DIURNAL DEPENDENCE OF THE GEOMAGNETIC EFFECT IN THE UPPER ATMOSPHERE

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Abstract: Substituting the main component of the geomagnetic effect in the DTM model by a linear function of Dst the residual density values (RES) indicate a diurnal dependence. Its amplitude increases significantly on disturbed days. According to the interpretation of the main component of the geomagnetic effect, this diurnal dependence may be connected with the asymmetry of the equatorial ring current.

СУТОЧНАЯ ЗАВИСИМОСЬ ГЕОМАГНИТНОГО ЭФФЕКТА ВЕРХНЕЙ АТМОСФЕРЫ

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Резюме Выражая в модели "ДТМ" геомагнитный эффект с учётом линеарной зависимости от Dst, описанной в предыдущей статье, получаются значения невязки (RES), показывающие суточную зависимость. Амплитуда этой зависимости значительно больше в дни геомагнитных возбуждений. Выходя из интерпретации линеарной главной части геомагнитного эффекта предполагается связь между суточным изменением и асимметрией экваториального кольцевого тока.

INTRODUCTION

In a previous paper it has been shown that the density increase $\Delta\rho$ -deduced from measurements of the CACTUS accelerometer and compared to DTM model values omitting the geomagnetic effect - proved to be a double-valued function of Kp at least at low latitudes [Illés-Almár et al., 1989]. As it was pointed out earlier, disregarding the main phases of geomagnetic storms $\Delta\rho$ is a different function of Kp during the recovery phase than in other periods and the separation of the two curves is not the same in the course of the day, the density increase is largest in day-time (Fig.1) [Illés-Almár et al., 1988]

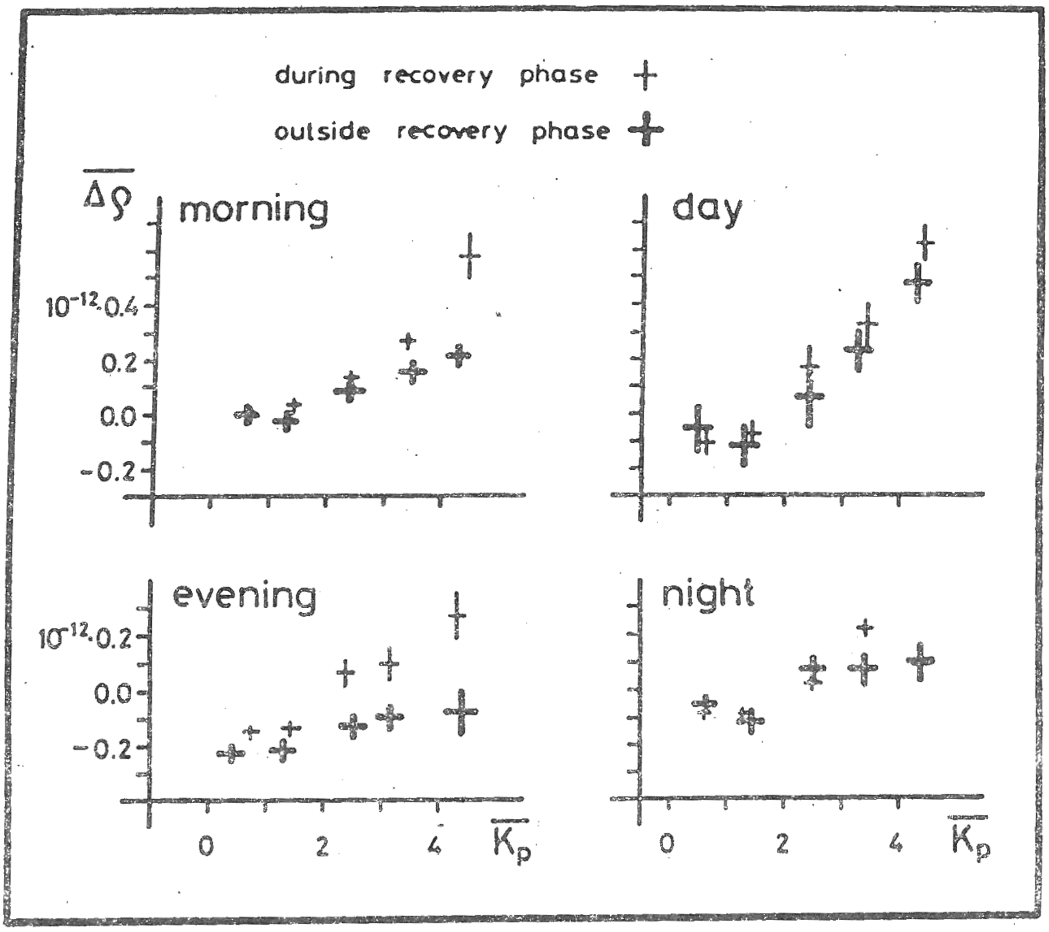


Fig.1 Deviation of measured density values from the corresponding model values with Kp=0 ($\Delta\rho$) (averaged for Kp domains) as a function of Kp in different parts of the day. The data refer to recovery phases (thin crosses) and to other periods (heavy crosses) excluding the main phases of geomagnetic storms.

