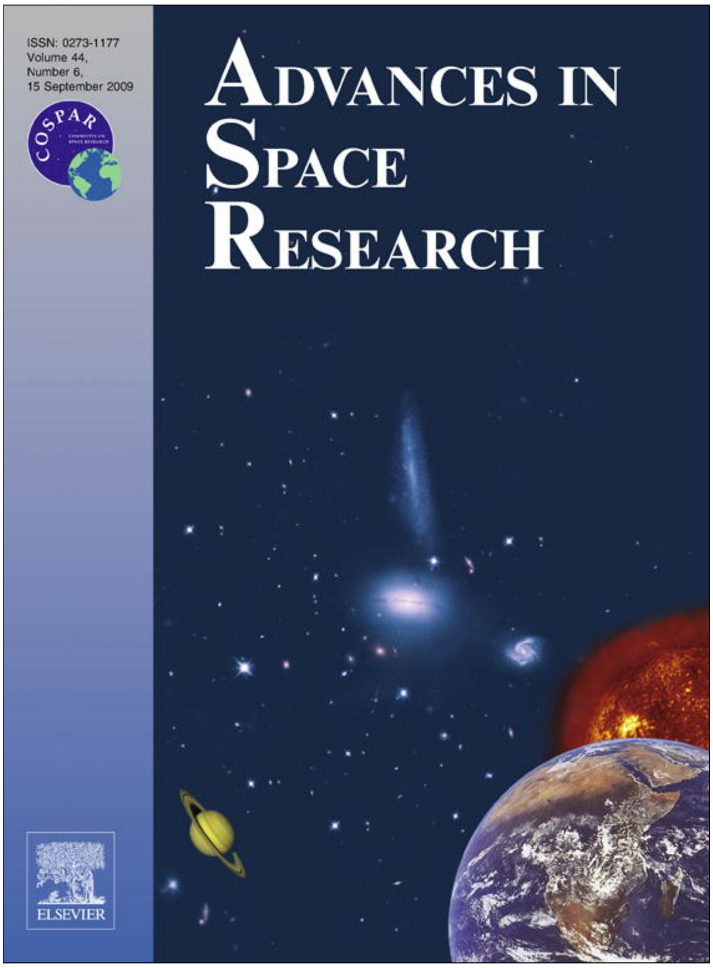
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IRI 2001/90 TEC predictions over a low latitude station

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Abstract

Total electron content (TEC) over Tucumán (26.9°S, 294.6°W) measured with Faraday technique during the high solar activity year 1982, is used to check IRI 2001 TEC predictions at the southern crest of the equatorial anomaly region. Comparisons with IRI 90 are also made. The results show that in general IRI overestimates TEC values around the daily minimum and underestimates it the remaining hours. Better predictions are obtained using ground ionosonde measurements as input coefficients in the IRI model. The results suggest that for hours of maximum TEC values the electron density profile is broader than that assumed by the model. The main reason for the disagreement would be the IRI shape of the electron density profile.

In a previous work using TEC measurements over Tucumán, obtained from GPS satellite signals during the high solar activity year 1999, a better agreement between IRI predictions and measurements has been observed. That better agreement was produced by the fact that 1999 GPS TEC measurements are 50% lower than those obtained by Faraday rotation technique during 1982. An equator ward movement of the southern peak of the EA plus the minor ionization level in 1999 could produce this reduction in TEC values.

Moreover, it can be seen that in most of cases IRI TEC values around daily minimum show an hour displacement with respect to the experimental data.

Keywords: IRI; Ionosphere; Electronic Density; TEC

1. Introduction

The behaviour of the ionosphere is very important for HF propagation. Most of the effects produced on a signal which traverses the ionosphere are proportional, at least to the first order, to the number of free electrons encountered by the wave on its passage trough it. Concerning to this, a useful parameter is the total electron content (TEC) and is defined as "the number of free electrons in a cylinder of unit cross section along the radio wave path". TEC is an ionospheric variable of great importance for systems that use transionospheric radio waves (Hartman and Leitinger, 1984). So, for ionospheric calculations, TEC predictions from ionospheric models can be useful tools when TEC measurements are not available.

