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Solitary, Giant Density-waves in the Thermosphere

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ABSTRACT

During its half-year lifetime in 1988, the DBI microaccelerometer on board of the Italian San Marco V satellite has observed 53 randomly distributed solitary, single-staying giant density waves. Their amplitude was 3 -10 times larger than the amplitude of the surrounding waves. Sometimes only a half-wave, sometimes a single sine type wave occurred, but never two sine waves one after the other. The giant waves seemingly did not disturb the background waviness of the atmosphere.

INTRODUCTION

This paper is part of a series of publications in which the authors deal with changes of the total neutral density on small spatial and temporal scale (Illés-Almár et al., 1997, 1998, 2000, 2001, Almár et al., 1999, Bencze et al., 2000). These investigations were made possible by the high time resolution of the total neutral density measurements by the DBI microaccelerometer on board of the Italian San Marco V satellite (Arduini et al., 1992, 1993). The data of the accelerometric measurements revealed not only atmospheric acoustic and gravity waves in the thermosphere, but also processes related to gravity waves, e.g. the effect of plasma instabilities, spatial resonance like variations and sudden, impulse like changes (solitary, giant waves), indicating that the interaction of the ionized and the neutral component of the atmosphere is in action not only in case of large dimensions, but also in volumes of smaller extension.

DATA

The total neutral density values were derived from the measurements of the DBI microaccelerometer on board of the Italian San Marco V satellite

The **inclination** of the satellite's orbit was 3°, thus it enabled the investigation of the phenomena in the neighborhood of the equator.

The **time interval** of the measurements: April–December 1988
this was a period of rising solar activity and of weak geomagnetic activity

The **height interval**: 130 - 600 km; the majority of the measurements were carried out above 250 km, lower heights have been reached by orbital decay only in the last ten days (**Fig. 1**).

The **time resolution** is one second in average.

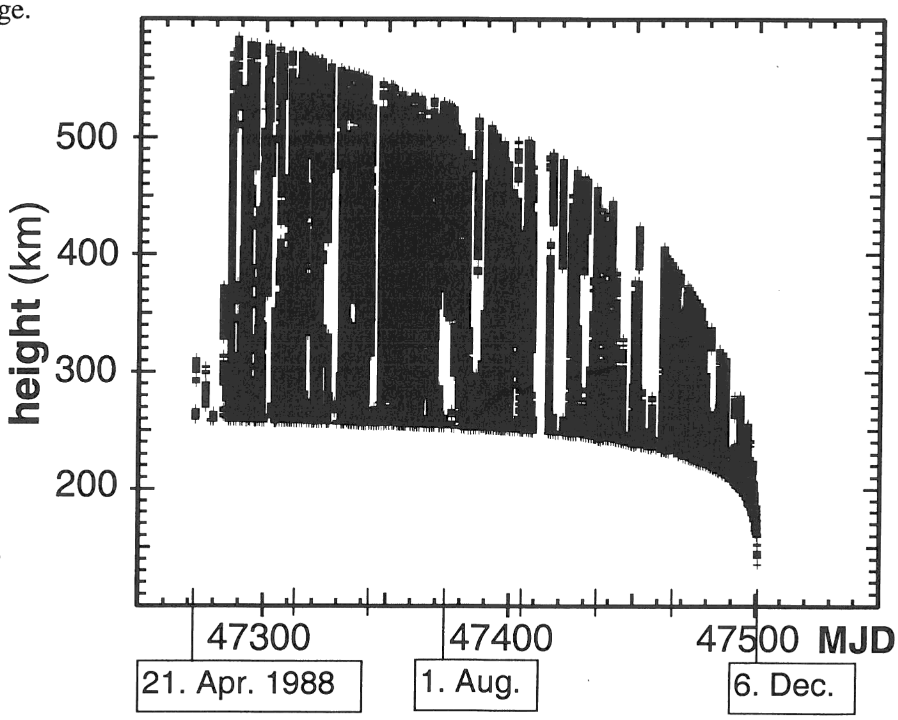

Fig. 1.
Altitude of the San Marco V satellite as a function of time.

