

Effect of March 9, 2016 Total Solar Eclipse on geomagnetic field variation

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Abstract. During solar eclipse, solar radiation to the Earth is blocked by the Moon. Thus, the ionization process in the ionosphere is disrupted, as well as the variation of geomagnetic field. The disturbance of geomagnetic field is caused by electric current in the E layer of the ionosphere. At low latitude, the current which is dominant in quiet day is the Sq currents. The blocking of solar radiation cause decrement in electron density in the blocked region. The aim of the research is to find the effect of total solar eclipse to the geomagnetic field. The measurement of the geomagnetic field variation during total solar eclipse on March 9, 2016 was carried out at the Meteorological station of BMKG in Ternate (0° 49' 45.20 "N; 127° 22' 54.00" E). By eliminating the geomagnetic disturbance that occurred in a daily geomagnetic field variation, the pattern of quiet day which is usually in a shape of smooth curve became affected. During the total solar eclipse on March 9, 2016 from 00:30 until 02:00 UT, we found that the geomagnetic field variation of the quiet day decreased by -5 nT.

1. Introduction

Total solar eclipse (TSE) is a natural event that can also be observed indirectly by using fluxgate magnetometer. In the event of solar eclipse, the Sun, Moon and Earth are in straight line. So that incoming solar radiation to the Earth is blocked by the Moon. Total solar eclipse on March 9, 2016 has crossed across several areas in Indonesia. The condition of ionosphere in the area along the path of totality was more likely to change as a result of the eclipse. It is an excellent opportunity to investigate more deeply the effects on geophysics. Studying geomagnetic with the change in the radiation coming from the solar corona is important because of the action of ionization in the ionospheric dynamo changes [4]. The main effects that may occur in the geomagnetic field disturbance caused by electrical currents in the ionosphere E layer on a quiet day was dominated by the solar quiet day (Sq) current. Solar radiation blocked by Moon could cause a reduction in electron density in the ionosphere and thus significantly reduce the conductivity in its region [7].

To study its impact to geomagnetic field, we measured geomagnetic variation in totality zone. Indonesian National Institute of Aeronautics and Space (LAPAN), especially research group of geomagnetic and space magnetism, conducts research on geomagnetic disturbance originated from extraterrestrial. When sunlight heading towards earth is obstructed by the Moon, the radiation and



ionization in ionosphere is decreased thus disturb ionosphere electricity. This event could affect geomagnetic daily variation. Geomagnetic variation describes the geomagnetic field fluctuations particularly quiet day variations, is heavily influenced by the process of heating and ionization layer of the ionosphere.

During the total solar eclipse, the ionization process will be disturbed. It is generally known that the daily variation quiet geomagnetic field caused mainly due to the current flowing in the ionosphere E layer. During the solar eclipse, part of the ionosphere is shielded from solar heating and ionizing radiation. It modifies the flow pattern in this area and affect the geomagnetic field observed at the surface of the earth. The ionosphere E layer change process and affect the geomagnetic daily variation which is commonly known as a Sq variation, originating mainly in the ionosphere. Therefore, the most significant changes appear in the ionosphere due to the close relation with the solar radiation. Obstruction of the Sun during solar eclipse potentially disturbs ionosphere.

The effects on the ionosphere during solar eclipse depends on several factors such as the level of solar activity and the level of geomagnetic disturbance [10, 11]. The purpose of this study is to determine the effect of the total solar eclipse to the geomagnetic variations in Ternate, North Maluku. Geomagnetic field measurements out from March 4 until 10, 2016.

2. Data and methods

Geomagnetic data used in this research was obtained from observations of geomagnetic daily variations in the meteorological observatory of class III Babullah BMKG Ternate with geographic coordinate ($0^{\circ} 49'45.20''N$; $127^{\circ} 22' 54.00'' E$) and geomagnetic coordinate ($\lambda 08,01^{\circ} S$; $\beta 156,31^{\circ} W$). We used fluxgate magnetometer with a resolution of 0.1 nT and sampling rate 1 Hz. The records within universal time (UT) and geomagnetic components were measured, they consist of components X (North-South), Y (East-West) and Z (Vertical). The horizontal component of the geomagnetic field (H) is the resultant of X component and Y components of the geomagnetic field. H component is used to reveal phenomena of extraterrestrial origin. The observation was conducted in Ternate from March 4 until 10, 2016, the period the geomagnetic condition on March 5, 2016 was quiet, while on March 9, 2016 there was geomagnetic storm.

