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I. Almár (1), **E. Illés-Almár** (1) **and P. Bencze** (2)

EFFECT OF GEOMAGNETIC STORMS ON THERMOSPHERIC NEUTRAL DENSITY AND WAVE ACTIVITY

(1) Konkoly Observatory, Hungarian Academy of Sciences, H-1525 Budapest P.O.B. 67 Hungary, FAX: (36) 12754668,
e-mail: almar@ogyalla.konkoly.hu
(2) Geodetic and Geophysical Research Institute, Hungarian Academy of Sciences, Sopron, Hungary

ABSTRACT

The reaction of the neutral upper atmosphere on geomagnetic heating is demonstrated through two phenomena: one of them is the variation of the atmospheric density, the second is the changing character of the wave pattern, present in the upper atmosphere, during geomagnetically disturbed days with respect to quiet periods. In the first case density values were derived from CACTUS micro-accelerometer measurements, while in the second case the investigation of the wave activity was based on the San Marco V accelerometer data as well. Since the geomagnetic term of the CIRA '86 (MSIS '86) model proved to be a double valued function of Kp (Ap), a model correction was suggested with an added Dst-dependent term. The new dMSIS model, based on the measurements of a quasi equatorial satellite, refers to the equatorial zone and hints at the existence of an equatorial heat source in addition to the auroral heating. As regards the wave activity in the thermosphere, our investigation demonstrated that the average deviation of the model residuals (representing the mean wave-amplitude) changes with the level of the geomagnetic disturbances, e.g. being higher in quiet perods at high altitudes.

OBSERVATIONAL MATERIAL

CACTUS data

Thermospheric density data (ρ) were derived from the CACTUS microaccelerometer measurements:

- time interval: 1975-79 (1304 days)
  low and rising solar activity!
- height interval: 220-700 km
- inclination: 30 degree
- geomagnetic latitude interval:
  +40 to -40 degree
- total number of observations: 1 101 564
- number of disturbed (storm) periods,
  when Ap>80: 10

San Marco data

Thermospheric density data (ρ) were derived from the DBI microaccelerometer measurements:

- time interval: April - December 1988
  (230 days) – rising solar activity!
- height interval: 130-600 km
- inclination: 3 degree
- geomagnetic latitude interval:
  +14 to -14 degree
- total number of observations: 570 252
- number of disturbed (storm) periods
  when Ap>80: 2

DISCUSSION

The behaviour of the δ values is consistent with our assumption that they are connected with some kind of wave activity in the thermosphere. Three wave sources of different character may contribute to the activity pattern discovered.

Plasma bubbles

According to the Italian group one of the important sources of the waves discovered by the San Marco satellite may be the plasma bubbles in the equatorial region. The resolving power of the microaccelerometer measurements would enable the direct observation of these bubbles and the sudden decreases on some of the San Marco registrograms (of 20 sec characteristic time) may be due to the crossing of such bubbles. On the other hand the temporal and spatial distribution of the bubbles is approximately the same as that of the residuals.

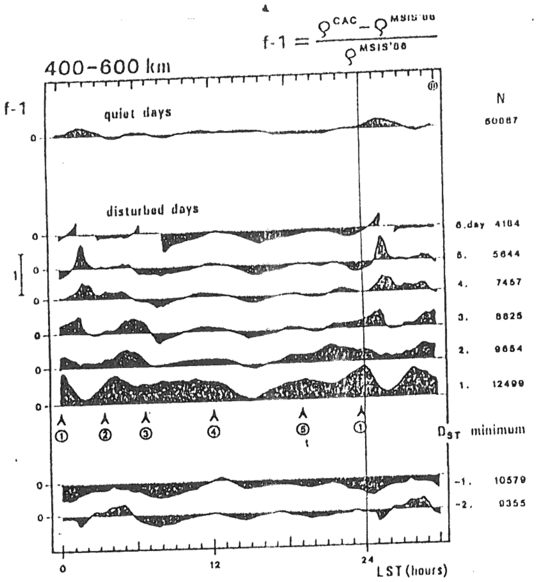
Equatorial electrojet

The second source of atmospheric waves in the equatorial region might be the equatorial electrojet which manifests itself at 100-110 km altitude. It can generate travelling ionospheric disturbances (TID). The dominant mechanism of the coupling to the thermosphere is the force transferred by the ions to neutrals through collisions (ion drag, Lorentz coupling). Fluctuations of the δ surface between 100 and 200 km might be attributed to waves generated by the equatorial electrojet.