INVESTIGATION OF THE DIURNAL DEPENDENCE

All $\Delta\rho$ values have been reduced (RES) by eq. /2/ of the previous paper [Illés-Almár et al., 1989]. Instantaneous RES values have been plotted in Fig. 2 as a function of LST on more (Dst $<$ -15) and on less disturbed (Dst $\geq$ -15) days separately. A diurnal dependence of the residuals is clearly visible in the figure and the scatter increases with increasing activity (with some extremely high values) in spite of the fact that RES values are in principle free from the geomagnetic effect.

The dependence of RES values on LST has been investigated by Fourier-analysis. The Fourier spectrum of the total material can be seen in the upper part of Fig. 3., those on more and on less disturbed days are

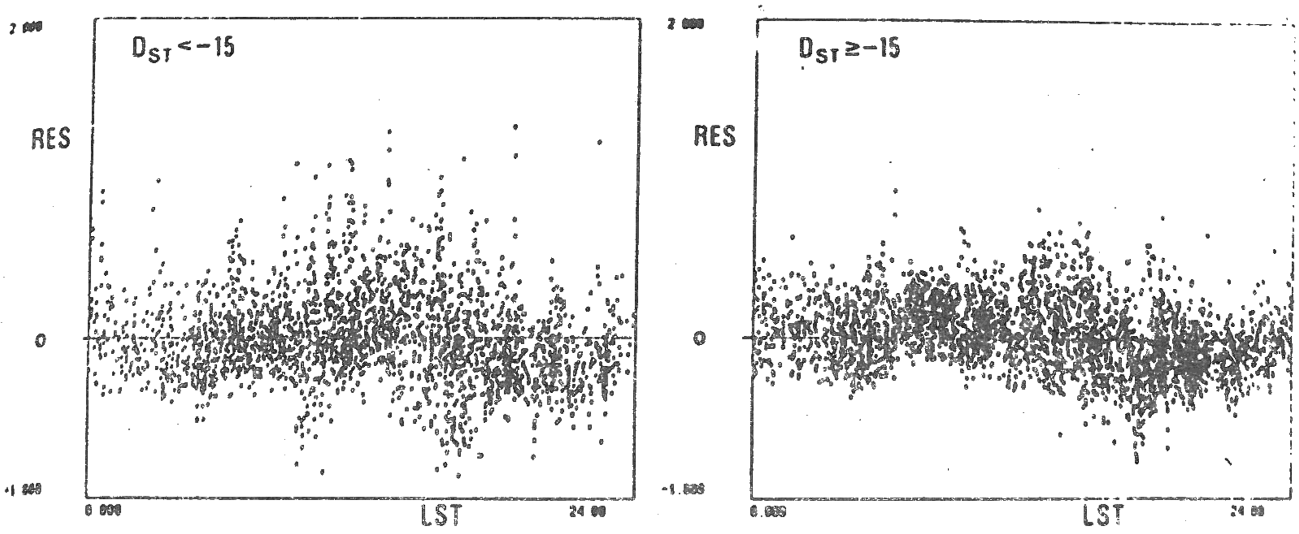


Fig.2 Momentary density residuals (RES) plotted as a function of local time (LST) on more and on less disturbed days (to the left and to the right, respectively).

presented in the lower part. The peak belonging to the one-day period emerges in each spectrum. There are, however, additional peaks indicating a non-linear coupling of the one-day oscillation with annual and semi-annual terms. The amplitude of the one-day oscillation is definitely larger (by 25 %) on more disturbed (Dst $<$ -15 nT) than on more quiet (Dst $>$ -15 nT) days, the same tendency appears in case of the peaks connected with non-linear coupling. This hints at the fact that the amplitude difference is not the consequence of an incorrect description of the diurnal variation in the model - but the geomagnetic effect indicates really diurnal dependence.

