Journal of Physics: Conference Series

Deformation Mapping of the 2018 Sulawesi Earthquake by Satellite Radar and Optical Remote Sensing

To cite this article: Togi Tampubolon *et al* 2020 *J. Phys.: Conf. Ser.* **1428** 012043

Deformation Mapping of the 2018 Sulawesi Earthquake by Satellite Radar and Optical Remote Sensing

[1]Togi Tampubolon, [2]Rita Juliani, [3]Juniar Hutahean, [4]Jeddah Yanti
[1,2,3,4]Department of Physics, State University of Medan, Indonesia

Jln. William Iskandar, Ps. V, Medan, 20221, Sumatera Utara, Indonesia
Corresponding author: topartam@gmail.com

Abstract. The 7.5-magnitude earthquake was intensified epicentre located in the Mountains Donggala Regency, Central Sulawesi. Devastating earthquake and tsunami on September 2018, that struck and erased urbans and suburbs in stricken city in Central Sulawesi and surrounded. The main priorities of the risk disaster management in post-event are fast and safe detection of geohazards to help search and rescue team do mitigation. Satellite radar and optical remote sensing represent the aim of this research to answer this task with Interferometric Synthetic Aperture Radar (InSAR) by Sentinel-1 Interferometric Wide (IW) Level-1 Single Look Complex (SLC) images and optical satellite data by Sentinel-2 Level-1C product. We collected both of satellite images covering the time interval October 2018 – July 2019. We improved the proposed approach, named as Goldstein interferogram filter and the landslide mapping in Central Sulawesi. The methodology, which is intended as an effective process to suppress phase noise to improve the accuracy assessment and represent the experimental information from a full stack of InSAR data and optical data, is ideally acceptable for geohazard mitigation strategies. This potential method refers to great performance for detecting more than 100 areas affected by active deformation that are most dangerous for one or more risky elements in several parts of three cities.

1. Introduction

On September 2018 Mw 7.5 Donggala earthquake occurred on 0.18 South Latitude and 119.85 East Longitude at 10:02:45 UTC, with a depth of 10 kilometres under sea level [1]. The geological epicentre was 27 kilometres northeast of Donggala and triggered a tsunami. Donggala earthquake and that tsunami are strongly related to Palu-Koro fault activities across to Central Sulawesi due to the tectonic movements under Earthquake crust of Palu-Koro faults with several parallel fault slip. The expansion of the impact region is intrinsically linked to the domination of sediment rocks, specific types are Holocene. The primary effects of Donggala earthquake and tsunami led to damage construct ground and structures, landslides and liquefaction.

The seismic monitoring system which provides valuable information to observing and monitoring the post-earthquake area based on remote sensing technology. Remote sensing techniques play an important role in obtaining building damage information because of their non-contact, low cost, wide field of view, and fast response capacities. The development of synthetic aperture radar (SAR) is one of the applications of remote sensing technology for earthquake damage detection. SAR, satellite imagery, provides remedies to major geohazards under critical situations around the world. SAR data provide by Sentinel-1 (radar satellite) and Sentinel-2 (optical image).

Sentinel 1A mission with the revisit period of 12 days helps to serve the objective in an effective manner. With the availability of interferometric wide (IW) Swath mode, Sentinel 1A mission is capable of monitoring the surface deformation using interferometric synthetic aperture radar (InSAR) techniques [2]. Sentinel 2 has a revisit frequency of 10 days to monitoring the land surface change.

Sentinel-2 data has the high-resolution bands (blue, green, red and near-infrared at 10 m), the difference between pre and post-area reflectance was most pronounced in the blue band [3].

