Lombok earthquakes using DInSAR techniques based on Sentinel 1A data (case study: Lombok, West Nusa Tenggara)

Rian Nurtyawan1*, Muhammad Fachri Yulanda1

Department of Geodesy Engineering, National Institute of Technology, 23 PH.H. Mustofa Street, 40124 Bandung, Indonesia
e-mail: nurtyawan70@gmail.com

Abstract. On July 29th, 2018 there was an earthquake of 6.4 magnitude occurred in Lombok Island, West Nusa Tenggara. The repercussions of the earthquake cause the area to deform. Deformation refers to any changes in the shape and size of an object. Hence the purpose of this research is to measure the deformation cause by the aforementioned earthquake in Lombok. The deformation calculation is conduct by using the SAR data from Sentinel-1A Satellite Imagery (Interferometric Wide Swath (IW)) using DInSAR method. The effect of deformation cause by an earthquake in Lombok based on DInSAR method is -0.001 m up to -0.134 m with the average -0.026 m and the image coherence is 0.32, with the range for coherence is 0 to 1. The small value of coherence cause by the vegetation density within the research area. The vegetation density will affect the imagery coherence value due to its movement and development thus effecting the backscatter. Hence, the deformation data situate within the vegetation density area will result less accurate data.

1. Introduction
Earthquakes are occurrence that tremble or quake the Earth due to movements or changes in the layers of the earth that suddenly occur due to the movement of tectonic plates [1]. Earthquakes occur by the reason of volcanic activity (volcanic earthquakes) or tectonic plate movements (earthquake tectonics). On July 29, 2018 there was an earthquake on the island of Lombok with the magnitude of the 6.4 magnitude earthquake which was located 47 km east of the Mataram city on the 24 Km. As an effect of the earthquake, Lombok Island was deformed.

Deformation is a change in the shape, position, and dimensions of an object [2]. Based on the definition of deformation it can be interpreted as a change in the point caused by a movement or shock, changes in points are absolute or relative [3]. Changes in a point on Earth can be known the displacement using satellite image data with the Differential Interferometric Synthetic Aperture Radar (DInSAR) method. DInSAR is a radar-based technique that exploits information that is in phase, at least two SAR images obtained in the same area, at different times, to obtain deformation measurements in an area [4]. One of the satellite images that can be used in the DInSAR method is Sentinel-1A satellite imagery.

Sentinel-1A satellite imagery is an image produced by the Sentinel-1A satellite which is designed and developed by the European Space Agency (ESA) on 2014. This the Sentinel-1A satellite mission monitors ice sea zones, surveillance of the marine environment, land surface mapping, and monitoring soil movements (Suhet, 2012). Sentinel-1A can observe the surface of the earth at day and night with a repeat cycle every 12 days. There are four acquisition modes that belong to Sentinel-1A, namely Stripmap (SM), Interferometric Wide Swath (IW), Extra Wide Swath (EW), and Wave (WV). In IW mode Sentinel-1A satellite imagery has a spatial resolution of 5 m x 20 m [5].
2. Research Methodology
The methodology of this research was carried out in several stages, namely data collection, the data used was Sentinel-1A SLC satellite imagery (See Looking Complex). At the processing stage, it consists of baseline estimation determination, image registration, interferogram making, coherence determination, topographic phase removal, multi-looking, Goldstein Phase Filter, phase unwrapping, phase to placement, geocoding, and results presentation. The research methodology can be seen in Figure 1. The research begins with inputting data in the form of Sentinel-1A (master) satellite images and Sentinel-1A (slave) satellite image. The next stage is determining baseline estimation. Baseline estimation aims to determine the spread of orbit points from SAR observations. Furthermore, image correlation is carried out, the purpose of image registration is to ensure that each image (master and slave) contributes the same pixel. There are three steps in image registration, namely Topsar Split, Apply Orbit File, and Backgeocoding. Afterwards, making of the interferogram and the determination of coherence values, where in this research the coherence value was determined $> 0.3$ [6]. Next is the Top Deburst, this stage is carried out to eliminate the demarcation zone and combine the subwath by Top Marge methods. In the stage of topographic phase removal, SRTM DEM is used for topographic phase removal. Next is Multi-looking and Goldstein Phase Filtering, which at this stage functioned to eliminate uncorrelated noise. Furthermore is Unwrapping Phase, where this stage purposes to get an absolute value and change the phase units from radians to metrics. And the final step is processing Geocoding, at this stage it aims to transform the radar coordinate system to the graphical coordinate system.
Figure 1. The flow diagram of research methodology.
3. Result and Discussion

