STUDY ON RELATIONSHIP OF MAGNETOSPHERIC SUBSTORM AND MAGNETIC STORM

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Abstract

Magnetic storm is generated magnetic reconnection between interplanetary magnetic field (IMF) and Earth's magnetic field at the dayside. The magnetic reconnection is accompanied with growth of ring current. Magnetospheric substorm is night-time phenomena that generated by magnetic field reconnection at Earth's magnetotail. The magnetospheric substorm related with auroral electrojet at the polar ionosphere. The magnetic storm could be diagnosed by Dst index and the magnetospheric substorm with AE index. In this paper we examined the relationship and shows the relationship magnetic storm and magnetospheric substorm by analyzing Dst and AE index.

INTRODUCTION

Magnetospheric substorm is a systematic response of the magnetosphere to an increase in coupling between solar wind and geomagnetic field (McPherron, 1991). During a magnetospheric substorm a large amount of energy is extracted from the solar wind and is pumped into the magnetopause and ionosphere. The substorm is characterized by three phases : growth, expansion and recovery phase. The growth phase begins when the interplanetary magnetic field turns southward and magnetic reconnection begins at the subsolar magnetopause. .Magnetic field lines of the solar wind merge with the geomagnetic field and are carried over the polar caps and stretched into a long tail behind the Earth. As open magnetic field lines accumulated in the tai lobes they exert increasing pressure on the plasma sheet causing it to thin. In the reaction to the increased drag on the tail, the tail current moves earthward and strengthens to correspond to the increased magnetic field in the lobes. At the same time, plasma and magnetic field begin to flow up the tail towards the reconnection line at the front of the magnetosphere to replace field lines removed by reconnection. This flow is diverted around the side of the Earth creating a two-celled convection system within the magnetosphere. This process continues until the plasma sheet become to thin at midnight about 20 Re (Earth's radius) behind the Earth. This signals the beginning of the expansion phase of the magnetospheric substorm.

During the growth phase of the magnetospheric substorm the size of the polar cap as more magnetic field lines are connected to the solar wind. The open magnetic field lines enable the solar wind electric field that points from dawn to dusk to be transmitted to the ionosphere. The electric field drives a Pedersen current down field lines on the morning side, across the polar cap, and up field lines on the dusk side. In addition, some of the dawn side current flows equatorward to the plasmapause where it closes upward along field lines. This portion of the current continues around the night side equator as a partial ring current. Near dusk and in the late afternoon it is diverted downward near the plasmapause, attaching to a poleward current in the dusk oval. The current merges with the current coming across the polar cap and flows out along field lines. The electric field also drives a Hall current in the ionosphere. It flows along the auroral oval towards midnight. On the dawn side this portion is called westward electrojet. On the dusk side it is called the eastward electrojet. Near midnight the currents meet and flow poleward across the polar cap diverging into the electrojets at the dayside auroral oval.

A magnetic storm is an interval of several days duration which there is a large reduction in the horizontal component of geomagnetic field at the Earth's surface (Gonzalez et al. 1994). A classic magnetic storm begin with a sudden commencement and a prolonged initial phase. There are caused by a sudden increase in the dynamic pressure of the solar wind as high speed and high-density plasma from Sun suddenly arrive at the Earth. The magnetopause is pushed earthward, strengthening its current and its positive effect on the ground. The sudden commencement is a packet waves triggered by the sudden displacement of the field lines in the magnetosphere that resonate in response to the change. The initial phase lasts from a few minutes to many hours and is usually followed by a rapid decrease in the surface field. This decrease is called the main phase of magnetic storm. A weak storm consist only a 50 nT decrease, a moderate storm about 150 nT, a strong storm up to 300 nT and a great storm more than 500 nT.

