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MAGNETOMETER/ RIOMETER CHANGES OVER INDIAN ANTARCTIC STATION MAITRI, AS A POINTER TO DISTURBANCES IN SPACE

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ABSTRACT

It is observed that the just sub-auroral Indian Antarctic station Maitri (geom. $62^0.8$S, $52^0.8$E) is very sensitive to the electromagnetic changes in the geoenvironment. Observations of the three components of the geomagnetic field X, Y, Z and the 30 MHz cosmic radio noise signal recorded by Riometer (RIO) at Maitri can provide clues to the state of Space Weather, and for that matter the state of Interplanetary space. Maitri data of X, Y, Z and RIO during Jan-Feb 1999 are used to highlight this aspect.

1. INTRODUCTION

"Geospace Weather" can be defined as the electromagnetic state of the Earth's space environment. This encompasses the electric and magnetic fields, the particle populations and their distributions in the entire ionosphere-magnetosphere system. Earliest recognition of Space Weather can be traced back amongst others to Gilbert (1600) for realising that the Earth's magnetic field extends into Space all around in 3 dimensional form, Graham (1724) and Celsius (and Hiorter) (1741) for noticing oscillations in compass needles and in ammeters during auroral displays and de Mairan (1754) for postulating that auroral and geomagnetic storms are caused by the entry of charged particles of solar origin into the geoenvironment.

The first instruments to detect disturbances in the Earth's environment were ground-based magnetometers (Harang, 1946; Silsbee and Vestine, 1942; Obayashi and Hakura, 1960) and ionospheric sounders (Appleton and Piggott, 1952). These could be easily operated at various latitudes of Earth, and it was understood quite early that the high latitudes were in a state of perpetual disturbance. The Riometer was found to be particularly useful in sensing these high-latitude disturbances (Little and Leinbach, 1959), while the VLF receiver technique of sensing these was realised at about the same time (Helliwell and Gehrels. 1958). Many techniques, both ground-based and satellite-based, have been developed for sensing geospace disturbance either directly or indirectly (Hargreaves. 1992). Optical all-sky cameras operated from the ground and aboard aircraft and satellites, have rendered yeoman service (Akasofu. 1974). while the Riometer and magnetometer when operated together at high latitudes provide a great deal of insight into the physical processes at work in these regions (Ranta et al., 1999).

In the light of the foregoing, the subject of Geospace weather is by no means a new one. It is just that in the present age with its increasing dependence on solid state technological devices, the use of transpolar airflights to shorten distances, and the reality of Space travel in the years to come, the subject has taken on a special importance (Jansen et al., 2000). In this work we study the Riometer and Magnetometer variations at the just-sub-auroral Indian Antarctic station Maitri (geomag. lat. 62^0 8 S, long. 52°.8 E, L = 4.8) on selected days, and compare these with Kp values, and the interplanetary magnetic field (IMF) and solar wind values obtained by the WIND satellite on the same days. The results indicate that Maitri (MAI) is very sensitive to disturbance in Geospace, and hence forms a very suitable location for monitoring Space Weather.

2. OBSERVATIONS AND DISCUSSION

The results, which follow, will be presented in a very terse form to conform to the brevity required. :

2.1 Progression From Quiet to Disturbed Days

Fig.) to Fig.3 show MAI moving progressively from ∑Kp = 2o, to ∑Kp= 11o. The left hand side (LHS) of each figure shows the 30 MHz RIO, and the Y, X and Z variations followed by the 3 hrly Kp values for the day. The right hand side (RHS) of each figure shows the WIND satellite observations of the Interplanetary Magnetic Field parameters B (total field) and the components Bx, By, Bz, all in nT. For the sake of brevity, graphs of solar wind velocity and density variations are not presented, but the average values of the Vx component have been stated. It may be noted that for MAI, UT and MLT (Magnetic Local Time) differ only by 1 hr. 10 min.

