Utilization of Synthetic Aperture Radar (SAR) Imagery to Identify Potential for Earthquake Disasters to Improve Disaster Preparedness

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Abstract. Indonesia is located in three collision zones of the world's three major plates, namely the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate. As a result of the plate collision, there were many earthquakes in Indonesia. One of the characteristics of the earthquake in this study is an active fault. Active faults are things that can cause earthquakes. The purpose of this literature review is to determine the differences in the accuracy of the Synthetic Aperture Radar (SAR) method with various types of satellites to identify earthquake characteristics. This literature review is limited by analysis of active faults on land using SAR imagery in the territory of Indonesia. Indonesia is located in the equator causes high cloud coverage throughout the year in Indonesian region. The advantages of this SAR image are that it can monitor the earth's surface without weather disturbances, can penetrate clouds, and can be used during the day or night. The results of this literature review show that to identify the impact of earthquakes with high slip fault sources, medium resolution SAR images can be used (such as using Sentinel-1 imagery), and to identify the effect of earthquakes with low slip faults, high resolution can be used (such as using ALOS-2/PALSAR imagery). Knowing the impact of deformation due to earthquakes can be used to improve disaster preparedness, particularly those caused by earthquakes.

1. Introduction
The geographical location of Indonesia, which is located at the equator, causes high cloud coverage throughout the year in the territory of Indonesia. The appropriate remote sensing technology is by using satellite radar or SAR. The advantages of this SAR image are that it can capture the earth's surface without weather disturbances, can penetrate clouds, and can be used during the day and night. Indonesia is located in three collision zones of three major world plates, namely the Eurasian Plate, the Indo-Australian Plate and the Pacific Plate. As a result of the plate collision, many earthquakes occur in the territory of Indonesia, both originating on land and sea. The impact of an earthquake can be minimized by knowing the characteristics of the earthquake. One of the characteristics of the earthquake in this study is an active fault. Active faults are things that can cause earthquakes to occur at a location. For the field of disasters, especially those caused by earthquakes, it requires high
temporal resolution image data, high to medium spatial resolution, and sufficient dual polarization of radar.

This can be an opportunity in utilizing remote sensing data to support the provision of geospatial information because of its ability to observe cloud-translucent land. SAR interferometry was first introduced in 1974 for topographic mapping, which is also used to determine changes in the land surface. In its development, InSAR has evolved from a theoretical concept to a technique that has revolutionized various fields of earth science [1]. Several InSAR techniques can be used to determine changes due to earthquakes, such as knowing changes in surface deformation, fault geometry, and slip fault distribution. InSAR to determine deformation due to earthquakes has been carried out since the Landers earthquake in 1992. With analysis of satellite images before and after the earthquake [2]. Then for the fault geometry analysis and slip fault distribution was carried out by [3], [4], [5], [6], and [7].

The purpose of this literature review is to determine the differences in the accuracy of the SAR method with various types of satellites to identify earthquake characteristics. Knowing the characteristics of an earthquake can improve disaster preparedness, especially earthquake disasters in Indonesia.

2. Research Methods
The method used in this study is a literature review. The steps used in this literature review can be seen in Figure 1, consists of four stages, namely identification, screening, grouping, and analysis. The identification stage is carried out by the topic search process with SAR keywords for earthquakes from journal sources on Google Scholar. The screening stage is carried out by selecting journals in accordance with the specified criteria, which are related to the use of SAR for earthquake disasters. At this screening stage, the InSAR method criteria for earthquake disasters are determined by the title, abstract, and keywords.

![Figure 1. Research design flow chart](image)

The third stage is the grouping stage, where journals are selected at the screening stage by searching at the research background, research objectives, research methods, results, analysis, and conclusions. The next process after receiving the journals that have been determined according to the criteria is to group the journals based on the type of SAR satellite used, the method of analysis, the resolution obtained, and the location that had been analyzed. The last stage is the analysis stage, by analyzing these journals to get a synthesis of the use of SAR for earthquake disasters. Analysis of the data used is by comparing the results of the processing of various SAR images, it is concluded which are the most effective and efficient for being practiced in the field of earthquakes.
3. Results of Analysis and Discussion

The results with a search using Google Scholar with the SAR keyword for earthquakes were obtained as many as 56,800 articles in any time range, sort by relevance, and sort by including citations. Then from several articles, 15 articles were selected that represent SAR techniques for earthquakes grouped into two groups, namely earthquake deformation and interseismic deformation.