The main phase is cause by the growth of a ring current around the Earth. This is traditionally though to be a doughnut-shaped region around the Earth containing a strong west ward current. This current is primarily created by ions including protons, helium ions and oxygen ions drifting westward around the Earth from midnight towards dusk and onward. This current acts much like a large solenoid around the Earth producing a magnetic disturbance that is southward along the Earth's polar dipole axis, whereas the geomagnetic field itself is northward. The creation of ring current is caused by a prolonged interval of strong southward magnetic field and high solar wind velocity. These are precisely conditions that cause magnetic reconnection on the dayside and intense convection in the magnetosphere. The ions creating the current are brought in from the tail and energized by magnetospheric electric field associated with convection. Most of the ions simply drift through the magnetosphere and exit through dayside boundary (Liemohn et al., 2001). Only after the recovery phase begins do some of these ion come onto closed drift paths that circle the Earth.

This paper will describe the relationship of magnetospheric substorm and the magnetic storm.

DATA USED

In this study we are using the Auroral Electrojet (AE) and Dst (Disturbances storm-time) indices to analyze the relationship of magnetospheric substorm and magnetic storm. The AE index is a measure of global electrojet activity in the auroral zone and is derived from geomagnetic variations in the horizontal component observed at 13 observatories along the auroral zone in the northern hemisphere. Meanwhile, the Dst index is geomagnetic disturbances in H-component of magnetic field at mid and low latitude during magnetic storm. The hourly Dst index is obtained from magnetometer stations near the equator but not so close that the E-region equatorial electrojet dominates the magnetic perturbations seen on the ground. At such latitudes the H (northward) component of the magnetic perturbation is dominated by the intensity of the magnetospheric ring current. Dst index is a direct measure of the hourly average of this perturbation. Large negative perturbations are indicative of an increase in the intensity of the ring current and typically appear on time scales of about an hour. The decrease in intensity may take much longer, on the order of several hours. The entire period is called a magnetic storm. During a storm it is usual to observe several isolated or one prolonged substorm signature in the AE index.

We chooses two events: super-storm at November 1991 and November 2003. At November 1991, the Dst decreased to -354 nT and at November 2003 to -422 nT. Plot of both magnetic storms are shown at Figure 1 and 2, respectively.

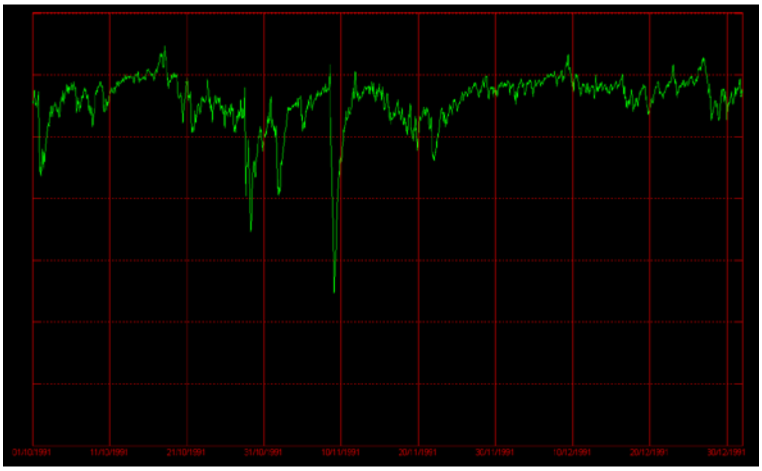

Figure 1: Dst index associated with super magnetic storm at 9 November 1991 with amplitude of H-component -354 nT. Data is plotted during 1 October – 31 December, 1991. Horizontal axis is date in Universal Time and vertical axis is amplitude of Dst in nT. Vertical axis range from -600 to 100 nT with 100 nT per grid.

