Adv. Space Res. Vol. 12, No. 6, pp. (6)313–(6)316, 1992
Printed in Great Britain.

0273-1177/92 $15.00

IMPROVEMENT OF THE MSIS 86 AND DTM THERMOSPHERIC MODELS BY INVESTIGATING THE GEOMAGNETIC EFFECT

I. Almár,* E. Illés-Almár,* A. Horváth,* Z. Kolláth,*
D. V. Bisikalo** and T. V. Kasimenko**

* *Konkoly Observatory, H-1525 Budapest, Box 67, Hungary*
** *Astronomical Council, Soviet Academy of Sciences, Moscow, U.S.S.R.*

ABSTRACT

Based on measurements of the CACTUS accelerometer it has been found that during the recovery phase of geomagnetic disturbances the models are unable to describe properly the total density changes in the equatorial thermosphere. Introducing the geomagnetic activity index Dst instead of Kp as a model input parameter gives a much better description of the measurements. The residuals show a diurnal dependence, hinting partly at model errors in the diurnal effect (though MSIS 86 is much better than DTM in this respect), partly at a diurnal term in the geomagnetic effect.

INTRODUCTION

While investigating the geomagnetic effect in the neutral upper-atmosphere both DTM and MSIS 86 (or CIRA 86) proved to be imperfect -- though deviations are within the limits of usual model errors. Our results concerning the geomagnetic and the diurnal effect are summarized in the present paper.

DATA BASE AND THE METHOD OF INVESTIGATION

The data base consists of CACTUS accelerometer measurements of the French CASTOR satellite during low solar activity, received by the courtesy of CNES. Densities referring to altitudes between 400 and 403 km have been used for the time period 27 June 1975 - 26 June 1977 (MJD 42590 - 43320). Because of the limited height interval, the measurements (6843 in all) belong to upleg and downleg groups separated by ~ 6 hours in LST. Since the orbital plane rotates slowly with respect to the Sun, the diurnal bulge can be scanned in about 150 days in any limited altitude interval.

Observed density data have been compared with corresponding model values. In the case of DTM the latter have been calculated putting Kp=0, whilst both Kp=0 and real Kp densities were computed from the MSIS 86 model. Because of the narrow height interval in question, $\Delta\varrho = \varrho^{obs} - \varrho^{model}$ differences were formed (instead of the usual $f = \varrho^{obs}/\varrho^{mod}$ ratios) and plotted as a function of geomagnetic indices. The $\Delta\varrho$ differences represent first of all the geomagnetic effect, but all other incorrectly modelled effects will also inevitably influence the result. Substracting the geomagnetic effect by a fitted function, the residuals (RES) are suitable to analyse further rest effects.

RESULTS

All $\Delta\varrho$ values excluding storm-time measurements have been divided into two groups: 1/ those belonging to the recovery phase of geomagnetic disturbances, 2/ those outside recovery phase. Mean $\Delta\varrho$ values calculated by a/ model DTM with Kp=0, b/ model MSIS 86 with Kp=0, c/ model MSIS 86 with real Kp respectively have been plotted as a function of Kp and Dst in Fig. 1. Since $\Delta\varrho$ proved to be a different function of Kp for group 1 than for group 2 in all three cases, consequently these atmospheric models need correction in this respect. On the contrary, both in DTM and in MSIS 86 models $\Delta\varrho$ values are a unique function of Dst -- another well-known geomagnetic index not used yet in any of the thermospheric models.

Plotting all $\Delta\varrho$ values (including also storm-time measurements) as a function of Dst the property of unicity is preserved (Fig. 2 and 3). In the case of DTM a linear /1/, in the case of MSIS 86 a quadratic fit has been calculated. A time delay analysis has been carried out for MSIS 86 with Kp=0 with respect to Dst. The correlation analysis resulted in a remarkably short, two hours time delay (see Fig. 4) which was taken into account in all consecutive figures derived using the MSIS 86 Kp=0 model.

Residuals (RES) with respect to the real Kp results of the MSIS 86 model indicate a certain systematic trend as a function of Dst (Fig. 5 and see also the lower part of Fig. 1). It means that the representation of the geomagnetic effect in the MSIS model can be improved. No trend as a function of Dst, but some deviations can also be observed in cases when RES values belonging to a linear (DTM with Kp=0) or quadratic (MSIS 86 with Kp=0) fit of Fig. 2 and 3 respectively are plotted as a function of time. It means that further imperfections exist in the models and we decided to analyse the residuals as a function of LST first.