METHOD

Trying to improve some upper-atmospheric models by the **CACTUS microaccelerometer** measurements
(on board of the French CASTOR satellite)
we came to the conclusion that residuals $f = \rho^{measured}/\rho^{model}$ present a **scatter considerably larger** than it should be on the basis of the accuracy of the measurements.
The **scatter** has been interpreted by Illés-Almár et al., (1996)
as a consequence of the effect of atmospheric density waves.

Investigating the Italian **San Marco V microaccelerometer** material of higher temporal resolution as case studies (Illés-Almár et al., 2001, Almár et al., 1999)
we have discovered four kinds of different phenomena with short characteristic timescale in the neutral upper atmosphere (Illés-Almár et al., 2000):

1/ sudden neutral density depletions (NDD) (Illés-Almár et al.,1998, 2001, Bencze et al., 2000, Schunk, 2003);
2/ sudden, impulse-like neutral density increases or giant "solitary" wave-like variations (GWs) (present paper);
3/ sudden increase with height in the amplitude of atmospheric waves (SAI; Bencze et al., 2005), and
4/ spatial resonance like fluctuations.

DESCRIPTION OF THE PHENOMENON

Solitary, Giant Wave-like Variations are sudden density increases or giant waves with amplitudes of 50 - 90% of the total density, exceeding 3 - 10 times the amplitudes of the surrounding waves.
Altogether 53 such cases have been found. **Fig. 2** shows some examples of GWs.