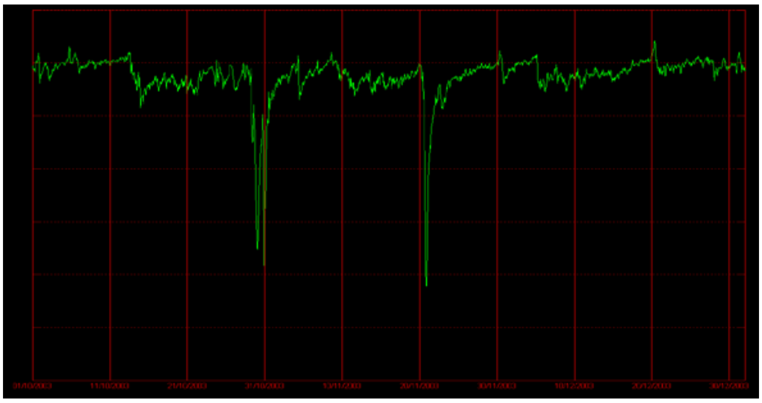

Figure 2: Dst index associated with super magnetic storms at 29 October and 20 November 2003 with amplitude of H-component -422 nT. Data is plotted during 1 October to 31 December, 2003. Horizontal axis is date in Universal Time and vertical axis is amplitude of Dst in nT. Vertical axis range from -600 to 100 nT with 100 nT per grid.

In the Figures 3 and 4 are shown the auroral electrojet (AE) index for same date with Figures 1 and 2, respectively.

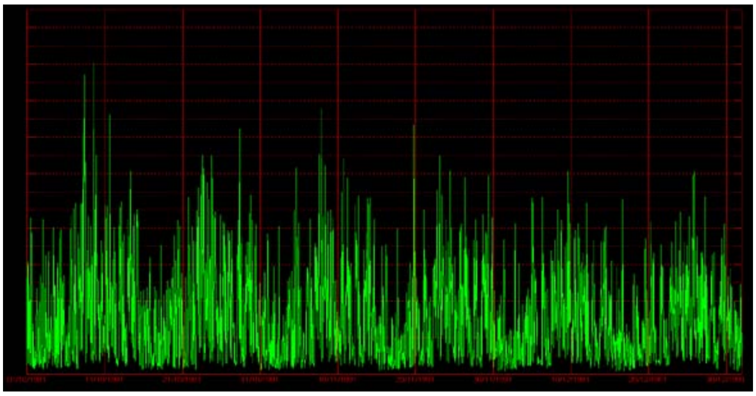

Figure 3: AE index associated with magnetic storm at 9 November 1991. Data are plotted during the same period with Figure 1. Horizontal axis is date in Universal Time and vertical axis is amplitude of AE in nT. Vertical axis range from 0 to 2000 nT with 100 nT per grid.

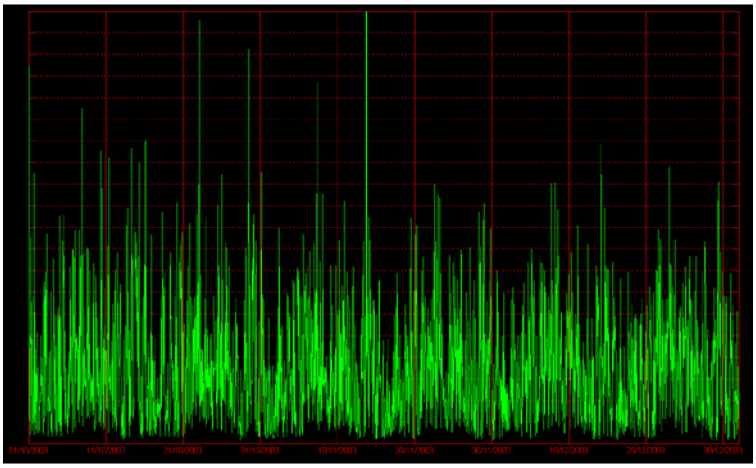

Figure 4: AE index associated with magnetic storms at 29 October and 20 November 2003. Data are plotted during the same period with Figure 2. Horizontal axis is date in Universal Time and vertical axis is amplitude of AE in nT. Vertical axis range from 0 to 2000 nT with 100 nT per grid.

ANALYSIS AND DISCUSSION

First, we presents our analyses concern to the magnetic storm at 9 November 1991. The magnetic storm seems is initiated by a sudden commencement at 14:00 UT, 8 November, 1991 where the magnitude of H component of magnetic field increased to 17 nT. After the sudden commencement, the H component of magnetic field decreased rapidly to -354 nT in during 18 hours until 03:00 UT, 9 November 2009 as shown in Figure 5.