When plotting RES values as a function of LST for the corrected models (Fig. 6) there is a clear diurnal dependence in both cases. On each part of Fig. 6 the dotted lines represent truncated Fourier series with one day and half day terms fitted to all points. The deviations of $\Delta\varrho$ values are clearly increasing on disturbed days. This fact was interpreted as the diurnal dependence of the geomagnetic effect, influenced additionally by some modelling errors of the diurnal effect itself. In order to distinguish between the two components, let us first investigate the original ϱ values in quiet periods, when model errors in the diurnal effect can be separated easily!

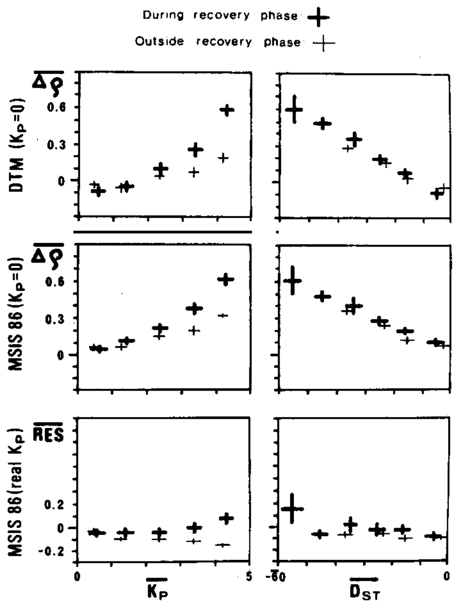

Fig. 1.

$\overline{\Delta\varrho}$ and $\overline{RES}$ versus $\overline{Kp}$ and $\overline{Dst}$ for time intervals inside and outside recovery phase using different models. Unit is 10^{-12} kg/m^3.

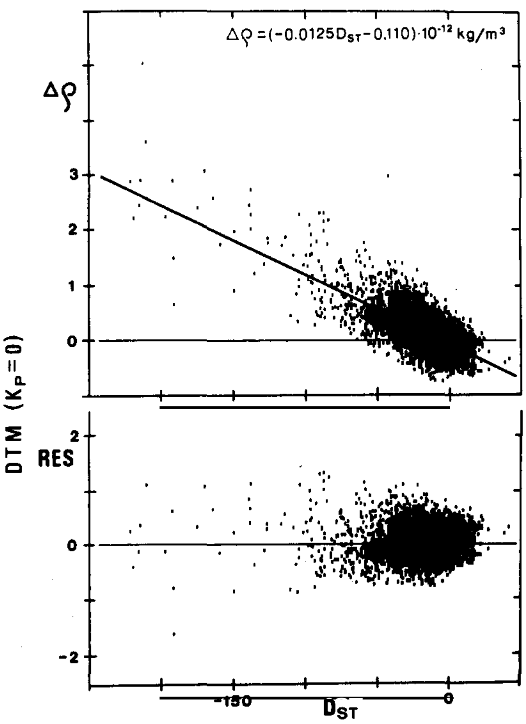

Fig. 2.

$\Delta\varrho$ and RES versus Dst for DTM Kp=0 model. A least squares fit is also given.

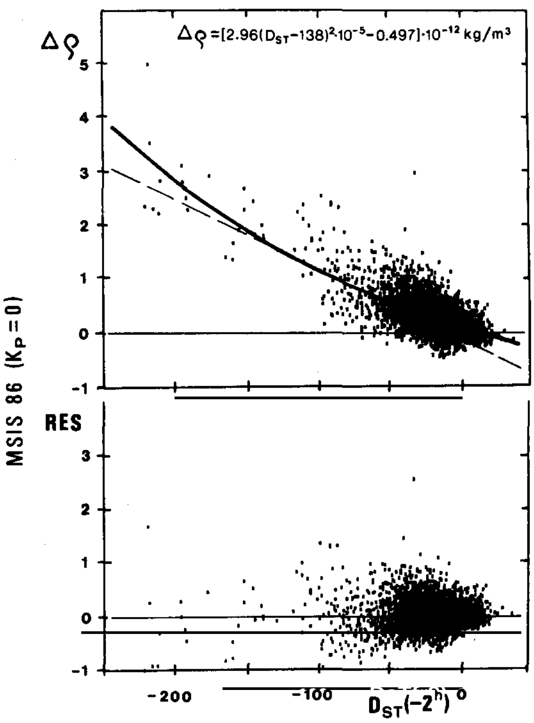

Fig. 3.