Figure 1 is for 26 Feb 1999 with ∑Kp = 2o. The RIO, Y, X and Z curves are all | calm and smooth on this very Quiet day, and show the characteristic signatures of a ! sub-auroral station. The three hourly Kp index has actually remained at Oo for most part | of the day, except during 03-06 UT, and during 12-18 UT, when it takes up values of 0+ I and 1o, at which times the Y. X, and Z components register magnetic disturbance. The |

Bz component of the IMF turned clearly negative at precisely these times with values 0-10 nT; the remaining hours experienced clear positive Bz. Over the whole day solar wind speeds were only moderate ($Vx = 350 \pm 20$ km/sec.) The satellite was located in the midnight dawn sector, above the plane of the ecliptic.

Figure 2 is for 9 Feb 1999 with ∑Kp = 6o. Very smooth traces of RIO, Y, X and Z are seen on this day, with a slight suggestion of disturbance when 3 hrly Kp values are elevated above 0. The RHS of Fig.2 shows that Bz has taken on negative values during these periods of elevated Kp, although its magnitude is less than 5 nT. The Vx component of the solar wind is slightly higher in this case (380 ± 40 km/sec).

Figure 3 is for 25 Feb 1999 with ∑Kp = 11 o. Again RIO, Y, X and Z exhibit fairly calm traces, with a ripple of disturbance over the whole day, in keeping with the 3 hrly Kp index having values exceeding 1 for the most of the day. When the Kp value elevates to a value of 4 (03 - 06 UT), the MAI magnetograms show clear bays in all three components, Y, X and Z, and the RIO also shows Cosmic noise absorption. In this case, beyond doubt, Bz takes on prolonged negative values of 0-5 nT. Solar wind speeds are a modest 350 40 km/sec. The sharp event between 03-06 UT seems to have been triggered by a local instability in the nightside magnetotail.

We next consider in Fig.4 and Fig.5, two days of moderate magnetic disturbance.

Figure 4 is for 27 Jan 1999 with ∑Kp = 18 - 3 hrly Kp over the whole day has values exceeding 2o, and this reflects as a ripple of magnetic disturbance on Y, X and Z components. A clear RIO absorption event is seen over 03-06 UT when the 3 hrly Kp shoots up to 3o, and bays are seen on the magnetic variations. Bz has clear negative values (0 to 5 nT) over the whole day, and this accounts for the disturbed conditions seen over the day. Solar wind speeds however are rather low ($Vx = 360 \pm 20$ km/sec), and this possibly inhibited the occurrence of severe electromagnetic disturbance in geospace.

Figure 5 is for 24 Jan 1999 with ZKp = 25 - This is beyond doubt a disturbed day as far as the Y, X, and Z variations go. Clear bays are seen between 03-06 UT and between 18-21 UT and are accompanied by absorption events on the RIO. Bz assumes prolonged negative values exactly at these intervals (value 0 to -7 nT). In contrast to the earlier day 27 Jan 1999 (Fig.4), solar wind velocities are very high on this day ($Vx = 525 \pm 50$ km/sec) and this seems to have caused the very elevated values of the Kp index seen over the whole day.

2.2 Geomagnetic Storm Days

We now go on to examine the response of the RIO, Y, X, Z at MAI to geomagnetic storms.

Figure6(a,b,c)are for 13,14. 15Jan 1999with ∑Kpvalues of 31o,31-and27_ respectively. During this entire interval the WIND satellite is in the Dawn-Noon sector. below the ecliptic plane.

On 13 Jan 1999 (Fig.6 (a)), a storm sudden commencement (ssc) is recorded as having occurred at 10:45 UT (Geomagnetic Indices published by IUGG, Niemegk, Germany). This is clearly seen in the IMF B component exactly at that time but it is very surprising that the Y, X, Z variations at MAI remained calm till shortly after 16 UT, although 3 hrly Kp values started rising right from 09 UT onwards. Subauroral MAI has certainly moved into the auroral zone, experiencing enhanced eastward auroral electrojet (EAE) from 16-21 UT, and then later the enhanced westward auroral electrojet (WAE) with substorm characteristics. The shift in the position of the EAE and the WAE from poleward of MAI to equatorward of MAI can be inferred from the two sharp negative jumps seen in Z shortly after 19 UT and prior to 22 UT. While the Y component shows variations, there is no major absorption event on the RIO, except after 21 UT.