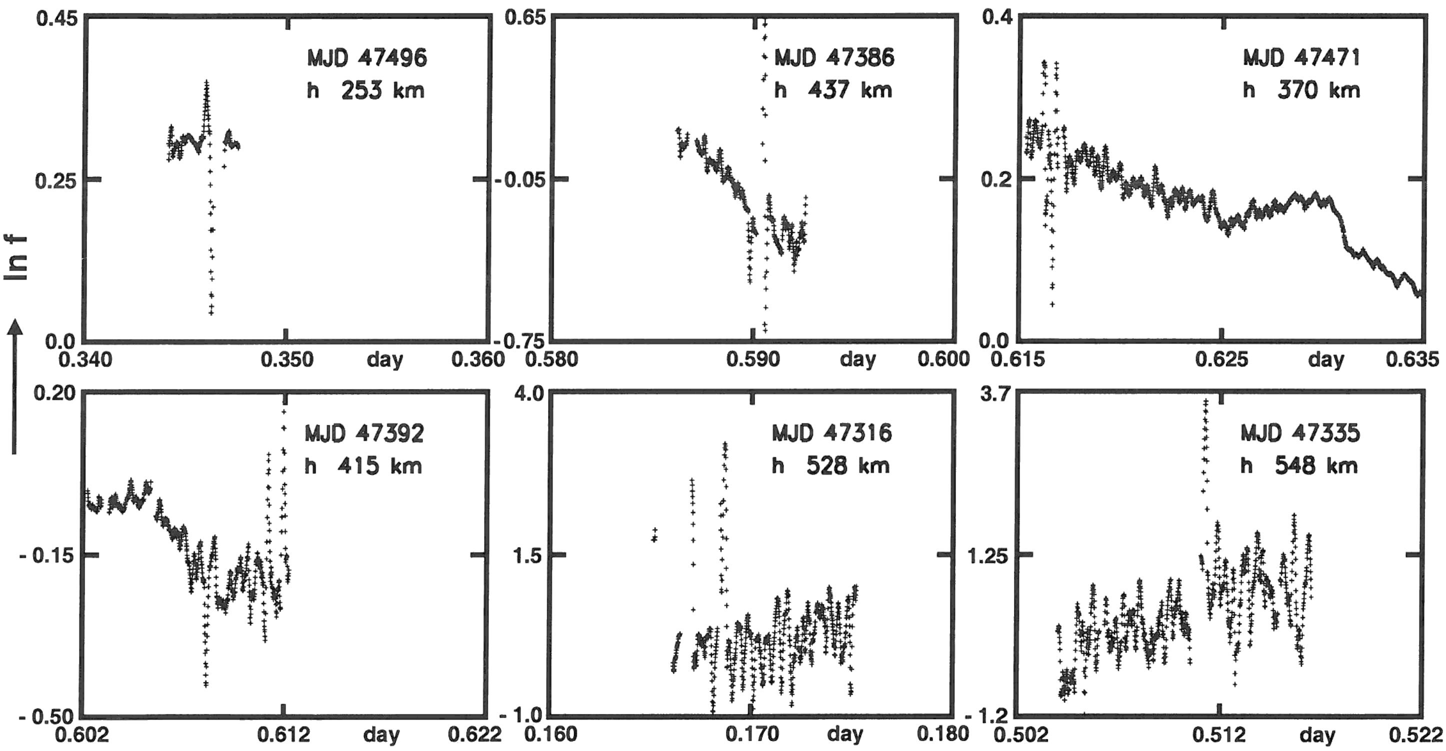

Fig. 2. Examples of the impulse-like changes at different times and in different heights.

STATISTICS

As regards the **temporal and spatial occurrence** of the giant waves we can investigate them by statistical methods. It is to be noted, however, that the small number of the cases is a definite limit. As the measurements are confined to the equatorial region, only their **height**, their **diurnal** and their **longitudinal distribution** can be investigated. So for GWs the diurnal (**Fig. 3**) the longitudinal (**Fig. 4**) and the height (**Fig. 5**) variation of the occurrence frequency have been plotted.

The **diurnal distribution** of the occurrence frequency indicates **maxima in the evening and at night** (**Fig. 3**).

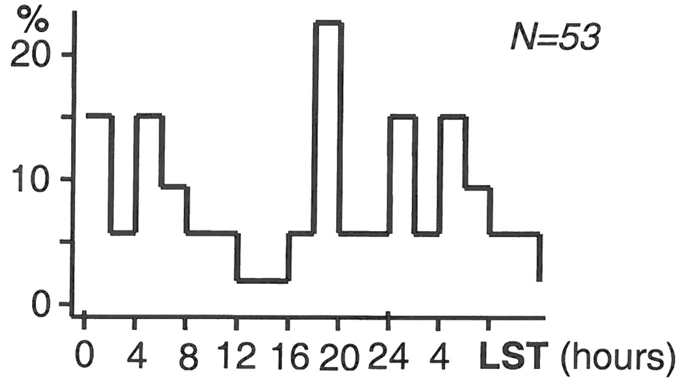

Fig. 3. Diurnal variation of the occurrence of the GWs (impulse-like changes) in the neutral density.

The **longitudinal distribution** of the occurrence frequency has a **maximum between 150 – 240° E (Fig. 4)**. The dominant feature is the broad maximum at a region corresponding to the area of the Pacific Ocean. This circumstance may be interesting from the point of view of the interpretation of the data.

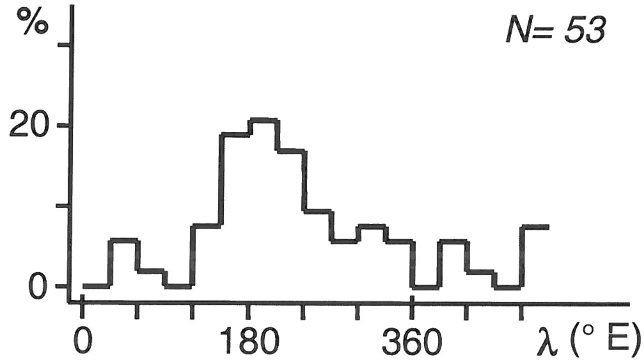

Fig. 4. Longitudinal variation of the occurrence of GWs (impulse-like changes) in the neutral density.

The **height distribution** of the occurrence frequency demonstrates **maxima at 150-200 km** and at a **broad height range from 300 km to 550 km** (**Fig. 5**).

