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Geomagnetic pulsation over conjugate locations during geomagnetic storms and substorm

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Abstract

Geomagnetic data collected during magnetic storm over magnetically conjugate pair (according to IGRF 2000) of high latitude stations viz., Maitri (70° 45′ S, 11° 42′ E) and Tromso (69° 40′ N, 18° 56′ E) reveal that amplitudes of Pc6 pulsation characteristically differ. The amplitude obtained from horizontal magnetic field for the Pc6 pulsation frequency range between 0.6 and 1.6 mHz significantly differs in time corresponding to peak amplitude. The relative differences in its time of occurrence found to gradually increase around initial phase of storm and remain exactly out of phase at peak amplitude of storm. Thence, it is found to be in agreement in phase gradually until storm unwinds. This indicates that simultaneous amplitude of Pc6 pulsation at conjugate pair of stations and its time of occurrence could be a key factor to infer storm arrivals somewhat prior to its peak effects. The emphasize remains on prediction of storm arrivals only by utilizing ground based magnetometer observations. However, it is necessary to understand differences on the basis of weak, moderate, strong, and super strong cases and more exactly how they behave along the line of magnetic Meridian. Nevertheless, the analysis implies that geo-effective magnetic ejecta/clouds/CIRs/sheaths/CMEs/ICMEs giving rise to geomagnetic storm can be predicted ahead of its peak effects by having magnetometer data over conjugate locations.

Keywords: Geomagnetic storms; Space weather; Magnetic pulsations

1. Introduction

The diurnal record of Earth's magnetic field variation (Rastogi, 2001) using ground based network of flux gate magnetometers in general reveal instantaneous field values measured on Earth's surface are associated to various plasma currents located radially outward from the point of observation. These plasma currents are mainly associated to ionospheric and magnetospheric currents. The magnetic field perturbations measured on ground further depend on magnetic latitude and longitude of observation due to the presence of various current systems and its changes owing to such currents situated overhead at different latitudes (Rastogi, 2001, 2006; James et al., 2008).

The magnetic storm influences almost all currents those normally exist before storm in the ionosphere and magnetosphere, i.e., the quiet time level of currents. The changes can happen with the normal time currents due to penetration of electric fields (Kelly et al., 1979; Somayajulu et al., 1987; Sastri et al., 1992) and solar wind plasma particles. The changes occurring with Earth's magnetic field on different time scales can be attributed to the Earth's ionospheric responses on corresponding scales to the storm (Reddy and Devasia, 1976). However, the short scale disturbances found to have less correlation with the observed magnetic field values at low latitudes (James et al., 2008). Further, the response of the ionospheric currents for the geomagnetic storm at equatorial, low, middle, auroral and polar latitude differ due to the prevailing current normally exists over such latitudes in the ionosphere during quiet conditions (Sastri et al., 2001; Rastogi, 1999; Ostgaard et al., 2002) as well as the storm time conductivity

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of the ionosphere. However, there are currents external to the Earth's ionosphere greatly influencing the magnetic components measured on the ground at equatorial latitude most significantly during storm time. One of such changes normally found during storm time is the intensification of the ring current (Chandra and Rastogi, 1997; Rastogi, 1999, 2006; Gonzalez and Echer, 2005). The changes that happen with the Earth's magnetic field during a magnetic storm are rather more complex. Often these changes are quite rapid and the measured intensities are due to the penetration of solar wind plasma as well as changes in ionospheric currents that are generated due to the penetration of electric fields associated with the storm time solar wind.

It is well known by now that eruption of energetic particles (Gopalswamy, 2003; Gopalswamy et al., 2003) and its associated magnetic fields called CMEs, ejecta, magnetic cloud, sheaths (Lakhina et al., 2005), Co-rotating Interaction Region (CIRs) and ICMEs (Webb et al., 1998; Gopalswamy et al., 2005a, 2005b, 2007; Tsurutani et al., 2006) from solar corona indeed remains main source of geomagnetic disturbances not only influencing Earth's magnetosphere, ionosphere, atmosphere, biosphere, in extreme cases they can even arrive on Earth's surface (Gopalswamy et al., 2010) and devastate electrical networks. Interplanetary magnetic field disturbances when it becomes geo-effective (Gopalswamy et al., 2005b) initiate geomagnetic storm (Akasofu, 1981; Gonzalez et al., 1994, 2002; Tsurutani et al., 1995; Echer et al., 2005, 2008, 2010) on the dayside Earth's magnetosphere and ionosphere while interplanetary magnetic field turn southward at the magnetopause boundaries. The deviation of magnetic field components measured above intrinsic magnetic field of the Earth using ground based network of magnetometers worldwide indicate that relative amplitudes of these storms differ pertaining to occurrence scenario as well as magnetic latitude and longitude. Geomagnetic storms are also inferred by monitoring physical conditions of interplanetary medium by using in situ measurements on various solar wind parameters made by satellites such as ACE satellite at L1 point (sunward direction) Miyake et al., 2005 and GOES satellite at ~6Re which is a near Earth space environment. The impact of increased upstream solar wind speed with high energetic particles during magnetic storm causes the Earth's magnetosphere to resonate like a bell. The resonating modes of magnetic field line oscillations are also due to the frozen in magnetic and electric fields associated to the solar wind during storm time. Impacts of this external energy often experienced as a shock by the Earth's magnetosphere; thus exciting several modes of magnetic field line oscillations that are called pulsations (Yumoto et al., 1989). These pulsations range typically from a few seconds to few tens of seconds. The return current or re-entry of solar wind particles from rear side of the Earth mostly influences high latitude magnetosphere and ionosphere which would cause substorm disturbances. These disturbances are in the range of few minutes to few tens of minutes known as substorm pulsations (Zhang et al., 2007). Such disturbances often would convolute with directly driven components i.e., the magnetic storm appearing on the dayside magnetosphere and ionosphere which are typically of few hours to few tens of hours (as long as the IMF is southward).

