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DEPENDENCE OF THE HIGH LATITUDE MIDDLE ATMOSPHERE IONIZATION ON STRUCTURES IN INTERPLANETARY SPACE

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As known from LAUTER et al. (1978) the precipitation of high-energetic electrons during and after strong geomagnetic storms into heights below 100 km in middle and subauroral latitudes is markedly modulated by the structure of the interplanetary magnetic field (IMF). In the present paper we want to show that also under relative quiet conditions the D-region ionization caused by high energetic particle precipitation (energies greater 20 - 50 keV) depends on changes of the interplanetary magnetic field and also on the velocity of the solar wind.

Following investigations by DUNGEY (1961) and by RUSSEL and McPHERRON (1973) the negative B_z component of the interplanetary magnetic field in the solar magnetospheric coordinate system should play an important role for the interaction of the solar wind with the magnetosphere and the accompanying acceleration processes. Such negative B_z components are induced in the solar magnetospheric coordinate system by the normal IMF sector structures only in dependence on regular daily and seasonal changes of the position of the dipole axis of the Earth's magnetic field in respect to the solar axis. If we assume a mean IMF fieldstrength of 5 nT we obtain a seasonal variation of the vertical magnetic fieldstrength in the solar magnetospheric coordinate system as shown in Fig. 1. Here we have calculated only daily mean values, neglecting the daily variation of B_z. Whereas T-sectors induce in spring maximum negative and in autumn maximum positive values, A-sectors cause opposite results. As we believe that negative B_z-values should favor particle precipitation into the lower ionosphere but positive B_z-values should reduce precipitation we define A-sectors in autumn and T-sectors in spring as so called 'pro-sectors', and T-sectors in autumn and A-sectors in spring as 'anti-sectors'.

To test this assumption, we have investigated the influence of IMF-sector boundary crossings on ionospheric absorption data of high and middle latitudes by the superposed-epoch method, with the first day of a new sector as "zero" key day. The dates of the sector crossings were taken from the catalog of SVALGAARD (1975), or from Solar Geophysical Data. In Fig. 2, the result of this analysis can be seen for noontime absorption measurements at vertical incidence on 1.75 MHz and 3.0 MHz as well as CNA observations on 22.4 MHz, obtained by the GDR participation groups during the 21st - 23rd Soviet Antarctic Expeditions at Novolazarevskaya (11.83°E, 70.77°S). A total of 67 sector crossings between June 1976 and November 1978 have been used. In the upper part of Fig. 2 the influence of all sector boundary crossings on the absorption data is presented (dashed-dotted lines) whereas in the lower part these data are subdivided into transitions from pro- to anti-sector (dotted lines) and from anti- to pro-sector conditions (full lines). In contr t to the small variations of absorption if all sector crossings are superimposed, a very pronounced influence of the IMF sector structure can be observed during the transition from anti- to pro- or pro- to anti-sector conditions. Absorption differences of about 8 -

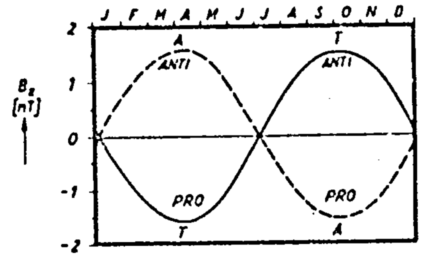

Figure 1. Mean seasonal variation of the B_z-component in solar-magnetospheric coordinate system for an undisturbed interplanetary magnetic field (magnitude B = 5 nT) with A- and T-polarization.

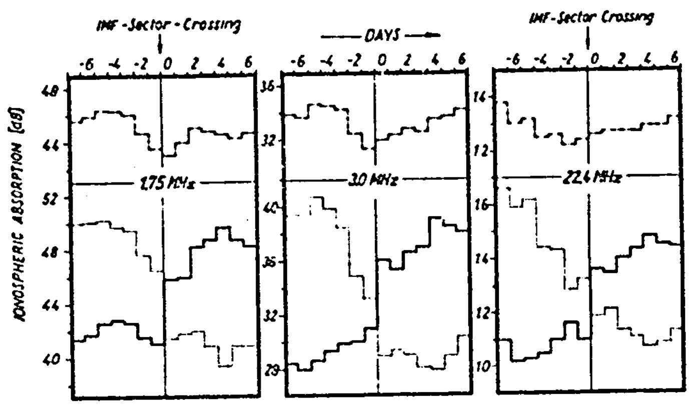

Figure 2. Variation of ionospheric absorption at high latitudes (Novolazarevskaya:70.8°S; 11.8°E) during IMF-sector boundary crossings