The steady rise in Kp from a value of 3o at 09 UT to 7o at e 21 - 24 UT. is very similar to the rise in the IMF B component from 5 nT to around 20 nT. Bz takes a sharp negative dip at 16 UT, remains southward till 23 UT and rises sharply to positive values at 23 UT - this almost suggests planet Earth to be within a magnetic cloud with a local negative Bz. It is to this negative Bz that the MAI magnetograms respond; strangely, no response is seen to the persistent and fairly large negative Bz (0 to -10 nT) seen over 11-13 UT but then solar wind velocities at this latter time had moderate values of 375 25 km/sec.

On 14 Jan 1999 (Fig.6 (b)), the Y, X, Z components show continuous magnetic disturbance over the whole day. The X trace shows a strong WAE (negative X) over the daytime hours (06 - 12 UT), and an EAE (positive X), persists from 14 UT right till midnight. The Z trace does not show any sharp jumps to indicate rapid changes in latitudinal position. Y would suggest the presence of field-aligned (fac) current at 08 - 12 UT and at 21 - 24 UT but the RIO however shows absorption due to particle precipitation only during the former time interval and not the latter. The Y changes over 21 -24 UT may therefore be associated with north-south current systems rather than with fac.

By 15 Jan 1999 (Fig.6(c)), all traces, RIO, Y, X and Z return to calm patterns after 07 UT. The earlier part of the day does however show disturbance, and the signature of an isolated substorm accompanies the increase in the 3 hourly Kp index to the value of 5 during 03 - 06 UT. Kp values are high over the whole day, and this is accompanied by a ripple of disturbance on the magnetograms at all hours. During the isolated substorm, the X trace shows the presence of a clear WAE, the Z trace shows changes indicating equatorward movement of the electrojet current, and a single positive spike in D is seen.

There is clear absorption in RIO during 03 - 07 UT. with periodic spikes suggesting quantas of energetic particle precipitation over the station.

The IMF B component too remains at values exceeding 5 nT over 00 - 06 LT levelling off to 5 nT for the rest of the day. The Bz has a large southward component over most of the day with values between 0 to -5 nT, and intermittent northward turnings. Solar wind speed over the whole day was very high (Vx = 560 ± 40 km/sec). This combination of negative Bz and high solar wind is no doubt responsible for the moderately high Kp values (3o and above) seen over the whole day. MAI registers this continued low disturbance in geospace and in interplanetary space, as a sustained ripple on the Y, X, Z components.

We have similar observations for another event at MAI, namely the storm of 18 Feb 1999 but this is not discussed here.

CONCLUSIONS

The foregoing observations suggest that the variations in the absorption pattern of RIO, and magnetic disturbance in the Y, X and Z components recorded at the just sub auroral location MAI reflect very sensitively the degree of disturbance in Geospace (as inferred from the 3 hrly Kp index), and in the Interplanetary Medium (as inferred from the variations in B, Bz and Vx).

Attempts to find a means of predicting conditions in Interplanetary space from the degree of magnetic disturbance seen on ground can be said to have commenced with Synder et al. (1963) when they related the daily sum Kp value to the velocity of the solar wind. This was followed by Wilcox etal (1967) when they related the 3 hrly Kp index to the intensity B of the IMF, and by Ballifet al. (1967) who pointed out that Kp was related to transverse fluctuations in the solar wind. Feldstein and Starkov (1967) related the size and shape of the auroral oval to value of the geomagnetic Q index. The purpose of this present work to point out that a just-sub-auroral station like MAI is a more suitable location than an auroral location for sensing Geospace and Interplanetary Weather, as its magnetic records change dramatically from calm, quiet patterns to disturbed ones, even for 3 hrly Kp values exceeding 2o. Clearly the Y, X and Z variations are related to disturbances in Geospace and in Interplanetary space.