The ionospheric storm often observed with a sudden commencement (Rastogi, 1980) of an increase in the horizontal magnetic field followed by a deep depression below the night time base level of horizontal magnetic field (Rastogi, 2001). However, the eruption may remain rich in excess of protons, electrons and magnetic fields with high energy capable of causing geomagnetic storm may develop gradually (reconnection process at sun's surface). These particles and magnetic fields radiate spirally with an oblique cone subtending a volume of space in the ecliptic plane. The entire important factor would be whether the Earth finds itself in such a cone of space on the ecliptic plane to encounter those excess radiations or not. In short the radiation associated with CME emissions/ICMEs/mass ejections/sheaths/CIRs/magnetic clouds required to be geo-effective (Gopalswamy et al., 2008) to cause any magnetic storm. It becomes a sudden phenomenon while the Earth either traverse into such region in particular time of a day appearing as a sudden event or the relative position of the Earth remains such that the gradual development of solar Coronal Mass Ejections (CME) and their associated features (Manoharan et al., 2000, 2001, 2004; Manoharan and Kundu, 2003; Xie et al., 2005, 2006; Iyer et al., 2006; Yumoto, 1986; Manoharan and Rahman, 2011) envelop the Earth after a rapid transit (Nandita and Venkatakrishnan, 2004) causing a sudden commencement. Further, if the Sun had been emitting the excess energy for an arbitrary length of time in a specific region but the Earth had been off from such a suitable location, then the Earth's magnetosphere would probably not witness any storm. On the other hand when the Earth has been occulting the same volume of space of a diverging cone which originates spirally from a large area of the Sun wherein the CMEs/Flares/X-ray emission/Proton events (Nandita and Venkatakrishnan, 2004; Alex et al., 2005; Huang et al., 2005) suddenly take place may also cause an ionospheric/magnetic storm. Such occasions Sun would remain active prior in time while expelling excess energy/particles thus the effect is gradual. This effect seen by the Earth in its orbit remains also gradual due to daily movement of the Earth approaching the region of increased solar wind speed/particle density. The incremental changes in its magnetic field components due to storm ought to be also gradual while the Earth approaches space environment wherein the increased solar wind conditions may prevail. In such case there would a fair opportunity to detect a storm since it develops gradually and subsequently may achieve a sudden burst. Thus its gradual development can be found on a series of days proceeding to the storm day with its maximum intensity on a storm day. In fact, such events have been observed on the ground using magnetic observations very often during solar maximum (Rastogi, 2000). Hence, in this paper we have made an attempt to understand how the storm effect is manifested by using fairly a lengthy series of data about either side of the storm day to understand the storm time characteristics, prior, after, and during the storm. The Earth's magnetic field components varying at different time scales at conjugate stations on such occasions are the subject of this study. We have attempted to retrieve the Fourier amplitudes of the Earth's horizontal components recorded corresponding to various periods from a few seconds to 11 day period since the length of the series comprises 22 days of data for each locations used in this study. The scope of this paper confines only to the discussion on conjugate nature of the magnetograms especially the Pc6 pulsation mode.