In a previous study, Stramondo et al. explored two case studies, Izmit (1999; Turkey) and Bam (2003; Iran) by combining the radar (SAR) and optical satellite data that the result of fusion imagery between SAR and optical data raised up to 89% of correct pixel-to-pixel classification [4]. Suresh & Yarrakul suggested the application of Sentinel 1A Imagery with InSAR technology to monitoring the deformation mapping of earthquake [2]. While, Tiwari et al. estimated the landslide activity in Sirobagarh, Uttarakhand, India by using LiDAR, SAR Interferometry, and geodetic surveys that complement the ability to highlight subsidence in subsurface landslides [5]. Polcari et al. integrated the Sentinel-1 InSAR and GPS data to estimate ground displacement field in 3D at 2014 South Napa earthquake [6]. In this paper we characterize the pattern and style of post-surface area across our field-survey region. And hence, this is a great problem where spatial variation involves and to represent this spatial variation, remote sensing technology and Geographic Information System (GIS) are very useful in analysing and decision making for the area being subjected to post-earthquake mapping.

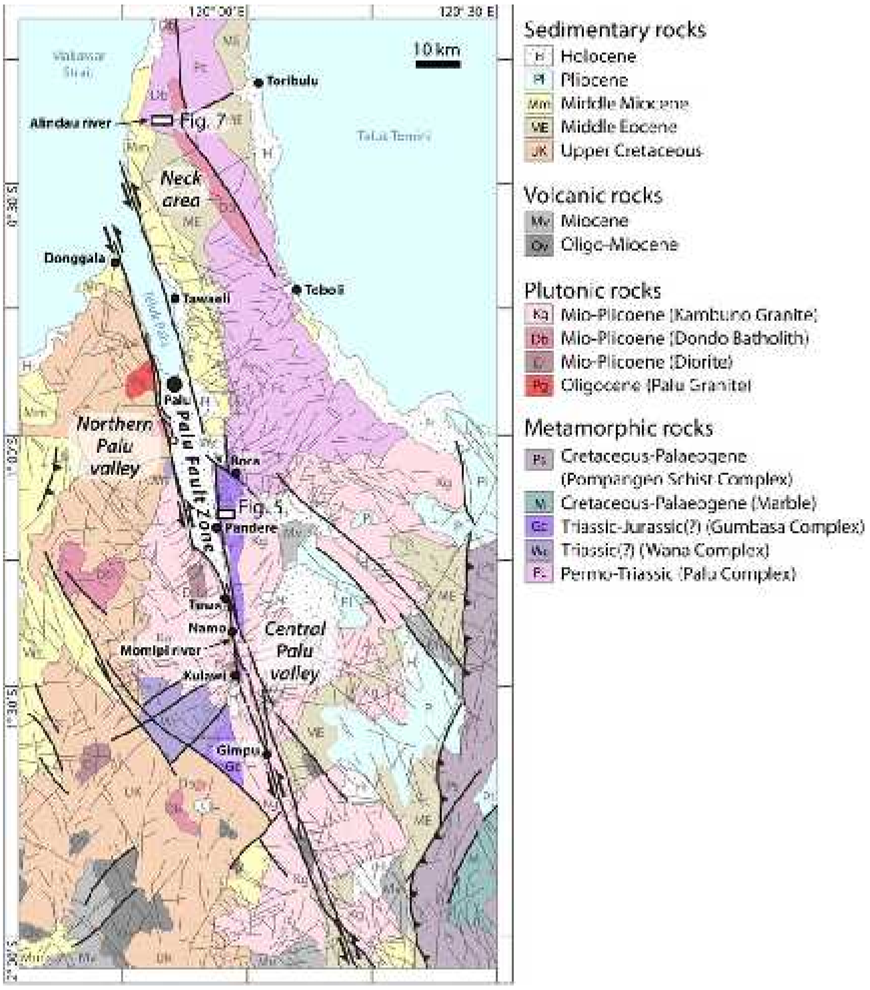

Figure 1. Geomorphic and structural map of Palu-Koro fault lies on Sulawesi Island.

2. Materials

The Sentinel-1 mission comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather. Sentinel-1 use Interferometric Wide (IW) swath mode which is the main acquisition mode over land and satisfies the majority of service requirements. It acquires data with a 250 km swath at 5 m by 20 m spatial resolution (single look). IW mode captures three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR). With the TOPSAR technique, in addition to steering the beam in range as in ScanSAR, the beam is also electronically steered from backward to forward in the azimuth direction for each burst, avoiding scalloping and resulting in homogeneous image quality throughout the swath [1].

