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INVESTIGATION OF THE DENSITY WAVE ACTIVITY IN THE THERMOSPHERE ABOVE 220 KM

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ABSTRACT

Based on CACTUS (Capteur Accélérométrique Capacitif Triaxial Ultra Sensible) microaccelerometer measurements it has been demonstrated that – after taking into account all effects included in the MSIS'86=CIRA'86 *(COSPAR, 1988)* model - there are residual fluctuations in the density of the upper atmosphere much larger than that the accuracy of the measurements can account for. These fluctuations are attributed to some kind of wave activity *(Illés-Almár, 1993, Illés-Almár et al. 1996a)*. The average deviations from a model are considered as a measure of the amplitude of the waves in the atmosphere and are analysed as a function of geomagnetic coordinates, altitude and local solar time, in order to identify possible wave sources either in the lower lying atmosphere or in the thermosphere/ionosphere system. As a first step, the present investigation intends to make a map of the wave pattern by this method.

MEASUREMENTS AND METHOD

Thermospheric density data (ρ) were derived from the CACTUS microaccelerometer measurements *(Barlier et al. 1975)*. The time interval of the measurements was 1975-1979 (low and rising solar activity), the height interval 220-700 km, the geomagnetic latitude (φ_{geom}) varied between +40° and -40° as the inclination of the orbit was only 30°.

The model used was our new upper atmospheric model *(*dMSIS, *Illés-Almár et al. 1996b)*:

$$\rho^{\mathrm{dMSIS}} = \rho^{\mathrm{MSIS'86}} + \rho^{\mathrm{MSIS'86}}\,[b(h)D_{ST} + c(h)]$$

where $b(h) = A_b + B_b \cdot h + C_b \cdot h^2 = 0.00719138 - 4.88831 \cdot 10^{-5} \cdot h + 5.12381 \cdot 10^{-8} \cdot h^2$
$c(h) = A_c + B_c \cdot h = -0.21 + 0.000355 \cdot h$
Dst is the axisymmetric component of the geomagnetic disturbance field
the height (h) is measured from the surface of the Earth in km.

The average deviation was defined by: $$\delta = \frac{\sum\left|\overline{\ln f} - \ln f\right|}{n}$$ where $f = (\rho^{\mathrm{CACTUS}} / \rho^{\mathrm{model}}) + 1$

and has been considered as a measure of the amplitude of the waves, especially of internal gravity waves in the atmosphere.

In different heights the δ values were calculated in appropriate altitude intervals to assure a more or less similar number of points for averaging. Quiet and storm time data were selected on the basis of the Dst curve (daily mean of hourly Dst values as a function of time). Quiet time data contain 29 time intervals of 100 days total length where the Dst curve remained constant in the vicinity of the maximum value at least for several days. Storm time data contain the observations of the 96 hours (4 days) following Dst minima of 21 quick geomagnetic disturbances where the descending branch of the Dst curve was steep enough to reach the Dst minimum in less than two days.

The δ average values have been investigated as function of different parameters:

- geomagnetic activity level
- altitude
- local solar time (LST)
- latitude (φ) in 5° intervals
- geomagnetic latitude
- season.

RESULTS

As can be seen on Figure 1 and 2, the height dependence of δ is an almost monotone increasing function of altitude that is generally steeper above 550-600 km.

As regards the dependence on geomagnetic activity, the δ values are dominantly larger on disturbed days under 550-600 km than on quiet days, but the tendency is reversed over 550-600 km (except in spring and in autumn).

The dependence of δ on latitude is demonstrated in Figure 1 for disturbed and quiet days separately. There is no dependence on latitude on quiet days below 500 km while the situation is different on disturbed days.

The δ values separated according to season (taking into account measurements 15° away from the equator only) are plotted on Figure 2 as a function of height. Below 550-600 km the average deviation is always larger on disturbed days while above 550-600 km the average deviation is larger on quiet days in the winter and summer periods but smaller in spring and autumn.

In Figure 3 there is a plot of δ as a function of LST for different heights for disturbed and quiet days separately. There is a definite dependence on LST with a maximum in the early hours and with a minimum in the daytime both for quiet and for disturbed days. On disturbed days, however, δ values are larger than on quiet days except in the midnight hours at higher altitudes.

