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EFFECTS OF GEOMAGNETIC STORMS ON THE IONOSPHERIC REGIONS OVER THE SOUTHWEST OF EUROPE. AN APPROACH TO THE INFLUENCE OF THE G CONDITION ON IONOSPHERIC VALUES

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The effects of three geomagnetic storms on the ionospheric F region and the influence of the G condition on TEC estimates have been analysed by using ionospheric data from INTA El Arenosillo Atmospheric Sounding Station (37.1N, 353.3E) and GPS TEC measurements obtained at the IGS station of San Fernando (36.5N, 353.8E). The results stress the importance of these perturbations and the need of using edited ionograms.

Keywords: F region; G condition; geomagnetic storms; GPS; TEC

Introduction

As it is shown in a wide variety of studies (Mikhailov 2000) the response to storm conditions in the mid-latitude F region generally exhibits two phases: (1) an initial positive one in which daytime f_oF2 and TEC are enhanced with respect to quiet conditions and (2) a negative one in which these values decrease below the pre-storm levels. The first phase occurs more frequently when the storm begins locally at daylight hours and is usually brief. On the contrary, the second one can last several days.

Parameters N_mF2 and h_mF2 are strongly perturbed during these particular storm conditions due to changes in composition and temperatures as well as to enhanced winds and electric fields. Anomalous conditions can produce a particular effect on the ionograms known as "G condition" characterised by F2 critical frequencies (f_oF2) smaller than those which correspond to the F1 layer. Usually this phenomenon is present at mid-latitudes during solar minimum summers in the quiet ionosphere (Pavlov and Buonsanto 1998) and during geomagnetically disturbed periods. It has been found that this effect is produced by a decrease of the production rates of oxygen ions which are dominant at the peak height of the F2 layer. This decrease raises the molecular to atomic ion concentration ratio (Buonsanto 1990).

The aim of this paper is to show that if this G condition is present, the ionospheric TEC estimates obtained from automatic scaling ionospheric parameters can

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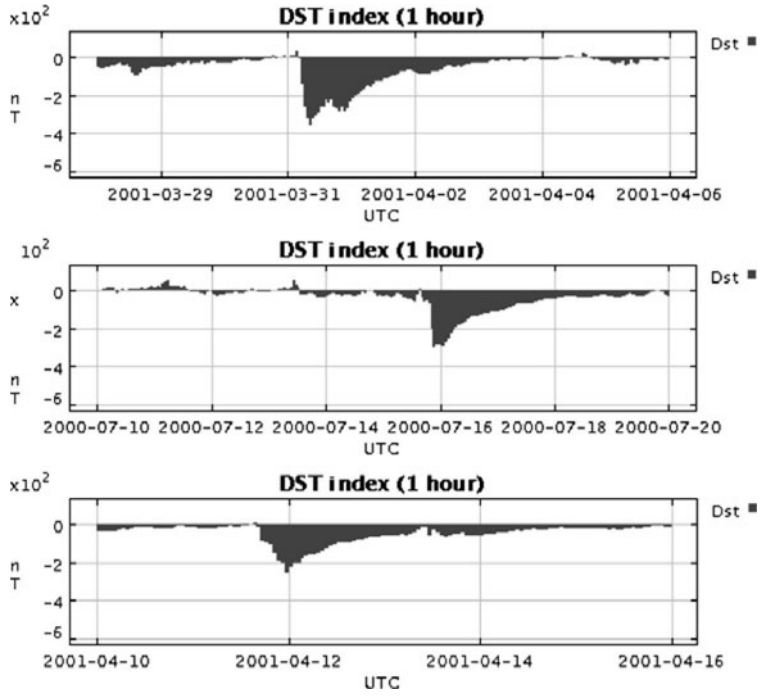

Fig. 1. D_{st} parameter corresponding to July 2000 and March and April 2001 periods

be very different from those deduced from data recorded by GPS receivers. As a consequence, the use of edited values must be considered in order to reduce the errors. As it has been mentioned before, under G condition ionograms show only the F1 layer because of the substantial decrease of f_oF2 to values lower than foF1. For this reason, the automatic scaling of f_oF2 and h_mF2 values actually correspond to foF1 and hmF1 and wrong conclusions are obtained if they are taken as F2 layer values. The influence of this fact in electron density profiles and TEC calculations is shown below.

Methodology

For this study three geomagnetic storm periods that occurred in July 2000 and March and April, 2001, whose corresponding D_{st} variations are displayed in Fig. 1, have been considered. The storm which took place in March 2001 started around midnight of the 30th and reached an A_p^* index of 191. As it can be seen on the top of Fig. 1, it included a brief positive phase. The second storm began at 6h (UT) of July 15 and had a A_p^* index of 192. The third storm occurred on April 11th 2001, and its beginning was observed at 12 UT. Its A_p^* value was 124.

