A PRELIMINARY STUDY OF INSAR TECHNIQUES FOR THE IMPACT OF 2016 TAITUNG EARTHQUAKE

Che-Wei Li[1], Tee-Ann Teo[2]

[1] Master Student, Dept. of Civil Engineering, National Chiao Tung University, Hsinchu, Taiwan 30010.
[2] Professor, Dept. of Civil Engineering, National Chiao Tung University, Hsinchu, Taiwan 30010.
E-mail: lee911047.cv07g@nctu.edu.tw; tateo@mail.nctu.edu.tw

KEYWORDS: InSAR, SBAS, Earthquake, Sentinel-1A

Abstract：On October 6th, 2016, there was an earthquake happened in the southeast of Taiwan. To understand the impact of the earthquake, differential interferometry synthetic aperture radar (DInSAR) such as Small Baseline Subset (SBAS) InSAR approaches is applied to extract the surface movement caused by earthquake using time-series Sentinel-1A images. DInSAR has been widely used to detect and monitor surface deformation with dependable precision. Many natural disasters happened in Taiwan, and many studies are related to these events. This study used Sentinel-1A images and GMTSAR to implement the SBAS for the analysis of surface deformation. The preliminary results show that the earthquake caused slightly uplift deformation in the study area.

1. INTRODUCTION

Taiwan is located in between the Eurasian Plate and the Philippine Sea Plate. Therefore, several earthquakes happened in Taiwan. On 6th October 2016, there was an earthquake (Mw=6.0, ML=5.8) happened near Taiwan. The hypocenter was located near the Taitung city at 22.63°N, 121.34°E, with a depth of about 23.7km.

Thanks to the development of the SAR techniques, we can now observe the surface deformation of the earth, such as the land subsidence, displacement of the mountain and the tiny movement of some structures and facilities (Borghero, 2017). Differential interferometry synthetic aperture radar (DInSAR) (Massonnet et al., 1993) is one of the methods which can monitor the land's variation efficiently. After interferencing Sentinel-1A images, we can receive several interferograms that can reveal the surface deformation with centimeter accuracy. The advanced DInSAR approach such as Small Baseline Subset (SBAS) (Berardino et al., 2002) may reduced the influence of the geometric distortion by restricting length of the perpendicular baselines. The DInSAR techniques have been used to analyze the displacement of the Shanghai coastal area (Yu et al., 2017) and landslide in Guanling (Kang et al., 2017). It can also be applied to analyze the ground deformation after the earthquake(Tung et al.,2019).

In this study, both DInSAR techniques was applied to generate the surface displacement in the Line-of-Sight(LOS) direction. Then, We transformed the LOS into the up-down displacement using elevation and azimuth angles. Finally, the results were compared with *in-situ* GPS station.

2. STUDY AREA

Taitung city is located at the south-east of Taiwan. The land area covers about 109 km^2. As the Beinan river and the Taiping river flowing tour west to the pacific ocean, plenty of sediments was deposited into this region and create a plain. Hence, it is suitable for the development of a settlement. When it comes to the conditions of operating the SBAS, the feature of the study area is one of the significant condition. The coherence shows how similar between the two SAR images. The less alternative to the building and hill in the area, the better coherence to the image pairs. For those regions that are mountainous or covered by vegetation, it is hard to generate stable interference fringe. The growth rate of the plant is usually rapid and will also change the landform severely. Consequently, the variety of vegetation leads to an incoherence situation. In Taitung city, there are many buildings that can lead to good coherence between the SAR images.

©Google ©Google ©Google

(a) Taiwan (b) Location of Taitung and the center of the earthquake (c) Taitung city

Figure 1. Study area

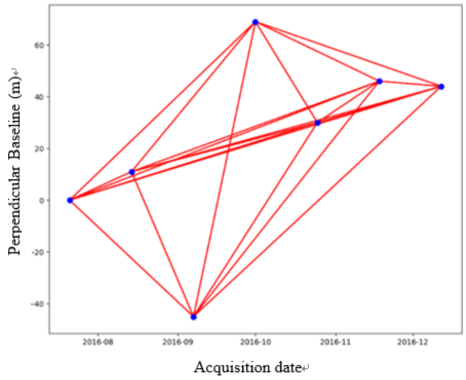
3. DATA AND METHODOLOGY

3.1 Data

We used 7 Sentinel-1A images for interference in our research. These images were with descending passes from July 21 to December 12, 2016. The side-looking angle of the sensor is about 39.3°, and the satellite's heading angle is about -167.6°. Sentinel-1A has four working modes, Interferometric Wide swath (IW), Strip Map Mode (SM), Extra-Wide Swath mode (EWS) and Wave. They are obtained by the IW mode in the single-look-complex (SLC). Their perpendicular baselines are between -45m to 69m.

