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Possible Influence of the Solar Eclipse on the Global Geomagnetic Field

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Abstract. We investigate the geomagnetic field variations recorded by INTERMAGNET geomagnetic observatories. We confirm that the effect of solar eclipse can be seen over an interval of 180 minutes centered at the time of maximum eclipse on a site of a geomagnetic observatory. It is found that the effect of the solar eclipse on the geomagnetic field becomes conspicuous as the magnitude of a solar eclipse becomes larger. The effect of solar eclipses is more evident in the second half of the path of Moon's shadow. We also find that the effect can be overwhelmed, more sensitively by geomagnetic disturbances than by solar activity of solar cycle.

Keywords. Solar Eclipse, geomagnetic Field, data Analysis

1. Introduction

A solar eclipse is such an uncommon event that one has to be regarded as serendipitous for observing it at a given location on the Earth (e.g., Ahn and Lee 2004). During the solar eclipse, solar radiation to the Earth is obscured by the Moon. The solar eclipse subsequently causes intricate changes in the atmosphere of the Earth, which occur at all heights from the surface layer to the upper ionosphere, or even up to the plasmasphere (Anderson 1999, Baran *et al.* 2003). In this contribution, we investigate an ensemble average of the 207 geomagnetic field variations observed by INTERMAGNET geomagnetic observatories when the Moon's umbra or penumbra passed over them on a day of the solar eclipse. Unlike previous studies in which efforts are mainly focused on a certain solar eclipse as a case study, we analyze as a whole results acquired by 100 geomagnetic observatories. We carry out examinations by dividing the data set into 2 or 3 subsets on the basis of parameters of solar eclipses, the geomagnetic field and solar activity to see whether the effect of the solar eclipse shows any dependence on circumstances under which solar eclipses occur.

2. Data

Procedures we have collected geomagnetic field data are as follows. Firstly, we complied the geographic longitude and latitude of the geomagnetic observatories from the 150 INTERMAGNET website†. Secondly, with information on solar eclipses occurring during the period from January in 1991 to September in 2016, which is obtained from the NASA eclipse website‡, we computed local circumstances for every solar eclipse visible

† http : //www.intermagnet.org/
‡ https : //eclipse.gsfc.nasa.gov/solar.html

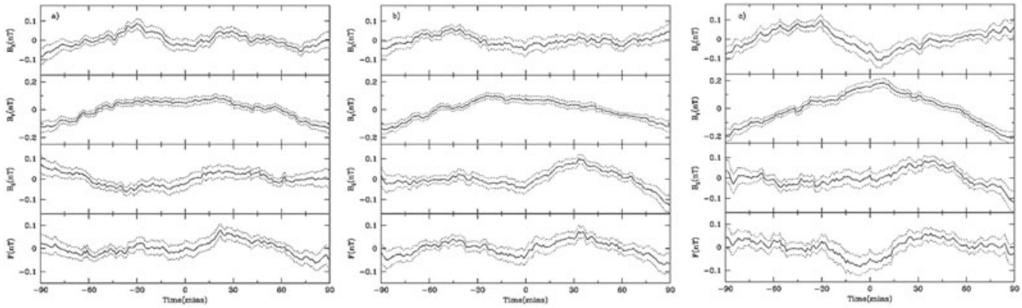

Figure 1. Variations of the three components of the geomagnetic field B_X, B_Y, B_Z and the total strength F are shown from top to bottom, respectively. Continuous and dotted curves represent the average and 1-σ envelopes, respectively. Plots result from data sets: (a) $0.7 \leqslant$ magnitude < 0.8, (b) $0.8 \leqslant$ magnitude < 0.9, and (c) $0.9 \leqslant$ magnitude.

from 150 geomagnetic observatories using the JavaScript provided by the NASA website. Thirdly, we identified only the geomagnetic observatories where the solar eclipse with its magnitude greater than 0.7 can be observed. Finally, for each geomagnetic observatory we obtained from the INTERMAGNET website minute mean values of the 4 geomagnetic components (B_X, B_Y, B_Z, F) from -90 minutes to +90 minutes with respect to the local time of maximum eclipse at the site of the geomagnetic observatory. We have thus obtained 207 geomagnetic manifestations observed by 100 INTERMAGNET geomagnetic observatories at events of the 39 solar eclipses spanning from the maximum of the solar cycle 22 to the end of the solar cycle 24.