For each case hourly ionograms from INTA El Arenosillo Atmospheric Sounding Station (37.1N, 353.3E) are used to estimate critical frequencies, heights and ITEC values. These values are obtained through the well known ARTIST and NHPC 4.3 programs (Huang and Reinisch 1996).

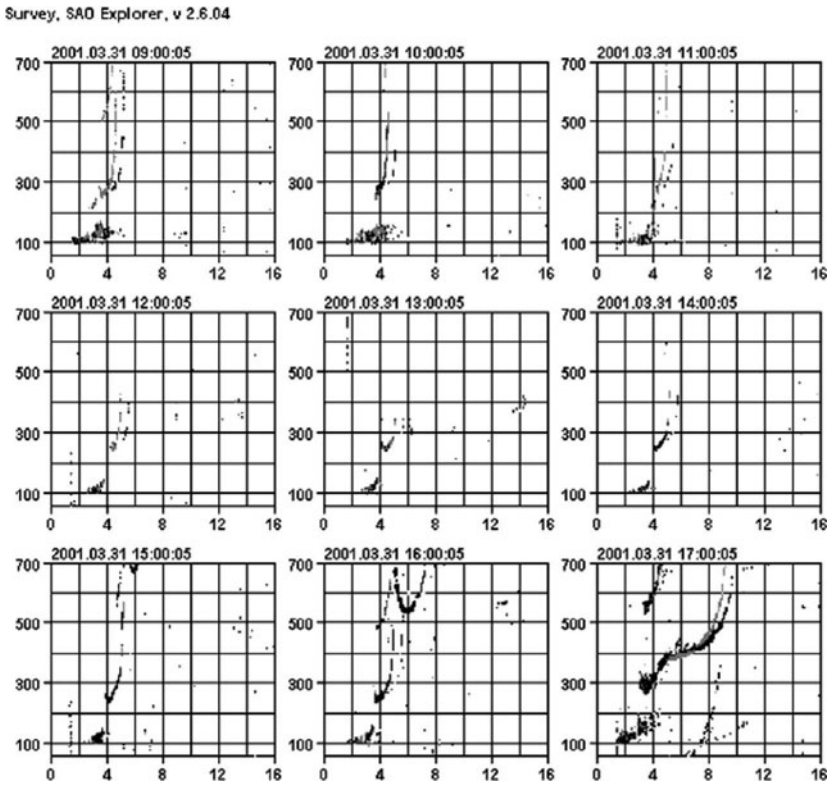

Fig. 2. Hourly ionograms from INTA El Arenosillo on 31 March 2001 (09–17 UT)

The G condition is present during several hours (09–15 UT) on March 31, 2001 (Fig. 2) and the corresponding fictitious h_mF2 values are always below 200 km. The same situation takes place on July 16, 2000 when all the h_mF2 values around noon are also lower than 200 km. On the contrary, the storm which appears on April 11 does not present anomalous low values of h_mF2. To check the TEC values calculated by the automatic scaling of ionograms they are compared with GPS TEC measurements taken at the IGS Station of San Fernando (36.5N, 353.8E).

Results

As it is shown in Fig. 3, critical frequencies and layer height variations have normal values before the start time of the ionospheric storm of March 2001 and the differences between GPS TEC and ITEC are below 14 TEC units around noon (09–15h, UT) of the 30th. These differences can be considered normal, taking into account that part of them can be attributed to the plasmaspheric electronic content that is not included in the ITEC. However, due to the G condition the data show the negative ionospheric storm effect in frequency and height with apparent h_mF2 close to normal hmF1 values during several hours around the noon of the 31st. The

