Merapi observed gravity anomaly changes in 2019

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Abstract: Volcano disasters are one of the natural disasters that often occur in Indonesia, one of which is Merapi. The impact of the periodic eruption of Mount Merapi is a major threat to the safety of the population periodically. The large eruption cycle of Merapi Volcano occurred in 1587, 1672, 1768, 1822, 1849, 1872, 1930, 1961 and 2010. The results of the 1988,1998 and 2011 studies showed the increasing number of magmas which can be observed from the dimensions of the magma chamber. The structure changes are predicted from phreatic eruptions in 2013, 2014 and 2016, whereas in 2018 and 2019 occurrence of pyroclastic flow. The research of gravity changes used observed gravity anomaly in 2019 as the first step of time-lapse Merapi activity analysis. The number of observation points was 100 with reference to the same position in 2011. The results of observed gravity anomaly changes are increasing mass in the summit area and decreasing mass in the southeast, west and the north of research areas on the elevation of 500 m to 1400 m.

1. Introduction

Volcano disaster is one of the natural disasters that often occurs in Indonesia. Merapi is an active volcano so its eruption is one of the natural disasters. The impact of the periodic eruption activity of Merapi Volcano is a major threat to the safety of the population. Big eruption cycle of Merapi Volcano occurred in 1587, 1672, 1768, 1822, 1849, 1872, 1930, 1961 and 2010 [1,19,22]. The eruption index of Merapi Volcano in 2010 is 4 VEI [11]. This was one of the large scale eruptions over the last 100 years [4]. The results of the study of Merapi in 1988,1998 and 2011 showed that an increasing number of magmas. Increasing magma was observed by reservoir dimensions changes [12]. The reservoir dimension became enlarged. The subsurface model by using gravity data in 2011 produced changes in the dimensions of the reservoir. The great eruption of Merapi shows a decresing mass amount if compared to 1998. The increase in mass from 1988 to 1998 was also shown by the growth of lava domes in the peak region, while in 2010 the mass of the peak area was reduced [2,3,4,5,10].

The seismic research result conducted by Widiantoro, 2018, was the mass beneath Merapi increased in 2015. The research result showed that the dimensions of the magma reservoir under the Merapi volcano are larger than before. If the amount of mass greater, it will contribute to the higher level of eruption that will occur [24]. The subsurface changes after the 2010 eruption are shown by the occurrence of phreatic eruptions in 2013, 2014 and 2016, while in 2018 and 2019 there was an eruption accompanied by a pyroclastic flow. Phreatic eruptions often occur after large eruptions occur. The phreatic eruption can also indicate that the presence of magma is approaching the surface as part of the process of refilling magma reservoir and conduits. Merapi activity in 2018 recorded an eruption in May. the eruption changed the status of Merapi. Merapi status was changed from normal to being alert. At the beginning of 2019, there was another Merapi activity was showed with lava flow. In February 2019 there had been 5 falls. A pyroclastic flow occurred on March 17, 2019, which was preceded by a quake 16 times, one earthquake, two low-frequency earthquakes, and one tectonic earthquake. BPPTKG seismogram on August 10, 2019, recorded there were 10 times of quake, 1 time of gust and low-frequency earthquake tectonic also and earthquakes occur twice and once of hybrid earthquakes. In July there were two lava flow to Kali Gendel. Lava flows up to a distance of 950 m from the crater . The lava flow was following 11 earthquake losses with an amplitude of 3-65 mm for 16.04-90.34 seconds and two-hybrid earthquakes with an amplitude of 2-6 mm and a duration of 8.92-12 seconds. Visual observations of the crater are the wind blowing weakly to the northeast and east, air temperature 16-22 degrees celsius, humidity 27-76 percent, and air pressure 629.7-710.7 mmHg. (BPPTKG, 2019) [25].

The phreatic eruption is a common phrase when volcanoes occur after large eruptions. The phreatic eruption can also indicate that magma is approaching the surface as part of the process of refilling magma reservoirs and conduits [18]. The occurrence of pyroclastic flows and lava slides indicates a change in the Merapi activity phase from phreatic to magmatic.

The prediction of increasing mass beneath Merapi can be conducted from gravity changes [14]. Observation of volcanic activity cannot be done at once but must be continuous [6,8]. Once observation can not describe the entire chronology of volcano activities. Observation should be a continuous project as observing a live object. Observing the activities of a volcano (Merapi) is expected to help people Which live around Merapi areas, to be able to live side by side safely. In this study, the observed gravity anomaly changing was made as an initial stage for further research of Merapi. This research will review the activities of Merapi 2011 to 2019 as a preliminary study of Merapi activity analysis by using the changes of observed gravity anomaly. The changes in observed gravity anomaly from time to time can be done by re-measuring observed gravity anomaly at the same point. The analysis of observed gravity anomaly can be used as a reference for the next step.

