World Research Journal of Biomaterials
ISSN: 2278-7046 & E-ISSN: 2278-7054, Volume 1, Issue 1, 2012, pp.-08-11.
Available online at http://www.bioinfo.in/contents.php?id=211

VARIABILITY OF HMF2 OVER ROME: COMPARISON WITH INTERNATIONAL REFERENCE IONOSPHERE (IRI) MODEL PREDICTIONS

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Received: February 16, 2011; Accepted: June 07, 2012

Abstract- This study presents the variations of the seasonal median values of the height of peak electron density of the F2-layer (hmF2). The values were derived from ionosonde measurements at a mid-latitude station in Rome (ROM) (41.8°N, 12.5°E). These values were analyzed and compared with the International Reference Ionosphere (IRI-2007) model, using Comite' Consultatif International des Radio Communications) (CCIR) and Union Radio-Scientific Internationale (URSI) options. The analysis covered hmF2 values for December Solstices (November, December and January), March Equinox (February, March and April), June Solstices (May, June, July) and September Equinox (August, September, October) during the high and low solar activity periods of 2001-2002 and 2007-2008 respectively. The IRI-2007 model prediction follow fairly well the diurnal and seasonal variation patterns of the observed values of hmF2 at all the three stations. However, the model overestimates and underestimates hmF2 at different times of the day for both solar activity periods and in all seasons considered. For both solar activity periods considered, the CCIR and URSI options of the IRI-2007 model give hmF2 values close to the ones measured. However, the CCIR option performed better than the URSI option.
Keywords - IRI-2007 model, CCIR, URSI models, Rome

Citation: Olaniyi G.A., Adewale A.O. and Oyeyemi E.O. (2012) Variability of hmF2 Over Rome: Comparison with International Reference Ionosphere (IRI) Model Predictions. World Research Journal of Biomaterials, ISSN: 2278-7046 & E-ISSN: 2278-7054, Volume 1, Issue 1, pp.-08-11.

Introduction

Several researchers have examined the prediction ability of the International Reference Ionosphere (IRI) model for ionospheric parameters [1,14]. IRI is an empirical ionospheric model based on experimental observations of the ionospheric plasma either by ground or by in-situ measurements. The IRI model provides two options for the predictions of height of the maximum electron density of the F2 layer (hmF2) and the critical frequency of the F2 layer (foF2). The Comite' Consultatif International des Radio Communications (CCIR) uses the CCIR coefficient [3] while the Union Radio-Scientifique Internationale (URSI) uses the URSI coefficient [6,13]. Models like the IRI provide a description of the monthly mean conditions. A user also needs an estimate of how far the real ionosphere might deviate from this monthly average.

A number of recent studies have revealed variability in ionospheric parameters (like hmF2 and foF2) between predicted measurements of the two options of the IRI model and the actual observed values collected from the Space Physics Interactive Data Resources (SPIDR). These studies take into significance, the latitudinal positions and the solar cycle spread of the data used [5,7] The improvement of the quality of telecommunication links is essentially hinged on the accurate knowledge of the ionospheric parameters, features, behaviours and characteristics [8]. The height of the peak electron density of the F2-Layer (hmF2) is one of the easiest accessible ionospheric parameters. It is a very useful parameter for ionospheric radio-wave propagation studies. This parameter is used to derive the angle of elevation to meet the antenna requirements for point-to-point communication [13].

Many researchers have compared the observed hmF2 values with the IRI model at equatorial and low latitudes during low and high solar activity periods [2,10,16].

The results of their studies have revealed that the IRI models are good for low and high solar activities, except for post-sunset conditions for equatorial latitudes during high solar activity when the

IRI does not reproduce the post-sunset peak, which is an important feature of equatorial regions. For the low latitudes, a few discrepancies have been reported by these researchers.

This study is therefore conducted to examine the diurnal and seasonal variations of hmF2 over a middle latitude station in Rome (ROM), (41.8N, 12.5E) during different periods of solar activity with the view to understand how the IRI-2007 model predicts hmF2.