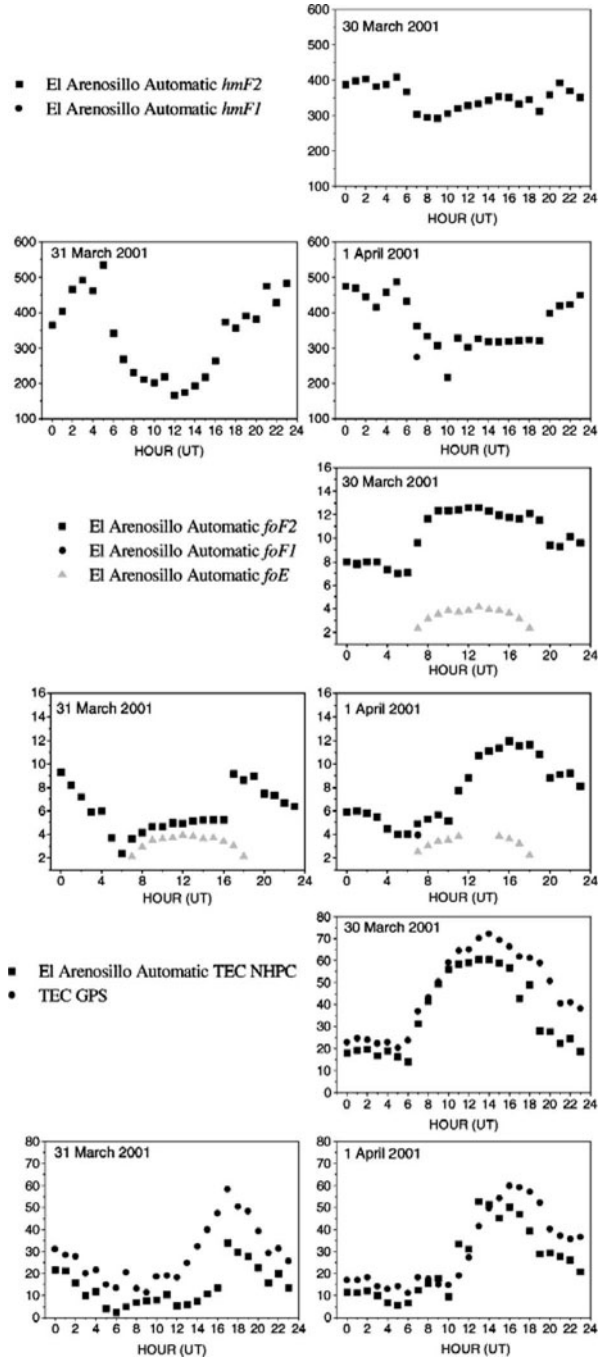

Fig. 3. f_oF2, foF1, foE, h_mF2, hmF1, ITEC and GPS TEC during the ionospheric storm of March 2001

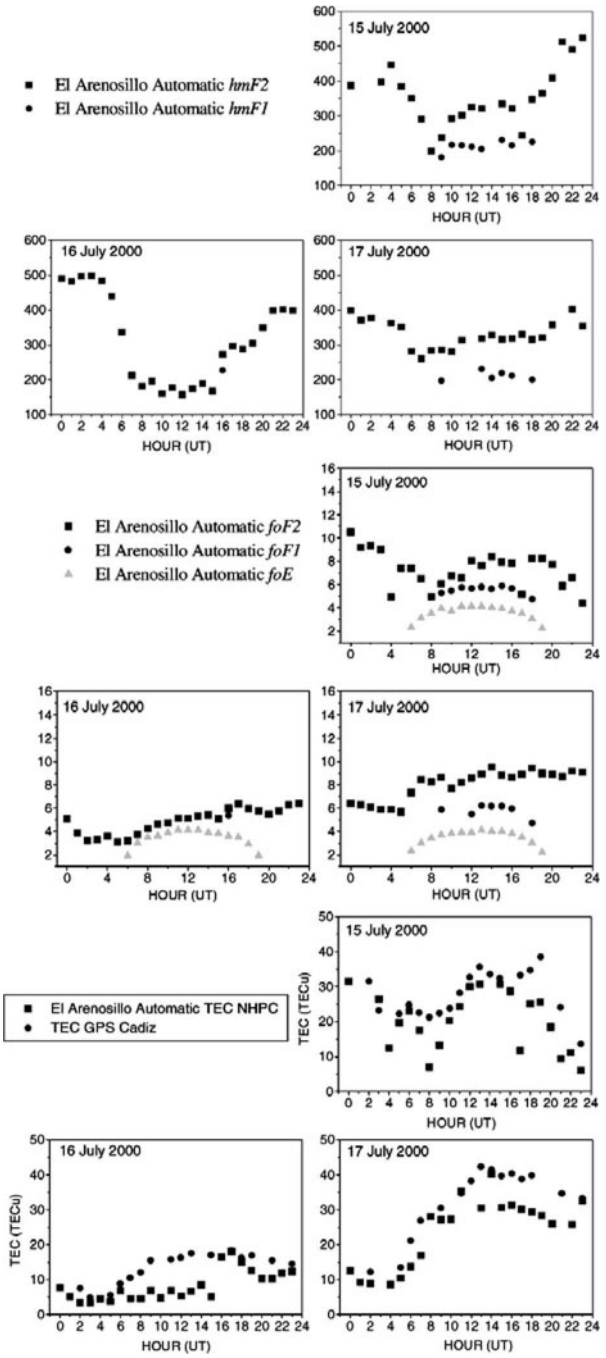

Fig. 4. f_oF2, foF1, foE, h_mF2, hmF1, ITEC and GPS TEC during the ionospheric storm of July 2000

