ANALYSIS OF THE TOTAL ELECTRON CONTENT OVER TWO EUROPEAN STATIONS USING DIFFERENT TECHNIQUES

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ABSTRACT
This paper studies the behavior of the vertical total electron content obtained with GPS satellites signals (GPSTEC) and total electron content derived from Digisondes (ITEC). The data base includes ionograms and GPS observations recorded at El Arenosillo and Pruhonice during a period of low solar activity. Comparisons between observations and the IRI total electron content predictions (IRITEC) have been also done. The shapes of the three estimations are similar and, as it is known, the GPS values are greater than the ITEC values. The IRI predictions generally overestimate the ITEC values. The differences between GPS TEC and ITEC are also analyzed.

RESUMEN
Este trabajo analiza el comportamiento del contenido electrónico total vertical obtenido con señales de satélites GPS (GPSTEC) y el contenido electrónico total derivado de Digisondas (ITEC). La base de datos incluye ionogramas y observaciones GPS obtenidos en El Arenosillo, y en Pruhonice, durante un período de baja actividad solar. Comparaciones entre las observaciones y las predicciones del contenido electrónico total del modelo IRI (IRITEC) han sido también realizadas. La forma de las tres estimaciones son similares y, como es conocido, los valores de GPSTEC son mayores que los de ITEC. Las predicciones del modelo generalmente sobrestiman los valores de ITEC. Las diferencias entre los valores de GPSTEC e ITEC son también analizadas.

INTRODUCTION

As it is known the total electron content, TEC, is the ionospheric parameter responsible for most of the effects that radio-waves undergo when they are passing through the ionosphere. The availability of TEC measurements is important to the development of ionospheric models such as the International Reference Ionosphere, IRI (Bilitza, 2001). Up to the last decade the techniques more used to measure TEC have been the Faraday rotation technique (Davies, 1980), the scatter incoherent radar, ISR and TOPEX passes.

Recently, Huang and Reinisch (2001) have introduced a new technique for estimating the total electron content from ground-based ionosonde data. Since an ionosonde cannot provide direct information about the topside electron density profile they calculate it from the bottom-side electron density and the total electron content is obtained by integration of the complete electron density profile *(ITEC)*.

The increase in availability of TEC data over the last ten years has largely come from a rapid increase in the number of Global Position System TEC data (GPSTEC) over land, providing now an important data base to study the ionosphere.

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Many studies are found in the literature that report comparisons of total electron content obtained by different techniques at different locations and comparisons of TEC measurements with predictions of models such as the IRI model (Jakowski et. al., 1998; Ezquer et. al., 1998, 2004; Huang and Reinisch, 2001; Sethi et al. 2001; Mosert et. al., 2002; Gulyaeva et. al., 2002; Belehaki et. al., 2003, 2004; Jodogne et. al., 2004)

The objective of this paper is to compare the IRI-2000 TEC predictions, *IRITEC*, (Bilitza, 2001) with *GPSTEC* and *ITEC* measurements from El Arenosillo and Pruhonice. A preliminary study of the variations of the differences between the *GPSTEC* values and the corresponding *ITEC* ones (considered as a measure of the plasmaspheric total electron content) is also done.

DATA USED

Vertical incidence ionograms from El Arenosillo (37.1N; 353.3E) and Pruhonice (50.0° N; 15.0°E) recorded by a DGS 256, during the year 2005 (Rz12=30) were used to calculate the integrated total electron content, *ITEC*, (Huang and Reinisch,2001). The database includes hourly ionograms obtained during summer (July), winter (January) and Equinox (April - October). The individual electron density profiles (Huang and Reinisch, 1996) corresponding to a given month and hour have been used to obtain the monthly median values of the integrated total electron content, *ITEC* (Huang and Reinisch, 1996; Huang and Reinisch, 2001). The corresponding IRI TEC predictions *(IRITEC)* were calculated with the last version of the model (Bilitza, 2001) and using the experimental values of foF2 and their heights (hmF2) as inputs in the model. Both TEC values *(ITEC and IRITEC)* were obtained integrating the electron density profile up to a height of 1000 km.