Using from the Fourier series only the one day and the half-day terms to represent the diurnal variation of the RES values on a normal day by

$$RES=[0.058 \cos (LST^h-9^h)+0.052 \cos (2\, LST^h-1.6^h)]\cdot 10^{-12} kg/m^3 \qquad /1/$$

a good fit can be obtained (see Fig. 4, dotted line). Points in Fig. 4 are hourly means for LST formed from the total material (upper diagram) and from values referring to disturbed days (lower diagram). The oscillation seen in the upper part of the Figure can properly be fitted by eq. /1/.

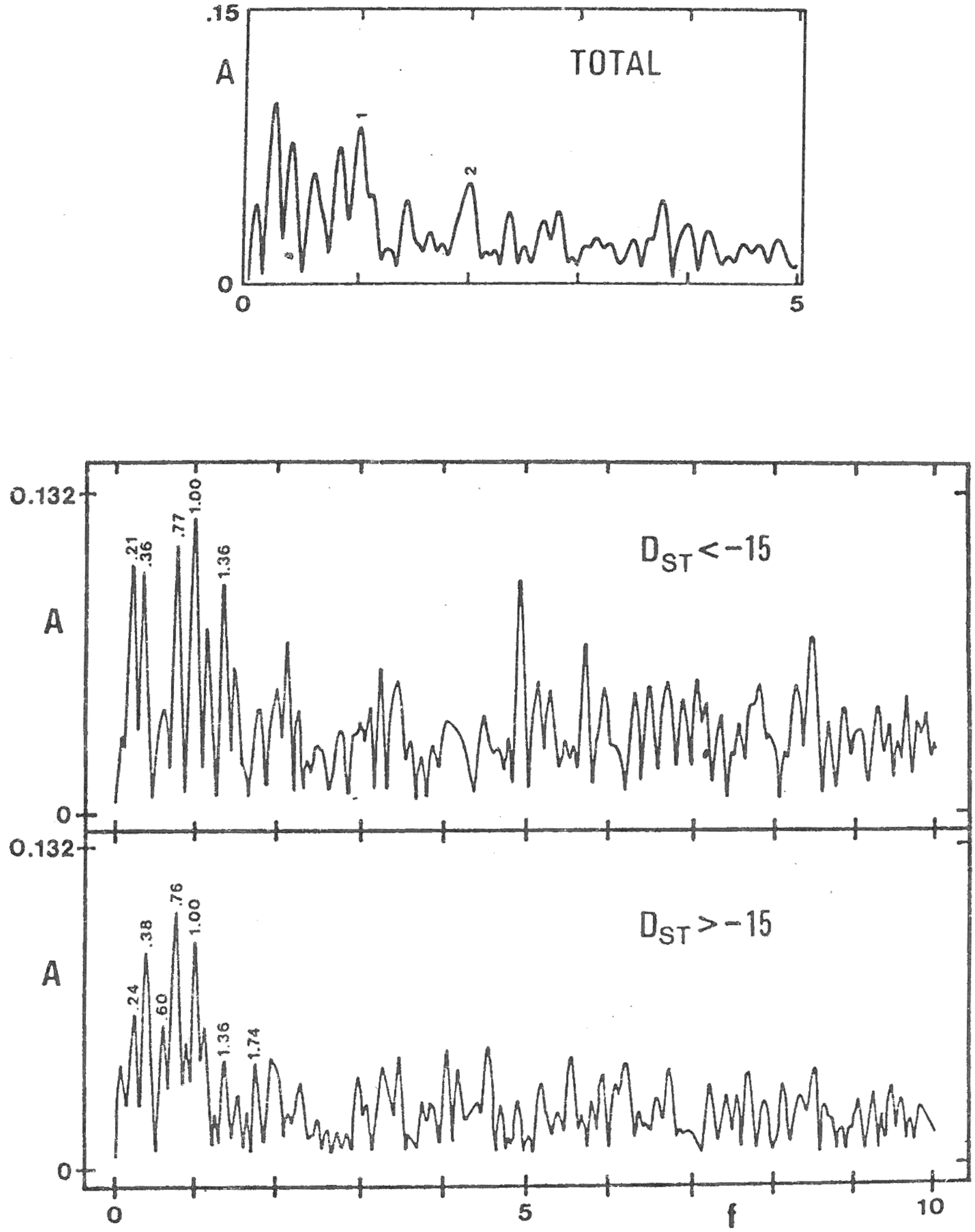
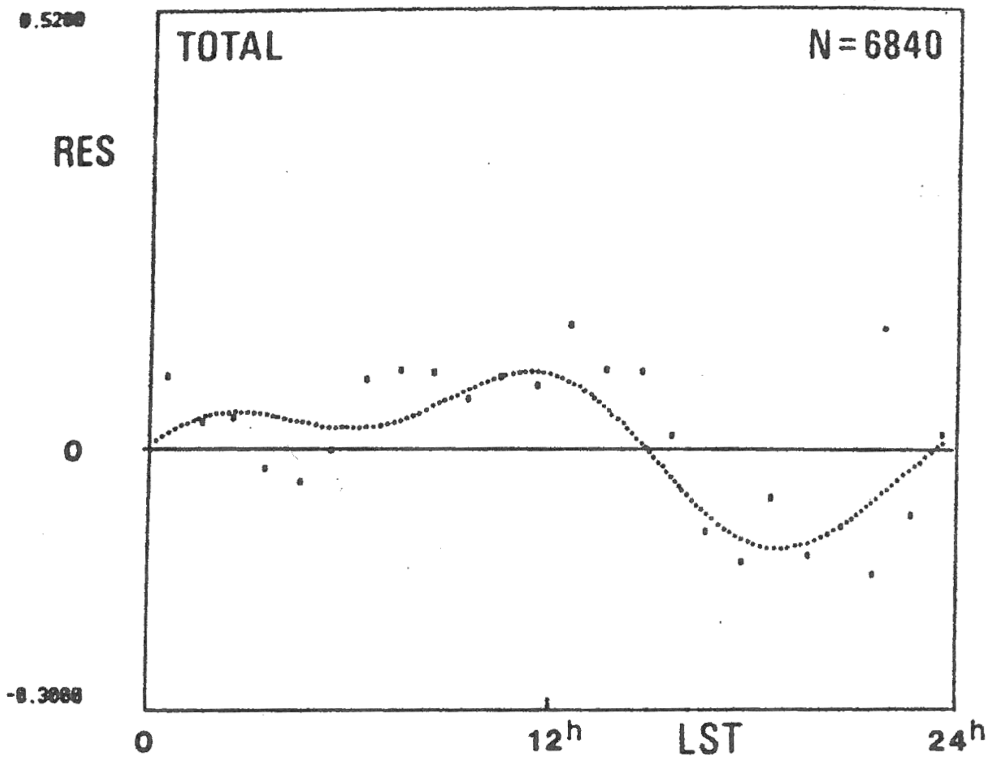


