MULTI-TEMPORAL INTERFEROMETRY FOR DETECTING AND MONITORING LANDSLIDE: MOUNT KINABALU EARTHQUAKE CASE.

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ABSTRACT: Landslide in Malaysia commonly occurs due to a combination of more than one cause. Due to infrequent occurrence of earthquake in Malaysia, the study on landslide due to combination earthquake and rainfall usually neglected, however, unlike any other state in Malaysia, Sabah recorded as Malaysia's most active seismic region and medium intensity. On the 5th June, an earthquake with a magnitude of 6.0 struck Ranau, Sabah, Malaysia, and another mainshock were felt on September 2017 and March 2018. This 2015 earthquake has triggered many questions regarding their nature of recurrence, characteristics in size and mechanism in and its surrounding region. This study aims to assess slope instability on Mount Kinabalu Earthquake case using multitemporal InSAR data using ALOS-2 from 2015 to 2018. Preliminary results indicate that multi-temporal InSAR analysis can provide us with temporal ground movements and understanding of the local earthquake activities in the study area.

1. INTRODUCTION

Sabah is the Malaysia state located at the northern part of Borneo. The third-largest main economy in Sabah which is after agriculture and manufacturing is tourism and has grown steadily in both supply and demand for the past twenty years. Nation nature, wildlife, adventure, culture, and heritage mostly reserve in Sabah. Sabah is the only region seismically active and the seismicity in Sabah is classified from low to moderate. On 1976, an earthquake with 6.2 Richter scale struck Lahad Datu in the past killed 8 peoples. Another earthquake struck Ranau in 1991 with 5.1 magnitudes. The worst recent earthquake happens on 5th June 2015 in Ranau with 6.0 magnitudes (Mw).

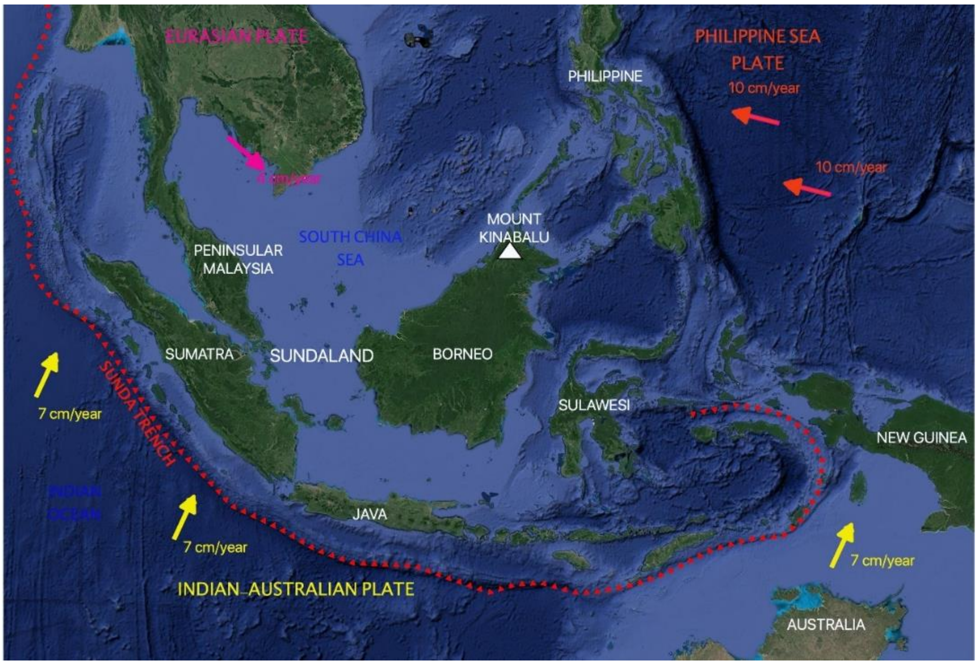


Figure 1 Three major active plates located closed to Mount Kinabalu

Sabah is located in between three major seismically active plates which are Australian and Eurasian Plate in the west and Philippine Plate in the east. Figure 1 shows the three plates come together from different direction and rates (Michel et al., 2001; Simons et al., 2007). The Eurasian plate that moving in a southeastward direction comprised of the South China Sea and Sundaland with rates of 4 cm/year. Meanwhile, at a rate of 7 cm/year the Indian Australian Plate moving northeastward direction and Philippine Sea-Pacific Plate moving west northward direction with 10 cm/year rate. N-S spreading of the seafloor in the Antarctic Ocean since about 50 million years ago affect the northward movement of the Indian-Australian Plate. The E-W spreading of the seafloor in the Pacific Ocean since about 42 million years ago contribute the westward movement of the Pacific Plate. Active subduction zones and strike-slip faults influence the interactions of the three tectonic plates (Felix, 2017).

