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INVESTIGATION AND MODELLING OF AN IMPROVED GEOMAGNETIC TERM FOR THE CIRA '86 MODEL AT LOW LATITUDES

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

* *Konkoly Observatory, H-1525 Budapest Pf 67, Hungary*
** *Astronomical Institute, Russian Academy of Sciences, Moscow, Russia*

ABSTRACT

Total density data based on CACTUS microaccelerometer measurements — carried out between 230 and 700 km altitudes at low latitudes in the period 1975-79 — have been compared to corresponding MSIS'86 = CIRA'86 model values. A Dst dependent geomagnetic term is presented with height dependent coefficients (hMSIS) to replace the inadequate Kp dependent term in the otherwise unchanged model. This new geomagnetic term is the generalisation of the previously published function to altitudes below 400 km.

INTRODUCTION

Kp or ap are exclusively used to represent the geomagnetic activity effect in all comprehensive models of the neutral upper atmosphere, although it has been pointed out by several authors since many years that it is an inappropriate parameter. In previous papers we gave a detailed demonstration of the fact that the dependence of the $\Delta\varrho$ geomagnetic term on Kp or ap is systematically different in the recovery phase of a geomagnetic disturbance therefore the $\Delta\varrho$ density increase connected with the geomagnetic activity is a double valued function of Kp /1/. It has been suggested in /2/ that at least at low and middle latitudes the Dst geophysical parameter is a more appropriate index of the geomagnetic activity: a simple, monotonous and single valued function of Dst describes the density variations almost perfectly in any phase of the geomagnetic activity.
As a first step an empirical $\Delta\varrho$(Dst) function has been derived for an altitude near 400 km, taking also into account all regular LST-dependent terms of the density variation to replace the MSIS geomagnetic term in an otherwise unchanged model (improved MSIS = iMSIS-model). Fig. 1 demonstrates the improvement connected with this iMSIS-model. In Fig. 1 the whole

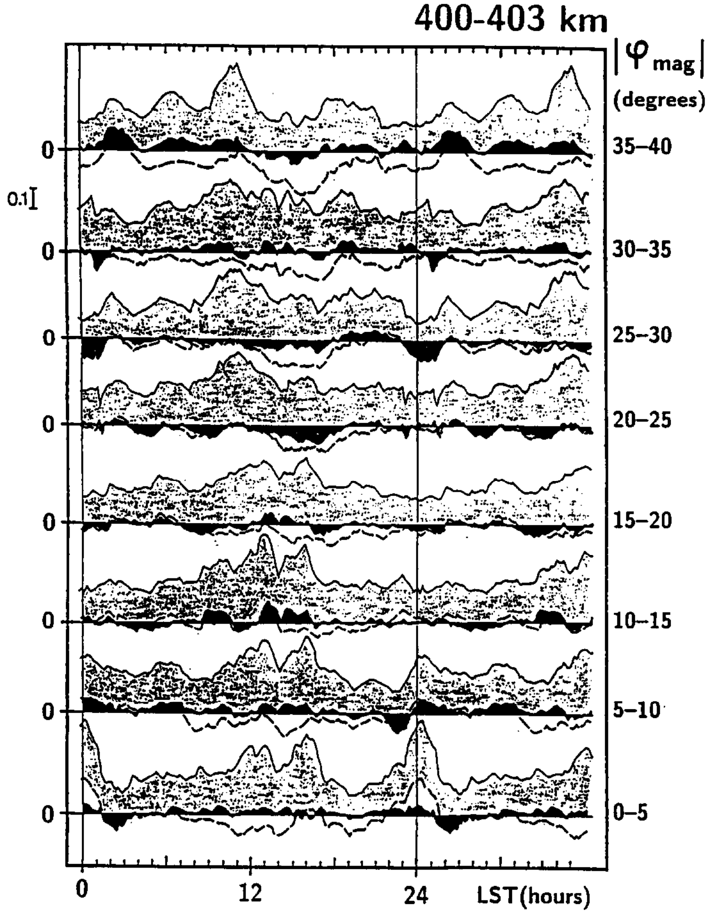

Fig.1. Density increase $\Delta\varrho$ (half-tone shaded area) plotted as a function of LST and geomagnetic latitude in the height interval 400-403 km. MSIS model residuals are represented by dashed lines, iMSIS model residuals in black.

