THE VELOCITY AND PARTICLE DENSITY OF SOLAR WIND RELATED WITH THE GEOMAGNETIC DISTURBANCES DURING 2008 – 2010

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ABSTRACT
It has been established that the geomagnetic disturbances are closely related with the solar wind velocity. They have an inverse correlation, i.e. the geomagnetic disturbance, which is represented by the Dst index, will have a lower value with the higher solar wind speed. However, the detailed correlation, particularly on their time profile, has not been known yet. We analyze the time profile of the solar wind and geomagnetic disturbance by comparing the correlation between the solar wind and the geomagnetic (Dst index) time profiles. We also analyze the correlation between the plasma density with the geomagnetic disturbance. We analyzed the solar wind velocity and density data from Advanced Composition Explorer (ACE) satellite around the disturbed days. The geomagnetic disturbance (Dst index) data are obtained from World Data Center for Geomagnetism Kyoto, for period of 2008 – 2010. We selected the event which has Dst index ≤ - 30 nT. By using this criteria we found 41 geomagnetic disturbance events. Negative correlation between the solar wind and Dst index time profiles means that solar wind speed will increase when the geomangetic filed is more depressed. On the contrary, the density profile show the positive correlation with the Dst index, which means that the density will increase when the disturbance becomes stronger. However, the increasing or the decreasing of the parameters did not occur simultaneously.

Keywords: Geomagnetic disturbance – Solar wind velocity – Solar wind density

1 INTRODUCTION

Manifestation of solar activity are frequently observed in the solar wind near Earth. The various processes on solar atmosphere play significant role in controlling the interplanetary and geomagnetic disturbances. Moreover, geomagnetic field variations have been explained as the result of the interaction of interplanetary filed with the Earth's magnetosphere. It has been known that the primary cause of geomagnetic storms is associated with interplanetary structures with intense, long duration and southward magnetic field (Bz) which interconnect with the Earth's magnetic field and allow solar wind energy transport into the Earth's magnetosphere [1,2].

The physical mechanism for solar wind energy transport into the magnetosphere is reasonably well understood. The coupling mechanism is magnetic reconnection between southwardly directed Interplanetary Magnetic Field (IMF) and northward magnetopause fields [3]. This is schematically shown in Figure 1. Interconnection of interplanetary fields and magnetospheric dayside fields leads to the enhanced reconnection of fields on the nightside with the concomitant deep injection of plasma sheet plasma in the nightside.

Geomagnetic activity is influenced by a variety of interplanetary parameters and their combinations. During solar minimum, high speed streams from coronal holes dominate the interplanetary medium activity. The high density, low speed streams associated with the plasma impinging upon the Earth's magnetosphere cause positive Dst values, which means as the storm initial phases [4]. When the solar activity driven solar wind (e.g. Coronal Mass Ejection, CME) interacts with the magnetosphere, ram pressure, which indicates combining effect of solar wind density and speed, is also an important contributor [5]. Recent studies (e.g. [6,7]) have identified the role of initial speed of solar eruption like initial speed, ram pressure in producing magnetic storm at the Earth. Local solar wind conditions also also play role in its evolution during its passage from the Sun to the Earth.

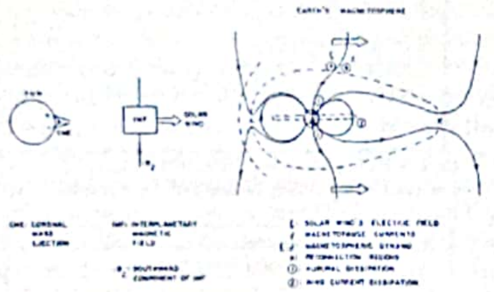

Figure 1. Schematic of interplanetary-magnetosphere coupling, showing the reconnection process and energy injection into the nightside magnetosphere, which lead to the formation of the storm-time ring current [8].

It is the purpose of this paper to review the solar wind velocity and the particle density to see the role of both parameters related to the geomagnetic disturbances. We analyze the four days data around the occurence of geomagnetic disturbance by calculate the correlation value between velocity and density with the geomagnetic disturbance index Dst.