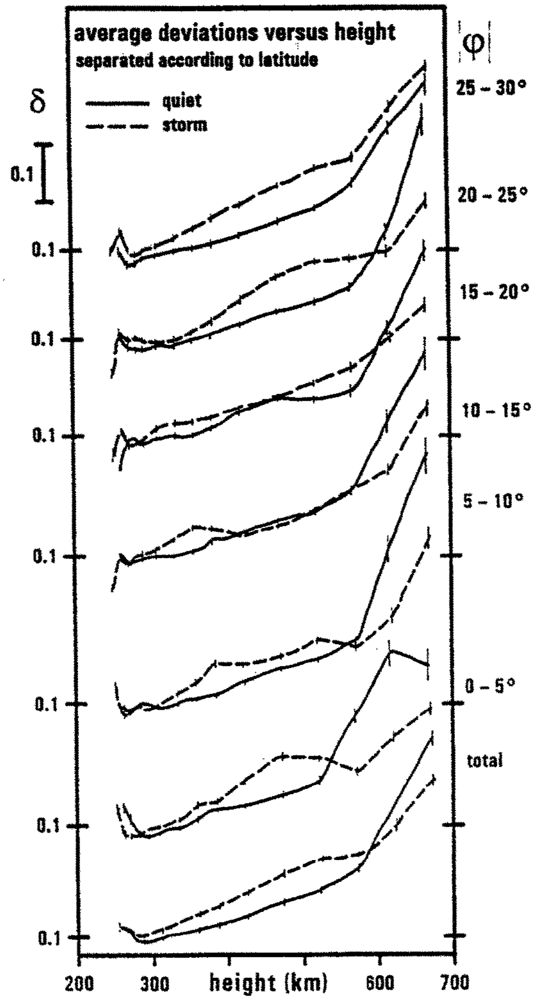

Fig.1. The height variation of the wave amplitude for different latitudes on quiet and disturbed days respectively. Error bars ±1σ are indicated.

DISCUSSION AND CONCLUSIONS

The existence and parameters of internal atmospheric gravity waves in the neutral upper atmosphere at heights above 200 km have only sporadically been studied. For the study of the density deviations it was reasonable to follow the idea of *Hines (1960)*, according to which the fluctuations of the wind speed, called the irregular component, was investigated assuming that it is related to atmospheric gravity waves. Considering the interpretation of the CACTUS data, it is necessary to take into account the sources of these internal gravity waves. It has been found that internal gravity waves have sources not only in the troposphere, but also in the upper atmosphere (for example *Gossard, 1975)*. It has also been revealed by *Booker (1979)* that gravity waves could play a role in the generation of irregularities in the F-region of the ionosphere (spead F). Recently, investigations at low latitudes have indicated that F-region irregularities generally occur when irregularities are observed at the altitude of the electrojet *(Blanc et al., 1996)*. Other studies have shown that at low latitudes there is a strong ion-neutral drag due to the plasma drift affecting the motion of the neutral atmosphere in the F-region during geomagnetically disturbed periods *(Fagundes et al., 1996)*. Moreover, during geomagnetic storms the zonal temperature gradients are varying and not well expressed possibly because of the occurence of gravity waves. It is to be noted that between 300 and 550 km the seasonal variation of the magnitude of the fluctuations indicates a summer maximum in geomagnetically quiet times and a winter maximum in geomagnetically disturbed times (Figure 2). The fact that the average deviation is generally larger on disturbed days hints at the conclusion that the increasing wave amplitude must be somehow connected to the geomagnetic activity effect – at least below 550 km.

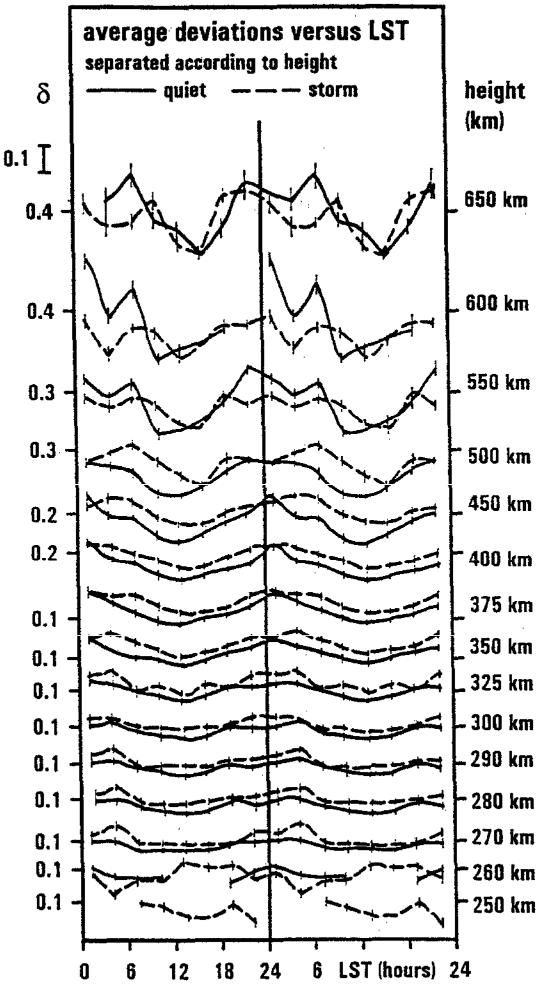

Fig. 3. The diurnal variation of the wave amplitude for different altitudes on quiet and disturbed days respectively. The 0-24 hours interval is repeated twice to recognize the night time behaviour more clearly. Error bars ±1σ are indicated.

