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SIMILAR BEHAVIOUR OF THE THERMOSPHERE AND THE IONOSPHERE IN THE RECOVERY PHASE OF GEOMAGNETIC DISTURBANCES

E. Illés-Almár,* I. Almár,* P. Bencze,** A. Horváth,*
N. Jakowski*** and A. Jungstand***

** Konkoly Observatory, H-1525 Budapest, Box 67, Hungary*
*** Geodetic and Geophysical Institute of the Hungarian Academy of Sciences, Sopron, Hungary*
**** Institute for Space Research of the Academy of Sciences, Germany*

ABSTRACT

The neutral density excess as compared to the MSIS 86 model indicates a double valued dependence on the Kp geomagnetic activity index; a very similar dependence was found in some ionospheric parameters. The similarity hints at coupling between the ionosphere and the neutral upper-atmosphere during geomagnetic disturbances. Relations between the changes of these parameters and the neutral density are considered.

INTRODUCTION

Studying the geomagnetic effect in the neutral upper-atmosphere led us to suppose coupling of certain phenomena with the ionosphere and the magnetosphere. In order to investigate these connections a parallel analysis of neutral atmospheric as well as ionospheric parameters was started. The present paper gives a report on preliminary results. First of all let us concentrate on the background, i.e. on a recently developed model of the geomagnetic effect.

RESULTS CONCERNING THE NEUTRAL UPPER-ATMOSPHERE

Some of our results based on in situ measurements of the CACTUS accelerometer at an altitude of 400 km in the equatorial zone are summarized in another paper /1/. Let us stress those of them which are hinting at an ionosphere/magnetosphere coupling! Our previous investigations pointed out that the density of the thermosphere is a different function of Kp in the recovery phase of geomagnetic disturbances than in other phases of relative quietness /2/. The density belonging to a given Kp value is larger in the recovery phase than otherwise. If, however, the Dst geomagnetic index was considered independent variable of the model, than the same relation to density holds both inside and outside the recovery phase. The correlation coefficient between the density and the corresponding Dst value proved to be highest in the case of a 2 hours time delay.

These observational facts point out the probability that an additional heat source -- precipitating particles from the ring current /3/ -- is contributing to the geomagnetic effect in the equatorial zone of the thermosphere /2/. Taking into account an appropriate function of Dst as an improved description of the geomagnetic effect, the residuals (RES) can be analysed. A diurnal variation has been found in RES which proved to be stronger on disturbed days. This fact led us to conclude, that the thermospheric geomagnetic effect has a diurnal dependence. Consequently the description of the effect is similar to that of the geomagnetic disturbance itself: it has a storm-time dependence (given as a Dst dependence in our model) and a disturbance daily variation (dependence on LST) which may be connected with the asymmetry of the ring current and of the precipitation /3/.

The diurnal variation of RES belonging to different levels of geomagnetic activity is plotted in Fig. 1 with a truncated Fourier series of f = 1,2,4 (the level has been defined in various ways). It is interesting to note that independently from the definition used, several humps appear at certain local times. The hump near 18^h may be connected with the bulge of the plasmasphere, the other at midnight with the injection zone. This latter supposition is supported by the fact, that separating all data according to their geomagnetic latitude (in 10^o intervals), the midnight hump is apparent only up to 10^o latitude in each group (Fig. 2). The morning and the afternoon humps are observed to stay at the same local time independently from latitude, but the amplitude of the peak at 18^h is increasing with latitude. The hump at noon, on the contrary, may be shifted to earlier hours with increasing latitude and its amplitude is also increasing.

RESULTS CONCERNING THE IONOSPHERE

All these properties point to the possible connection between the neutral and the ionized components. Therefore the investigation of ionospheric data -- belonging to different magnetic latitudes -- has been initiated and its extension to different magnetic longitudes is also planned. Up-to-now night-time foF2, TEC, τ and hmF2 data of a station at middle geomagnetic latitude (Havana, Cuba), as well as foF2 data of an equatorial station (Ouagadougou, Africa) have been investigated using the same methods as for the CACTUS measurements (Fig. 3). It is obvious that some of the parameters are similarly separated if Kp is used as an independent variable, because their behaviour is different inside and outside the recovery phase. Similar preliminary consequences can be deduced from these figures supporting our previous conclusion that an additional heating -- independent from the auroral oval -- can be traced at the equatorial zone.

