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A NEW GEOMAGNETIC TERM FOR THE CIRA '86 MODEL AT LOW LATITUDES

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ABSTRACT

Total density data based on CACTUS microaccelerometer measurements — carried out between 400 and 600 km altitudes at low latitudes in a quiet solar activity period (1975-77) — have been compared to corresponding MSIS'86=CIRA'86 model values. The differences proved to be a double valued function of Kp but a single valued one of Dst. The residuals are a function of local solar time (LST), of geomagnetic latitude (φ_{geom}) and of the intensity of geomagnetic activity respectively. A new geomagnetic term is presented to replace the Kp dependent term in the otherwise unchanged model. The improved MSIS (iMSIS) model represents the observations better and hints more directly at the physical background of the geomagnetic phenomenon in the equatorial zone.

THE NEW GEOMAGNETIC TERM AT 400 KM

The data base and the method of investigation were described in previous publications /1,2,3/. Densities referring to the altitudes 400-403 km have been analysed as a first step. An improved MSIS model (iMSIS) was constructed, where $\Delta\varrho$ a new geomagnetic term, contains a Dst-dependent quadratic term as well as Dst and φ_{geom} dependent diurnal terms.
The following empirical formula was derived for 400 km (units: $\Delta\varrho$ 10^{-12} kg m^{-3}, LST hours):

$$\begin{aligned}
\Delta\varrho^{iMSIS} = {} & 0.0000370\ \mathrm{Dst}^2 - 0.00739\ \mathrm{Dst} + 0.0651 + \\
& + 0.0110 \sin[15(\mathrm{LST}+17)] - \\
& - 0.00408\ \mathrm{Dst} \sin|\varphi_{geom}| \sin[15(2\ \mathrm{LST}+5)] + \\
& + (0.0127 - 0.00159\ \mathrm{Dst} \sin|\varphi_{geom}|) \sin[15(4\ \mathrm{LST}+4)] + \\
& + 0.00116\ \mathrm{Dst} \sin|\varphi_{geom}| \left[(\mathrm{LST}-13.5)^2 - 6.25\right] + \\
& \qquad \text{if } 11 < \mathrm{LST} < 16 \\
& + 0.00424\ \mathrm{Dst} \sin|\varphi_{geom}| \left[(\mathrm{LST}-18.5)^2 - 2.25\right] + \\
& \qquad \text{if } 17 < \mathrm{LST} < 20 \\
& + 0.00648\ \mathrm{Dst} \cos(9\ \varphi_{geom}) \left[(\mathrm{LST}-24.5)^2 - 2.25\right] \\
& \qquad \text{if } 23 < \mathrm{LST} < 26 \text{ and } |\varphi_{geom}| < 10^\circ
\end{aligned} \qquad /1/$$

In Fig. 1 a global plot of all measured ϱ^{CAC} versus model ϱ values proves in general the superiority of the iMSIS model. In Fig. 2 $\Delta\varrho$ values are plotted as a function of LST and φ_{geom} respectively. The shaded areas represent the differences between measurements and the corresponding model values and are much smaller in the case of the new iMSIS model, e.g. the midnight and other local humps are better taken into account. Finally the results of two case studies are given in Fig. 3. The correspondence between measured and model curves is satisfactory in the case of iMSIS.

ANALYSIS OF DATA AT HIGHER ALTITUDES

At 400 km altitude we have found that the deviations between measured and corresponding Kp=0 model values ($\Delta\varrho$) are different functions of Kp during the recovery phase than outside it, while $\Delta\varrho$ values are a unique function of Dst (see lowest part of Fig. 4). Extending the plot to higher altitudes (with a suitably modified scale) into height intervals 425-428, 450-453, 500-503, 550-553, 597-600 km respectively, a similar conclusion can be drawn: Dst is the proper unambiguous parameter to be used in the new geomagnetic term at low latitudes. (In the case of the original MSIS'86 model some dependence of the residuals on Dst remained, however, at every height interval.) The $\Delta\varrho$(Dst) relation has been determined as a quadratic

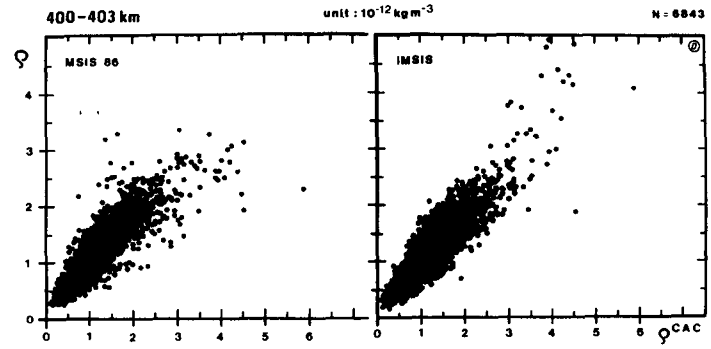


Fig. 1
Comparison of measured densities (CAC) with corresponding MSIS'86 and our iMSIS model values.

