ATMOSPHERIC SCIENCE

Twenty Second Indian Expedition to Antarctica, Scientific Report, 2008
Ministry of Earth Sciences, Technical Publication No. 20, pp 39-52

Geomagnetic and RIOmeter Observations at Maitri during 22nd Expedition

Arun Hanchinal, Ajay Dhar, Anand K. Singh and B.M.Pathan
Indian Institute of Geomagnetism, New Panvel, Navi Mumbai - 400 218

INTRODUCTION

Indian Institute of Geomagnetism has been the part of Indian Antarctic Expedition programme since from the First expedition (1981-82). Earlier geomagnetic observations at Dakshin Gangotri - Maitri were short time measurements. Through out the year measurements started only in 1986. Since then we have fairly good continues analog and digital Data. The analysis of geomagnetic data has proved that Maitri occupy sub-auroral position during quiet times, with increasing disturbance, the auroral oval expand and Maitri begins to experience auroral electrojet (AE) and field-aligned currents (FAC) (Hanchinal et al.1996), this is an ideal condition to study "Storm and Sub-stoitn relations". It has been observed that being just sub-auroral location, Maitri is very sensitive to the electromagnetic changes in the geo-environment. Now Proton Precision Magnetometer (PPM) and 30 MHz Radio Ionosperic Opaque meter (RIOmeter) are also operated at Maitri to monitor total field F and cosmic radio noise absoiption throughout the year. RIOmeter measures the degree of ionization in D region ionosphere. Observations of the three components of geomagnetic field H, D, Z and the 30 MHz cosmic radio noise signal recorded by RIOmeter will provide greater understanding of magnetosphere and ionosphere coupling.

New digital fluxgate magnetometer (Model FGE version K, of DMI Denmark shown in Fig.l) is installed at Indian Antarctic Station Maitri in March 2003 first time. The sensors are supplied with compensation coils wound on quartz tubes in order to obtain a sensor drift of less than a few nT per year and a temperature coefficient of 0.25/°C or less. This makes the magnetometer very well suited for Maitri.Measurements on EDA Fluxgate FM-100B were also continued . Combined with H, D, Z components PPM observations for Total field (F) and 30 MHz RIOmeter observations for cosmic wave absorption have made Maitri an excellent Geomagnetic observatory at par with other developed countries.

Figure 2 shows the 6 hourly Dst index variations for the year 2003 from WDC, Kyoto. There are about 60 storms occurred between 1st Jan 2003 and 31st Dec 2003. Outstanding Solar Energetic Particle Events (SEP)

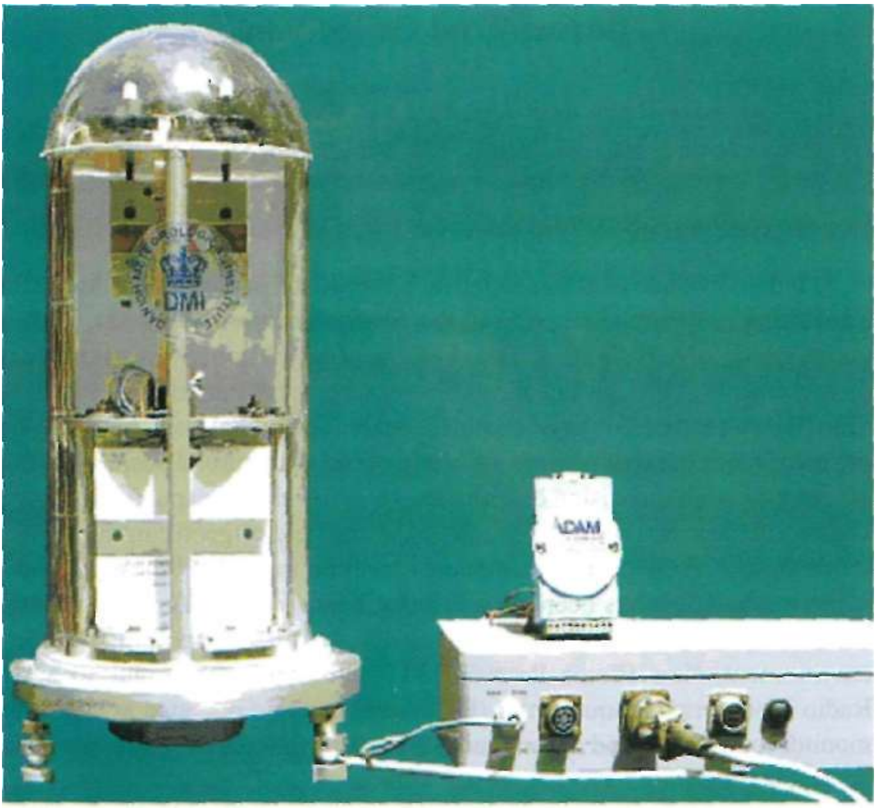


Fig.1: New digital fluxgate magnetometer(Model FGE version K)

associated with flare and Coronal Mass Ejection (CME) eruptions observed during solar cycle 23. A series of powerful solar flares and CMEs erupted from the Sun during October- November 2003 produced intense magnetic storms during this period. Anomalous solar wind parameters like solar wind velocities of up to 2000 km/s and Bz of -60 nT stimulated the development of the strongest magnetic storms, during which the AE index reached 4000 nT and the Dst variation was -400 nT. Three strong geomagnetic storms were observed in this period, two during Oct.29-31,2003 in quick succession and third during Nov. 20-21, 2003.

