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ScienceDirect
Advances in Space Research 39 (2007) 661–667
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Ionospheric behavior of the F2 peak parameters foF2 and hmF2 at Hainan and comparisons with IRI model predictions

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Received 20 December 2005; received in revised form 27 March 2006; accepted 30 March 2006

Abstract

Monthly median values of foF2, hmF2 and M(3000)F2 parameters, with hourly time interval resolution for the diurnal variation, obtained with DPS-4 digisonde observations at Hainan (19.4°N, 109.0°E) are used to study the low latitude ionospheric variation behavior. The observational results are compared with the International Reference Ionospheric Model (IRI) predictions. The time period coverage of the data used for the present study is from March 2002 to February 2005. Our present study showed that: (1) In general, IRI predictions using CCIR and URSI coefficients follow well the diurnal and seasonal variation patterns of the experimental values of foF2. However, CCIR foF2 and URSI foF2 IRI predictions systematically underestimate the observed results during most time period of the day, with the percentage difference ΔfoF2 (%) values changing between about −5% and −25%, whereas for a few hours around pre-sunrise, the IRI predictions generally overestimate the observational ones with ΔfoF2 (%) sometimes reaching as large as ~30%. The agreement between the IRI results and the observational ones is better for the year 2002 than for the other years. The best agreement between the IRI results and the observational ones is obtained in summer when using URSI coefficients, with the seasonal average values of ΔfoF2 (%) being within the limits of ±10%. (2) In general, the IRI predicted hmF2 values using CCIR M(3000)F2 option shows a poor agreement with the observational results. However, when using the measured M(3000)F2 as input, the diurnal variation pattern of hmF2 given by IRI2001 has a much better agreement with the observational one with the detailed fine structures including the pre-sunrise and post-sunset peaks reproduced reasonably well. The agreement between the IRI predicted hmF2 values using CCIR M(30,000)F2 option and the observational ones is worst for the afternoon to post-midnight hours for the high solar activity year 2002. During daytime hours the agreement between the hmF2 values obtained with CCIR M(30,000)F2 option and the observational ones is best for summer season. The discrepancy between the observational hmF2 and that obtained with CCIR M(30,000)F2 option stem from the CCIR M(3000)F2 model, which does not produce the small scale structures observed in the measured M(3000)F2.

Keywords: Low latitude ionosphere; F2 peak parameters; IRI model

1. Introduction

The International Reference Ionosphere (IRI) is a model that has many practical applications, e.g., in satellite designing and operation. IRI was developed, and is updated periodically, by a joint working group of COSPAR and URSI. Since its first release in 1978, many improvements had been made to this model (Rawer et al., 1978; Bilitza, 1990, 1997, 2001; Radicella et al., 1998; Bilitza et al., 2000). IRI uses an analytic formula (Ramakrishnan and Rawer, 1972) to calculate the F2 layer electron density profile based on four important parameters: foF2, hmF2, B0 and B1. The F2 peak parameters (foF2 and hmF2) are two key parameters when producing the electron density profile using IRI model. Their accuracy affects the accuracy

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doi:10.1016/j.asr.2006.03.047

of the profiles produced. The IRI model uses either CCIR or URSI coefficients to predict the foF2 and hmF2/M3000(F2) based on the 12-month running average sunspot number Rz12. However, since the ionospheric data from the Chinese continent were not used when producing both CCIR and URSI coefficients, a validation study of the model compared with observational results from this continent is a necessity. In this paper, data from Hainan (19.4°N, 109.0°E), China is used to study the low latitude ionospheric variation behavior and comparisons with IRI model results are made. The IRI model used in the present study is IRI2001 (Bilitza, 2001). This is a continuation work of a previous paper (Zhang et al., 2004) in which ionospheric characteristic parameters including foF2 and hmF2 for Hainan were used to make a comparison study with IRI2000. However, the data used in that paper covered only 6 months, March–August 2002, a time period with available data when the work was reported at the 34th COSPAR Assembly in 2002. Data used for the present study are based on a database with much longer time period coverage (3 years).