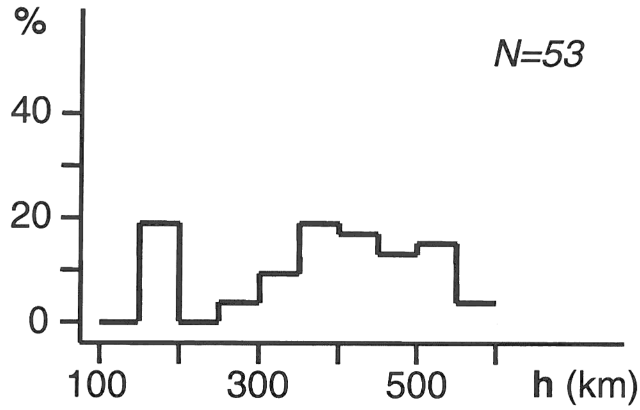

Fig. 5. Height distribution of the occurrence of GWs (impulse-like changes) in the neutral density.

DISCUSSION

The **Giant Wave-like variation (GW)** phenomenon might be due to atmospheric shock waves of magnetospheric origin propagating in the thermosphere, or due to interference of waves originating from both auroral ovals. In both cases the equatorial orbit is the most suitable to study the sudden impulse-like changes.

Concerning the GWs, the *diurnal variation* of this phenomenon (**Fig. 3**) hints at a mostly night-time process producing impulse-like solitary waves. As it can be seen, the height distribution (**Fig. 5**) of these waves indicates two maxima, one in the height region of the **F layer "valley"** (150-200 km), where the electron density is smaller between the E and F regions of the night-time ionosphere, and the other in the **night-time F region** of the ionosphere. Thus, both observations might support the assumption that the GWs are mostly due to a night-time process.

A possible source for the **double nighttime maxima** of GWs (0-1 and 4-5 hours; see **Fig. 3**) might be the substorm (*Baistörung*) phenomenon. Substorms discovered in the changes of the geomagnetic field in the **premidnight** and **postmidnight** hours are related to processes in the tail of the magnetosphere, to the **sudden release of energy accumulated in the tail**. The energy input into the auroral zone is accompanied by an **intensification of the current flowing in the auroral oval** and thus a **sudden heating** (Joule heating) **of the neutral upper atmosphere**. As a result of this heating, an **impulse like expansion** of the atmosphere takes place along the active part of the auroral oval. The intensification of the current [DP1 current system (Clauer and McPherron, 1974; Clauer and Kamide, 1985)] and thus, the increased heating along the active part of the auroral oval can be observed **before midnight** (~22^h) and **after**

midnight (~02^h). Considering the temporal occurrence of the GWs, in the vicinity of the equator one must take into account the **time lag** of the disturbance. Assuming a **~2 hours time delay**, the impulse-like disturbances may appear after 24^h and 04^h, respectively. The disturbances arriving from the northern and southern hemisphere can amplify each other leading to the formation of an impulse of large amplitude. However, further investigations are needed for the proof of this suggestion.

The **evening maximum appearing at 18 - 20 hours** in the diurnal variation might be related to the **sudden change of the direction of the electric field in the F region from eastward to westward** due to the prereversal enhancement of the eastward electric field (Heelis et al., 1974). This sudden change of the electric field would mean a **sudden switch over from a gravitationally stable condition** of the plasma **to gravitationally unstable conditions**. This process may be indicated by the neutral density too. At sunrise, on the contrary, the change from the westward to the eastward electric field is already gradual.

In connection with the *height distribution* of GWs (**Fig. 5**) it is to be noted that irregularities appear in the F region valley on geomagnetically moderately disturbed nights (Shen et al., 1976). The impulse like disturbances indicated in the height distribution of these changes between 150 and 200 km might be related to the **irregularities in the F layer valley** activity, where gravity waves are generated.

As regards the *longitudinal variation* of the occurrence of GWs (**Fig. 4**), a definite maximum appears in the longitude region from 150° to 240°, coinciding with the equatorial zone of the Pacific Ocean, a zone of strong convection.

SUMMARY

During its half-year lifetime in 1988, the DBI microaccelerometer on board of the Italian San Marco V satellite has observed 53 randomly distributed solitary, single-staying giant density waves (GWs) with their amplitude 3 -10 times larger than the amplitude of the surrounding waves. The giant waves seemingly did not disturb the background waviness of the atmosphere.

The **Giant Wave-like variations** phenomenon might be due to atmospheric shock waves of magnetospheric origin propagating in the thermosphere, or due to interference of waves originating from both auroral ovals.

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