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Geomagnetic Field Variation during Winter Storm at Localized Southern and Northern High Latitude

Babita Devi[1], Smita Dubey[1], Shailendra Saini[1], Rajni Devi[1], Rashmi Wahi[1], Ajay Dhar[3], S. K. Vijay[2] & A. K. Gwal[1]

[1]*Space Science Laboratory, Department of Physics, Barkatullah University, Bhopal 462 026, India.*

[2]*Government Geetanjali College, Bhopal, India.*

[3]*Indian Institute of Geomagnetism, New Panvel, Mumbai, India.*

Abstract. This paper presents the effect of geomagnetic storm on geomagnetic field components at Southern (Maitri) and Northern (Kiruna) Hemispheres. The Indian Antarctic Station Maitri is located at geom. long. 66.03° S; 53.21° E whereas Kiruna is located at geom. long. 67.52° N; 23.38° E. We have studied all the geomagnetic storms that occurred during winter season of the year 2004–2005. We observed that at Southern Hemisphere the variation is large as compared to the Northern Hemisphere. Geomagnetic field components vary when the interplanetary magnetic field is oriented in southward direction. Geomagnetic field components vary in the main phase of the ring current. Due to southward orientation of vertical component of IMF reconnection takes place all across the dayside that transports plasma and magnetic flux which create the geomagnetic field variation.

Key words. Dst—vertical component of interplanetary magnetic field and geomagnetic field components.

1. Introduction

The magnetic field is one of the important properties of the earth. The main magnetic field originates from hydromagnetic processes in the liquid outer core, and its configuration and secular variations also depend upon the structure and dynamic processes in core mental boundary. The geomagnetic field has a regular variation which depends on local time, latitude, season and solar cycle. These variations indicate that the geomagnetic signatures at high latitude are those left by the southern limb of the quiet time *Sq* current loop in the Southern Hemisphere and those left by the northern limb of the quiet time *Sq* current loop in the Northern Hemisphere. The disturbances in the geomagnetic fields are caused by fluctuations in the solar wind impinging on the earth. The most energetic magnetic storms occur during peaks in solar activity and when the vertical component of interplanetary magnetic field (IMF) becomes intimately connected with that of the earth (Gonzales *et al.* 1994). The disturbances may be limited to the high-latitude region unless the vertical component of interplanetary magnetic

Table 1. List of all severe storms that occurred in winter season.

Month	Day	Dst nT	Kp	Ap	IMF	Storm
January 2004	22	−149	7^-	64	−19	Severe
February 2004	11	−109	3^+	12	−15	Severe
November 2004	7	−373	8°	50	−51	Severe
	7	−373	8°	50	−51	Severe
	7	−373	8°	50	−51	Severe
	9	−223	9^-	119	−39	Severe
	10	−289	9^-	161	−28	Severe
January 2005	18	−121	8^-	84	−26	Severe
	21	−105	8°	66	−30	Severe

field carried by the solar wind has long periods (several hours or more) of southward orientation with magnitudes (greater than 10–15 nT). In this paper, we examine and compare the winter variations in geomagnetic field components with respect to the variation in global parameter.

2. Data selection

The data used in this study was collected from the Swedish Geomagnetic Observatory "Kiruna" for Northern Hemisphere. For Southern Hemisphere we used Indian Antarctic Research Station "Maitri". Digital data of magnetic field is collected by fluxgate magnetometer. The vertical component of interplanetary magnetic field discontinuities of the same time (winter season of year 2004–2005) is also detected from ACE satellite. Dst index, Kp and Ap index are taken from World Data Center, Kyoto, Japan. With global indices we compare the local phenomenon to study the variation of geomagnetic field component at localized Northern and Southern Hemispheres.

3. Results

To study the effect of storms on localized stations we have analyzed the winter storms of year 2004–2005. Table 1 shows the list of the most severe storms. Depending upon the Dst value we have categorized the geomagnetic storm in minor (Dst > -50 nT), moderate (Dst ≥ -100 nT) and severe (Dst < -100 nT) and we have selected those events in which Dst is < -100. Before considering the various component of earth's magnetic field we have considered the vertical component of IMF and compared geomagnetic field component with its orientation at both hemispheres.

Case 1. January 22, 2004. Dst index Kp and Ap sum is shown in Table 1. The initial phase of the ring current started from 1:36 UT to 11:00 UT. The vertical component of IMF oriented to southward direction with value −19 nT for two hours and after that it remains southward for more than 24 hours. At Southern Hemisphere the X component shows the increase of 600 nT. Y component shows the decrease of 600 nT and the Z component shows the decrease of 900 nT. At Northern Hemisphere the X component decreases upto 600 nT, *Y* component fluctuates and *Z* component decreases upto 400 nT. In the main phase of the ring current and southward orientation of interplanetary magnetic field the geomagnetic field components show the maximum variations. Due to southward orientation of vertical component of IMF there is the increase in the central plasma sheet ions. Because of increase in central plasma ions the geomagnetic field varies.