The Total Solar Eclipse (TSE) on November 23-24,2003 in Antarctica was observed by many scientists and amateurs. The first author is one of the few to observe the TSE at Maitri. About 120 people from different part of the world gathered to witness the very rare event on Antarctic continent

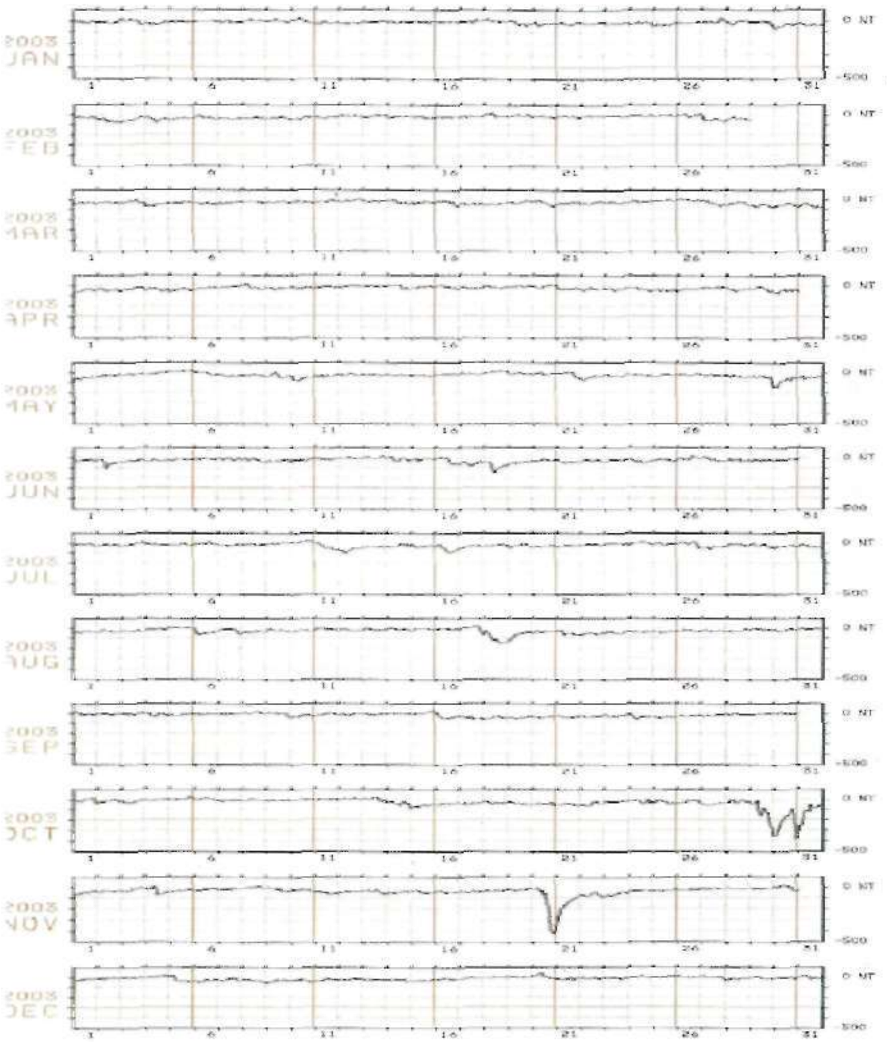


Fig.2: Six hourly Dst variations for the year 2003 from WDC, Kyoto

very near to Maitri in the temperature of -25°C. Maitri and Russian station Novolazarevskaya observed Total eclipse.

In this report we have made qualitative assessment of how the geomagnetic field variations as measured on the ground respond to the changing solar wind conditions, during October-November storm events and Geomagnetic and Riometer changes observed during the Solar Eclipse.

Storm Events of October - November, 2003

INTRODUCTION

IMF wind parameters like Bz, wind velocity (V), ion density (N), ion pressure (P) etc. greatly influence the geomagnetic surface variations at auroral stations. Though Maitri qualifies as mid-latitude station by virtue of its location during geomagnetic quiet conditions, with increasing geomagnetic activity the auroral oval expands and Maitri comes under the influence of Auroral Electrojet (AE) currents and Field Aligned Current (FAC) (Kalra et al., 1995). When the interplanetary field turns southward (-Bz) the rate of energy entering the magnetosphere increases. Some of the energy dissipates directly in to the ionosphere and some will be stored in the tail. That stored energy some time later could suddenly be dumped into mid-night sector ionosphere where it causes the sub-storm expansive phase. The energy that gets in directly deposited in ionosphere will contribute to increase directly driven electrojet currents (the east-ward electrojet (EAE) across dusk and west-ward electrojet (WAE) across dawn sector.in the auroral region The WIND IMF data is downloaded from the site http://lepmfi.gsfc.nasa.gov/mfi/laura/mfi-wplt.html.