Materials and Methods

The data used for this research were obtained from the Space Physics Interactive Data Resources (SPIDR) (http://spidr.ngdc.noaa.gov), a resource of the World Data Centre in Boulder. Hourly median values of hmF2 for December Solstice (DEC SOLS) (November, December, January), March Equinox (MAR EQUI), (February, March, April), June Solstice (JUN SOLS) (May, June, July) and September Equinox (SEP EQUI) (August, September, October), have been used for this study. The International Reference Ionosphere (IRI) 2007 model values used for this study were obtained from http://ccmc.gsfc.nasa.gov/models/index.php.

For the clearer observation of the variations of the hmF2 during the different levels of solar cycle, data from 2001-2002 (which is close, to the peak of the solar cycle), with an average sunspot number R_z of 111.0 and 119.0 respectively to represent a period of high solar activity (HSA) and 2007-2008 with an average sunspot number R_z of 7.5 and 2.9 respectively, to represent a period of low solar activity (LSA), were obtained for analysis. These observed values of hmF2 are compared with values predicted by the IRI 2007 model, using the CCIR and URSI coefficients.

To calculate the differences the hourly mean of the observed values and the predicted values, the equation below was used:

$$d = (x - y)^2 \qquad (1)$$

Where x = observed values and y = predicted (CCIR or URSI) values.

The root mean square (rms) error between the IRI-2007 (CCIR and URSI) models results and the observed values of the hmF2 was also analyzed, according to the following equation.

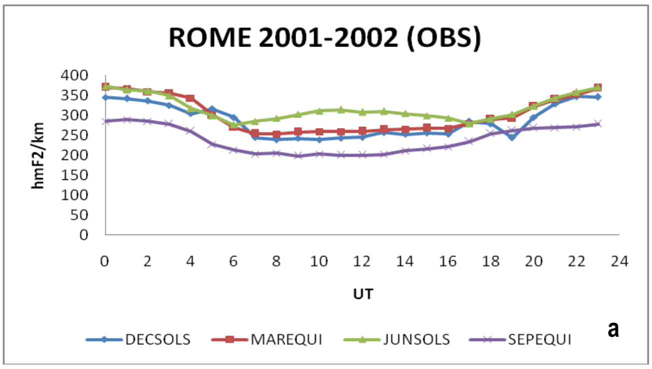
$$\text{RMS error} = \sqrt{\left(\frac{\sum_{i=1}^{24} d_i}{24}\right)}$$

Where di represents differences of the observed and predicted values and Σ means summation.

Results and Disscussion

Diurnal and seasonal variation of hmF2

The diurnal and seasonal variations of hmF2 values during high solar activity (HSA) (2001-2002) and low solar activity (LSA) for ROM (41.8°N, 12.5°E) are presented in Figure 1a and b. The result shows that the monthly median values of hmF2 are higher during HSA period for all seasons. This is because temperature variations cause hmF2 to increase with increasing solar activity (Stubbe, 1964). Also, the height of F2 peak depends on the temperature profile in the thermosphere and increasing solar activity raises thermospheric temperature, thus causing thermal expansion which lifts the pressure level at which hmF2 is situated (Rishbeth, 1993). For all the months considered for this study, hmF2 has lower values during daytime compared with night time values. This might be caused by the meridional winds, because they produced a strong upward drift at night and a downward drift during the day (Rishbeth and Garriot, 1969).Diurnal variation of hmF2 is well explained in terms of the following: ion production rate, temperature variations, thermospheric neutral winds and electromagnetic drifts (Fejer, 1997). The hmF2 values decrease during 0300-1200 UT after which it starts to increase gradually until it reaches its maximum value around midnight, during 0100-0300 UT, Figures 1a and b. The midday minimum is observed between 1100 and 1300UT. The diurnal pattern of the observed median hmF2 values has peaks occurring characteristically between 2400 and 0100 UT. The hmF2 has minimum around midday. This is seen for both HSA (2001-2002) and LSA (2007-2008) period.



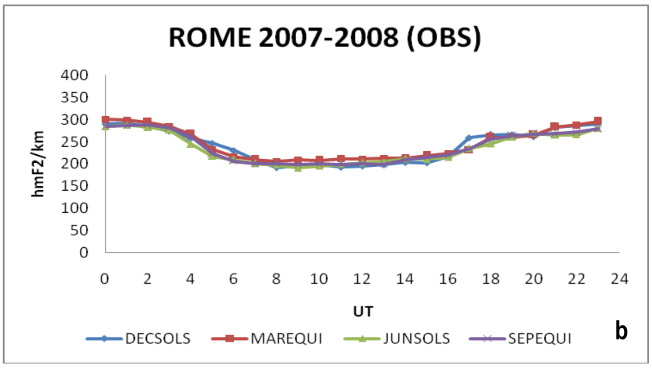


Fig. 1- Diurnal variations of observed median values of hmF2 during high solar activity **(a)** and low solar activity **(b)** periods for Rome.