As a matter of fact, the measured changes with magnetic field over an arbitrary location on the Earth at a given instant of time is a result of changes occurring with various sources at different radial distances outward from such an arbitrary location located in the ionosphere/magnetosphere. The intensity of such changes varies as we move on from equatorial latitude to polar latitude as the changes associate to various current sources. These changes are quite complex and the sources which generate these disturbances are both internal and external to the Earth's ionosphere. Nevertheless, these reinforced amplitudes can be resolved with the careful analysis of high resolution data obtained during magnetically quiet and disturbed days. It is indeed possible to quantify those amplitudes and their corresponding phases. Further, it would also be plausible to separate out the changes based on their time scales. This is achieved by subjecting the measured series of data to low or high pass filtering for a specific range of periods. In the case of gradual storm event as low pass filter would provide detail on the event whereas high pass filters in the case of impulsive events. Similarly, the source of energy for such events originating from the solar atmospheres may also found to be either impulsive or gradual (Lario et al., 2005; Lario, 2005). A solar eruption may create a gradually developing storm or an impulsive one. Such storms may have direct implication on the magnetic fields that we measure on the ground. However the changes that we measure on the ground may have direct correspondences only if the erupted solar wind retains such characteristics during transit. Also, it is to be reminded that every storm event is unique in its behavior; this is because the amplitude and phase of every disturbance field associated to the storm induced currents of every individual source does not remain same. This is owing to the fact that the variability of interplanetary magnetic field (IMF), geomagnetic main field configuration with respect to latitude and longitude, and most importantly the changes occurring with ionosphere currents and its conductivity. Furthermore, physical conditions and composition of the dynamic solar wind indeed remains different for different geomagnetic storms. On the other hand the amplitude and phase relationship between the Fourier amplitudes of the prevailing ionosphere and magnetosphere currents may remain such that, it would require relatively a stronger magnitude above an arbitrary value of southward IMF magnitude to show any signature of magnetic storm. On the similar way of argument, IMF magnitude would also suffice to be less, if prevailing currents are relatively smaller. Hence, it appears that IMF magnitude which can cause storms also depends on the magnitude of prevailing currents internal to the Earth's ionosphere as well as external to the ionosphere (magnetospheric currents). However, it is to be reminded that for the occurrence of auroral magnetic storm viz., the substorm, the IMF not necessarily be witnessed being southward and its magnitude seem to be unrelated as well, as to make the magnetospheric tail side reconnection process to be effective. Although IMF reversal normally favor for the onset of storm/substorm (Husu and McPherron, 2004) at auroral latitudes. On the other hand the equatorial ionospheric storm often found to coincide with the reversal of equatorial electric fields which are penetrated during storm time from magnetopause (Abdu et al., 1995; Abdu, 1997; Anderson et al., 2002, 2004, 2006; Tsurutani et al., 2008) in conjunction with the change in neutral wind dynamics over thermosphere. In fact, thermospheric neutral wind dynamo significantly governs the equatorial, low, and mid-latitude ionospheric currents thereby confining to the equatorial processes. Hence, penetration of electric field as well as change in neutral wind dynamo ought to be the sources for any changes observed with the equatorial ionospheric currents (Fejer, 2002 and references therein). This necessitates the mechanism of reconnection process being effective for magnetic storm to occur at low and middle latitudes. Further, it is also very important to understand amplitude and phase relationship during prevailing conditions at respective locations with individual components in addition to the above details. Hence it becomes necessary to understand generation of storm by including series of data corresponding to preceding days into our analysis. Similarly analysis was also required to be extended for following days of the storm event since it would reveal details of recovery process.

2. Data and method of analysis

Magnetic field components H, D, and Z due to overhead current have been measured using flux gate magnetometer at Pondicherry and Hanley, with 1 min and 1 nT resolution in time and magnitude respectively. These components have been examined with the long series of data for each of the above stations from 20th October–11th November 2003 as well as 28th October–18th November 2004 so as to bring out the storm time characteristics of the Earth's magnetic field during series of days. All these components are collected with the time resolution of 1 s at Maitri. The data obtained from Tromso are with 10 s resolution for both the series of days having storm events. The study includes overall about 132 days of data obtained from all stations using digital flux gate magnetometer at low, middle and sub-auroral latitudes for two different occasions.

The Fourier analysis is applied to the series of data containing 11 days from both side of storm day, hence, includes 22 days of data for each location. This series of data is used to understand the relative role of different periodic amplitudes with the horizontal component of the overhead currents during storm time at low, middle and high latitudes.

3. Results and discussion

Fig. 1 shows the measured intensity of magnetic field found for a series of days at Pondicherry (11° 55′ N, 79° 55′ E), Hanley (32° 45′ N, 78° 57′ E), and Maitri (70° 45′ S, 11° 42′ E) representing low, middle and high latitude stations respectively for the major storm case on 29th October 2003. The storm event was among very few intense events during October–November months. This extreme event has been discussed in detail on its geometry, morphology, composition and statistics by various researchers (Kuwabara et al., 2004; Quiang Hu et al., 2005; Lario et al., 2005; Gopalswamy et al., 2008). It could be seen that the storm effect was nearly 10-fold more intense at Maitri on 29th October 2003, dropping below 3500 nT in horizontal magnetic field. Further, the time scales of variability with the horizontal field at Maitri implicate substorm process. It appears that Maitri experiences largely of substorm phenomenon as well as field line resonances due to the rear side plasma flow towards the auroral regions; remarkably during storm hours. Although it has been estimated that the energy injection into the auroral and ring current differ only subtly (Alex et al., 2006), excess energy ought to have largely resulted from rear entry of plasma toward the auroral ionosphere from the night side during stormy conditions.