-.-.-.-: all sector crossings
______: only crossings from anti- to pro-sector
. . . .: only crossings from pro- to anti-sector

10 dB at 1.75 or 3 MHz, and about 0.4 dB at 22.4 MHz, demonstrate the importance of negative B_z-values of the IMF for the precipitation of high-energetic particles in high latitudes.

For the same sector boundary passages we have also investigated the behavior of f_{min}-data from ionosonde measurements in different latitudes. Fig. 3 shows the results. Whereas in high latitudes a strong dependence of the f_{min}-data on pro- and anti-sector condition could be detected, this influence is smaller in middle latitudes. A somewhat larger effect can be seen again at Port Stanley where particle precipitation is more effective because of the South Atlantic anomaly of the Earth's magnetic field. In lower latitudes there seems to be also a retardation of about 3 or 4 days of the ionospheric effect in respect to the sector crossing, most clearly seen for the anti- to pro-sector transition at Juliusruh and Port Stanley. This effect may be caused by the

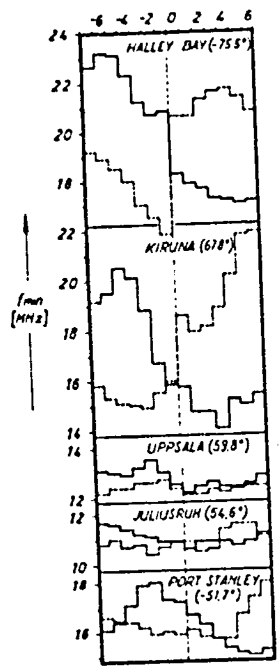

Figure 3. Variation of f_{min}-data during IMF-sector boundary crossings in dependence on latitude (geogr. lat. in brackets)
. . . .: crossings from anti- to pro-sector
- - - -: crossings from pro- to anti-sector

diffusion of high-energetic electrons from high to middle latitudes, an effect which we know also from investigations of post storm events (LAUTER et al., 1979).

Besides the IMF sector structure, the velocity of the solar wind could be important for particle precipitation, especially in high latitudes. Therefore, we have also tested the influence of solar "high speed plasma streams" after a catalogue of LINDBLAD and LUNDSTEDT (1981). High speed plasma streams were mainly defined as solar plasma streams which increase their velocities by more than 100 km/s within 24 hours with simultaneous enhancements of their ion density and/or changes of the interplanetary magnetic field. From the period between 1964 and 75 we used 171 such streams with a duration of more than 4 days and investigated their influence on f_{min}-data of Halley Bay, and on the geomagnetic AE index.

In Fig. 4 the results of a corresponding superposed-epoch analysis with the f_{min}-data are represented. The "zero" key day is the beginning of the high speed plasma stream. The data analysis was made for two data sets: high speed plasma streams with small velocity changes $\Delta v \leq 230$ kms^{-1} (a) and large velocity changes $\Delta v \geq 300$ kms^{-1} (b). With the beginning of the plasma stream also the ionospheric absorption increases, rather slightly at low velocity streams (a) but very pronouncedly with high velocity streams (b). In the lower part of Fig. 4 the two collectives of data were again divided into streams with IMF of pro- and anti-sector conditions. For low velocity streams (c) the influence of the sector structure dominates markedly, e.g. plasma streams during anti-sector conditions cause far less particle precipitation than before the occurrence of the streams. At high velocity streams (d) the precipitation during the stream is always higher than before, but again markedly modulated by the IMF sector structure.