Comparisons with IRI-2007

Figures 2a and b and c and d show the comparison of the observed hmF2 with those of the IRI-2007, using both CCIR and URSI coefficients. There is a reasonable agreement between the observed hmF2 and the predicted values during HSA and LSA periods. During the HSA period (2001-2002), the observed pre-noon minimum occurs between 0600 and 0800 UT. For the LSA period (2007-2008), the observed pre-noon minimum values occurred between 0800 and 1200UT. The height of the F2 peak falls because of the rapid production of ionization in the lower F region, and reaches minimum before noon (Rishbeth and Garriott, 1969). The CCIR and URSI coefficients predicted accurately the observed pre-noon minimum at Rome. The two coefficients predicted accurately the observed midnight maximum at 0100UT at ROM for DEC SOLS, MAR EQUI and JUN SOLS, the observed pre-noon minimum lies between 0700 and 0100UT and the predicted values are between 0600 and 0100UT. The midnight maximum for MAR EQUI, JUN SOLS and SEP EQUI occurred at 0000 and 0200UT, except during DEC SOLS where it occurred at 0100UT. The predicted values show that the midnight maximum lies between 0000 and 0200UT in all the seasons. For all the seasons' simulations in ROM the observed pre-noon minimum occurred between 0600 and 1000UT and the predicted values occurred between 0700 and 1000UT. Also, the observed midnight maximum occurs between 0000 and 0100UT and the predicted values show that the midnight maximum lies between 0000 and 0100UT.