$\Delta\varrho$ and RES versus Dst (2 hours earlier) for MSIS 86 Kp=0 model. A quadratic fit is also given.

Comparing Kp=0 model values to corresponding quiet day (Kp ≤ 2) densities we concluded that the DTM model overestimates the density in the afternoon hours (Fig. 7). The diurnal variation in the DTM model is less symmetric and the maximum density occurs later than in reality. The MSIS 86 model proved to be better in this respect.

Every observation has been compared with corresponding real Kp model values in order to decide whether MSIS 86 is satisfactory under all conditions. Plotting all hourly mean residuals as a function of LST there is a minimum around 16^h indicating that even the original MSIS 86 is overcompensating the diurnal variation (Fig. 8) on quiet days in particular (see the middle part of Fig. 8). The result is in satisfactory agreement with observations on disturbed days (see upper part).

Using our quadratic correction to corresponding MSIS 86 with Kp=0 values (see Fig. 3), the hourly mean residuals have no systematic deviation from zero if plotted as a function of LST.

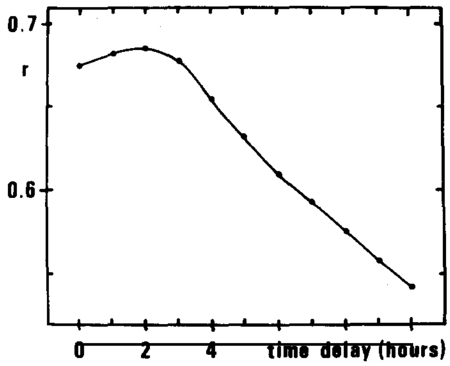

Fig. 4.
Correlation analysis to determine the time delay of $\Delta\varrho$ versus Dst for MSIS 86 Kp=0 model.

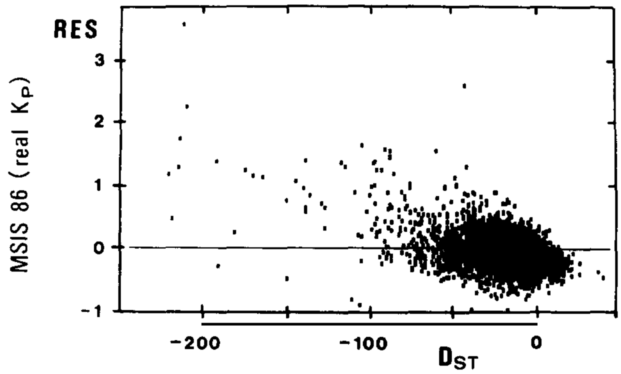

Fig. 5.
Residuals of MSIS 86 (real Kp) model versus Dst.

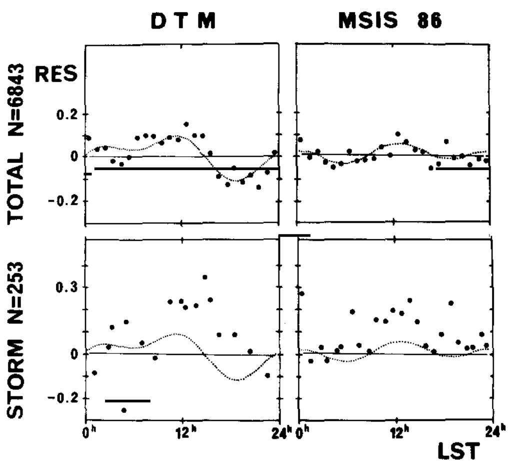

Fig. 6.
Diurnal variation of residuals for both DTM and MSIS 86 Kp=0 models. The two term Fourier curve was fitted to all points.

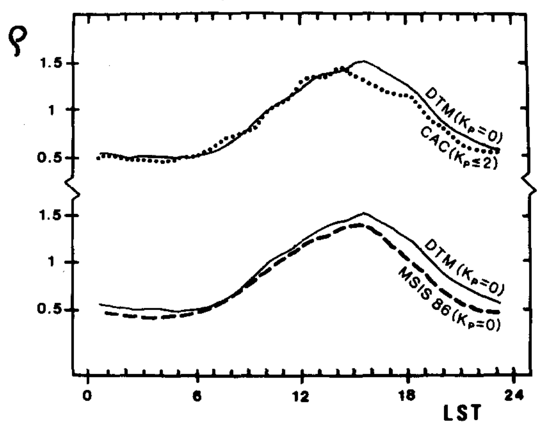

Fig. 7.
Diurnal density variation in models and in reality.

