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Comparison of Sentinel-1A Ascending and Descending Image Processing Results on the Tukul Dam Using SNAP Software

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Abstract
This study analysed and compared the accuracy of the results of Sentinel 1A satellite image processing in the ascending and descending orbit directions with SNAP software. The research is located at Tukul Dam, Karanggede Village, Arjosari District, Pacitan Regency, East Java Province, with a range of observation data for one year in 2022-2023. Sentinel 1A satellite image processing uses the Differential Interferometry Synthetic Aperture Radar (DInSAR) method. The results of Sentinel 1A image processing were validated using measurement data from 38 dam surface measurement points that had been measured terrestrially. The accuracy calculation uses the Root Mean Square error (RMSe) to measure the vertical movement of coordinates (Z) from the results of Sentinel 1A image processing in the ascending and descending orbit directions with the actual position in the field measured terrestrially. The result is the RMSe value of vertical movement from the Sentinel 1A image processing in the ascending direction is 0.015m. In comparison, the result of Sentinel IA image processing in the descending orbit direction is 0.234m. Based on the calculation results of the RMSe value of vertical movement, the results of Sentinel 1A image processing in the ascending direction are better used for calculating vertical movement at Tukul Dam.
Keywords: Sentinel, Ascending, Descending, DInSAR, Dam

1. Introduction

Synthetic Aperture Radar (SAR) imagery has been widely used for observations on the earth's surface such as volcanic activity (Sri Sumantyo et al., 2012), landslides (Calò et al., 2014), land subsidence (Prasetyo & Subiyanto, 2014), and infrastructure (Luzi et al., 2017). One of the SAR images that can be used to monitor and assess land surface movement is the Sentinel 1A image which can achieve accuracy up to millimetres (Bourbigot, 2016).

Sentinel 1A image acquisition process is in two orbital directions, ascending and descending as shown in Figure 1. The specification of Sentinel 1A image data in the ascending and descending orbital directions is in principle the same, the only difference is the orbital direction. In general, satellites orbit from 2 opposite directions such as 2 opposite vector directions. Radar systems are capable of imaging in a continuous path so they can operate in path mode with a sweep width limited by the system on the satellite. This stems from the satellite orbit travelling from south to north (ascending) and from north to south (descending), hence the pointing SAR antennas are usually mounted to the same side of the orbital plane concerning the velocity vector (Simons & Rosen, 2007).

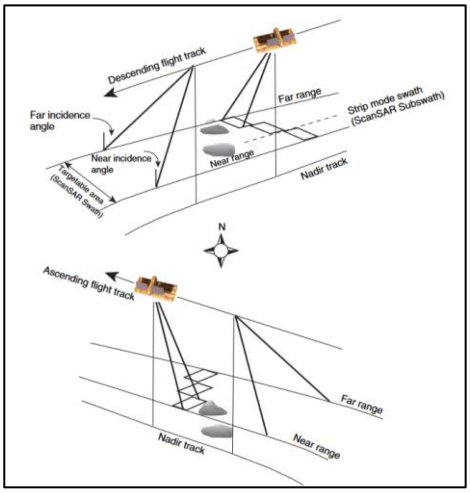

Figure 1. Ascending and Descending orbit directions

The radar-generated image is distorted compared to the planimetric view. The slope facing towards or away from the radar appears shorter. Foreshortening causes the projection of the imaged object to be shorter than its actual length. This distortion depends on the look angle of the radar, the larger the look angle, the smaller the foreshortening effect. Steep slopes that are reached by radar can cause layovers and areas covered by shadows are called shadows. These effects affect the accuracy of radar imaging results. (Lusch, 1999) .

Analysis of Sentinel 1A image processing results using the DInSAR method can produce measurement data with high precision. (Di Stefano et al., 2022).. The DInSAR method enables monitoring ranging from regional/national scales to highly detailed scales such as single buildings, thus providing a large number of displacement measurements at a low cost. (Gheorghe et al., 2018). DInSAR processing can be effectively used for dam monitoring, by validating the results with in situ measurements (Ullo et al., 2019).