3. Dependence on Circumstances of Solar Eclipse

To examine *patterns* of the geomagnetic field variations induced by solar eclipses, we have firstly detrended slowly varying parts of geomagnetic field variations with the first order polynomial fit before taking an average of time series of the geomagnetic field data. When averaging, we have further normalized the detrended geomagnetic field variations so that the height of the curve from the minimum value to the maximum value is equal to unity. By doing so, in some sense we average a shape of the geomagnetic field variation possibly produced by solar eclipses.

Magnitude of solar eclipse.

In Figure 1, we show three data sets divided according to the magnitude of a solar eclipse, respectively. That is, from Figure 1a to Figure 1c results are shown from data sets where $0.7 \leqslant$ magnitude < 0.8, $0.8 \leqslant$ magnitude < 0.9, and $0.9 \leqslant$ magnitude, respectively. Obviously, the effect of the solar eclipse on the geomagnetic field, such as, an increase in B_Y and decreases in B_X, B_Z and F, becomes conspicuous as the magnitude becomes larger.

Location in the path.

In Figure 2, we show results from two data sets where observing site is located in the first half of the path, and observing site is located in the second half of the path, respectively. An increase in B_Y is clear in Figure 2a, but other possible effects seem undetectable. On the other hand, decreases in B_X and F are also clear in Figure 2b. Hence, we conclude that the effect of solar eclipses depends on observing site. That is, the effect of solar eclipses is more evident in the second half of the path of Moon's shadow.

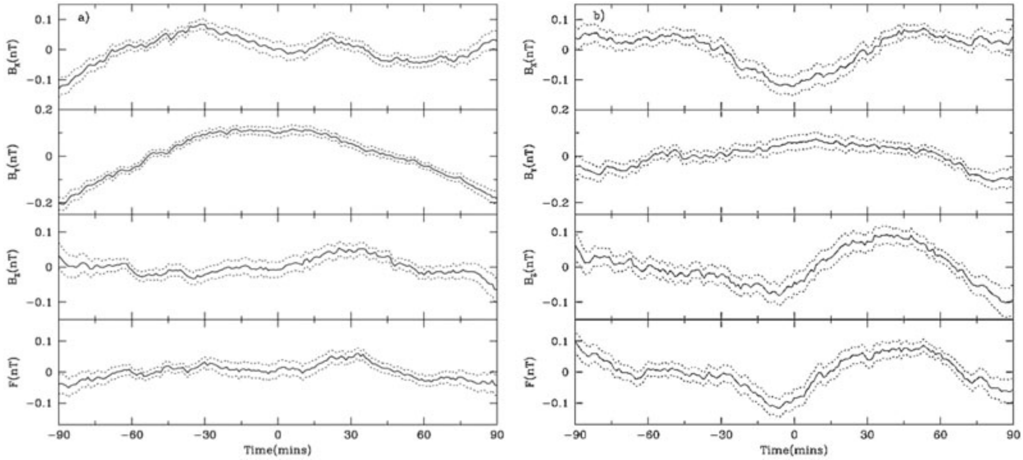

Figure 2. Similar plots as in Figure 1. Plots result from data sets where: (a) observing site is located in the first half of the path, (b) observing site is located in the second half of the path.