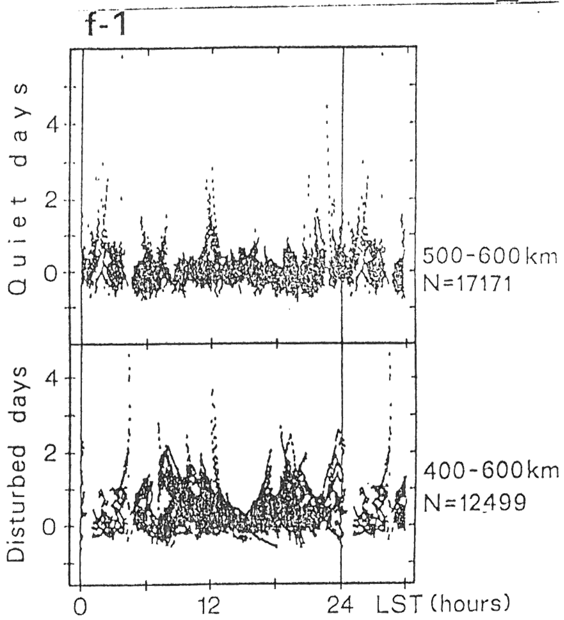
Equatorial ionospheric anomaly

Atmospheric gravity waves might also be due to the equatorial ionospheric anomaly (EIA) the physical representation of which is the so-called fountain effect. The plasma stream due to the fountain effect can deliver energy to the neutral part of the atmosphere and this neutral gas is constrained to movement by ion drag. The effect would be of considerable importance in the height interval 350-550 km in geomagnetically disturbed periods.

