A physical model for one-dimension and time-dependent ionosphere. Part II. Results and discussion

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Abstract
Results of a one-dimension time-dependent ionospheric theoretical model when experimental critical frequency of the F_2 region are used as input data are given. Evidences of the validity of the mentioned model are shown; and it is indicated that the bottom side F region described by IRI90 empirical model for Wuchang (30.5°N, 11.4°E) is well reproduced by the theoretical model for different seasons and low solar activity, meanwhile, it is shown that IRI gives values of the electron concentration in the topside larger than the model. Also, the effect of the dynamics and the photo-ionization on the variation of the height of the peak is discussed.

Key words *aeronomy – ionosphere*

1. Introduction

Electron density height profiles and the main parameters of the F_2 layer – foF_2 and hmF_2 may be obtained either from the solution of physical equations, such as momentum or continuity equations, or from empirical and semi-empirical models like the IRI (Bilitza, 1990). A very wide spectrum of theoretical models has been developed, while further work concerning the use of experimental results within the theoretical schemes is still open. A one-dimension and time-dependent ionospheric model, based on the momentum and continuity equations and 10 photo-chemistry reactions for major ionic compositions O^+, N_2^+, O_2^+ and NO^+, has been developed (Zhang, 1993). This model uses as input the experiment-based models of background data as MSIS86 (Hedin, 1986), HWM90 (Hedin *et al.*, 1991). As it is well known, a major problem of the ionospheric simulation is the appropriate determination of the upper boundary condition. They can be given by the experimental data or by model predictions or by theoretical considerations. The observed values of foF_2, could not be utilized directly as the upper boundary condition. The present study uses the upper boundary values obtained by fitting the profile of electron density to the experimental peak value determined by the measured foF_2.

Concerning the above mentioned we present here the results of the model. The comparison with the IRI profiles and the deduced height of the F_2 peak is carried out, and relevant discussion is also given.

2. Results and discussion

The simulation is conducted with the introduction of the experimental foF_2 over Wuchang (30.5°N, 114.4°E) for 1986 and 1987, years of low solar activity.

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Model variations of the temperature and the wind for June 1986, as an example, are shown in fig. 1a,b. The neutral temperature, from MSIS86, almost does not vary with height in the range of 200-500 km over the whole day except around 17.00LT when it approaches the maximum (fig. 1a). The meridional wind obtained from HWM90 is characterized by the tidal variation below 200 km; for the upper region, however, the southward maximum occurs at 05:00LT, the sub-maximum at noon, and then the wind gradually reverses reaching the northward maximum at 20:00LT. The height-dependence of the wind is only evident around the maxima in the diurnal course (fig. 1b).

Figures 2a,b show calculations of electron density with the present theoretical model for Wuchang and June 1986. Figure 2a gives the isolines of electron density as a function of time and height. The dashed line indicates *F* region peak height. It can be seen that, as expected, the bottom side ionosphere shows sharp height gradients at nighttime and the