The next step in this work would logically be the derivation of quantitative relationships between the disturbance variations in the Y, X and Z, and the variations in three hourly Kp, and in B, Bz, Vx and also the density of the solar wind. Once definite relationships are established, RIO and Y, X, Z patterns recorded at MAI can be used to predict Geospace Weather. The inclusion of an all-sky imager at MAI to supplement

RIO absorption and Y, X and Z magnetic variations would prove very useful indeed towards this goal, and steps are being taken for this.

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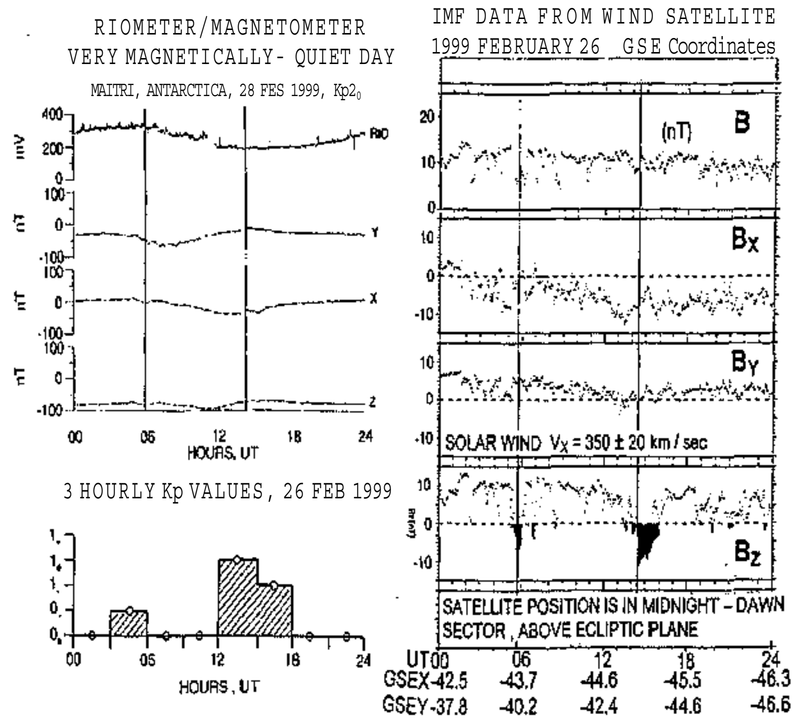

Fig. 1. Riometer and magnetometer (Y, X and Z) patterns tor Feb 26,1999. Kp values are shown below graphically, and Interplanetary Magnetic Field parameters (B_1 B_{x1} B_y and B_z) plotted on the right hand side.