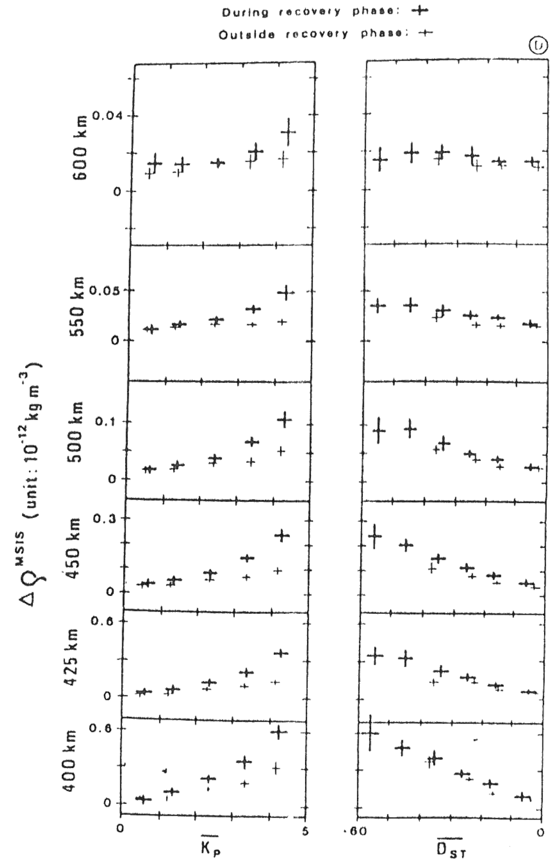
Neutral density



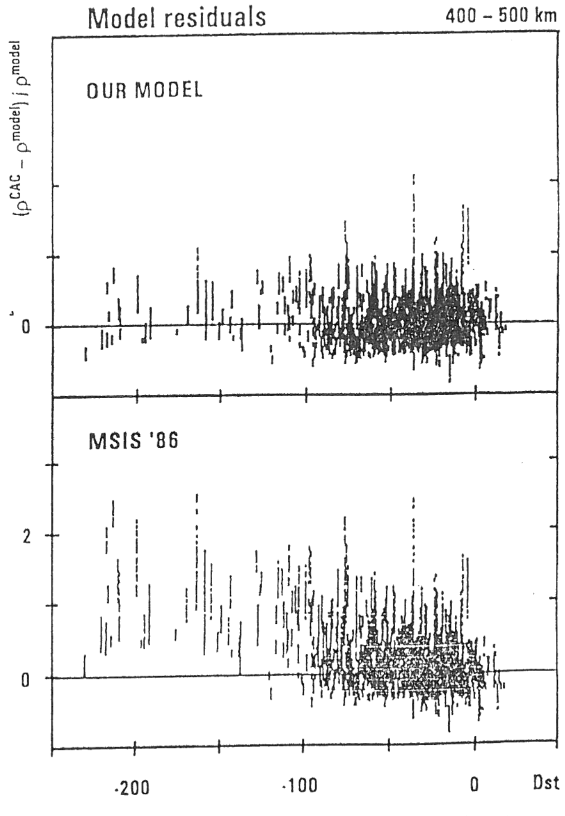
The diurnal variation of the MSIS '86 residuals according to CACTUS measurements are represented here by running mean curves for quiet and for disturbed days (on days around Dst minima).
Red: MSIS model *under*estimates the measurements
Green: MSIS model *over*estimates the measurements



The diurnal variation of the MSIS '86 residuals, according to CACTUS measurements, are represented here by momentary values.
Disturbed days: every first day after Dst minima.



If neutral density values are separated during recovery phases and outside recovery phases then the residuals of the MSIS '86 model are a double valued function of kp (left side) but a single valued function of Dst (right side).



The residuals of the MSIS '86 model have a strong Dst-dependence.
Momentary individual data, 400-500 km.

Our empirical dMSIS model, based on CACTUS measurements (1975-79 and 220-700 km) and on the MSIS '86 model, contains both kp and Dst dependent terms of the geomagnetic effect (hinting at the auroral and the equatorial zone heat sources respectively).

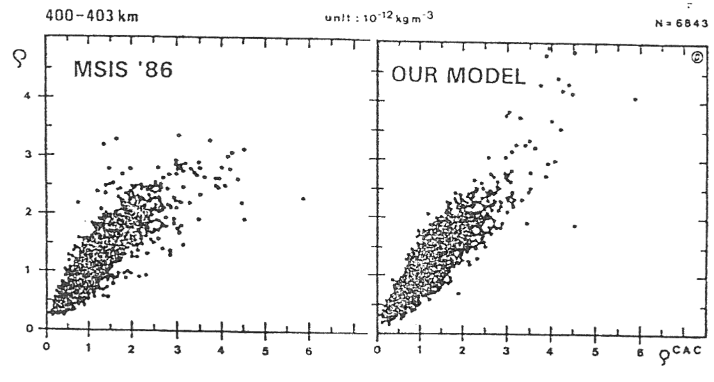
$$\rho^{\mathrm{dMSIS}} = \rho^{\mathrm{MSIS(real\ kp)}} + \rho^{\mathrm{MSIS(real\ kp)}}\left[b(h)D_{ST} + c(h)\right]$$

