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Effect of Earthquake Intensity to Land Deformation Observed from Space

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Abstract— High intensity of earthquake on Chiba prefecture lead to the potential deformation occurrence. Observe the phenomena of land deformation, SAR data analysis is required. Persistent Scatterer Interferometry (PSI)technique was applied to extract the information using Synthetic Aperture Radar (SAR) data of ALOS-2 PALSAR-2 provided by the Japanese Aerospace Exploration Agency (JAXA). The technique is capable of measuring the changing in earth surface. The time acquisition of SAR data is taken from September 9, 2014, to January 9, 2018, for descending orbit. The result present land deformation in some area on Chiba prefecture. The data obtained from PSI processing is comparing with the data of epicenter of the earthquake in the study area.

1. INTRODUCTION

The high intensity of the recurrence of the earthquake in the Chiba prefecture has the potential to cause deformation especially in the eastern region of the Chiba city. From January 2015 to January 2019, 97 times of earthquake occurrence with magnitude $M > 4$–6. The most epicenter of earthquake located around 35° 34′ 18.53″ N and 140° 10′ 31.15″ E with 20 km-70 km depth in land area, and two zone in coastal area with coordinate 35° 35′ 57.55 N, 140° 45′ 21.84 E and 35° 17′ 38.32″, 140° 28′ 38.74″ E (Fig. 4). Geologically, there is not fault zone on the land. However, it is part of subduction zone of Pacific plate into Okhotsk plate in eastern of Chiba prefecture. Japan government has included this area into high priority for observation to reduction disaster risk.

Observation of the land deformation in the study area, L-band Synthetic Aperture Radar (SAR) data of Advanced Land Observation Satellite (ALOS-2) provided by the Japanese Aerospace Exploration Agency (JAXA)is used. The data acquisition is taken from September 9, 2014, to January 9, 2018,in Stripmap (SM) mode observation with 3-meter resolution.The data processing carried out by Persistent Scatterer Interferometry (PSI) technique. The technique is selected to obtain land deformation information from time to time [1] and measure its trend.

Persistent Scatterer Interferometric (PSI) Synthetic Aperture Radar (SAR) technique is a powerful technique to quantify the movement of Earth surface in time series [2]. The technique is more advanced than Differential Interferometry Synthetic Aperture Radar (D-InSAR) that can eliminate the effect of spatial decorrelation, temporal decorrelation, and atmospheric effect by exploiting multi SAR images [3]. In the workways, the technique searches point-like radar target and identify its movement during acquisition time over the same area. The movement point like radar target direct close to the radar sensor identifies as uplift — otherwise, the movement the point directly away from radar sensor namely as subsidence.

PSI technique was successfully the to observe surface earth phenomena such as landslide monitoring [3], deformation volcanos eruption [4–6], land subsidence [7], flood area [8] with high accuracy. However, deformation in the coastal area is necessity to observe due to the subduction the Pacific plate to Okhotsk plate.

The main objectives of this research are monitor and mapping land deformation in subduction area of Boso Peninsula area using PSI SAR technique observed by ALOS-2 PALSAR-2. The result projected on the ground using google earth with KML format. Observation land deformation on the study area is useful as scientific information about the activity in a subduction zone that will give amounts of attention for potential of earthquake and tsunami occurrence.

2. STUDY AREA AND SATELLITE DATASET

The study area of this research is in eastern of Chiba Prefecture, Japan that located in 35° 34′44.75″N and 140° 25′48.71″E. The area is part of subduction zone of Pacific plate to Okhotsk plate.In along coastal zone approximately 405,316 people are living in site.

Based on the topography, four kilometers from coastal line in study area has altitude around 4 meters above sea level. The soil type on the area with altitude from 8 to 50 meter above sea level is contain with sand and mud varied by gravel (yellow), and area with altitude from 0 meter to 8 meters along 9 km from coastal line is contain by sand. This because the area is facing the Pacific Ocean that has high wind speed that forcing the sea's sand moving to land.

For monitoring land deformation in Boso Peninsula area, 12 scenes of ALOS-2 PALSAR-2 data with ascending orbit was extracted. The acquisition time of data was taken from September 9, 2014, to January 9, 2018. The satellite data is Stripmap mode with L-band Frequency (1.27 GHz). Additionally, the SAR data has a very high resolution in 3×2 meters in range and azimuth. The polarization of the data is HH (Horizontal transmit and Horizontal receive) with off-nadir angle 34.30. The dataset of ALOS-2 PALSARis shown in Table 1.

