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DENSITIES FROM THE CACTUS ACCELEROMETER AS AN EXTERNAL TEST OF THE VALIDITY OF THE THERMOSPHERIC MODELS

J. L. Falin,[1] G. Kockarts[2] and F. Barlier[1]

[1]*Centre d'Etudes et de Recherches Géodynamiques et Astronomiques, Grasse, France*
[2]*Institut d'Aéronomie Spatiale de Belgique, Bruxelles, Belgium*

ABSTRACT

Total density data were obtained from the accelerometer CACTUS on board of CASTOR-D5B 1975-39A. Numerous and precise data were obtained between 250km and 600km altitude in the equatorial region (±30° latitude) for a period extending from May 1975 (minimum of solar activity) to February 1979 (already important solar activity). Since CACTUS data have not yet been used for the construction of empirical thermospheric models, a significant part of the data file is compared with several thermospheric models in order to provide an external test of the reliability of such models. Standard deviations of the order of 20% are apparent. The most significant differences extend over a few weeks and cannot be represented by the geophysical indices as they are presently used in the empirical models. Such an experimental fact suggests that the mathematical and physical aspects of the empirical models should be refined in order to achieve a better representation of physical reality.

INTRODUCTION

Several three dimensional thermospheric models have been recently developed by using satellite drag data, mass spectrometer measurements, optical data and incoherent scatter results [1-6]. Although these empirical models represent significant progress in the representation of the terrestrial thermosphere, a systematic comparison [7] has shown that important differences are present, particularly for extreme geophysical conditions.

The total density data obtained with the CACTUS accelerometer on board the CASTOR-D5B satellite provide an excellent means to test the validity of specific models and to stress the most important deviations. Data are obtained between 250 and 600km altitude with an accuracy of a few percent. The time resolution is 2.8s and the presently available data cover a period of 2.5 years. The present analysis deals with systematic variations covering periods of the order of a few weeks. Very short fluctuations of the order of a few seconds have already been analyzed [8] as well as problems related to geomagnetic activity [9].

DATA ANALYSIS AND GLOBAL COMPARISON

For each observed density ρ(CACTUS) and each model density ρ(MODEL) it is possible to compute a correction factor $f = \rho(\text{CACTUS})/\rho(\text{MODEL})$. Using 130,000 points uniformly distributed over the period 06/30/75 to 12/30/77 one obtains an histogram of the decimal logarithm of f as shown in Fig.1 for three models, i.e.DTM [5] (adjusted model in order to take into account the under-estimation of high geomagnetic activity effects [7]), MSIS [2-3] and J71 [10], the last model being chosen since it has been widely used and since it takes much less computer time than the most recent one J77 [1]. Although CACTUS data have not been used in the construction of the empirical models, Fig.1 indicates a global agreement between the observed total densities and the model values with a standard deviation of the order of 20%. Such an external test is satisfactory but it gives no insight into any particular phenomenon which is not represented by any available model. Therefore, we have taken advantage of the fact that the CACTUS accelerometer data provide total densities between perigee at 250km and 600km altitude along each ascending and descending part of every orbit. Between 600km altitude and apogee height (1200km) radiation pressure effects become more and more predominant. Moreover, density determinations at 450km correspond to a local time difference of 7 to 8 hours and to a latitudinal change of 10° to 20° between the ascending and the descending parts of a specific orbit.

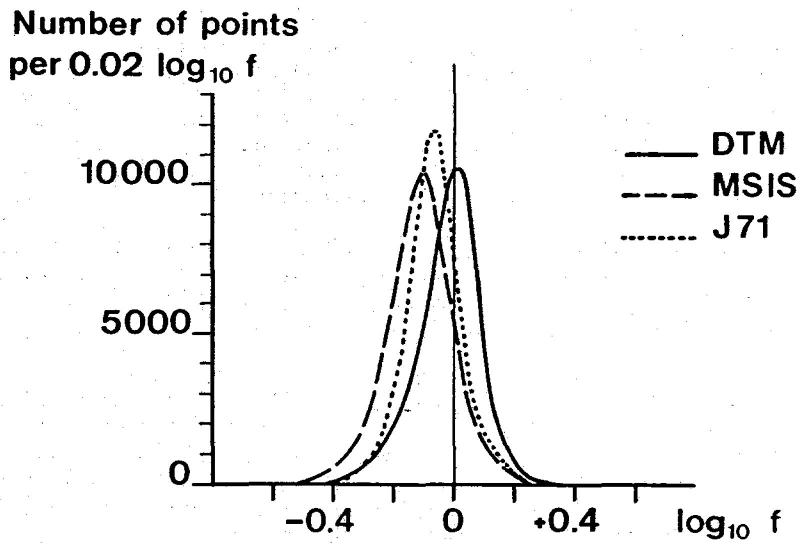

Fig. 1 - Histogram of f = ρ(CACTUS)/ρ(MODEL)for three models. DTM(solid line), MSIS (dashed line), J71 (dotted line)