where

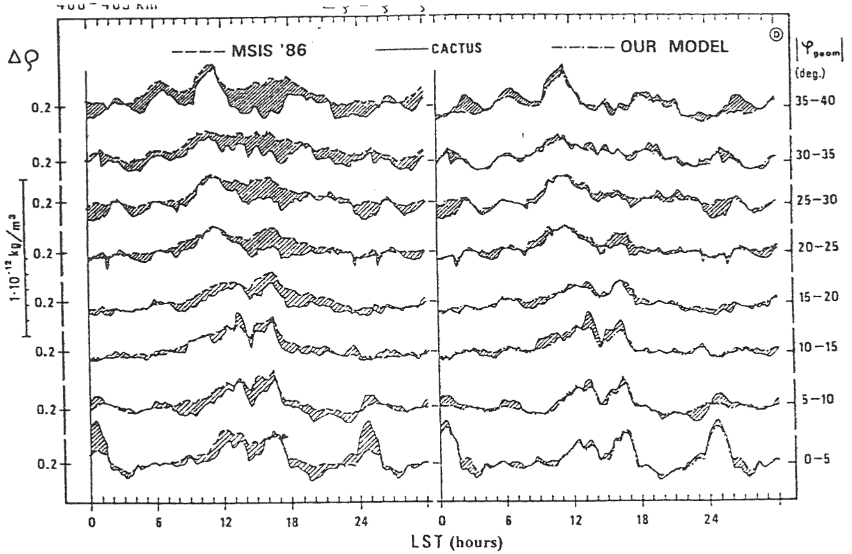
$$b(h) = A_b + B_b \cdot h + C_b \cdot h^2 =$$
$$= 0.00719138 - 4.88831 \cdot 10^{-5} \cdot h + 5.12381 \cdot 10^{-8} \cdot h^2$$

$$c(h) = A_c + B_c \cdot h = -0.21 + 0.000355 \cdot h$$

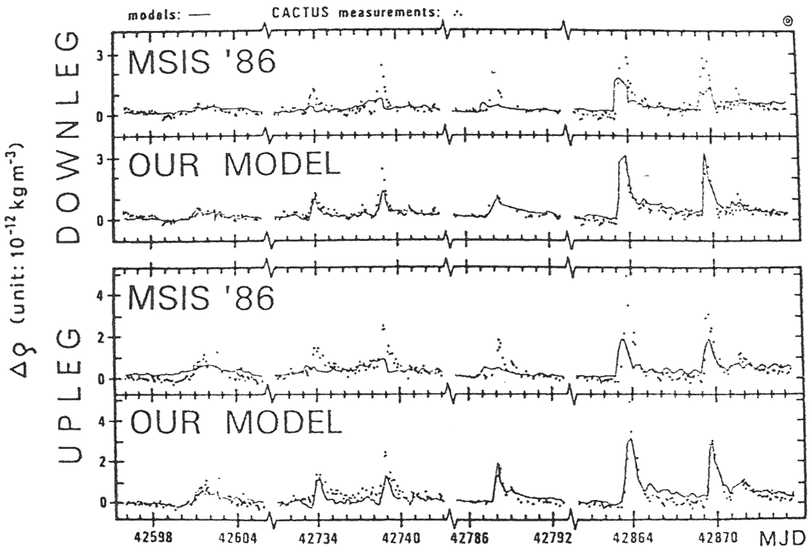
and the height (h) is measured from the surface of the Earth in km.



Comparison of measured density data to model values illustrating the improvement of our model including the Dst dependent term.

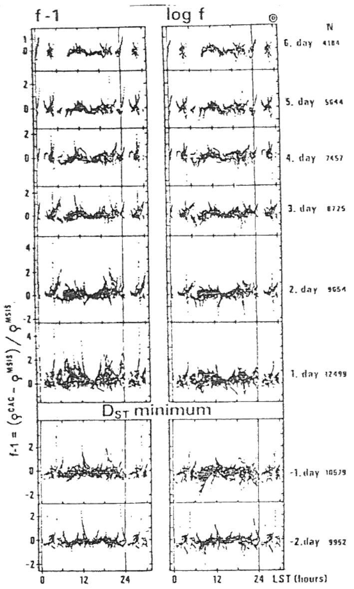


Comparison of the diurnal dependence of measured density data at different geomagnetic latitudes to model values (*shaded areas*). It is illustrating the superiority of our model including the Dst dependent term.

