

PAPER • OPEN ACCESS

Land deformation modelling of Taiwan earthquake using interferometry technique

To cite this article: Pakhrur Razi *et al* 2020 *J. Phys.: Conf. Ser.* **1481** 012009

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing together innovative digital publishing with leading authors from the global scientific community.

Start exploring the collection—download the first chapter of every title for free.

Land deformation modelling of Taiwan earthquake using interferometry technique

Pakhrur Razi^{1*}, Josaphat Tetuko Sri Sumantyo², Yulkifli¹, Joko Widodo², Daniele Perissin³ and Jefriza⁴

¹Physics Department, Universitas Negeri Padang, West Sumatra 25131, Indonesia

²Center for Environmental Remote Sensing, Chiba University, Chiba 236-8522, Japan

³Lyle School of Civil Engineering, Purdue University, West Lafayette, IN 47907 USA

⁴University Sains Malaysia, 11800 USM Penang, Malaysia

*fhrrazi@fmipa.unp.ac.id

Abstract. A strong earthquake with M 6.4 in 14 km shallow depth occurs in the Eastern of Taiwan. To clarify the land deformation model and area damage covered, the SAR data of Sentinel-1A/B in ascending and descending orbit extracted. The data is collected from co-seismic and post-seismic. In processing SAR data, Differential Interferometry Synthetic Aperture Radar (D-InSAR) technique applied. The result presents significant deformation reach to 250 millimeters in line of sight (LOS) for ascending and descending orbit.

1. Introduction

Taiwan is located on the western circum-Pacific seismic belt. A strong earthquake with M. 6.4 with 17 km shallow depth in the Eastern of Taiwan (Hualien City) on February 6, 2018. The epicenter of the earthquake is 24.131°N and 121.659°E[1]. The earthquake impacted serious damage to the building and 117 fatalities. In the last decade, the earthquake events appear on the area with an average 50 times per day that most of them in shallow depth.

Measuring the crustal deformation caused by the earthquake is necessary to analyze its impact. In observation, we used satellite technology of C-band synthetic aperture radar (SAR) of Sentinel-1A/B data provided by the European Space Agency (ESA). The satellite data has a resolution 5 x 20 meters in range and azimuth[2],[3] with vertical transmit and vertical receive (VV) electromagnetic waves. In processing, differential Interferometric synthetic aperture radar (D-InSAR) technique was applied.

The technique calculates phase difference before and after an earthquake occurs[4],[5]. Based on the phase difference and another factor that contributes to the phase removed, the displacement obtained.

The aim of the research is to measure crustal deformation on Hualien City of Taiwan due to the earthquake M.6.4 on February 19, 2018. The result projected and geocode into an optical layer of google earth. Hopefully, the result can be beneficial as scientific information about the damage level in the area.

2. Study area and satellite data set

The study area is in Hualien city of Taiwan that locate at 23° 58'N and 121° 37'E Figure 1. In observation is using ascending and descending C-band SAR data of Sentinel-1A/B before and after earthquake acquired. The data in a single look complex (SLC) format with Interferometry Wide (IW)



mode. The SAR data has a range and azimuth resolution 5m x 20 m with VV polarization. The satellite dataset of Sentinel-1A/B listed in Table 1.