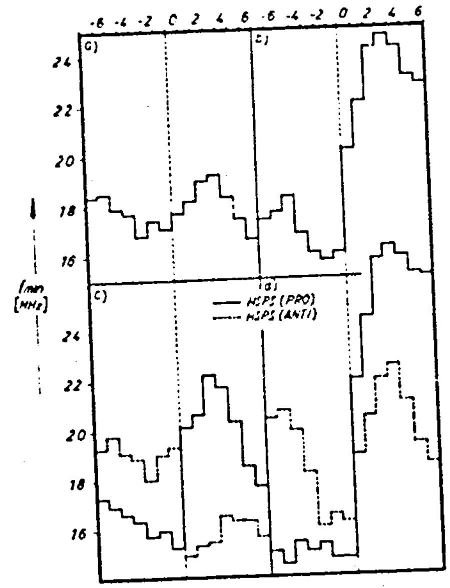

Figure 4. Variation of f_{min}-data (Halley Bay) during high speed plasma streams (HSPS) with $\Delta v \leq 230$ km/s (a and c) or $\Delta v \geq 300$ km/s (b and d). In (c) and (d) the data of (a) and (b) are subdivided corresponding to their IMF polarity during pro- and anti-sector conditions.

For investigating a comparable dependence of the lower energetic particle precipitation we have chosen as indicators the geomagnetic A_p index and the auroral electrojet index, AE, which are mainly produced by ionospheric currents in polar latitudes between about 100 and 120 km corresponding to 1 - 10 keV electron precipitation, in contrast to the absorption measurements which may be influenced below 100 km corresponding to energies of more than 20 keV. Fig. 5 shows the result of a superposed-epoch analysis of AE-values for the same high speed plasma streams as in Fig. 4. The lower-energetic particle precipitation is positively correlated with the velocity changes of the plasma streams, too, but in contrast to the f_{min}-values the influence of sector structure changes is obviously not so dominant. For instance, with low velocity plasma streams the AE Index is enhanced also with IMF anti-sector conditions, contrarily to the f_{min}-variations in Fig. 4. These differences in particle precipitation at different energies indicate that the higher-energetic electron precipitation is stronger controlled by sector structure changes than the lower one. This can be a hint that the IMF structures do differentiate the magnetospheric acceleration processes of energetic particles. Finally the following conclusions should be mentioned: The presented results on the dependence of particle precipitation on the negative B_z-component of the interplanetary magnetic field and on the velocity of the solar wind support the concept of AKASOFU's energy transfer function (PERREAULT and AKASOFU, 1978) as a first approximation for the description of the energy transfer from the solar wind into the atmosphere. The observed differences in the precipitation of particles in dependence on their energy, however, cannot be explained by this energy transfer function.

For investigations of the influence of IMF sector boundary crossings upon the plasma of the middle atmosphere the different physical behaviour of the

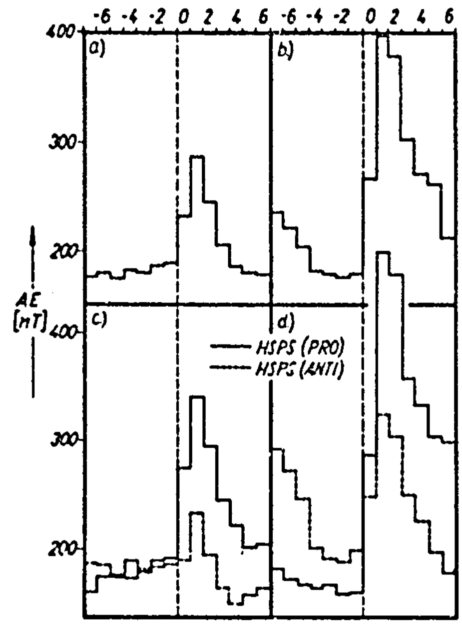

Figure 5. Same as in Fig. 4 but for AE-data.

IMF-sectors during the spring and autumn halfyear should be taken into consideration. Our classification of IMF-sectors after their B_z-components in the solar magnetospheric coordinate system (pro-, anti-sectors) seems to be more appropriate than the usual classification after the direction of the IMF in relation to the sun (A- and T-sectors).

As the excessive D-region ionization due to precipitation of high energetic particles markedly influences the radio wave propagation especially in high latitudes, the derived dependence of particle precipitation on structures of the interplanetary magnetic field can improve the prediction of radio propagation conditions in polar regions.

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