Fig.3 Fourier spectrum of the RES values referring to the total material (upper part) as well as to more and less disturbed days separately (lower part).



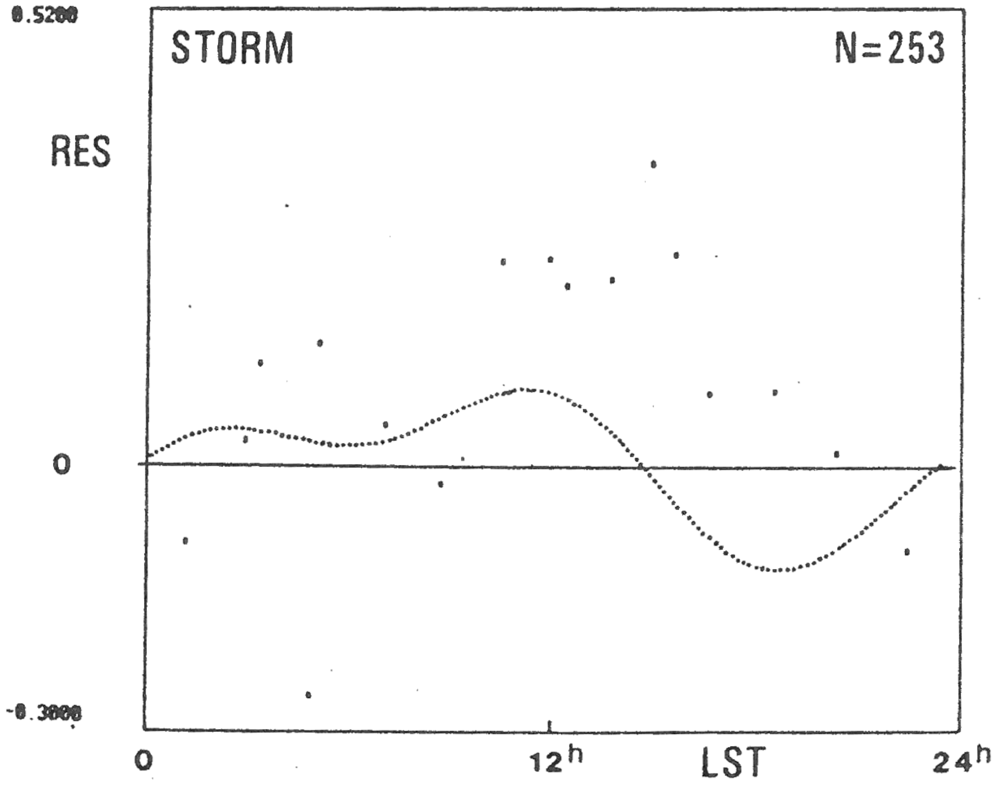


Fig.4 Hourly average RES values plotted as a function of LST for the total material (upper part) and for disturbed days only (lower part). The dotted curves on both diagrams correspond to a truncated Fourier series with one-day and half-day terms only.