From Fig. 1 it is obvious that Pondicherry and Hanley have responded for storm time magnetic fields promptly corresponding to the reversal time of IMF to southward in terms of the changes associated with the horizontal currents; because the prevailing currents which are oppositely directed were relatively weaker for such changes. Further the absence of variability with magnetic field on short time scales at low latitude stations indicate that the changes are due to electric field penetration at magnetopause levels, largely weakened due to strong low latitude ionosphere currents. The currents at low latitude are largely governed by global scale dynamo electric field generated by thermosphere global scale wind dynamo, which in fact does not undergo rapid variations. Hence, short time electric field perturbations become not effective as it penetrates down to the low latitude ionosphere. On the contrary, the characteristic changes with the longer periods and their corresponding peak amplitudes found to be very similar at low latitude stations to middle and significantly differ with the high latitude during storm time. In fact, changes in currents during storm hours for any storm day observed at low and middle latitude are possibly associated to the Equatorial Electrojet currents, ring currents, and Sq currents respectively (Rastogi, 2006).

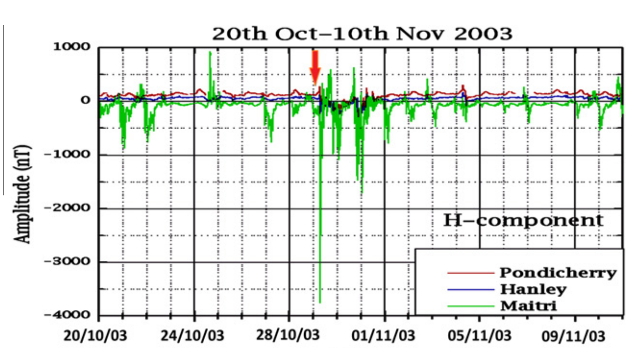

Fig. 1. The H component measured at low, middle, and subauroral latitudes.

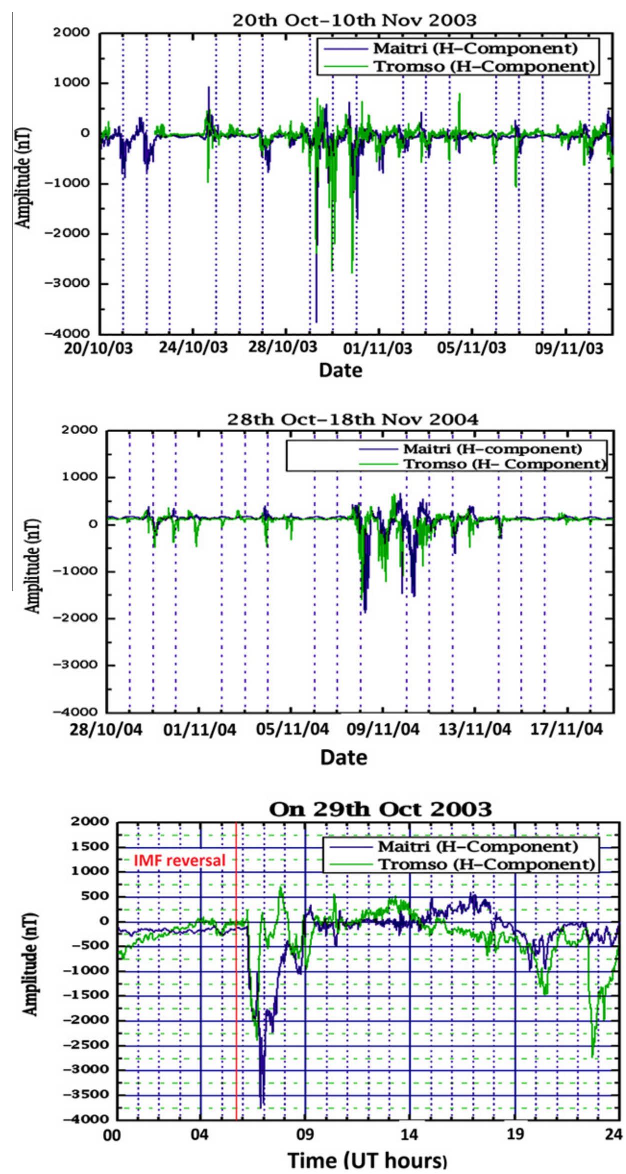

Fig. 2. The storm time H field for two intense events at a near conjugate station corresponding to Maitri.

