Gravity waves propagation in the thermosphere observed from electron density profile and total electron content measurements

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Abstract
Ionospheric observations with five minute intervals between ionograms were made during a campaign from 19th to 23rd June 1996 at the Rome station (41.8N, 12.5E). The data obtained from ionospheric vertical sounding have been analysed together with the Total Electron Content (TEC) data obtained by the GPS receiver measurements. Both the apparatus were installed in the same station. Short periodicity phenomena occurring in the considered period were observed and interpreted as resulting from the propagation of AGWs in the thermosphere. TEC and electron density were then analysed during AGWs activity.

Key words *gravity waves – total electron content*

1. Introduction

The ionosphere is characterised by highly variable parameters that can be deduced from several kinds of measurements. The variability at the planetary scale due to the ionospheric storms has been studied for a long time because hourly data have been available since the first systematic ionospheric measurements. In fact, the ionospheric variability was well studied in coincidence with magnetic and solar disturbances and a close relationship among these phenomena was found.

In recent years, an increasing interest was focussed on the small and the medium scale Travelling Ionospheric Disturbances (TIDs) which have been explained since 1950 as resulting from the propagation of Atmospheric Gravity Waves (AGWs).

In order to study the propagation of AGWs it is necessary to perform campaigns of ionospheric measurements with sample periods of a few minutes. Nowadays this problem can be solved by using PC based data acquisition, with a large memory. For this reason many works have been done on this subject. The simultaneous observations available have demonstrated that there are two types of TIDs: a Large Scale (LS) and a Medium Scale (MS) (Georges, 1968). LS TIDs have long periods (30-180 min), lasting for a few cycles, and a horizontal velocity of at least 300 m/s. MS TIDs have shorter periods and the horizontal velocity is smaller (Williams, 1988). These different types of TIDs are excited by different sources. LS TIDs are now identified as the ionospheric effect of GWs in the neutral atmosphere generated in the auroral region. On the contrary, the mechanism of excitation of MS TIDs is not clearly known and several mechanisms have

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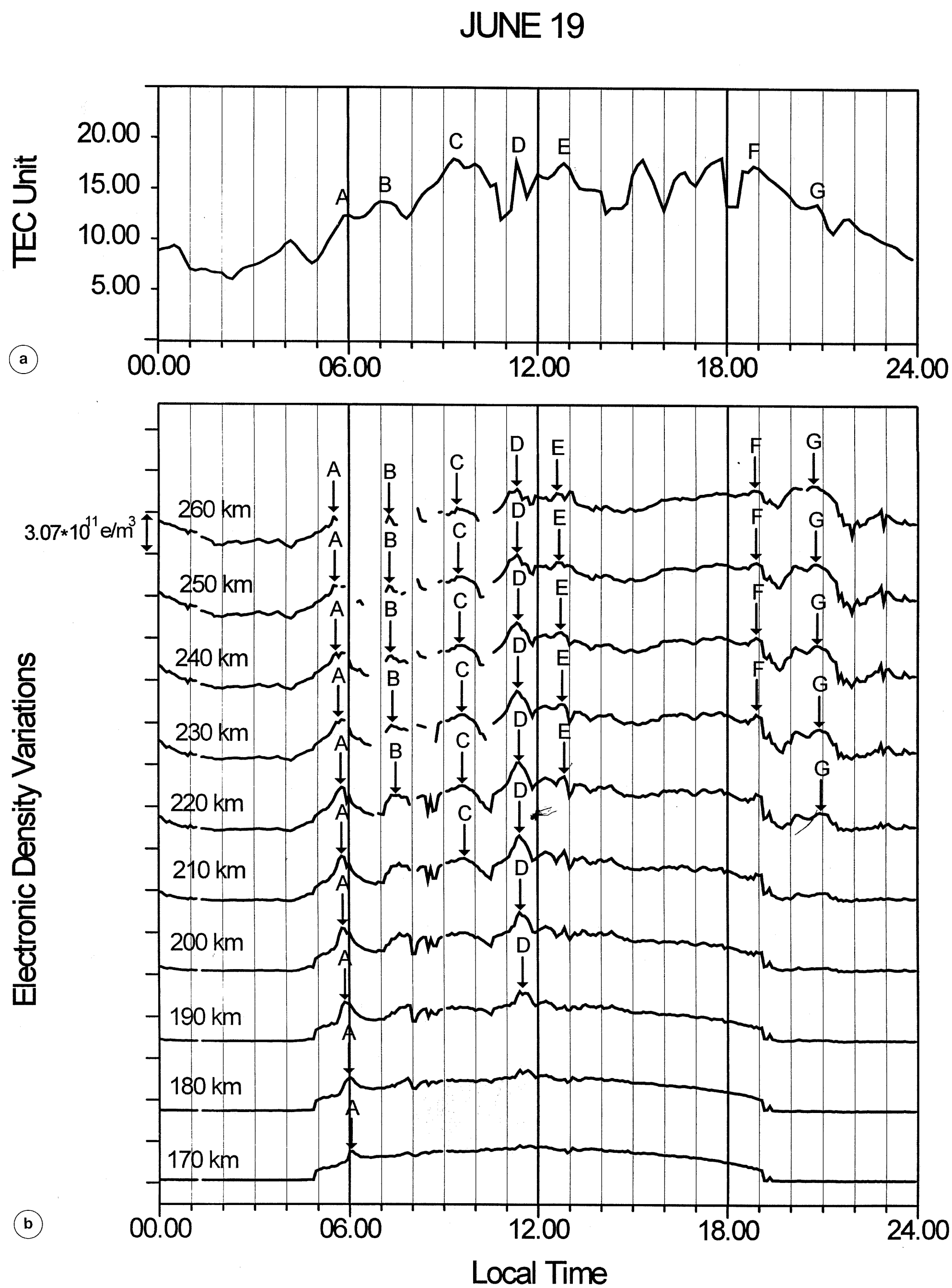