Acquisition date	Perpendicular Baseline
7/21	0m
8/14	11m
9/07	-45m
10/01	69m
10/25	30m
11/18	46m
12/12	44m

(a) Images' perpendicular baseline and their acquisition date



(b) Distribution of the SAR image pair and their perpendicular baseline

Figure 2. Test data

3.2 DInSAR

The InSAR technique calculates the phase difference between two SAR image over the same area, and the interferogram can be generated by InSAR technique. Furthermore, the DInSAR remove the topographic effect from the interferograms and show only the surface deformation pattern between two images taken at different dates. The SBAS proposed by Berardion et al. (2002) uses multiple small-baseline image pairs to generated small-baseline interferograms. The SBAS can resolve the error caused by long perpendicular baseline and reduce the difficulty of the selection of persistent scatterer point. It can preserve the correlation between small baseline and provide dense deformation maps.

3.3 Persistent point selection

There are many buildings in Taitung city that can steadily reflect the radar signal and can be treated as persistent scatterer points (Ferretti et al 2001). It is benefit for us to choose the points which can be used to observe through these images. The correlation threshold is set to be **0.05** in both conventional DInSAR and SBAS to gain persistent points. By setting this threshold value, we will get more stable and reliable points. If we have enough points, we can generate trend surfaces in different time-series by interpolating these points.

3.4 Line-Of-Sight transformation

After the processing of DInSAR and SBAS, the displacements in LOS direction can be obtained in Taitung city. However, Line-Of-Sight cannot show us the real displacement in vertical direction. In order to see the real impact to the vertical direction, we have to transform Line-Of-Sight(Fuhrmann et al.,2019). The side-looking angle ($\boldsymbol{\theta}$) of the sensor is about 39.3°. We use the Equation (1) (Figure 3) for conversion from Line-Of-Sight to the vertical direction.

$$d_{LOS} \times (\cos\theta) = d_{Up} \qquad (1)$$

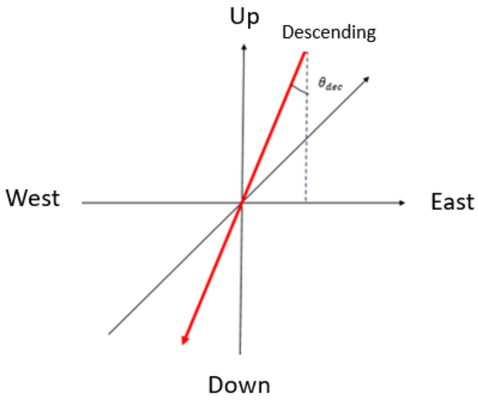
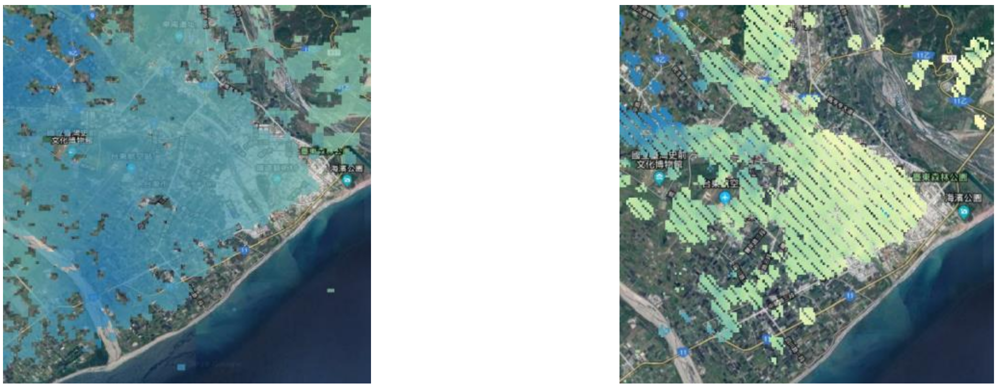


Figure 3. Line-of-sight direction of the satellite observe in descending orbit

4. PREMILANARY EXPERIMENTAL RESULTS

This section presents the results of DInSAR and SBAS. We choose 67 persistent points on both conventional DInSAR and SBAS methods. These persistent points were interpolated into trend surface for the analysis of surface deformation in Taitung city.