Fig. 2 shows the horizontal component measured at Maitri and Tromso on a series of days corresponding to 20th October–10th November 2003, and 28th October–18th November 2004. The bottom panel describes the behavior of the magnetic field on 29th October 2003 in particular. The impulsive raise of H-field at Pondicherry and Hanley is due to the closest approach (compression) of the magnetopause before the reconnection process due to arrival of shock/sheath (also shown in Fig. 1). The absence of such peak at Maitri is understandable because the magnetosphere compression remains less effective at such latitudes due to tangential direction of field lines with respect to the solar wind direction at high latitude magnetosphere. Further the equatorial compression and relaxation (magnetopause oscillation about its mean position) of magnetosphere seems to have taken place within 31 min between 0606 to 0637 h. The reversal time of maximum negative H-field on the ground is found at 0609 h and it is delayed by about 13 min and 48 s just after the IMF start reversing (<-25 nT) below zero measured during 05:45:22 h at 1.5 million km (L1 point of ACE satellite) away from the Earth towards the Sun. Hence, the estimated velocity of enhanced solar wind from the time delay and the corresponding distance remain $\sim$1810 km/s. This indicates that the solar wind plasma ejected with CME was decelerated (Sakurai and Chao, 1974; Pick, 1998) in the interplanetary medium after its coronal acceleration, because its initial speed of ejection was estimated to be $\sim$2500 km/s. The dynamic solar wind after transit through interplanetary medium has encountered the Earth's magnetic field imparting its changes to the Earth's built-in currents. The corresponding changes measured during storm at conjugate locations reveal that the arrival of such disturbances can be predicted. It is very obvious that the resultant magnetic field value does change with some correspondences according to the storm time currents; however, it would require extremely simplified assumptions to draw any conclusive behavior based on the unresolved component values. This is because each component measured above conjugate locations perhaps largely remains similar or dissimilar in its respective Fourier amplitudes measured at their respective locations, but the similarity or dissimilarity will not be distinguishable only when the final amplitudes are examined. This implies that the possibility of two characteristically different magnetospheric storms with different scenarios of internal/external currents of ionosphere resulting in similar outcome indeed being different in its individual Fourier components.

Fig. 3 illustrates (left upper) the space weather overcast by the CME erupted from sun's corona. It is quite evident that the bright spot on the lower limp of the Sun corresponds to the X-ray emission followed by increased solar wind particle concentration measured by GOES satellite which is shown in the right side panels of Fig. 3 with red[1] pointers. The red pointers indicate that a delay was about 1.2 h between the initial time of X-ray flux increase and corresponding time of proton flux increase. The X-ray fluxes have advanced in time when twisted magnetic field line reconnection took place at sun's surface. The subsequent proton flux increase is followed when the magnetic loops containing solar plasma particles were ejected out of solar coronal region. In fact, the Sun was hyperactive over this period and its corona blasted away several times from its atmosphere during October–November, 2003 (Gopalswamy et al., 2005a, 2005b, 2005c, 2005d). On top of all the events an intense burst took place on 28th October 2003 with the solar wind ejection velocity of about 2029 km/s at 11:12:10 UT hours. The intensity of the corresponding X-ray flux and density of solar wind particles (shown at upper right of Fig. 3) have increased at Earth environment about 50% above normal conditions measured by GOES satellite. The magnetic field parallel component H_p measured during day side by the GOES corresponds to the movement of the magnetopause about GOES orbital distance from the Earth. The H_p variations during 1730 to 0530 UT on 29th October 2003 indicate a possibility of observing intense substorm as well as geomagnetic tail currents during magnetic storm, since, the GOES satellite remaining on the tail side during such time. The intensification of high latitude auroral emission also has been witnessed during such period at the southern hemisphere by the IMAGE satellite (shown at left bottom of Fig. 3).

Fig. 4 depicts the changes found with the intense mode of substorm pulsation, i.e., the Pc6 pulsations at conjugate stations. The figure provides the continuous change of amplitude, thus the time track of the amplitude on every day basis of the Pc6 pulsation for a series of days. It is evident that as the changes in amplitude approach the storm day the relative time difference between the Pc6 mode of Maitri and Tromso for the maximum amplitude remain 180° (out of phase). Thereafter it starts settling to be in phase gradually. This behavior is quite interesting with this mode of pulsation. Conversely during quiet time of the magnetosphere the amplitude changes of the same mode of pulsation are found to behave with the very same manner at these two stations suggesting that the impact of the storm only has severely altered the position of the magnetic field lines as well as the auroral Electrojet by the excess rear end plasma flow into and out of that region (Region 1 and Region 2 currents) on storm days. Such disturbances normally intensify auroral Electrojet current at ionospheric heights (thus causing aurora), simultaneously expands and shifts the auroral oval towards the equator (Girija et al., 2002) and it often locates itself over Maitri during substorm. During increased solar wind speeds the magnetosphere encounters gradual build up of solar wind pressure counteracting terrestrial magnetic pressure on the dayside while IMF is northward. The balance between these two forces often fails when a sudden southward IMF makes a reconnection with the dayside magnetosphere causing a magnetic storm. This implies that

[1] For interpretation of color in Figs. 1–5, the reader is referred to the web version of this article.