However, it is obvious that deviations from the curve given by eq. /1/ are considerable in the lower Figure. This indicates that there is an excess day-time reaction of the upper atmosphere on disturbed days.

Since only few measurements were available during storms, in order to limit the influence of the scatter running mean values were computed and plotted in Fig. 5. Each 0.01 days a running mean value was calculated for consecutive ± 0.1 day intervals. In this figure the excess density as compared to the mean curve is even more pronounced in the late morning hours of disturbed days.

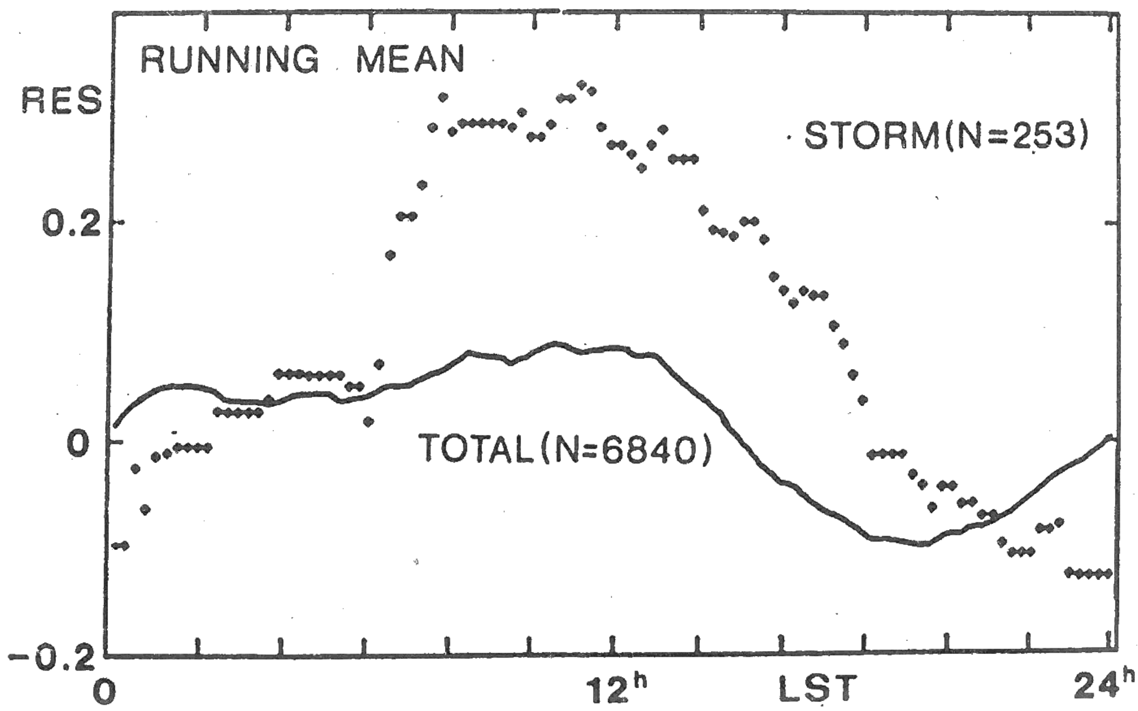


Fig.5 Running means of RES values plotted as a function of LST for the total material (continuous curve) and for disturbed days (dots) respectively (Disturbance daily variation of ρ)

The amplitude of the mean diurnal variation found in the residuals represents a few percent of the mean density at the same altitude.

DISCUSSION AND CONCLUSIONS

Former and recent investigations have indicated that the effect of geomagnetic disturbances in the neutral upper atmosphere has two components; one of them is independent while the other is dependent on local time (longitude). Both of them, however, can be a function of latitude and storm time reckoned from the beginning of the disturbance. That part of the geomagnetic effect, which is independent of local time is revealed by the better correlation of the $\Delta\rho$ data on Dst than on Kp or Ap at low latitudes [Illés-Almár et al., 1987, 1988]. The local time dependent part of the geomagnetic effect appears in the residuals obtained by substracting the Dst dependent part from the $\Delta\rho$ data. Thus, the morphology of the effect of the geomagnetic disturbance in the neutral upper atmosphere can be described in a similar way as the morphology of geomagnetic disturbances themselves, at least at low latitudes ($< 30^o$) [e.g. Akasofu and Chapman, 1972], as well as to that of ionospheric storms at these latitudes [Matsushita, 1959; Bencze, 1965]. Ionospheric indications of the geomagnetic activity are used here to support the explanation of neutral density changes.