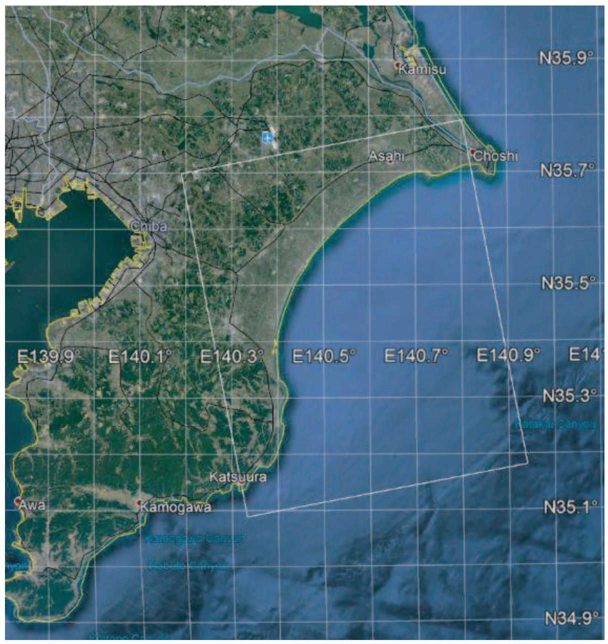


Figure 1: Footprint study area in Boso peninsula, eastern of Chiba prefecture.

Table 1: ALOS-2 PALSAR-2 dataset with ascending orbit.

No.	Acquisition date (YYYY/MM/DD)	Mode	Polarization	Normal Baseline B_n (m)	Temporal Baseline (B_t)	Off-nadir angle
1	20140909	SM 3 m	HH	37.36	980	34.3°
2	20141104	SM 3 m	HH	17.19	924	34.3°
3	20150224	SM 3 m	HH	29.38	812	34.3°
4	20150602	SM 3 m	HH	177.02	714	34.3°
5	20151020	SM 3 m	HH	131.83	574	34.3°
6	20151103	SM 3 m	HH	236.54	560	34.3°
7	20160531	SM 3 m	HH	150.91	350	34.3°
8	20161101	SM 3 m	HH	42.63	196	34.3°
9	20170207	SM 3 m	HH	51.01	98	34.3°
10	20170516	SM 3 m	HH	0.0	0	34.3°
11	20171017	SM 3 m	HH	41.08	154	34.3°
12	20180109	SM 3 m	HH	105.07	238	34.3°

The normal baseline maximum of SAR data fora scene on May 16, 2017, selected as the master is 236 meters, and the minimum is 41 meter with temporal baseline maximum 980 days. This combination included into short normal baseline B_t. Short normal baseline better for accuracy in elevation and reduce the geometrical decorrelation [9]. Moreover, a short temporal baseline better for coherency [3].

3. METHODOLOGY

3.1. Persistent Scatterer (Q-PS) Interferometry Technique.

In this research, the Persistent Scatterer Interferometry (PSI) technique was applied for mapping land deformation in subduction area of Boso Peninsula eastern of Chiba City. PSI technique advanced than differential interferometry synthetic aperture radar (DInSAR) technique [10]. Also, the PSI technique can reduce the temporal and geometrical decorrelation, and atmospheric disturbance by explore the multi-SAR images. Furthermore, the technique allow: (1) monitor the land deformation in time series, (2) observe the value of atmospheric disturbance and remove the effect, (3) calculate the average velocity of land deformation, (4) calculate the residual error of topographic, and (5) detect the small area deformation precisely.

In SAR processing, the PSI technique finds the coherence radar target and then identify its movement from time to time that used as an indicator to represent the land deformation [11]. Selecting coherence radar target that called as Persistent Scatterer (PS), the radar images are gridded in range and azimuth. The coherence level of a radar target is in range 0 to 1 with the acceptable value is selected equal and more than 0.6 in amplitude stability index or amplitude depressing index equal and small than 0.4 [12]. The amplitude depression D_a defined as [13].

$$D_a = \frac{\sigma_a}{m_a} \tag{1}$$

where σ_a the standard deviation of the amplitude value and m_a the mean of the amplitude value.