The monthly median values of the vertical GPS TEC measurements *(GPSTEC)* were derived from oblique GPS signals using La Plata Ionospheric Model, LPIM (Brunini et al, 2001). As it is known *GPSTEC* represents a measure of TEC up to around 20200 km (height of the GPS satellites), including the major part of the plasmaspheric electron content (Belehaki et. al. 2003, 2004).

ANALYSIS OF THE RESULTS

Figure 1 shows the comparison of the monthly median values of *ITEC, GPSTEC* and *IRITEC* in TEC units of 10^{16} m^{-2} (TECU) at Pruhonice and El Arenosillo for winter, summer and equinox during the low solar activity year 2005. It can be seen that:

(1) In general, the shapes of the 3 estimations are similar. A clear diurnal variation of the TEC values is observed in the three curves. The TEC increases gradually from hours of minimum TEC (03-06 UT) in all the seasons reaching maximum values around midday. At sunset the TEC values begin to decrease reaching minimum values around sunrise. The diurnal maximum is almost flat during summer at Pruhonice, but relatively sharp during winter and equinox in the three TEC estimations.

(2)The diurnal variations of *GPSTEC* and *ITEC* show the good correlation between both techniques. The
GPSTEC values, as it is expected, are larger than the *ITEC* values activity in all the seasons.

(3) The *IRITEC* predictions overestimate the *ITEC* values in all the seasons at the two stations. During winter time and equinox the model also overestimates the *GPSTEC* values at Pruhonice during daytime.

(4) Both TEC measurements *(ITEC* and *GPSTEC)* present lower values in winter time than in summer.

(5) The shape of the seasonal variation of the *IRITEC* predictions is, in general, similar to that observed in the electron content obtained with the two techniques: the winter values are lower than the summer ones,

Taking into account that the most contribution of TEC comes from the topside electron density profile, these results suggest that the discrepancies between *IRITEC* and *ITEC* values can be attributed to the shape of the topside IRI profile.

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Figure 2 shows for Pruhonice and El Arenosillo 2005 the diurnal variations of *DTEC* values in percentage: *DTEC%= (DTEC/GPSTEC)* x 100, during the different seasons (summer, winter and equinox) During nighttime (19-05 UT) the *DTEC %* values range around 40 and 65% and around midday (09-13 UT) they vary from 10 to 35% depending on the season and the station. Although some exceptions have been found, *DTEC%* values are generally lower in summer than in winter

The diurnal and seasonal variations of the percentage contribution of plasmaspheric electron content to the total electron content calculated using *ITEC* derived from digisondes and *GPS TEC* data are similar to those reported in previous studies by Belehaki et al. (2004) and Mosert et al. (2007) analyzing TEC measurements obtained at Athens (38.0° N; 23.5°E) and Ebro (40.8° N; 0.5° E) respectively.

This study has been done with a limited database. However it shows that it is possible to know the behavior of the plasmaspheric electron content in the places where ionospheric soundings are carried out simultaneously with GPS measurements. An extension of this study will be done using measurements obtained in other locations and under different geomagnetic conditions.

CONCLUSION

This paper studies the diurnal and seasonal behavior of the total electron content obtained using *ITEC* values calculated using the Reinisch and Huang (2001) technique and *GPS TEC* measurements derived from oblique GPS signals using La Plata Ionospheric Model , LPIM (Brunini et al, 2001). The data base includes TEC measurements recorded at El Arenosillo (37.1N; 353.3E) and Pruhonice (50.0° N; 15.0°E) during a year of low solar activity:2005 (Rz12=30). Monthly median values of *ITEC* and *GPS TEC* have been used to compare the TEC estimations with the corresponding IRI-2000 model predictions (Bilitza, 2001).The comparisons show that, in general, the IRI predictions overestimate the *ITEC* values and in some cases the *GPSTEC* values. These differences between can be attributed to the shape of the topside IRI profile.

As it is expected, the *GPSTEC* values are greater than the *ITEC* measurements. The differences between the electron content obtained by the two techniques, considered as a measure of the plasmaspheric contribution, show a clear diurnal and seasonal dependence. These results are in agreement with those reported by Belehaki et al. (2004) and by Mosert et al. (2007) using data from Athens (38.0°; 23.5°) and Ebro (40.8° N; 0.5° E) respectively.

This paper shows that it is possible to know the behavior of the plasmaspheric electron content in the places where ionospheric soundings are carried out simultaneously with GPS measurements. An extension of this study will be done using measurements obtained in other locations and under different geomagnetic conditions.