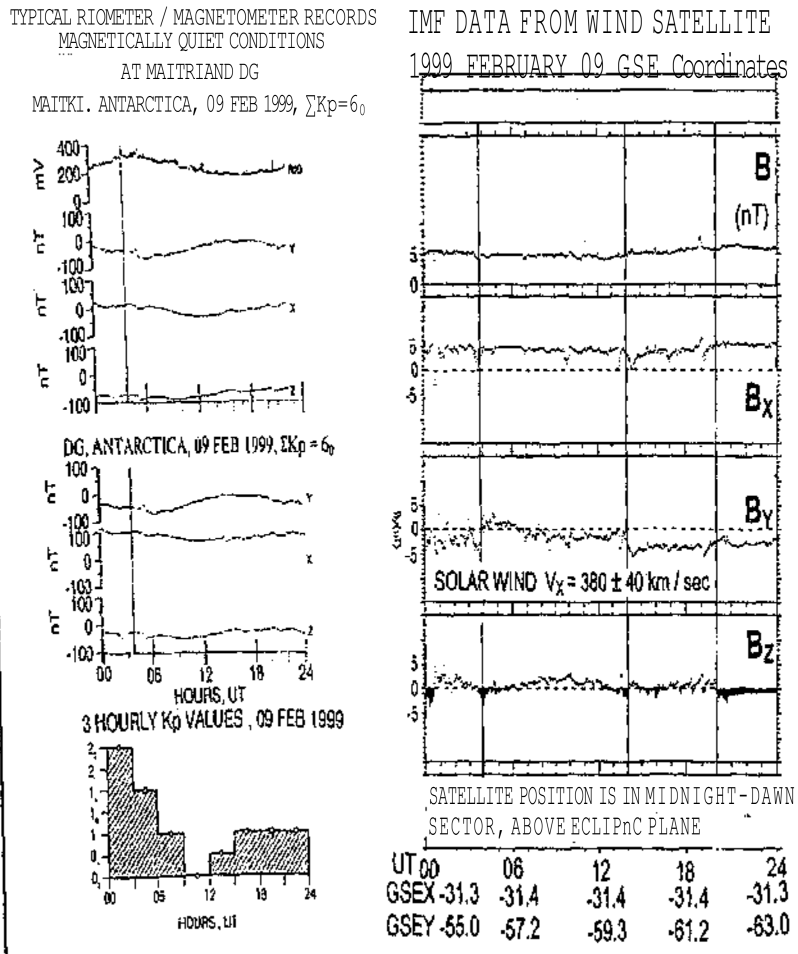

Fig. 2 Plots for Feb 9,1999. Figure format similar to figure 1, except that Dakshin Gangotri (DG) magnetograms are also shown.

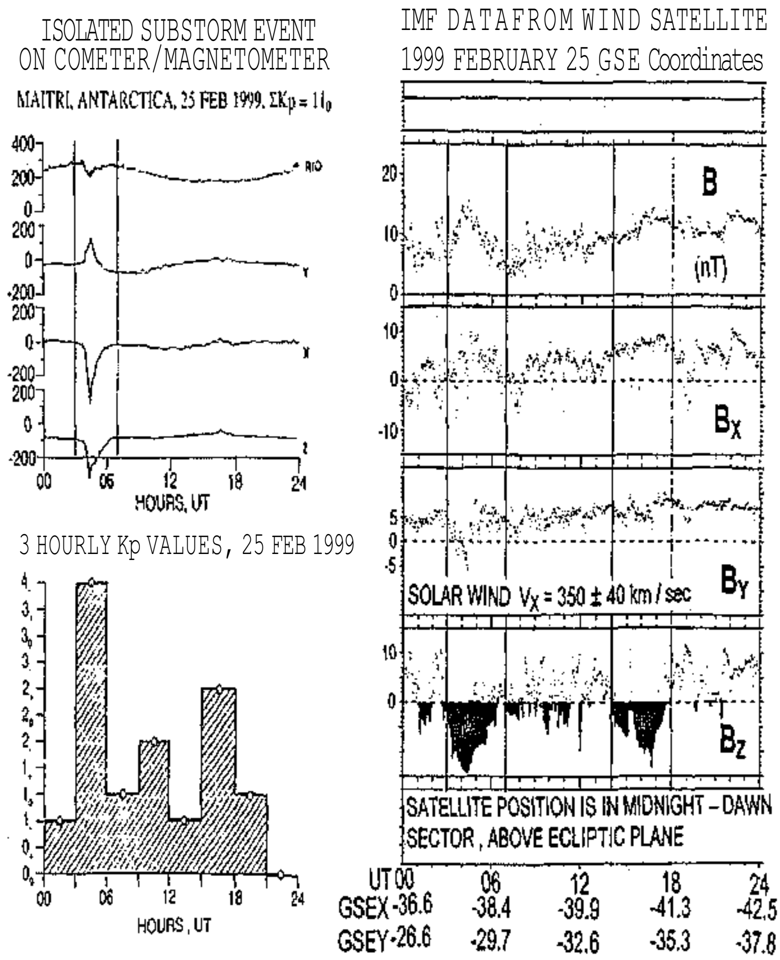

Fig.3. Plots for Feb 25,1999.Format similar to Figure 1.