Case 2. February 11, 2004. As its maximum negative excursion value is −109 nT. But the geomagnetic field component does not show any significant variation at Maitri, the *X* component increases with 300 nT, *Y* component fluctuates and *Z* component decreases with values 400 nT. At Kiruna *X* component decrease of 200 nT and the decrease in *Y* component is of 200 nT and there is the decrease of 400 nT in *Z* component.

Case 3. November 7, 2004. There are three storms on 7 November 2004. The maximum negative excursion of the ring current is −373 nT at 06:00 UT. When the vertical component of interplanetary magnetic field turns to southward direction for 12 hours with value of −51 nT at 22:00 UT. At Southern Hemisphere, the *X* decreases upto 2000 nT, *Y* component fluctuates and *Z* component increases upto 1400 nT. At Northern Hemisphere, the *X* component decreases upto 1700 nT, *Y* component increases upto 1200 nT and *Z* component fluctuates.

Case 4. November 9, 2004. The maximum negative excursion of the ring current is −223 nT as shown in Fig. 1. When the vertical component of interplanetary magnetic field (B_Z) turns southward direction for 15 hours on 10 November 2004, with value of −39 nT at 21:00 UT, at Southern Hemisphere, the *X* decreases upto 1600 nT, *Y* increases upto 1200 nT and *Z* increases upto 1200 nT. At Northern Hemisphere, *X* decreases upto 800 nT, *Y* decreases upto 900 nT and *Z* increases upto 1000 nT. At Southern Hemisphere, the amplitude of variation is more as compared to the Northern Hemisphere.

Case 5. November 10, 2004. Maximum negative excursion of Dst, Ap, Kp and vertical component of IMF are shown in Table 1. At Southern Hemisphere, there is the decrease of 1525 nT in *X* component and *Y* and *Z* component increases with value 1232 and 1146 nT respectively. At Northern Hemisphere, the variation in *X* component is −1000 nT and increase in *Y* component and *Z* component fluctuates.

Case 6. January 21, 2005. The maximum negative excursion of the ring current is shown in Table 1. The vertical component of interplanetary magnetic field turns to southward direction at 16:00 UT with value of −30 nT. At Southern Hemisphere, the *X* component decreases upto 800 nT, *Y* component increases at 900 nT and *Z* component decreases upto 750 nT. At Northern Hemisphere, the geomagnetic *X* component decreases upto 800 nT, *Y* component increases upto 900 nT and *Z* component increases upto 700 nT.

Case 7. January 18, 2005. Dst, Ap and Kp vertical component of IMF are shown in Table 1. At Southern Hemisphere, the *X* component decreases upto 1000 nT and *Y* and *Z* components increase with values of 300 nT and 400 nT respectively. At Northern Hemisphere, *X* and *Y* components decrease upto 600 nT and 200 nT and *Z* component increases with value 200 nT. Geomagnetic field component also shows smooth behaviour during the recovery phase of the event. Due to southward