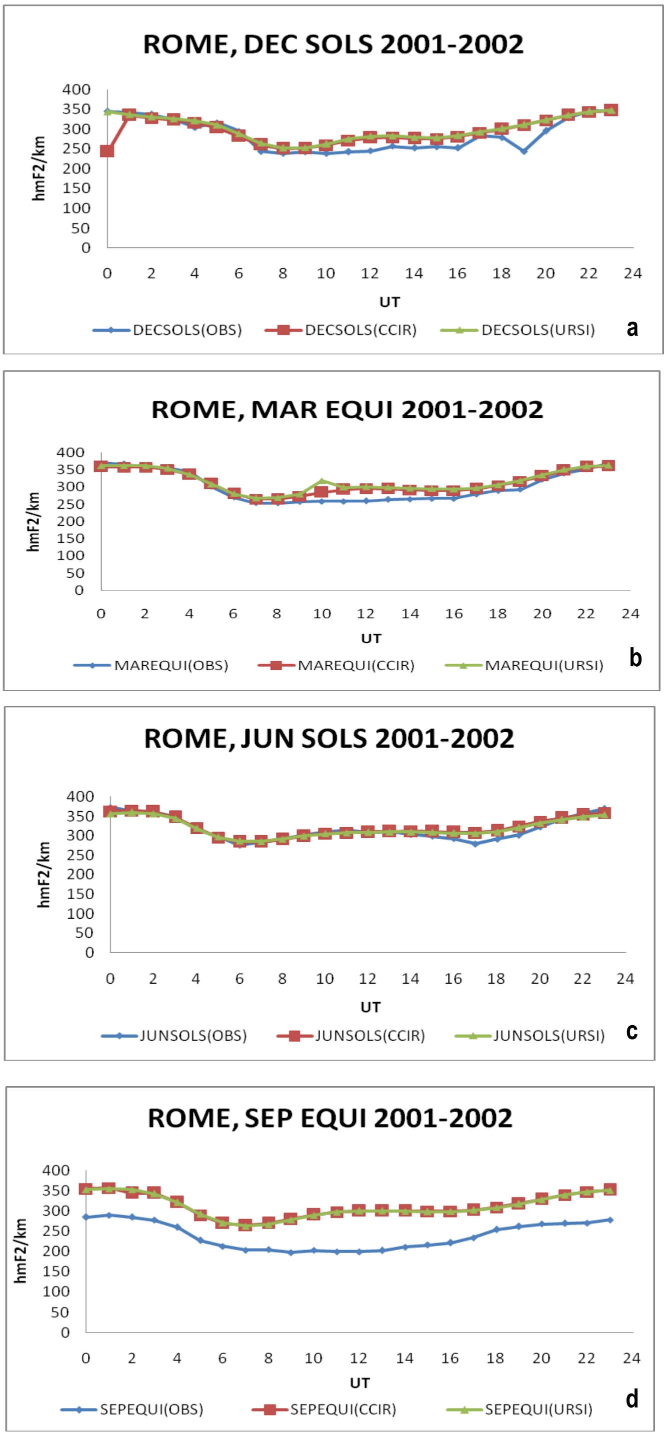


Fig. 2- a, b, c and d

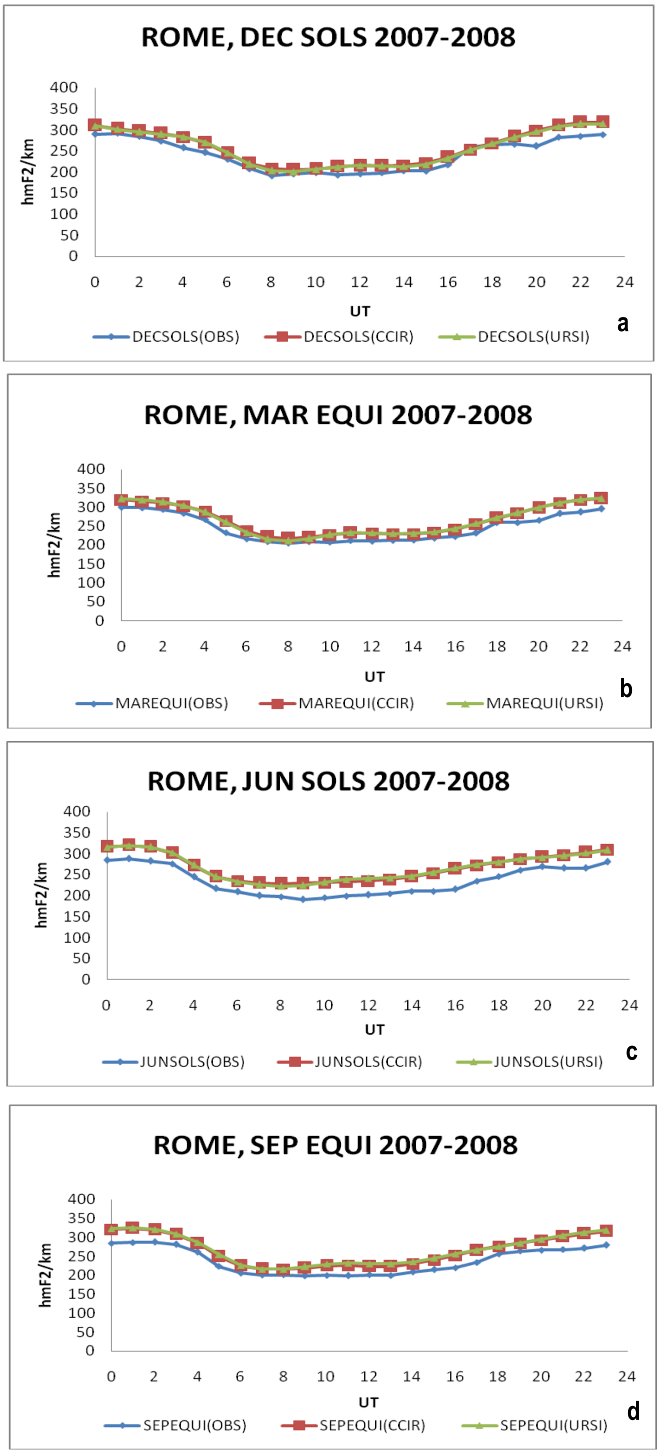


Fig. 3- a, b, c and d

Seasonal Predictions Errors

Tables 1a and b show the calculated percentage errors in the predicted values to the observed one. Apart from the inaccuracies observed in the predictions of maximum and minimum hourly values, errors can also be observed in the variations of the hmF2. JUN SOLS, though had low errors, like 10.93% (CCIR)/10.4% (URSI) for ROM (2001-2002). SEP EQUI predictions also had high errors: 73.8% (CCIR)/73.7% (URSI) for ROM (2001-2002).