In Fig. 6a. the disturbance daily variation of the neutral density has been presented. In Fig. 6b. the disturbance daily variation (SD) of the horizontal component (H) of the geomagnetic field at low latitude is shown (indicating the diurnal variation of the geomagnetic activity). Both curves display a maximum in forenoon and a minimum in the afternoon. For comparison in Fig. 6c. the disturbance daily variation of the ionospheric parameter foF2 at mid-latitudes has been plotted. foF2 is proportional to the maximum electron density of the F region (and at the same time to the maximum electron density of the ionosphere). The time of the extremes of foF2, however, is dependent on latitude. Proceeding from mid-latitudes to low latitudes the maximum is shifted from the afternoon to the forenoon hours [Matsushita, 1959].

Considering on the one hand the relation between density changes of the neutral upper atmosphere and geomagnetic activity, and on the other hand the connection between electron density variations in the F region and geomagnetic activity, a consistent interpretation of the above disturbance daily variations can be given.

It is known from previous investigations that the density of the neutral upper atmosphere icreases with geomagnetic activity. We find the same phenomenon in case of the disturbance daily variation, namely at low latitudes the maximum of the disturbance daily variation of ρ in forenoon may be connected with the morning maximum of the disturbance daily variation in the horizontal component of the geomagnetic field.

As regards the electron density of the F region at low latitudes it

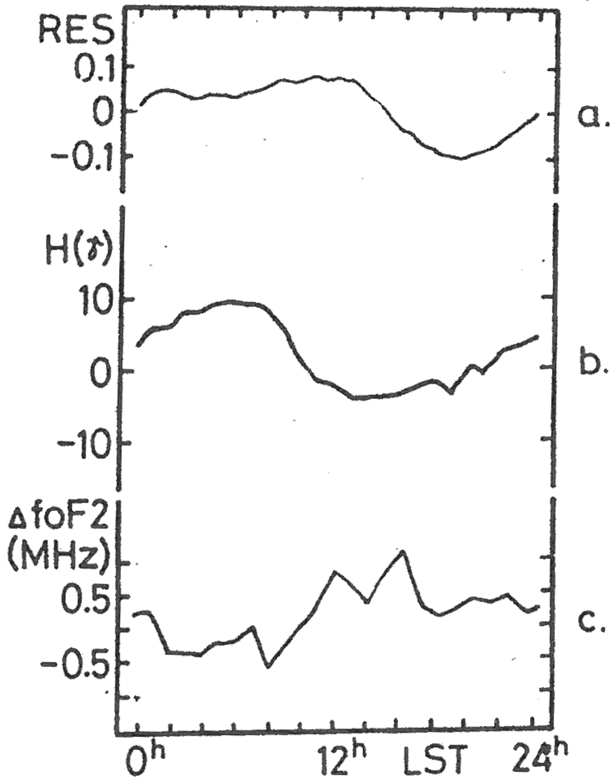


Fig.6

a. Diurnal variation of RES values (referring to the ±30° latitude zone).

b. Disturbance daily variation of the horizontal component of the geomagnetic field at 22° latitude.

c. Disturbance daily variation of foF2 at a mid-latitude station.

increases with increasing geomagnetic activity (positive ionospheric storms). That is, the disturbance daily variation of foF2 is consistent with this circumstance having a maximum simultaneously with the maximum of the disturbance daily variation in the horizontal component of the geomagnetic field. Thus, the storm time increase of the electron density in the F region could be caused in addition to neutral (zonal) winds and an electric field by particle heating. The neutral wind and the electric field - depending on its direction lifting or lowering the F region in the geomagnetic field - causes an increase or decrease of the electron density by the variation of the composition in the neutral atmosphere with height. However, the effect of these two factors can be neglected because of the negligible change of the composition with height at the altitude considered here. Considering the above mentioned processes, the behaviour of the ionosphere confirms our earlier suggestion that the disturbance daily variation of ρ at low latitudes can be explained by particle precipitation [Illés-Almár et al., 1988].

In the search for the source of energetic particles the disturbance daily variation in the horizontal component of the geomagnetic field can be decisive. As it is known, this variation is attributed partly to the asymmetry of the ring current, partly to polar magnetic disturbances. In case of the ring current, the energetic particles are produced by charge exchange between ring current ions and hydrogen atoms in the geocorona, thus forming energetic neutral atoms (ENA). These neutral atoms not limited by the geomagnetic field move already freely and a part of them precipitate into the upper atmosphere mainly at low latitudes.