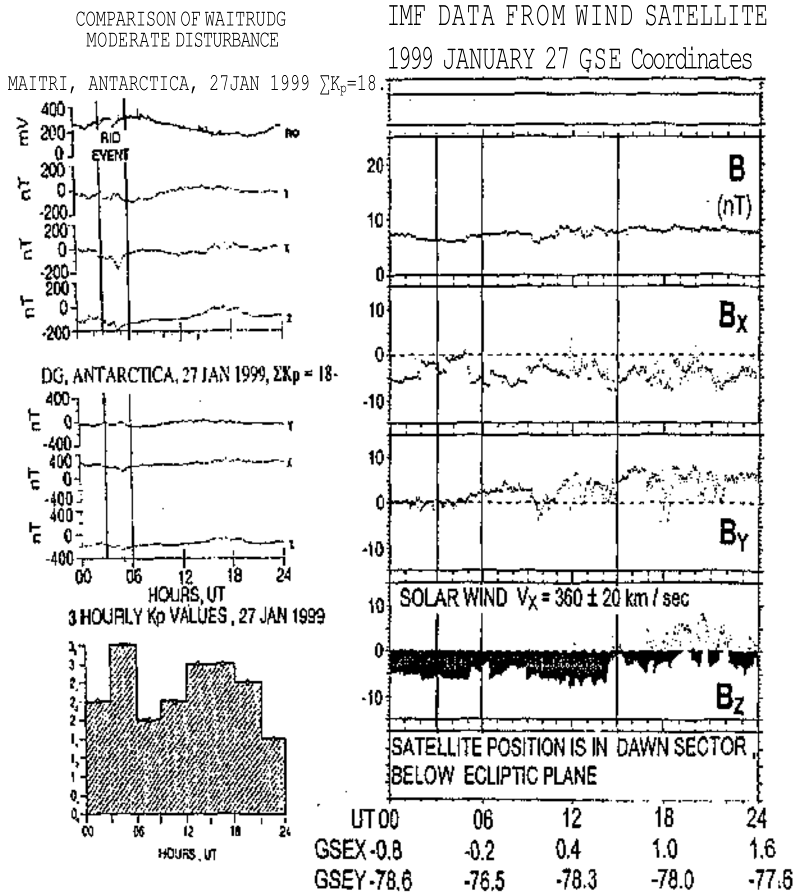

Fig. 4. Plots for Jan 27,1999. Format similar to figure 2.

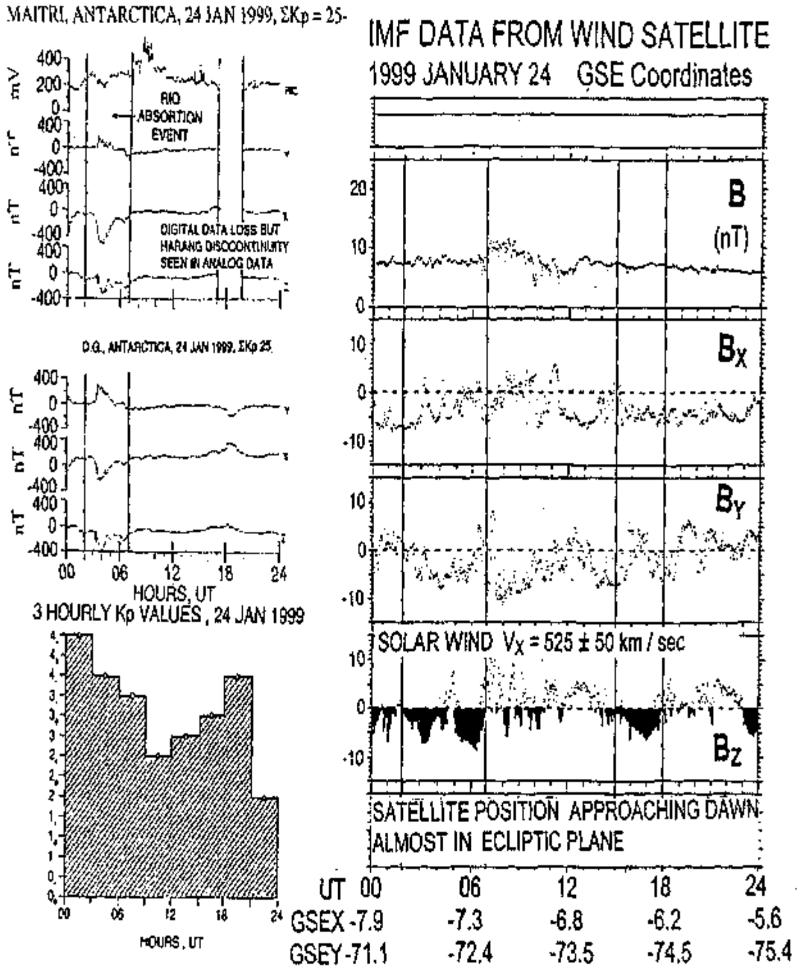

Fig. 5. Plots for Jan 24, 1999. Format similar to figure 2.