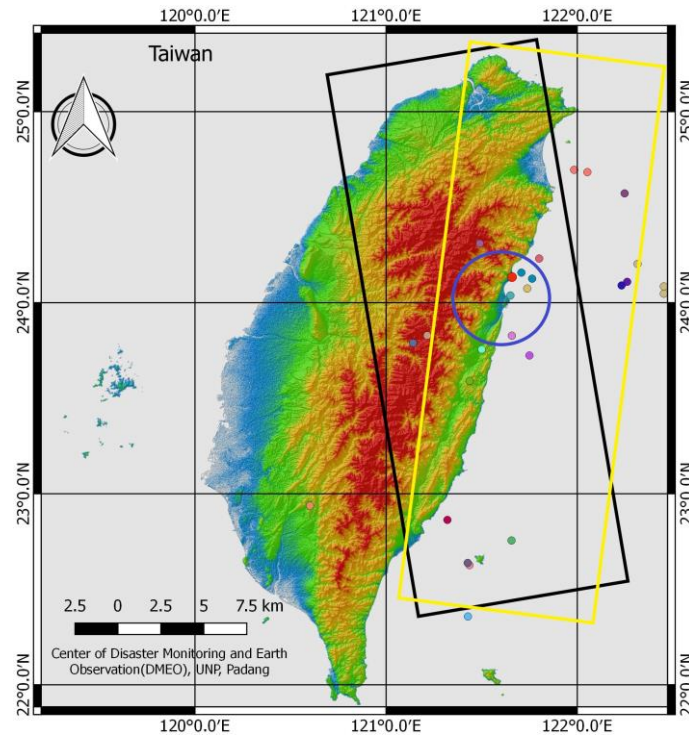


Figure 1. Map of Taiwan in hillshade, covered area observation with ascending orbit (black square) and descending orbit (yellow square) and an epicenter of the earthquake in the last decade.

Table 1. Satellite dataset of Sentinel-1A and Sentinel-1B ascending orbit (part:143, frame: 1189) and descending orbit (part:62, frame:581).

Satellite mission	Acquisition time	λ (cm)	f_0 (GHz)	orbit	Beam mode	Pol.	Incidence angle ($^\circ$)
Sentinel-1A	03/02/2018	5.5	5.4	Ascending	IW2	VV	39.4
Sentinel-1B	09/02/2018	5.5	5.4	Ascending	IW2	VV	39.4
Sentinel-1A	05/02/2018	5.5	5.4	Descending	IW1	VV	33.8
Sentinel-1B	11/02/2018	5.5	5.4	Descending	IW1	VV	33.8

3. Methodology

In processing SAR data for measuring the deformation in the Hualien earthquake, Differential Interferometry Synthetic Aperture Radar (D-InSAR) technique employed. The Principle of technique is comparing phase difference between two-time observations[6]. The phase difference generates to the interferogram of the phase in wrap form. Base on the interferogram, the phase in wrap form is unwrapped to obtain the real value of the phase[7]. Five parameters that contributes to the phase difference, it's come from the curvature of the Earth, topographic, surface deformation, atmospheric disturbance, and noise. A simple mathematical formula can be expressed as[8]

$$\Delta\varphi = \Delta\varphi_{Curv} + \Delta\varphi_{Topo} + \Delta\varphi_{disp} + \Delta\varphi_{atm} + Noise \quad (1)$$

Phase component due to the earth curvature estimated and removed from orbit and metadata of SAR images[9]. The topographic phase calculated based on the digital elevation model (DEM). The atmospheric disturbance is estimated and removed using filtering and multi looking[10].

4. Result and Discussion

Land deformation and the covered area measurement of the Hualien earthquake carried out by extracting c-band SAR data of Sentinel-1A/B. The area observed from ascending and descending orbit of SAR satellite before and after the event. The pair of SAR data for both ascending and descending orbit has a six-day temporal difference. In processing, the D-InSAR technique was applied to calculate the flat earth phase, the topographic phase, displacement phase atmospheric phase, and noise. The topographic phase component that contributes to deformation is calculated and removed based on the SRTM and orbital data[11]. Maintaining high interferometric coherence, the SAR data is multi look 3 x 3 in range and azimuth. The coherence map of SAR data shown in Figure 2.

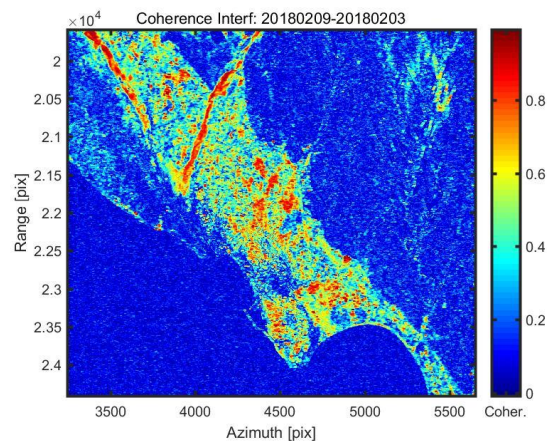


Figure 2. Interferometric coherence of SAR data in ascending orbit

The area observation has high coherence with 0.6-0.8 value. It is a fine value to obtain a reasonable interferometric phase. Obtaining the level of deformation due to the Hualien earthquake carried out a multiplication complex phase difference of two SAR data observations before and after an earthquake. The reduction phase due to the atmospheric and noise was carried out by applying the filtering and multi looking. The interferometric phase of both ascending and descending orbit shown in Figure 3