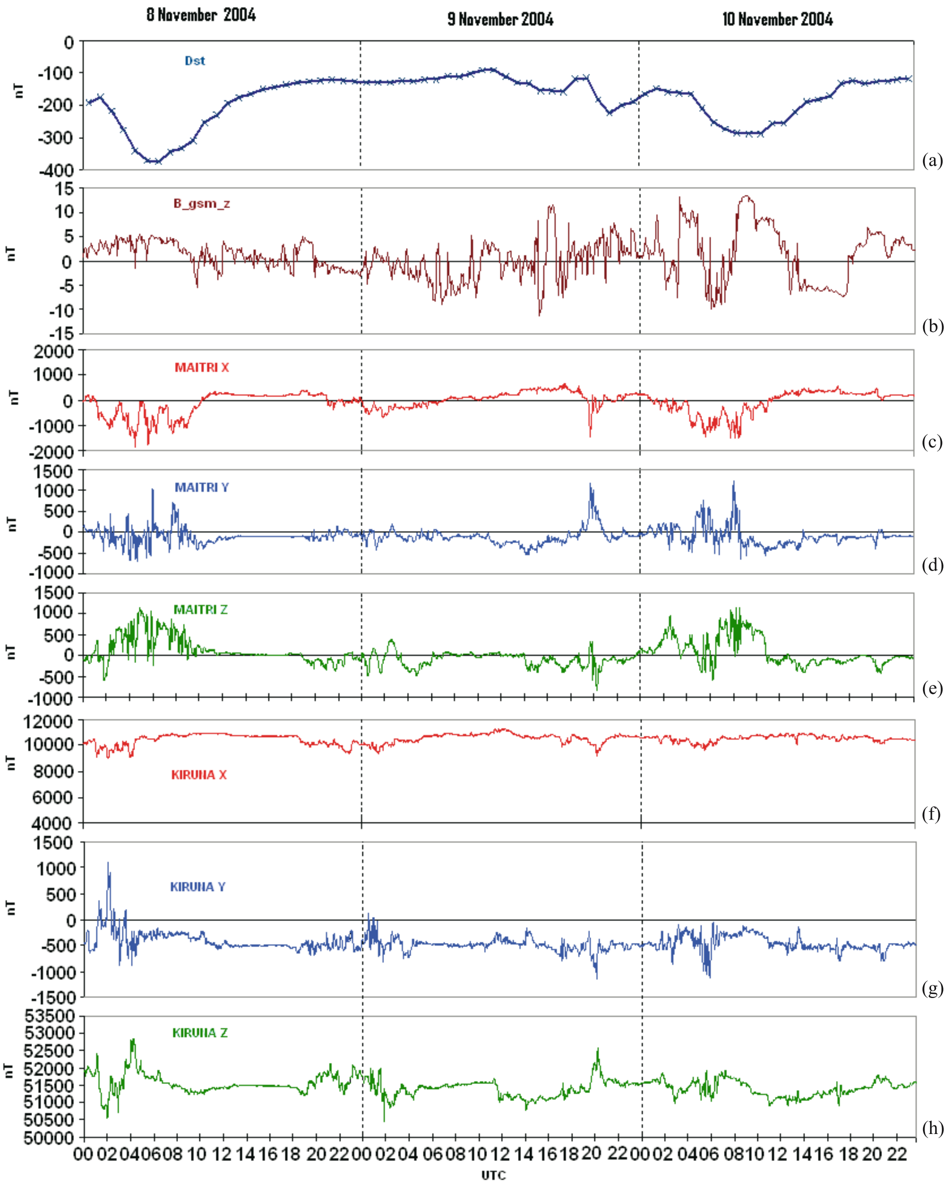

Figure 1. Storm of November 9, 2004, Panel (a) shows the Dst variation, panel (b) shows the vertical component of IMF while panels (c, d, e) show the variation of X, Y and Z components at Maitri and panels (f, g, h) show the variation of X, Y and Z component respectively at Kiruna.

orientation of vertical component, increase in solar wind speed and density, there is an increase in the dynamic pressure which in turn increases the central plasma sheet ions. Because of the increase in central plasma ions the geomagnetic field varies.

4. Summary and discussion

We find a good relation between geomagnetic field components and its causative parameter, i.e., ring current and vertical component of interplanetary magnetic field. When there is a disturbance in the solar wind the current systems existing within the magnetosphere are enhanced and cause magnetic disturbances and storms. The southward orientation of the vertical component of IMF produced substorm activities and large negative Dst variations extending to −350 nT and/or −400 nT, on the ground. On 7 November 2004, the Dst value is observed to be −373 nT. It is observed by (Arnoldy 1971; Foster *et al.* 1971) that the vertical component of (IMF) has been associated with geomagnetic activity. Tsurutani *et al.* (1997) show higher intensities in the ring current and consequently a higher occurrence of geomagnetic storms. The solar wind increases the central plasma sheet ions density. The central plasma sheet ion density controlled mostly by the solar wind proton density and by the northward IMF component. Larger/smaller solar wind ion densities and northward/southward interplanetary magnetic filed results in larger/smaller density in the central plasma sheet which in turn results in the hotter/cooler central plasma sheet. According to Ebihara & Ejiri (1998, 2000) the solar wind plasma is supplied to the plasma sheet. Due to the return convection, particles of a boundary transitient layer are transported to the inner edge of the plasma sheet and are accelerated. Magnetic field lines of the dayside magnetopause are transported to the tail increasing a magnetic flux. Hence from the above study of all the severe geomagnetic storms of winter season of the year 2004–2005, we observe that

- At Southern Hemisphere the geomagnetic field variation is larger as compared to that of the Northern Hemisphere.
- The geomagnetic field components vary in the main phase of the ring current and when the southward orientation of (IMF) is observed.

In the recovery phase there is smooth variation. In this study we examined winter season storms only, but in future we will analyze the storms during all seasons and their correlation with geomagnetic field components.

5. Conclusion

With disturbed conditions at the front of the magnetosphere, the geometry is unstable and field reconnection occurs with the geomagnetic field and causing acceleration of charged particles in the magnetosphere, where neighbouring but appositively directed field lines can reconnect, with resulting recoil and acceleration of charged particles in the magnetosphere. A related effect occurs in the tail of the magnetosphere. During the disturbed condition when the vertical component of IMF is southward the maximum convected magnetic energy is integrated over the dayside magnetopause. Due to this, reconnection takes place all across the dayside that transporting plasma and magnetic flux which create the geomagnetic field variation. These variations are more at Southern Hemisphere due to the dayside as compared to the Northern Hemisphere.

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