The correlative study between IMF data and occurrence of sub-storm showed that possibility of sub-storm occurrence frequency increase as the southward IMF component increases, although substorms are not entirely absent during intervals of northward IMF (Kamide et al.,1977). When Bz turns substantially negative, the equatorial Dst attains large negative values, indicating a sharp but mostly smooth decrease in geomagnetic field (storm main phase). When negative Bz ends, the storm main phase is over, but the recovery of the geomagnetic field is not immediate. It is no more dependent on solar wind but is guided by the dissipation process of the ring-current particles in the terrestrial ionosphere and thermosphere. The Dst recovery is exponential, first fast, later slower. In contrast, Nishida (1971) showed that in the polar regions, DP2 type variations were closely associated with the southward turning of interplanetary Bz and showed short-lived oscillations of about an hour.

OBSERVATIONS

Figure 3 shows the plots of B (Magnitude of IMF Magnetic Field), Bz (Z component of solar wind), V (Magnitude of solar wind velocity), Np (IMF proton number density) and P (solar wind ram pressure) (all 1 min values downloaded from NASA site). H, D, Z are three components of geomagnetic field variations at Maitri (1 min). RIO is the riometer observation (1 min) **from** 29 **Oct** 2003,0000 UT to 31 Oct 2003,2359 UT. At the bottom are shown plot of hourly values of AE and Dst index. All these parameters are stacked together in one figure for easy comparison.

From Dst variations it is clear that three storms occurred from October 29 to 31. The first storm began at 0615 UT on 29 Oct, **the** minimal Dst values of -180, -363 and -401 nT were observed at 1000 UT on **Oct** 29 and at 0100 and 2300 UT on October 30 respectively. These Dst variations show that the second and third storms appeared against the background of the main phase of the first storm.

On 29 October at 0615 UT Bz suddenly turned southward, resulting in sudden changes in ground H, D and Z components. H registered sudden decrease, at 0649 UT reached maximum decrease of -3574 nT, signifying very strong directly driven westward electrojet. Sharp increase in D reaching maximum 2470 around same time as H indicate strong inward Field Aligned Current (FAC). Rapid decrease of Z to -1389 and reaching very high **+ve** values (1029) showed rapid intensification of westword electrojet and its subsequent movement towards lower latitudes. The geomagnetic activity continued unabated, at around 2000 UT for short period again the Bz turned -ve, the velocity continued more than 2000 kms/sec, H and D showed pronounced decrease and increase respectively. Corresponding decrease of Z showed movement of auroral oval down northward. Correspondingly, AE shows sudden increase between 06 UT and 07 UT reaching to 4000 nT. **Till** 30 0200 UT it remained high around 2000 nT. Showed another peak between 20 UT and 21 UT on 29 (4000 nT). Dst also start falling when AE reached maximum between 06 and 07 UT and reach first minima at (-180) AT 1000 UT and second minima at 0100 UT on 30 (-363) and start recovering at the same time AE decreases to pre storm conditions. Showing clear correlation between AE and Dst. Wind velocity crossed more than 1500 km/sec. No much change in the proton density and Pressure observed. Riometer also did not show any absorption event.

On the background of the main phase of the STORM 1, the second storm appeared (say STORM2) at 1600 UT on 30th, which is evident from