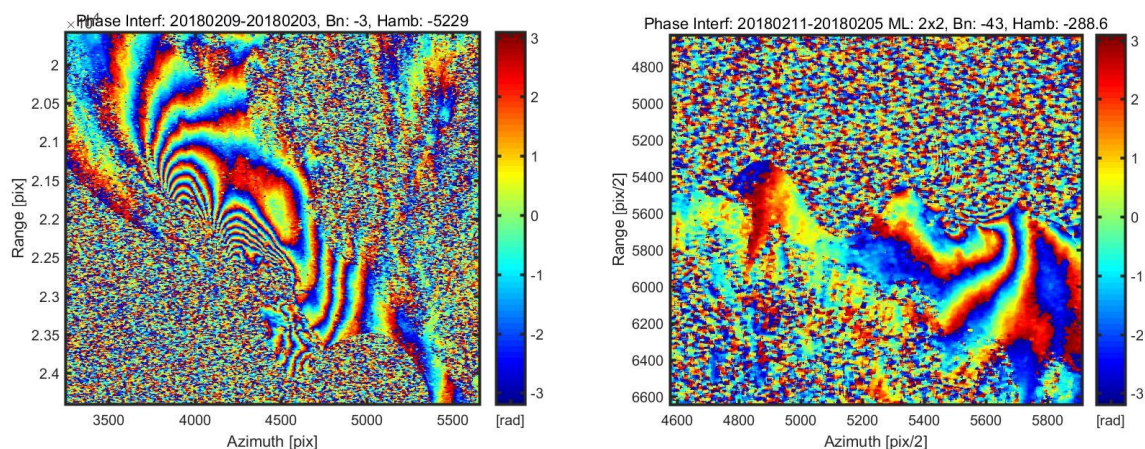


Figure 3. The interferometric phase of Hualien Earthquake pairs of 03/02/2018-09/02/2018 and 05/02/2018 in ascending and descending orbit, respectively.

Unwrapping is required to obtain a real phase of phase interferogram because the phase contains ambiguity measurement of terrain altitude. Unwrap phase interferometry presented in Figure 4

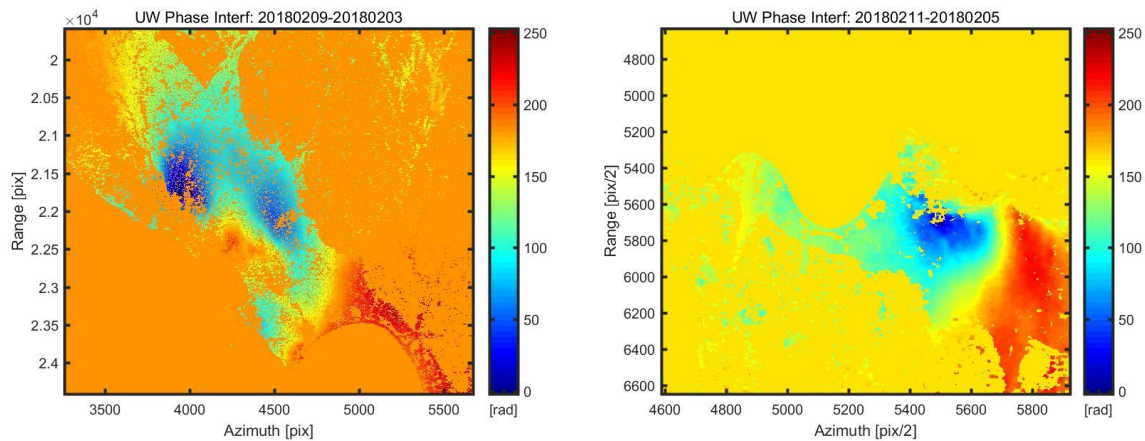


Figure 4. Unwrap phase interferometry of accusation time 03/02/2018-09/02/2018 and 05/02/2018-11/02/2018 pairs for ascending and descending orbit, respectively.