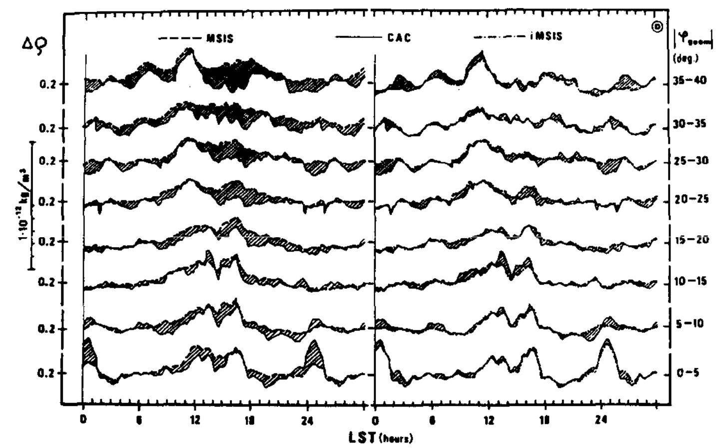


Fig. 2
Similar comparison as in Fig. 1 but data are separated according to local solar time and geomagnetic latitude. Running mean curves.

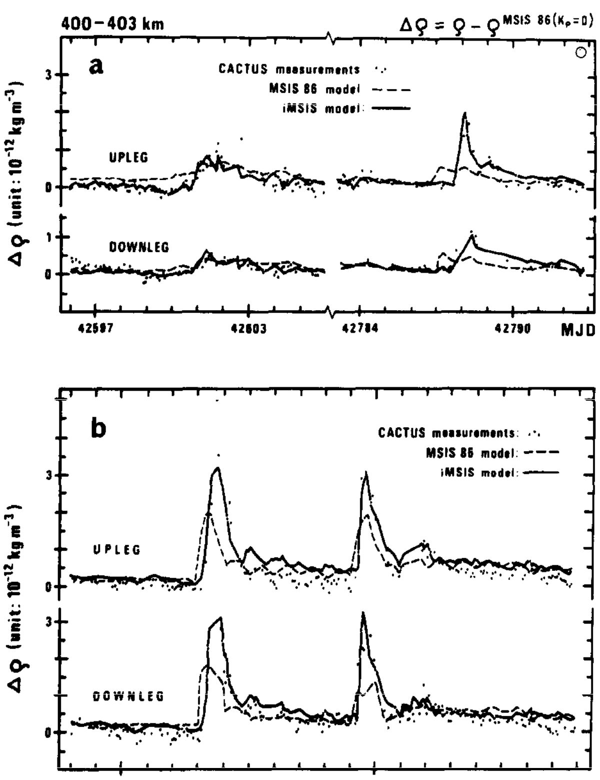


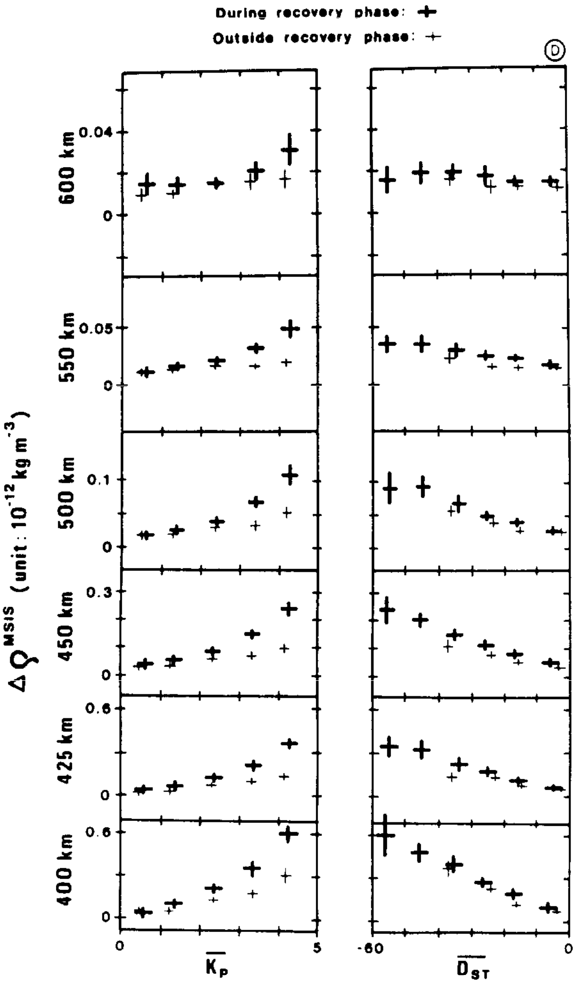
Fig. 3
Similar comparison as in Fig. 1 and 2. Case studies.

function at different altitudes separately (Fig. 5). The residuals were analysed as a function of LST and $|\varphi_{geom}|$. The characteristic course of the curves including excess densities at certain LST values can be followed up to 600 km altitude. A detailed investigation of this diurnal course of the residuals is given in another paper /4/.

THE ALTITUDE DEPENDENCE

The altitude dependence of the coefficients of the $\Delta\varrho$(Dst) quadratic function was used to derive a general simplified geomagnetic term for the 400-600 km height interval.
The result is the following:

$$\Delta\varrho^{*}=(1.522\ 10^{9}\ h^{-5.26}-2.772\ 10^{-6})Dst^{2}-$$
$$-(5.454\ 10^{25}\ h^{-10.67}+2.385\ 10^{-4})Dst+$$
$$+(9.822\ 10^{17}\ h^{-7.38}+8.665\ 10^{-3}) \qquad /2/$$