2. Methods

Analysis of gravitational field changes is done by observing changes in the gravitational field between 2 epochs. The change in the gravitational field which is analyzed is the change in the observed gravitational field. Observation of elevation changes also is used as a complement of volcanic activity research. Changes in the observed gravitational field and elevation can produce information on volcano activities that are happening [5,7,14]. Calculation of changes in gravitational field observations between 2 epochs can be done using simple mathematical equations [14,20].

Analysis of observed gravity anomaly can be done at the same point or the same area. In this case, the observations were made at the same point. The number of observation points was 100 points. Gravity data in 2011 is owned by Geophysics Laboratory, Gadjah Mada University and gravity data in 2019 were taken in July 2019 for 10 days. The points in 2019 were chosen with reference to the 2011 points (Figure 1). Distribution of observation points surrounds the Merapi area but there is no data on the peak area of Merapi. There was not any data at the peak cause of a warning to entering the peak area. The prohibition of entering the peak area is caused by the increase in the status of Merapi, which is indicated by the occurrence of pyroclastic flow and increasing seismicity record. The acquisition is carried out 3 times at each point, with a looping system every 2 hours. There are 4 base station several assistive base stations on the field. The weather during data acquisition is sunny to cloudy with a temperature of 26^0 C s.d. 28^0 C. Absolute gravity points location at Yogyakarta Volcanology (BPPTKG). The equipment consists of Gravity meters LaCosta and Rhomberg Type G-1115 and GPS Altus AP-3. The GPS base point is located in the village of Cepogo, Boyolali. Gravity meter calibration using absolute gravity points at BPPTKG Yogyakarta.

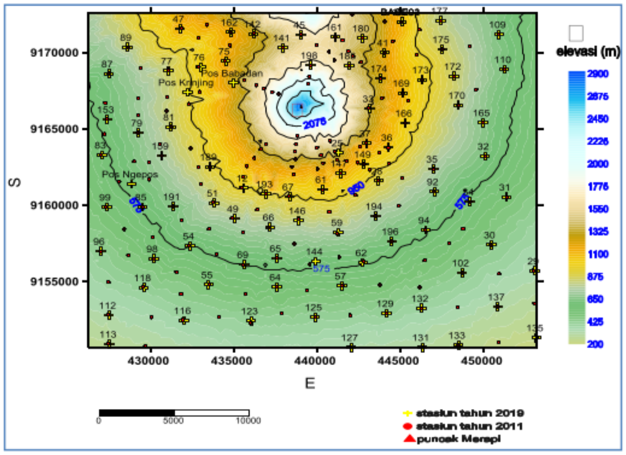

Figure 1. Station distribution in 2011 and 2019

3. Result and discussion

The quality of measurement data is an important part of the proceeding. The observed gravity anomaly is obtained through several stages of correction consisting of tidal correction, correction of tool height and drift correction. The results of the data quality test showed good results that were marked by a graphical pattern that reversed between the elevation and the observed gravity anomaly. If the QC doesn't have reserve relation the further process can't be done. Quality test results as in Figure 2.

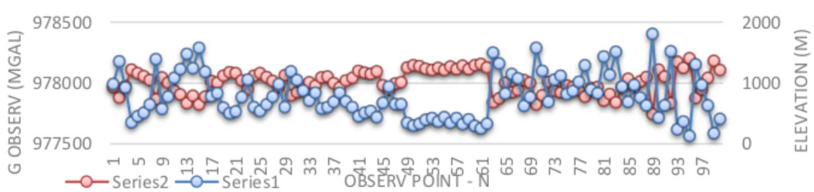

Figure 2. QC gravity data (observed gravity vs elevation)

The next process was the calculation of observed gravity anomaly. The results of observed gravity anomalies in 2011 and 2019 are mapped in Figure 3. The value of observed gravity anomalies is 977740 mGal to 97878160 mGal. The anomaly in 2011 and 2019 has a similar contour pattern. Both contours are almost the same that is decreasing value towards the peak and increasing value towards the south of the research area. Generally, both contour has the same pattern. The contour which of 2019 is shifted for the same value. Shifting contour lines on the same value indicates an increasing value of observed gravity anomaly in 2019, but in some regions, it shows an increase in the value of the observed gravity anomaly. The peak area of Merapi has a minimum value of observed gravity anomaly. In the 2019 minimum area is wider than 2011.

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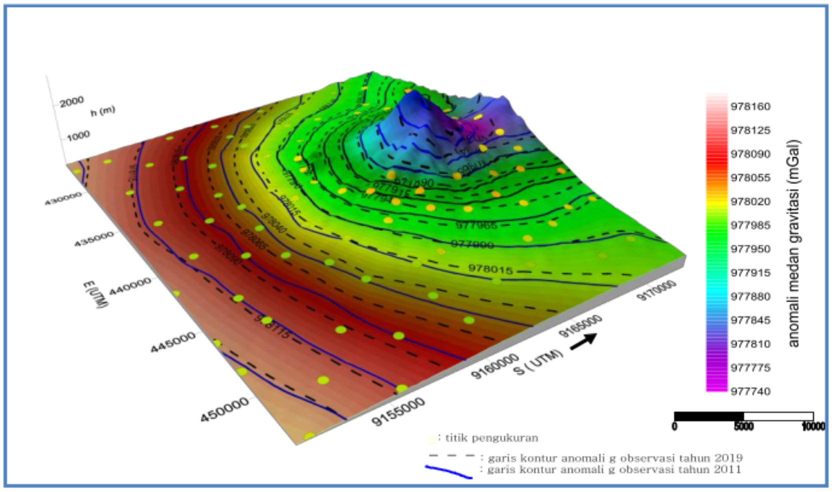

