http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 9 No 1 2024

RESEARCH ARTICLE

The Utilization of LiCSBAS for Deformation Monitoring in Geresa Segment of Matano Fault, Central Sulawesi, Indonesia

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Received: Apr 20, 2023. Accepted: Mar 7, 2024.
DOI: 10.25299/jgeet.2024.9.1.14212

Abstract

Sulawesi is situated between the confluence of three plates, resulting in a very complex tectonic setting on the island. This has an impact on the occurrence of geological structures, including faults. One of them is the Matano Fault which consists of 6 segments (Kuleana Segment, Pewusai Segment, Matano Segment, Pamsoa Segment, Ballawai Segment, and Geresa Segment). The research area is located in Morowali Regency, covering the Geresa Segment. Morowali Regency recorded an earthquake with a magnitude of 5.7 in 2012. This indicates that deformation has occurred. Therefore, this study aims to identify the deformation velocity around the Geresa Segment area. The methods used are geological observation and satellite image data processing to obtain information on deformation rates. The geological field study includes aspects of geomorphology, geological structure, and the rock types distribution. Meanwhile, the processing of satellite image data in the form of InSAR is carried out through the LiCSBAS package tools that has been integrated with LiCSAR. The analysis results illustrate the difference in deformation velocity around the Geresa Segment area. The area which is composed of Tolaka formation and Ultramafic complex tends to uplift with a deformation rate of up to 17 mm/year. In addition, alluvium that covers the southeastarn part has a land subsidence of up to 7 mm/year.

Keywords: Geresa Segment, Matano Fault, Deformation, LiCSBAS

1. Introduction

Sulawesi is located between the triple junction of the Eurasian Continental Plate, the Pacific Plate, and the Indo-Australian Plate, which is also included in the Ring of Fire. This condition creates a very complex geological setting for Sulawesi. It is not only related to morphology, but also its stratigraphy and geological structure. Based on its tectonics and stratigraphy, Sulawesi is structured from four geological mandalas, specifically the West Sulawesi Volcanic Belt, the Central Sulawesi Metamorphic Belt, the East Sulawesi Ophiolite Belt, and the Microcontinent (Panggabean, 2011) (See Fig. 1).

Sulawesi has a complex tectonic setting which has led to geological structure such as faults. Some of the most common faults are thrust faults close to the subduction zone, namely the Tolo Fault and Tomini Fault. On the other hand, strike slip faults include Palu Koro Fault and Matano Fault with sinistral strike slip, and Gorontalo Fault with dextral strike slip (PUSGEN, 2017).

The research area is sited in Morowali Regency, Central Sulawesi, near the Geresa Segment of the Matano Fault. In terms of morphology, the Matano Fault is divided into several segments including the Kuleana Segment, Pewusai Segment, Matano Segment, Pamsoa Segment, Ballawai Segment, and Geresa Segment (Kurniawati, 2020). Based on geodetic estimation, the Matano Fault has a shear rate of 14-44 mm/year (PUSGEN, 2017). So, the Matano Fault is an active fault and potentially lead to earthquakes (Sarsito, 2010). An earthquake with a magnitude of 5.7 was observed in Morowali Regency in 2012, and it damaged houses, primarily in the Central Bungku and East Bungku Subdistricts (Pertiwi, 2022). Accordingly, this study uses geological data and satellite image to find out the deformation rate around the Geresa Segment.

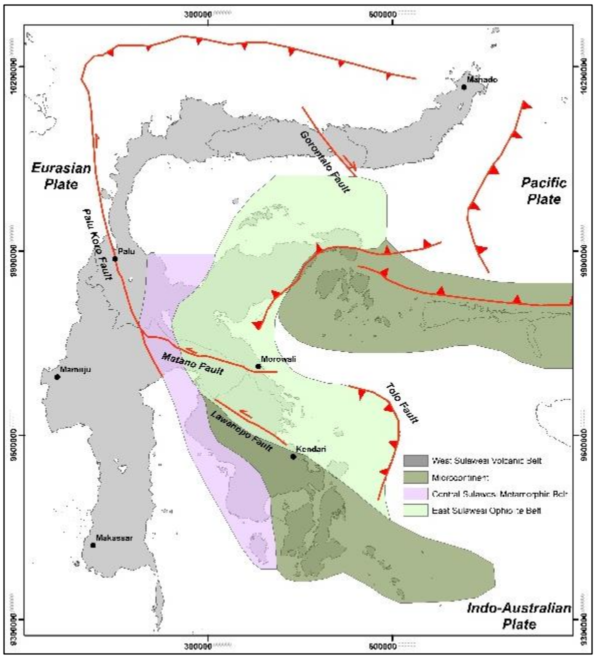

Fig. 1. Four Geological Mandalas of Sulawesi (Modified from Panggabean, 2011)