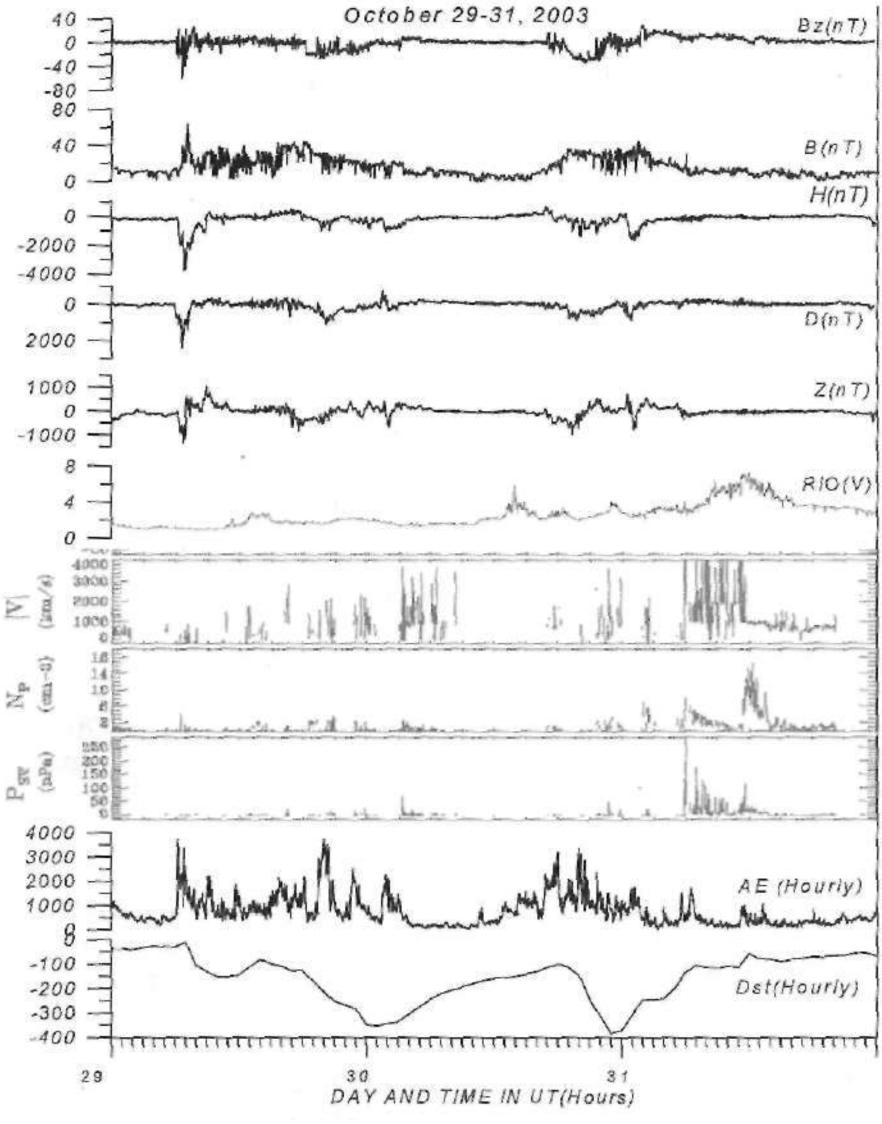
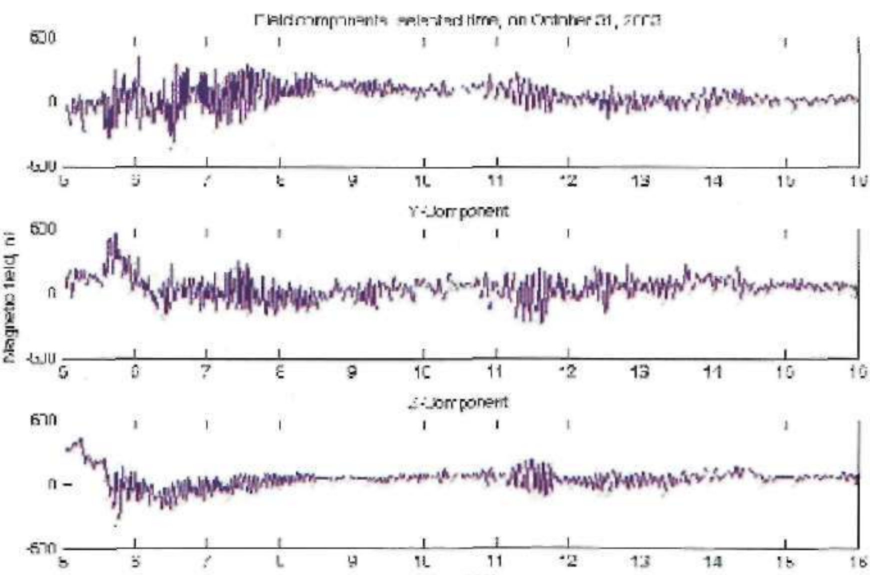


Fig. 3: Stack plots ofB (Magnitude of solar wind Magnetic Field),Bz (Z component of IMF), V (Magnitude of solar wind velocity), Np (solar wind proton number density) and P(solar wind ram pressure) (all 1 min values downloaded from NASA site). H, D, Z are three components of geomagnetic field variations at Maitri(l min). RIO is the riometer observation!I min) from 29 Oct 2003, 0000 VT to 31 Oct 2003, 2359 VT. At the bottom are shown plots hourly values ofAE and Dst index

the Dst. B started increasing and Bz turned -ve around 1700 UT. Simultaneously H showed decrease of about 2000 nT, D showed increase of about 1000 nT, Z also showed brief decrease and increase. AE started to increase gradually much before i.e. at 1000 UT showed two peaks in the vicinity of starting point of this storm then gradually decreased. Riometer showed an absorption during this period. At 0600 UT on 31 RIO showed pronounced increase, simultaneous increase was seen in velocity, density and pressure. Velocity reached saturation, density showed a peak at Rio peak, also pressure showed increase. During this absorption event no long period deviations were seen in geomagnetic components. Careful observations revealed fine micro pulsations during this period. The power spectral analysis of the H, D and Z components shows peaks at 4.88 mHz, 83.01 **mHz and** 92.77 mHz. Fig. 4(a) is the highlighted part of the magnetogram (between 05 UT and 16 UT) on which the spectral analysis was carried out. Fig. 4(b) is the amplitude spectra on log scale. This suggest the direct particle penetration through cusp and precipitation near earth environment, arising because of increase in wind density and velocity. Starting