(The altitude dependence of the diurnal variation will be the topic of further investigations.) All 29353 CACTUS measurements were compared with the corresponding $\varrho^{*}=\varrho^{MSIS(Kp=0)}+\Delta\varrho^{*}$ values by defining an $f^{*}=\varrho^{CAC}/\varrho^{*}$ ratio and plotted as a function of altitude in the upper part of Fig. 6. A similar plot was constructed for the original MSIS model ($f^{MSIS}=\varrho^{CAC}/\varrho^{MSIS'86}$) in the lower part of Fig. 6. The scatter belonging to the present model is definitely smaller and there is no dependence on the altitude as in the case of the original MSIS model. Finally, as a case study, the observed density values belonging to two selected arcs (8 minutes each) were compared with corresponding model values

Fig. 4
$\Delta\varrho^{MSIS}$ (the difference between the measured densities and the corresponding MSIS'86 model values calculated with Kp=0) representing the geomagnetic term in itself is a characteristic double valued function of Kp during and outside the recovery phase of geomagnetic storms respectively while it is a unique function of Dst at every selected altitude.

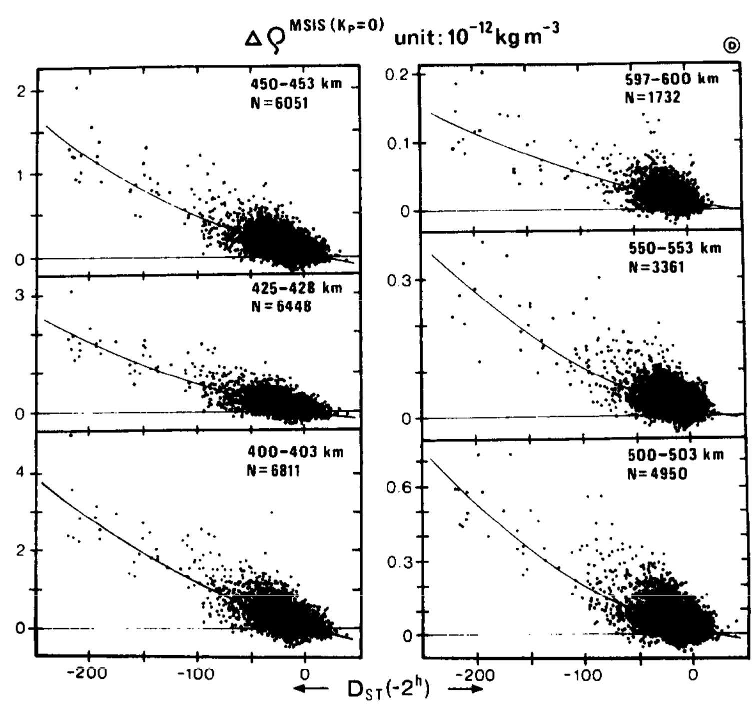


Fig. 5
Momentary values of $\Delta\varrho^{MSIS(Kp=0)}$ versus Dst with 2 hours time delay. The solid curves are separate quadratic fits for every height interval.

