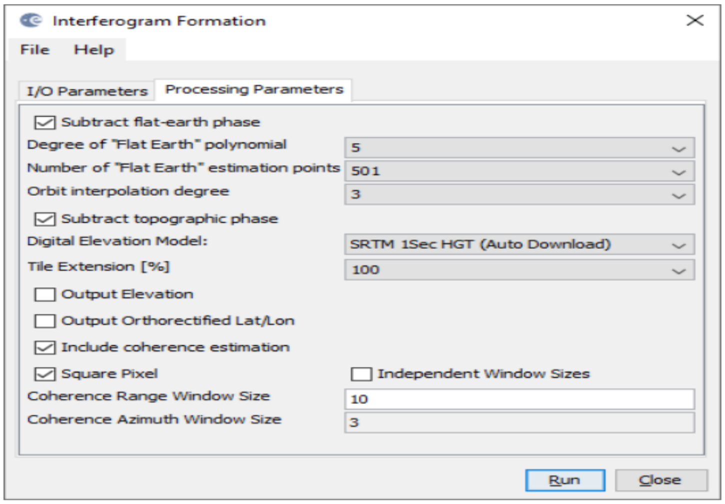

Fig 10: Interferogram Formation.

Output:

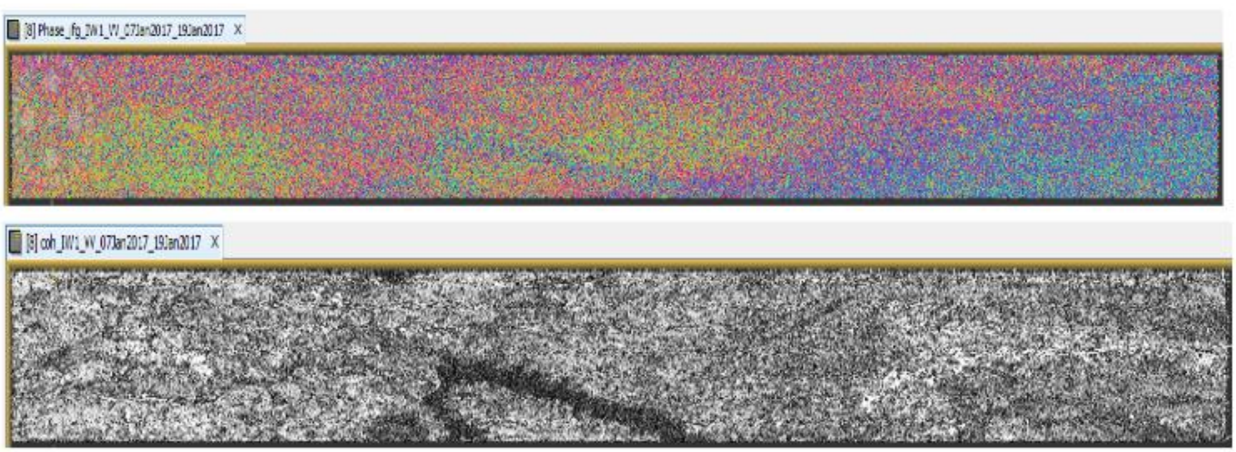

Figure 11: Interferogram (top) and coherence (bottom)

7. **Product Deburst** : Radar → Sentinel-1 TOPS → S1 TOPS Deburst.

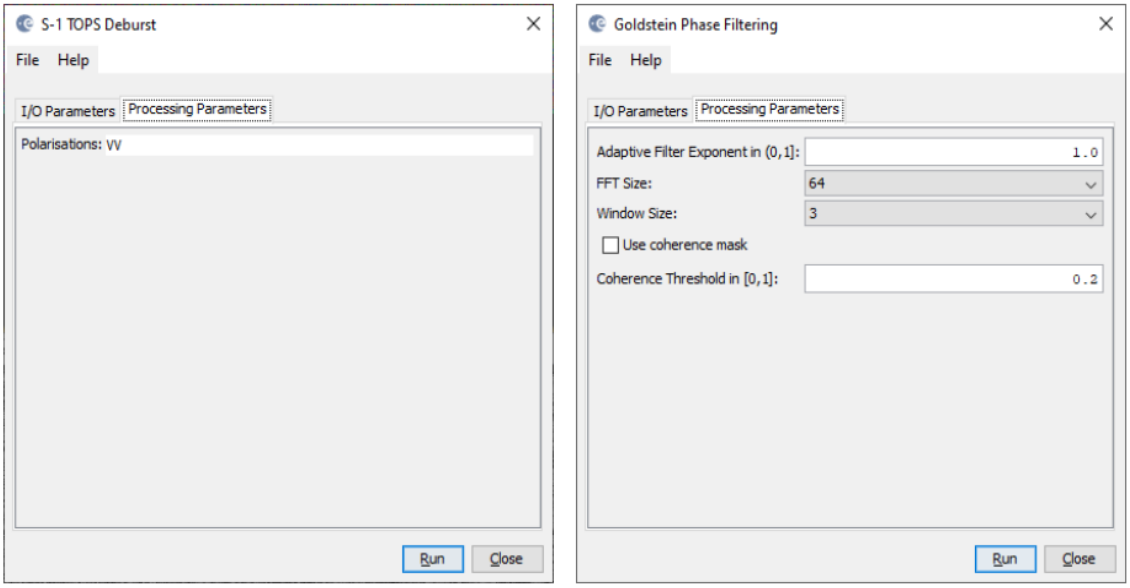

Fig 12: TOPS Deburst (left) and Goldstein phase filtering (right).

8. **Phase filtering** : *Radar → interferometric → Filtering → Goldstein phase filtering.*

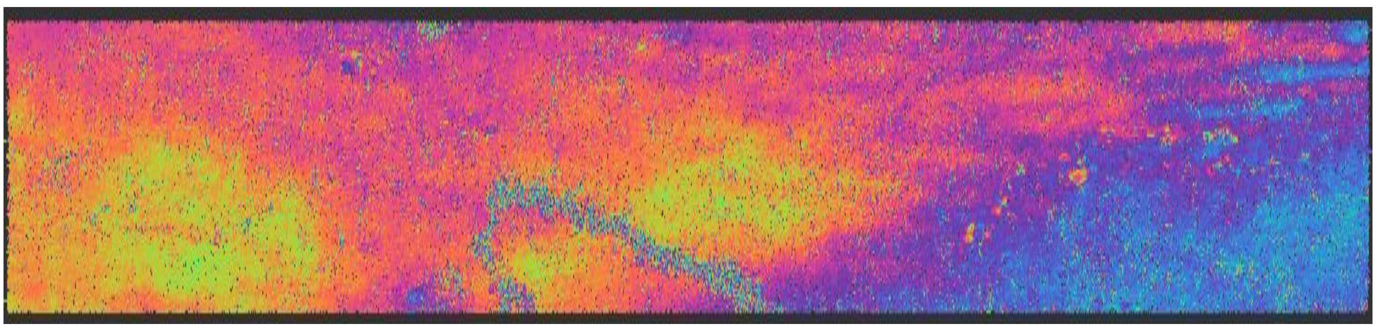
Fig 13: filtered product

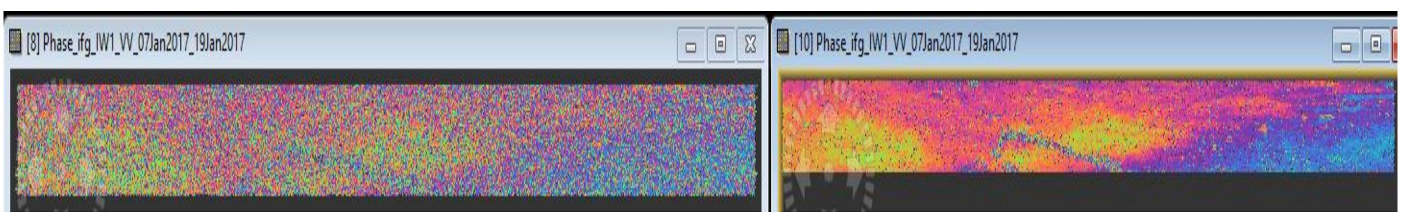

Figure 14: Interferogram before (left) and after (right) Goldstein phase filtering.

9. **Create subset (if needed)** : Raster→ subset → select the *filtered product* in the Product Explorer and Enter the Pixel coordinates (if known) or you can use geo coordinates.