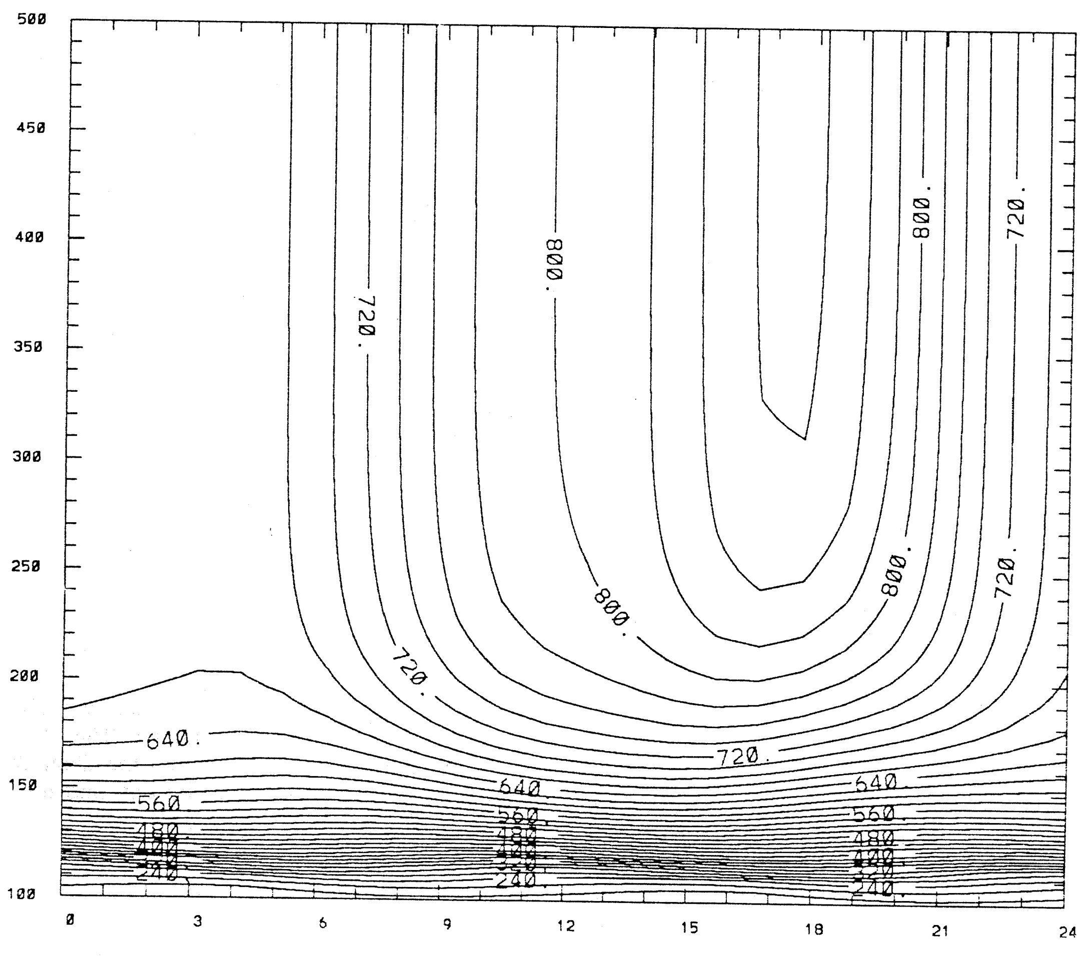

Fig. 1a. Distribution of the neutral temperature for June 1986.

time gradients at sunrise are more pronounced than at sunset. The electron density profile appears to be thicker and denser around 17:00LT.

In the absence of experimental profiles, the present model calculations have been compared with the profiles given by the IRI model with the different bottom side thickness parameter B_0 provided by such a model (Bilitza, 1990). Figure 3a-c shows the comparison between IRI model calculations when the experimental foF_2 and deduced hmF_2 (Dudeney, 1983) are used, and the present theoretical model profile obtained with foF_2 experimental values as input (thereafter: Case 1 calculation). The comparison is made for noon and midnight on March, June and December months. In general, the agreement with F region is good and in particular for March and December IRI and the present model profiles are consistently very similar.

It must be noted that the standard thickness parameter B_0 profile of IRI usually gives thinner F region valley at noon than the Gulyaeva