Quantitation of ground displacement changes due to natural disasters (Didier et al., 1993) and inventory of built environment (R. T. Eguchi et al., 2000) using phase information from SAR interferometric analyses has been proven successful. Besides, damage to building areas due to earthquake can be obtained from complex coherence of interferometric analysis (M. Matsuoka et al., 2000). However, interferometric analysis sensitive to the satellite geometry, data period and wavelength of radar (H. A. Zebker et al., 1992). This study aims to assess slope instability on Mount Kinabalu Earthquake case using multitemporal InSAR data using ALOS-2 from 2015 to 2018.

2. MATERIALS AND METHOD

2.1 Study area

Sabah located at the northern part of Borneo and second-biggest state in Malaysia which is shown in Figure 2. Sabah located in between the Philippines at the north and Sulawesi, Indonesia at the east, both separated by sea. The population of Sabah approximately 4 million. The average daily temperature of Sabah 32°C and High humidity and high temperatures.

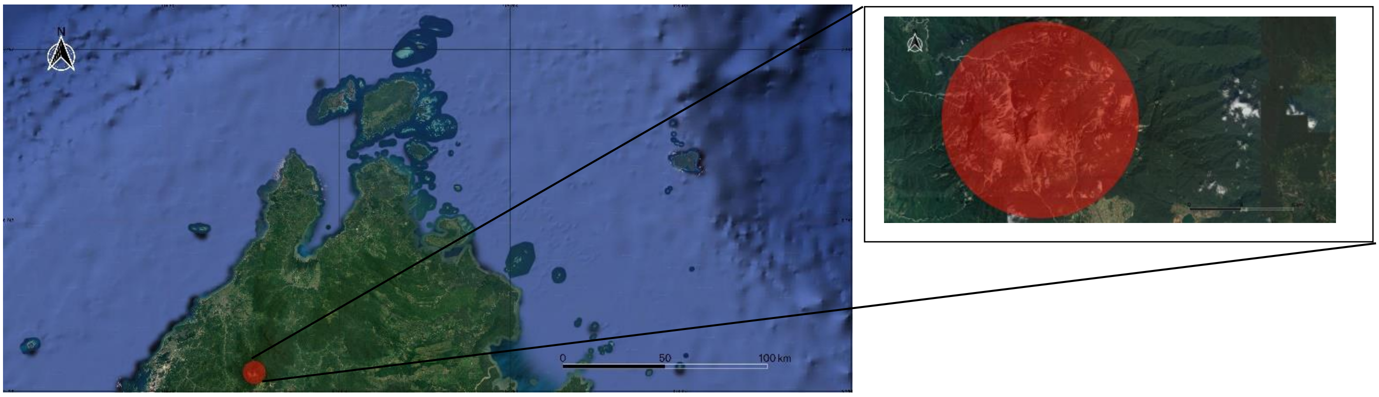


Figure 2 The location of Mount Kinabalu. The red circle shows location of the active fault.

Mount Kinabalu is the highest mountain in Borneo with 4,095 meters height and the highest point between the Himalayas and the snow-capped mountains of New Guinea. The weather in the rainforest is warm and humid year-round. Temperatures will usually be between 23-31 °C with Relative Humidity ranging from 70-90%. Annual rainfall in this the region is 4000mm.

2.2 Satellite data

Advanced Land Observing Satellite 2 (ALOS-2) which is a Japanese L-band synthetic aperture radar satellite with processing level 1.1, are used to detect earthquake using InSAR. The images used in the study are listed in Table 1.

Table 1 List of ALOS-2 used in this study

Satellite/sensor	Pass	Frame	Observation date
ALOS-2/PALSAR-2	Ascending	100-110	January 19, 2015
			June 22, 2015
			January 18, 2016
			August 28, 2017
			January 01, 2018
			March 12, 2018

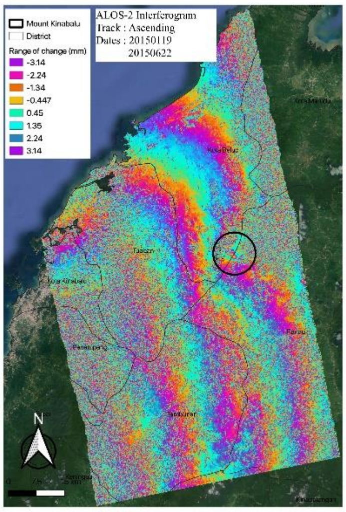
2.3 Method

ALOS-2 data from ascending track 100 to 110 were processed using GMTSAR. GMTSAR is an open-source (GNU General Public License) InSAR processing system designed for users familiar with Generic Mapping Tools (GMT). The basic InSAR observable is called an interferogram and represents the per-pixel phase difference between two SAR acquisitions.