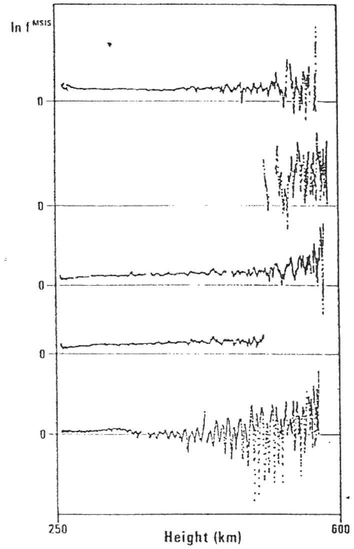


Comparison of measured CACTUS density data to model values in a case study.

Wave pattern



After the elimination of every kind of known effects by the MSIS '86 model the remaining noise in the CACTUS residuals indicates the influence of atmospheric waves. They have a diurnal course and are stronger on geomagnetically disturbed days.



The measurements of the DBI instrument on the San Marco V satellite confirm our hypothesis that the noise is caused really by atmospheric density waves.

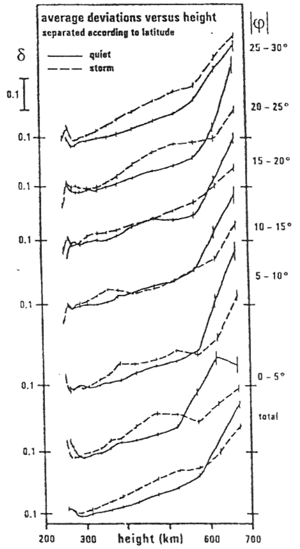
The δ average deviation is characterizing the mean amplitude of the waves:

$$\delta = \frac{\sum \left| \overline{\ln f} - \ln f \right|}{n}$$

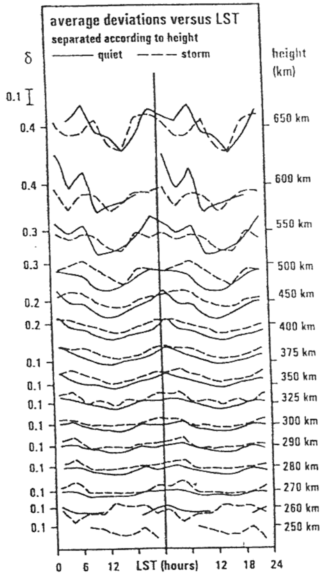
$$\sigma_\delta = \sqrt{\frac{\sum \left[\delta - \left| \overline{\ln f} - \ln f \right| \right]^2}{n(n-1)}}$$

where

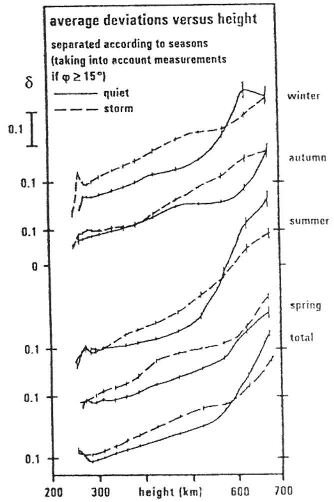
$$f = \frac{\rho^{\mathrm{CACTUS}}}{\rho^{\mathrm{model}}}$$



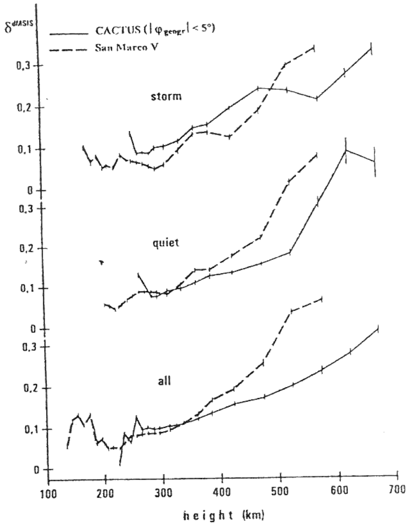
Based on CACTUS data the δ average deviation, characterizing the mean amplitude of the waves, is plotted as a function of height and separated according to *latitude*. The course of the curves is obviously different for quiet and for disturbed periods.