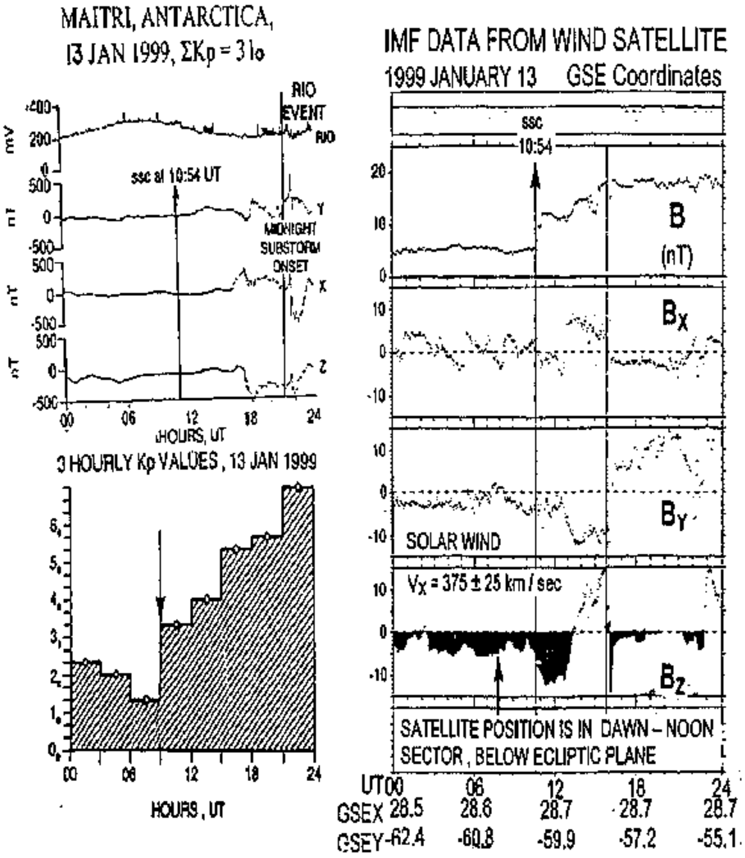

Fig. 6(a). Plots for storm day Jan 13,1999, Format similar to figure 1,

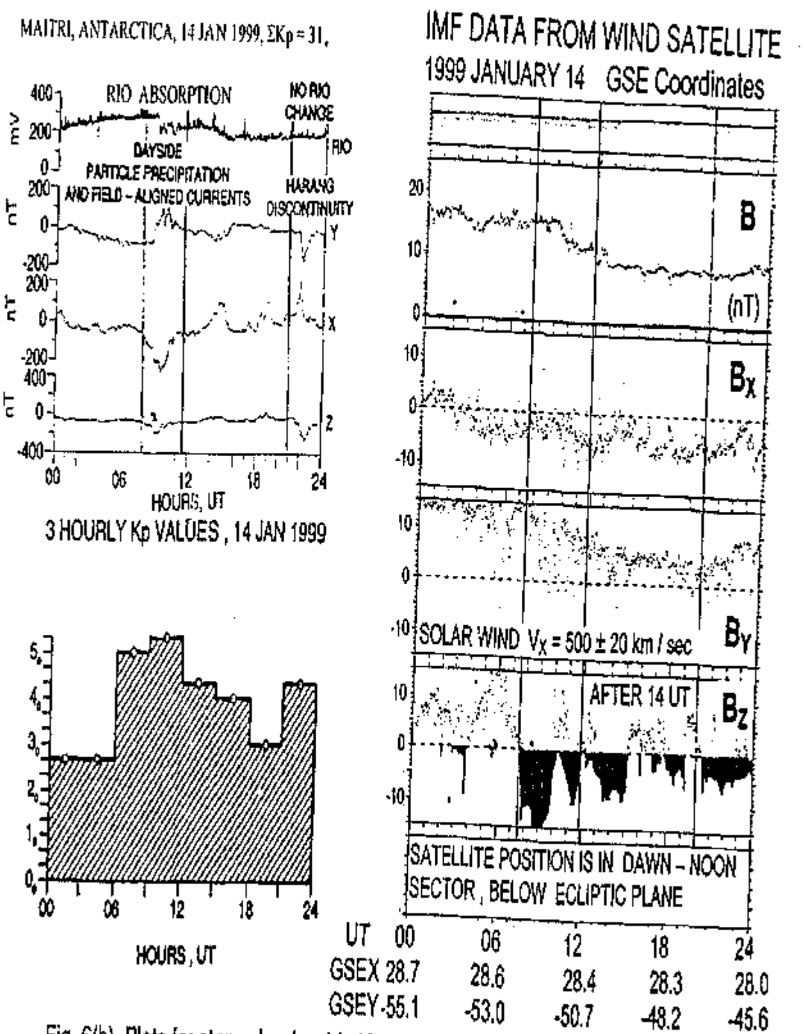