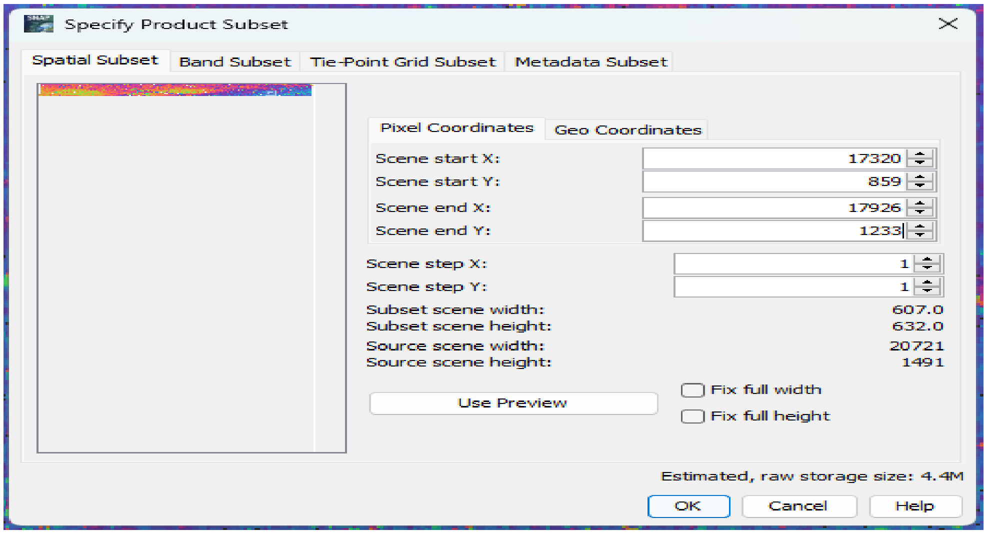

Figure 15: Subset process step.

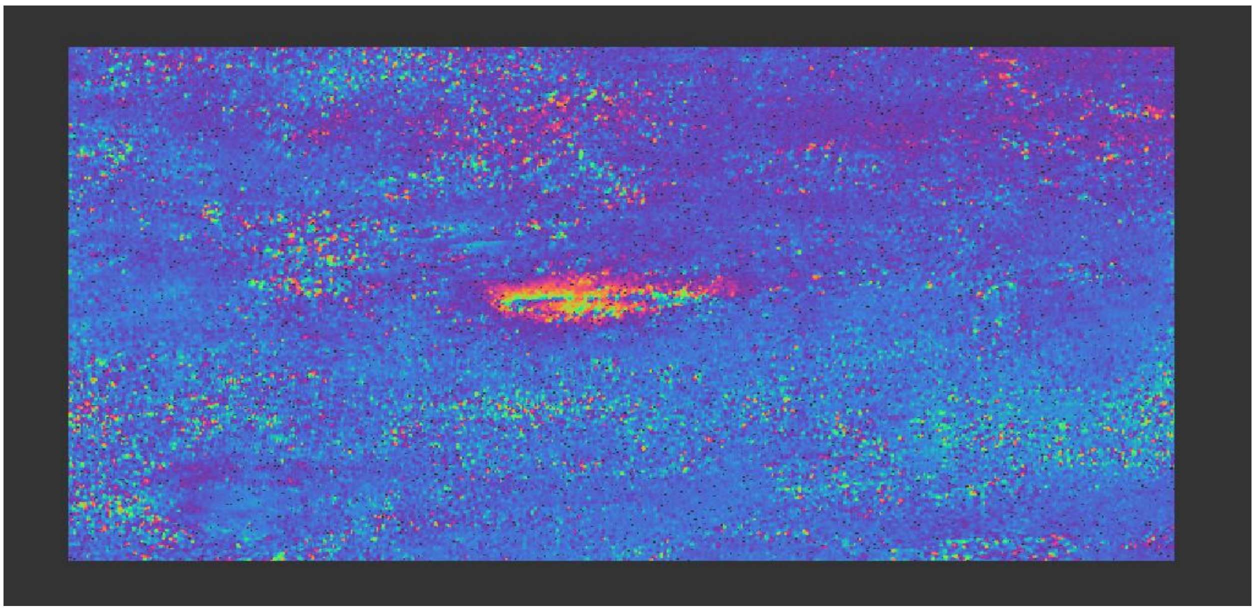

Fig 16: subset output

10. **Multi-looking:** Radar → SAR utilities → Multilooking.

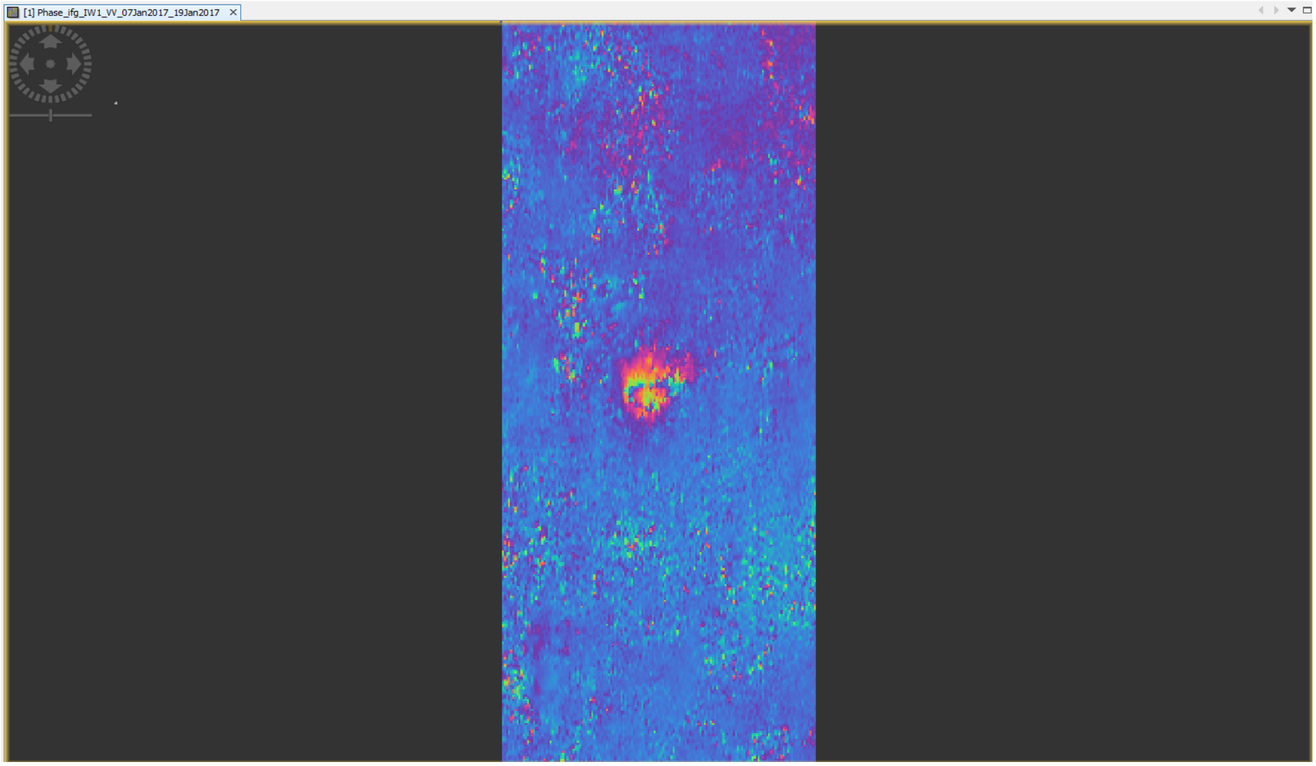

Fig 17: Multilooking output

11. Phase Unwrapping:

Note: Snaphu unwrapping plugin required.