Fig, 4(a): Highlighted part of the magnetogram (between 05 UT and 16 UT) on which the spectral analysis was carried out

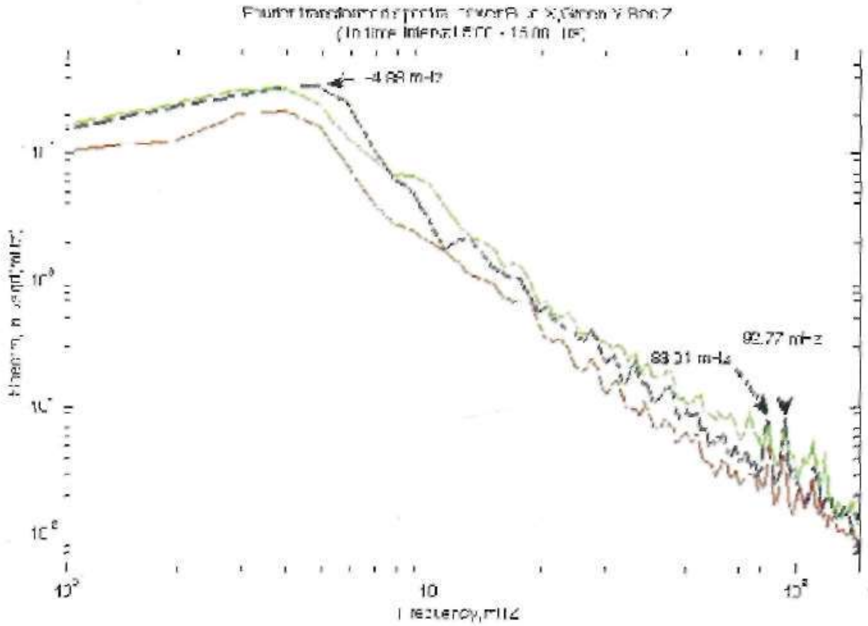


Fig. 4(b): Amplitude spectra on log scale.(H,D,Z data between 05 UT and 16 UT on 31 Oct, 2003)

if io 13=
i lEsifrcy.rlU

F/g. 4(6J: *Amplitude spectra on log scale. (H,D,Z data between 05 UT and 16 UT on 31 Oct, 2003)*

from 1800 UT onwards sharp and steady southward Bz persists for almost 6 hours leading to an intense geomagnetic storm occurrence with peak intensity of 400 nT in Dst at 2400 UT. A slow recovery of the storm followed when a steady turning of the Bz field occurred. The main phase of the 30 October magnetic storm started rather sharply at 1800 UT when the Bz turned southwards and increased to-32 nT and produced 400 nT. Abrupt turning of the Bz to northward direction around 2100 UT resulted in the beginning of recovery.

Fig. 5 is again plot similar to Fig. 3, showing the comparison of H,D,Z variation to solar wind parameters for the storm observed between November 20 and 22. This storm is characterized by classic Dst variations, when the main phase and recovery phase, with a deep Dst minimum of -465 nT at 2000UT on Nov 20. AE showed gradual strenghening of electrojet during initial and main phase of the storm and gradual weakning during recovery phase.

It appears this event is triggered because of sudden northward turning of Bz (Rostoker, 1983 has observed many events of expansive phase intensification of the kind reported above during northward turning of IMF)