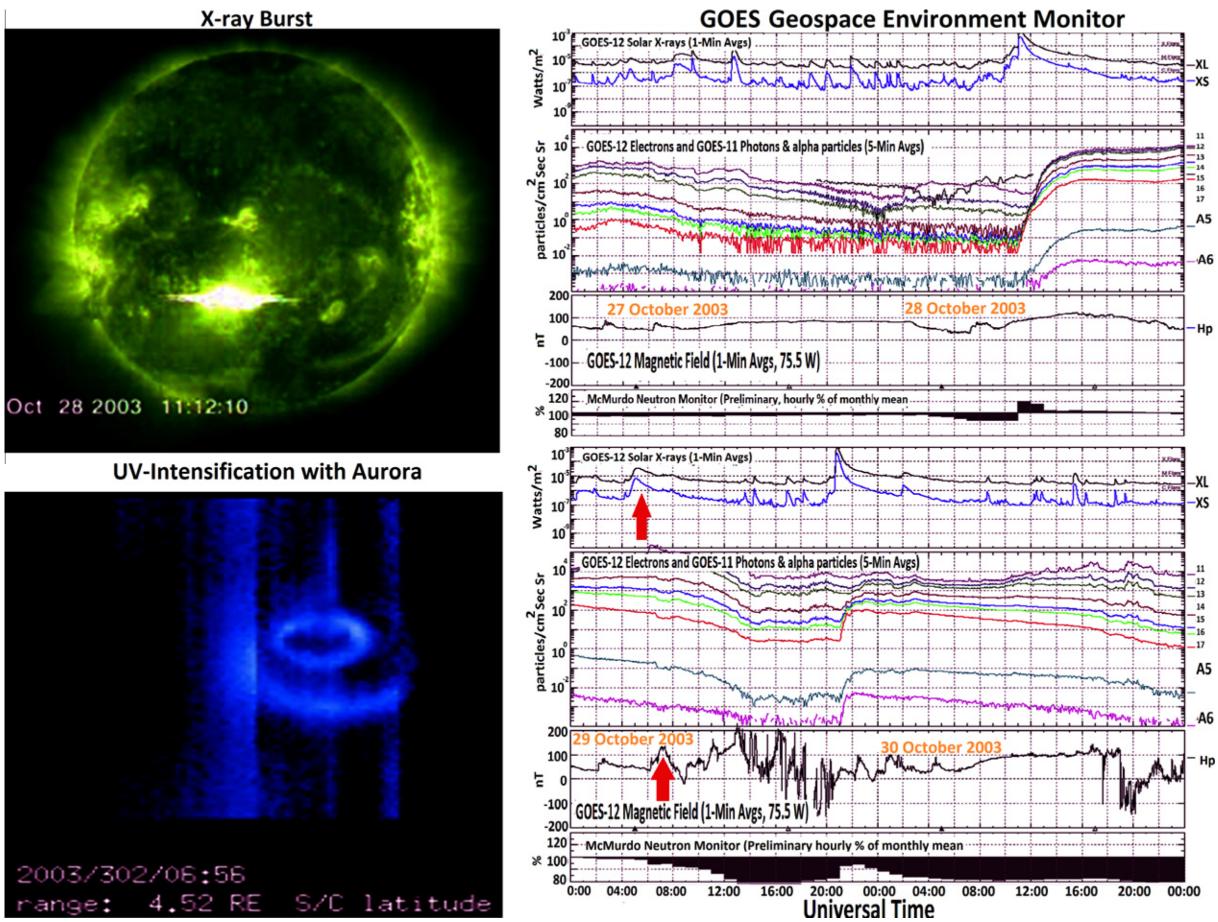

Fig. 3. The storm time intensification of aurora, solar Coronal Mass Emission and its solar wind physical conditions.

