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12/19/2024

Radar AssignmentCourse: Advanced Remote Sensing (651.030)

CONTENTS

Step 1: Dataset Search and Download	2
Step 2: Data Preparation and Analysis with SNAP:	3
Step 3: Generation of Topographic Interferogram:	5
Step 4: Generation of Differential Interferogram	6
Step 5: Generation of displacement map	8
References:	13

Figure 1 Dataset search in Copernicus browser	2
Figure 2 Search Results from Copernicus Browser	2
Figure 3 Dataset selection and download from Copernicus Browser	3
Figure 4 Loading the products into Snap	4
Figure 5 S-1 TOPS Split tool parameters	4
Figure 6 Orbit file application	5
Figure 7 S-1 Back Geocoding tool parameters	5
Figure 8 Phase interferogram generated with burst boundaries (black lines in the image)	6
Figure 9 S-1 TOPS Deburst tool has removed the burst boundaries from the image	6
Figure: 10 Result after Topographic phase removal	6
Figure: 11 Topographic Phase isolated from the interferogram	7
Figure: 12 Result of Multilooking process	7
Figure 13 Result after applying the Goldstein Phase Filtering	7
Figure 14 Snaphu extracted to the snap installation folder	8
Figure 15 Running the Snaphu Export tool in Snap	8
Figure 16 Updating the CORRFILE parameter in snaphu.conf	9
Figure 17 Executing Snaphu in Command prompt	9
Figure 18 Displacement map after range terrain correction with a DEM	10
Figure 19 Collage of 2023 Turkey–Syria earthquake (Wikipedia, 2023)	11
Figure 20 Final Displacement Map	12

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_B E0B. (January 29, 2023).
- After the event: S1A_IW_SLC__1SDV_20230210T033451_20230210T033518_047168_05A8CD_E 5B0. (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.

SNAP 11	
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help	
: <== \$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$\$	% I
Product Explorer × Pixel Info _	
V 🗟 [1] S1A_IW_SLC_1SDV_20230210T033451_20230210T033518_047168_05A8CD_E5B0	
> 🛄 Metadata	
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> 🖾 Bands	
[2] S1A_IW_SLC_1SDV_20230129T033452_20230129T033519_046993_05A2FE_BE0B	
> 🛄 Metadata	
> 🛄 Vector Data	
> 🛄 Tie-Point Grids	
> 🔯 Quicklooks	
> 🖾 Bands	

Figure 4 Loading the products into Snap

Sub-swath Selection: To focus on the specific region of interest, we extracted the relevant subswaths 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.

S-1 TOPS Split ×	S-1 TOPS Split ×
File Help	File Help
Price reip I/O Parameters Source Product source: [1] S1A_W_SLC_1SDV_20230210T033451_20230210T033518_047168_05A8CD_E580 Target Product Name: S1A_IW_SLC_1SDV_20230210_IW2_split If Sive as: BEAM-DIMAP	File Help Processing completed in 120 seconds (11 MB/s 5 MPixel/s) I/O Parameters Processing Parameters Subswath: IW2 Polarisations: VH WV Bursts: I to 9 (max number of bursts: 9) I to 9 (max number
Directory: C:\Users\Bamidele\Downloads\Radar Assignment	
<u>R</u> un <u>C</u> lose	<u>R</u> un <u>C</u> lose

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.

C Apply Orbit File X	C Apply Orbit File X
File Help	File Help
Processing completed in 23 seconds (58 MB/s 30 MPixel/s)	Processing completed in 19 seconds (71 MB/s 37 MPixel/s)
I/O Parameters Processing Parameters	I/O Parameters Processing Parameters
Source Product	Source Product
source:	source:
[3] S1A_IW_SLC1SDV_20230210_split ~	[4] S1A_IW_SLC_1SDV_20230129_IW2_split ~
Target Product	Target Product
Name:	Name:
S1A_IW_SLC1SDV_20230210_split_Orb	S1A_IW_SLC_1SDV_20230129_split_Orb
Save as: BEAM-DIMAP	Save as: BEAM-DIMAP
Directory:	Directory:
C:\Users\Bamidele\Downloads\Radar Assignment	C:\Users\Bamidele\Downloads\Radar Assignment
✓ Open in SNAP 11	✓ Open in SNAP 11
Run Close	Run Close

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.

S-1 Back Geocoding			C 5-1 Back Geocoding		
ProductSet-Reader Back-Geocodi	ing Write				ProductSet-Reader Back-Geocoding Write Target Product
File Name S1A_IW_SLC1SDV_20230210_split_Orb S1A_IW_SLC1SDV_20230129_split_Orb	Type Derived fro Derived fro	Acquisition 10Feb2023 29Jan2023	Track 21 21	Orbit 47168 46993	Name
S-1 Back Geocoding ProductSet-Reader Back-Geocodi	ing Write				SIA_WL_SICISOV_20230210.ppir_Oht_Stack Save as: BEAM-DIMAP Unectory: C:\UternBamideleiDownload/Radar Assignment
Digital Elevation Model:	SRTM 3Sec (Auto Download)				
DEM Resampling Method:	BILINEAR_INTERPOLATION				
Resampling Type:	BILINEAR_INTERPOLATION				
 Mask out areas with no elevation Output Deramp and Demod Phase Disable Reramp 					Processing completed in 9.4 minutes (7 MB/s 2 MPixel/s) By Save Processing

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.