The highest TEC values occur at the equatorial anomaly (EA) peaks located at approximately 15° either side from the magnetic equator. In this work, the validity of International Reference ionosphere 2001 model (IRI 2001) is checked and compared against experimental data of TEC measured at Tucumán (26.9°S, 294.60°W), station placed near the southern peak of the EA in the American sector. Predictions of IRI 90 are also considered. In a previous work, Ezquer et al. (1998), using IRI 95 version, checked the validity of the IRI model in predicting the VTEC over Tucumán, using geosynchronous satellite signals received during 1982 and they founded that in general the model

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overestimates VTEC during the daily minimum and underestimates it the rest hours of the day.

The goal of this study is to compare the IRI 2001 TEC predictions for 1982 with those obtained with IRI 90 to check the validity of IRI 2001 TEC predictions after the improvements made especially at the low latitudes bottomside parameters.

Our conclusion is that no significant improvements were observed when comparing IRI 2001 against IRI 90 version, for low latitude TEC predictions.

2. IRI model

The Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI) formed a working group to produce an empirical standard model of the ionosphere, based on all available data source. This model is called the International Reference Ionosphere, IRI, is the international standard for the specification of ionospheric densities and temperatures. A new version of IRI was developed for year 2000 (Bilitza, 2001) and it includes important changes, as follows: (1) an improved representation of the electron density in the region from the F peak down to the E peak including a better description of the F1 layer occurrence statistics and a more realistic description of the low-latitude bottomside thickness, (2) inclusion of a model for storm-time conditions, (3) inclusion of an ion drift model, (4) two new options of the electron density in the D region, (5) an improved model for the topside electron temperatures, as the most important.

Comparisons with a large number of TEC data (McNamara and Wilkinson, 1983; McNamara, 1984, 1985) have shown large discrepancies of the Bent and IRI models close the magnetic equator. Ezquer et al. (1998) in a study that used TEC and foF2 measurements for 1982 (HSA) from Tucumán, a station close to the southern crest of the equator anomaly, found that IRI underestimates at day time.

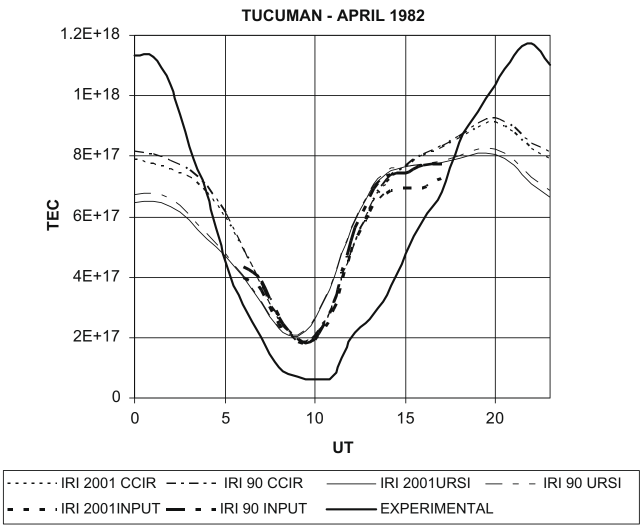


Fig. 1. TEC predicted and measured (by Faraday techniques) values over Tucumán, for April 1982.