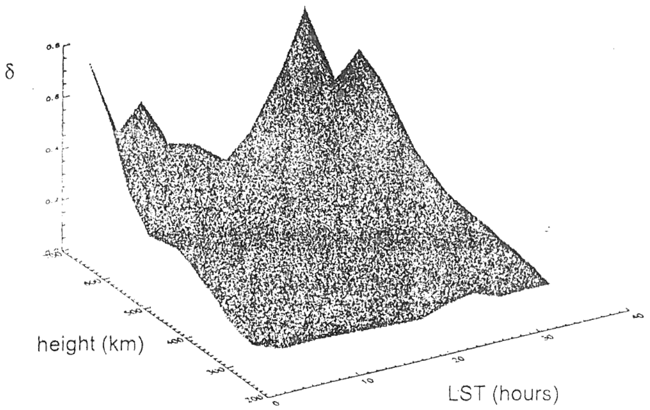
Based on CACTUS data the δ average deviation, characterizing the mean amplitude of the waves, is plotted as a function of LST for quiet and disturbed periods.



Based on CACTUS' data the δ average deviation, characterizing the mean amplitude of the waves, is plotted as a function of height and separated according to *seasons*. The course of the curves is obviously different for quiet and for disturbed periods.



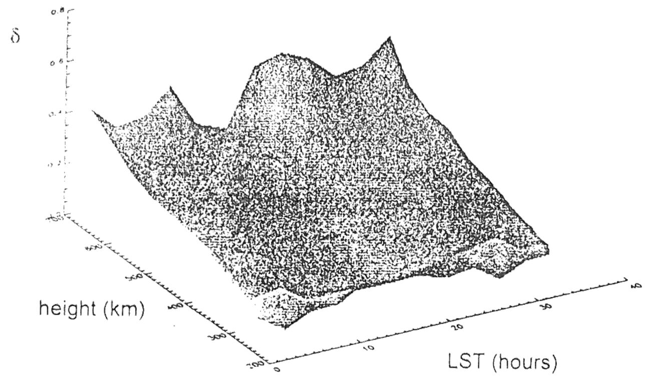
Based on *CACTUS and San Marco V* data the δ average deviation, characterizing the mean amplitude of the waves, is plotted as a function of height for quiet and disturbed periods. The character of the curves does not depend on the observational material, but they are steeper in 1988 during San Marco V measurements.



QUIET DAYS

UNSEPARATED

Average deviation (δ) characterising the gravity wave pattern.
The same daily pattern is plotted twice from 0-24 and from 24-48 hours LST.
The diurnal structure of the variation of δ and its height dependence is clearly visible.