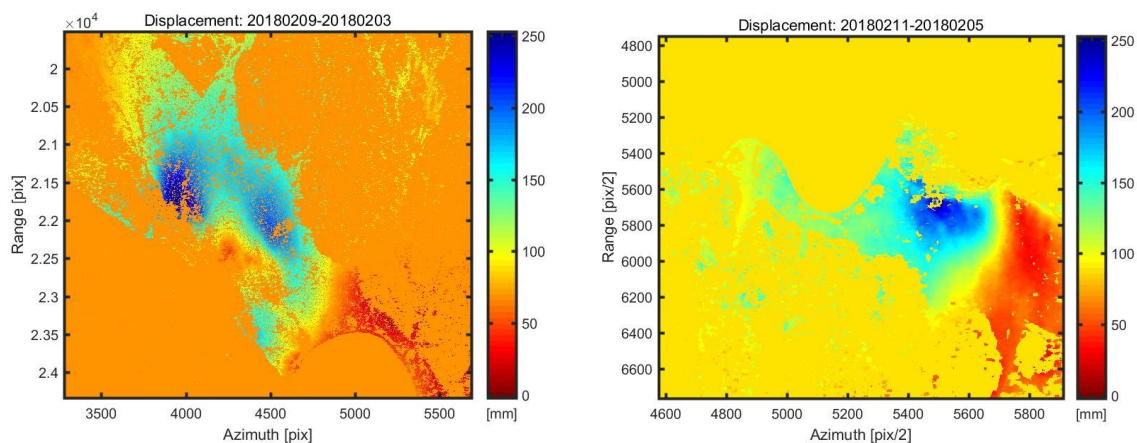


Figure 5. Displacement map and value for both pairs in ascending and descending orbit, respectively

Figure 5 presents the level of ground deformation in millimeters unit. The maximum of land displacement is 250 millimeters in line of sight (LOS). The area in blue color has a higher value of deformation than others.

5. Conclusion

In this study, the Author successfully applied the D-InSAR technique is for modeling the crustal deformation of the Hualien City of Taiwan due to the earthquake M.6.4. The deformation range is 10-25 cm uplift. Also, based on the co-seismic and post-seismic data founded the fault location in the area. According to the level of deformation, the building and area on the blue color have high-level damage than another. The local authority should be given more attention in the development settlement in the area.

References

- [1] USGS, "Hualien earthquake," 2018. [Online]. Available: <https://earthquake.usgs.gov/earthquakes/eventpage/us1000chhc/executive>.
- [2] P. Razi, J. T. S. Sumantyo, D. Perissin, and H. Kuze, "Long-Term Land Deformation Monitoring Using Quasi-Persistent Scatterer (Q-PS) Technique Observed by Sentinel-1A: Case

- Study Kelok Sembilan,” *Adv. Remote Sens.*, vol. 07, no. 04, pp. 277–289, 2018.
- [3] V. B. H. G. Ketelaar, *Satellite radar interferometry: Subsidence Monitoring Techniques*. The Netherlands: Springer, 2009.
- [4] A. Hooper, P. Segall, and H. Zebker, “Persistent scatterer interferometric synthetic aperture radar for crustal deformation analysis, with application to Volcan Alcedo, Galapagos,” vol. 112, no. B7, pp. 1–21, 2007.
- [5] P. Razi, J. T. S. Sumantyo, D. Perissin, F. Febriany, and Y. Izumi, “Multi-Temporal Land deformation monitoring in V shape area using Quasi-Persistent Scatterer (Q-PS) Interferometry Technique,” in *2018 Progress in Electromagnetics Research Symposium*, 2018, pp. 910–915.
- [6] R. Bamler and P. Hartl, “Synthetic aperture radar interferometry Synthetic aperture radar interferometry,” *Inverse Probl.*, vol. 14, no. 4, p. 55, 1998.
- [7] P. Razi, J. T. S. Sumantyo, D. Perissin, H. Kuze, M. Y. Chua, and G. F. Panggabean, “3D land mapping and land deformation monitoring using persistent scatterer interferometry (PSI) ALOS PALSAR: Validated by Geodetic GPS and UAV,” *IEEE Access*, vol. 6, 2018.
- [8] B. M. Kampes, *Radar Interferometry*, vol. 12. The Netherlands: Springer, 2006.
- [9] D. Perissin and T. Wang, “Time-series InSAR applications over urban areas in China,” *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. 4, no. 1, pp. 92–100, 2011.
- [10] A. Ferretti, *Satellite InSAR Data Reservoir Monitoring from Space*. Netherlands: EAGE, 2014.
- [11] P. Razi *et al.*, “Ground deformation measurement of Sinabung vulcano eruption using DInSAR technique,” *J. Phys. Conf. Ser.*, vol. 1185, p. 012008, 2019.