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Measuring Earthquake Induced Deformation in South of Halabjah (Sarpol-e-Zahab) Using Sentinel1 Data on November 12, 2017

Hamit Beran GÜNCE [1] and Bekir Taner SAN [2,*]

[1] Akdeniz University, Dept. of Geological Engineering 1; hamitberan@gmail.com
[2] Akdeniz University, Dept. of Geological Engineering 2; tanersan@akdeniz.edu.tr
* Correspondence: tanersan@akdeniz.edu.tr; Tel.: +90-242-310-63-59

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Abstract: InSAR technology is a one of the powerful tool to measure deformation and/or deposition on the ground surface. In addition to that the mass movement can be monitored using Synthetic aperture radar interferometry (InSAR) techniques. The earthquake that occurred on 12 November 2017 in South of Halabjah the magnitude of 7.2 caused 350 people to lost their lives and more than 2,500 people were injured. The aim of this study is to measure the deformation due to the earthquake using "Interferometric Wide Swath" which is one of the four display types of Sentinel 1 data. In order to carry out this process, two type of data sets were used which are SRTM data and Sentinel 1 images acquired on November 7 and 19, 2017. In this study, VV polarization with C band were used generate interferogram. During the study, SNAP 5.0 free image analysis and processing software by ESA. According to obtained results, minimum and maximum surface displacement were acquired as -0.45 and 0.49 meters. When comparing the results with faults, the results are appropriate for the tectonic structures. Using InSAR technologies with open source software and free data, it is possible to produce displacement maps just after the earthquake.

Keywords: InSAR, Sentinel 1, Halabjah

1. Introduction

Earthquakes are one of the most destructive natural phenomena in the world. The rapid and accurate estimation of the location and the amount of deformation is an challenging task in geosciences. In addition, it is important for rescue operation [1,2]. InSAR technology is a one of the powerful tool to measure deformation and/or deposition on the ground surface. Sentinel-1 (A/B) data provides Synthetic Aperture Radar (SAR) images for investigating geohazard in all over the world [3]. Sentinel 1 provides and radar data having a range between 5 m to 22 m depend on the different products [4]. Before Sentinel 1 operating, there are some other SAR systems such as ERS-1 and 2, Radarsat-1 and 2, ENVISAT and JERS. However, these sensor systems have complited their lives. Sentinel 1 can be easily accessible was launched on 2014 [5,6].

The destructive earthquake of magnitude 7.2 struck South of Halabjah (Sarpol-e-Zahab) on November 12, 2017. The oblique-thrust faulting at mid-crustal depth (almost 19 km) caused the earthquake. The preliminary mechanism solutions reveals the rupture happened on a fault dipping shallowly to east-northeast, or on a fault dipping steeply to the southwest. The Arabian plate moves towards the north at a rate of approximately 26mm/yr. The earthquake location is on this area [7]. As a result of the two convergent palates which are Eurasia and Arabia, the Zagros mountains in

Iran was formed. This earthquake caused at least 452 people to lost their lives and thousands people were injured [8].

Due to this devastating earthquake, no healthy news was obtained and the extent of the damage to the area could be determined by remote sensing. The aim of this study is to measure the deformation due to the earthquake using "Interferometric Wide Swath" which is one of the four display types of Sentinel 1 data.