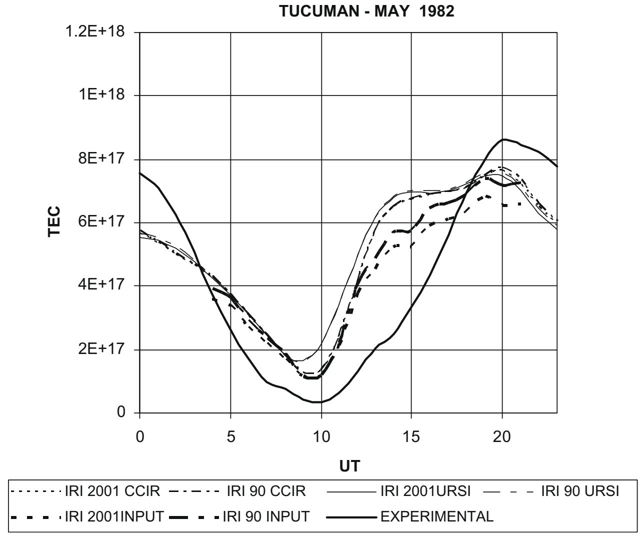


Fig. 2. TEC predicted and measured (by Faraday techniques) values over Tucumán, for May 1982.

In this study, we compare the IRI 2001 TEC predictions for 1982 with those obtained with IRI 90 in order to check the validity of IRI 2001 after the improvements made, especially for low latitudes bottomside parameters.

3. Data and results

TEC measurements over Tucumán obtained with Faraday technique using geosynchronous satellite signals received during the high solar activity (HSA) year 1982 are considered. These TEC values are similar to those obtained at the low latitude station Ascension Island with the same technique during the HSA years 1980, 1981 (Klobuchar, 1985).

To obtain the modelled TEC values, IRI 2001 and IRI 90 models have been used. The CCIR and URSI options

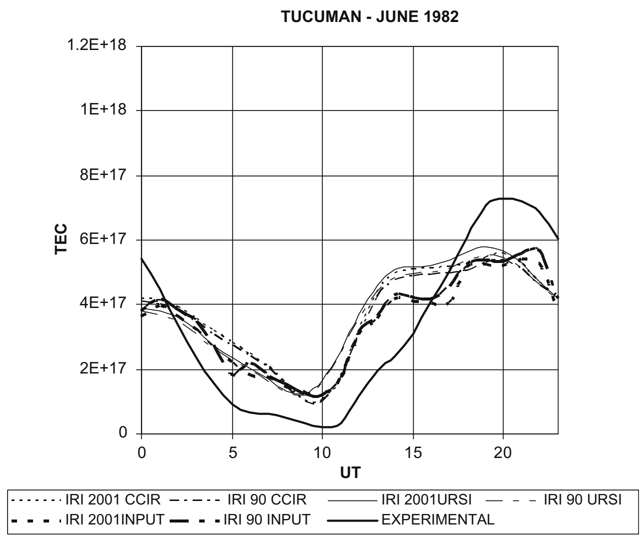


Fig. 3. TEC predicted and measured (by Faraday techniques) values over Tucumán, for June 1982.

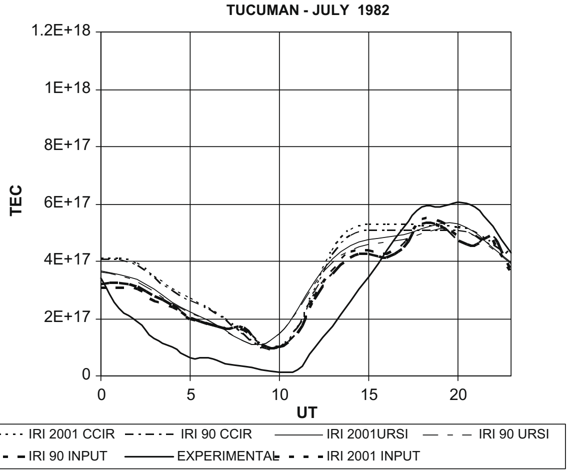


Fig. 4. TEC predicted and measured (by Faraday techniques) values over Tucumán, for July 1982.