At the same time, the Copernicus Sentinel-2 mission also comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) will support monitoring of Earth's surface changes. The coverage limits are from between latitudes 56° south and 84° north.

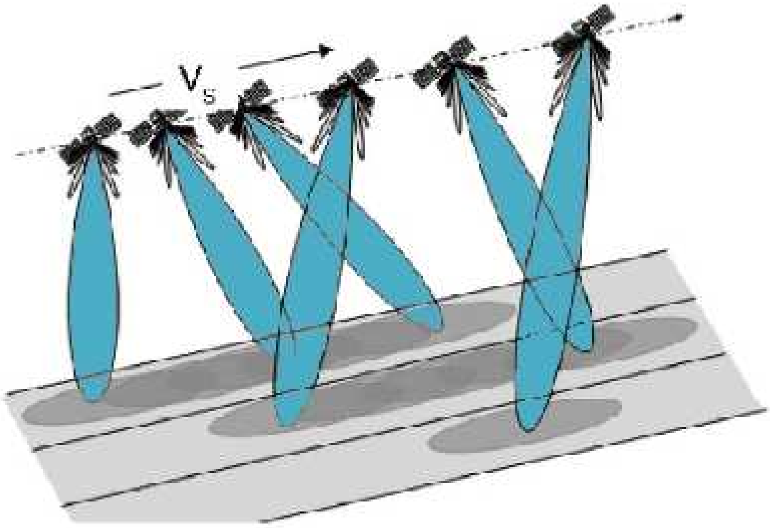

Figure 2. SAR Sub-Swath Acquisition

Study area has geographical center with latitude -0.8679° S and longitude 119.9047° E in Palu city and its surroundings. The specific boundary area (for Talise beach) stretches around 0°52′0″ S to 1°0′0″ S and 119°48′0″ E to 119°56′0″ E.