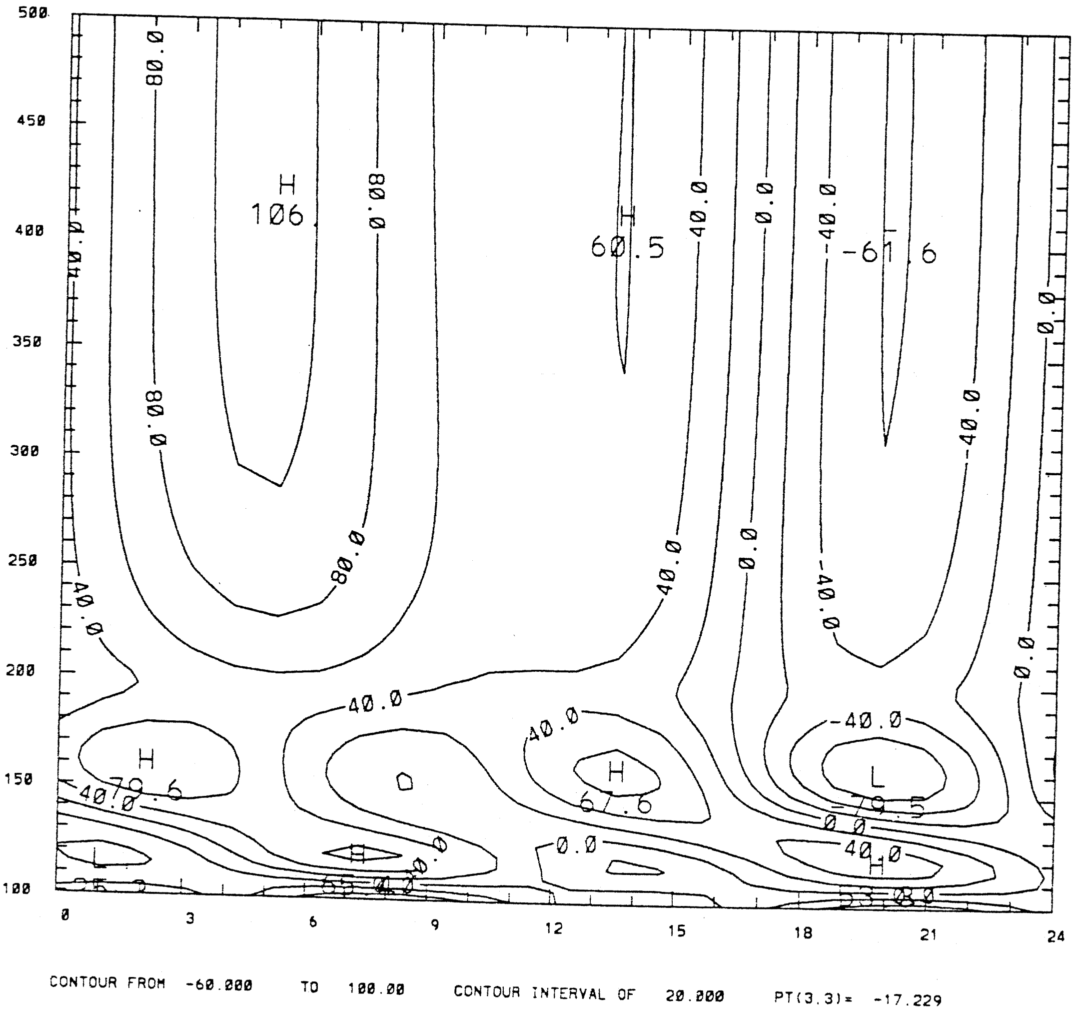

Fig. 1b. Variation of the meridional wind for June 1986.