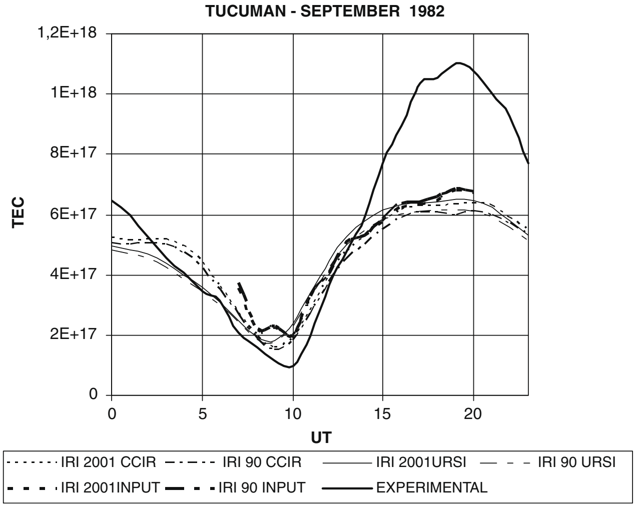


Fig. 6. TEC predicted and measured (by Faraday techniques) values over Tucumán, for September 1982.

are used to model maximum electron density of F2 region (NmF2) and its height (hmF2). Values of NmF2 and hmF2 obtained from Tucumán ground ionosonde measurements were also used as input coefficients in the models.

Fig. 1 shows similar results for IRI 2001 and 90 when CCIR option is used, except for the maximum ionization hours where IRI 2001 predicts smaller values than IRI 90.

When the URSI option is used the values observed are similar for both IRI models.

During maximum ionization hours, the CCIR option shows greater values than URSI option for both models, IRI 2001 and 90.

When ionosonde data are used as input, IRI 2001 shows smaller values than IRI 90 for maximum ionization hours. The disagreement between IRI 2001 and 90 is greater when the input option is used than using CCIR or URSI options.

These observations would suggest that the IRI 2001 N profile is narrow than that for IRI 90, for the maximum ionization hours.

In general, the figure shows that all the options overestimate TEC around the daily minimum (about 200% and more) and underestimates TEC values on maximum ionization hours (about 20–40%). Similar conclusions were obtained in previous papers (Ezquer et al., 1995, 1998).

The daily minimum hour is predicted almost one hour before than observed values when using CCIR and URSI options, for IRI 2001 and IRI 90.

Fig. 2 shows similar results to those observed for April. For the hours between 0 and 8 UT, CCIR and URSI options for both models give similar predictions. From 9 to 15 UT, URSI option shows greater values than CCIR

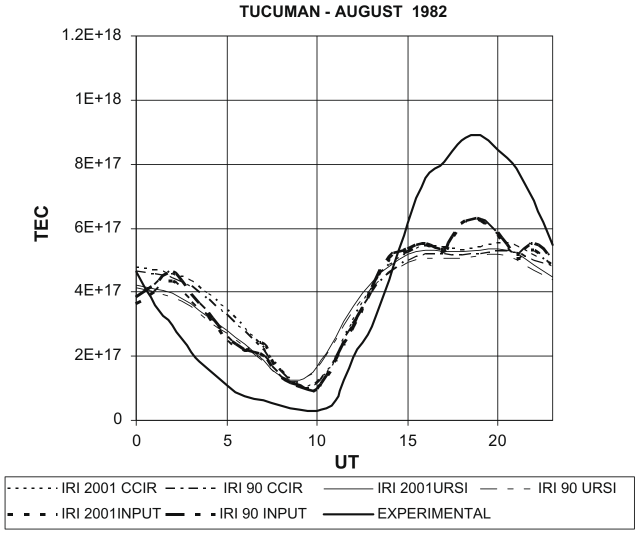


Fig. 5. TEC predicted and measured (by Faraday techniques) values over Tucumán, for August 1982.