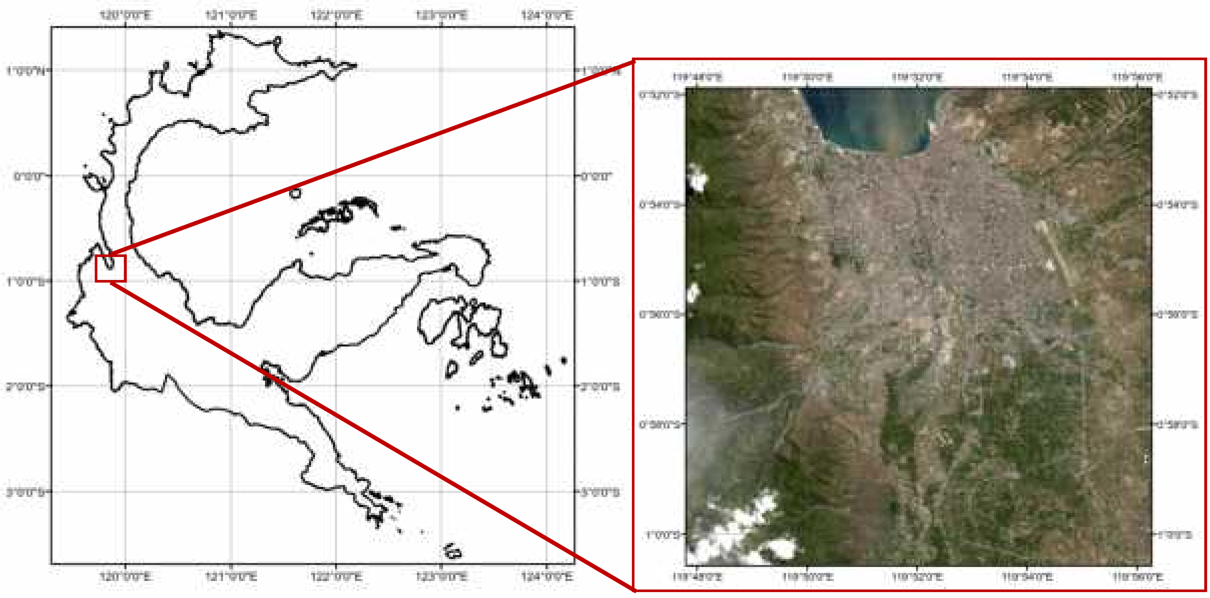

Figure 3. Study area in Talise Beach and its surroundings

3. Methods

Design of experiment for the case study, Differential Interferometric Synthetic Aperture Radar (DInSAR) is a sideways radar imaging method utilizing phase differences of two or more SAR images with different acquisitions in processing to obtain topography and deformation. To calculate the deformation model, the DInSAR method can be seen in Eq. 1 [7]. The main purpose of DInSAR is extracting-removing-minimizing the total phases difference magnitudes that caused by deformation. Atmospheric factor has also the influence in DInSAR methods but it can be suppressed by over image or corrected from other sources (such as GPS). So, we will collect the main information that comes from topography to determine the deformation.

$$\Delta\varphi = \Delta\varphi_{topo} + \Delta\varphi_{defo} + \Delta\varphi_{atm} + \Delta\varphi_{orb} \ldots\ldots (1)$$

Where:

φ = Phase difference magnitudes
φ_{topo} = Topographic Phase
φ_{defo} = Deformation Phase
φ_{atm} = Atmospheric Phase
φ_{orb} = Orbit phase

The DInSAR method requires two radar images, assuming deformation that occurs at the time of the acquisition and is known as a two-pass method. Several methods were applied statistical by built code of Single Look Complex in Interferogram, and then determining Baseline Coherence to estimate the phase correlation. Next, co-registration imagery by determined master image and slave image, do the phase unwrapping to decide the absolute phase and then do geocoding. Finally, the profile of absolute phase over study area can be determined by geocoding.

4. Result and Discussion

The deformation zone of Donggala earthquake is located in Central Sulawesi, Indonesia. Figure 4 shows that natural-image of Donggala and surrounding is covered about 100 x 100 km exist with pixel size of spatial resolution of 10 m. This allows Sentinel-2 to contribute in purposes including but not limited to vegetation, land cover, plant health, deforestation and environmental monitoring such as deformation. The advantages of Sentinel 2 are cloud free image, for any location, is displayed by default, and analysis ready with TOA correction applied [8].

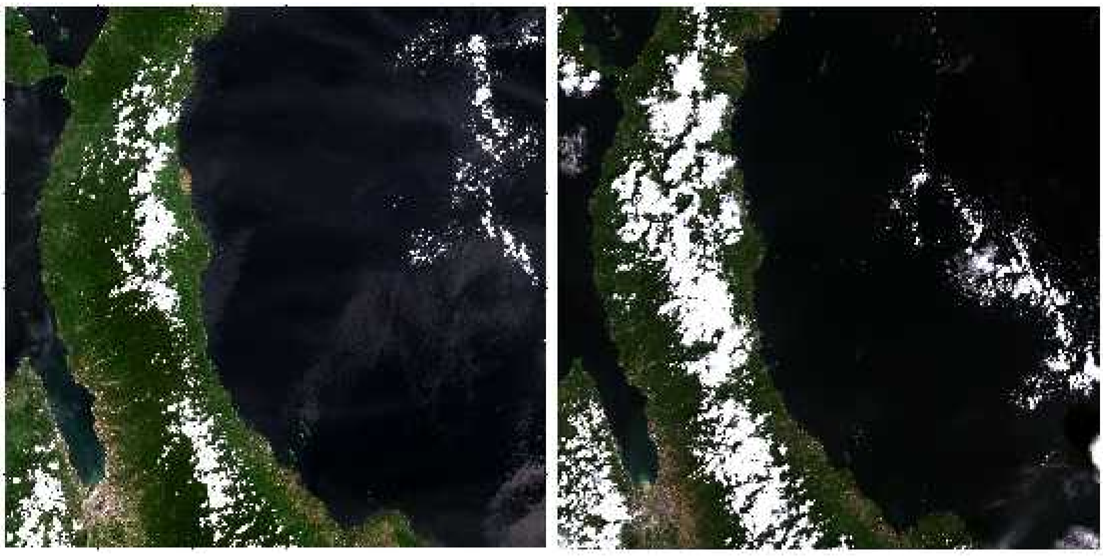

Figure 4. Real-Look Imagery by Sentinel 2 in (a). Before Donggala earthquake and (b) After Donggala earthquake on September 28, 2018.