The disturbance daily variation of the density may be connected partly with the asymmetry of the ring current. The asymmetry of the ring current is caused by several factors [Roelof, 1988]. First, ions injected from the plasma sheet on the night side of the magnetosphere can not all compass the Earth. Furthermore, the field-aligned (Birkeland) currents - leaving the ionosphere in the auroral zone, in the morning sector and entering the auroral zone ionosphere in the evening sector (region II currents) - form a partial ring current on the night side [Schield et al., 1969; Stern, 1983; Iijima et al., 1988]. Thus, the intensity of the ring current is augmented by this partial ring current on the night side. Both phenomena intensify the ring current on the night side as compared with the day side. Then, the production rate of ENAs depends also on the concentration of H atoms in an extended height range of the upper atmosphere which shows a diurnal variation with a maximum in the morning (Fig.7b) [Meier and Mange, 1973]. The local time distribution of the ion pitch angle anisotropy can be considered as an indication of this process (Fig.7a) [Garcia and Spjeldvik, 1985].

ENA observations on ISEE1 indicated that while during the main phase of a large geomagnetic storm (Dst 241 nT) ENA fluxes came from the near midnight sector (Roelof, 1987) during the recovery phase of another large storm ENA emissions originated mainly in the morning sector (Roelof, 1984). Thus, the elongated maximum of the average disturbance daily variation in the forenoon (Figs. 4, 5) could be explained by the joint and lasting effect of ENA emissions during the main and recovery phases of geomagnetic storms. As regards the disturbance daily variation of ρ during the main and recovery phases of geomagnetic storms, its increased amplitude can be explained by the dominance of O^+ ions on the dayside in these periods (Lundin et al., 1983). Using a relation between the recovery rate of the ring current and the ENA flux, it has been found that the charge exchange loss of O^+ ions was the dominant process in the recovery phase (Roelof et al., 1985). If it is considered that O^+ ions are more abundant on the day side, this circumstance can cause an increased production of effective ENAs on the day side. The delayed response of the upper atmosphere to the

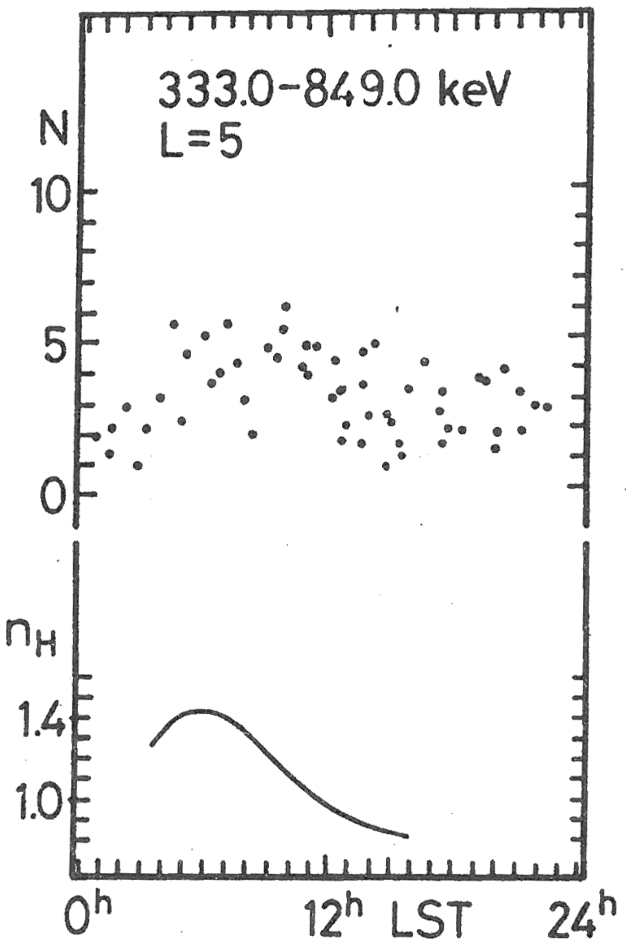


Fig.7

a. Diurnal variation of the ion pitch angle anisotropy N in the ring current belt.

b. Diurnal variation of the relative density of H atoms (n_H) as compared to local noon.

geomagnetic disturbance can also contribute to the shift of the maximum in the disturbance daily variation of ϱ to noon.