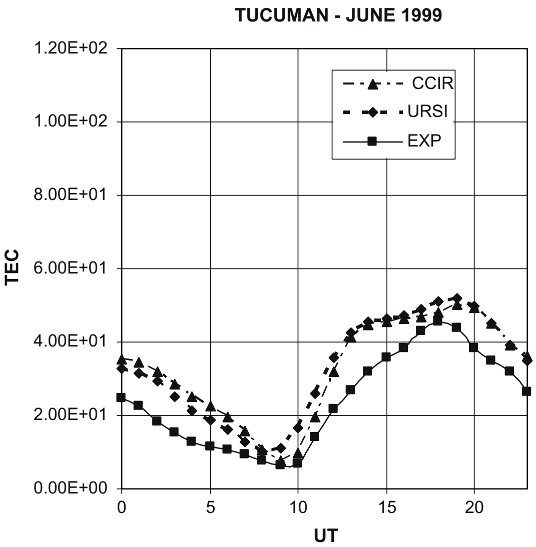


Fig. 7. TEC predicted by IRI 2001 and measured (by GPS signals) values over Tucumán, for June 1999. (Data from Ezquer et al., 2004a).

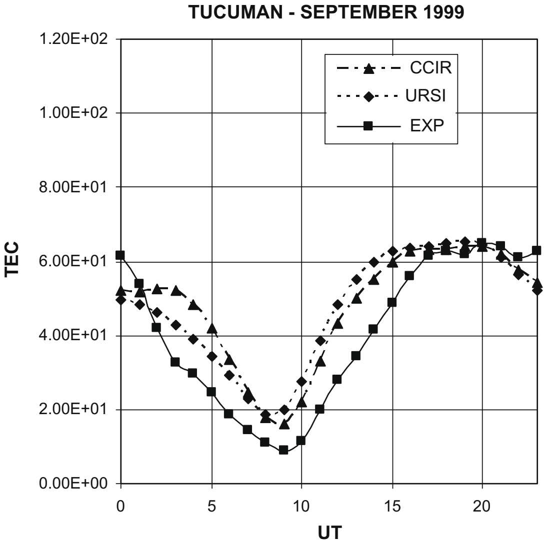


Fig. 8. TEC predicted by IRI 2001 and measured (by GPS signals) values over Tucumán, for September 1999. (Data from Ezquer et al., 2004a).

for models, IRI 2001 and 90. On maximum ionization hours on May, less underestimation than April is observed.

For June, Fig. 3 shows the same behaviour as Fig. 2.

In Fig. 4, corresponding to July, we can observe different values for URSI and CCIR options in both models, IRI 2001 and IRI 90, for hours near 0 UT. Between 0 and 16 UT the model overestimates the TEC values. For the maximum ionization hours, there is an underestimation but closer to the experimental data.

For August, Fig. 5 shows similar results to those for June but the underestimation for the maximum ionization hours is worse.

In September, Fig. 6 shows similar results to those observed for August but we can find a good agreement from 04 UT to 07 UT when using the URSI option, for both models. On the other hand, a strong underestimation for maximum ionization hours is observed.

Ezquer et al. (2004a) compared TEC measurements over Tucumán obtained from GPS satellites signals with IRI 2001 modelled values. They considered data obtained in June and September of HSA year 1999. Figs. 7 and 8 show the obtained results. It can be seen that, in general, the model overestimates TEC values. For September, good agreement between predictions and measurements is observed at hours of maximum TEC, which was produced by the fact that 1999 GPS TEC measurements are 50% lower than those obtained by Faraday rotation technique during 1982.

In order to check the ionization level in June and September corresponding to 1982 and 1999, we compared the maximum electron density of the F2 region (NmF2) over Boulder, Rome and Chilton. Figs. 11–13 show the obtained results. It can be seen that for the three stations the daytime data corresponding to September 1982 is slightly greater than those of 1999. For June, the opposite behaviour is observed. On the other hand, Ezquer et al. (2004b) studied the GPS TEC behaviour over nine stations in the South American sector. They found that TEC values over Arequipa (−16.4; 288.5; geomag.lat.−5.0), station placed near the valley of the EA, for June and September 1999 were greater than those obtained at Tucumán (−26.9°S, 294.6°) station placed under the southern peak of the EA. The authors suggested that the Southern peak of the EA could move equator ward during that period. So, the fact that GPS TEC values obtained during 1999 were lower than those obtained with Faraday technique during 1982, would be produced by a different ionization level and a movement of the southern peak of the EA.