2. Data and Method

Geological analysis is required to determine geomorphology, geological structure, and stratigraphy in the Geresa Segment area. The study area is included in the Geological Map of Bungku Quadrangle (Simandjuntak, 1993). In general, there are four rock units from old to young, namely the Tolaka Formation (Middle Triassic to Middle Jurassic), Ultramafic Complex (Cretaceous), Tomata Formation (Late Miocene to Pliocene), and Alluvium (Pleistocene to Holocene). Moreover, the study area is controlled by the Matano fault, especially the Geresa segment. The presence of the Matano fault is accompanied by the emergence of several next-order faults that are relatively north-south oriented. This results in the formation of undulating hilly morphology. The geological map of study area can be seen in Figure 3.

Many studies on deformation monitoring have been conducted using various methods. One of the commonly used methods is through monitoring and processing GNSS CORS data (Afifuddin, 2022). Along with technological developments, satellite image data is also widely used for deformation monitoring such as InSAR (Interferometric Synthetic Aperture Radar) (Jefriza, 2020 and Ulin, 2019). InSAR is a remote sensing technology that records the earth's surface without being disturbed by weather changes, and can operate throughout the day (Pepe, 2017). On the other hand, InSAR data can be obtained quickly, on a daily scale, and with a wide coverage. InSAR utilizes phase measurements from two or more SAR data, and is based on differences in orbital position and time. Therefore, InSAR data is often used to collect topographic information (Zhou, 2009).

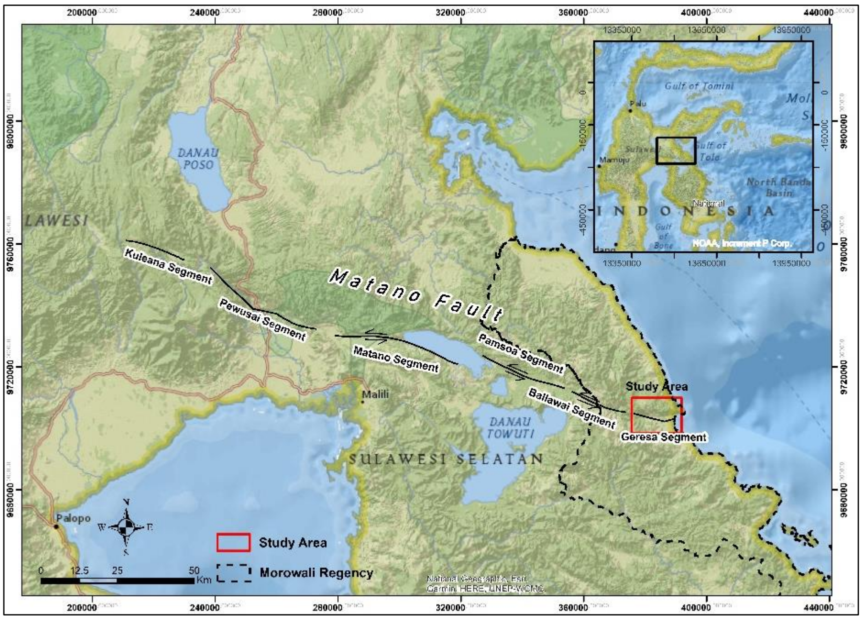

Fig. 2. The Research Area Around Geresa Segment (Matano Fault) (Modified from PUSGEN, 2017)

