

AN ANALYSIS OF IONOSPHERIC PARAMETERS OVER THE ANTARCTIC SECTOR USING DIFFERENT TECHNIQUES.

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ABSTRACT

The objective of this paper is to analyze the behaviour of the ionosphere over the Antarctic region using ionosonde data and GPS measurements. The data base includes hourly monthly median values of the critical frequency of the F2 region observed ($foF2$) at San Martín (68.1°S; 293.0°E geographic; 53° S magnetic) and Belgrano (77.9°S; 321.4°E geographic, 67.5° magnetic). The vertical GPS total electron content values ($GPS\ TEC$) have been derived from observations at O'Higgins (63.3°S, 302.5°E; magnetic 48.6°S). Data from different hours, seasons and solar activity periods are considered. The results show that the $foF2$ daily peak in the Antarctic stations occurs around the local noon in winter and fall. In summer a maximum diurnal value of $foF2$ is observed during night time and a minimum diurnal value of $foF2$ is found around noon, exhibiting an anomalous diurnal variation of $foF2$. This behaviour is observed at low solar activity and high solar activity. The winter anomaly is not observed in $foF2$ but the semi annual one is present around noon or post noon hours. The solar activity effect on $foF2$ is observed: the values are higher during high solar activity than during low solar activity. Related to the total electron content derived from GPS observations, similar variations have been observed. The observational database in the Antarctic Sector can help to describe better the morphology and modelling of the high latitude ionosphere particularly in the Southern hemisphere.

Keywords: Ionosphere; High latitude; Critical frequency; GPS total electron content

RESUMEN

El objetivo de este trabajo es analizar el comportamiento de la ionosfera sobre el sector antártico usando datos de ionosondas y mediciones de satélites GPS. La base de datos incluye medianas mensuales de la frecuencia crítica de la región F2 ($foF2$) observadas en San Martín (68.1° S; 293.0° E geographic; 53° S magnetic) y Belgrano (77.9° S; 321.4° E geographic; 67.5° S magnetic). Los correspondientes valores de contenido electrónico total vertical derivados de observaciones GPS ($GPS\ TEC$) en O'Higgins (63.3° S, 302.5° E; magnetic 48.6° S). Mediciones realizadas durante diferentes condiciones estacionales y de actividad solar se han utilizado en el estudio. Los resultados muestran que el pico de ionización en las estaciones antárticas ocurre alrededor del mediodía local en invierno y otoño. En verano un valor máximo en $foF2$ es observado en horas nocturnas y un mínimo diurno alrededor del mediodía tanto en baja como en alta actividad solar. Similar comportamiento es observado en las variaciones del contenido electrónico total derivado de observaciones GPS. Se discuten las posibles causas de este comportamiento y la utilidad que brinda la base de datos ionosféricos antárticos para describir mejor la morfología de la ionosfera de alta latitud y su modelado, particularmente en el hemisferio Sur.

Palabras claves: Ionosfera; Alta latitud; Frecuencia Crítica; Contenido Electrónico Total GPS

INTRODUCCION

The terrestrial ionosphere may be divided broadly into three regions that have rather different properties (Hunsucker and Hargreaves, 2003): the equatorial zone, within 20° of the magnetic equator, the high-latitude zone, poleward of about 60° geomagnetic and the temperate zone in between. The high latitude zone may be sub-divided into the auroral zone (approximately 60° - 70° magnetic) and the polar cap (poleward of the auroral zone).

The ionospheric parameters, strongly dependent on the solar conditions and on the complex behaviour of the magnetosphere, are very interesting for studying the complex phenomena and high degree of space/time variability of the ionosphere occurring at the high latitude regions. Moreover, the analysis of the ionospheric data contributes to give a real time evaluation of HF radio-propagation conditions "in situ" and to test the available ionospheric prediction methods.

The known features of the high latitude region have been derived mainly from observations in the North hemisphere. However marked differences between the hemispheres have been observed (Mallis and Essex, 1993).

In the Argentine Antarctic sector there are two ionospheric stations: San Martín and Belgrano. They have been operating for more than 4 decades. However, only some few studies can be found in the literature using the Antarctic ionospheric data base.

The Antarctic San Martín station has a high geographic latitude, but due to the offset of the geographic and geomagnetic poles and the differences between the geomagnetic field center and the Earth's center, it is a geomagnetically mid-latitude station in terms of its geomagnetic coordinates. Belgrano station is an auroral station from the geographic and geomagnetic point of view. As a result, both stations present a particular set of physical conditions very useful for understanding more clearly the behavior of the Antarctic ionosphere.