3.1. Result
From the implementation of the research to measure deformation that caused by the earthquake in Lombok using Sentinel-1A satellite imagery, was produced the soil subsidence in Lombok Island. The results of the research can be seen in Figure 2. It can be obtained information that the size of the deformation value of Lombok Island as a result of DInSAR processing ranges from -0.001 m to -0.134 m.

![Map of deformation](image)

**Figure 2.** Map of deformation.

In the findings above, the island of Lombok is deformed represented by blue, yellow and red. Where blue is a small area of minor deformation ranges from 0.001 m to -0.0238 m, yellow is a region that is experiencing a moderate deformation which ranges from 0.0239 m to 0.1339 m, and red is an area that experiences the largest deformation is 0.1340 m.

3.2. Analysis
The results of DInSAR processing show that there is deformation on Lombok Island which is an average of -0.026 m. According to the Table 1, the largest deformation area is East Lombok. East Lombok experienced the greatest land subsidence because the area was close to the epicenter of the earthquake, with a large land subsidence of -0.134 m and the area that experienced the smallest land subsidence caused by the earthquake in Lombok was the city of Mataram where land subsidence in the area the amount is -0.009 m.
The baseline length is the most significant factor in measuring surface deformation with InSAR (Ferreti, 2007). To determine the spread of orbit points from SAR observations, a short perpendicular baseline (≤150 m) or a short temporal baseline can be chosen. The length of the baseline in this research is 55.83 m, the length of the baseline is a factor obtained by a high coherence value between the master and slave images. In the interferometry process it can be said to be good and accurate if the image coherence value is between 0.5-1, if the coherence value is below 0.5 accordingly the results of interferometry still have signify information, however the image with a small coherence value also displays an increase in noise level which is proportional to the smaller of image value coherence. In Figure 3 is a graph of the coherence value of the image which shows that the amount of coherence of the image is below < 0.5.

According to the graph of Figure 3, it can be concluded that the high value of image coherence is 0.000005 to 0.99 with an average of coherence value is 0.32. In coherence imagery there are dark and bright colors, where in the dark colour means the coherence value in the area means low, while the brightly colour ones explain that the coherence value in the area is high.

Table 1. Deformation Value of Lombok Island

| No | District/City    | Average (m) | Minimum (m) | Maximum (m) |
|----|------------------|-------------|-------------|-------------|
| 1  | North Lombok     | -0.0166     | -0.0818     | -1.0434E-6  |
| 2  | East Lombok      | -0.0294     | -0.1340     | -1.0059E-6  |
| 3  | Central Lombok   | -0.0182     | -0.0942     | -1.0003E-6  |
| 4  | West Lombok      | -0.0163     | -0.0985     | -1.0726E-6  |
| 5  | Mataram City     | -0.0036     | -0.0095     | -6.5203E-5  |

Figure 3. Coherence of Image (left) & Value of Graph Coherence (right).
Figure 4. Spread of vegetation.

Table 2. Coherence on Each Vegetation

| No | Type of Vegetation | Coherence Value | Amount of Pixel |
|----|--------------------|-----------------|-----------------|
| 1. | Mixed Plants       | 0.38            | 54.856          |
| 2. | Reed               | 0.36            | 107.584         |
| 3. | Field              | 0.33            | 645.568         |
| 4. | Bush               | 0.33            | 641.801         |
| 5. | Paddy Field        | 0.32            | 1.442.050       |
| 6. | Wet Forest         | 0.29            | 19.546          |
| 7. | Garden             | 0.29            | 589.993         |
| 8. | Dry Forest         | 0.28            | 1.304.436       |

Based on the overlay result from vegetation spread data (Figure 4) and coherence imagery, obtained the value of coherence on each vegetation that shows in Table 2.