Goto tool → plugin → install/check for Snaphu unwrapping

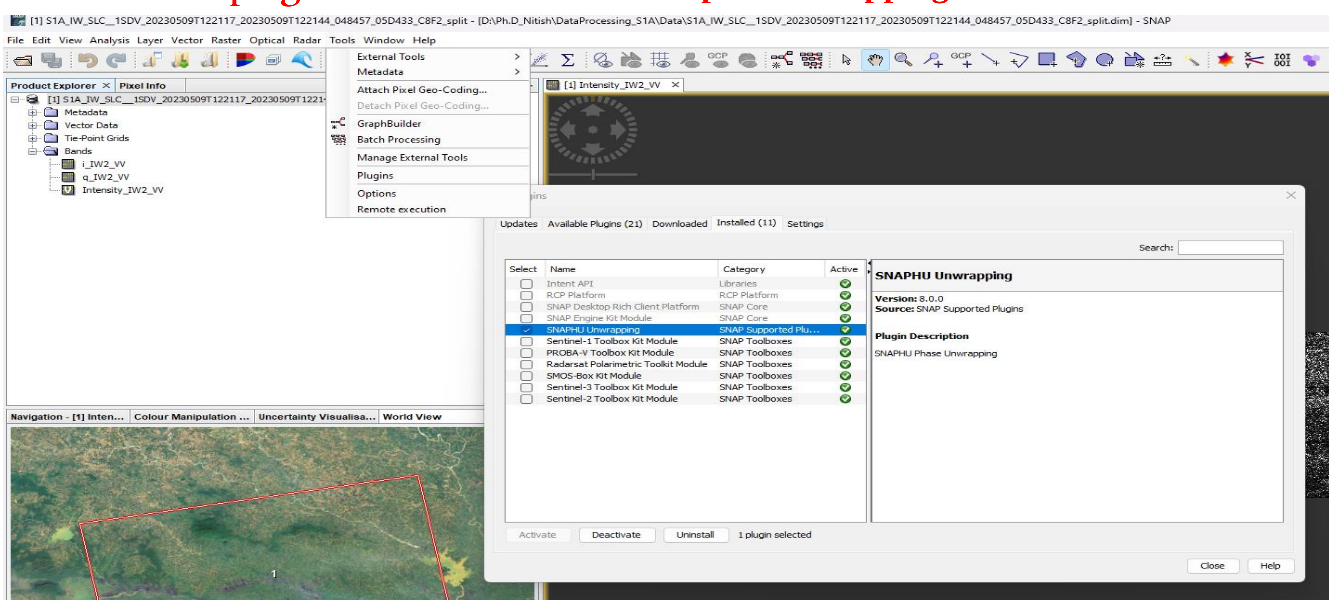

Fig 18: Snaphu plugin check/ install

11.1. **Export (**convert wrapped phase into Snaphu readable format**)**

Note: Error [NodeId: SnaphuExport Please add a target folder]

To be safe from the above error, copy and paste the location where you want to create export output.

Radar → interferometric → unwrapping → Snaphu export.

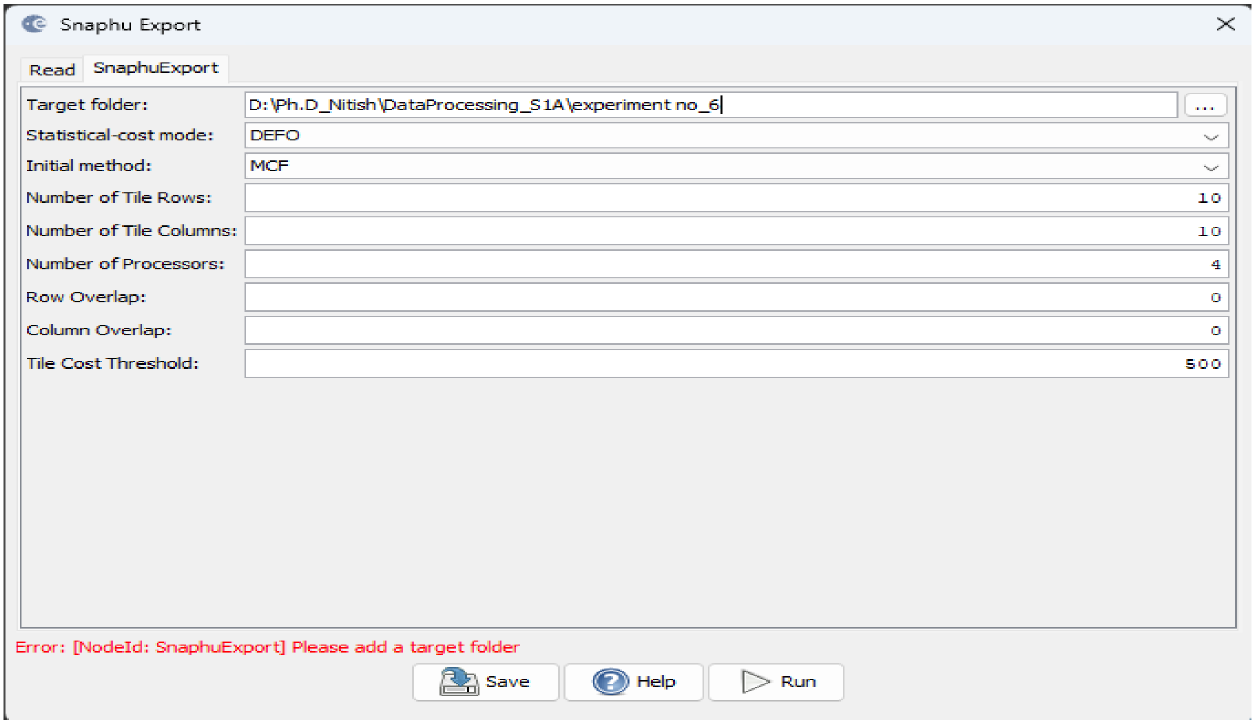

Fig 19: Snaphu export

Data can be modified as per input product.

Output: New folder will be created with the same name as the input product.

11.2. Unwrapping with Snaphu

Notes: for execution of the unwrapping process, there is a need to manually configure the tool.

For configuration: *Tool*→ Left click on *manage external tool* external tool window will open, select snaphu-unwrapping then click on  **shown in below figure.**

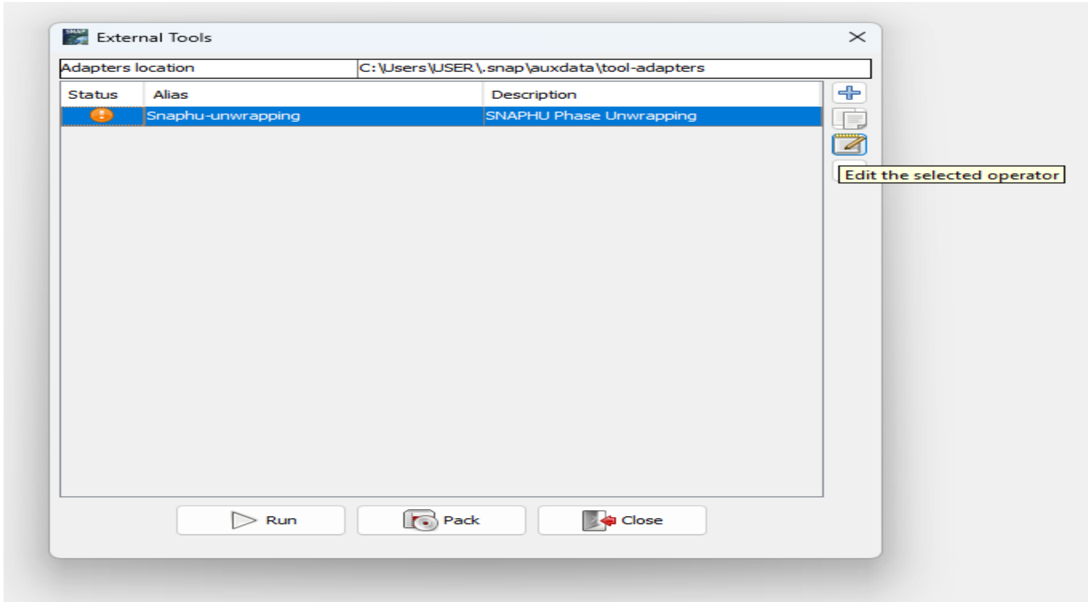

Fig 20: before snaphu unwrapping

In the next window, click on ***system variables*** → check ***USERPROFILE***→ double click on the value ***section*** of userprofile→ paste the ***location of the directory*** **created after the** ***export process.***