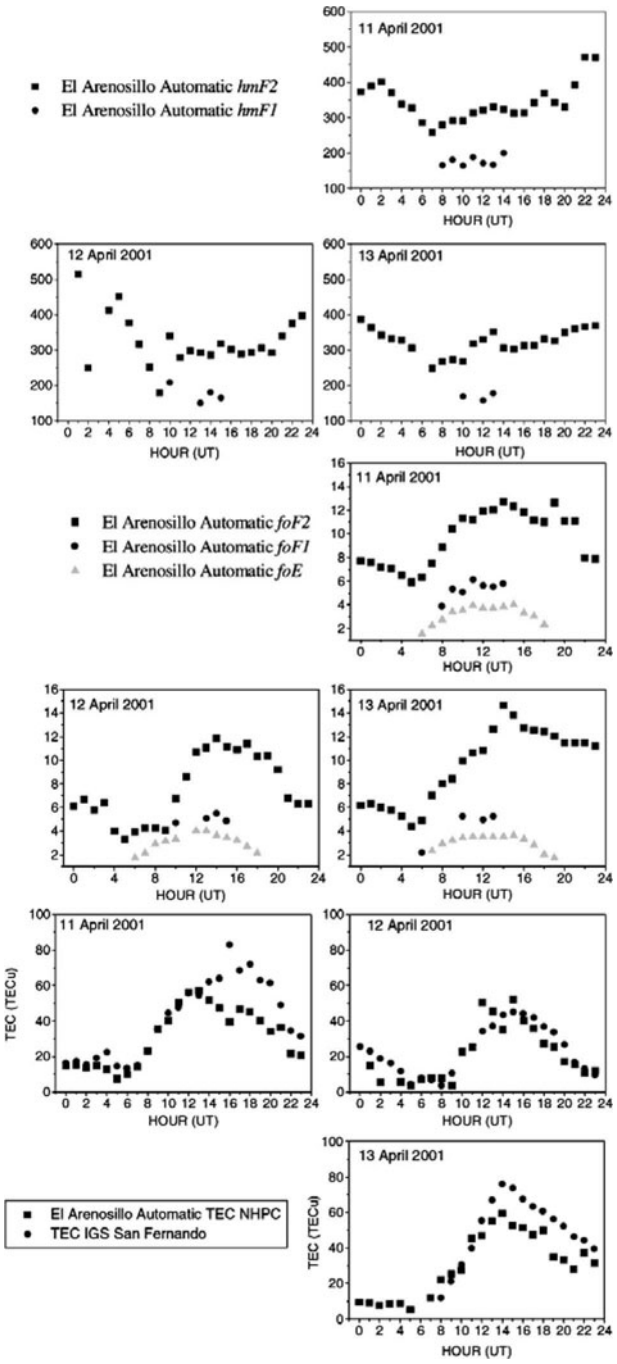

Fig. 5. f_oF2, foF1, foE, h_mF2, hmF1, ITEC and GPS TEC during the ionospheric storm of April 2001

differences between GPS TEC and ITEC rise to 30 TEC units at 15h UT and the diurnal trend of ITEC appears unrealistic during several hours.

With regard to the ionospheric storm of July 2000 (Fig. 4), G condition is observed during several hours of the 16th and the h_mF2 values diminish to 200 km. At 13h (UT), GPS TEC and ITEC differences are about 11 TEC units. This value is not very large in absolute terms but the percentage difference and the diurnal trend of ITEC appear unrealistic again.

Figure 5 shows that the third storm does not present the G condition. GPS TEC and ITEC variations do not indicate an unrealistic behaviour but follow a normal diurnal variation during the whole period. In this case there is no confusion between F1 and F2 layer values and the automatic scaling offers values closer to the reality.

Conclusion

Two examples of one of the most interesting ionospheric phenomena which appear during geomagnetic storms at mid-latitudes are studied. It has been seen that the automatic scaling of the ionograms under the G condition consider the values that actually correspond to the F1 layer as belonging to the F2 layer. Therefore, values obtained from these wrong data do not correspond to the real ionosphere and particularly errors in ITEC estimates must be taken into account. Therefore in order to avoid the consequences of the confusion between h_mF2 and h_mF1 values it is recommended to calculate ITEC values only from edited ionograms, particularly during disturbed conditions.

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