Estimating the atmospheric effect on radar images carried out by connecting the PS point that refer to one ground control point (GCP). After removing the atmospheric effect with equal GCP, height and velocity of PS estimated.

Figure 3 shows the image configuration in PSI technique that called as Star configuration with SAR data on May 16, 2017, selected as a master image. The normal baseline maximum reached to 250 m and a minimum 50 m with total acquisition time is 1,218 days.

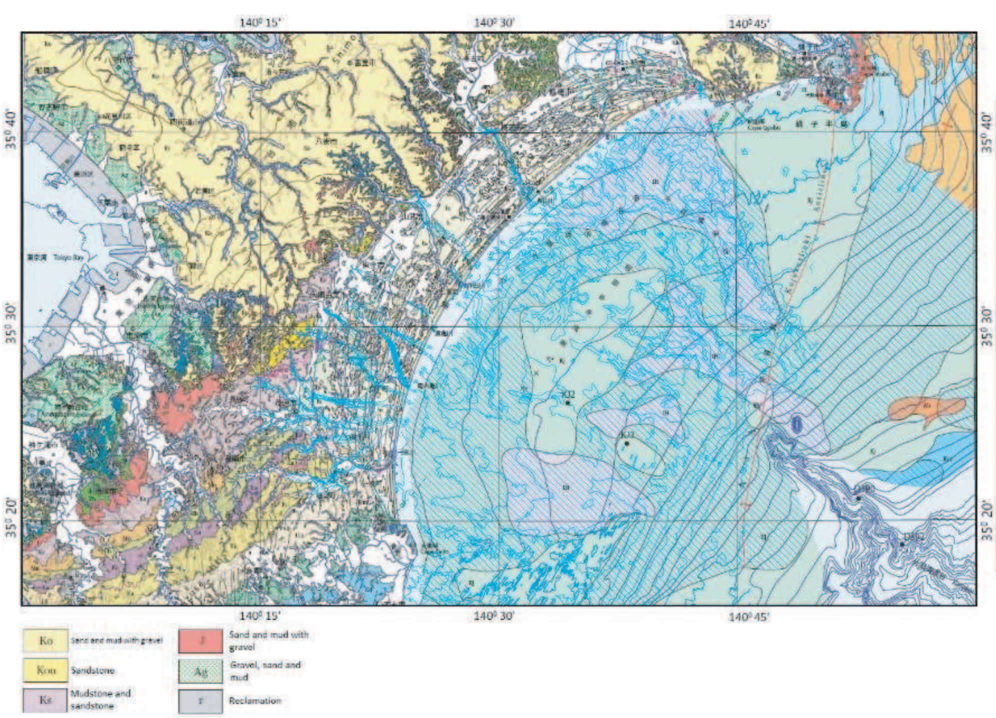


Figure 2: Geological map of Boso Peninsula, Eastern Chiba Perfecture, Japan.

4. RESULT AND DISCUSSION

Processing SAR data for mapping the land deformation in Boso Peninsula area is using PSI-SAR technique. The data observation is taken from September 9, 2014 to January 9, 2018, provided