Fig. 1a,b. Comparison between the TEC (a) and $N(h = \text{const.})$ (b) *vs.* time for the 19 June 1996. The arrows indicate the peaks due to the AGWs propagation.

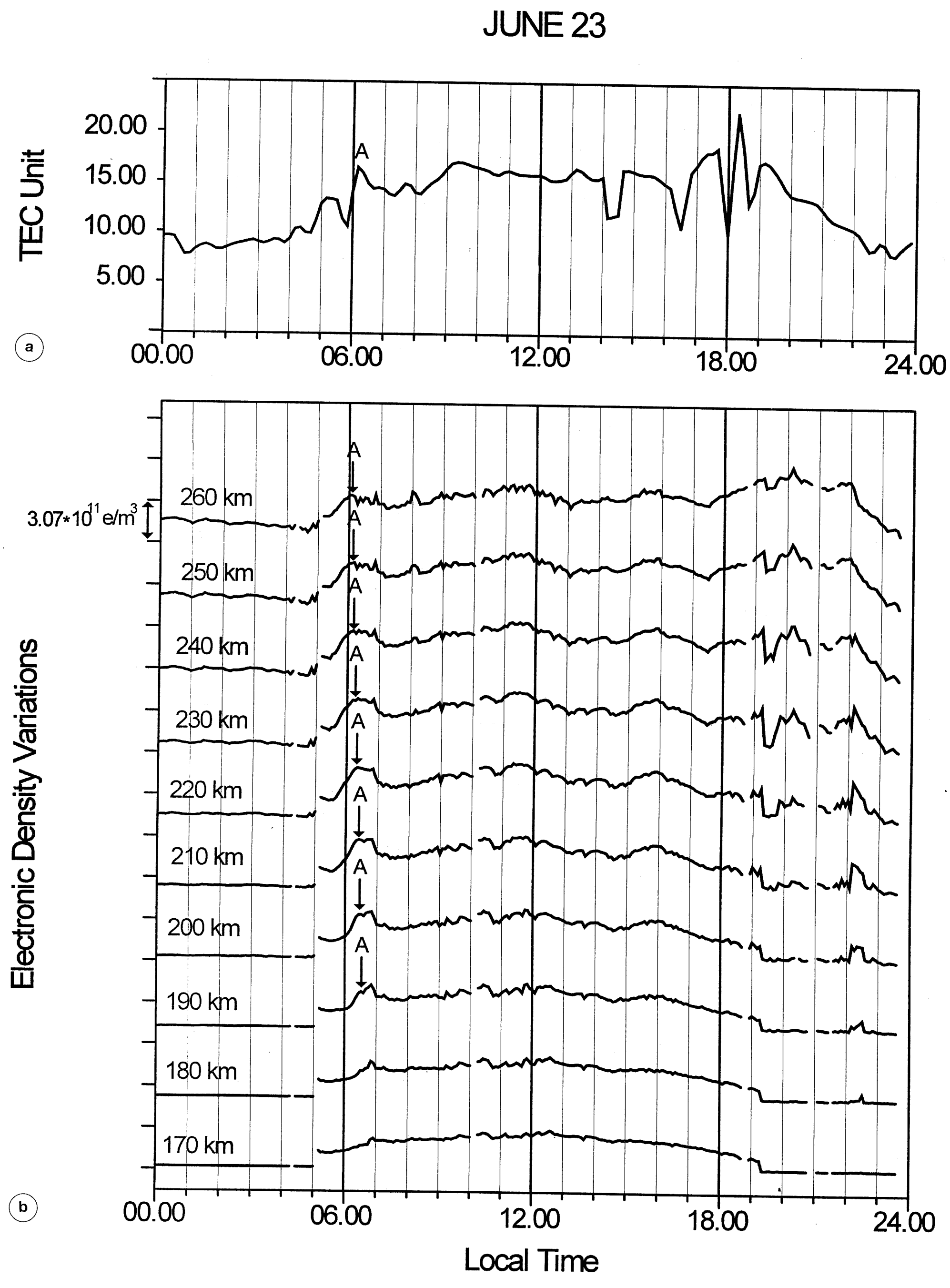

Fig. 2a,b. Comparison between the TEC (a) and $N(h = \text{const.})$ (b) *vs*. time for the 23 June 1996. The arrows indicate the peaks due to the AGWs propagation.

been proposed. As an example one possible source of MS TIDs is considered the solar terminator (for a review, see Somsikov, 1991).

Nowadays GPS measurements are extremely important both for precise positioning and for time correction devices. TEC measurements over the vertical of the ionospheric station are also analysed in order to attempt the evaluation of the effect of GWs propagation on the TEC variability.

2. Experimental observations and discussion

We analysed five days in June 1996 during which the geomagnetic activity index was $K_p = 18$ the first day and $K_p < 11$ for the remaining days. We believe that during these days there is no strong activity of LS TIDs of auroral origin. A high repetition ionospheric sounding campaign (five minutes between ionograms) was performed by a chirp modulated ionosonde. Then these data were digitised by an operator using software facilities and electron density profiles were obtained. This procedure was necessary because a great accuracy in the scaling of ionogram traces is required. The inversions from the ionogram traces to the electron density profiles were performed by the POLAN program (Titheridge, 1988). It is important to note that, although the measurements were continuous, the reduction of the ionograms to the true heights was difficult especially for days 20, 21 and 22 because of the presence of sporadic E-layers. From the electron density profiles we obtained values at fixed heights $N(h = \text{const.