2. Study Area and Data Used

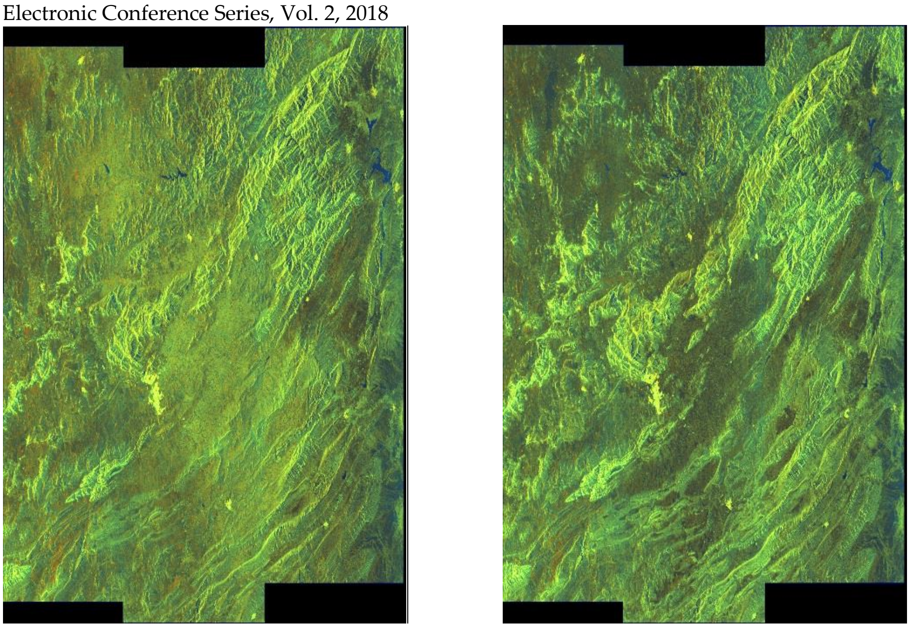
Study area is located in South of Halabjah which is the closest city of the earthquake epicenter that was located at 34.88°N and 45.84°E near the Iran–Iraq border (According to the National Center of Broadband Seismic Network of Iran). The most of the damages occurred in Sarpol-e Zahab, Qasr-e Shirin and Eslamabade-e gharb counties [9] (Figure 1).

Figure 1. Study aera (from Google Earth)

In this study main data source is Sentinel 1 data sets. Sentinel-1Asatellite was launched on April 3rd, 2014, by ESA [5,6]. In this study, a dataset that consists of four SAR having the C-band from S1A sensor of Sentinel satellite in TOPSmode [5] (Figure 2).

During the study, image processing process were carried out using the open source software, SNAP 5.0 from ESA (European Space Agency) [10]. The study area is covered by the data, and assemble 3 slices of SAR data along tracks for better ground coverage. Figure 2 shows the quick look images of the used data sets.

A pair of Sentinel-1A radar image acquired in TOPS mode on the descending track 6 were used as shown in Table 1. These datasets have the shortest temporal and perpendicular baselines available (Table 1).



(a) **(b)**

Figure 2. Sentinel-1 Data 20171107 (a), 20171119 (b)

Table 1. Detailed parameters of the Sentinel-1 data

Master-slave (yymmdd)	Orbit direction	Track	Incidence (degree)	Pixel spacing in slant range (m)	Pixel spacing in azimuth (m)	Wavelength (cm)
20171107-20171119	Descending	6	41-46	2.3	13.9	5.6

3. Methodology

This study can be categorized into four main processing steps which are coregistration of SAR images, InSAR data analysis, phase unwrapping, and finally displacement measurements. At the beginning of all process steps, the Sentinel-1 IWS SLC data sets can be acquired from the ESA's Sentinel Scientific Data Hub website. This product contains three sub- swaths ("burst SLC: Single Look Complex"). Figure 3 shows the processing steps of methodology. After radiometric calibration, the individual bursts can be merged into one Single Look Complex (SLCFollowing the radiometric calibration, the individual bursts can be merged into one SLC. Next, resampling of SLC was performed with a reference SLC image. This can be called as rough coregistration process. This operation was generated with a consideration of the terrain topography.

3.1. Coregistration of the Data Sets

Coregistration process is indispensable step for InSAR image processing. This is because, this step directly affects the resultant data. Accuracy of the coregistration can be obtained at a 1/100 azimuth pixel level [11]. The strong Doppler variations within each burst cause significant phase jump effects, even with coregistration accurcy at 1/100 pixel level in the azimuth direction.