although the storms appear to be a sudden event, perhaps the force buildup by increased solar wind conditions remain gradual in its strength at magnetopause levels due to the CME accelerations (Gopalswamy et al., 2000, 2005a) in the presence of fast moving solar wind. This happens because of the increased solar wind speed due to CME associated shock continually exerting the force on the terrestrial magnetosphere during daytime. Further, the magnetic fields frozen in solar wind those are not effective in making reconnection with the terrestrial magnetic field, i.e., when IMF is northward can influence the Earth bound ionospheric electric currents by induction before penetration since the interplanetary magnetic field flux continuously undergo temporal changes. As a matter of fact the solar wind flow and its dynamic changes are continuously present and it would possibly have its effect on magnetosphere and ionosphere. The coupling becomes more effective especially when increasing magnetic fields are associated to solar wind plasma. Fortunately, this seems to largely differ at two different hemispheres especially at conjugate stations during geomagnetic storms. Hence, the precursors of storm occurrence can be identified with the network of ground based magnetometer data connecting conjugate stations and a few such evidences have been presented in this paper. The dynamical equilibrium between the interplanetary magnetic field pressure (associated to the solar wind) and terrestrial magnetospheric pressure ought to be a slow and a continuous process but sudden changes are due to the reconnection process. Hence, it becomes obvious that the signature of any magnetic storm can be identified with individual Fourier amplitudes of the Earth's magnetic field. Fourier amplitudes is obtained from a series of days interweaved with the storm day recorded at conjugate locations. Further the storms seem to generate signatures in terms of perturbed magnetic field with their asymmetric phase of magnetic field line oscillations at the opposite hemispheres. In other words the magnetic field components recorded at conjugate points implicitly depict the excitation of pulsations with the relative phase differences ahead of a well-defined storm occurs, perhaps, soon as the shockwave encounters the magnetopause, as it is very obvious from Fig. 4. On contrary to this, the magnetic field components recorded during a quiet time magnetospheric conditions (e.g. 15th November 2004, average $K_P = 2$) at respective conjugate stations reveal that there are no such differences (red pointers in Fig. 5).

Fig. 5 presents the harmonic analysis of horizontal component measured during quiet day at conjugate stations showing near identical behavior of Pc6 pulsation ampli-

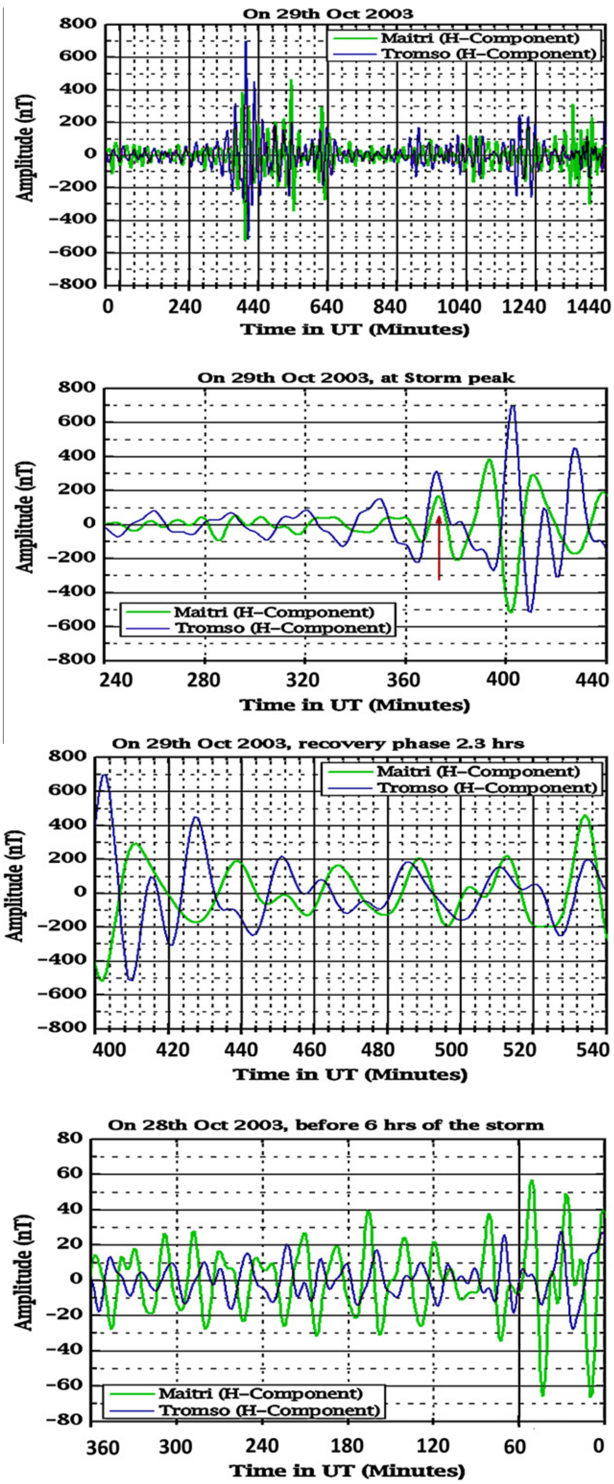

Fig. 4. Storm time behavior of PC6 (substorm) pulsation mode at conjugate locations prior, during and after an intense magnetic storm.