$\Delta\varrho$ density increase (to be modelled and corresponding to the geomagnetic activity effect, half-tone shaded area) has been plotted as a function of LST and the geomagnetic latitude in the height interval 400-403 km. The MSIS'86 model /3/ residuals are indicated by dashed lines, while that of our iMSIS model by black areas. It is obvious that the residuals are definitely smaller in the case of our model, when the Dst dependent term was used.

As a second step a simpler Dst function — without the LST dependent terms — has been suggested for the 400 to 600 km height interval. It has been demonstrated that the addition of this Dst term (with height dependent coefficients) to the basic MSIS (Kp=0) model leads to an improved empirical model (hMSIS) describing the actual density measurements of the French CACTUS microaccelerometer better than the original MSIS (COSPAR) model. Fig.2 demonstrates the correctness of this height dependent model between 400 and 600 km for selected 24 hours storm time periods just after the 21 deep Dst minima in the time and height interval used for the determination of the model.

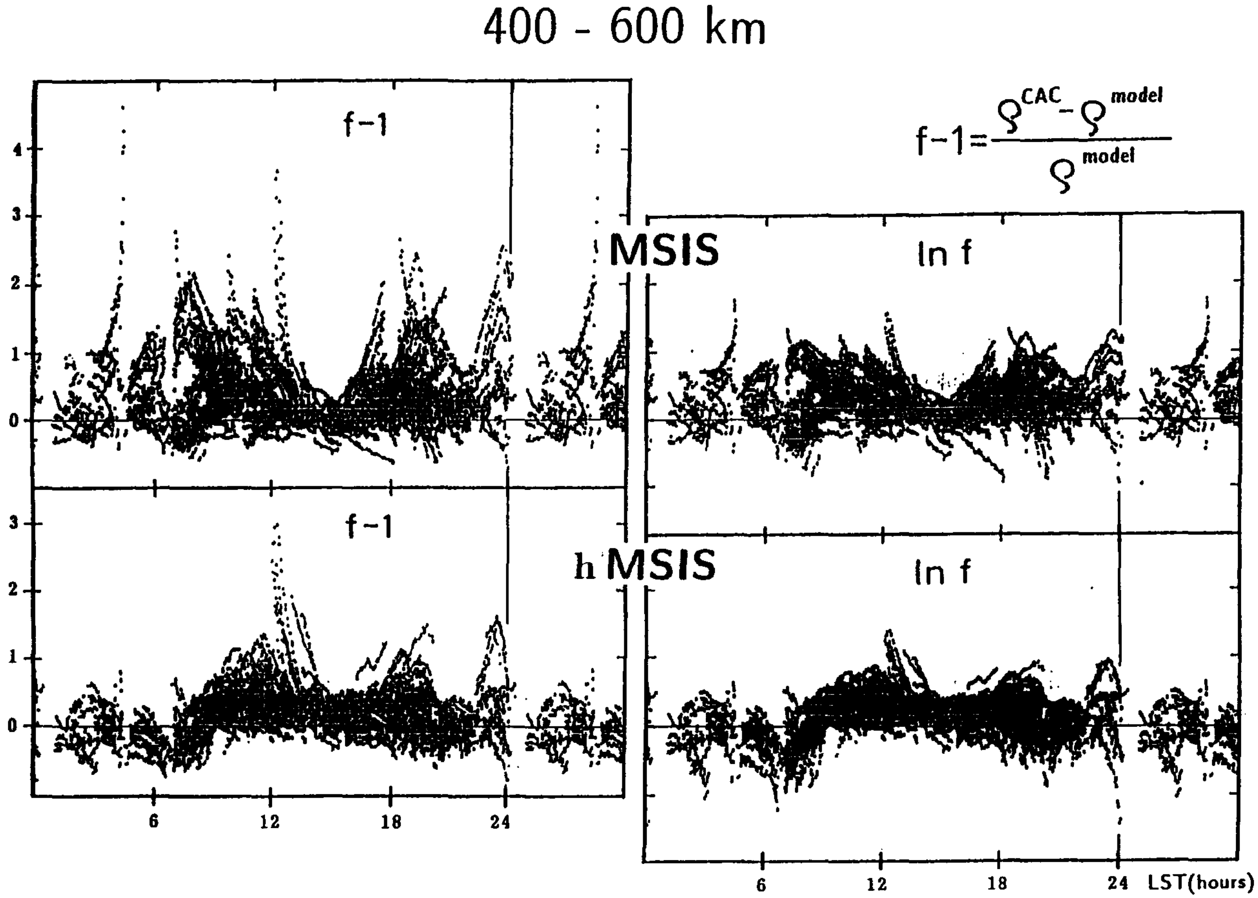

Fig.2. Residuals (f-1) of the CACTUS measurements with respect to the MSIS'86 and the improved hMSIS models respectively. 21 days of deep Dst storm periods have been plotted versus LST in the 400-600 height interval.

GENERALISATION OF THE MODEL

There are three possible directions to control the general use of this height dependent model instead of MSIS in modelling the geomagnetic effect: since it was based on the very accurate, but limited (in space and in time) observational material of the CACTUS micro-accelerometer /4/, the empirical Dst term can obviously not be considered automatically correct outside the limits of determination in height (400-600 km), in geomagnetic latitude (not larger than 40°) and in solar activity level ($S_{10,7}$ between 70 and 100).