The application of InSAR in the study of crustal deformation has been widely carried out since early 1989 [8]. In this method, measurements of horizontal angles, distances, or height differences between benchmarks at the study site are carried out and compared from time to time, so that the difference in changes that indicate crustal deformation. It is this measurement data from time to time that is very important in developing and improving our understanding of the mechanism of earthquake cycles and active deformation in plate boundary zones. While the terrestrial method can also produce precise deformation measurements, this method is time-consuming and expensive, limited to measurements at one location. It does not allow for direct three-dimensional measurements.

Using satellite radar data ERS-1 can describe the deformation caused by the 1992 Landers earthquake, by collecting satellite image data before and after the earthquake [2].

3.1. Earthquake deformation

Earthquake deformation analysis using InSAR has been widely carried out since the 1992 Landers earthquake, California, United States [2]. The Landers earthquake and its aftermath imaged with the ERS sensor demonstrate InSAR’s unique capabilities contributing to the study of crustal deformation.

The Landers earthquake of June 28, 1992, was the first tectonic event to be captured and studied in detail with InSAR [2]. Although wide-field deformations are well captured by conventional GPS measurements, InSAR imagery provides a wealth of information about small-scale deformations in the near and far fields of the object. Furthermore, InSAR data prove invaluable in the investigation of post-earthquake deformation patterns.

3.2. Interseismic deformation

Plate boundary zones deform very slowly during most of the earthquake cycle as an elastic strain builds up. Typically, a few centimeters per year of displacement are distributed over an area tens of kilometers wide. Errors introduced by orbital and atmospheric effects and decorrelation over time have long spatial scales, so measuring the widely distributed deformation presents a significant challenge for InSAR [9].

Of great importance for earthquake hazard studies is determining the contribution of seismic deformation to slip along major faults. Several major faults of the San Andreas fault system appear to accommodate most of their slip by seismic creep, including the central San Andreas Fault and the Hayward and Calaveras Fault. However, these faults have also experienced large earthquake cracks. We need to understand better the detailed distribution of the locked and creeping patches to improve estimates of potential earthquake occurrence.

Conducted research using Seasat radar data for locations in Imperial Valley, California [8]. The SAR technique measures very small objects (1 cm or less) with a resolution of 10 m within a monitoring area of 50 km. The method used is InSAR, where two images are obtained from taking using two separate antennas, which are carried out simultaneously. Then [10] conducted research related to geodetic measurements of basic interferometry used to estimate the movement of the Sierra Nevada microplate, which consists of the Sierra Nevada and the Great Valley. Conducted a study on the distribution of slip on faults caused by the 1992 Landers, California earthquake [2]. Using ERS-1 satellite SAR data before and after the earthquake by combining topographic information. SAR
interferometry, first introduced in 1974 for topographic mapping, can also be used to detect changes in the ground surface, by removing signals from the topography. SAR interferograms provide denser spatial sampling (100 m per pixel) than survey methods and better precision (~3 cm) than previous spatial imaging techniques.

Conducted research on the use of InSAR techniques to map active deformation along the Hayward fault between 1992 and 1995 [1]. During the 3-5 years following the 1989 M 7.1 Loma Prieta earthquake, creep along the southern Hayward Fault, California, slowed or stopped. The slip appears to have continued its pre-earthquake level by 1994 except for a locked segment of ~3 km at the southern end of the fault, which consistently slipped at ~9 mm/yr prior to 1989. Then [3] performed an InSAR technique analysis to explain the slip distribution due to the earthquake Izmit 1999. Conducted a study related to deformation due to the earthquake in Duzce, Turkey, November 12, 1999 [4]. One of the methods used was the InSAR technique. The aim is to estimate the geometry and slip distribution of coseismic ruptures.