In this study, we focus on monitoring the dam, which is one of the infrastructures resulting from the National Strategic Project (PSN) that is very important for water resources management activities, but it is condition is increasingly critical (Adzan & Samekto, 2008). Figure 2 shows the availability of data at the Tukul Dam location in two different orbital directions so further selection needs to be done to determine the best data. The availability of Sentinel 1A satellite image data is quite a lot and can be obtained for free. This choice's utilisation needs selection to obtain the best results.

Figure 2. Sentinel 1A ascending (red) and descending (blue) satellite image data over the Tukul Dam (yellow dot)

Comparison of the accuracy of Sentinel 1A image data in ascending and descending orbital directions has not been widely discussed. It is important to discuss to find out which orbital direction is the most optimal for use in monitoring changes on the earth's surface. The purpose of the study is to determine the comparison of the accuracy of vertical displacement of Sentinel 1A image data processing results in the ascending and descending orbital directions. The results are also validated using the results of terrestrial measurements of dam surface measurement points.

2. Data and Method

2.1. Data

The data needed to obtain the displacement value of the Tukul Dam body include terrestrial measurement data of the shear peg instrument on the dam body, Sentinel 1A image data in the ascending orbit direction and Sentinel 1A image data in the descending orbit direction at the research location. Measurement data of dam body shear stakes were obtained at 2 observation times in approximately one year, namely in March 2022 and April 2023 as shown in Table 1. Sentinel 1A image data in the ascending orbit direction and Sentinel 1A image data in the descending orbit direction were also downloaded for approximately one year and adjusted to the time of shear stake measurement. The distribution of the Tukul Dam shear peg instrument can be seen in Figure 3.

Table 1. Data used in this study

No	Data	Year	Source
1	Sentinel 1-A Ascending Image	2022 and 2023	European Satellite Agency (ESA)
2	Sentinel 1-A Descending Image	2022 and 2023	European Satellite Agency (ESA)
3	Data Patok Geser bendungan	2022 and 2023	BBWS Bengawan Solo

In the process of monitoring ground movement, the Sentinel-1 imagery that is often used is Level-1 imagery of the VV Interferometric Wide mode polarisation type. VV polarisation is known to have high backscatter. The Sentinel-1A image data used in this research is SLC (Single Look Complex) level 1.0 with VV polarisation type and IW (Interferometric Wide Swath Mode) acquisition mode.

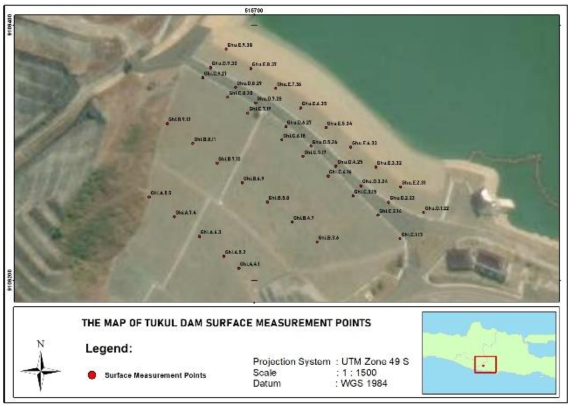

Figure 3. Distribution Map of Tukul Dam Surface Measurement Points

The instrument contained in the Tukul Dam totalled 38 surface measurement points. In the upstream part of the dam body, there are 8 points, at the top of the dam body there are 18 points, and in the downstream part of the dam, there are 12 points. The surface measurement points are routinely observed using the Global Navigation Satellite System (GNSS) Real-Time Kinematic (RTK) method.

2.2. Methods

Sentinel 1A image data processing method is Differential Interferometry Synthetic Aperture Radar (DInSAR) method using Sentinel Application Platform (SNAP) software. The basis of this method is a SAR image pair analysis technique to identify surface changes down to sub-centimetres along the Line of Sight (LoS) of the sensor to the target. DInSAR is a useful technique for accurately detecting ground displacement or ground deformation in the line-of-sight (LoS) direction of an antenna using SAR data taken at two separate acquisition times (Tralli et al., 2005).