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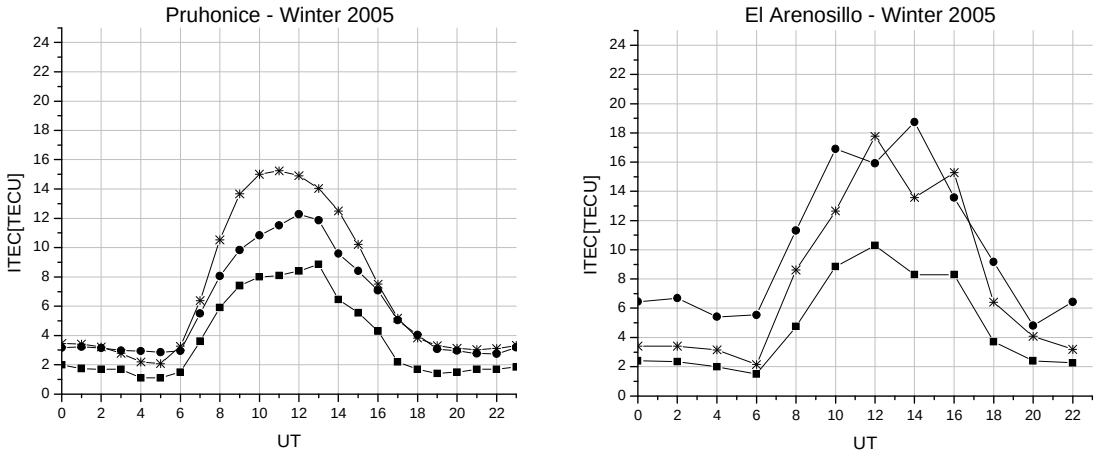

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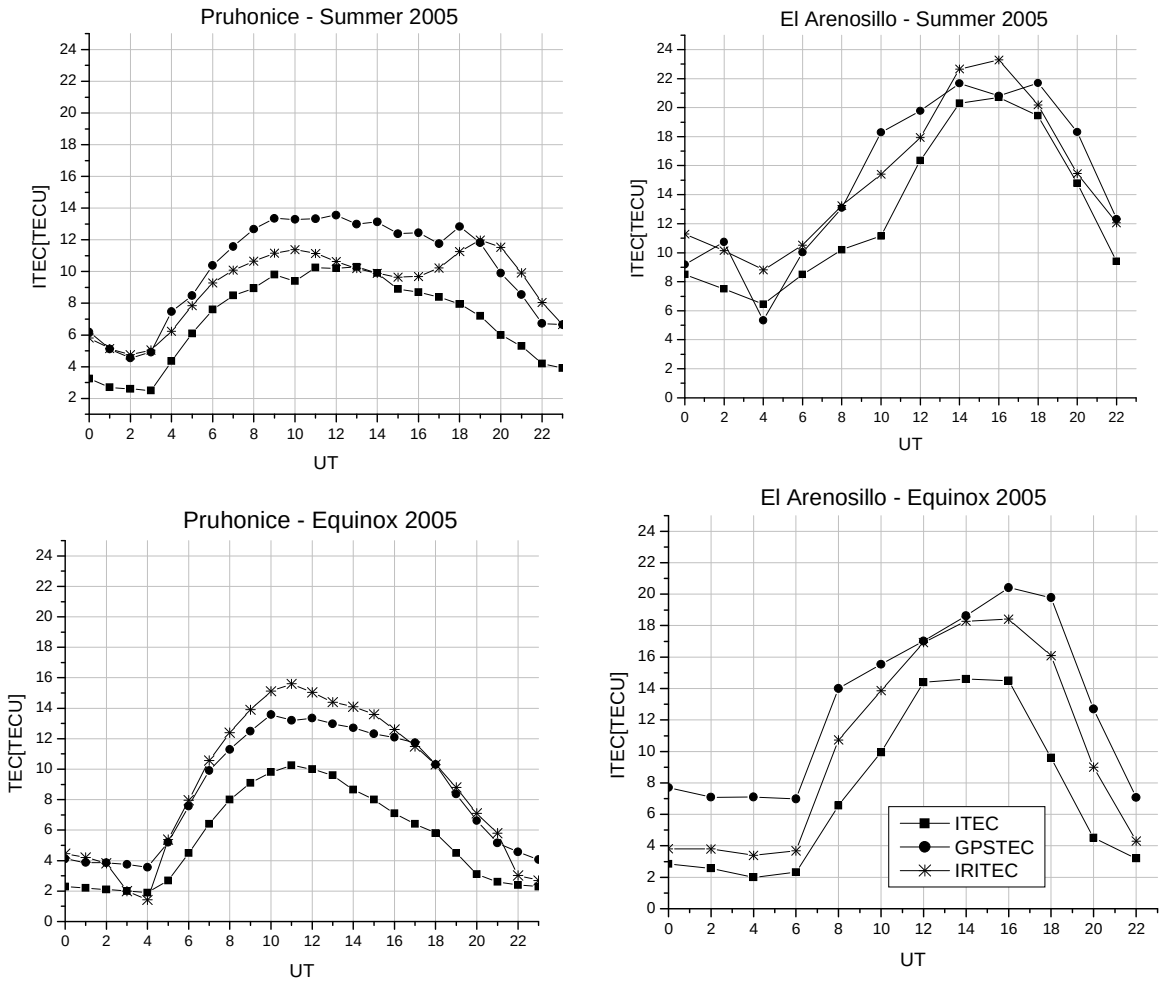