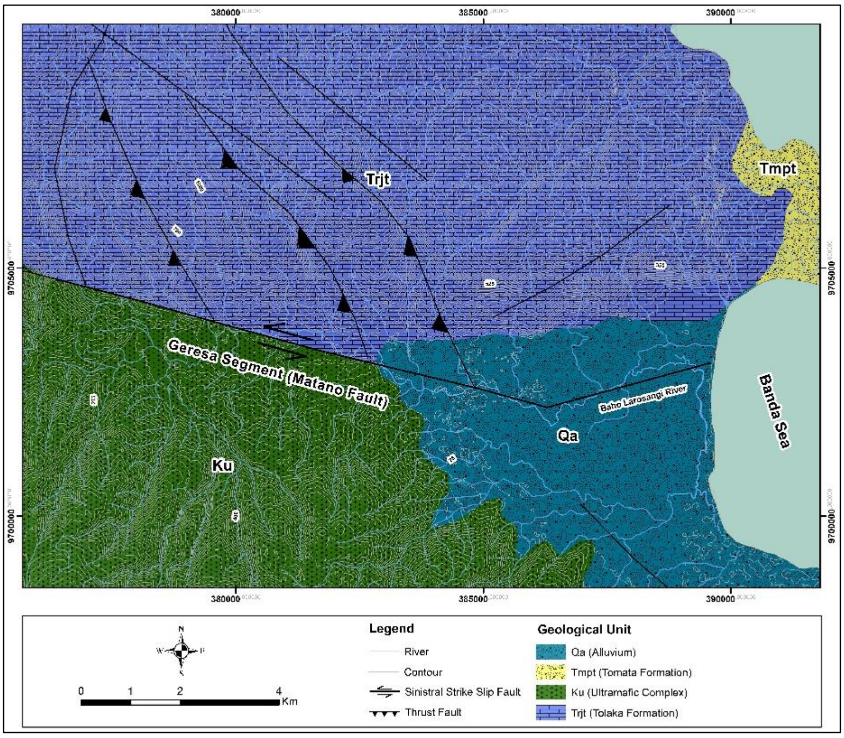

Fig. 3. Geological Map of Study Area (Modified from Simandjuntak, 1993 and PUSGEN, 2017)

Currently, InSAR data can be automatically collected and processed by the system. This was introduced by Lazecký (2020), known as LiCSAR (Looking into Continents from Space with Synthetic Aperture Radar) and is developed by COMET (Center for the Observation and Modeling of Earthquakes, Volcanoes and Tectonics). Interferograms are the product of LiCSAR that can be accessed directly through the web portal (https://comet.nerc.ac.uk/comet-lics-portal/). As of August 2023, LiCSAR has produced 1.2 million interferograms and are available on its website.

InSAR data can be processed in various methods and LiCSBAS is an alternative. LiCSBAS is an open source InSAR time series analysis tool that has been integrated with LiCSAR (Morishita, 2020). LiCSBAS uses interferograms generated by LiCSAR, so users do not need to process SLC (Single Look Complex) data. Another advantage of using LiCSBAS is that users can monitor ground deformation easily, quickly, and in large coverage area with the availability of LiCSAR data. Some scientific research regarding LiCSBAS method includes deformation monitoring studies in Southern Sumatra (Al Ghiffari, 2022 and Nugroho, 2022), around the Opak Fault area (Dewanto, 2020), landslide zones (Rosyidy, 2021), volcanic activity on Mount Raung (Kriswati, 2021), and subsidence due to groundwater exploitation (Ghorbani, 2022).

Deformation analysis using the LiCSBAS method is generally divided into two main parts, i.e. stacking unwrapped data and InSAR time series analysis.

2.1 Stacking Unwrapped Data

This step begins with downloading the unwrapped data generated by LiCSAR (GeoTIFF file type) automatically. Previously, users had to find out the frame ID of the research area, as well as the time range of the data to be downloaded. The data frame has an area of approximately 250 x 250 km. The second step is to convert the downloaded data into single-precision floating-point format. GACOS (Generic Atmospheric Correction Online Service) is applied for tropospheric correction in the next step. The use of GACOS aims to eliminate the effects of atmospheric errors on the interferogram (Wang, 2019). Users can download GACOS data for free through the portal (http://www.gacos.net/) by preparing time range according to interferogram data from LiCSAR and coordinates of the study area. The fourth and fifth steps are mask and clip interferograms. These steps aim to reduce data that has unwrapping errors and narrow the research area if it is not the same as the frame size. So that data processing in the next stage can be faster and the resulting file size is reduced.