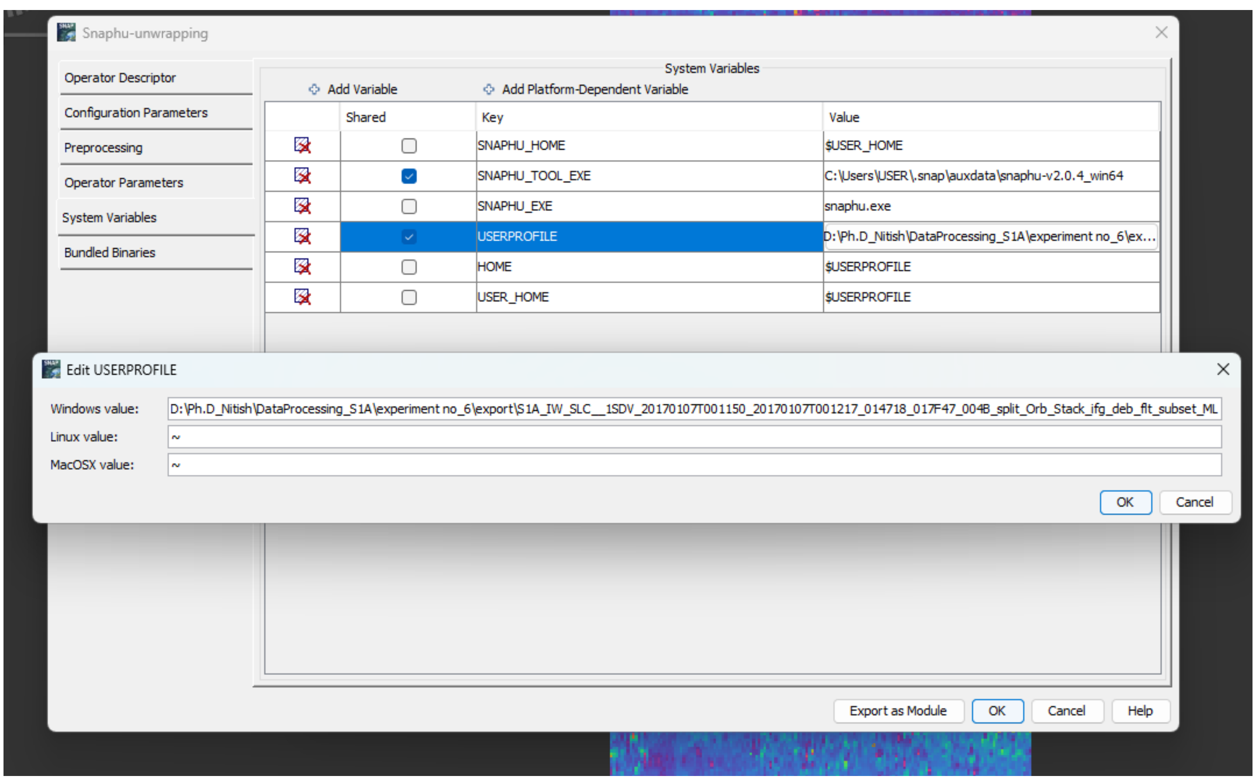

Fig 21: System variables of the Snaphu plugin

Now unwrapping can be started:

Goto *Radar → interferometric → Unwrapping*

Provide *input as per your choice (interferometric/ subset/ multilooking)*, then check on *display execution output*, provide *output folder created after export*, then click on RUN.

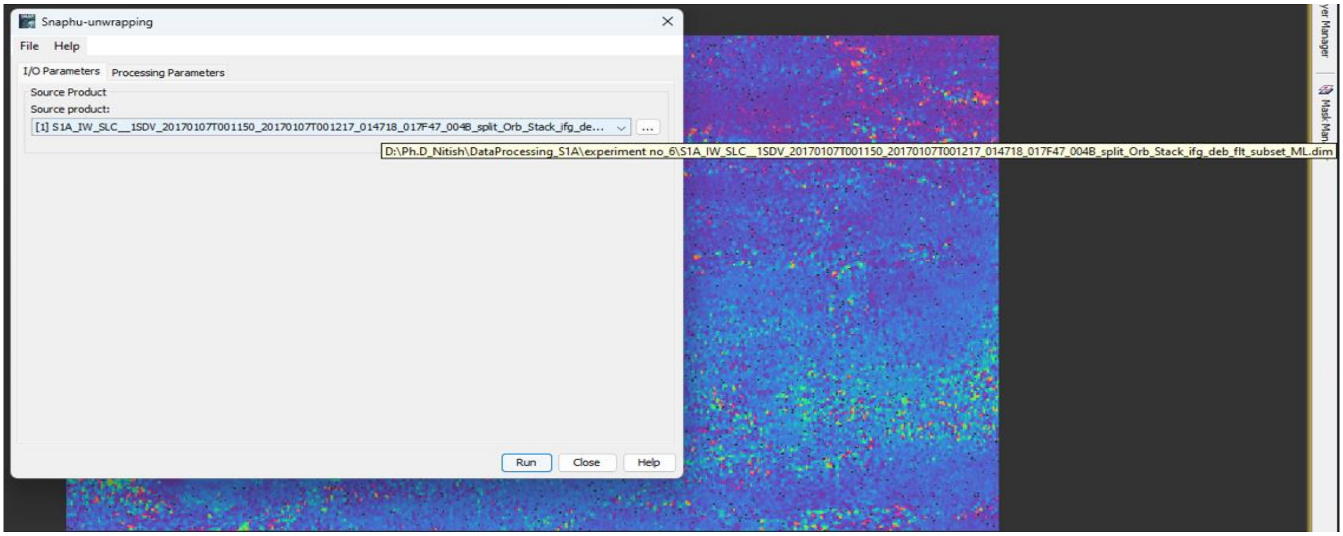

Fig 22: input product for unwrapping.