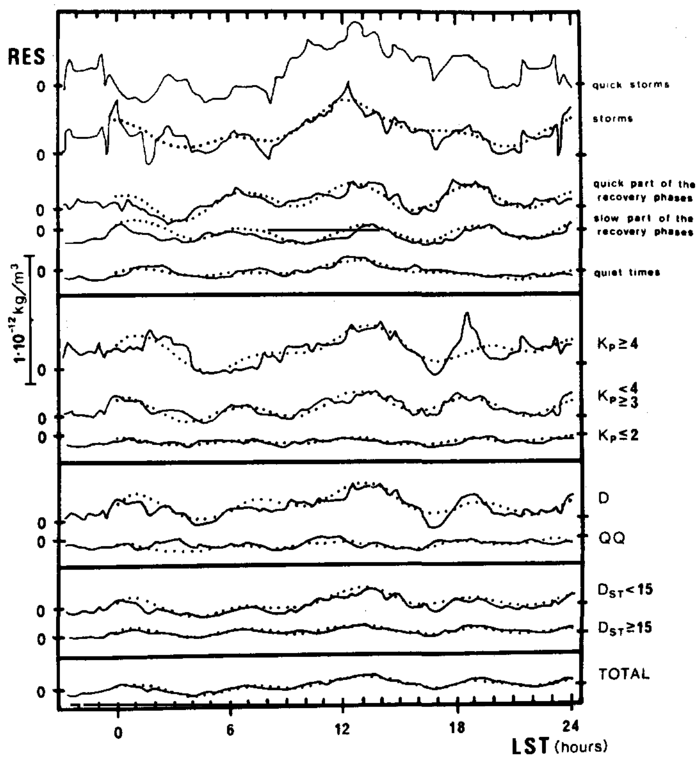

Fig. 1. Running means of residuals as a function of local solar time (LST) for different levels of geomagnetic activity (the levels have been defined in various ways)

Concerning the separation of the Δ foF2 curves of Ouagadougou and Havana on Fig. 3 respectively, i.e. that during the recovery phase there are smaller Δ foF2 values at Havana and larger at Ouagadougou, hints at the different behaviour of ionospheric storms at geomagnetic midlatitudes (Havana) or low latitudes (Ouagadougou).

DISCUSSION

The inclusion of ionospheric parameters may support the interpretation of the results obtained by the analysis of density data. The increase of the maximum electron density of the F2 layer represented by foF2 can be due to increased ionization, as well as to decreased N_2/O ratio caused by the rising of the layer or sinking of air /4/. It can be connected with decreased electron temperature, the latter being the consequence of enhanced cooling related to the increased electron density. Changes of the height of the F2 layer maximum, hmF2, are due to the rising or sinking of the layer which is connected with equatorward and poleward winds respectively, or with ExB drifts depending on the direction of the zonal component of the electric field /5/. The use of the total electron content, TEC, is motivated by the fact that in TEC integrated effects appear and thus refers not only to one altitude. It should be noted, however, that the total electron content and foF2 are not independent of each other /6/. The slab thickness $\tau = \mathrm{TEC}/\mathrm{const.}(\mathrm{foF2})^2$ is also an indicator of the sum of the neutral and electron temperatures (see also /7/, /8/).

Taking into account that changes of ϱ, foF2, hmF2, TEC and τ can be caused by heating, vertical motion, electric fields and ionization, at least five different relations can be distinguished between the changes of these parameters and the neutral density. Combined effects can also occur.

1/ An increase of ϱ and τ, unchanged foF2, hmF2 and TEC can be the consequence of an increase of both the neutral and electron temperatures due to heating indicated by the enhancement of τ. This temperature increase results not only in an increase of ϱ, but unchanged foF2, TEC and hmF2 indicate also that the effects of the temperature increase, on the one hand the decrease of foF2 and TEC produced by the increase of the N_2/O ratio and on the other hand ionization/reduced recombination compensate each other.