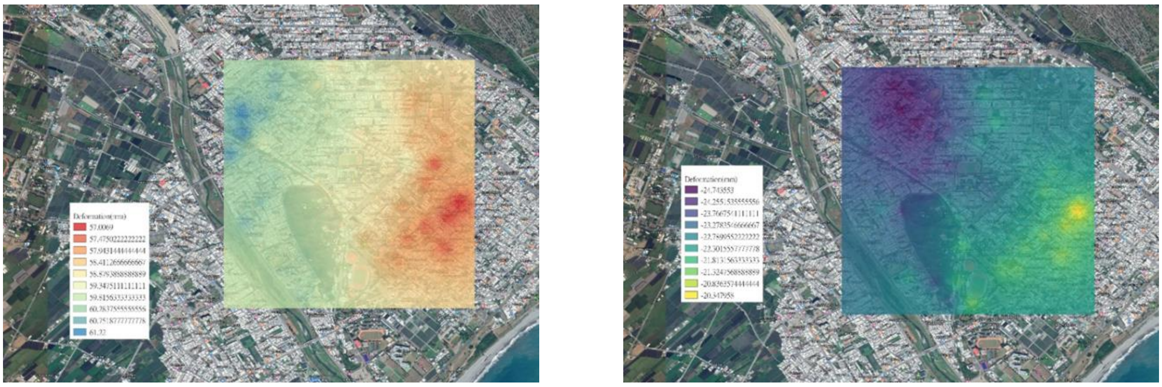


(a) Results of conventional DInSAR (b) Results of SBAS

Figure 4. Results of conventional DInSAR and SBAS

4.1 Results of Conventional DInSAR

We applied conventional DInSAR method to analysis the study area and find out that there is some difference after the earthquake happened. Since the earthquake was happened on October 6, 2016, we observe the alternative of the surface movement during and after the earthquake. The following figures are the trend surface made by the deformation value during 2016/10/1 to 10/25 and 10/25 to 11/18. The deformation had declined from +57mm to -20mm, which means that this area might be facing land subsidence challenge after the earthquake.

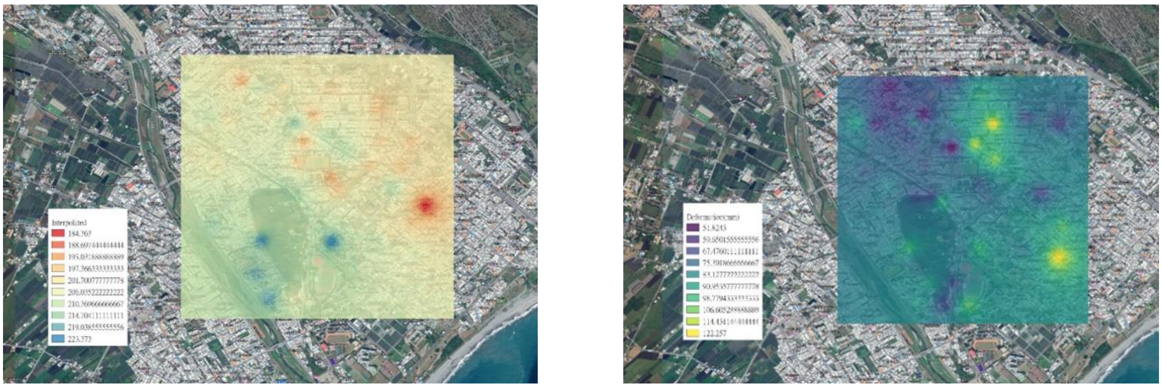


(a) Deformation during 10/1 to 10/25 (b) Deformation during 10/25 to 11/18

Figure 5. Deformation before and after earthquake using conventional DInSAR.

4.2 Results of SBAS

Figure 6a shows that the test region is uplift, ranging from 184mm to 223mm. Figure 6b also shows a similar behavior but ranging from 51mm to 122mm. Before and after earthquake has consistent trend. The results of SBAS were much higher than the results from DInSAR. Additional analysis is needed in the future study.



(a) Deformation during 10/1 to 10/25 (b) Deformation during 10/25 to 11/18

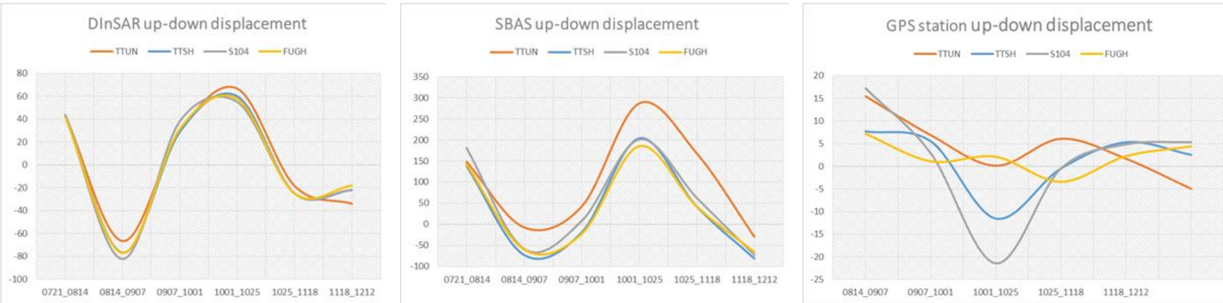
Figure 6. Deformation before and after earthquake using SBAS