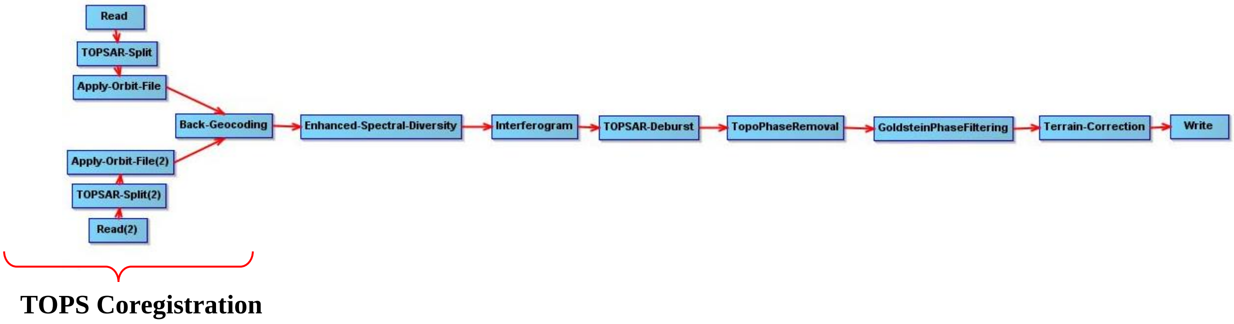


Figure 3. Flow chart of the Sentinel-1 TOPS data coregistration.

3.2. InSAR Data Analysis

In order to generate interferogram, minimum two coregistered images are required. One image is used for master and the other one(s) is/are used as the slave(s) [12]. The interferometric image was created with cross multiplying the master image with the complex conjugate of the slave. while the phase represents the phase difference between the two images, the amplitude of both images is multiplied [12]. In this study, minimum time period of the two image data sets is 12 days. One is before the earthquake and the other one is after earthquake [13].

3.3. Phase Unwrapping

Another important processing step is phase unwrapping which is related to interferogram determination [14]. The information about the height is computed from the interferometric phase using SAR analysis technique. This computation also maintains the generation of the Digital Elevation Model (DEM) [15]. The fundamental observation is the 2-D phase signal which is one of the absolute phase signal for interferometric applications [16].

The interferograms are smoothed with a power spectrum filter and then unwrapped using the SNAPHU software. SNAPHU is a statistical-cost network-flow algorithm for phase unwrapping developed at Stanford University by Curtis Chen and Howard Zebker [12].