})$ shown in figs. 1b and 2b. By observing the figures we noted the presence of oscillations in the family of curves. Such oscillations show different periods and amplitudes depending on time. Moreover, the phase lets us infer a vertical downward propagation as shown by the position of the peaks at different heights. The periods of the oscillations suggest the GWs activity in the ionosphere as confirmed by observations of vertical phase propagation. During night-time the oscillations appear less evident than during the daytime, due to the depletion of the lower ionospheric layers. More remarkably, disturbances were observed on June 19, in agreement with the moderate magnetic activity.

Using GPS measurements taken every 30 s we obtained TEC values at 10 min intervals. Figures 1a and 2a show the TEC trend during the same days. Comparing the TEC and $N(h = \text{const.})$ behaviour we find a fairly good correlation mainly in the first day examined. The peak position of TEC oscillations during this day is practically coincident with the $N(h = \text{const.})$ peaks.

3. Conclusions

The ionospheric disturbances, specifically the AGWs propagation, induce oscillations in the TEC as shown in the plots. Ionospheric models are not able to consider these variations that could introduce disturbances in GPS measurements.

We have shown that short period fluctuations of the electron density are due to the propagation of GWs in the thermosphere. These oscillations are observable both as isodensity surfaces and as TEC. In fact, there is a reasonable correlation in time between the total electron content oscillations and $N(h = \text{const.})$ oscillations. This phenomenon was observed more clearly in coincidence of magnetic activity. Similar behaviour (but with less amplitude) was observed also in the magnetically quiet days.

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