2.2 InSAR Time Series Analysis

The time series analysis basically consists of 6 steps. The first step is to check the interferogram data quality through the level of coherence and the percentage of valid unwrapping data pixels. The second step is the loop closure phase, when the loop closure value is close to zero then the interferogram data has minimum unwrapping errors. Conversely, when the interferogram data has high unwrapping errors, the loop closure value is also high. Consequently, poor interferogram data will be eliminated for better InSAR time series analysis results. The next step is to calculate velocity displacement through small baseline inversion. The last three steps are estimating the standard deviation value, masking the interferogram data that has noisy pixels, and filtering the data spatiotemporally.

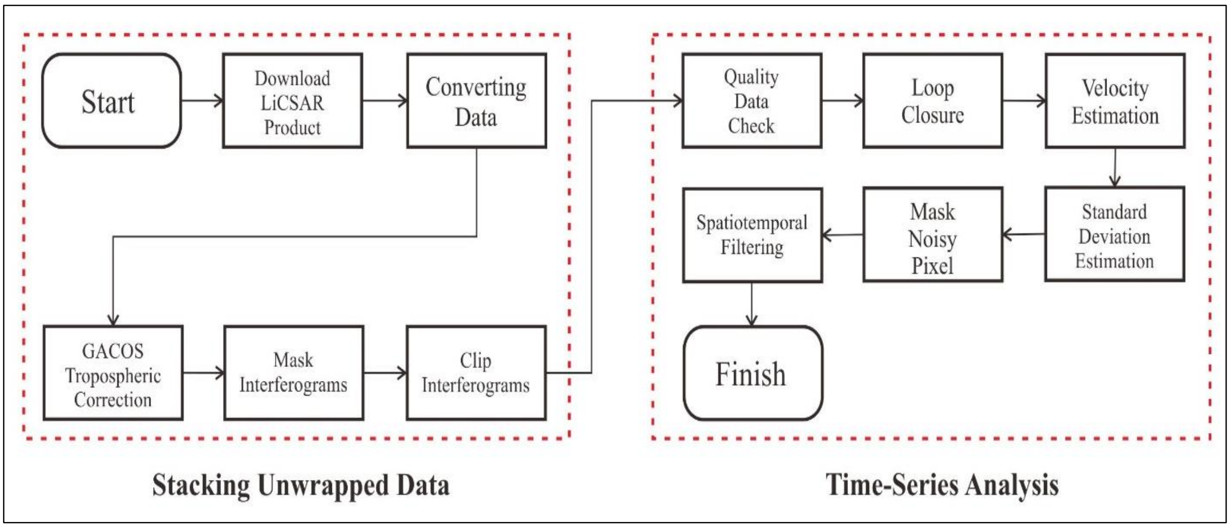

Fig. 4. The Workflow of InSAR Processing Data Using LiCSBAS (Simplified from Morishita, 2020)

3. Result and Discussion

3.1 Geomorphology and Geological Structure

The geomorphological aspects of the study area are assessed in terms of landform and slope. The Geresa Segment area is particularly divided into two landform types, which are plain and hills. The plain landform dominates from central to the eastern part, with an elevation range of 0 to 100 masl. This area has a flat to slightly steep (2-4 degree). Meanwhile, the hills is distributed on the north and south sides of the study area. It has elevations of up to 1000 masl and moderately to highly steep slopes (8-55 degree). This significant landform change between plains and hills is an indication of geological structure, the Geresa Segment of Matano Fault. Geresa Segment is a sinistral slip fault that extends from west to east. The landform map and field photos are presented in Figure 5.

3.2 Stratigraphy

According to Simandjuntak (1993) and observation in the field, the study area is composed of four rock units sorted from old to young including:

a. Tolaka Formation (Trjt)

The Tolaka Formation in the northern part of the study area consists of crystalline limestone with fresh white color and brownish yellow weathered color (Fig. 6). The outcrop is massively exposed, and has a high hardness level. The local people exploit the limestone as a quarry material.