Due to the i=30 degree inclination of the satellite, the density variations could not be investigated at higher latitudes. The height limits can be somewhat broadened as CNES made us the complete material — even below 270 km (in the very last days of the satellite's lifetime) and above 600 km (up to 700 km) — available. Finally the third possible extension of the model was the inclusion of a new time interval (1977-79) when the level of solar activity was significantly higher ($\overline{S_{10,7}}$=160) with frequent and superposed geomagnetic activity and correspondingly enhanced density maxima.

The height dependence in the $\Delta\varrho$(Dst) term of the 400 to 600 km model is not satisfactory in the extended height interval, below 300 km in particular. Therefore quadratic Dst functions have been fitted also in the extended height interval for each 10 km. Corresponding ln a, ln b and ln c coefficients of the quadratic Dst functions proved to be linear in the lowest height intervals (Fig. 3), suggesting to use an exponential function there. The empirical function gives the same results between 400 and 500 km as the previous one. So a simple combination of the two Dst functions has been used below and above 400 km.

$$\Delta\varrho = 0.005874 \exp(-0.01334\ h)\ Dst^2 - 16.677 \exp(-0.01865\ h)\ Dst + 213{,}37 \exp(-0.01992\ h) \quad \text{for } h \le 400 \text{ km} \quad (1.a)$$

(1)

$$\Delta\varrho = (1.522\ 10^{9}\ h^{-5.26} - 2.772\ 10^{-6})Dst^2 - (2.835\ 10^{20}\ h^{-8.67} + 4.151\ 10^{-5})Dst + (9.822\ 10^{17}\ h^{-7.38} + 8.665\ 10^{-3} \quad \text{for } h > 400 \text{ km} \quad (1.b)$$

The corresponding hMSIS model can replace the Kp dependent term in the otherwise unchanged MSIS model (Fig. 4).

There is, however, an interesting and definite downward turn in the observed ln a and ln c parameters below 250 km as well as some deviation from a straight line in the case of ln b. This phenomenon can be connected to the energy deposition by particle precipitation /5/. These deviations were not taken into account in our model because of the insufficient number of points in these extremely low altitudes. There is another deviation above 600 km, as the scatter of the observed values increases considerably. We have no suggestion yet to explain these phenomena, therefore the hMSIS model is restricted to the height interval 250 - 600 km.