Conducted research on coseismic deformation due to the Mw 7.1 Hector Mine, California earthquake [5]. The data used are from the ERS-1 and ERS-2 satellites. Then [6] conducted a study related to the distribution of fault slips in the Mw 7.1 Hector Mine, California earthquake using estimates from radar satellites. Data used from InSAR from ascending and descending orbits. Data sources from InSAR satellites with multiple geometric data capture of ascending and descending orbits. Radar data from the ERS-1 and ERS-2 satellite radars before and after the earthquake. Conducted a study related to the use of InSAR in the Mw 7.9 Denali earthquake, November 3, 2002, to detect the slip distribution and fault geometry [7]. Data used from Canada's Radarsat-1 satellite. Five interferogram datasets were used to map surface deformation, determine fault geometry and determine slip model. Conducted research related to the Yogyakarta earthquake on May 26, 2006, with InSAR to detect the fault location and fault geometry due to the earthquake, as in Figure 2. Data used by the Phased Array Type L-band Synthetic Aperture Radar (PALSAR) radar satellite, an instrument from Japan [11].

Conducted research related to the 2011 Tohoku earthquake with the InSAR technique to determine the slip distribution [12]. The data used are satellite images of ENVISAT and ALOS PALSAR. The ENVISAT radar data uses six frames in track 189, 6 frames in track 347 and 5 frames in track 74 in the ENVISAT descending pass section. Then [13] conducted research related to the 2018 Palu Mw 7.5 earthquake using the InSAR technique to determine the rupture area. The data uses the descending ALOS-2 radar. Conducted research related to the 2018 Palu magnitude 7.5 earthquake by utilizing space geodetic technology [14]. The data used is from ALOS-2 by taking data before (August 21, 2018) and after the earthquake (October 2, 2018). Conducted research related to the 2018 Lombok earthquake using the InSAR technique to determine the characteristics of the seismogenic fault [15]. InSAR analysis was carried out for the earthquakes of July 28, August 5, and August 19, 2018. The imagery used was from ESA Sentinel-1 SAR. Three SAR datasets were used to obtain a better inverse slip model.

From the results of the literature review above, it can be summarized that there are two uses of SAR for earthquakes, namely earthquake deformation and interseismic deformation. The method used in analyzing earthquake deformation and interseismic deformation is relatively the same, namely by comparing satellite images before and after the earthquake. From the image data analyzed changes in deformation, slip distribution, and slip geometry of an earthquake event. The difference between the studies above is the type of satellite used. Where this type of satellite affects the resolution of the data and the results of the analysis. In the early days of using SAR, the ERS-1 and ERS-2 satellite types were used. Then some use satellite imagery from Radarsat-1 from Canada, Phased Array Type L-band Synthetic Aperture Radar (PALSAR) radar satellite from Japan. Furthermore, currently using satellite imagery from ENVISAT, Sentinel-1 from ESA and ALOS PALSAR from Japan.
Figure 2. The Yogyakarta earthquake on May 26, 2006, with InSAR to detect the fault location and fault geometry due to the earthquake. Data used by the Phased Array Type L-band Synthetic Aperture Radar (PALSAR) radar satellite [11].

4. Conclusion
From the analysis result above, it can be concluded that the use of SAR techniques can be used to analyze earthquake characteristics. By comparing satellite images before and after an earthquake, it can be seen the changes that occur on the surface, such as deformation, slip distribution, and slip geometry. Of course, the selection of the type of satellite will determine the level of resolution produced. The results of this literature review show that to identify the impact of earthquakes with high slip fault sources, medium resolution SAR images can be used (such as using Sentinel-1 imagery) and to identify the impact of earthquakes with low slip faults, high resolution can be used (such as using ALOS-2/PALSAR imagery). Knowing the impact of deformation due to earthquakes can be used to improve disaster preparedness, particularly those caused by earthquakes so that it can be used to increase awareness of the danger caused by earthquake.

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