The availability of TEC measurements is important to the development of ionospheric model such as the International Reference Ionosphere IRI (Bilitza, 2001; Bilitza and Reinich, 2008). Historically, most of the TEC measurements have used the Faraday rotation technique, incoherent scatter radar measurements, and TOPEX surface reflections. The increase of TEC data over the last years has largely come from a rapid increase in the number of Global Position System TEC data (*GPSTEC*) over land.

The objective of this paper is to analyze the behaviour of the ionosphere over the Antarctic region using ionosonde data and GPS measurements.

DATA USED

The analysis have been done using values of the critical frequency of the F2 region (from now *foF2*) and of the vertical GPS total electron content measurements (from now *GPS TEC*) observed at the Antarctic region.

The *foF2* values have been recorded at San Martín (68.1°S ; 293.0°E geographic; 53°S magnetic) and Belgrano (77.9°S ; 321.4°E geographic, 67.5° magnetic). The *GPS TEC* values have been derived from GPS observations at O'Higgins (63.3°S , 302.5°E ; magnetic 48.6°S). The data base includes hourly monthly median values of *foF2* and *GPS TEC* corresponding to the representative months of winter (July), summer (January), fall (April) and spring (October) for a high solar activity (HSA) period: 2000 (RZ12=117) - 2001 (Rz12=111) and for a low solar activity (LSA) period: 1996 (RZ12=9)-1997 (RZ12= 23). La Plata Ionospheric Model (LPIM), described in detail by Brunini et al. (2001), has been used to obtain the *GPSTEC* from the GPS slant TEC observations.

RESULTS

Figure 1 illustrates the variations of the hourly monthly median values of *foF2* in Mhz at San Martín during the representative months of January (summer), April (fall), July (winter) and October (spring) during the high solar activity period 2000-2001 and the low solar activity period 1996-1997.

The results for San Martín indicate that the daily *foF2* peak occurs around the local noon and the minimum value around sunrise in July and April, indicating, as it is expected, a solar zenith angle

dependence. In October the diurnal variations of $foF2$ are not clear during HSA. During LSA the values of $foF2$ show a solar control. In January an anomalous daily maximum of $foF2$ is observed during night time and lower values are present around noon. This behaviour is observed at low solar activity (1996-1997) and high solar activity (2000-2001) and it has been also reported by other authors (Sojka et al., 1988; Patlov et al., 2008).

The explication of the summer variations can be associated to the separation of the geographic and magnetic poles. The neutral air wind in the thermosphere blows over the polar regions generally away from the Sun. At around 0600 UT in the Antarctic regions is the midnight side of the magnetic pole and the drag of the neutral particles against the ions therefore acts to lift the ionosphere. The rate of recombination of ions is thereby reduced and the net ion density is increased. This is also the time of the day when the largest amount of the geomagnetic polar cup is sunlit, and it is therefore when the circulation pattern will be most effective at bringing solar produced ionization over the pole (Sojka et al., 1988).

The winter anomaly (higher values of $foF2$ in winter than in summer) is not observed. The only exception found is at 1700 UT during the year 2000. The semi-annual anomaly (equinoctial peaks of $foF2$) appears around noon and post noon hours. The influence of the solar activity on $foF2$ is also found: higher values of $foF2$ are observed at high solar activity than at low solar activity

Although some differences have been found, the behaviour of the $foF2$ over Belgrano is, in general, similar to that observed at San Martín. (For space constraints the variations of $foF2$ over Belgrano are not shown).

Figure 2 illustrates the variations of the median values of *GPS TEC* measured at O'Higgins in TEC units (TECU) of $10^{16} / m^2$ for the months of January, April, July and October during the high solar activity period 2000-2001 and the low solar activity period 1996-1997. Note that *GPS TEC* data are missing during the winter of the high solar activity year 2000. It can be seen that, in general, the diurnal, seasonal and solar activity variations of *GPS TEC* are similar to those observed in $foF2$ at San Martín. The more important differences in the variations compared with the corresponding $foF2$ ones, is observed in October of the years 2000-2001 where a clear maximum *GPS TEC* value is found around the local noon and minimum values around sunrise indicating a solar zenith angle control.

Taking into account that the observational database from the Argentine Antarctic Sector can help to describe better the morphology and modelling of the high latitude ionosphere particularly in the Southern hemisphere, additional studies will be done using a larger database.

CONCLUSIONS

Using ionosonde and GPS observations at three Antarctic stations: San Martín, Belgrano and O'Higgins hourly monthly median values of $foF2$ (critical frequency of the F2 region) and GPS TEC (vertical GPS total electron content) have been derived. The diurnal, seasonal and solar activity variations of both parameters have been analysed. The study shows that the maximum values of $foF2$ are observed during night time January (summer) and the minimum values of $foF2$ are found around noon. This behaviour is observed at low solar activity (1996-1997) and high solar activity (2000-2001). The explication of the summer variations can be associated to the separation of the geographic and magnetic poles. These anomalous variations of $foF2$ is not found in winter and fall when the daily $foF2$ peak occurs around the local noon with lower values around sunrise indicating, as it is expected, a solar zenith angle dependence. Related to the *GPS TEC* measurements, similar variations have been generally found.