2 DATA AND METHOD

We analyzed the solar wind velocity, particle density and Dst index. The velocity and the density data are hourly data which is observed by ACE (Advanced Composition Explorer) satellite, and downloaded from http://omniweb.gsfc.nasa.gov/, while the hourly Dst data comes from World Data Center for Geomagnetism, Kyoto University. We choose the period between 2008 – 2010 which the period of quiet solar activity, so that the occured geomagnetic storms are weak and moderate storms. Therefore we selected the data which has Dst ≤ -30 nT. In this period, we found 41 geomagnetic disturbance events.

We then calculate the correlation between velocity and Dst, as well as the density and Dst, at the coincide time. Then we shifted the Dst data, and find the correlation between shifted Dst data with the original data of velocity. If the time difference between original and shifted Dst data is positive, it means that we correlate the velocity to the Dst data hour(s) later, and vice versa. Similarly, we do this to the particle density.

3 ANALYSIS

We analyzed the solar wind data and the related Dst in years 2008 – 2010. During that period there were 41 geomagnetic disturbance with Dst less than -30 nT. The solar wind parameters include the velocity and density, while the geomagnetic disturbance is represented by Dst index. Fig 2 shows the Dst index and geomagnetic disturbance – related solar wind parameters (velocity and density) for the period of 7 – 13 March 2008. In this figure we can see the geomagnetic disturbance which is indicated by the decrease of Dst and the increase of the velocity and density of solar wind.

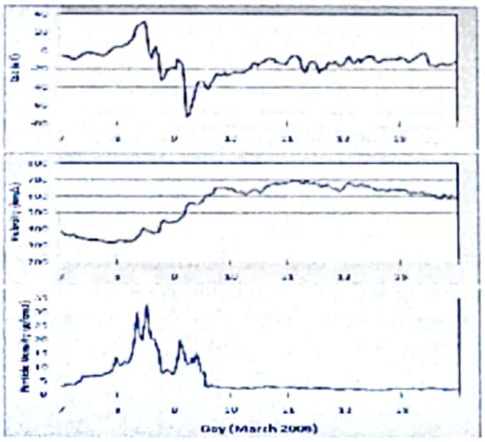

Figure 2. One of the 41 events that analyzed to find the best correlation between the parameters. The Intensity of Dst (top), solar wind velocity (middle) and particle density (bottom) on 7 – 13 March 2008.

In order to understand the relation between the geomagnetic disturbance with the solar wind velocity and density, then we calculate the correlation coefficients between the Dst index and solar wind velocity as well as with the density. Fig 3 shows the correlation between solar wind velocity and the geomagnetic disturbance index Dst with coefficient correlation R= -47.8%. It represent the inverse correlation from 41 events. The plot shows that the increase of solar wind related with decrease of Dst, which is represented by the equation Y= -0,0523 X + 10,984, where X is solar wind velocity, and Y is the intensity of geomagnetic disturbance. However some strong disturbances occured with slower speed solar wind. The solar wind which is related with geomagnetic disturbance has velocity > 270 km/s.

The next step we have to find the best correlation between both parameters of solar wind (velocity and density) with the Dst index. It can be done with shift the solar wind data against the Dst data. If we correlate the velocity and the density in the same time of occurence, we say that Dst – V = 0 (zero). It becomes a negative value if the velocity change earlier than Dst (the change of velocity precedes the Dst). And the contrary, it becomes a positif if the velocity change after the change of Dst (the change of velocity follows the Dst).

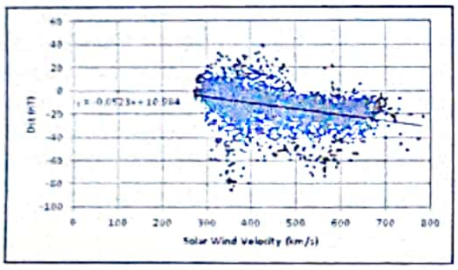

Figure 3. Plot between solar wind velocity with the geomagnetic disturbance index Dst. The plot shows that the increase of solar wind related with decrease of Dst.