Figure 1. Diurnal variation of the monthly median values of *ITEC*, *GPSTEC* and *IRITEC* (in TEC iunits of 10^{16} m^{-2}= TECU) at Pruhonice and El Arenosillo for winter, summer and equinox during the low solar activity 2005.

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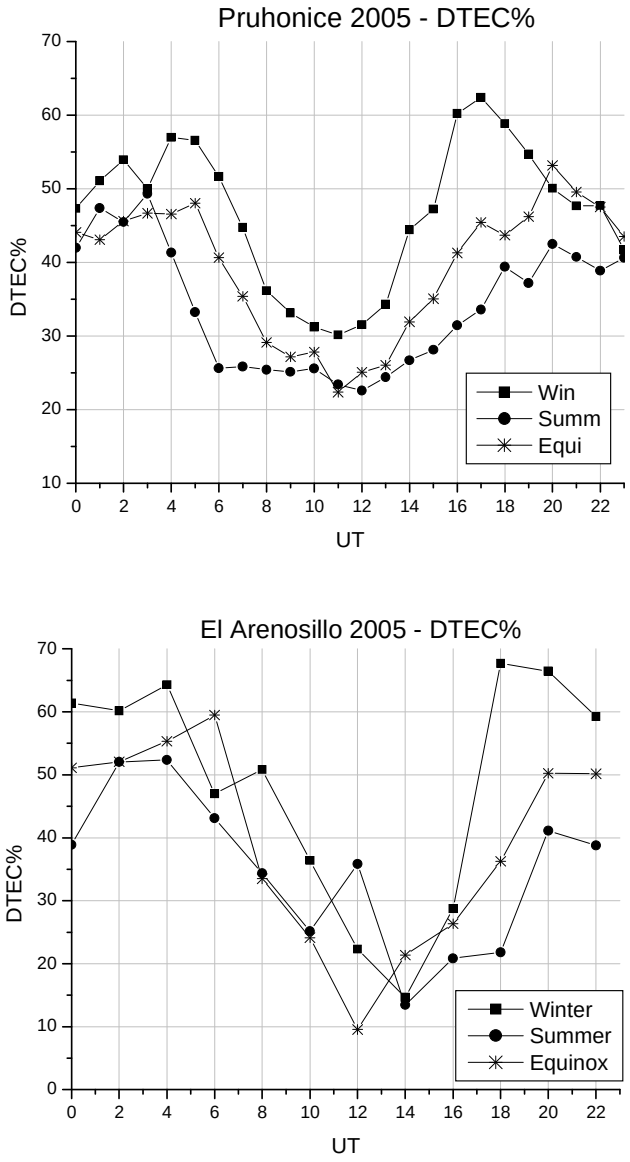

Figure 2. Variations of the *DTEC%* values at Pruhonice and El Arenosillo, during different seasons (winter, summer and equinox) of the year 2005.

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