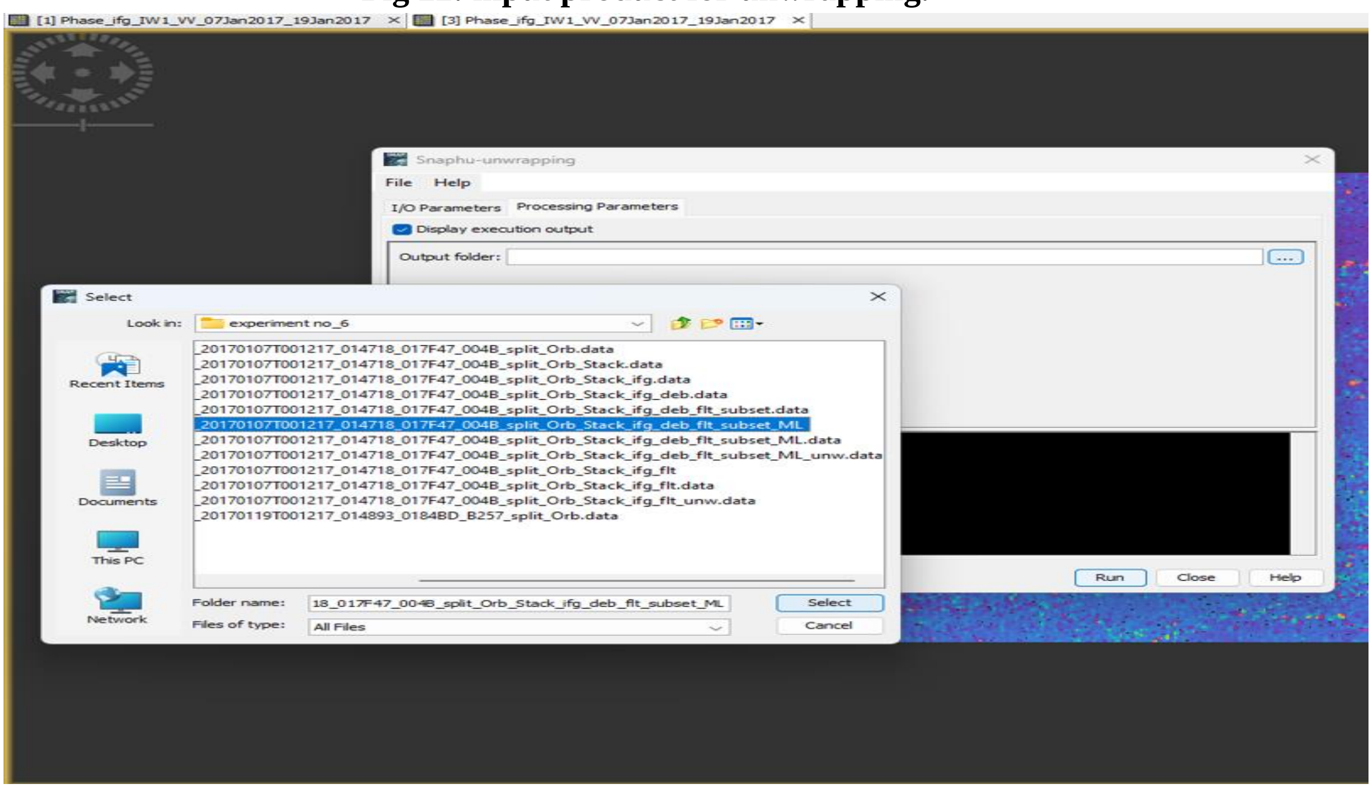

Fig 23: provided output directory

11.3. Import (add required metadata/ geocoding to unwrapped phase):

Radar → interferometric → Unwrapping → Snaphu import

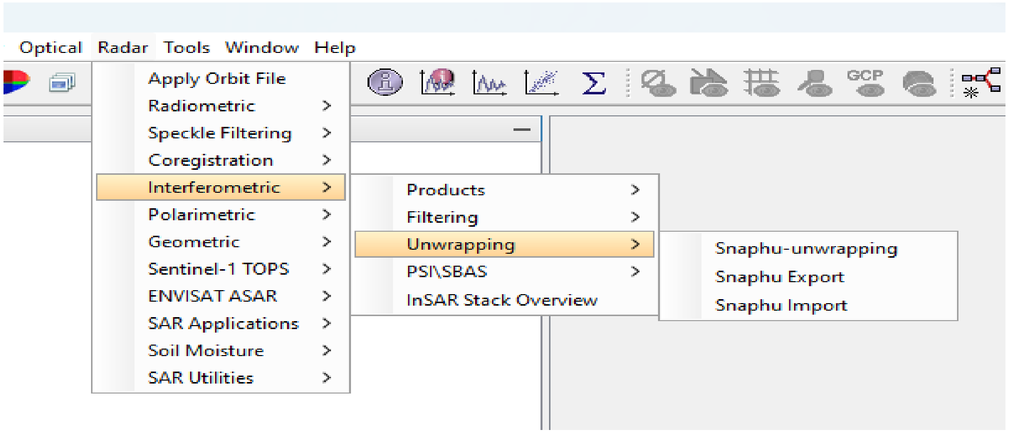

Fig 24 : Snaphu import

Includes:

- **Read-Phase:** Here, you select the *output product* (before the export) from the dropdown menu.
- **Read-Unwrapped-Phase:** Select the icon to ... n a file menu and navigate to the export directory. Select the *.hdr file of the unwrapped phase (here UnwPhase_ifg_[…].hdr). Note: The error message will then vanish if you proceed to the next tab.
- **SnaphuImport:** *Leave the option* "Do NOT save Wrapped interferogram in the target product" unchecked, because it is required in the later step.
- **Write:** To store the imported unwrapped band in a separate product recommended), add '_unw' to the output name (here: S1A_IW_SLC__1SDV_20170107T001150_20170107T001217_014718_017F47_004B_split_Orb_Stack_ifg_flt_unw) and click Run

Output

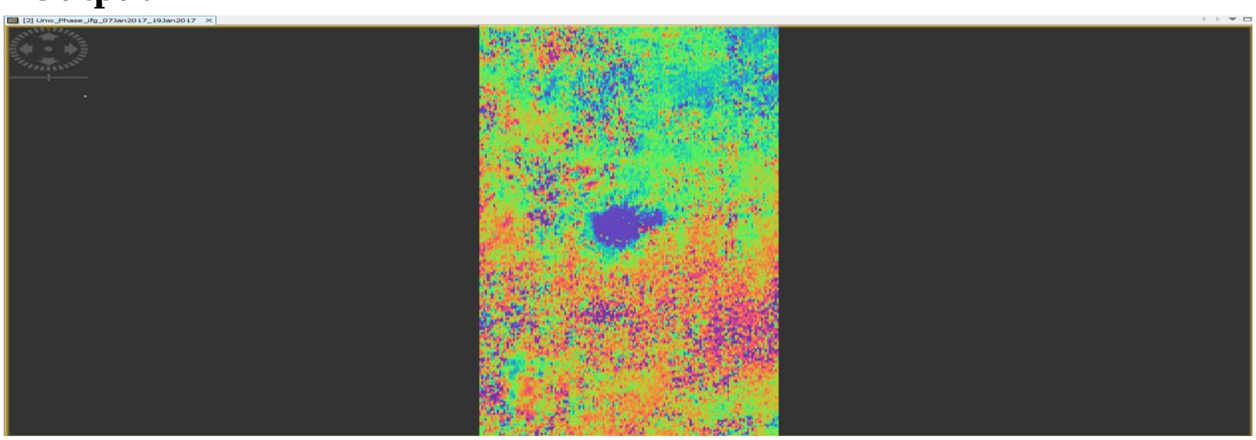

Fig 25 : unwrapped phase

12. Phase to Displacement *(convert radian units into absolute displacements)*:

Radar → Interferometric → Product → Phase to Displacement.

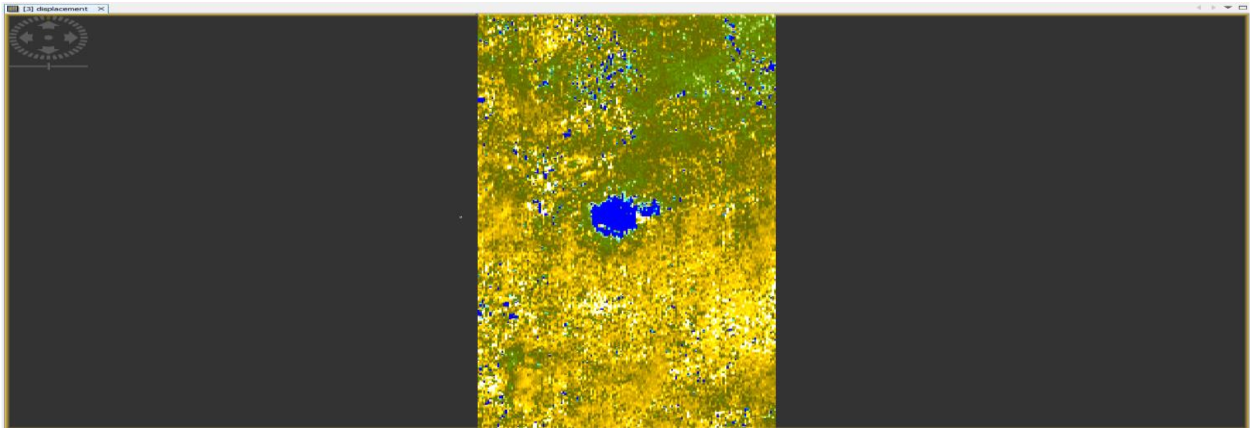

Fig 26: displacement product.

Histogram.