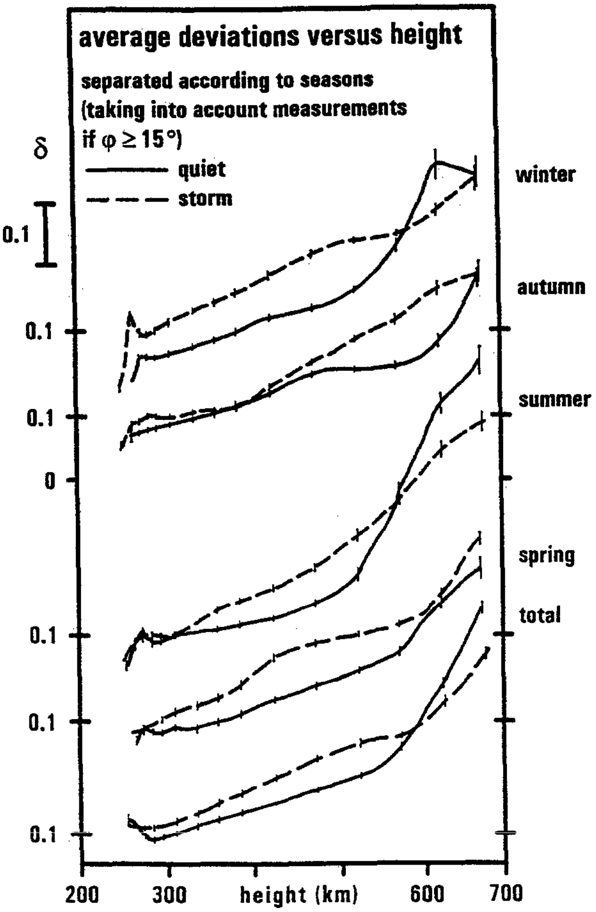

Fig. 2. The height variation of the average deviations for different seasons on quiet and disturbed days respectively. Error bars ±1σ are indicated.

Gravity waves can be generated in the upper atmosphere above 100 km by wave-wave interaction as a result of the nonlinearity of atmospheric tidal waves. Further source of gravity waves at low latitudes can be the fluctuations of the equatorial electrojet *(Knudsen, 1969, Chimonas, 1970)*. Our results indicate that in the height range between 300-550 km there may be two different sources of the density fluctuations. One of the sources is limited to equatorial latitudes < 15°, the other occurs at latitudes >20° (Figure 1). The equatorial sources can be fluctuations of the intensity of the equatorial electrojet. Namely, the waves generated by the intensity fluctuations of the equatorial electrojet with periods from 40 to 50 minutes propagate both upwards and horizontally away from the source *(Knudsen, 1969, Chimonas, 1970)*.

The source appearing in the latitudinal range 20° – 30° might be attributed to wave-wave interaction due to the diurnal tide becoming nonlinear, or the residuals are small scale and small amplitude TIDs. As it is known, small scale TIDs as gravity waves can be attributed to phenomena in the troposphere (meteorological fronts, jet streams etc.), but the propagation of which is affected by the wind system and attenuation in the stratosphere. Thus, the appearance of small scale TIDs does not depend on geomagnetic activity, they are always present. The same argument can be brought up in connection with the wave-wave interaction related to the nonlinearity of the diurnal tide. The probability of both wave-wave interaction and small scale TIDs show diurnal changes. There are signatures of both of these sources, as the amplitude of the residuals indicates diurnal type variations (Figure 3). The amplitude of the fluctuations is, however, larger in geomagnetically disturbed periods and the disturbed daytime values are also larger than the corresponding quiet time values. It seems that the residuals attributed to gravity waves are not related to atmospheric disturbances originating in the auroral zones, since their magnitude does not increase with increasing geomagnetic latitudes above 30°. The fact, however, that the amplitude of the fluctuations increases to 30°, hints at a possible connection rather with the equatorial ionospheric anomaly. In this case, namely, the fluctuations can be related to the descending branch of the plasma stream in a narrow latitudinal range at about 20° on both sides of the equator and in the time interval from 06 to 20 h. The development of the equatorial anomaly depends on the eastward zonal electric field, which in turn is related to geomagnetic activity through the z component of the interplanetary magnetic field *(Fejer, 1986)*.

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