Based on Table 2, the coherence value of mixed planting vegetation types has the huge value, taking consideration to the fact that mixed planting does not have such a large area (54,856 pixels) and the existence of mixed planting is also not tightly enough in the research area. And the smallest coherence value is dry forest, where the area of dry forest is the second largest area (1,304,436 pixels) and the presence of dry forests in the study area is quite tight. The wet forest area is the smallest (19,546 pixels) however the coherence value is small, by the reason of that in the area the vegetation is tight. While the type of rice field vegetation which is the most extensive area has a value of coherence over wet forests, gardens, and dry forests. Therefore, it can be concluded from Table 2 that the area does not affect the magnitude or small value of coherence, which causes large or small coherence values to be vegetation density.

In Figure 5 is the result of the correlation of coherence value and vegetation density on Lombok Island where the influence of vegetation density on coherence values can be represented by the equation \( y = -0.2967x + 0.423 \). It can be seen from the equation that vegetation density with the value of coherence has a very strong relationship. The results of the linear regression correlation between the value of coherence and vegetation density on Lombok Island produce a determinant coefficient \( R^2 \) of 0.9486 while the value of the correlation coefficient \( R \) is 0.9739.
According to Boediono and Koster 2002 [7] the meaning of correlation values is as follows:

1. If 0.90 < R < 1.00 or -1.00 < R < -0.90, it means it has a strong coherence
2. If 0.70 < R < 0.90 or -0.90 < R < -0.70, it means it has a powerful coherence.
3. If 0.50 < R < 0.70 or -0.50 < R < -0.70, it means it has the moderate coherence.
4. If 0.30 < R < 0.50 or -0.50 < R < -0.30, it means it has the weak coherence.
5. If 0.0 < R < 0.30 or -0.30 < R < 0.00, it means it has the highly weak coherence.

This shows that the coherence between vegetation density and coherence value is very strong with a value of $R = 0.9739$. The regression coefficient value of the vegetation density is minus or inversely proportional, which means that the denser the vegetation, the smaller the coherence value.

4. Conclusion

Based on the research that has been done, it can be concluded that on the island of Lombok deformation caused by the earthquake on 29 July 2018 in the amount of -0.001 m to -0.134 m. The deformed areas are North Lombok, West Lombok, Central Lombok and East Lombok. East Lombok is the largest deformation area, amount -0.134 m, by taking consideration to the fact that East Lombok is the area closest to the source of the earthquake. On Lombok Island there is still a small coherence value due to the density of vegetation in the area, vegetation density will affect the value of image coherence because movement and changes in vegetation will affect the scattering value.

5. References

[1] Sunarjo, M. Taufik Gunawan, and S. Pribadi, Gempa Bumi Indonesia Edisi Popule. Badan Meteorologi Klimatologi dan Geofisika, 2012.
[2] S. Kuang, Geodetic Network Analysis and Optimal Design: Concepts and Applications. Ann Arbor Pr Inc, 1996.
[3] Ma’ruf, “Analisis Deformasi Gunungapi Merapi dengan Metode Geodetik-GPS,” Institut Teknologi Bandung, Bandung, 2001.
[4] T. A. Mathisen and T.-E. S. Hanssen, “The Academic Literature on Intermodal Freight Transport,” Transp. Res. Procedia, vol. 3, pp. 611–620, 2014.
[5] Suhet, Sentinel-1 User Handbook. Paris: European Space Agency., 2012.
[6] A. Ferretti, M. . Andrea, P. Claudio, and R. Fabio, InSAR Principles: Guidelines For SAR Interferometry Processing And Interpretation, 2007.
[7] Boediono, Teori dan aplikasi statistika dan probabilitas: sederhana, lugas, dan mudah dimengerti / Boediono, Wayan Koster. Bandung : Remaja Rosdakarya, 2002.