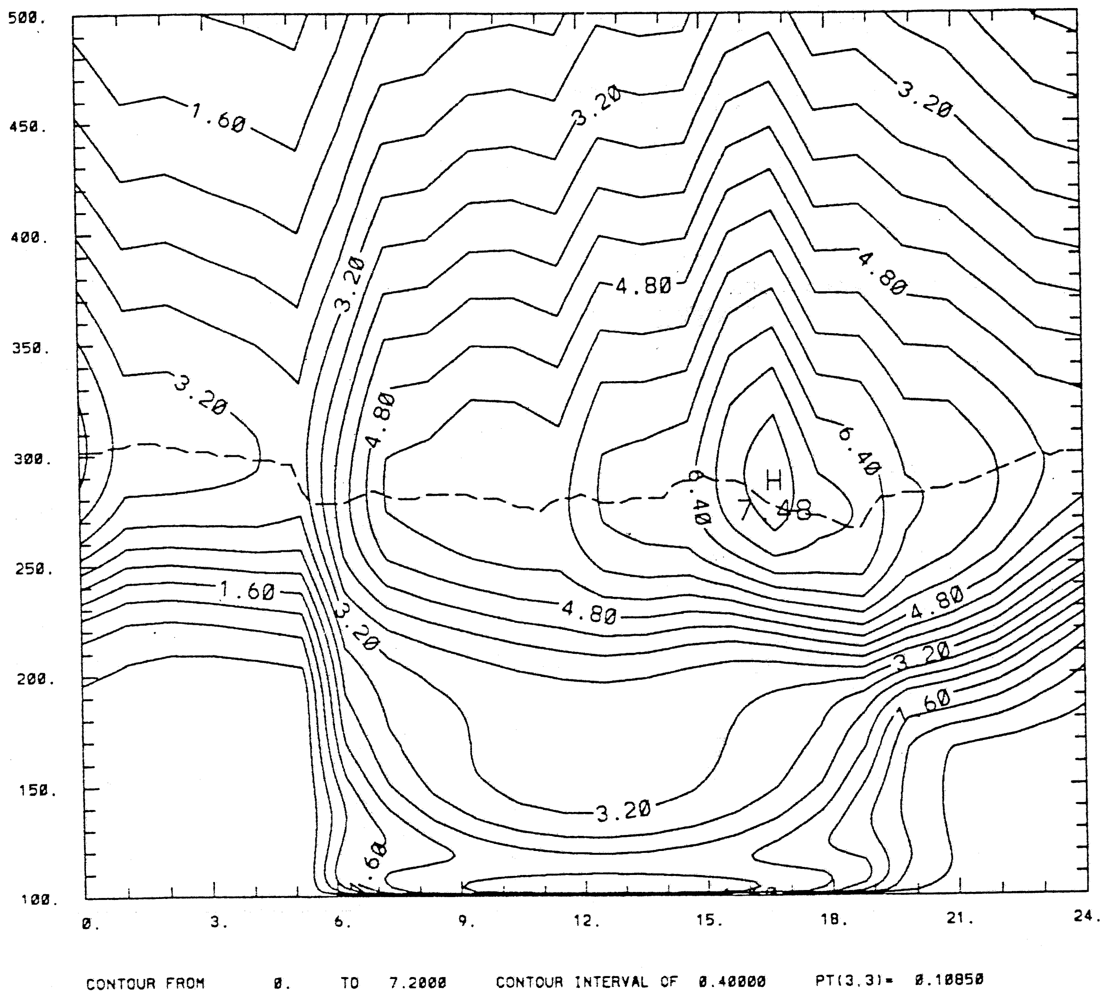

Fig. 2a. Contours of electron density for June 1986.

B_0 profile. This behaviour is reversed at midnight. In order to determine the difference in shape of the two model profiles, the foF_2 and hmF_2 values calculated by the present theoretical model are used as input for the IRI model profile. As shown in fig. 4a-c, the simulated profiles are closer to the IRI standard B_0 profile at noon and to the IRI Gulyaeva B_0 profile at midnight, confirming the previous observation.

The theoretical model profile including the electron density peak can also be calculated by introducing only topside values from IRI or any other topside data with no information about the experimental foF_2 (hereafter: Case 2). The results show that with the present model it is possible to use only electron density data from a given height in topside ionosphere to calculate the full profile, including the peak values (*i.e.* foF_2 and hmF_2). As an example, fig. 5a-c gives the observed values of foF_2 and those calculated by the model when IRI top-