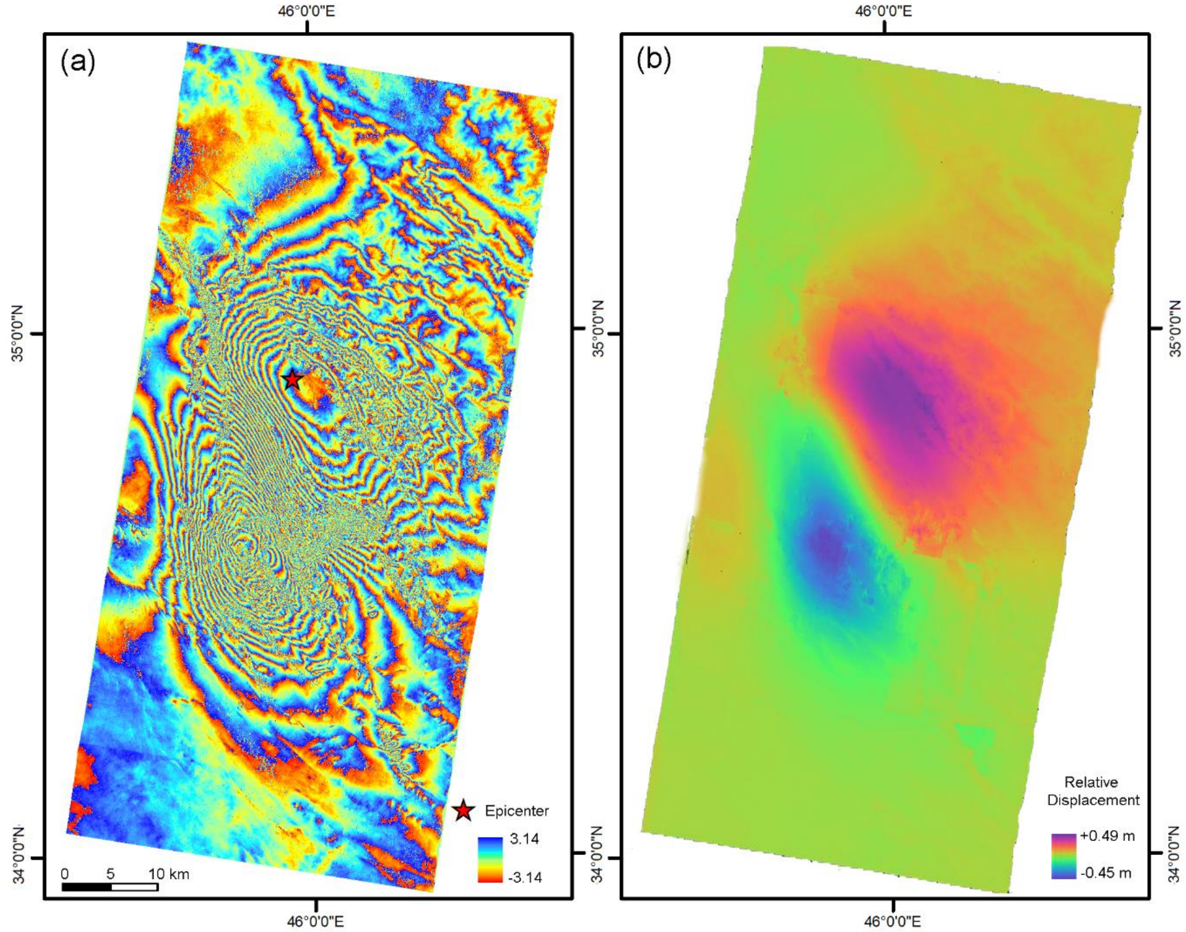
3.4. Displacement Measurements

During the InSAR application, a variation in range the look direction is measured. However, this measurement is not able to determine the 3-D displacement vector. In order to measure displacement vector, additional information is required such as information from interferograms from both ascending and descending satellite orbits or integrated data from multiple platforms which can be defined as different satellite positions [15].

4. Results and Discussion

The interferogram and the deformation obtained from Sentinel-1 data sets on the study area is given in Figure 4 (a) and (b). This results were obtained from a 12-day period as given in previously. In Figure 4 (a), each rainbow color cyle shows the deformation fringes. It can be thought as deformation contours. These color fringes are close to each other in the high deformation areas. As can be seen from the Figure 4 (a), the fault line which results in earthquake can be clearly detected.

Finally, all the color fringes were unwrapped using image processing operation. In Figure 4 (b), reddish and bluish colors show relative deformations. This figure also provides the thrust fault along the study area. In the study, minimum and the maximum surface deformations were obtained as -0.45 and 0.49 meters according to InSAR process. The obtained deformation amounts are directly related about the distance of sensors. This measurements gives the distance differences between sensors and the terrain. Even though this information is relative measurements, it gives us an idea about the spatial distribution about the measurements and the relative amout of the surface deformation.



(a) **(b)**

Figure 4. Geocoded Interferogram(a), Geocoded Unwrapped Phase (b)

5. Conclusions

In this study, Halabjah earthquake on November 12, 2017 were investigated using Sentinel-1 images. The determining surface deformation is important task for earth scientists, planners and also rescue teams. This study was carried out using free data sets (i.e. Sentinel-1) by ESA. This is also important for quick response of producing scientific outputs.

The number of studies will be increased with the amount of high accuracy by increasing the number of free data sets for scientists and researchers in future. This type of various satellite images is required for determining and understanding our tectonically dynamic planet.

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