To monitor the geomagnetic disturbance coming from solar activity, or ring currents, we used the geomagnetic activity data (Dst index) [12]. It was used to eliminate or separate the geomagnetic disturbance resulting from the ring currents in order to obtain a variation of the geomagnetic quiet. Daily variation of geomagnetic field was obtained from March 5, 2016 data, classified in one of the groups of geomagnetic quiet days. The geomagnetic quiet day pattern obtained by are eliminated daily geomagnetic variation from geomagnetic disturbances (Dst index) and the effects of the ring currents [5, 6]. The equation (1) and (2) are used to eliminate the effect of ring currents [7], and filtered using Fourier analysis.

$$X_D = X - Dst \cos\lambda \cos(-11^{\circ}) \quad (1)$$

$$Y_D = Y - Dst \cos\lambda \sin(-11^{\circ}) \quad (2)$$

X is a magnetic field with a north-south component, Y is the east-west magnetic field component, λ is the latitude geomagnetic observatory. The 11° angle is difference between the geographic and geomagnetic poles.

To obtain the equivalent current density in the ionosphere altitude of 110 km [7] we use equation 3.

$$J = \frac{2}{\mu_0} \sqrt{X_D^2 + Y_D^2} \quad (3)$$

Where μ_0 is the permeability in a vacuum.

3. Results and analysis

Horizontal (H) component of geomagnetic daily variation can be calculated by determining the geomagnetic resultant of the north-south (X) component and the east-west (Y) component. Based on the geomagnetic activity of the H component, we can select the quiet day geomagnetic variation.

The level of the geomagnetic disturbance index (Dst) [12] on 5 March 2016 was used to obtain a pattern of a geomagnetic quiet day in Ternate. By using equations (1) and (2), we calculated the variation of quiet horizontal component (H). The quiet day geomagnetic illustrates that there was a very weak geomagnetic disturbance ± 10 nT. It indicates that the geomagnetic disturbance caused by the ring currents or solar activity did not occur. Quiet day variation was filtered by using Fourier analysis and the result is known as the geomagnetic quiet day pattern in Ternate, where the condition geomagnetic on March 5, 2016, was included in the order of one day of quiet geomagnetic International [7].

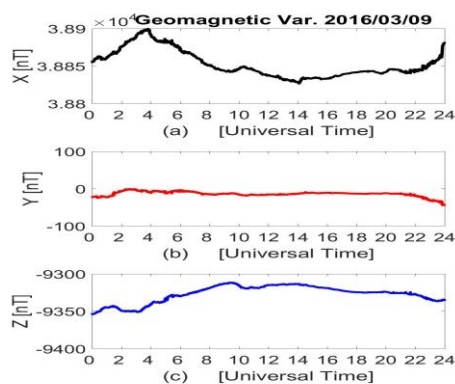


Figure 1. Daily variation of geomagnetic components X(north-south), Y(east-west) and Z(vertical) in Ternate on March 9, 2016. (X,Y,Z) is three orthogonal strength components of geomagnetic.

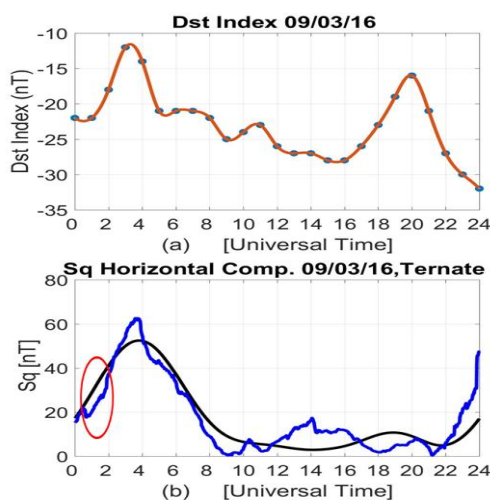


Figure 2. a) Dst index curve [12] and b) The pattern of quiet day variation in Ternate on March 9, 2016 (blue line) and March 5, 2016 (black line). The red ring is shown the period of total solar eclipse (TSE).