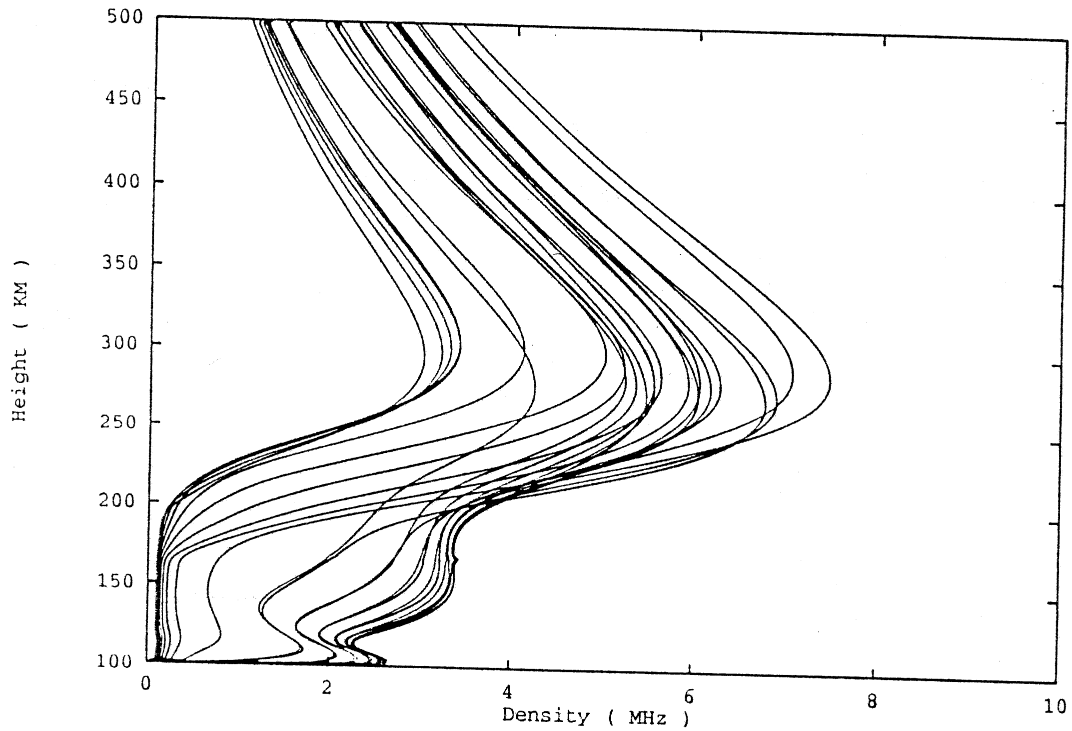

Fig. 2b. Evolution of electron density profiles for June 1986.

side values are used. The diurnal trend is quite similar for the model and observed values. However, those calculated by the model using IRI topside data are always larger.

It can be seen that the difference between the simulated height of the peak in Case 1 and Case 2 is not significant at night and in the daytime the departure is within 10 km (fig. 6 a-c). The «experimental» hmF_2, derived from the Dudeney formula (Dudeney, 1983), shows good agreements for December 1986. In the case of the other two months, deviations are small from noon through the late night whereas they are large from the pre-dawn to the pre-noon hours.

The height of the peak density is influenced by the wind and electrical field induced drift, the diffusion, as well as the photo-ionization. As shown in fig. 7, by magnifying the meridional wind by a factor of 0.5 (curve 2), it can be seen that the height of the peak declines by about 10 km for the whole day except between the noon and 20:00LT. With the increase of the northward wind by 20 m/s (curve 3), the whole curve of the height of the peak moves downward by 5 km, and this value almost remains constant for the whole day. Without the electrical field (curve 4), hmF_2 decreases by about 5 km for the nighttime, whereas no obvious alteration can be found for the daytime. The above mentioned results demonstrate that the effects caused by the changes of the dynamical parameters are not likely to be responsible for the difference between simulated and observed hmF_2.

From fig. 7 and 8, it can be noted that when the production rate as a function of local time and height is magnified by 2 times, the height of the peak decreases significantly by nearly 30 km in Case 1 (fig. 7), and 10 km only in Case 2 (fig. 8). This means that as long as the topside condition remains un-

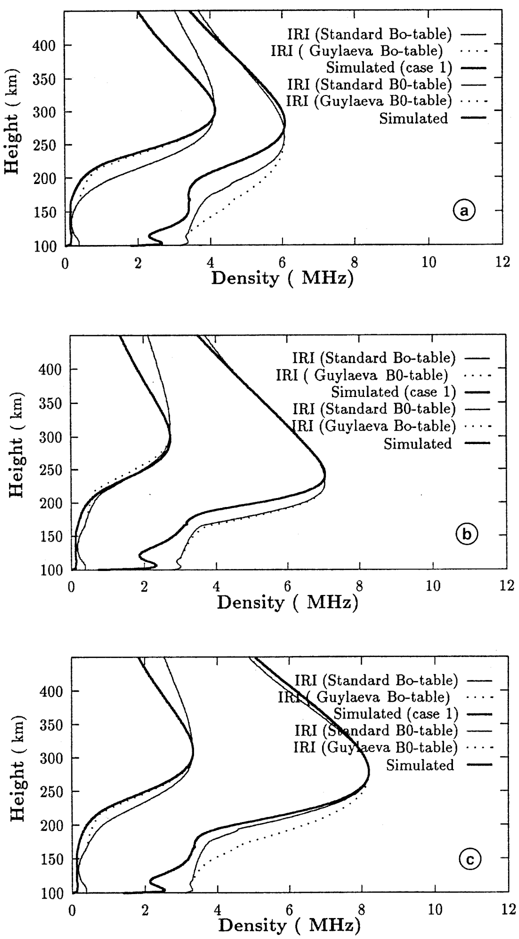

Fig. 3a-c. Comparison of the simulated profiles with IRI profiles at noon and midnight for: a) June 1986; b) December 1986; c) March 1987.