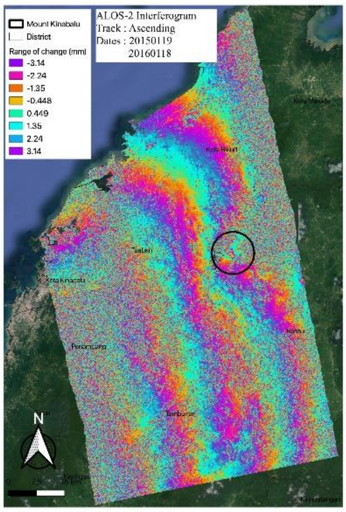
In general, Interferometric Synthetic Aperture Radar (InSAR) using two images at a different time and on the same area to measure signal phase change. When there is a ground deformation, the distance between the sensor and the point changes and so the phase value recorded by the sensor will be affected too. An interferogram will provide both topographic and surface motion information. The topographic component can be obtained by using DEM or a second SAR image pair are removed to detect the surface motion.

3. PRELIMINARY RESULTS AND DISCUSSION

Figure 3 shows the interferogram obtained from the whole ascending orbit data of path 100 and 110 acquired before, and after, the earthquake event from the year 2015 until 2018. The displacements away from the satellite are in the range of ~-3.3 to 3.3. The most concentrated crustal deformation is located at Mount Kinabalu which highlighted inside the circle. Some other inland earthquakes had lost the interferometric coherence significantly in the vicinity of the hypocentral area because of serious changes in the scattering conditions on the ground and too high displacement gradients. Besides, interferogram created from ALOS-2 between 2015 January 19 and 2015 June 22 and interferogram created using ALOS-2 between 2015 January 19 and 2016 January 18 shows an obvious crustal deformation compared to interferogram created from ALOS-2 between 2017 August 28 and 2018 January 01. This presumably suggests that these faults contributed from the seismic ruptures of the 6.0 Mw earthquake event in some way.



a)



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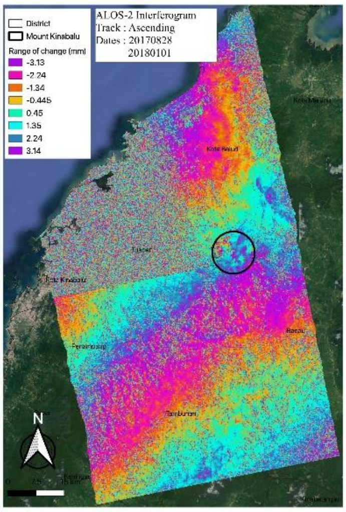

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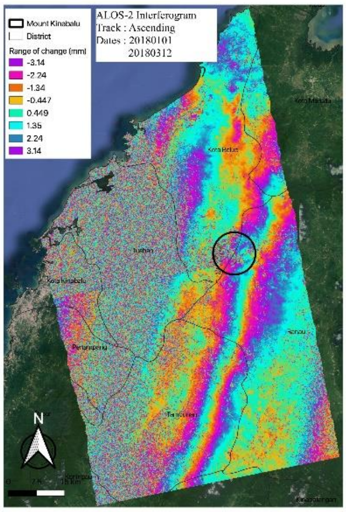
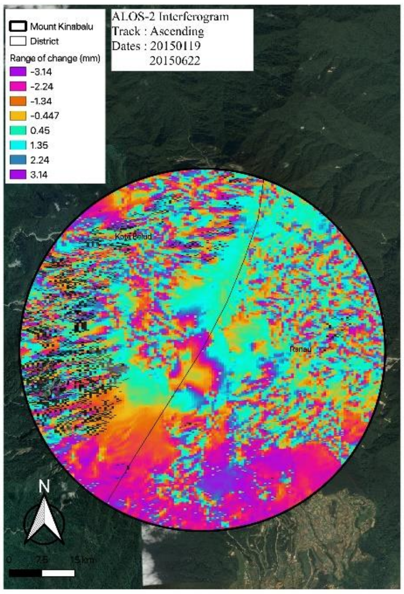