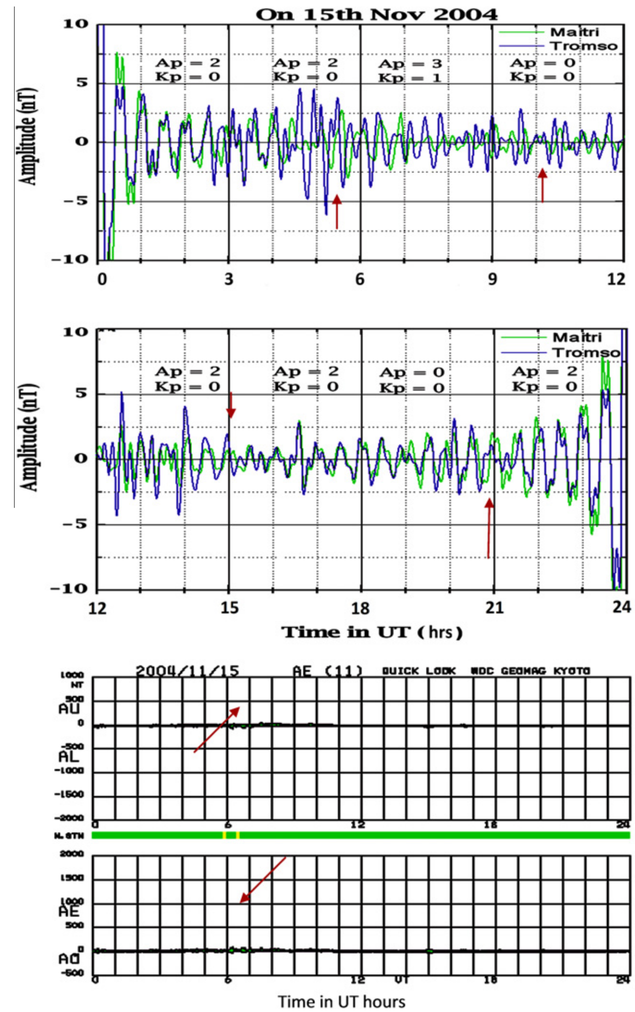

Fig. 5. PC6 (substorm) pulsation behavior during quiet time of the magnetosphere.

tudes. The small differences between the momentary phases could have been due to the short time negligible disturbances taking place on the quiet day for a brief time. The time and the duration of such disagreements in phases on quiet day is understood, since, the auroral indices also have shown an exceptional agreement with the time and duration of such disturbances which is shown in Fig. 5, with the red pointers. Hence, it is to be emphasized that the ground based observations at conjugate locations can reveal even a slightest disturbance caused to the magnetosphere corresponding to a storm time IMF, which influence quiet time magnetospheric currents. Hence, the penetration of electric fields from the magnetosphere to the ionospheric heights causing the electric currents to change thus the magnetic field changes on ground. Such changes corresponding to conjugate locations are found to be most sensitive for the ground based records at high latitudes. Thus simultaneity in amplitude of real time magnetic records at conjugate locations seems to have a remarkable potential for providing a storm alert to any kind of services that on the Earth which are affected by the magnetic storm/shock arrivals.

4. Conclusion

The ground based records of Earth's magnetic field components during storm time reveal that the CME induced shock waves and magnetic field frozen in solar wind generate field line resonances and reconnection process causing magnetic storm. Thus the magnetic storm to the Earth's magnetosphere and its magnetic field line resonances are of integrated effect that a ground based magnetometer would record during a magnetic storm. Nevertheless, the analysis have revealed that the field line resonances are more prominent over auroral latitudes since field lines converge and remain in situ to the ground observer over such places whereas at low and mid latitudes the field line resonances remain much weaker to a ground observer due to its far field relationship. Moreover intervening currents in the ionosphere such as S_q and Equatorial Electrojet would shield such resonances, at low and middle latitudes. The ground based magnetic records at middle and low latitude largely demonstrate that the changes are corresponding to the Equatorial S_q as well as ring currents.

The Fourier amplitude of ground magnetic record obtained from the stations used in this study reveals that the substorm pulsation Pc6 modes were the most dominant components with its dramatic changes along the magnetic meridian. Further the substorm Pc6 mode of pulsation shows distinct phase progression between conjugate stations. The near conjugate stations viz., Maitri and Tromso as well as low and middle latitude stations record on magnetic field components during a couple of intense storm events ($D_{st} < -400$ nT, and $D_{st} < -175$ nT) seem to signify such relationship. However, the amplitudes and its pulsations at these two stations during magnetically quiet time are in exceptional agreement with each other whereas during storm time it indeed has shown characteristically a different behavior. The analyses on the behavior of Pc6 pulsation during storm time is shown to improve our understanding about the storm arrivals. Thus arrival of geomagnetic storms associated with the solar burst and its "frozen in" magnetic fields causing disturbance fields on substorm time scales to the Earth has been presented in detail. The study stipulates to have a co-ordinated pair of ground based magnetic field observations on a continuous mode at conjugate stations for understanding storm arrivals on a real time basis. Hence, it is also recommended to have a chain of magnetometers in the line of magnetic Meridian along the Indian magnetic longitude connecting conjugate stations to reveal more details.

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