Donggala earthwuake is considering relative area to trigger liquefaction at some area such as Balaroa, Jonooge and Petobo as area demand on liquefaction event. Figure 5a shows the topographic mapped in Petobe after the earthquake phenomenon. Two differentiated altitude of Petobo are 50 m that probabily related to cause the changing in shape or distorting due to the application of pressure such as earthquake [9]. Figure 5b shows the topographic mapped in Jonooge after the earthquake phenomenon. This image is initially providing the differentiated-altitude around 40 m. Figure 5c shows the topographic mapped in Balaroa after the earthquake phenomenon. This image is initially provide the differentiated-altitude around 30 m [10]. To analyze the deformation, Sentinel-1 SAR mapped as shown in Final result. We are using Sentinel-1 as data for ground deformation monitoring with the SNAP processing.

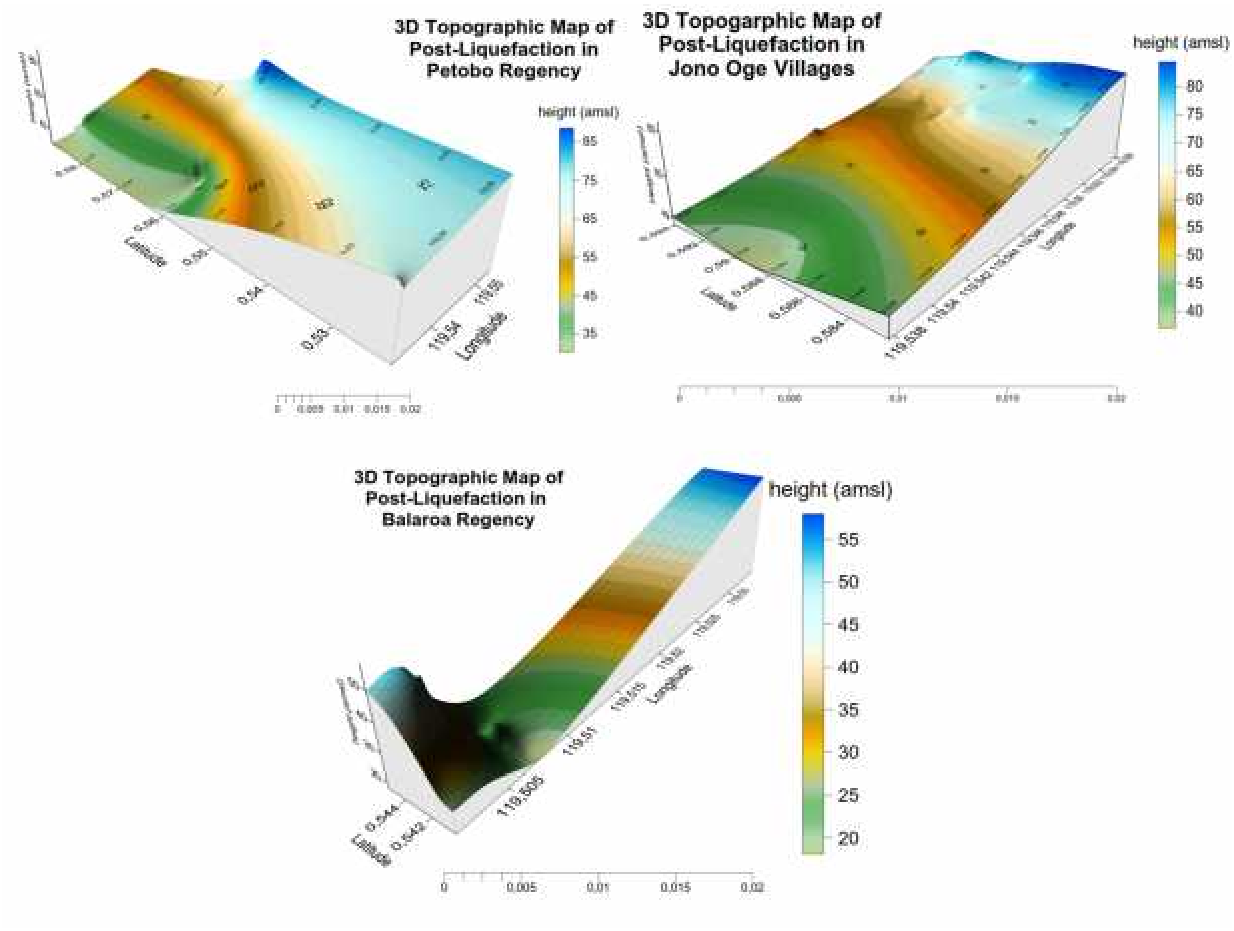

Figure 5. 3D topographic map for the post-liquefaction on a. Petobo regency, b. Jono Oge Villages and c. Balaroa regency.

Conclusion

A preliminary imagery data analysis indicates that Sentinel-2 contributes well in optical remote sensing to deliver the deformation evidence. On the other hand, Sentinel-1 is hopefully indicates the land damage and deformation damage in specific phase information. The field survey more heavily weights the contribution to ground surface damage from impact-area of deformation which liquefy closer to the ground surface. Preliminary analyses indicate that for the range of seismic demands imposed by the recent earthquakes are effectively investigate by using remote sensing optical imagery and radar dataset.

References

[1] GDACS 2018 M 7.5 Earthquake and Tsunami (1.5 m) in Indonesia on 28 Sep 2018 10:02 UTC, http://www.gdacs.org/gts.aspx?eventid=1157757&eventtype=EQ
