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Monitoring of Land Surface Change in Padang City Using Dinsar Sentinel-1a Method

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Abstract

Padang City is the capital city of West Sumatra Province which is located on the west coast of the island of Sumatra which is generally associated with tectonic earthquakes. This condition causes the city of Padang to become a disaster-prone area, one of which is land surface changes. The earthquake that occurred caused shocks to the rock and soil layers, causing water below the earth's surface to come out and resulting in changes to the soil surface. Besides, changes in soil surface are also caused by several things, including excessive groundwater extraction and soil type factors. To reduce the bad impacts, it is necessary to monitor the ground surface and to reduce the risk of a disaster. In a broad scope, the use of SAR imagery using the DinSAR method can monitor changes in the land surface in the city of Padang. The data used were Sentinel -1A imagery based on 3 earthquakes with a strength of more than 5 magnitudes centered on the Mentawai Islands, on September 8, 19, and 21 October 2020. From this research, the results obtained from the earthquake 8 September 2020 with satellite recording data 28 August (slave) and September 9, 2020 (master), there was land subsidence with a range of 0 - 25 mm along the coast of Padang City. The 19 and 21 October 2020 earthquakes with satellite recording data of 27 October 2020 (slave) and 15 October 2020 (master) obtained almost even surface subsidence with a range of 0 - 40 mm throughout the residential area of Padang City.

Keywords: Padang City, DinSAR, earthquake, the land surface change

1. Introduction

Earthquakes are natural phenomena that can occur at any time on the surface of the earth. Padang City is the capital city of West Sumatra Province which is located on the west coast of Sumatra Island which is generally associated with earthquakes. West Sumatra, especially the city of Padang, has a high disaster risk index, one of which is an earthquake (BNPB, 2021), this condition causes the city of Padang to become a disaster-prone area, one of which is land surface changes. The earthquake that occurred caused shocks to the rock and soil layers, causing water below the earth's surface to come out and resulting in changes to the soil surface. In addition, changes in soil surface are also caused by several things, including excessive groundwater extraction, which makes the soil more easily subsidence, causing loss of soil buoyancy due to loss of water in pores so that surface pressure becomes more effective. (Prasetyo & Subiyanto, 2014).

The accumulated land surface chance over a certain period of time will be able to reach the magnitude of the decline of up to several meters more, so that the impact can damage urban infrastructure which can then become a disruption to economic stability and social life in the region (Prasetyo & Subiyanto, 2014). Efforts to monitor changes in land surface are important as a means of mitigating natural disasters. Monitoring land surface changes can be studied by utilizing the Sentinel-1 SAR (Synthetic Aperture Radar) image (Fikri, Anjasmara, & Taufik, 2021), the method used by the DInSAR method (Differential Interferometric Synthetic Aperture Radar) .DInSAR is a method that has been well developed over the last few decades to observe land subsidence with high accuracy in centimeters (Islam, Prasetyo, & Sudarsono, 2017). The use of Sentinel-1A data in monitoring land surface changes in various methods has been widely used (Devanthéry et al., 2016; Fárová, Jelének, Kopačková-Strnadová, & Kycl, 2019; Islam et al., 2017; Lazecký, Hlaváčová, Martinovic, & Ruiz-Armenteros, 2018; Lazecký, Hlaváčová, Phase, et al., 2018; Loibl, Bookhagen, Valade, & Schneider, 2019). Some of the uses of the Sentinel-1A are the imaging capabilities of the Interferometric Wide (IW) method where this imaging mode is able to cover a large area with a spatial resolution of 5 x 20 m(ESA, 2012). IW is Sentinel-1 standard ground level observation type suitable for interferometric applications. With the sweep area and spatial resolution that is owned by IW mode, it can specifically support operations related to regular observations of the earth's surface (Rucci, Ferretti, Monti Guarnieri, & Rocca, 2012)

2. Methods

2.1 Data Collection

Sentinel-1 is designed to tackle mid-to-high resolution by displaying wide swath (250 km) and radiometric resolution (5 × 20 m), enabling high-resolution imaging of land, coastal zones, sea ice, polar regions, and shipping routes. Sentinel-1 has imaging missions to monitor sea ice zones and the polar environment, mapping in support of human needs in monitoring the marine environment, monitoring the risk of ground surface movement, and mapping the surface of the land. (ESA, 2012). Based on 3 earthquakes that occurred on 8 September 2020, 19 and 21 October 2020, in this study we used Sentinel 1A (SLC) imagery to record before and after the earthquake with VV + VH polarization with descending direction using the DinSAR method. Selection of image pairs (master and slave) based on the prepedicular baseline and temporal baseline is selected automatically in processing (European Space Agency, 2018). The pairs of images used in this study can be seen in Table 1.