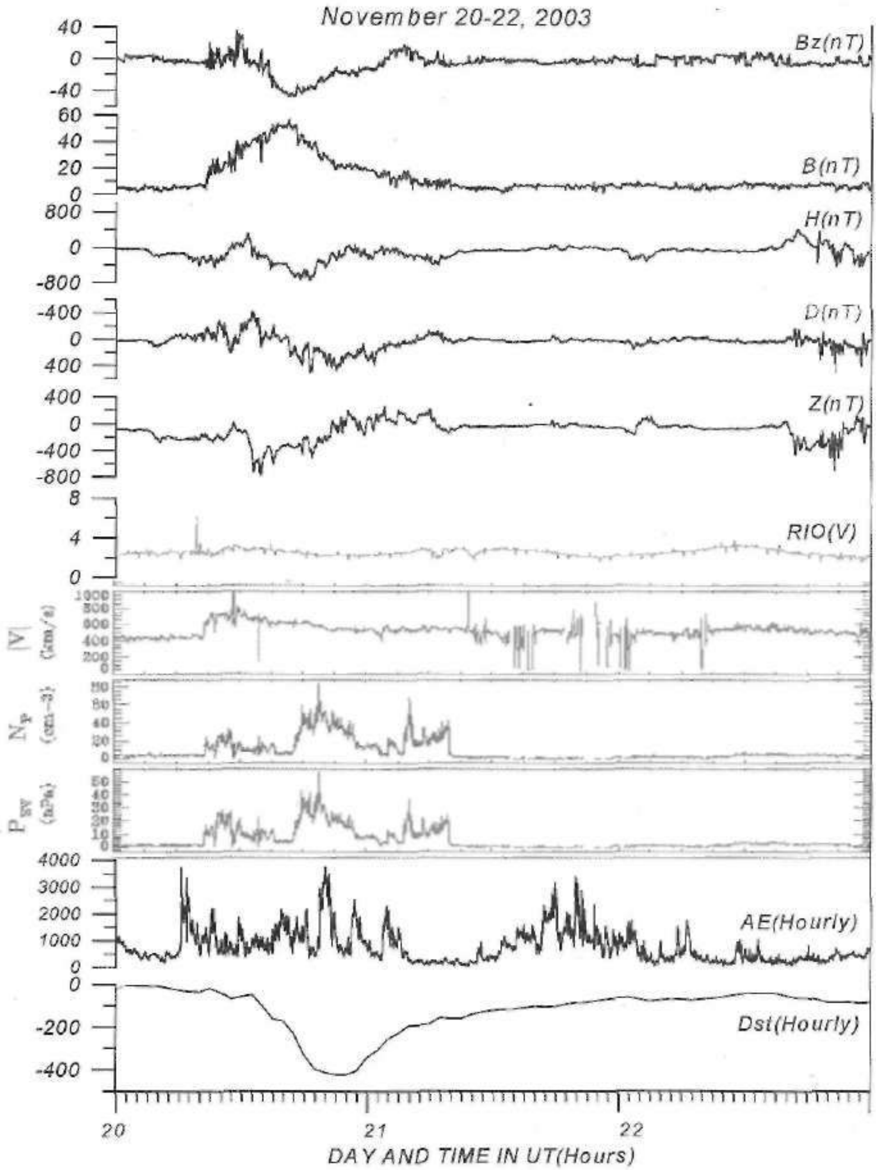


Fig. 5: Stack plot similar to Fig.3, from 20 Nov 2003, 0000 UT to 22 Nov 2003

at 0800 UT on Nov.20, gradually attaining maximum at 1130 UT Bz turned -ve. At the onset H showed +ve increase, with Bz turning negative H also turned negative at 1700 UT. At the recovery of Bz from -ve H also started recovering towards +ve. D showed initial -i-ve and -ve and at -ve turning of Bz D started towards -i-ve. Z- component rapidly built up to negative values 300 nT indicating quick building up of westward electrojet and its subsequent movement towards equator overhead 'Maitri' and returning back to pre storm condition. Velocity increased to 800 kms/sec, density and pressure showed marked increase throughout the event. Riometer records did not show any significant absorption (precipitation) during the event.

At 1300 UT Bz turned southward and attained large values nearly -50 nT for several hours. This lead Dst to reach -465nT. The recovery started with sharp turning of Bz to northward at 1800 UT.

Geomagnetic and RIOmeter Signature of Total Solar Eclipse (TSE)

Solar eclipse may cause changes in geomagnetic effects by disturbing the flow of the electric currents in the ionosphere. Moving shadow of moon temporarily create night like condition over short period of time. The blockage of sun rays reduce the ionization process in the ionosphere and we can expect reduction in radio noise absorption and also reduction in H component of geomagnetic field for that duration.

A total solar eclipse occurred at Maitri between 23 Nov 2003, 2229 UT and 24 Nov 24 0005 UT, totality was at 2317 UT. Fig.6 shows the path of total solar eclipse that crossed the Antarctic continent. Fig.7 is the picture of the eclipse during totality, elevation was 2° at the time of eclipse. We are presenting first hand account of changes observed in geomagnetic and riometer observations during this eclipse time.

Fig. 8 shows the plot of geomagnetic H, D and Z components and Riometer between 2130 on Nov 23 and 0030 on Nov 24, marked are Beginning (B), Total Eclipse (TE) and End (E) of eclipse.

The three hourly kp for eclipse duration was 4+, it was mildly disturbed time. The eclipse began at 2229 UT, at the same time H, D and Z also show depression setting in, At 2342 a mild geomagnetic event occurred and further effect was overshadowed by the event. A clear depression during eclipse time is seen in all three components with overlapping of mild storm time variations, Riometer readings also show decrease in the absorption pattern with onset of eclipse, reaching maximum decrease at totality.