4.2 Comparison between conventional DInSAR and SBAS and GPS

This study also used time-series GPS measurement as reference data. The distribution of GPS stations were shown as Figure 7a. Figure 7b provides the horizontal displacement of these GPS stations. In order to compare the data between convertional DInSAR, SBAS and GPS station, we produced three graphs by the data collected from the place which 4 GPS stations located (Figure 8). The behavior of DInSAR and SBAS looks similar, but the intensity of displacements are different level.

(a) Position of GPS stations and epicenter **(b)** Displacements of GPS stations

Figure 7. Distribution of GPS stations



(a) conventional DInSAR (b) SBAS (c) GPS

Figure 8. Displacement in elevation directions.

We found out that although the extent of the displacement between DInSAR and SBAS has a huge variety, the shape of both curves is similar. The displacement on SBAS is much bigger than conventional DInSAR. However, these results are very different from the GPS station. So we select the only station located in Taitung city (TTSH) to compare with conventional DInSAR and SBAS. Due to the tremendous difference among conventional DInSAR, SBAS, and GPS, Figure 9 can not show the changing trend of GPS station. Further investigation is needed on the comparison.

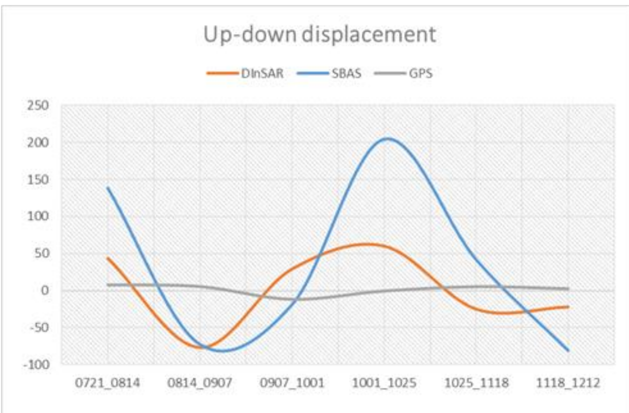


Figure 9. Three datasets at TTSH location

5. CONCLUSIONS AND FUTURE WORKS

The variety tendency between conventional DInSAR and SBAS is similar, but the displacement calculated in SBAS is much bigger than the others. After the earthquake happened in 10/6, the surface deformation had been uplifted in a short time-series and then kept in the subsidence. The deformation value of both conventional DInSAR and SBAS are very different when compare to the GPS station. Additional verification and study are needed to improve the results.

REFERENCE

Berardino, P., Fornaro, G., Lanari, R., Sansosti, E., 2002, A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms. Geoscience and Remote Sensing, 40(11), pp. 2375-2383.

Borghero, C., 2018, Feasibility study of dam deformation monitoring in Northern Sweden using Sentinel1 SAR interferometry. Master's Thesis, University of Gävle, Gävle, Sweden, 2018

Ferretti, A., Claudio, P., Fabio, R., Permanent scatterers in SAR interferometry. IEEE Trainsactions on Geoscience and Remote Sensing 39(1) pp.8-20

Fuhrmann, T., Garthwaite, M.C., 2019, Resolving Three-Dimensional Surface Motion with InSAR: Constraints from Multi-Geometry Data Fusion. Remote Sensing 11(3) pp. 241

Kang, Y., Zhao, C., Zhang, Q., Lu, Z., Li, B., 2017, Application of InSAR techniques to an analysis of the Guanling landslide. Remote Sensing 9(10) pp.1046.

Massonnet, D.,& Feigl, K.L., 1993, Radar interferometry and its application to changes in the Earth's surface. Reviews of geophysics, 36 (4), pp. 441-500.

Tung, H., Chen, H.Y., Hsu, Y.J., Hu, J.C., Chang, Y.H., Kuo, Y.T., 2019, Triggered slip on multifaults after the 2018 M w 6.4 Hualien earthquake by continuous GPS and InSAR measurements. Terrestrial, Atmospheric & Oceanic Sciences 30(3) pp.285-300

Yu, L., Yang, T., Zhao, Q., Liu, M., Pepe, A., 2017, The 2015–2016 ground displacements of the Shanghai coastal area inferred from a combined COSMO-SkyMed/Sentinel-1 DInSAR analysis. Remote Sensing 9(11) pp. 1194.