Figure 3. The observed gravity anomaly in 2011 and 2019

The observed gravity anomaly changes from 2011 to 2019 can be mapped in Figure 4. In the processing of 2011 gravity data, there were 195 data so that there is a selection process to obtain the distribution of data that is almost the same as 2019. The changes of observed gravity anomaly showed the maximum value on the peak region and the minimum value at the elevation of 600 m s.d. 1400 m. The observed gravity anomaly changes are ± -1 to 1 mGal becomes the dominant value. From these results, it is shown that there was no significant change of the observed gravity anomaly, except at the peak area and the north research area. Setiawan's research, 2003, Which uses 20 fix point gravity data, shows that changes in the surround of the Merapi volcano are caused by the number of groundwater changes in the study area, but on the peak area because of magma intrusion [7,14,16]. Likewise, research by Jentzh,1998, which also explains that the change in the value of the Merapi gravity field is caused by 2 things, namely due to magma intrusion and changes in the amount of water mass below the surface [7]. Rina, 2017, which mapping distribution of observed gravity anomaly changes of the Merapi in 1998 until 2011 and 1988 until 1998, show that changes were on the west to the southeast of the research area [13]. Changes of observed gravity anomaly are related to the distribution of volcanic material during eruptions that have occurred previously and in the past. BPPTKG map of the material eruption distribution shows the distribution material at west to the southwest, but in 2010 the eruption material distributes to the southeast area and the open crater strike to southeast too [12].

Fig. 4 show a decrease of observed gravity anomaly at the southeast of the peak and in the north of the study area. Other regions do not show any significant changes. The areas with negative changes of observed gravity anomaly may be related to Merapi's subsurface dynamic regions. The subsurface area of Merapi is an area that may be related to the existence of a reservoir, either a groundwater reservoir or a magmatic reservoir. Some modeling result explains that reservoir of Merapi on 3000 m to 5000 m to the southeast from peak [3,9,12,15,16,17,21,23]. The dimension reservoir changes may be related to the observed gravity anomaly changes at the peak area at 1800 m to the peak. The high value of observed gravity anomaly changes Which are at the peak area can be expected as mass increasing between 2011 until 2019. Merapi activities record from 2011 until 2019 such as lava slide, pyroclastic flow, etc, Those can be suspected as a recharge process. The 2010 eruption loaded 150 million m^3 material which was a large amount in the history of the Merapi eruption in the last 100 years. Events that have occurred since 2013 to 2019 show a rapidly increasing activity.

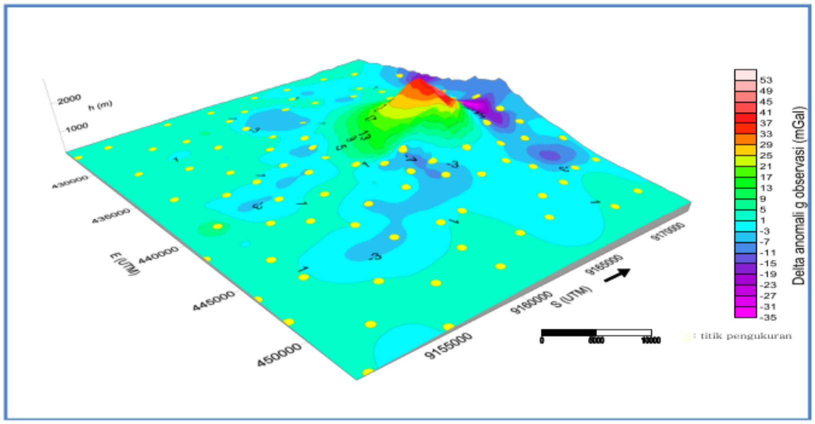

Figure 4. The observed gravity anomaly changes from 2011 to 2019

The further calculation is needed to determine the distribution of a complete Bouguer anomaly so that a more complete structure of subsurface mass distribution can be obtained. The subsurface mass distribution describes the changing dimensions of the Merapi magma reservoir that can be correlated to the energy which provides for the next eruption.

4. Conclusion

The results of observed gravity changes are the anomaly value of -5 mGal s.d. 40 mGal. The decrease in value appears to surround the Merapi volcano at an elevation of 600 m s.d. 1400 m. The reservoir dimension changes maybe related to the observed gravity anomaly changes at the peak area at 1800 m to the peak. The high value of observed gravity anomaly changes Which are at the peak area can be expected as mass increasing between 2011 until 2019.

Acknowledgment

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