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Short Note

Electron density profile modeling

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Abstract
The Base Point Model (BPM) is used to model the electron density (N) profile in the ionosphere. This model assumes two Chapman profile expressions one for the bottomside and one for the topside, and requires a characteristic point called «F region base point». The comparison among the modeled and experimental bottomside N profiles obtained from Tucumán (26.9°S; 65.4°W) ionosonde shows that, in general, there is a very good agreement within 30 km below the height of the maximum $N(h_m)$. Cases with a very good agreement for the entire N-profile are observed. The study of the electron content below h_m and the Total Electron Content (TEC) measured over Tucumán shows that, the difference among predicted and measured TEC is due to the disagreement in the topside N-profile more than that observed in the bottomside N-profile.

Key words *ionosphere – electron density – total electron content*

1. Introduction

One of the most widely measured ionosphere variables is the critical frequency of the F_2 region (f_0F_2) from which the maximum electron density (N_m) can be obtained. Total Electron Content (TEC) defined as the number of free electrons in a column of unit cross section extending from the ground to the top of the ionosphere, is a measure of the total ionization of the ionosphere and it was measured at different stations.

Several ionospheric models have been developed to describe the average behavior of the Earth's ionosphere (Anderson *et al.*, 1987, 1989; Bilitza, 1986). But sometimes it is necessary to model an ionospheric variable for a given particular time (not average). Adler and Ezquer (1989) developed a method to calculate the TEC over Tucumán (26.9°S; 65.4°W) for a given particular time at predawn hours, which is the period generaly used to calibrate the polarimeters that measure TEC. This method is based on a modified Chapman layer and requires bottomside ionosonde data, an exospheric temperature model, and a fitting coefficient that must be obtained. These workers showed that is possible to calibrate polarimeters with this method even when the transmitted polarization angle is unknown.

Ezquer *et al.* (1992) reported a new simpler model to calculate TEC, which eliminates the need for an exospheric temperature model. This model (hereafter refered to as Base Point Model BPM) assumes two Chapman profile expressions one for the bottomside and one for the topside N-profile, and only requires ground ionosonde data. These workers showed that it is possible to calculate the total electron content at hours of minimum TEC starting exclusively from ionograms data. They also reported that BPM can be used to calibrate polarimeters.

Taking into account that TEC is an integral parameter, this paper checked the validity of BPM to model the shape of the electron density (N) profile.

2. Model and discussion

It was shown that the Chapman function offers a simple way to explain the vertical structure of plasma in the upper atmosphere in some cases (Yonezawa, 1955 a,b; Long, 1962).

Wright (1960) proposed a Chapman layer with scale height (H) equal to 100 km.

As we said, Adler and Ezquer (1989) modeled TEC over Tucumán using a modified Chapman expression.

Anderson *et al.* (1987) developed a semiempirical low-latitude ionospheric model to obtain the F region N-profile. This model consists of functions and coefficients which reproduce sets of theoretically calculated low-latitude N-profiles which covered three levels of solar activity (low, moderate and high) for each of three seasons (equinox, June Solstice and December Solstice). To determine an N-profile with this model six parameters (N_m, h_m, H_{up}, H_{lo}, C_{up}, C_{lo}) and the following modified Chapman expresion are required

$$N(z) = N_m \exp \{ c [1 - z - \exp(-z)]\} \tag{2.1}$$

where N_m is the maximum electron density, h_m is the altitude, where $N(z) = N_m$, $z = (h-h_m)/H$,