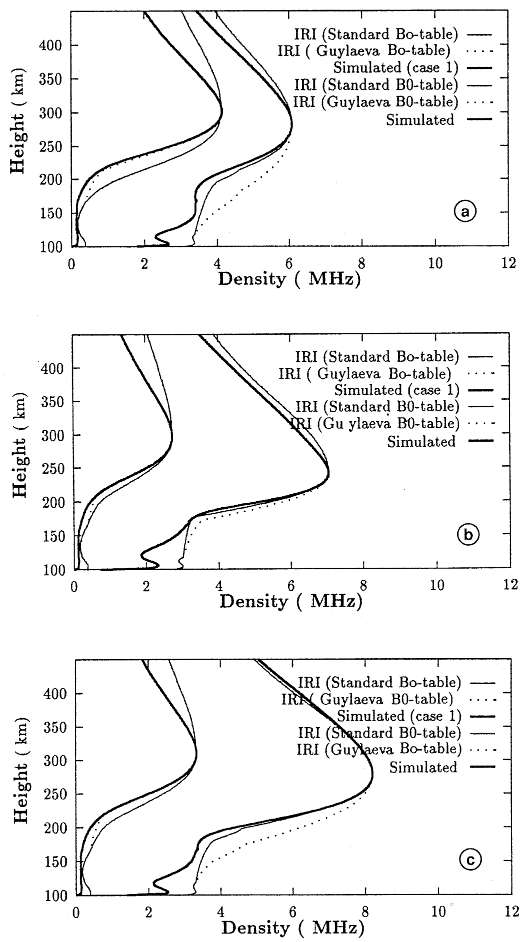

Fig. 4a-c. Comparison of the shape of the simulated profiles with IRI profiles at midday and midnight for: a) June 1986; b) December 1986; c) March 1987.

changed (Case 2) the maximum electron density in the *F*-layer, within the background of the enhanced solar radiation flux, will be raised, while the height of the peak will be slightly lowered; and if the maximum density is expected not to be influenced (Case 1) by the enhanced solar radiation, the height of the peak should fall significantly. The above discussion may also imply that for June condition at the low solar activity, additional ionization flux from the topside is necessary from midnight to noon in order to have agreement between simulated and «experimental» hmF_2.

3. Conclusions

1) When the present theoretical model is used with the experimental critical frequency of the ionospheric F_2 layer as input, a reasonable vertical profile can be obtained under the

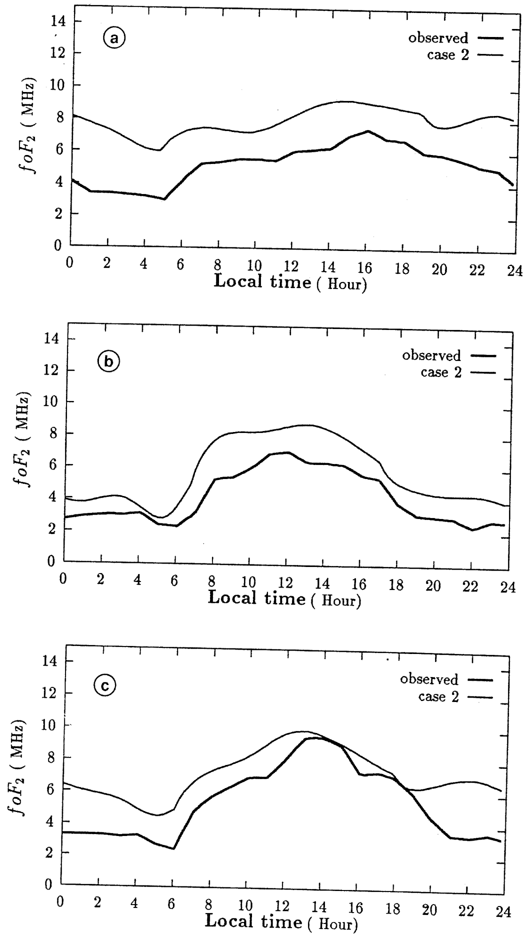

Fig. 5a-c. foF_2 variation as observed (Case 1) and simulated (Case 2) for: a) June 1986; b) December 1986; c) March 1987.