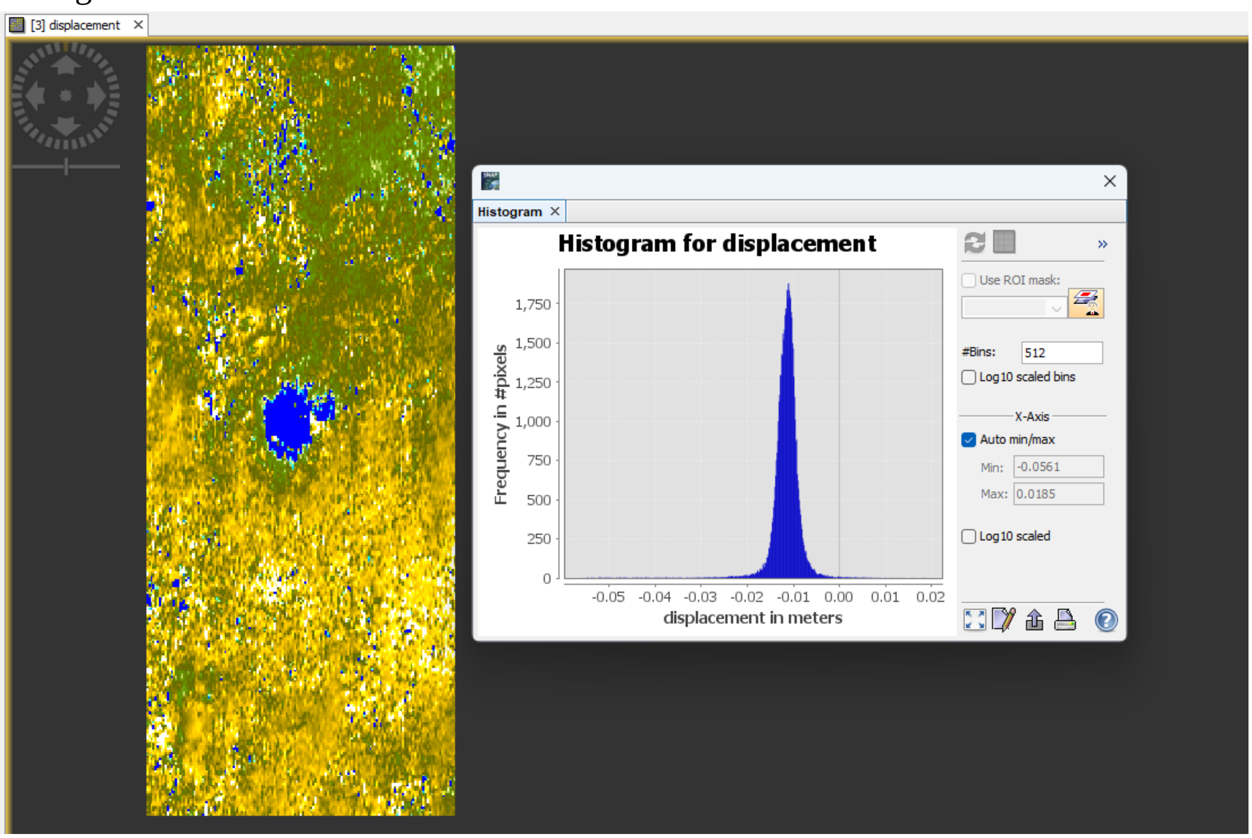

Fig 27: Histogram for displacement.

- Using this w diagonally to know profile plot of specific area
- digitize a line and use the Profile Plot tool to alize single displacement patterns and their ranges.

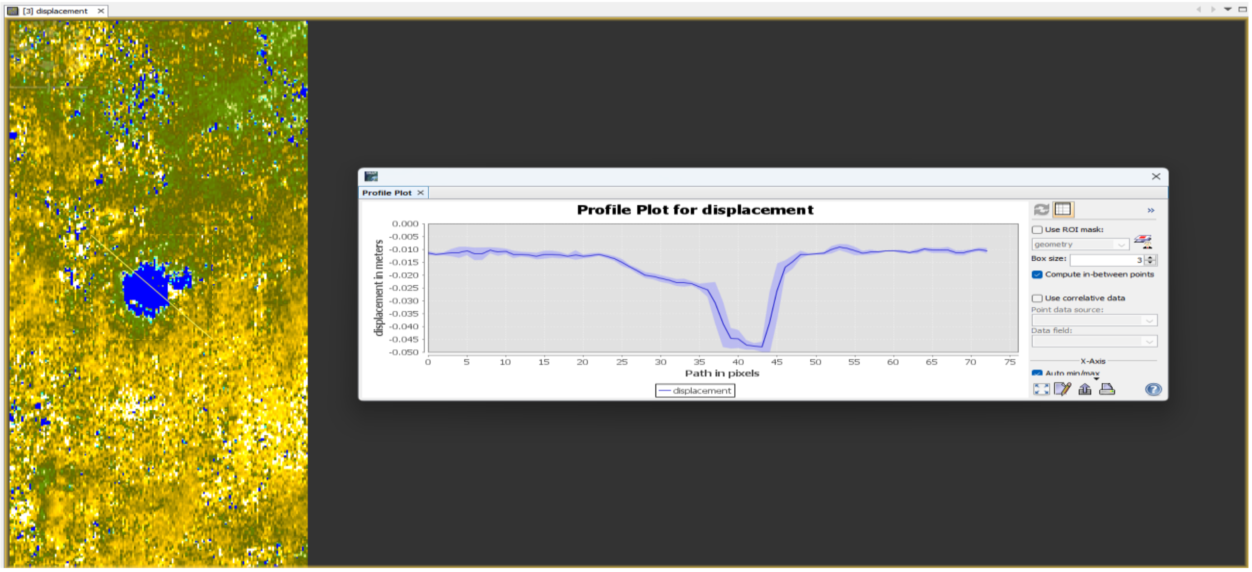

Fig 28: profile plot for displacement.

13. Terrain Correction (Do this for both multilooking product and displacement product)

Radar → Geometric → Terrain Correction → Range Doppler Terrain Correction.

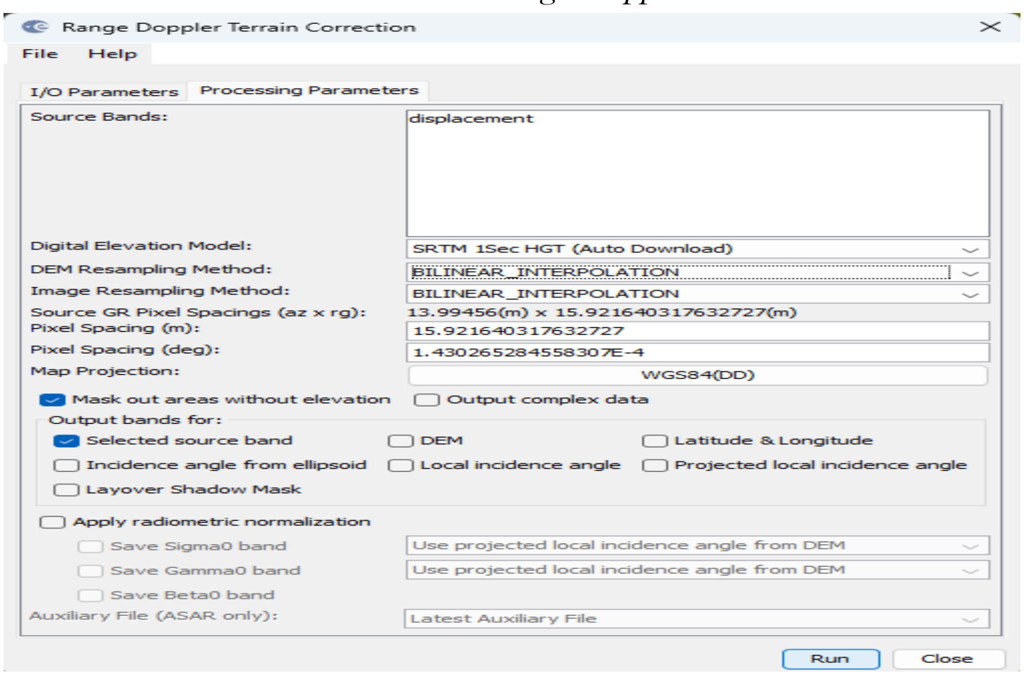

Fig 29: terrain correction processing parameters

Output:

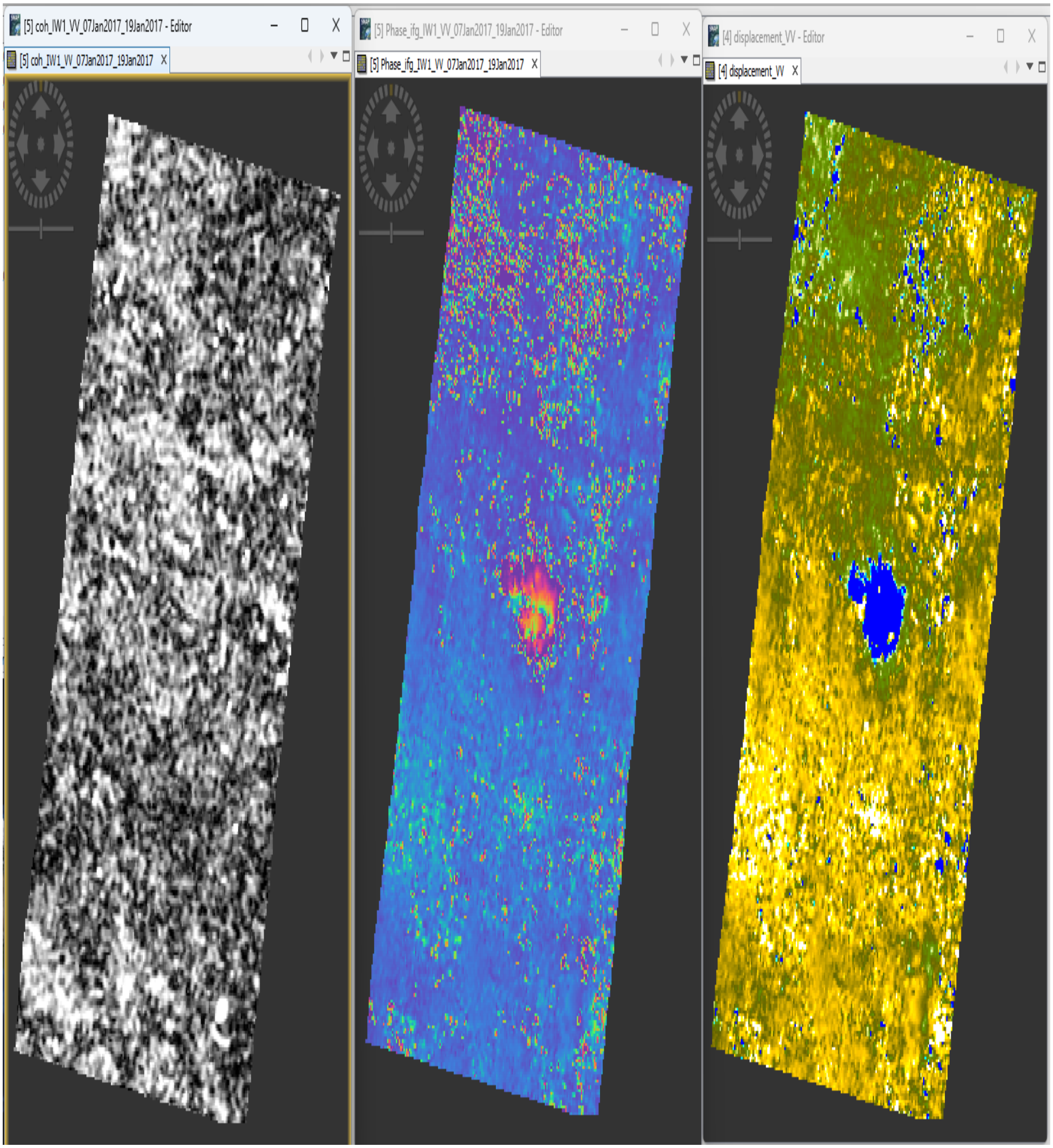

Fig 30: a. Coherence b. Interferogram c. displacement.