[2] Suresh D and Kiran Yarrakul 2018 InSAR based Deformation Mapping of Earthquake using Sentinel 1A Imagery *Geocarto International* p 1-17
[3] Dong L and Shan J 2013 A Comprehensive Review of Earthquake-Induced Building Damage Detection with Remote Sensing Techniques *ISPRS Journal of Photogrammetry and Remote Sensing* **84** p 85–99
[4] Stramondo S, Bignami C, Chini M, Pierdicca N and Tertulliani A 2006 Satellite Radar and Optical Remote Sensing for Earthquake Damage Detection: Results from Different Case Studies *International Journal of Remote Sensing* **27**(20) p 4433-4447
[5] Tiwari A, Narayan A B, Dwivedi R, Dikshit O and Nagarajan B 2018 Monitoring of Landslide Activity at The Sirobagarh Landslide, Uttarakhand, India Using LiDAR, SAR Interferometry and Geodetic Surveys *Geocarto International* p 1-31
[6] Polcari M, et al. 2016 3D Displacement Field Retrieved by Integrating Sentinel-1 InSAR and GPS Data: The 2014 South Napa Earthquake European *Journal of Remote Sensing* **49**(1) p 1-13
[7] Yun H-W, Kim J -R, Yoon H, Choi Y, Yu J 2019 Seismic Surface Deformation Risks in Industrial Hubs: A Case Study from Ulsan, Korea, Using DInSAR Time Series Analysis *Remote Sensing* **11** p 1190-1199
[8] Sun T, Wang K and He J 2018 Crustal Deformation Following Great Subduction Earthquakes Controlled by Earthquake Size and Mantle Rheology *Journal of Geophysical Research: Solid Earth* **123**(6) p 5323–5345
[9] Xu C J, Fan Q B, Wang Q, Yang S M and Jiang G Y 2014 Postseismic Deformation After 2008 Wenchuan Earthquake *Survey Review* **46**(339) p 432-436
[10] Kongar I, Tiziana R and Sonia G 2017 Evaluating Simplified Methods for Liquefaction Assessment for Loss Estimation *Natural Hazards Earth System Science* **17** p 781–800