2/ If ϱ, foF2, TEC increases, but hmF2 and τ decreases, it can be assumed that the concentration of atomic oxigen increases due to the sinking of air rich in atomic oxigen /4/. An increase in the temperature, however, produced by compression can not be excluded. Thus, ϱ increases since atomic oxigen is the dominant constituent in the thermosphere and also foF2, as well as TEC are enhanced as a consequence of increased probability of ionization. τ decreases because of enhanced cooling by the increased electron density.

3/ If ϱ and τ does not change, foF2, TEC and hmF2 increase, the F region ascends due to southward wind or to eastward electric fields resulting in a decrease of the N_2/O ratio /5/.

4/ Unchanged ϱ and τ, a decrease of foF2, TEC and hmF2 hint at the sinking of the F region caused by northward wind, or by westward electric fields producing an increase of the N_2/O ratio /5/.

In these latter two cases one can argue that the decrease/increase of the electron temperature related to the enhanced/reduced cooling by increased/decreased electron density is compensated by the change (increase/decrease) of the electron temperature with height.

5/ If ϱ does not change, but an increase of foF2 and TEC is observed, τ and hmF2 decreases, ionization is enhanced as a result of ionizing radiation by which the density of the neutral atmosphere is uneffected.

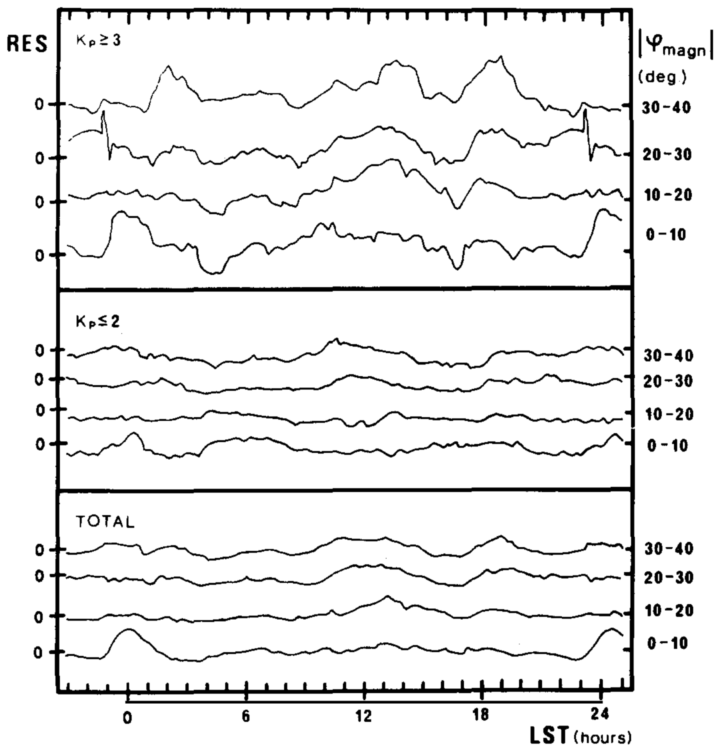

Fig. 2. The same as for Fig. 1, but separated according to geomagnetic latitudes.

According to the previous investigations of the authors, the cause of the density increase in geomagnetically disturbed periods would be heating due to energetic neutral atoms (ENA) at low latitudes and energetic charged particles at midlatitudes /3/. These ENAs are produced by charge exchange between ions of the ring current belt and the geocorona /9/, while the energetic charged particles are due to wave-particle interaction /10/.