The DInSAR method aims to separate the contribution of the topographic phase of the earth's surface and the portion of the displacement phase to show the magnitude of the displacement. The image from the DInSAR process is still in radian units (phase angle units) in the range of -2π to 2π. The ascending DInSAR results and descending DInSAR results use a coherence threshold of 0.5 where the threshold affects the value of phase changes that occur in the area around the research site. (Wu et al., 2021).

In an ideal configuration, the DInSAR technique allows the measurement of LOS displacements of an order of a fraction of a wavelength, provided that the coherence between the two different images is high enough (Ullo et al., 2019). Image coherence has an important diagnostic function. From the literature, images with coherence higher than 0.35-0.4 can provide good results (Ferretti et al., 2007). Poor coherence is mainly caused by geometric and temporal decorrelation. While the former depends on the acquisition geometry and can be controlled by choosing an appropriate baseline, the latter also depends on the backscatter properties of a target (Ferretti et al., 2007).

The downloaded data was subjected to a coregistration process, which is the merging of the master image with the slave image. This registration process coincides with back geocoding using SRTM, burst selection and pixel quality improvement of each image using the bilinear interpolation method. The next step is to perform the interferogram formation process. The interferogram results are still not perfect, because there are still black lines due to the difference in bursts. The improvement will be done in the deburst stage.

The debursted interferograms were then subjected to topographic phase removal concerning DEM and filtering using Goldstein's method to reduce noise in the phase wave (Kampes, 2006). Multilooking is then performed to convert the relative phase into absolute phase so that later the phase data can be converted into height or displacement values.

3. Results and Discussion

Based on the calculation results of the Tukul Dam surface measurement points from the GNSS geodetic measurement results, the vertical movement value, and standard deviation for each of these points are obtained. The results of the calculation of the standard deviation of the shear peg measurements show that the lowest deviation is located at point Ghi.B.3.6 with a standard deviation Z of 0.004 m. The highest deviation value is at point Ghi.E.3.6. Then the highest deviation value is at point Ghi.E.6.35 which has a standard deviation Z of 0.049 m. In Table 2, Figure 4, and Figure 5 the vertical movement value shows a minus value which indicates a decrease.

The results of Sentinel 1A image processing with the DInSAR method in this study are divided into 2 (two) pairs, namely pair 1 consisting of Sentinel 1A images in the ascending orbit direction dated 23 April 2022 with 30 April 2023 and pair 2 consisting of Sentinel 1A images in the descending orbit direction dated 07 April 2022 and 14 April 2023. Based on the processing results, it can be seen from each pair of Sentinel 1A images that the value of the displacement that occurred in Tukul Dam is obtained as shown in Figure 4 and Figure 5.

The results of Sentinel 1-A image processing using the DInSAR technique of dam body elevation change points can be obtained up to millimetre accuracy. The results of the processing using the DInSAR method obtained a spatial resolution of 15m x 15 m/pixel. In Figure 4 and Figure 5, the value of the Sentinel 1A image displacement on the dam body is obtained by overlaying the image with 38 measurement points of the dam shear stakes. Sentinel 1A orbit ascending image processing produces the smallest displacement value of 0.025m. Then the largest displacement was 0.040 m. On average, the displacement was 0.032 m. Image processing Sentinel 1A descending orbit produces the smallest displacement value of 0.238m. Then the largest displacement is 0.290 m. On average, the displacement is 0.266 m. The comparison of the data results can be seen in Table 3, Figure 6 and Figure 7. Data presentation is done by comparing the displacement values per point based on DInSAR and terrestrial measurements and presented in graphical form so that the trend of each data can be seen.

Calculation of accuracy using Root Mean Square Error (RMSe) in vertical displacement measurements that need to be taken into account are the coordinates (Z) of the Sentinel 1A image processing point and the actual position in the field measured by terrestris. Analysis of position accuracy using RMSe describes the value of the difference between the test point and the actual point. Table 3 shows the smallest, largest, average, and Root Mean Square error (RMSe) values. Furthermore, a significance test is carried out to determine whether or not there is a significant difference between the vertical movement value of the Sentinel 1A ascending and descending orbit images and the vertical movement value of the terrestrial measurement results. The results of the t-significance test can be seen in Figure 8 and Figure 9.