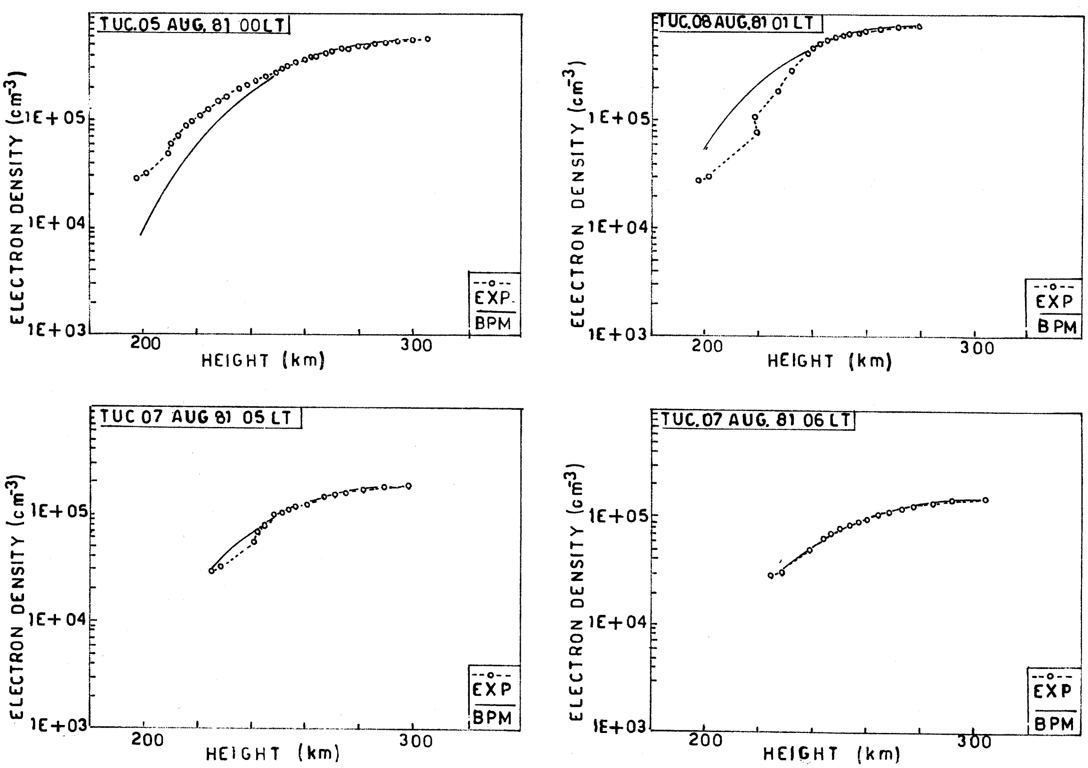

Fig. 1. Experimental (dashed line) and modeled (solid line) bottomside N-profile over Tucumán for August 5, 1981, August 8, 1981 and August 7, 1981.

and the subscripts *up* an *lo* refer, respectively, to the topside and bottomside profiles.

The Chiu (1975) empirical model assumes that the N-profile in the F region can be expressed by the standard Chapman profile expression where the coefficient c is taken to be unity in (2.1). The Chiu formulation assumes two expressions for z, one for the bottomside of the F region N-profile and one for the topside, given respectively by

$$z_{lo} = \frac{h - h_m}{H_{lo}} \qquad (2.2)$$

$$z_{up} = \frac{h - h_m}{H_{up}}. \qquad (2.3)$$

In all, four coefficients (N_m, h_m, H_{lo}, H_{up}) are required to determine the entire N-profile with the Chiu model.

In the BPM (Ezquer *et al.*, 1992), as in the Chiu (1975) and Anderson (1987) models, two Chapman profile expressions like (2.1) are assumed to describe the entire N-profile. These expressions have the same coefficients H, that is, $H_{lo} = H_{up} = H$, but different coefficients c are used one for the bottomside and one for the topside of the F region N-profile. For the bottomside the following expression is assumed:

$$N(z) = N_m \exp\,[1 - z - \exp(-z)]; \qquad C_{lo} = 1 \qquad (2.4)$$

and for the topside this one

$$N(z) = \exp\{0.5\,[1 - z - \exp(-z)]\}; \qquad C_{up} = 0.5 \qquad (2.5)$$

where $z = (h - h_m)/H$.

So with (2.4) and (2.5) only three parameters (N_m, h_m and H) are required to specify the N-profile. From ground ionosonde data N_m and h_m can be obtained.