Returning to Fig. 3 its peculiarity consists in the different behaviour of $\Delta\tau$ during and outside the recovery phase. The ΔfoF2, ΔTEC and ΔhmF2 values concerning the period outside the recovery phase indicate an increase with geomagnetic activity. At the same time $\Delta\tau$ shows a decrease in this period because of increased cooling due to the increased electron density. This tendency can be explained by the combination of cases 2 and 3; that is it could be produced by the sinking of air rich in atomic oxygen enhancing ϱ and by eastward electric field or southward winds which result in the rise of the F2 layer and hereby in the increase of ΔfoF2, ΔTEC and ΔhmF2. The ΔfoF2, ΔTEC and ΔhmF2 values referring to the recovery phase indicate also an increase with geomagnetic activity, though it is less definite than that obtained for the period outside the recovery phase. At the same time, however, $\Delta\tau$ displays increasing values with geomagnetic activity (except high Kp) in contrast to the period outside of the recovery phase. This behaviour of $\Delta\tau$ suggests a different energy source producing these changes of parameters during the recovery phase, than in the other periods of geomagnetic activity. The features of the variations can be explained by the combination of cases 1 and 3; that is it could be established by heating indicated by the increase of $\Delta\varrho$ and by eastward electric fields or southward winds, the latter inducing the rise of the F2 layer and increased values of ΔfoF2, ΔTEC and ΔhmF2 as before.

After all it can be stated that the changes of ionospheric parameters seem to confirm the conclusion of extra heating suggested in previous studies, further investigations are, however, needed.

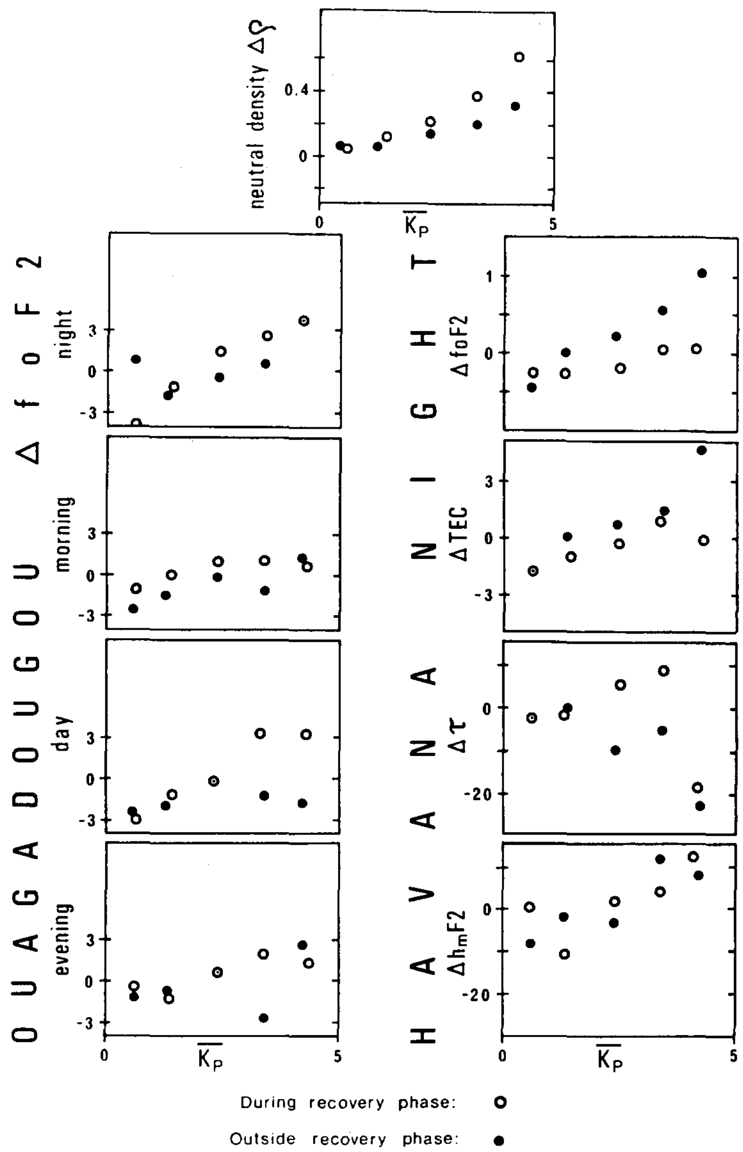

Fig. 3. $\Delta\varrho$ and departures from their 31 day mean of some ionospheric parameters measured during and outside the recovery phase (except the main phase) as a function of Kp.

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