Fig. 6(b). Plots for storm day Jan 14, 1999. Format similar to figure 1.

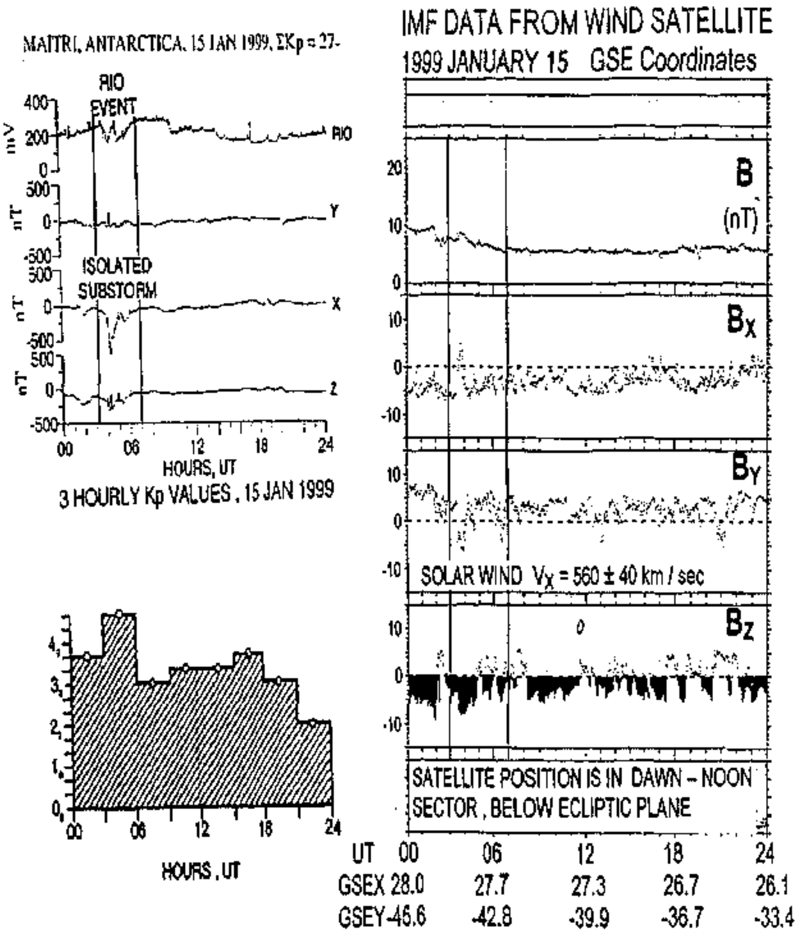

Fig. 6(c). Plots for storm day Jan 15, 1999. Format similar to figure 1.