The intensity of the ring current can also significantly be influenced by the loss of particles due to its interaction with the plasmasphere [Cornwall et al., 1970; Kozyra, 1988]. The plasmasphere is namely asymmetrical its extension being larger on the day side than on the night side [Decreau et al., 1982; Gringauz, 1983]. The distance of the ring current's central line from the Earth's centre decreases during geomagnetic storms [Frank, 1970]. Thus, the particle loss can be larger on the day side than on the night side. This interaction can also contribute to the weakening of the ring current on the day side and after all to its asymmetry.

Summarizing, the conclusion can be drawn that in general the probability of particle loss and the production of ENAs is greater in the first half of the day than in the second half. This can contribute to the disturbance daily variation of ϱ with a maximum near noon (Fig. 6a).

REFERENCES

Akasofu, S.I. and Chapman, S. (1972), Solar-terrestrial Physics, Oxford University Press, London, 1972.

Bencze, P. (1965), Investigation of the connections between the components of the geoelectromagnetic field and the ionosphere (in Hungarian). Thesis, Sopron, 1965.

Cornwall, J.M., Coroniti, F.V. and Thorne, R.M. (1970), Turbulent loss of ring current protons, J. Geophys, Res., 75, 4699-4709.

Decreau, P.M.E., Beghin, C. and Parrot, M. (1982), Global characteristics of the cold plasma in the equatorial plasmapause region deduced from the GEOS 1 mutual impedance probe. J. Geophys. Res., 87, 695-712.

Frank, L.A. (1970), Direct detection of asymmetric increases of extra-terrestrial "ring current" proton intensities in the outer radiation zone. J. Geophys. Res., 75, 1263-1268.

Garcia, H.A. and Spjeldvik, W.N. (1985), Anisotropy of geomagnetially trapped ions. J. Geophys. Res. 90, 347-358.

Gringauz, K.I. (1983), Plasmasphere and its interaction with the ring current. Space Sci. Rev., 34, 245-258.

Iijima, T., Potemra, T.A. and Zanetti, L.J. (1988), Large scale characteristics of the ring current determined by AMPTE/OCE. Paper presented at the XXVII. Plenary Meeting of COSPAR, Helsinki, 1988.

Illés-Almár, E., Almár, I., Bencze, P. and Horváth, A. (1987), Investigation of the thermosphere-ionosphere interaction by means of the neutral post-storm effect. Adv. Space Res., 7 (8), 53-57.

Illés-Almár, E., Almár, I., Bencze, P. and Horváth, A. (1988), On a possible ring current effect in the density of the neutral upper atmosphere. Submitted to Adv. Space Res., 1988.

Illés-Almár, E., Almár, I., Bencze, P., and Horváth, A. (1989),Dst as a better index for the description of the geomagnetic effect in the upper atmosphere at low latitudes. Paper presented on the Interkozmos 18. seminar in Kraków, Poland, 1989. VI. 12-17.

Kozyra, J.U.(1988), Sources and losses of ring current ions: an update. Paper presented at the XXVII. Plenary Meeting of COSPAR, Helsinki, 1988.

Lundin, R., Hultqvist, B., Pissarenko, N. and Zacharov, A. (1983), Composition of the hot magnetospheric plasma as observed with the Prognoz-7 satellite. In: Energetic ion composition in the Earth's magnetosphere (ed. R.G. Johnson). Terrapub, Tokyo, 1983 p. 307.

Matsushita, S. (1959), A study of the morphology of ionospheric storms. J. Geophys. Res., 64, 305-321.

Meier, R.R. and Mange, P. (1973). Spatial and temporal variations of the Lyman-alpha airglow and related atomic hydrogen distirubitons. Planet. Space Sci. 21, 309-327.

Roelof, E.C. (1984), "Imaging the ring current using energetic neutral atoms measured by ISEE-1. EOS Trans. AGU, 65, 1055.

Roelof, E.C. (1987), Energetic neutral atom image of a storm time ring current. Geophys. Res. Letters, 14, 652-655.

Roelof, E.C. (1988), Remote sensing of the ring current using energetic neutral atoms. Paper presented at the XXVII. Plenary meeting of COSPAR, Helsinki, 1988.

Roelof, E.C., Mitchell, D.G. and Williams, D.J.(1985), Energetic neutral atoms (E 50 keV) from the ring current: IMP 7/8 and ISEE-1. J. Geophys. Res., 90, 10991-11008.

Schield, M.A., Freeman, J.W. and Dessler, A.J. (1969), A source for field aligned currents at auroral latitudes. J. Geophys. Res., 74, 247-256.

Stern, D.P. (1983), Electric currents and voltage drops along auroral field lines. Space Sci. Rev., 34, 317-326