Table 2. Results of terrestrial measurement of Surface Measurement Point using geodetic GNSS

Number of Points	Displacement (m)			RMSe (m)
	Smallest	Largest	Average	
38	-0,005	-0,070	-0,034	0,038

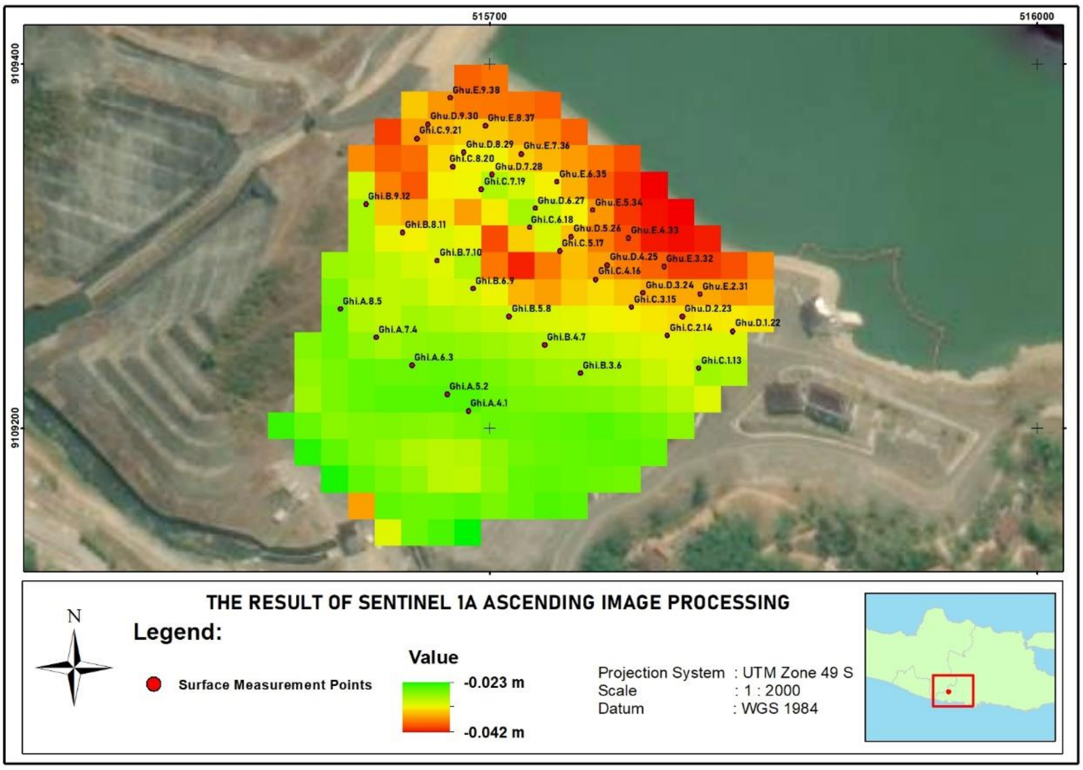

Figure 4. Sentinel 1A image processing results in the ascending orbit direction

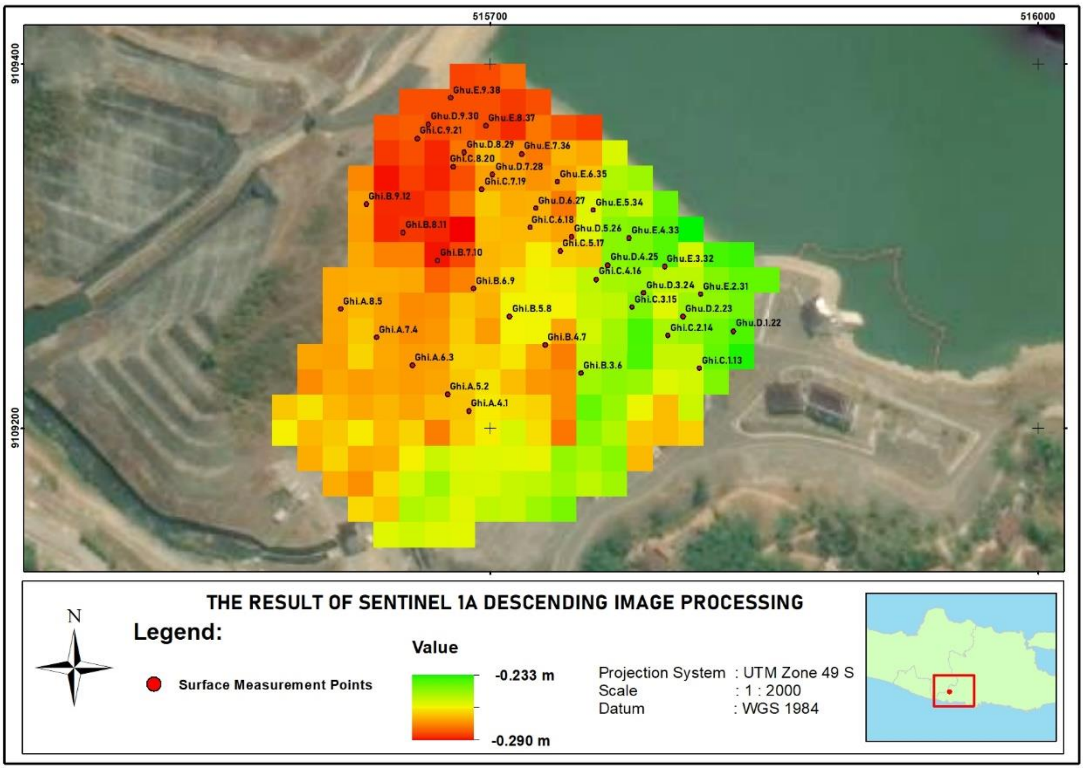

Figure 5. Sentinel 1A image processing results in the descending orbit direction