However, DEC SOLS predictions errors are fairly low.

Table 1(a)- Percentage errors in the predicted values of hmF2 during high solar periods to the observed values for Rome

ROME 2001-2002	%CCIR	%URSI
DECEMBER SOLSTICES: 2001-2002	30.0531	23.23693
MARCH EQUINOXES:2001-2002	18.24151	23.71028
JUNE SOLSTICES:2001-2002	10.93297	10.42343
SEPTEMBER EQUINOXES:2001-2002	73.84079	73.67035

Table 1(b)- Percentage errors in the predicted values of hmF2 during high solar periods to the observed values for Rome

ROME 2007-2008	%CCIR	%URSI
DECEMBER SOLSTICES:2007-2008	19.68279	17.98511
MARCH EQUINOXES:2007-2008	21.34433	21.43144
JUNE SOLSTICES:2007-2008	33.21126	33.48874
SEPTEMBER EQUINOXES:2007-2008	27.44654	30.0558

Conclusion

This study had examined the variations in observed and predicted values of the hmF2. It was achieved by analyzing the diurnal and seasonal averages of HSA (2001-2002) and LSA (2007-2008) hmF2 values for Rome (ROM) (41.8^{o}N, 12.5^{o}E) in comparison with those predicted in the IRI-2007 models. There is a very close similarity in the pattern of the daily maximum and minimum values. There were few exceptions to this pattern. However, there are discrepancies between observed values and the IRI-2007 predictions using CCIR and URSI coefficients. IRI model underestimates and overestimates the values of hmF2 at different times of the day for all the seasons, during the different solar activity periods considered. There are great variations between the observed values and the IRI-2007 model predictions, for low solar activity. Both the CCIR and URSI options of the IRI-2007 model gave hmF2 values close to the ones measured, the CCIR gave more accurate predictions than the URSI results.

References

[1] Adeniyi J.O., Radicella S.M. (1998) *J. Atmos. Sol-Terr. Phys.* 60, 381-385.
[2] Adewale A.O., Oyeyemi E.O., Mckinnell L.A. (2008) *J. Atmos and Solar Terr. Physics*, 71, 273-284.
[3] CCIR (1991) *Int. Telecommum. Union, Geneva*.
[4] Fejer B.G. (1997) *J. Atmos. Sol. Terr. Phys*. 59, 1465-1482.
[5] Fotiadis D.N., Baziakos G.M., Kouris S.S. (2004) *Adv. Space Res.* 33(6), 893-901.
[6] Fox M.W., McNamara L.F. (1988) *J. Atmos. Terr. Phys.* 50, 1077-1086.
[7] Kouris S.S., Fotiadis D.N. (2002) *Adv. Space Res.*, 29(6), 977-985.
[8] Lilensten J., Blelly P.L. (2002) *J. Atmos. Sol-Terr. Phys.* 64, 775-793.
[9] Miller K.L., Lemon M., Richards P.G. (1997) *J. Atmos. Terr. Phys.* 59, 1805-1822.
[10] Oyeyemi E.O., Adwale A.O. (2009) *J. Sci. Res. Dev.* 11, 110-121.
[11] Rishbeth H., Garriott O.K. (1969) *Introduction to Ionospheric Physics. Academic Press, New York and London*.
[12] Rishbeth H. (1993) *J. Atmos Sol-Terr. Phys.,* 165-171.
[13] Rush C.M., Fox M., Bilitza D., Davies K., McNamara L., Stewart F.G., Pokempner M. (1989) *Telecommun. J.* 56, 179-182.
[14] Sethi N.K., Dabas R.S., Sharma K. (2008) *J. Atmos. Sol-Terr. Phys.* 70, 756-763.
[15] Stubbe P. (1964) *J. Atmos. Terr. Phys.* 26, 1055-1068.
[16] Wang X., Shi J.K., Wang G.J., Gong Y. (2009) *Adv. Space Res.* 43, 1812-1820.