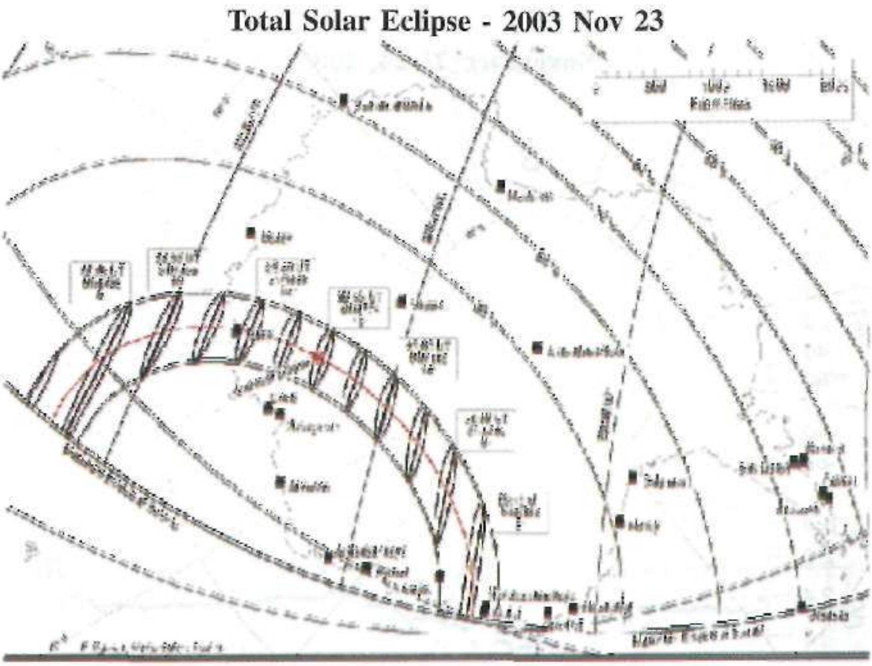


Fig. 6: Picture showing the path of eclipse on Antarctic continent

Fig. 7: Eclipse picture during totality

Maitri
November 23-24, 2003

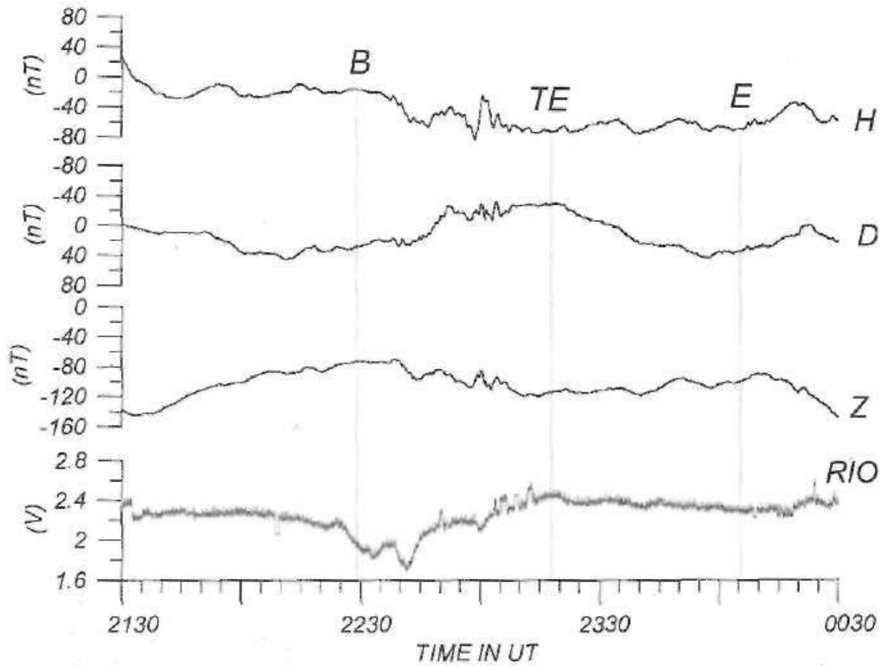


Fig. 8: Stack plot of geomagnetic H, D and Z components and Riometer between 2130 on Nov 23 and 0030 on Nov 24, marked are Beginning(B), Total Eclipse (TE) and End (E) of eclipse

The RIOmeter readings are compared with two Australian stations Casey, Davis and South African station SANAE IV for eclipse time variations. Fig. 9 shows similar kind of variation for these stations, confirming the decrease in the absorption shown is clearly the effect of the eclipse. Further investigation will be carried out, for quantitative study.

CONCLUSIONS

1. The intensity of the storm is controlled mainly by the magnitude of the peak of the southward component of the IMF Bz and its duration rather than the Solar wind velocity. That is why large southward Solar Wind lasting for larger time gave rise to more intense magnetic storm on 20 November 2003 despite the low Solar wind velocity.