Table 3. Comparison of the accuracy of the Sentinel 1A image processing results to the realistic measurement of surface measurement points using geodetic GNSS

Orbit	Number of Points	Displacement (m)			RMSe
		Smallest	Largest	Average	
Ascending	38	-0,040	-0,025	-0,032	0,015
Descending	38	-0,290	-0,238	-0,266	0,234

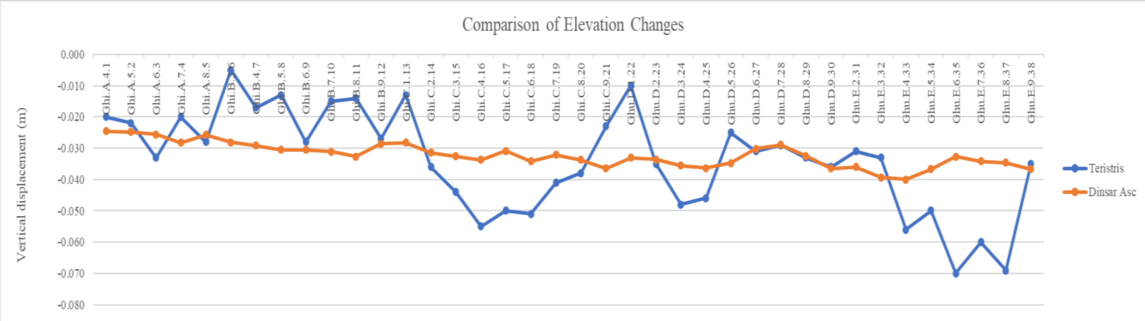

Figure 8. Comparison of Sentinel 1A orbit ascending image processing results with terrestrial measurements of dam surface measurement points