Tabel 1. Set Data Sentinel-1A

Master	Slave	Earthquake	Direction
20201015	20201027	19 & 21 October 2020	Descending
20200828	20200909	8 September 2020	Descending

Table 1 shows the installation of master and slave images in this study. In the earthquakes that occurred on 19 and 21 October we used sentinel data on the recording of 15 October (master) and 27 October (slave), for earthquakes that occurred on 8 September we used image pairs 28 August (master) and 9 September (Slave) where the earthquake that occurred more than 5 on the Richter scale.

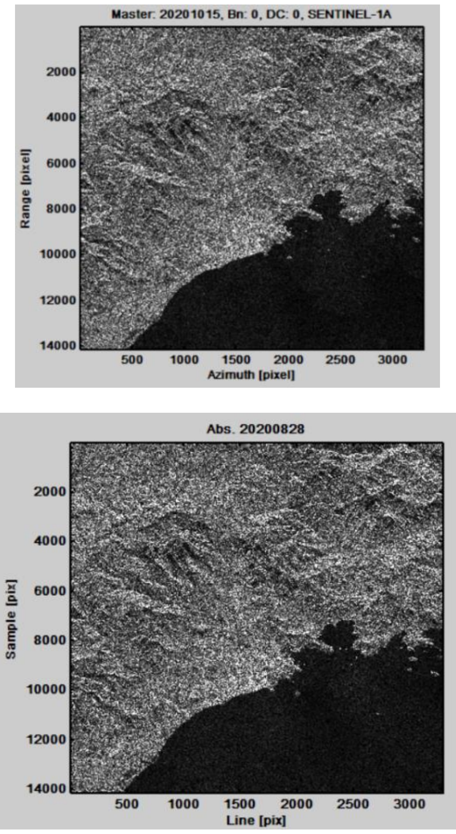

Figure 1. Master Image 20201015 and 20200808

Figure 1 shows the sentinel data that became the master image in our research. We selected this master image based on the values of the baseline perpendicular and the temporal baseline between the two acquisitions during the observation

2.3 Method

InSAR or the so-called interferogram represents the difference in each pixel phase between the two SAR acquisitions. In general, an interferogram will contain topographic information and surface motion (Tolomei, Salvi, Boncori, & Pezzo, 2015). Changes in surface deformation can cause phase changes in the acquired radar data. The observed phase information is limited or limited in the interval $-\pi$ to π, which is part of the component of the interferogram signal. An interferogram that is formed from SLC data is usually referred to as a "raw interferogram", in other words, it contains all the phase information (Liu, 2015). The development of the InSAR method leads to the DInSAR method, which is a SAR image pair analysis technique to identify surface changes to sub-centimeters along the line of sight of the sensor to the target or Line of Sight (LOS).

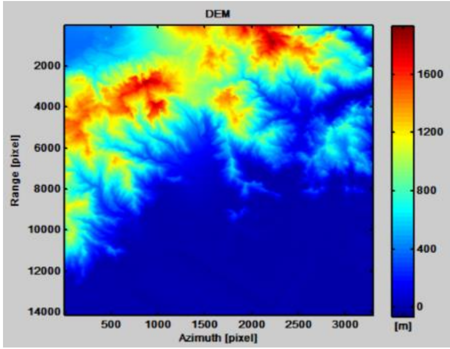

Figure 2. DEM SRTM 1s resolution 30 m

Each pair of interferograms still contains noise due to atmospheric effects, temporal decoration, and still contains topographic elements. Therefore, at this stage, a topography removal process was carried out with the help of 30m DEM SRTM data (Figure 2). The DEM modeling process is sampled into the master image coordinate system. Then the steps to determine the baseline length and topography removal are carried out (Yulyta, Taufik, & Hayati, 2015). Determination of the Baseline Length aims to find the intersection area between the master data (interferogram image) and the SRTM DEM data that has been simulated in the master image geometry, while topography removal aims to remove topographic effects contained in the resulting intererogram of two image pairs.

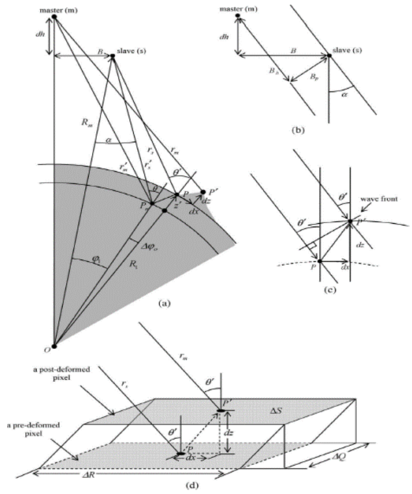

Figure 3. DInSAR geometry. (a) DInSAR geometry for land deformation (uplifting). (b) Baseline geometry. (c) The geometry of soil deformation at the earth's surface (lift). (d) Pixel-based volume change geometry (Sumantyo, Shimada, Mathieu, & Abidin, 2012)

In DinSAR Geometry (Figure 3), where m (master) and s (slave) represent the pixel lines and lines in the SAR image and dh is the horizontal distance of the master and slave. λ is the wavelength, Bh and Bp are the prepedicular horizontal and baseline lines, αm, s is the off-nadir angle, θ'm, s is the incidence angle of the pixel, R is the transient slope range, and rm is the slope range. In addition, z'm, s is topographic information and φm, a is the phase difference. Soil deformation is assumed to be in the vertical direction (subsidance or uplift) dz, and the horizontal deformation dx is negligible, ΔS = ΔRΔQ spatial resolution along soil span and azimuth direction [17]. The resulting image from the DInSAR process is still in radians (phase angle unit) in the range -2π to 2π. To determine the shift in metric value, the formula for displacement of the earth's surface along the LOS sensor is used (Ferretti, Monti-guarnieri, Prati, & Rocca, 2007).