14. Export steps.

- *File > Export > Other > View As Google Earth KMZ*
- *File > Export > GeoTiff*

15. Import to google earth

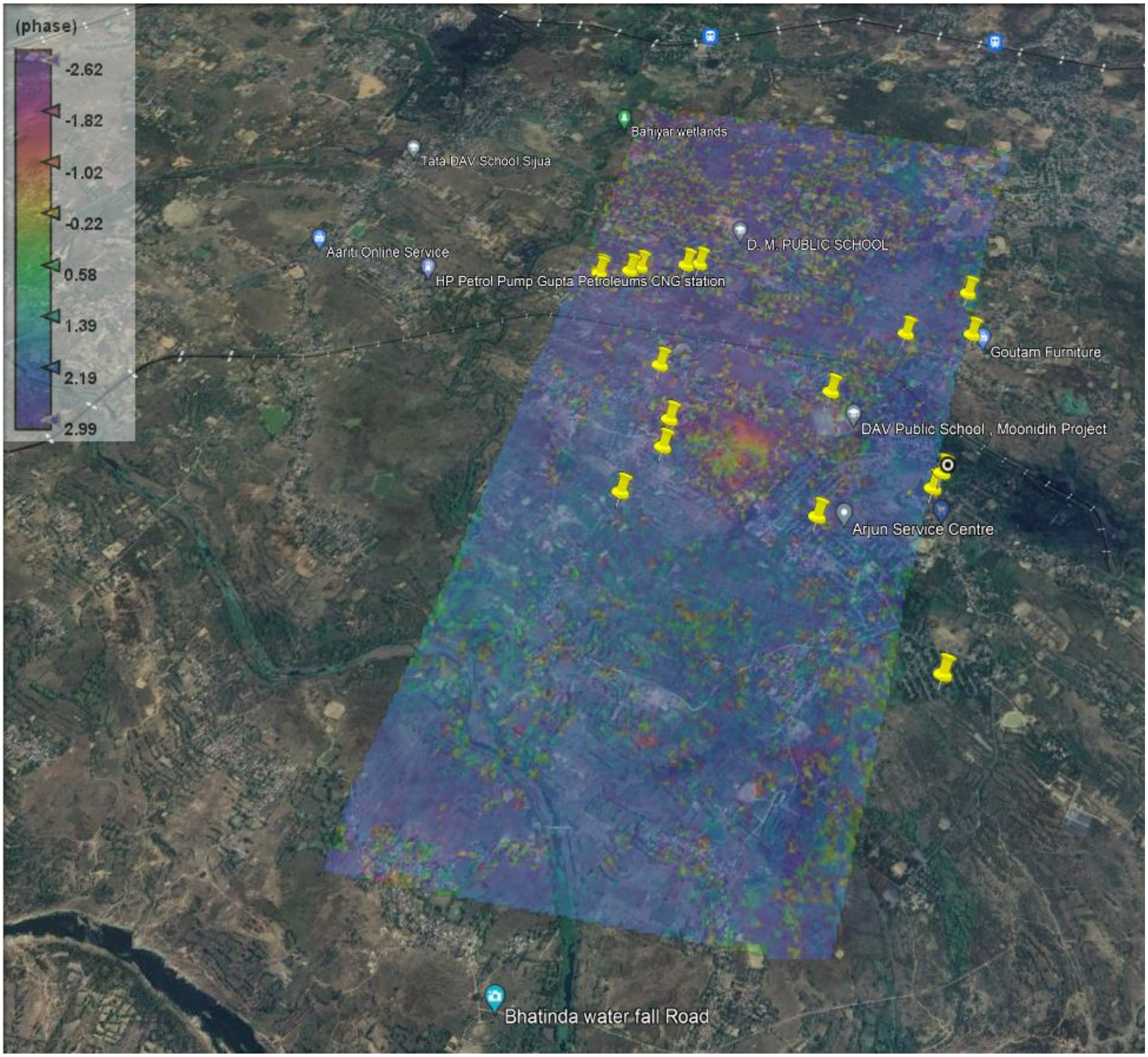

Fig 31: interferogram as kmz file on google earth

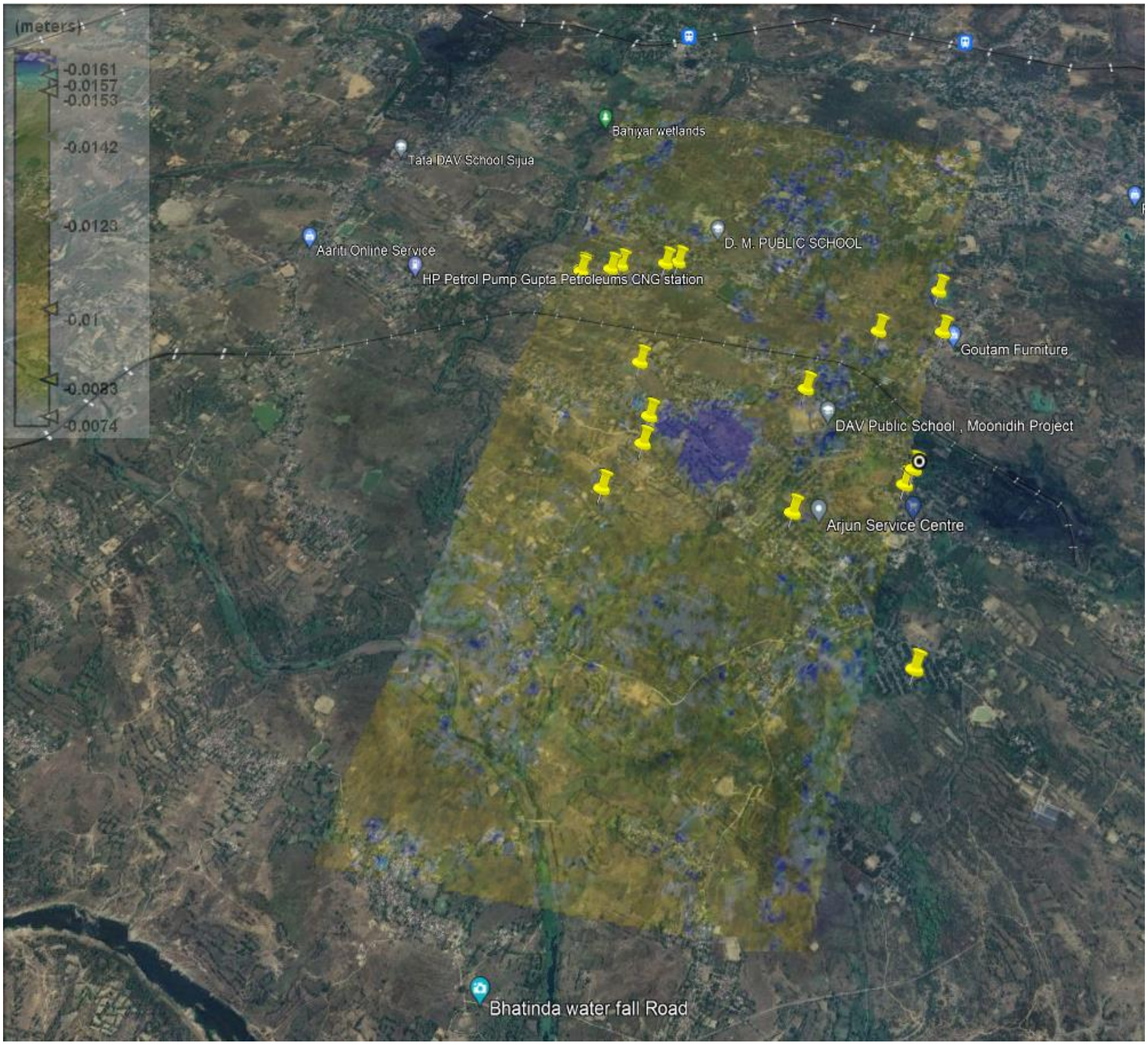

Fig 32: Displacement as kmz file on google earth

16. **Map generation using Arcmap**

- Using geotiff create maps in Arcmap application.

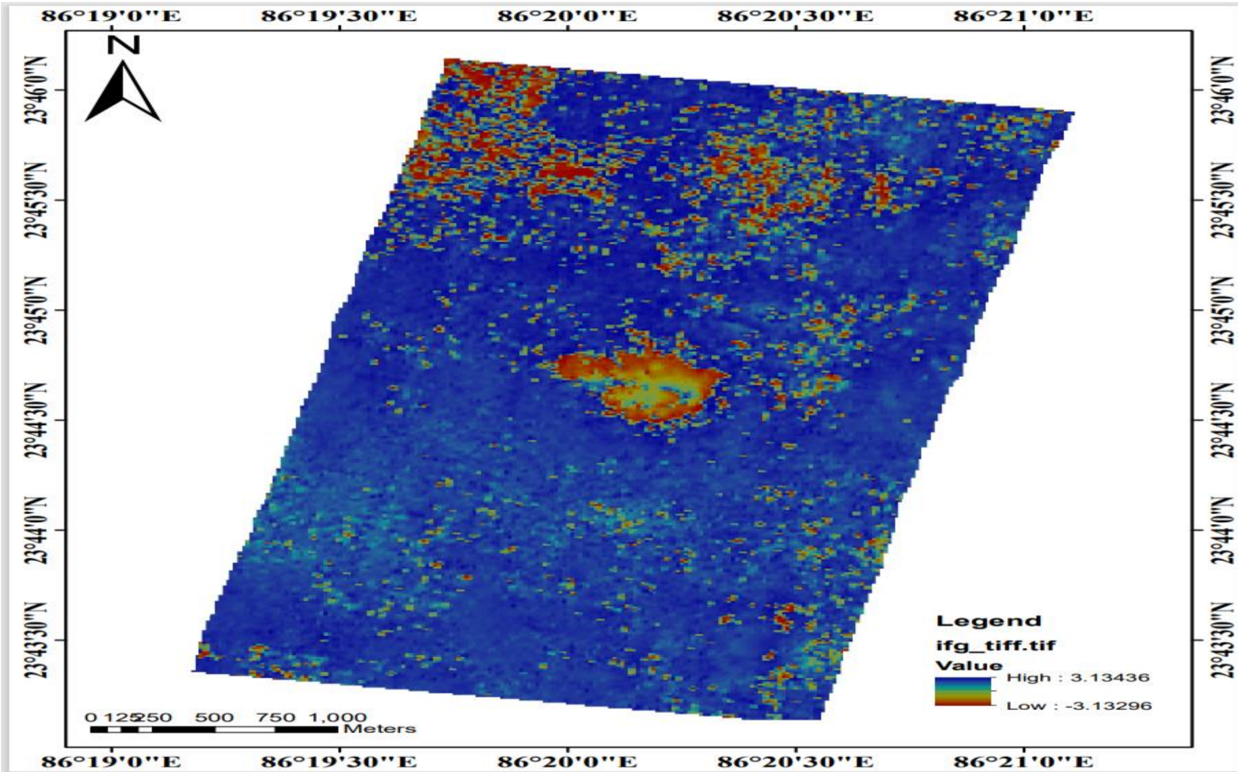

Fig 33: Interferogram map.

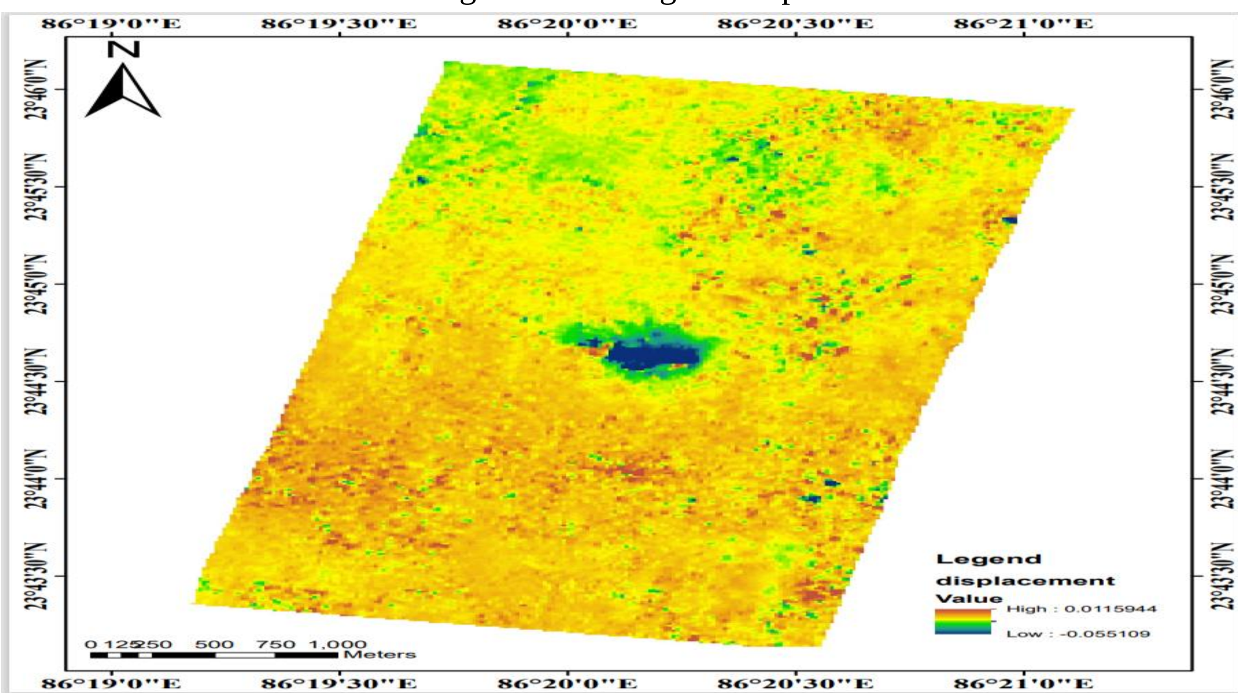

Fig 34: displacement map.