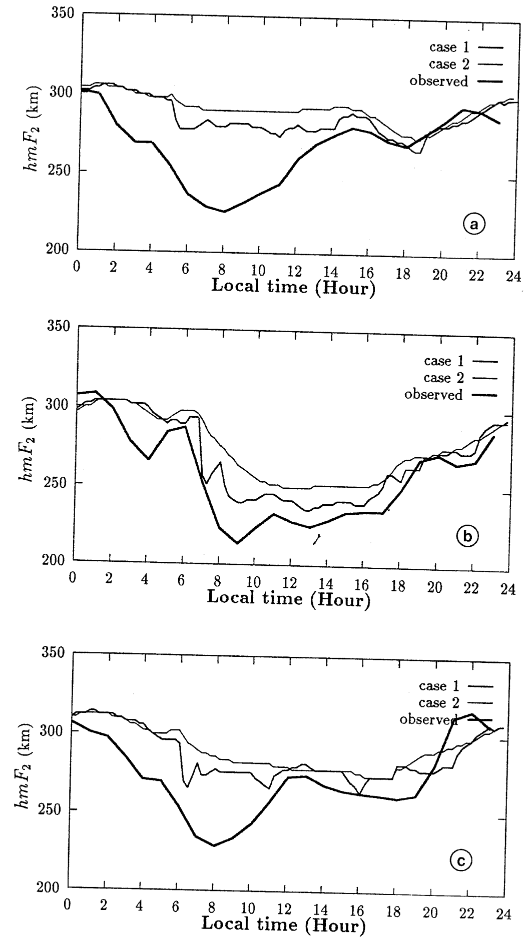

Fig. 6a-c. Diurnal variation of the observed and simulated (in Cases 1 and 2) hmF_2 for: a) June 1986; b) December 1986; c) March 1987.

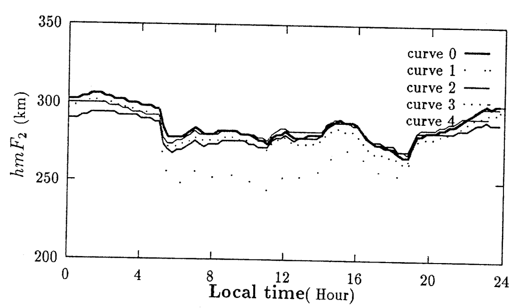

Fig. 7. Effects of the dynamical and photo-ionization parameters on hmF_2 (Case 1) for June 1986.

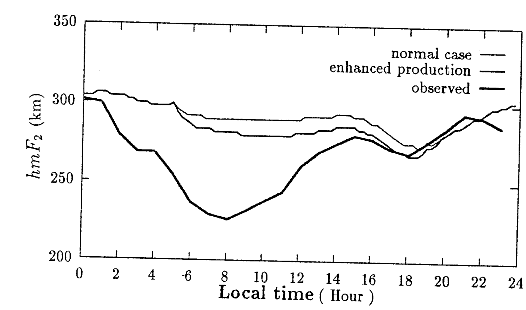

Fig. 8. hmF_2 response (Case 2) to the enhanced production rate caused by the photoionization for June 1986.

condition of time, season and solar activity used in this paper.

2) The simulation indicates that the calculated profiles are closer to the IRI standard B_0 profile at noon and to the IRI Gulyaeva B_0 profile at midnight.

3) the present theoretical model can be used to simulate height profiles of the electron density if topside data at a given height are known.

4) The influence of the topside flux of the ionizations is likely to be an important factor that may be the cause of the disagreement of the height of the peak obtained by the simulation presented in this paper and the experiment for the month of June 1986.

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