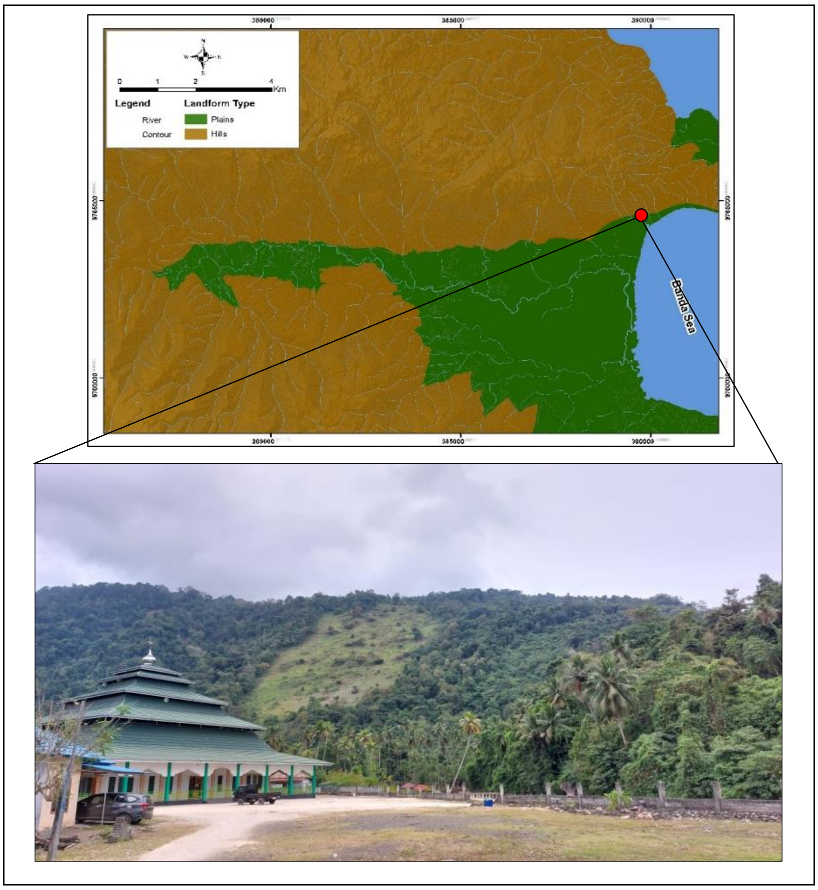

Fig. 5. Landform Type in Study Area. The light green is allegedly to be landslide before.

Fig. 6. The Outcrop of Limestone, Tolaka Formation (Trjt)

b. Ultramafic Complex (Ku)

The Ultramafic complex is distributed in the southern part of the study area. This ultramafic rock has a fresh greenish ash color, gray-white weathered color, faneritic, holocrystalline, weak to strong weathering level, and mineral composition of olivine, pyroxene in megascopic scale (Fig. 7). Simandjuntak (1993) mentioned that this Ultramafic Complex consists of Harzburgite, Lherzolite, Wehrlite, Websterite, Serpentinite, Dunite, Diabase, and Gabbro.

Fig. 7. Ultramafic Rocks Outcrop

c. Tomata Formation (Tmpt)

The Tomata Formation is found in the northeast and is the smallest formation in the study area. Based on field observation, this formation is composed of sandstone and conglomerate. The sandstone has a brownish yellow fresh color, brown weathered color, coarse sand grain size, closed fabric, medium-good sorted. While the conglomerate has a fresh brown color, brown-black weathered color, polymictic, opened fabric, poorly sorted, and coarse sand matrix (Fig. 8).

Fig. 8. Conglomerate Outcrop of Tomata Formation

d. Alluvium (Qa)

Alluvium covers the southeastern part of the study area and is composed of loose material ranging in size from clay to pebbles. It lies on a flat terrain with densely populated settlements. It is also traversed by the Baho Larosangi River which is quite large, with a width of 10 to 15 meters (Fig. 9).

3.3 Ground Deformation in Geresa Segment Area

The deformation analysis begins by downloading the unwrapped data from the LiCSAR web portal with Frame ID 061D_09234_131313. The data is available from September 2020 to February 2021. Afterward, the interferogram data was clipped into the study area. The data processing results that the deformation velocity shows uplift in the Tolaka formation and Ultramafic complex. Both show deformation velocity of up to 17 mm/year. This condition is in line with the tectonic setting of the study area which receives tectonic forces from the eastern side of the microcontinent as well as pressure between the Matano fault (Geresa segment) and the Lawanopo fault (figure 1 and figure 3). In contrast with the alluvium which has a lower position, experiencing subsidence of up to 7 mm/year. The existence of the Baho Larosangi river in this area causes fluvial material to be deposited.