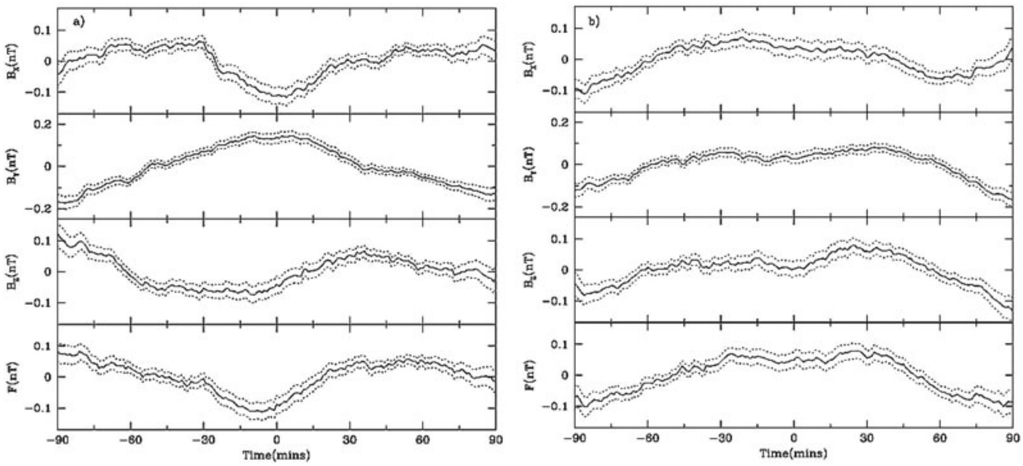

Figure 3. Similar plots as in Figure 1. Plots result from data sets where: (a) the Ap index is less than or equals to 7 representing magnetically quiet days, (b) the Ap index is greater than 7.

Geomagnetic activity.

In Figure 3, we show results from two data sets where the Ap index is less than or equals to 7 and where the Ap index is greater than 7, respectively. An increase in B_Y and decreases in B_X, B_Z and F can be clearly seen from Figure 3a. On the contrary, any signatures of solar eclipse effects are absent in the patterns of the geomagnetic field variation data shown in Figure 3b. Our finding here, therefore, implies that when the day of the solar eclipse is geomagnetically quiet an evidence of the solar eclipse effects is likely to be revealed and that when the geomagnetic field is disturbed on the day effects of the solar eclipse on the observed geomagnetic field variation seems to be overwhelmed by other geomagnetic disturbances.

Solar activity.

In Figure 4, we show results from two data sets due to solar eclipses occurring during separate time intervals, respectively, which correspond to periods around the solar minimum and the solar maximum. Decreases in B_X and F can be noticed from Figure

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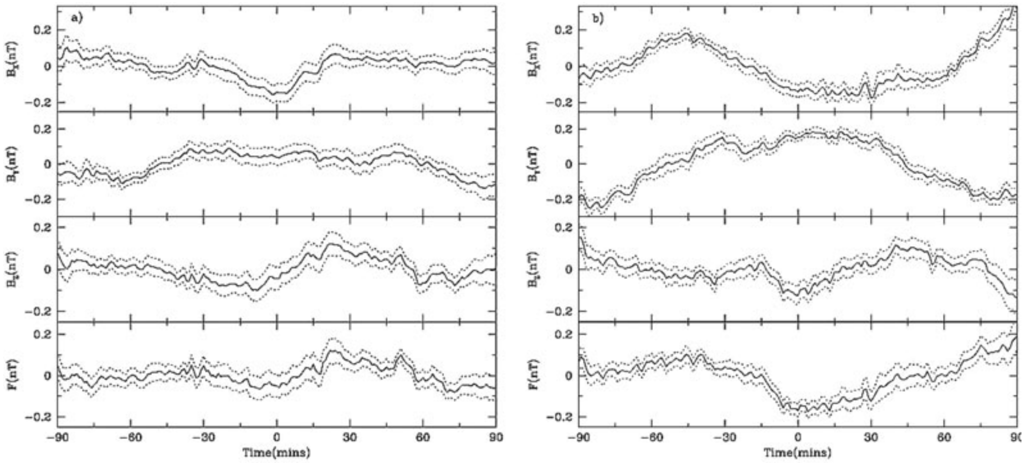

Figure 4. Similar plots as in Figure 1. Plots result from solar eclipses occurring during two separate time intervals, respectively, corresponding to periods around: (a) the solar minimum, and (b) the solar maximum.

4a, though an increase in B_Y appears to be very broad. However, an increase in B_Y and decreases in B_X, B_Z and F can be more clearly seen from Figure 4b than Figure 4a. Mean values of Ap indices corresponding to the data sets resulting in Figure 4a and 4b are 6.4 and 5.7, respectively. Hence, we conclude that the effects of the solar eclipse on the observed geomagnetic field variation depend only on daily geomagnetic events.

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