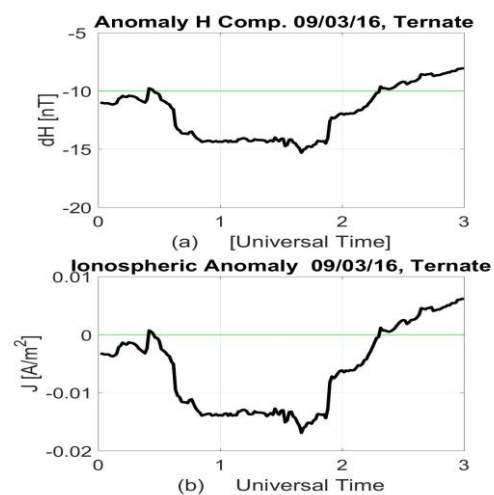


Figure 3. a) The curve of geomagnetic quiet day anomaly during the total solar eclipse on March 9, 2016, and b) The current density equivalent ionospheric anomaly curve. On period TSE, geomagnetic H component and currents density drops.

Figure 1 shows observation of the daily variations geomagnetic on March 9, 2016. The three components magnetic are measured. They are north-south (X), east-west (Y) and vertical (Z) components. On March 9, 2016, the magnetic field measurement data was affected by total solar

eclipse event. During 00:30 UT until 02:00 UT there is a decrease of the daily variation of geomagnetic X component and an increase in the Y component. The magnetic field intensity during the total solar eclipse decreased. In the previous studies, several researchers have studied the geomagnetic field variations during the solar eclipse with most of the results showed positive anomalies in geomagnetic variations of the component east-west (Y) and decrease on the component north-south (X) [1, 2, 8, 9].

Variation of geomagnetic disturbance that occurred on March 9, 2016, is shown in the figure (2.a). Dst index curve ranges from -15 to -30 nT. Dst index variation is used to separate of disturbance in the quiet day from daily geomagnetic variation. In a similar way as data processing on March 5, 2016, variation in geomagnetic quiet day and the pattern of March 9, 2016 was obtained as shown a blue line in the figure (2.b). Variation in the quiet geomagnetic obtained is not as smooth as the pattern of the quiet day because there are other sources suspected that the effect of the total solar eclipse that lasts about 00:30 - 02:00 UT that caused an anomaly on quiet geomagnetic variation. The H component of quiet geomagnetic variation shows the decline from the quiet day pattern average -5 nT, shown in the figure (3.a). It is also known that the solar eclipse effects the field geophysics at Novosibirsk Russia as 5 nT decrease in the amplitude [3]. In figure (3.b) curve shows equivalent ionosphere currents density anomalies calculated from equation 3, where during a total solar eclipse March 9, 2016, equivalent ionosphere current density decreased 12 mA/m². The process of solar radiation to the earth disturbed by the presence of a total solar eclipse has led to the decrement of a current density of the ionosphere, so the magnetometer recorded the geomagnetic variations with the decline of the horizontal component (H).

4. Conclusion

Geomagnetic field measurement was conducted in Ternate from 4-10 March 2016. During the period, the geomagnetic quiet day was happened on March 5. The total solar eclipse occurred on March 9. From the recorded data on March 9, 2016, in the interval from 00:30 to 02:00 UT, we obtained that the X component of geomagnetic variation decreased while the Y component was increased during the eclipse. We obtained that there was an anomaly of variations of geomagnetic quiet day about -5 nT on H component which is equivalent with the ionospheric current density 12 mA/m². It is associated with lower ionization process on the layer of ionosphere caused by the total solar eclipse.

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