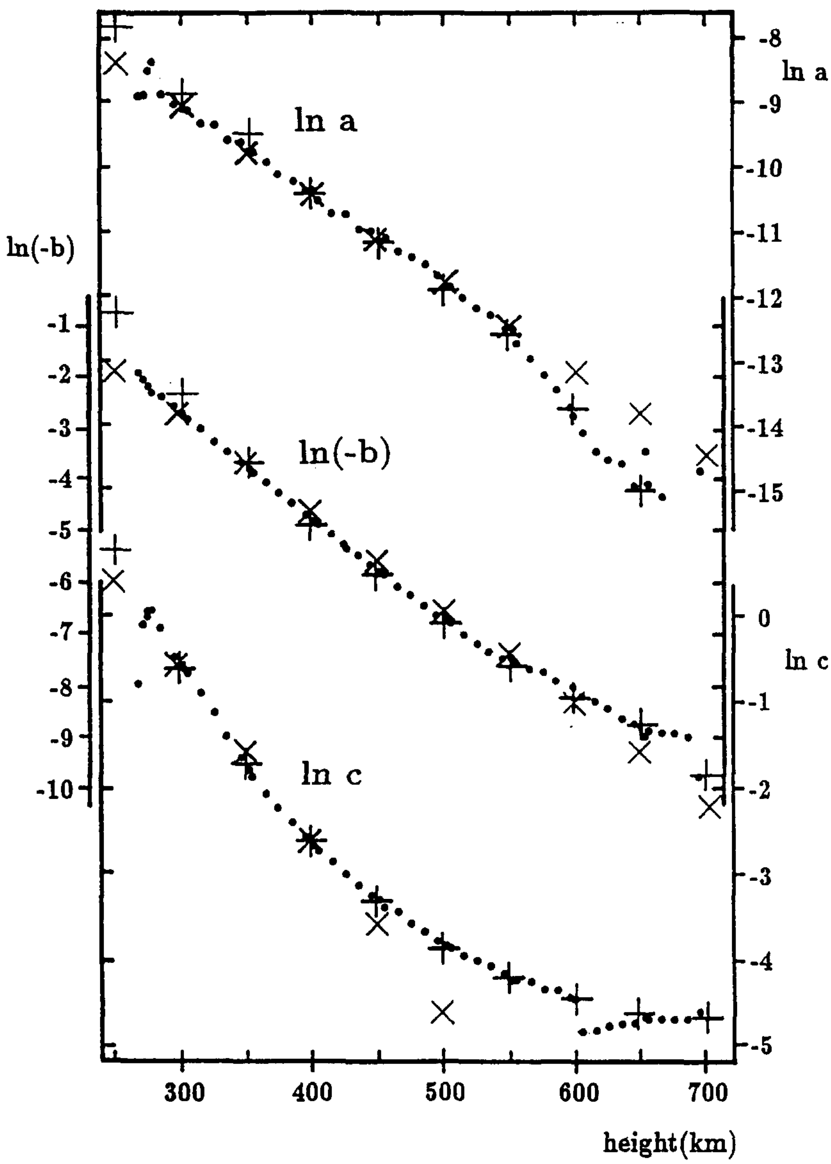

Fig.3. Coefficients of the (Dst) quadratic functions at different altitudes. • — derived from observations, x — calculated from equation (1a), + — calculated from equation (1b). Heavy symbols indicate coefficients accepted by the hMSIS model.