The observational database in the Antarctic Sector can help to describe better the morphology and modelling of the high latitude ionosphere particularly in the Southern hemisphere.

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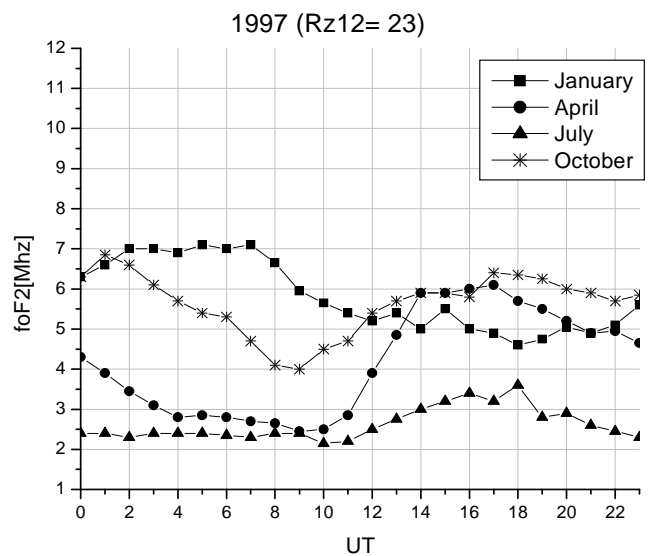
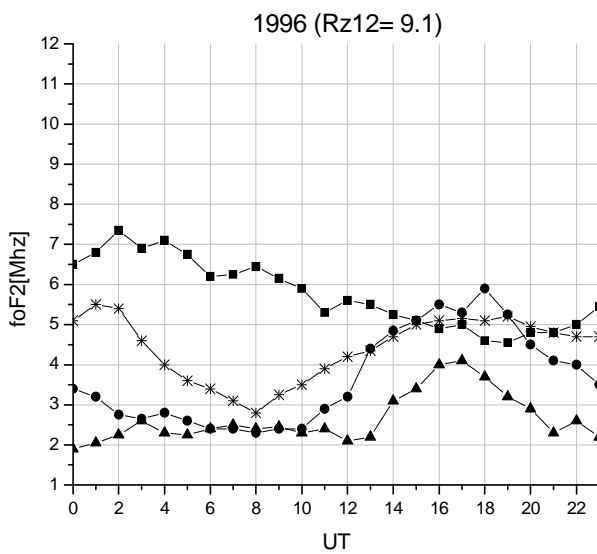
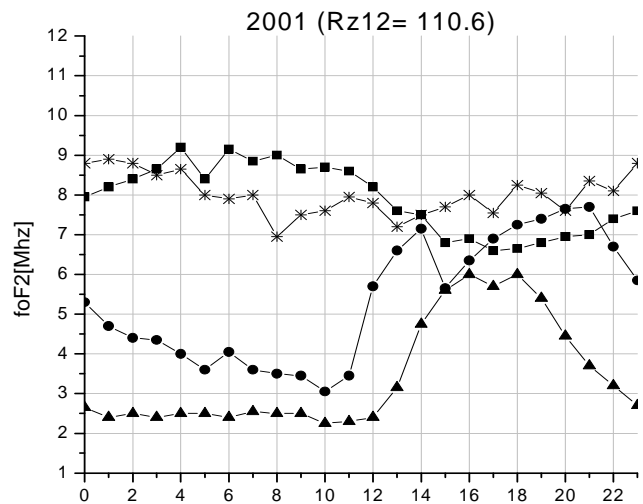
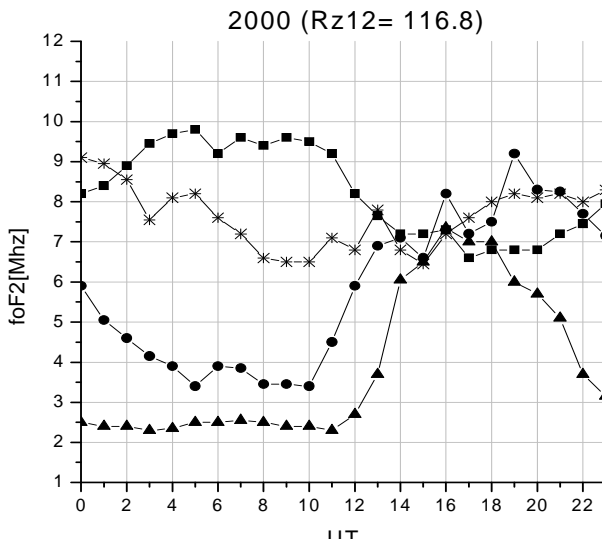


Figure. 1 Variation of the hourly monthly median values of $foF2$ measured at San Martín during the representative months of summer (January), winter (July), fall (April) and spring (October). High solar activity: 2000 ($Rz12= 116.8$), 2001 ($Rz12= 110.6$) and Low solar activity 1996 ($Rz12= 9.1$) and 1997 ($Rz12= 23$).