calculated by the original and by the present geomagnetic term during a large and a small geomagnetic disturbance respectively (Fig. 7). It has been clearly demonstrated that there is a significant improvement when using Equation 2 instead of the complete MSIS model. (It is to be mentioned that in this case Equation 2 was applied to measurements in between those layers originally used to derive the formula.)

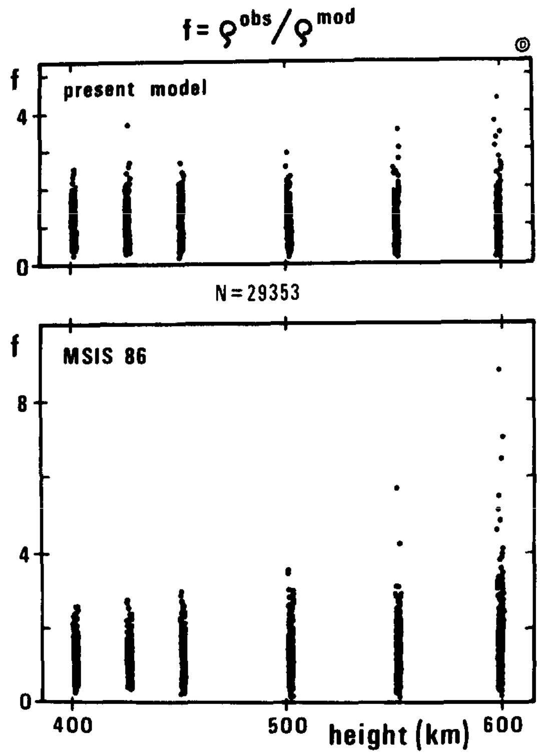


Fig. 6
Comparison of MSIS'86 and the present model to CACTUS measurements.

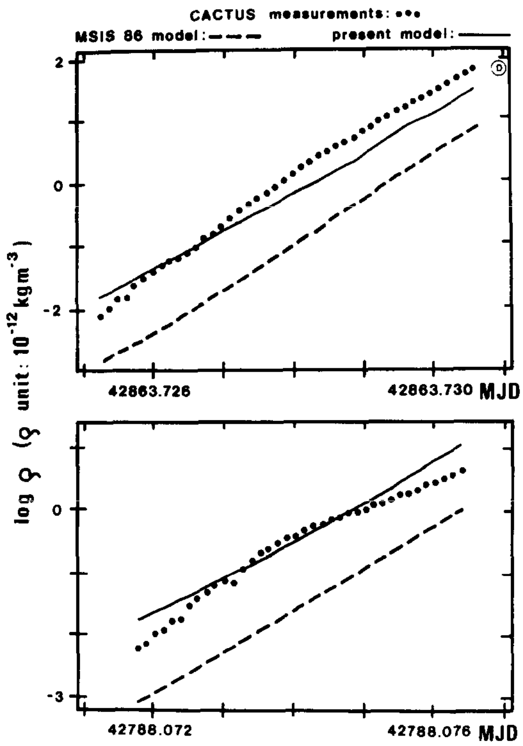


Fig. 7
Comparison of models on two selected arcs during a larger and a smaller geomagnetic disturbance as case studies.

CONCLUSION

Equation 1 includes an approximation also of the diurnal and the latitudinal variation of the geomagnetic term at 400 km but Equation 2 represents only the altitude dependence (from 400 to 600 km) of the main term of the geomagnetic activity effect. In spite of the fact that the results refer only to low latitudes and to a relatively quiet period of solar activity, we can conclude that the new geomagnetic term represents a significant improvement and hints at the physical background. The original MSIS model generally overestimates density values by 8-10% in quiet periods and underestimates them by 6-8% on disturbed days (see Fig. 7) or even by 30% in special cases, belonging to certain LST values.

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