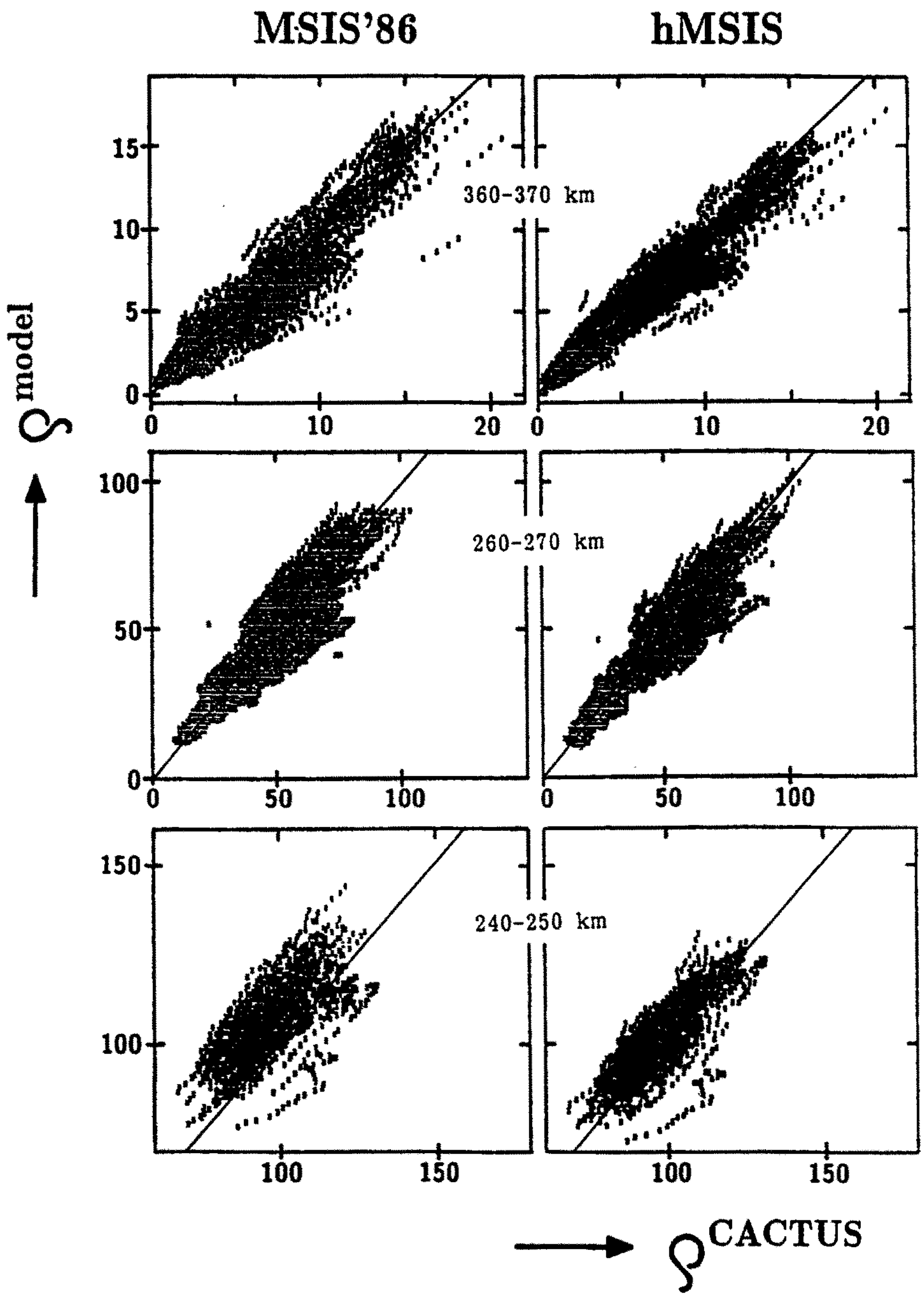

Fig.4. Demonstration of the improvement corresponding to the hMSIS model at lcw latitudes. Observed and calculated (by MSIS and hMSIS models respectively) density values are compared at different altitudes.

The generalisation of the hMSIS model to higher levels of solar activity proved to be a more difficult problem. In this relatively short time interval the number of observations is not quite sufficient and there are excess density peaks at every altitude which are not really connected to geomagnetic activity. Their appearance is probably due to some unknown parameter not taken into account in present atmospheric models. Other unmodelled density variations have been thoroughly investigated in another paper /6/.

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