C Interferogram Formation X	
File Help	and the second
Processing completed in 95 seconds (42 MB/s 11 MPixel/s)	and the second
I/O Parameters Processing Parameters	
Source Product	
Source product:	
[7] S1A_IW_SLC_1SDV_20230210_split_Orb_Stack ~	
Target Product Name:	
S1A_IW_SLC_1SDV_20230210_split_Orb_Stack_ifg	the second se
Save as: BEAM-DIMAP	
Directory:	
C:\Users\Bamidele\Downloads\Radar Assignment	
Open in SNAP 11	
Run Close	

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.

C Topographic Phase Rer	noval >		
File Help			
Processing completed in 7.	7 minutes (13 MB/s 3 MPixel/s)		2 Section
I/O Parameters Proce	ssing Parameters	the subject of the second s	
Orbit Interpolation Degree	· B		
Digital Elevation Model:	SRTM 1Sec HGT (Auto Download) 🗸 🗸	the second s	
Tile Extension [%]	100 ~	And the second	
	Output topographic phase band	Contraction of the second s	
	Output elevation band		and the state
	Output orthorectified Lat/Lon bands		
		and the second	
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	<u>R</u> un <u>C</u> lose		

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.

Q	> ··· Program Files	> esa-snap	> snaphu >	Search	n snaphu Q
lõ		∜ Sort ~ 🔳	View ~ ···		Preview
	Name		Date modified	Туре	Size
	💼 bin		12/17/2024 12:49 PM	File folder	
•	🚞 config		12/17/2024 12:49 PM	File folder	
	🧰 man		12/17/2024 12:49 PM	File folder	
	src 🔁		12/17/2024 12:49 PM	File folder	
	README		12/17/2024 12:45 PM	File	5 KB

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.

😨 Snaphu Export	×
Read SnaphuExport	
Target folder: C:\Users\Bamidele\Downloads\Radar Assignment\snaphu_export	
Statistical-cost mode: DEFO	~
Initial method: MCF	~
Number of Tile Rows:	10
Number of Tile Columns:	10
Number of Processors:	4
Row Overlap:	0
Column Overlap:	0
Tile Cost Threshold:	500

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.

					4117
	snaphu.e	conf	×	+	
File	Edit	View			
####	*****	####			
CORR	FILE		coh_IW2_VV	_10Feb2023_29Jan2023	.snaphu.img
#### # Ou ####	######## tput fi ########	##### les # ######			
OUTF #LOG	ILE FILE		UnwPhase_i snaphu.log	fg_W_10Feb2023_29Ja	n2023.snaphu.img

Figure 16 Updating16 the CORRFILE parameter in snaphu.conf

Unwrapping tile at row 9, column 8 (pid 68136)
Unwrapping tile at row 9, column 9 (pid 31552)
Assembling tiles
Running optimizer for secondary network
Flow increment: 1 (Total improvements: 0)
153 incremental costs clipped to avoid overflow (0.005%)
Treesize: 9755 Pivots: 19623 Improvements: 836
Flow increment: 2 (Total improvements: 836)
107 incremental costs clipped to avoid overflow (0.004%)
Treesize: 9755 Pivots: 11 Improvements: 0
Flow increment: 3 (Total improvements: 836)
102 incremental costs clipped to avoid overflow (0.004%)
Treesize: 9755 Pivots: 3 Improvements: 0
Flow increment: 4 (Total improvements: 836)
102 incremental costs clipped to avoid overflow (0.004%)
Treesize: 9755 Pivots: 0 Improvements: 0
Integrating secondary flows
Output written to file UnwPhase_ifg_VV_10Feb2023_29Jan2023.snaphu.img
Program snaphu done
Elapsed processor time: 0:09:07.87
Elapsed wall clock time: 0:02:15
PS C:\Users\Bamidele\Downloads\Radar Assignment\snaphu_export\S1A_IW_SLC1SDV_20230210_dinsar_ML_flt>

Figure 17 Executing17 Snaphu in Command prompt.

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

Snaphu Import	t		×
1-Read-Phase	2-Read-Unwrapped-Phase	3-Snaphulmport 4-Write	
Source Product			
Name:			
UnwPhase_ifg_VV_10Feb2023_29Jan2023.snaphu.img			~
Data Format:	Any Format		~
Advanced optio	ns		

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 <u>https://en.wikipedia.org/wiki/2023_Turkey%E2%80%93Syria_earthquakes#/media/Fi</u> le:Collage of 2023_Turkey%E2%80%93Syria_earthquake.jpg