The AE index concern this magnetic storm is shown in Figure 6. At the sudden commencement that initiated the magnetic storm at 14:00 UT, 8 November 1991, the AE index shows small activity. This is presented by small value of AE index about 190 nT. Then, during the growing and expansion phases of magnetic storm, from AE index during 14:00 UT, 8 November 1991 to 03:00 UT, 9 November 1991 observed 3 magnetospheric substorm events : (**1**) 15:00 – 20:00 UT, 8 November 1991 with magnitude 894 nT at 16:00 UT, 8 November 1991, (**2**) 21:00 UT, 8 November 1991 to 02:00 UT, 9 November 1991 with magnitude 897 nT at 01:00 UT, 9 November 1991 and (**3**) 03:00 – 15:00 UT, 9 November 1991 with magnitude 856 nT at 09:00 UT, 9 November 1991. The very strong auroral electrojet seems flow at the polar ionosphere during the (**1**) and (**2**) magnetospheric substorms.

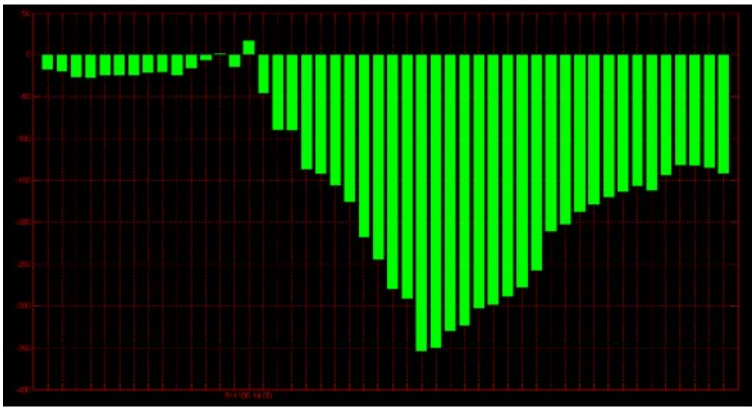

Figure 5: Growth and expansion phases of magnetic storm at 9 November 1991. Horizontal axis is date in universal time where 1 hour per-grid and the vertical axis represent the magnitude of Dst in nT.

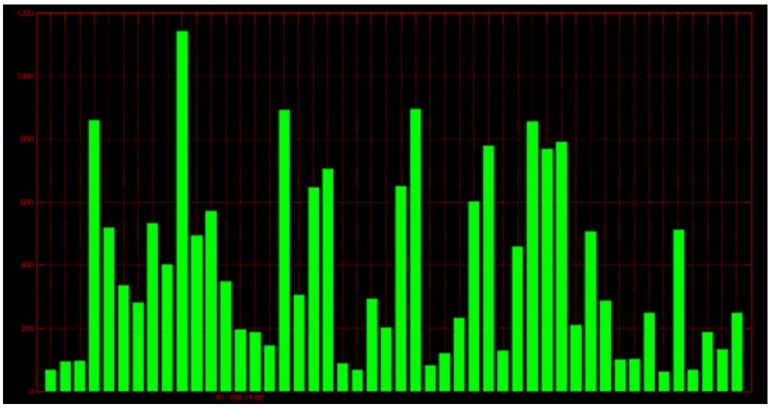

Figure 6: AE index during growing and expansion phases of magnetic storm at 9 November 1991. Horizontal axis represent date where data plotted in universal time, 1 hour per grid. Vertical axis represent the amplitude of AE index in NT.

As explained above the magnetospheric substorm is triggered by magnetic field reconnection in magnetotail in night side of the Earth that caused by thickening of plasma sheet in magnetotail. After the magnetic field reconnection in the magnetotail, plasma and particles are transferred from magnetotail and solar wind to polar ionosphere. This affect an enhancement of electric current that called as auroral electrojet at polar ionosphere and then create partial ring current.