Fig 4 shows that the best correlation between velocity and Dst (correlation is -47.8%) for the 41 events is reached when Dst – V has negative value (= -1 hour). It means that the increase of solar wind velocity starts one hour precedes the decrease of Dst.

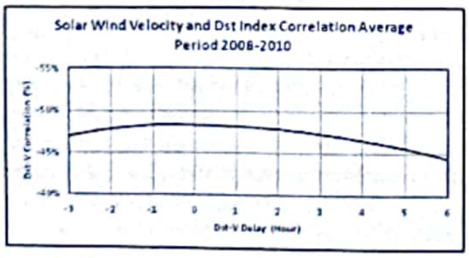

Figure 4. Average correlation value between solar wind velocity and Dst from 41 events with Dst ≤ -30 nT. The vertical component shows the correlation value. The horizontal shows the shift between velocity and Dst. Negative means that the increase of solar wind speed occured after the decrease of Dst, and vice versa.

Plot between the particle density and Dst index in the period of 2008 - 2010 is presented in Fig 5. It can be represented by equation Y = 1.0953X – 17.842, where X is particle density and Y = geomagnetic disturbance index Dst. The best correlation between density and Dst is reached when V – Dst = -2hours with coefficient correlation R= 39.3%, which means that the particle density is increased two hours before the increase of Dst (see Fig 6).

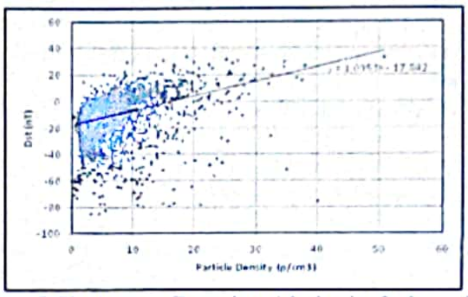

Figure 5. Plot between Dst and particle density. It shows that the increase of the density related with the increase of Dst.

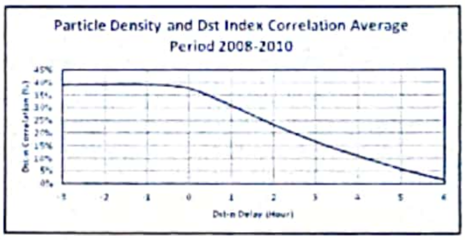

Figure 6. Average correlation value between particle density and Dst. The vertical component shows the correlation value. The horizontal shows the shift between density (n) and Dst. Negative means that the increase of density after the decrease of Dst, and vice versa.

We have analyzed relationship of the geomagnetic disturbance with its precursor in the solar wind. We find the correlation of its physical parameters (velocity and density) with the geomagnetic storm index (Dst) which is the indicator of the geoeffectiveness. The storm itself shows the decrease of Earth's magnetic filed that is influenced by the changes of the energetic charged particles in the ring current, which come from the solar wind. The velocity and density of solar wind define the dominant pressure at the magnetosphere as shown by the following equation [9]

$$P = \rho_{SW} \upsilon_{SW}^2 \quad (1)$$

where P = dynamic pressure
ρ = density of solar wind
υ = velocity of solar wind

However, the best correlation of the solar wind parameters (velocity and density) and the Dst does not occur simultaneously. There is a time delay between both parameters. The correlation coefficients are not good enough (-47.8% and 39.3 %). It shows that the velocity and particle density of solar wind are not the key factor which trigger the geomagnetic disturbance.

4 CONCLUSION

The velocity and particle density of solar wind have roles in the intensity of geomagnetic disturbances, although they are not the key factor in triggering the storm. The correlation values show that the speed of solar wind has negative correlation, while the density has positive correlation with the geomagnetic disturbance index (Dst), which the less Dst means stronger storm intensity. The increase of solar wind speed and the decrease of particle density can strengthen the disturbance. However our analysis of the time profiles of velocity, density, and Dst shows that the increase (decrease) of the velocity and density profiles do not occured simultaneously with the decrease of Dst. The Dst start to decrease before the increase (decrease) of solar wind speed (density).

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