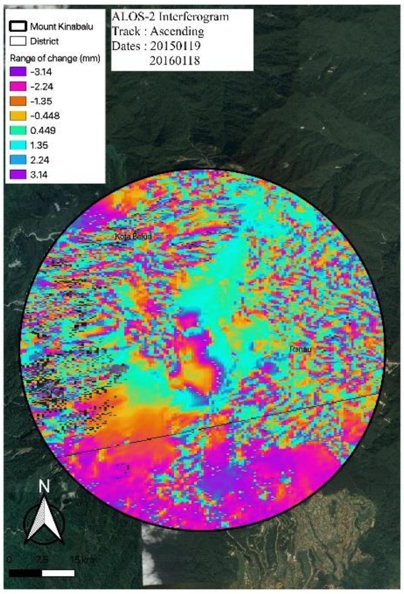
d)

Figure 3 InSAR coseimic map deduced from pre- and post-event ALOS-2 data a) Master: 2015/01/19 Slave: 2015/06/22 b) Master: 2015/01/19 Slave: 2016/01/18 c) Master: 2017/08/28 Slave: 2018/01/01 d) Master: 2018/01/01 Slave: 2018/03/12

Figure 4 shows the phase change map with high coherence for the Mount Kinabalu region. The InSAR map of the 2015 event enables us to investigate the temporal ground surface change over the entire source area in detail.



a)



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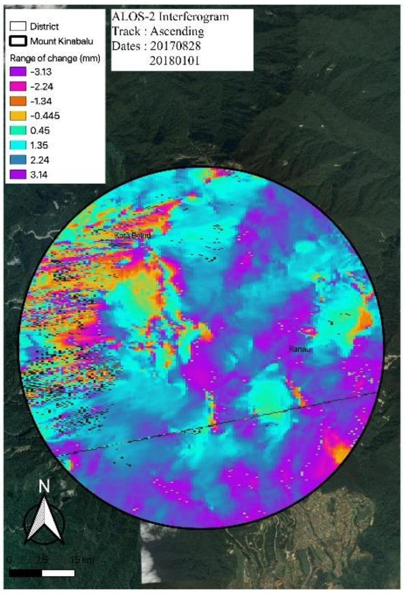

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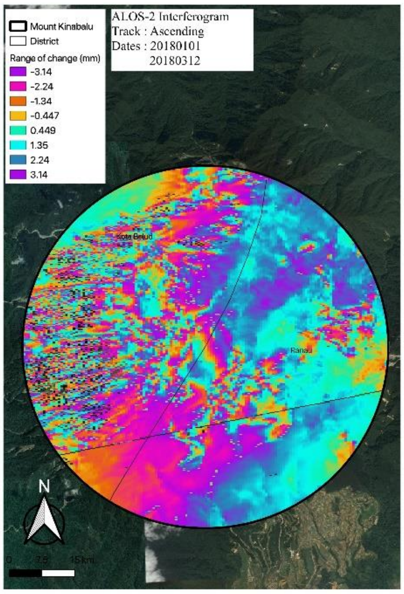

d)

Figure 4 InSAR coseimic map deduced from pre- and post-event ALOS-2 data specifically at Mount Kinabalu a) Master: 2015/01/19 Slave: 2015/06/22 b) Master: 2015/01/19 Slave: 2016/01/18 c) Master: 2017/08/28 Slave: 2018/01/01 d) Master: 2018/01/01 Slave: 2018/03/12

In the interferogram of Fig. 3(a), which is obtained from the SAR data pair of 2015 January 19 and 2015 June 22, an ear-shaped displacement distribution, caused by the 6.0 Mw earthquake event that occurred on 5th June 2015. The ear-shaped displacement distribution can still be seen on data pair in Fig. 3(b) between 2015 January 19 and 2016 January 18. Both 3(a) and 3(b) show range of change between -1.34 to 2.24 mm which towards positive displacement and this means that uplift has occurred at the east side of Mount Kinabalu. Figure 3(c) shows an interferogram obtained from the SAR data pair of 2017 August 28 and 2018 January 01. There is no distinct displacement distribution take place during this period. Figure 3(d) shows interferogram of 2018 January 1st and 2018 March 12. During this period a slight land deformation has taken place with a range of change in between 1.36 to 3.14 mm. This is fault movement contributed from Sabah earthquake on 2018 March 08 with 5.2 Magnitude.

4. CONCLUSION

This study focus on using application of InSAR to detect seismic movement and slope instability. The preliminary results show the mainshocks of sizes greater than 5.2 Mw led to the slight land deformation in Mount Kinabalu with a range of change in between 1.36 to 3.14 mm while, Earthquake greater than 6.0 Mw can contribute to a greater range of changes -1.34 to 2.24 mm with a clear land deformation. The landslide will plausible if earthquakes more than 5.2 Mw were to occur shortly.

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