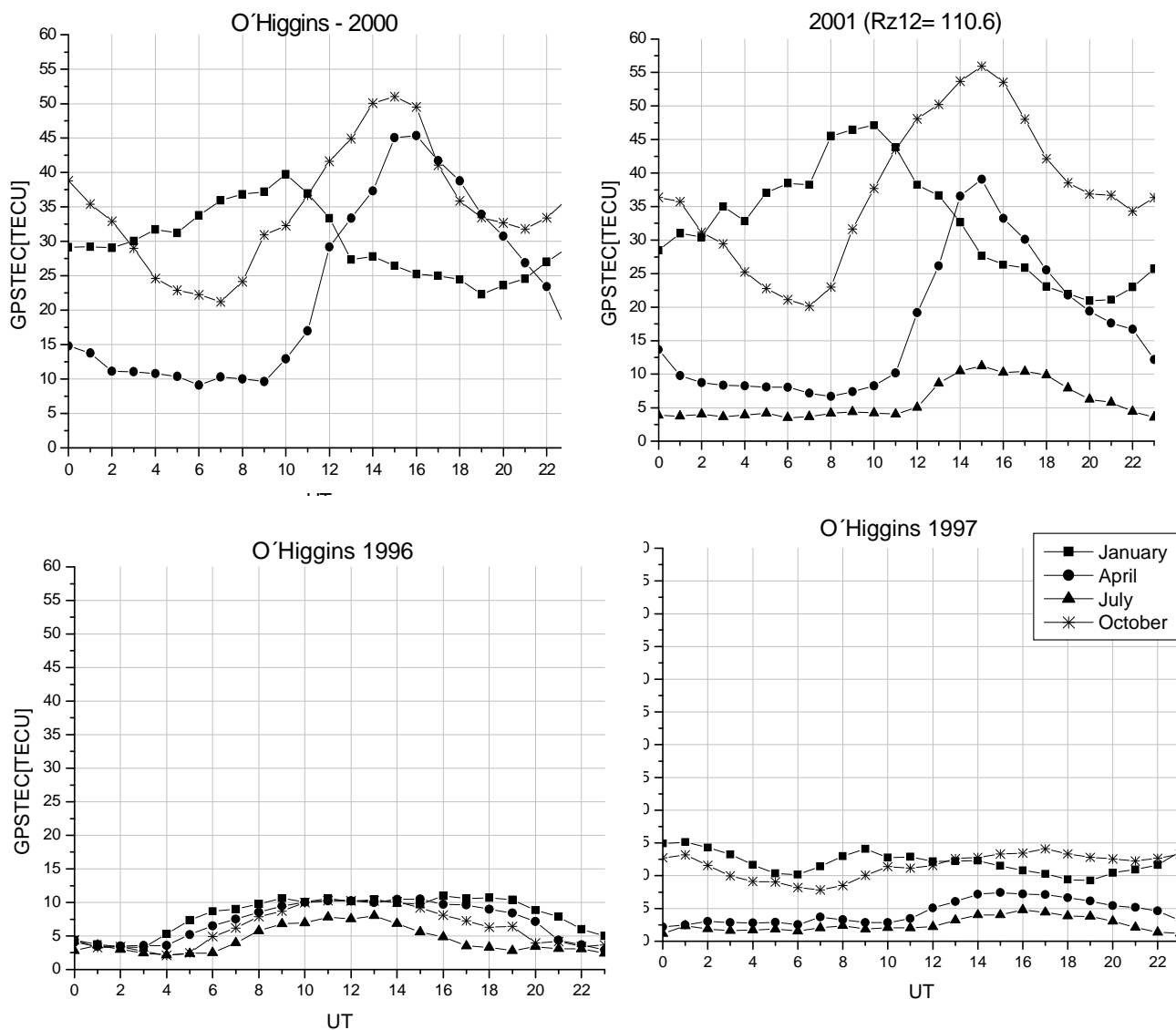


Figure. 2 Variation of the hourly monthly median values of $GPSTEC$ measured at O'Higgins during the representative months of summer (January), winter (July), fall (April) and spring (October). High solar activity: 2000 ($Rz12= 116.8$), 2001 ($Rz12= 110.6$) and Low solar activity 1996 ($Rz12= 9.1$) and 1997 ($Rz12= 23$).