There is, however, some indication of at least 4 humps on the residual curve. After an analysis of the dependence of these humps on the level of geomagnetic activity /2/ we concluded that whatever classification of the geomagnetic activity had been used the humps appeared always around the same time. The reality of these humps is supported by Fig. 9 where the running mean of the residuals was plotted as a function of LST in different geomagnetic latitudes. The midnight hump is present only between $\pm 10^{\circ}$ geomagnetic latitudes. It has been assumed earlier /1/ that because of the good correlation of $\Delta\varrho$ to Dst the ring current is mainly responsible for the geomagnetic effect in the equatorial zone. Then the physical background of these humps may be connected with the bulge of the plasmasphere (around 18^h), with the compositional asymmetry of the ring current (around noon), and the injection zone (around midnight) respectively.

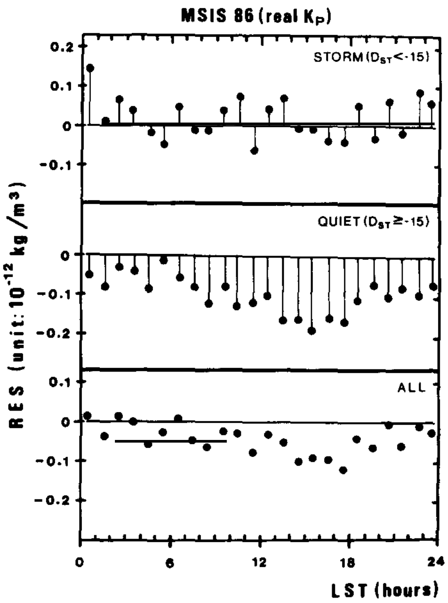

Fig. 8.
Diurnal variation of residuals of the original MSIS 86 model.

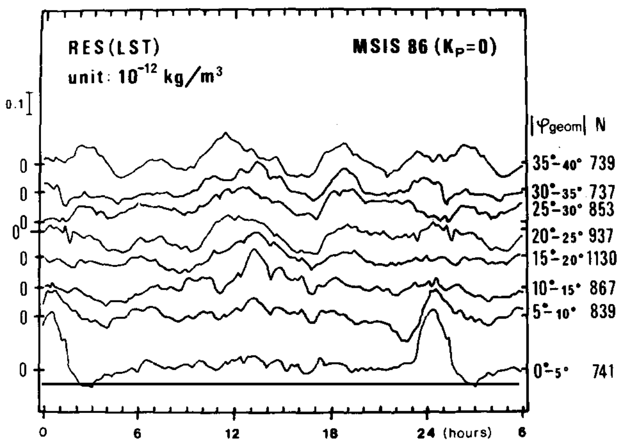

Fig. 9.
Diurnal variation of residuals of the corrected MSIS 86 Kp=0 model as a function of geomagnetic latitude.

CONCLUSION

In spite of the fact that the results refer only to one narrow band of the upper-atmosphere (near 400 km), there are evidences of an equatorial source of particle heating in addition to the well-known geomagnetic heating from auroral zone /1/, /3/, /4/. The energy of this equatorial heat source comes from the ring current and can be described by the sum of a Dst dependent and a LST dependent component. The coefficient of this diurnal term may change with the level of geomagnetic activity and the coefficients of both terms depend probably on geomagnetic latitude. Consequently the auroral input of energy, included exclusively in all thermospheric models, is not sufficient to characterize the geomagnetic effect.

Acknowledgement: Mrs. M. Nagy and Mr. P. Decsy are thanked for their able help in the preparation of this paper.

REFERENCES

1. E. Illés-Almár, I. Almár, P. Bencze, A. Horváth, Adv. Space Res. 9, 12, 205 (1989).
2. E. Illés-Almár, I. Almár, P. Bencze, A. Horváth, N. Jakowski, A. Jungstand, paper MC.4.3.11 (COSPAR, The Hague, 1990).
3. E. Illés-Almár, I. Almár, P. Bencze, A. Horváth, Nabl. ISZ in print (1990).
4. E. Illés-Almár, I. Almár, P. Bencze, A. Horváth, Z. Kolláth, Nabl. ISZ in print (1990).