Fig. 9. Baho Larosangi River in Study Area

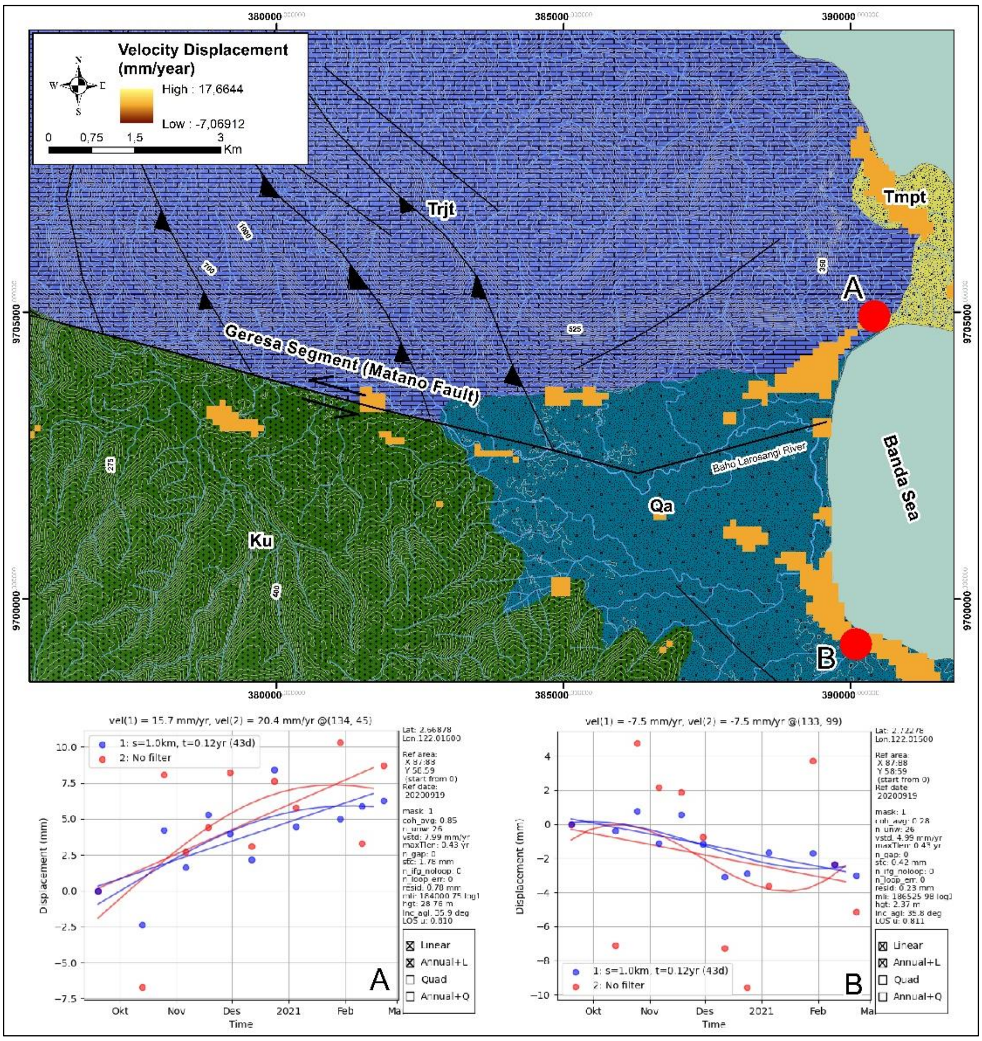

Fig. 10. Velocity Displacement Map in Geresa Segment Area

4. Conclusion

The history of earthquakes predicted to be caused by the Geresa Segment of Matano Fault indicates the deformation in the study area. This is shown by the subsidence rate of alluvium up to 7 mm/year. Whereas, the Tolaka formation and Ultramafic complex illustrates uplift at a rate of up to 17 mm/year. The analysis shows a difference in the deformation rate around the Geresa Segment due to the tectonic settings. However, the data used with a longer time span will provide more optimal analysis results.

Acknowledgement

LiCSAR contains modified Copernicus Sentinel data (2020-2021) analysed by the Centre for the Observation and

Modelling of Earthquakes, Volcanoes and Tectonics (COMET). LiCSAR uses JASMIN, the UK's collaborative data analysis environment (http://jasmin.ac.uk). We acknowledged LiCSBAS for permission to process InSAR data. We extend the gratitude to all reviewers for their suggestion of the manuscripts. We are also deeply indebted to National Research and Innovation Agency (BRIN) for supporting this research.

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