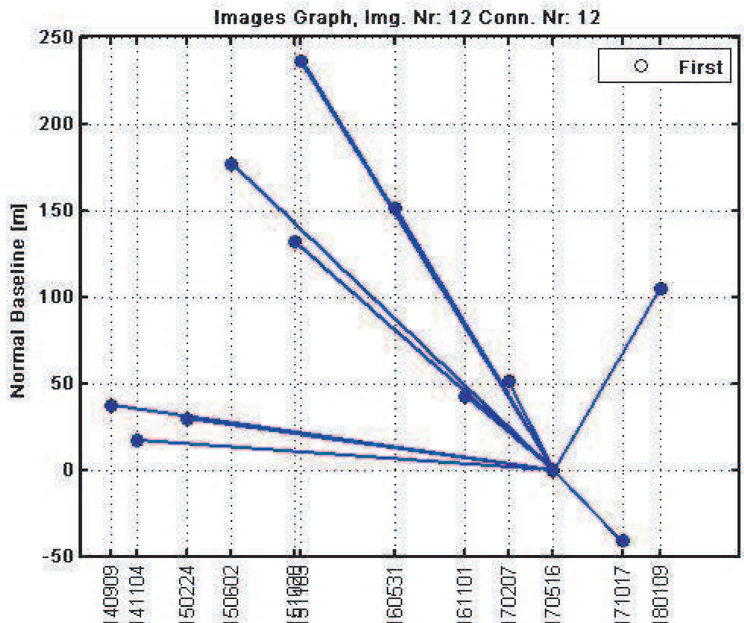


Figure 3: Start image graph configuration of 12 scenes ALOS-2 PALSAR-2 satellite using PSI technique.

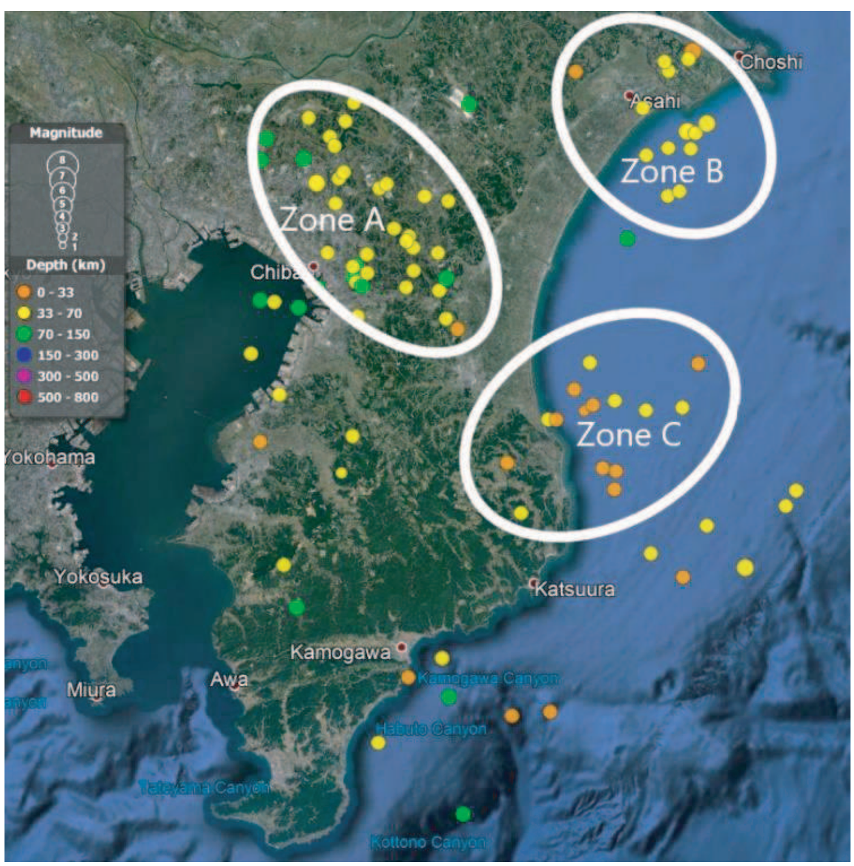
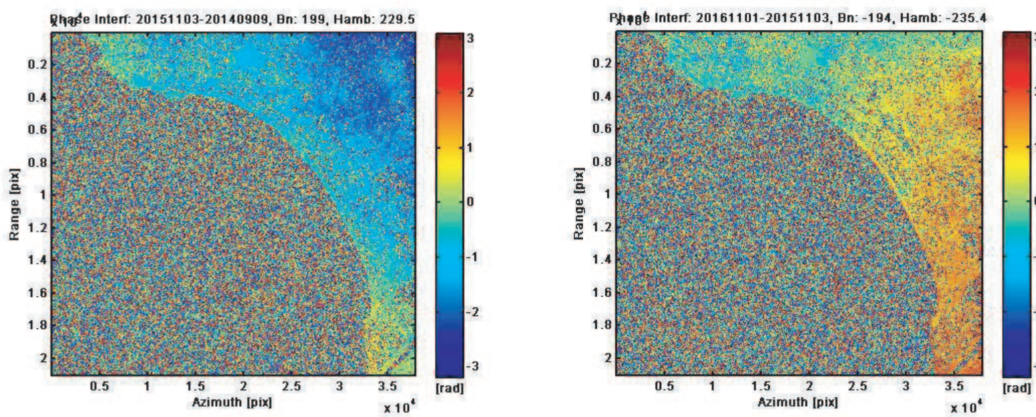