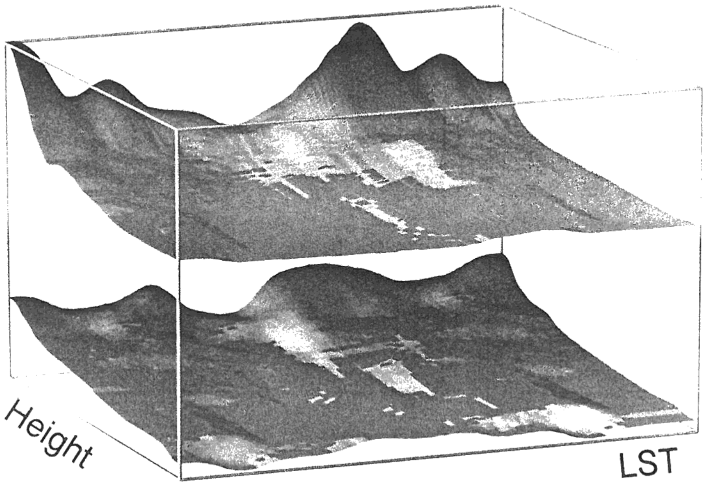


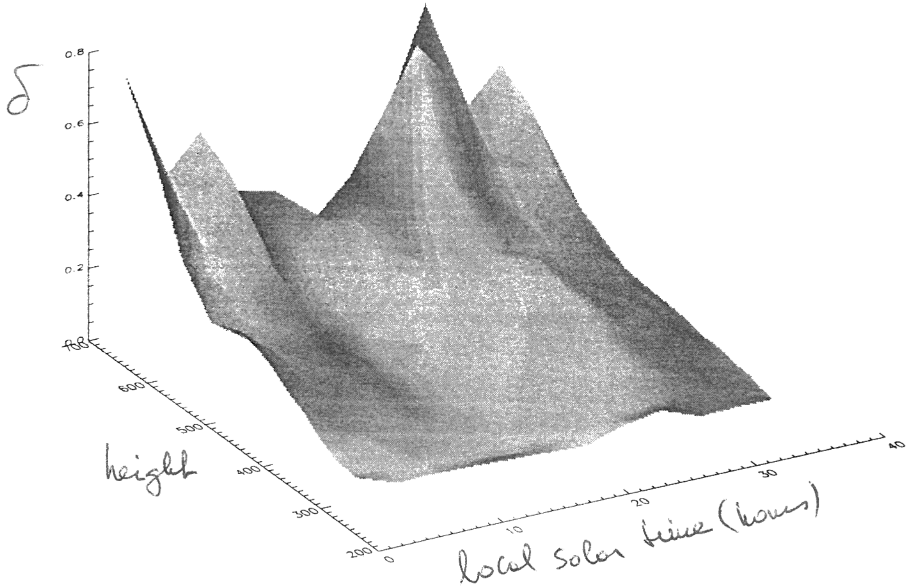
STORM DAYS

UNSEPARATED

Average deviation (δ) characterising the gravity wave pattern.
The same daily pattern is plotted twice from 0-24 and from 24-48 hours LST.
The diurnal structure of the variation of δ and its height dependence is clearly visible.

These figures demonstrate the dependence of the average deviation δ (representing the mean amplitude of the waves and calculated from MSIS '86 residuals according to CACTUS measurements) on LST and on altitude for quiet and for disturbed periods respectively.





δ CACTUS DHSIS [illegible] [illegible]

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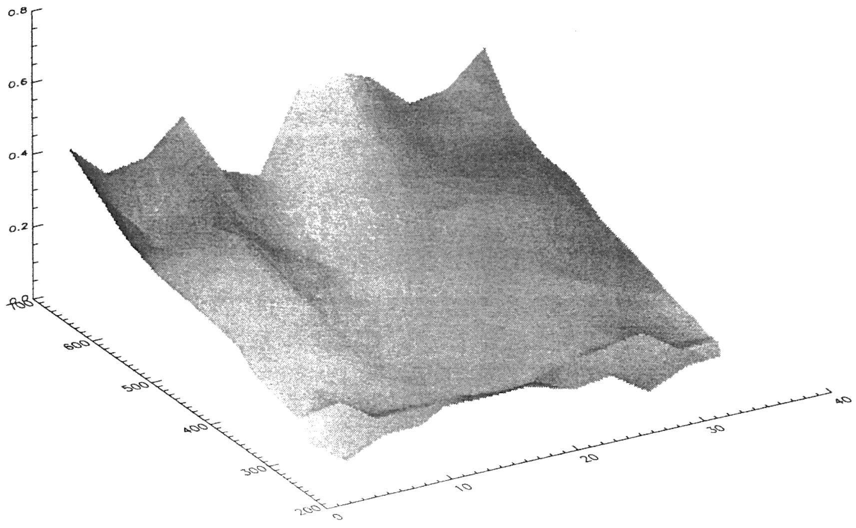

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