Comparisons between predictions using ionosonde data as input, against CCIR and URSI options, on IRI 2001 model (for the best and the worst cases), are shown in Figs. 9 and 10.

The results show a better TEC prediction when using ionosonde foF2 and M3000F2 input data in comparison

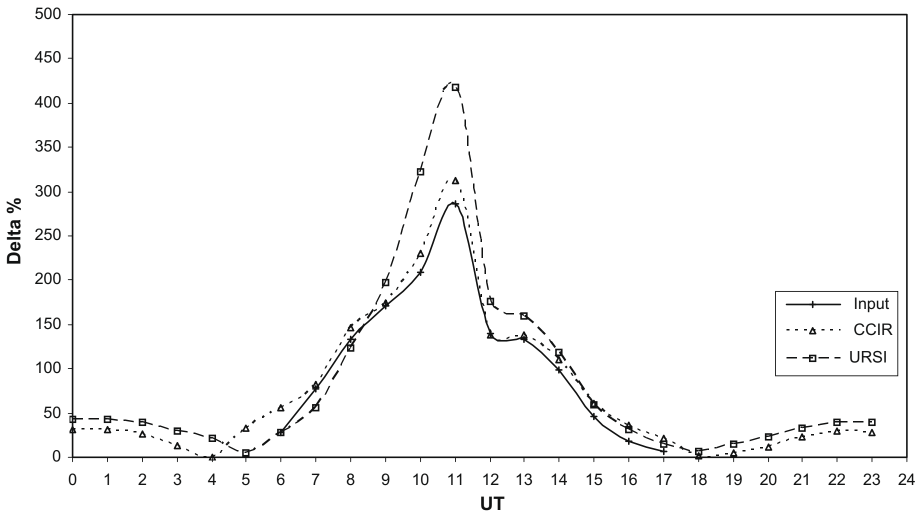


Fig. 9. Relative deviation from experimental TEC values for April 1982. Delta% = ((measured TEC − modelled TEC)/measured TEC)·100.

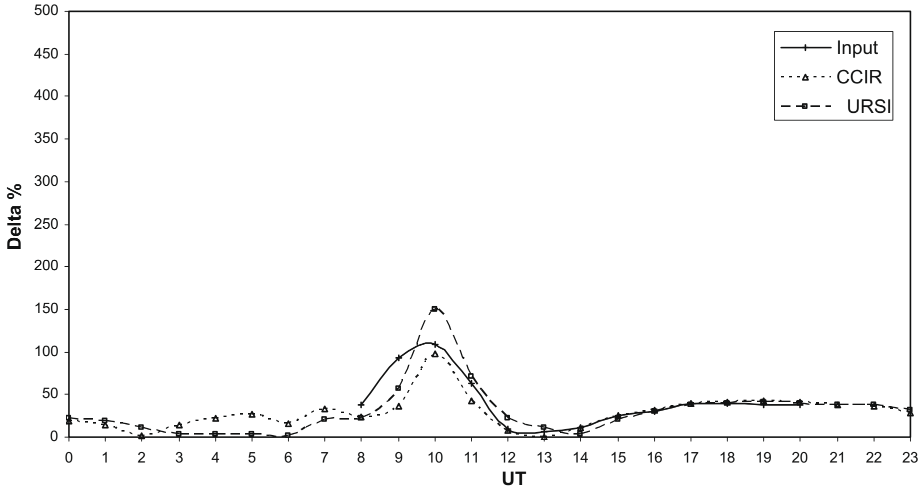


Fig. 10. Relative deviation from experimental TEC values for September 1982. Delta% = ((measured TEC − modelled TEC)/measured TEC)·100.