Figure 4: The epicentre of Earthquake in Boso Peninsula area recorded from November 26, 2014 to January 7, 2019.

by the Japan Aerospace Exploration Agency (JAXA). The frequency of SAR data is 1.27 MHz (L-band) in stripmap mode with 3-meter resolution. The polarization of SAR data is HH (horizontal transmit and horizontal receive) with ascending orbit. In co-registration process, the SAR data Gridded into 2.67 range and 1.92 azimuth.

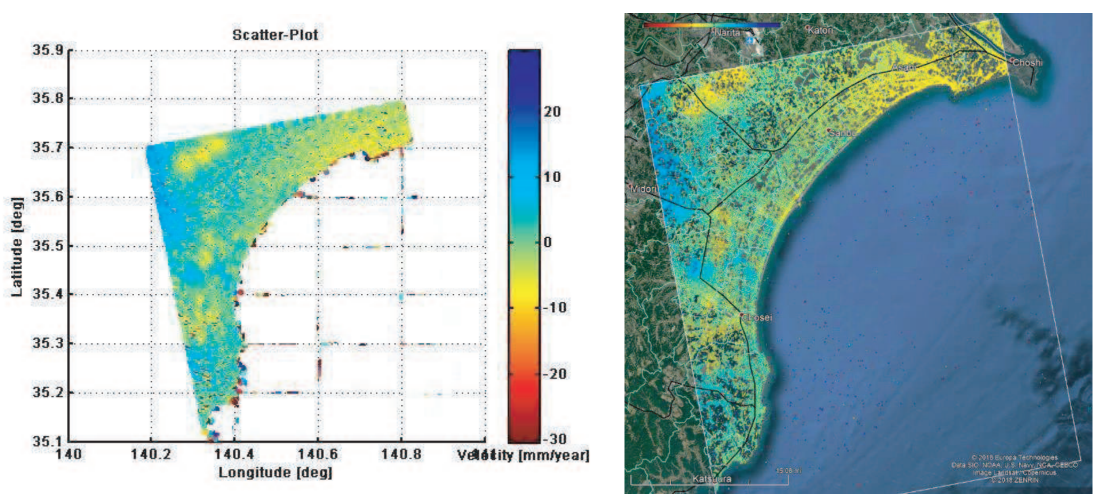
Figure 4 presents the epicenter of an earthquake during observation from November 26, 2014, to January 7, 2019. The epicenter is concentrated into three areas that namely zone A, zone B, and zone C. Zone A located in high land area with elevation 14.3 meters above sea level that dominated with sandstone (Fig. 2). Zone B and C are located in a coastal area with 43 km distance each to other. In both zone B and C, the most epicenter of the earthquake is in the sea. Additionally, the area has equal distance with an undersea fault in eastern Boso Peninsula (Fig. 2).

Figure 5 shows area in zone B most area is subsidence that reaches to −10 mm/years and some spots in coastal line reach to −20 mm/years. However, in zone A and zone C, both uplift and subsidence is occurrence with a maximum of 20 mm/years and −10 mm/years, respectively.



Interferometric phase pair of 20151103-20140909

Interferometric phase pair of 20161101-20151103



(a)

(b)

Figure 5: Land deformation map on Boso Peninsula area, eastern Chiba City, Japan. (a) Velocity of land deformation in geographic coordinate (latitude and longitude). (b) Resampling the land deformation map geocodes into optical image of google earth.

5. CONCLUSION

In this research, using ALOS-2 PALSAR-2 data, stripmap mode with 3 meter resolution, PSI technique successfully extract information about velocity of land deformation at Boso Peninsula in four years. Some area in zone A is uplift with approximately 20 mm/years. However, in Zone B and Zone C is subsidence with velocity approximately 10 mm/year. Base on the analysis, the phenomena is caused by the pacific plate that infiltrate under Okhotsk plate. The cumulative displacement for zone A 80 mm (uplift) and Zone B and Zone C is approximately 40 mm (ubsidence).

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