As a consequence, common phenomena observed at different heights during one orbit cannot be attributed to local time variations or to latitudinal variations. The present analysis is made for three standard altitudes, i.e. 270km, 350km and 450km. Observed densities along each orbit are reduced to a standard altitude by using a vertical model successively near perigee and in the height ranges 300km to 400km and 400km to 500km. Fig.2 shows observed total densities and model densities DTM [5] (for the perigee height) as well as the correction factor f = ρ(CACTUS)/ρ(DTM) as a function of time from MJD 42820 to 42970 (February to July 1976), i.e. a period of 150 days. The geomagnetic index K_p and the solar decimetric flux F in $10^{-22} Wm^{-2} Hz^{-1}$ are also indicated as well as the latitude and the local time at perigee. For the altitudes 350km and 450km only the correction factor f is shown. However a distinction is made between ascending (upleg) and descending (downleg) parts of each orbit in order to analyse their common features. Since the orbital period of CACTUS-D5B is of the order of 100 min a specific altitude can be sampled 14 times per day for upleg and downleg crossing. It appears that the correction factor is almost constant during a whole day. This implies that any departure of f from unity in Fig.2 is neither a universal time nor a longitudinal effect.

DETAILED COMPARISON

Although the histogram of the correction factors f, Fig.1, resembles a gaussian curve, these factors do not vary randomly on a time scale of a few weeks. They are characterized by apparent oscillations with a recurrence of the order of 20 to 30 days corresponding to the times of low solar activity, Fig.2. The minima appear in phase with the minima of the solar flux F and the differences of the factors f are greatest for the solar flux minima. This general aspect is found when other empirical models are used, such as J71 and MSIS. The amplitude of the oscillations increases with height and this fact could be interpreted as a temperature effect. Minima values of the correction factors correspond to an observed total density decrease of the order of 50% with respect to the model value at 450km altitude and could be interpreted in terms of a thermospheric temperature decrease of about 50K. In the model, the thermospheric temperature variation $\Delta T(K)$ related to the solar activity by the indicator $\bar{F}$(mean of F over three months) and $(F-\bar{F})$, is given by : $\Delta T = a\bar{F} + b(F-\bar{F})$ with $2.7<a<3.6$; $1.2<b<1.4$. During low solar activity $\bar{F}$ is nearly constant and $(F-\bar{F})$ is less than 10 units, the necessary temperature variation (50K) could not be represented by this formula. Very different values of the coefficients a and b should be used for solar minimum activity. However, the values above are satisfactory for medium solar activity (for example, $\bar{F} = 140$). Other solar indicators could be also used with advantage.

Another period of 150 days following the period of Fig.2 is presented in Fig.3 and corresponds to very small variation of solar flux. The oscillations of the factors f are smaller and in several cases nonexistant. This is also the way that the observed oscillations in Fig.2 are related to the variations of solar flux.

However, all features cannot be explained by this effect; certainly other processes are needed to interpret the behaviour among the different curves in Fig.2 and Fig.3, such as diurnal and annual variation, geomagnetic activity or other phenomena. Our purpose was only to draw attention to a particular point related to the minimum of the solar activity for which empirical representation must be revised. Another purpose is also to emphasize that we need to look carefully at all these different features before revising the thermospheric model.