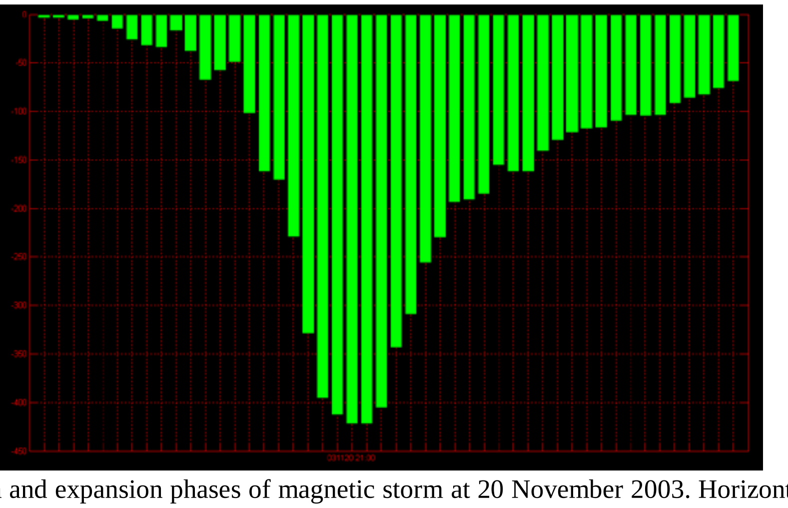

Figure 7: Growth and expansion phases of magnetic storm at 20 November 2003. Horizontal axis is date in universal time where 1 hour per-grid and the vertical axis represent the magnitude of Dst in nT.

Concern to the magnetic storm at 9 November 1991, Dst index shows minimum value reached at 03:00 UT, 9 November 1991. This means that the ring current at the mid and low latitude growth to completed ring current at 03:00 UT. Partial ring current that generated by magnetospheric substorm may be give some contribution to growing phase of ring current at mid and low latitude. During the magnetospheric substorm (**1**) to (**3**) the partial ring currents at polar ionosphere enlarge to reach the mid latitude. Magnetospheric substorm (**1**) and (**2**) seems give contribution to create a complete ring current and the (**3**) magnetospheric substorm give contribution to maintain the complete ring current during the recovery phase of magnetic storm to 09:00 UT, 11 November 1991.

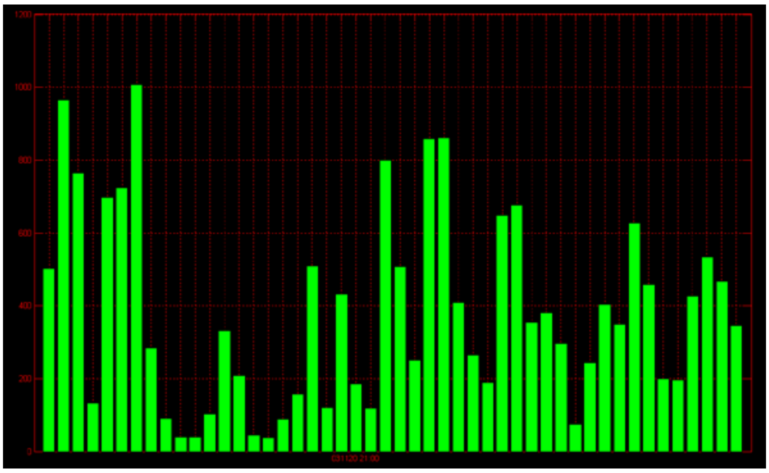

Figure 8. AE index during growing and expansion phases of magnetic storm at 20 November 2003. Horizontal axis represent date where data plotted in universal time, 1 hour per grid. Vertical axis represent the amplitude of AE index in NT**.**

As magnetic storm 9 November 1991, the magnetic storm at 20 November also accompanied by magnetospheric substorms, as shown in Figure 7 and 8. A strong auroral electrojet concern the magnetospheric substorm observed several hours before the minimum of Dst index. This means that partial ring currents grow before the ring current at mid and low latitude grow to complete ring current.

CONCLUSION

We have analyzed the AE and Dst indices as measured of magnetospheric substorm which relate with auroral electrojet in the polar ionosphere and magnetic storm which relate with growing of ring current at mid and low latitude. The magnetic storms are accompanied by several magnetospheric substorms during its growth and expansion phases. Magnetospheric substorm that responsible for creation of partial ring current at polar ionosphere have contribution for growing of a ring current during the magnetic storm, but in future we need to analyze more magnetospheric substorm and magnetic storm events to understand mechanism of transport energy from polar ionosphere to the mid and low latitude.

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