3. Result and Discussion

In this study, the interferogram formation and the unwrap process were carried out simultaneously, because the software used in this study provided the ability to determine parameters before the process started. The filtering used in this research is Goldstein Modeling, which functions to perform filtering which aims to reduce the correlated phase noise in two SAR images, so that the noise contained in each pair of SAR images is eliminated (Goldstein & Werner, 1998).

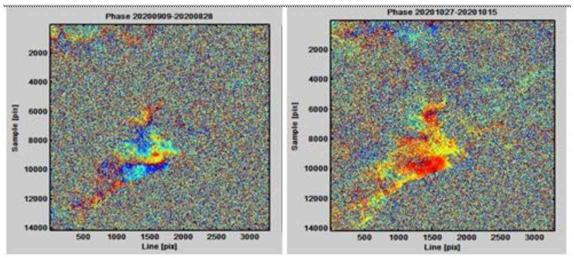

Figure 4. Interferometry Pair Image 20200909 – 20200828 and 20201027 – 20201015

In Figure 4, we can see the formation of fringes due to phase differences in the 2 SAR images which are the main data in this study. The formation of an interferogram from each image will produce a phase difference where this phase difference can indicate the initial identification of changes in the earth's surface which is the subject of research (Lu, Ni, Chang, Yen, & Chuang, 2018). Implementation of phase information from two complex data as DInSAR data to retrieve volume changes caused by successive long-term ground surface deformation, especially subsidence or increase thereof.

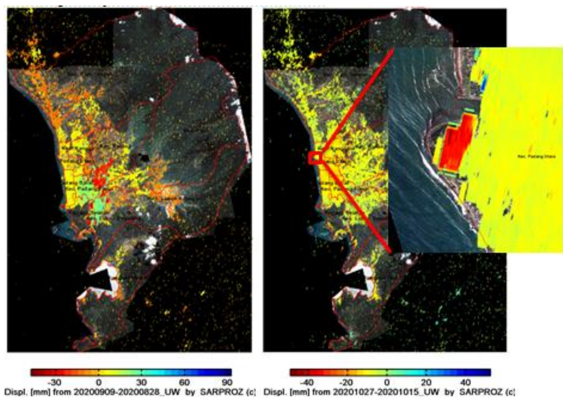

Figure 5. Displacement Pair Image DInSAR LOS

Based on 3 earthquakes with a strength of more than 5 magnitudes centered on the Mentawai Islands, on September 8, 19, and October 21, 2020. From this study, the results obtained from the earthquake on September 8, 2020 with satellite recording data of August 28 (slave) and September 9 2020 (master), there is land subsidence in the range of 0 - 30 mm. The earthquake on 19 and 21 October 2020 with satellite recording data of 27 October 2020 (slave) and 15 October 2020 (master) obtained almost even surface subsidence along the coastal area with a range of 0 - 40 mm in all residential areas of Padang City. In the earthquake that occurred on September 8, there was a significant change in the surface of the land in Kuranji sub-district and part of the East Padang sub-district there was a subsidence of 24 mm in residential and Uplift areas with a range of 0 - 30 mm in West Padang, North Padang and Nanggalo districts. The earthquake on 19 and 21 October based on pairs of images recorded on 27 October 2020 and 15 October 2020 subsidence that is evenly distributed along the coastline of Padang city. In the North Padang sub-district, especially the Bung Hatta University (Ulak Karang) campus, the city of Padang has decreased by 40 mm, and the subsidence is evenly distributed with a range of 0 - 20 mm along the coast of Padang city.

4. Conclusion

Based on the results of the analysis carried out in this study, the earthquakes that occurred on September 8, 19 and October 21, 2020, saw subsidence and uplift in the city of Padang. From the results of Sentinel-1A data processing using the DInSAR method, it was found that subsidence was almost evenly distributed along the coast during the September 8 earthquake with a range of 24 mm in residential areas and uplifts with a range of 0 - 30 mm. The earthquakes that occurred on 19 and 21 October showed evenly distributed subsidence along the coastline of Padang City. In the North Padang sub-district, especially the Bung Hatta University (Ulak Karang) campus, the city of Padang has decreased by 40 mm, and the subsidence is evenly distributed with a range of 0-20 mm along the coast of Padang city. The value of land surface change in this study is in the form of LOS, so it takes ascending data to obtain changes in the vertical land surface, and also validates it by measuring using the GPS method.

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