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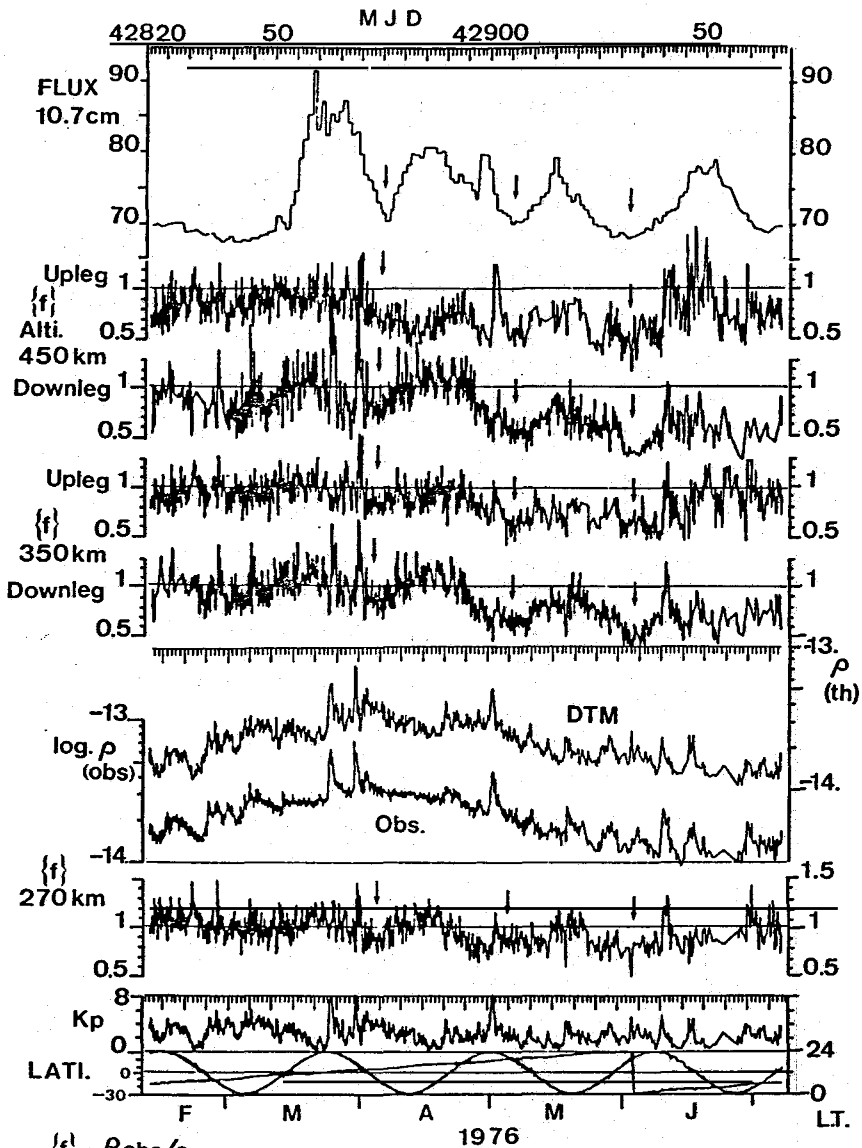
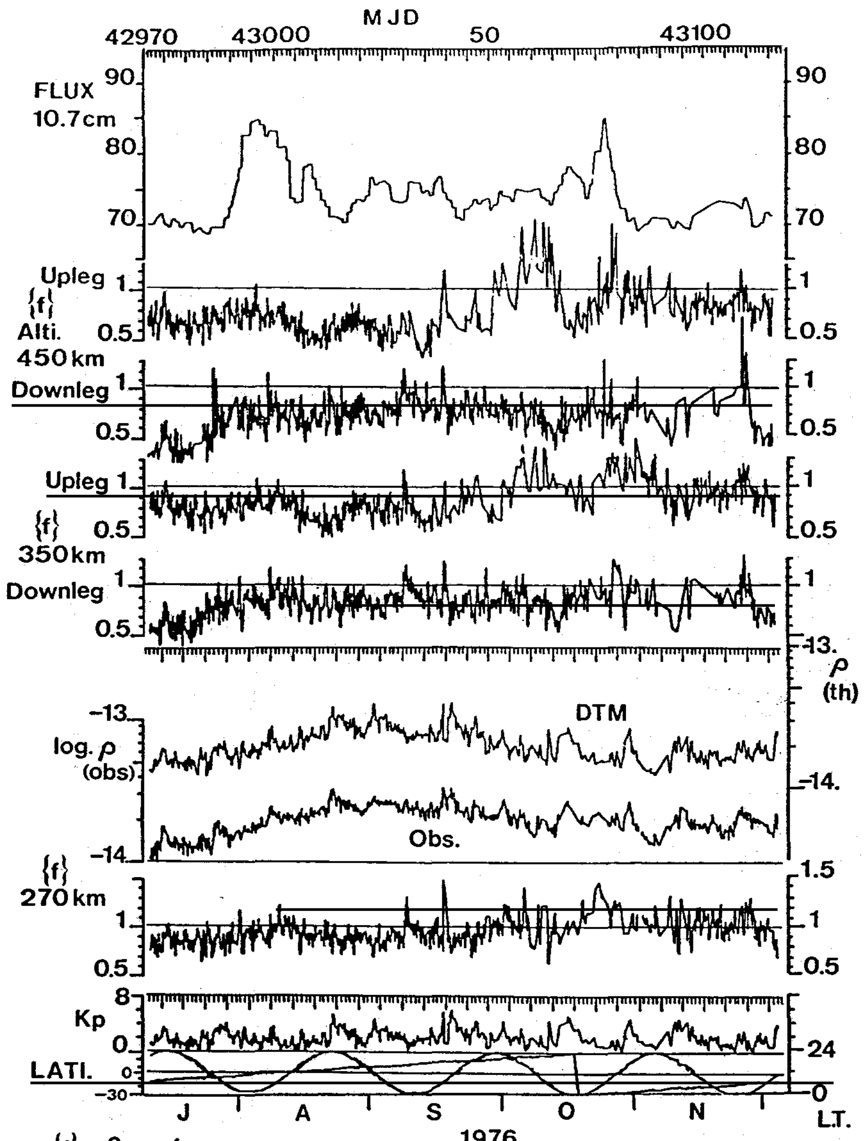


FIG. 2



{f}= ρ_{obs}/ρ_{theo} -DTM-

FIG. 3