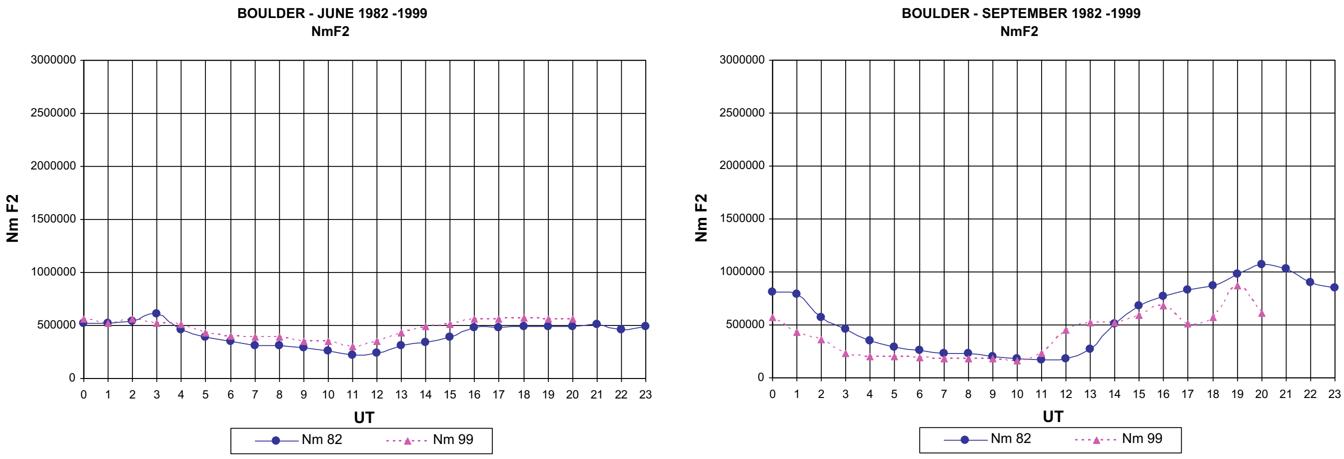


Fig. 11. Boulder station (−40.03; −105.3). Data source: UK Solar System Data Center. http://www.ukssdc.ac.uk/wdccl/ionosondes/secure/iono_avail.shtml.

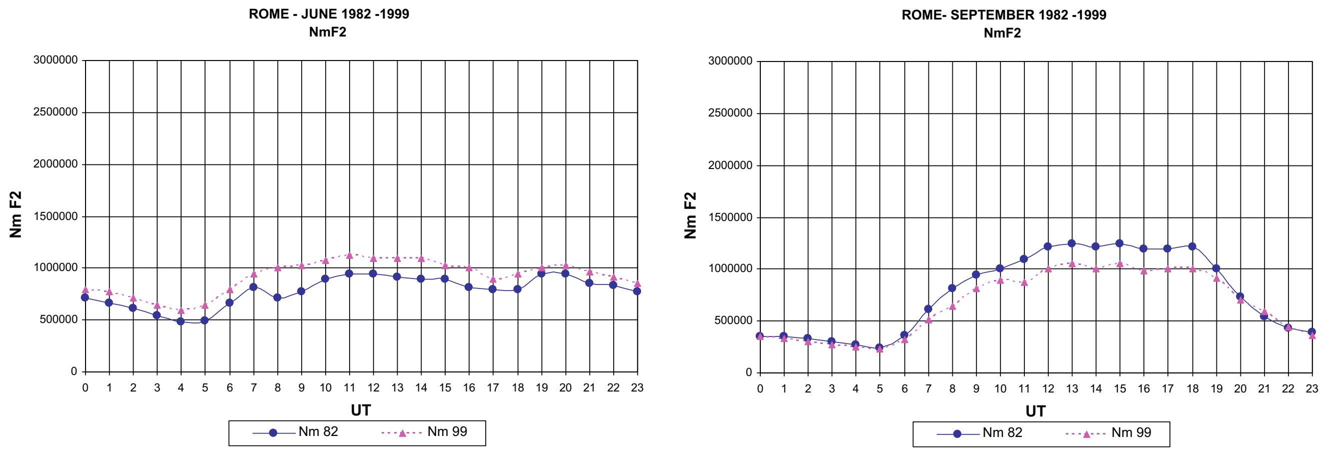
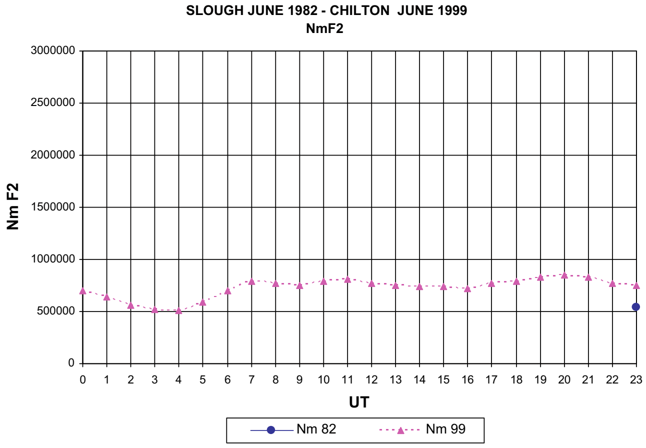