2. Data used

Data used for the present study are monthly median values of foF2, hmF2 and M(3000)F2 parameters, with hourly time interval resolution for the diurnal variation. These monthly median values are calculated from the daily hourly values scaled from the ionograms recorded routinely by the DPS-4 digisonde at Hainan (19.4°N, 109.0°E), China. When calculating the monthly median values of each parameter, all days of the month with available data are used. All recorded ionograms used for the present study were manually edited using the SAO-explorer software (Sao Explorer, Interactive Ionogram Scaling Technologies, http://ulcar.uml.edu/SAO-X/SAO-X.html; Reinisch et al., 2004) developed by the University of Lowell Massachusetts, Center for Atmospheric Research for quality control before obtaining the daily hourly data from ionograms. The time period coverage of the data used is from March 2002 to February 2005 (yearly average values of Rz12 = 102, 64, 40 and 30, respectively). In some cases data are divided into groups according to seasons: the winter season includes January, February, November and December, the equinox season includes March, April, September and October, the summer season includes May–August.

3. Results

3.1. *foF2*

Fig. 1 shows the contour plot of the observational monthly median values of foF2 parameter versus universal time (UT) and month during the period from March 2002 to February 2005 for Hainan. Notice that the local time of Hainan is LT = UT + 109/15 ≈UT + 7.3 h. From Fig. 1, it

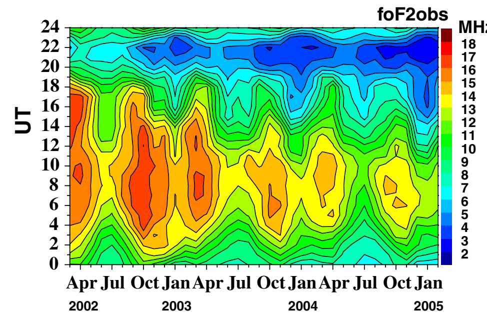

Fig. 1. Contour plot of the monthly median foF2 observed at Hainan during March 2002–February 2005.

can be seen that foF2 parameter shows a diurnal variation pattern with highest values occurring at daytime hours and lowest values occurring at pre-sunrise hours. For the daytime values, it has an evident semi-annual seasonal variation pattern with highest peaks occurring in equinox and lowest peaks occurring in summer. However, for the pre-sunrise hour low values, an annual variation pattern is observed, with the minimum values occurring in equinox–winter and maximum values in summer. Fig. 1 also shows that foF2 has an evident solar activity dependence with its value decreasing from the higher solar activity year 2002 to the lower solar activity year 2005.

The results obtained by IRI model using both CCIR and URSI options, foF2ccir and foF2ursi (plots not shown here), showed very similar diurnal and seasonal variation patterns and solar activity dependence to the observational ones. However, the magnitudes of foF2 values produced by IRI model with CCIR and URSI options have some differences with the observed ones. Fig. 2 shows the diurnal and seasonal variations of the difference between the observational foF2 value (foF2obs) and that produced by IRI model (foF2iri). The difference ΔfoF2 and ΔfoF2 (%) are defined as: ΔfoF2 = foF2iri − foF2obs and ΔfoF2 (%) = [(foF2iri − foF2obs)/foF2obs] × 100%, where foF2iri = foF2ccir for CCIR option and foF2iri = foF2ursi for URSI one. It can be seen that during most time period of the day, both foF2ccir and foF2ursi underestimate the observational foF2 values with ΔfoF2 (%) values changing between about −5% and −25%, whereas during a few hours around pre-sunrise, the IRI predictions generally overestimate the observational ones with ΔfoF2 (%) sometimes reaching as large as ∼30%. However, there was an exception for the spring–summer period of the year 2002. During this period there was no evident overestimation in the IRI results for the daytime hours. The IRI predictions had a better agreement with the observational ones during this period than during the other periods.

Fig. 3 shows the seasonal averages of ΔfoF2 and ΔfoF2 (%). It can be seen that (1) for CCIR option, during daytime hours there seems no big seasonal difference in ΔfoF2 and ΔfoF2 (%), with the seasonal average of ΔfoF2 (%) changing between about −8% and −15%. However, at nighttime there are some seasonal differences, the worst