RIOMETER
November 23-24, 2003

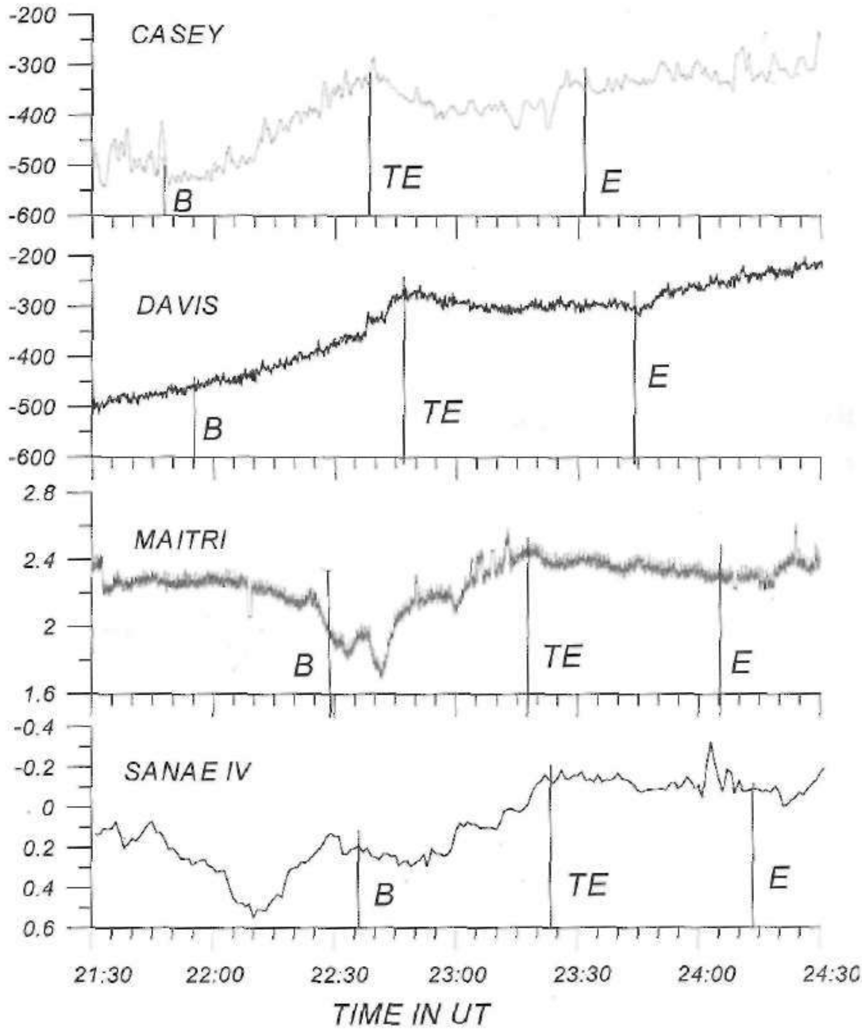


Fig. 9: Comparison of Maitri Eclipse time riometer variations with Australian stations Casey, Davis and South African station SANAE IV

2. Possible geomagnetic signature of Total Solar Eclipse was seen in all three components of geomagnetic field.
3. Riometer showed a clear reduction in the ionospheric radio absorption during the eclipse.

ACKNOWLEDGEMENTS

We are thankful to the then Directror, Indian Institute of Geomgnetism Prof. G.S.Lakhina for all his support and deputing the first author to Maitri, Antractica. We are thankful to the National Centre for Antarctic and Ocean Research (NCAOR) and Department of Ocean Development (DOD) for providing all logistic support for carrying out the experiment. We acknowledge NASA/GSFC and CDAWEB for providing data on IMF and Solar wind parameters. We also acknowledge Australian Antarctic Division and South African National Antarctic Programme (SANAP) for providing the geomagnetic and RIOmeter data from Australian Antarctic stations and SANAE IV Antarctic station respectively. Also we are grateful to all the members of 22nd Indian Antarctic Expedition for providing all the help in collecting the data.

REFERENCES

1. Response of Geomagnetic Field at Indian Antarctic station, Maitri to Increasing Electromagnetic disturbance in Geospace A N Hanchinal, K Jeeva, Ajay Dhar and Girija Rajaram (In Scientific Report of Twelfth Indian Expedition to Antarctica, Technical Publication No. 10 (1996). Dept. of Ocean Development, New Delhi, 47-57
2. Changes in Auroral Electrojet currents Inferred from Geomagnetic Field variations at Maitri and Northern Conjugate stations.Rajesh Kalra, Ajay Dhar, K Unnikrishnan, K Jeeva, D M Daga and Girija Rajaram. (In Scientific Report of Eleventh Indian Expedition to Antarctica, Technical Publication No. 9 (1995), Dept. of Ocean Development, New Delhi, 87-101
3. Dependence of substorm occurrence probability on the interplanetary Magnetic Field and on the size of the Auroral oval Kamide Y., Perrault P.D., Akasofu S.I., Winningham J.D., *J. Geophys. Res.*, 82 (1977), 5521
4. DP2 and polar substorm, Nishida, *A.Planet. Space Set*, 19 (1971), 205-221
5. Triggering of expansive phase intensification of magnetospheric substorms by northward turnings of the interplanetary magnetic field. Rostoker G.J., *Geophys. Res.*, 88 (1983), 6981