Fig. 12. Rome station (−41.9; 12.52). Data source: UK Solar System Data Center. http://www.ukssdc.ac.uk/wdccl/ionosondes/secure/iono_avail.shtml.

with CCIR and URSI maps IRI versions. In Fig. 9, we observe that the main disagreement takes place at the minimum ionization hours, where the relative difference for TEC values at 10 UT obtained from input data are 10% smaller than those obtained from CCIR maps model and around 30% smaller than those values obtained from the



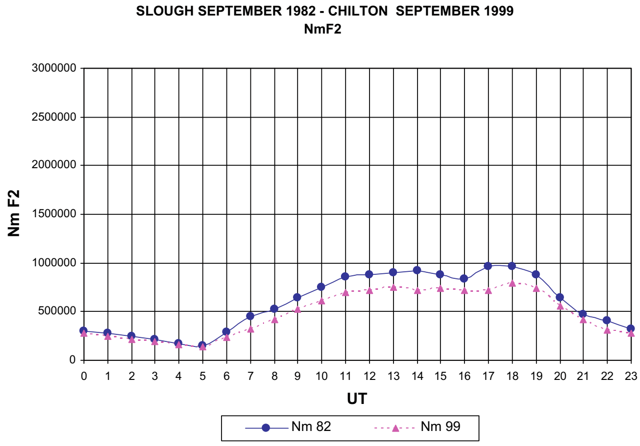


Fig. 13. Station Slough and Chilton (−51.48; −0.57). Data source: UK Solar System Data Center. http://www.ukssdc.ac.uk/wdccl/ionosondes/secure/iono_avail.shtml. Solar Activity Rz 1982: June 117; September 101. Solar Activity Rz 1999: June 93; September 102.

URSI maps version. Similar results are shown in Fig. 10, where input and CCIR deviations are similar but URSI deviation is around 50% higher at 10 UT.

4. Conclusions

There is not an important improvement in IRI 2001 in relation to earlier versions for TEC predictions for Tucumán.

In general, IRI overestimates TEC values around the daily minimum and underestimates it the remaining hours. Better predictions are obtained using ground ionosonde measurements as input coefficients in the IRI model. Nevertheless, in some cases like April and May 1982, there is a more important underestimation using the input option for the maximum ionization hours.

The better agreement observed between models predictions and GPS TEC measurements in 1999 was produced by the fact that the mentioned measurements are 50% lower than those obtained by Faraday rotation technique during 1982. An equator ward movement of the southern peak of the EA plus the minor ionization level in 1999 could produce this reduction in TEC values.

Moreover, it can be seen that in most of cases IRI TEC values around daily minimum show an hour displacement with respect to the experimental data.

Taking into account the disagreements between TEC modelled values and measurements, we think that the IRI model improvements on B_0 and B_1 parameters, which determine the thickness and shape of the bottomside F2 layer (Reinisch and Huang, 2000), were not enough for an accurate TEC prediction for Tucumán, particularly on maximum ionization hours. It seems to be reasonable since the bottomside electron density contributes 20–40% to the TEC (Bilitza, 2001).

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