To determine H a characteristic point of the bottomside N-profile called F region base point (Mosert de González and Radicella, 1990) is needed. This point is that where the gradient of N is a maximum. At the base point the gradient is given by

$$\left(\frac{dN}{dh}\right)_b = N_b\left[-1 + \exp\left(\frac{h_b + h_m}{H}\right)\right]\frac{1}{H}. \qquad (2.6)$$

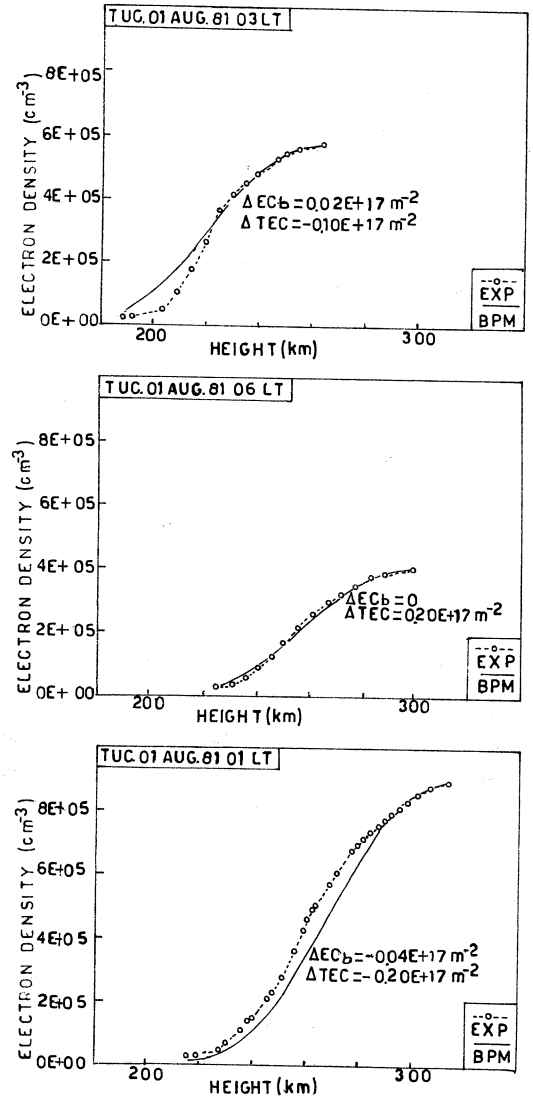

Fig. 2. Experimental (dashed line) and modeled (solid line) bottomside N-profile over Tucumán for August 1, 1981.

From the bottomside N-profile $(dN/dh)_b$, N_b and h_b are obtained, and H is determined by iterations.

Ezquer *et al.* (1992) have shown that with BPM the total electron content is given by

$$TEC = 3.80\, N_m H. \tag{2.7}$$

Nevertheless, the validity of BPM was checked with TEC which is an integral parameter. In order to check the performance of BPM to predict the shape of the N-profile we compare those given by (2.4) with the corresponding true bottomside N-profiles obtained from Tucumán's ionosonde data. The period of minimum TEC was considered. Some of the obtained results are shown in the present paper.

Figure 1 shows the experimental and calculated bottomside N-profiles for August 5, 1981 00 L.T., August 8, 1981 01 L.T., August 7, 1981 05 and 06 L.T.. It can be seen that the best agreement among modeled and measured values is obtained from the peak electron density to about 30 km below h_m. A very good agreement among predicted and measured bottomside N-profile at all altitudes is observed for August 7, 1981 06 L.T.

In order to determine if the difference between modeled and measured TEC (ΔTEC) observed by Ezquer *et al.* (1992) is produced by a disagreement in the bottomside N-profile, the electron content below h_m(EC_b) was calculated. Figure 2 shows some of the obtained results and the corresponding ΔTEC and ΔEC_b. It can be seen that ΔEC_b is lower than ΔTEC. These results suggest that ΔTEC is produced by the disagreement between modeled and true topside N-profiles more than that observed in the bottomside N-profile.

3. Conclusions

A study was done to check the performance of BPM to predict the shape of the N-profile. The results show that, in general, there is a very good agreement between modeled and measured N values within 30 km below h_m. Cases with a very good agreement for the entire bottomside N-profile have been reported. The observed ΔTEC is thought to be produced by the disagreement in the topside N-profile more than that corresponding to the bottomside profile.

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