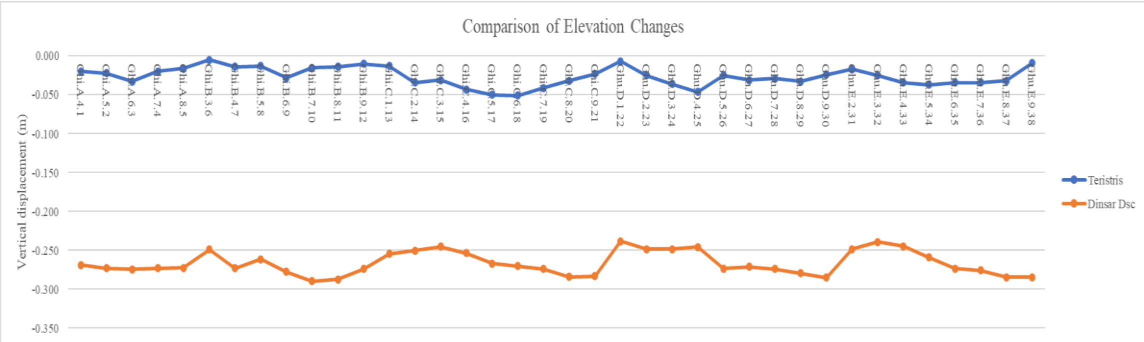

Figure 7. Comparison of Sentinel 1A orbit descending image processing results with terrestrial measurements of dam surface measurement points

```
> t.test(Ujistat3$Teristris,Ujistat3$Asc_3S, paired = FALSE)

        Welch Two Sample t-test

data:  Ujistat3$Teristris and Ujistat3$Asc_3S
t = -0.6393, df = 41.208, p-value = 0.5262
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.007176293  0.003724925
sample estimates:
  mean of x   mean of y
-0.03394737 -0.03222168
```

Figure 6. Significance test results of Sentinel 1A ascending orbit image displacement values

```
> t.test(Ujistat4$Teristris,Ujistat4$`Dinsar Dsc`, paired = FALSE)

        Welch Two Sample t-test

data:  Ujistat4$Teristris and Ujistat4$`Dinsar Dsc`
t = 64.928, df = 73.588, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 0.2253998 0.2396736
sample estimates:
  mean of x   mean of y
-0.03394737 -0.26648408
```

Figure 9. Significance test results of Sentinel 1A descending orbit image displacement values

The RMSe value of the Sentinel IA image processing results in the ascending orbit direction is smaller (0.015 m) than the Sentinel 1A image in the descending orbit direction (0.234 m). The next concern is how the DInSAR vertical displacement results compare with terrestrial measurements. If it has a reading value that is close per point, of course, this is a very good thing and can be used to fill data gaps when not taking measurements. (Di Stefano et al., 2022). The vertical displacement value based on the results of sentinel 1A orbit ascending image processing using the DInSAR method shows a good extraction of the decrease value (0.032 m) and after the significance test the P value (0,5262) is greater than the 0.05 confidence level which indicates there is no significant difference with the vertical displacement of the points measured at Tukul Dam. While the vertical displacement value based on the results of the descending orbit 1A sentinel image processing using the DInSAR method shows a poor extraction of the decline value (0.266 m) and after the significance test the P value is smaller than the 0.05 confidence level which indicates a significant difference with the vertical displacement of the points measured at Tukul Dam. This indicates the existence of temporal decorrelation and the possible layover and shadow effects of hills in the descending orbit direction for sentinel 1A image data at the study site (Lusch, 1999).

4. Conclusion

The results of the comparative analysis show that the RMS value of the vertical displacement of the Sentinel 1A image processing results in the ascending direction is 0.015 m. In comparison, the Sentinel IA image processing results in the descending orbit direction are 0.234 m. Based on the significance test results, the vertical displacement value of the Sentinel 1A image processing results in the ascending direction is not significantly different from the vertical displacement value of the terrestrial measurement, while the vertical displacement value of the Sentinel 1A image processing results in the descending direction is significantly different. Based on these results, the results of Sentinel 1A image processing in the ascending direction are better used for calculating vertical displacements in Tukul Dam.

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