FITTING THE IRI F2-PROFILE FUNCTION TO MEASURED PROFILES

Bodo W. Reinisch and Xueqin Huang
University of Massachusetts, Center for Atmospheric Research,
600 Suffolk Street, Lowell, MA 01854, USA
E-mail: reinisch@cae.uml.edu

1. Introduction

The IRI profile for the bottomside of the F2 layer is described by an analytic function [Bilitza, 1990]

$$N(h)/NmF2 = exp(-X^{B1})/cosh(X) \tag{1}$$

with

$$X = (hmF2 - h)/B0 \tag{2}$$

The entire profile is specified by only two parameters, B0 and B1, an ingenious approach as long as equation 1 is accurately representing the vertical electron density distribution in the F2 region. The performance of the IRI profile function is discussed in Section 2 by comparing measured profiles from low latitude stations with the IRI function. The currently used parameters B0 and B1 have been described in the literature [Bilitza, 1990; Ramakrishnan and Rawer, 1972; Gulyaeva, 1987; Gulyaeva et al., 1996]. Section 3 shows how the "best" B0 and B1 parameters for a given profile can be calculated in a least-squares-fitting approach. The procedure of calculating the parameters is discussed in a companion paper [Huang and Reinisch, 1997].

2. IRI F2-profile assessment

For performance evaluation the IRI profile is best compared with monthly representative profiles (MARP), as discussed in the companion paper, rather than with individual profiles. We have made such comparisons for three Digisonde sites: Ramey (Puerto Rico), Jicamarca (Peru), and Puerto Madryn (Argentina) for summer and winter seasons [Reinisch and Huang, 1996]. The results are summarized in Table 1, where the measured F2 peak values were used for the IRI profiles. The worst deviations occur at Jicamarca. To find the causes for these deviations, the best B0 and B1 parameters were calculated from the MARP data for different seasons. Figure 1 shows the diurnal variations of the best B0 and B1 values for summer (December) and winter (August) at Jicamarca. The dashed line gives the IRI values. IRI-B0 shows very good agreement for the daytime (local noon is at 17 UT) in summer but is way off in winter. A strong diurnal variation is observed for B1 in winter, not only for Jicamarca but also for Ramey (Figure 2), and to somewhat lesser degree for Puerto Madryn in summer (Figure 3).

Table 1. IRI F2 Profile Assessment

Station	Month	Daytime	Nighttime
Jicamarca, Peru	December 1993 ($R_{12} = 39$)	Too thick (-15, -18)	Too thick (-10, -15)
	August 1993 ($R_{12} = 52$)	Too thin (+15, +40)	Slightly thin (+7, +10)
Ramey, Puerto Rico	December 1992 ($R_{12} = 73$)	Good (+4, +8)	Slightly thin (+9, +8)
	June 1993 ($R_{12} = 67$)	Too thick (-18, -20)	Good
Puerto Madryn, Argentina	December 1993 ($R_{12} = 39$)	Too thick (-20, -25)	Too thick (-10, -8)
	March 1993 ($R_{12} = 67$)	Good	Slightly thick (-10, -10)

3. Fitting the IRI Function to a Measured Profile

If the electron density profile between the bottom (frequency f_s) and the peak (frequency f_m) of the F layer is given in terms of Chebyshev polynomials [Huang and Reinisch, 1996]

$$h = hmF2 + \sqrt{g}\ SA_i\ T_i^*(g) \tag{3}$$

it is advantageous to also express the IRI function in this form. Replacing (1) by

$$\frac{f^2}{f_m^2} = \frac{2\exp(-X^{B1})}{e^X + e^{-X}} \tag{4}$$

or

$$2\ ln \frac{f}{f_m} = ln\ 2 - X^{B1} - ln\ (e^X + e^{-X}) \tag{5}$$

and setting

$$g = \frac{ln\ (f/f_m)}{ln\ (f_s/f_m)} \tag{6}$$

one obtains

$$2g\ ln\ \frac{f_s}{f_m} = \ln\ 2\ - X^{B1} - ln\ (e^X + e^{-X}) \tag{7}$$

The starting frequency f_s is either the starting frequency of the F2 trace or $0.4883f_m$, whichever is larger. Equation (7) shows that the function X in (2) depends on the variable g and the parameter B1 as illustrated in Figure 4. As expected, X is independent of B1 at the peak were X=0, and at the point X=1. The electron density for X=1 is given by (1) as N = 0.2384Nm, or $f=0.4883f_m$. Since the function X for any value of B1 is given, it can be approximated by a sum of Chebyshev polynomials with coefficients C_i:

$$X'(B1) = \sqrt{g}\ \Sigma\ C_i(B1)\ T_i^*(g) \tag{8}$$

Solving (2) for h and substituting (8) yields:

$$\begin{aligned} h_{|R|} &= hmF2 + \sqrt{g}\ \Sigma\ [B0\ C_i(B1)T_i^*(g)] \\ &= hmF2 + \sqrt{g}\ \Sigma\ D_i(B0; B1)\ T_i(g)] \end{aligned} \quad (9)$$

The unknown coefficients D_i are determined by minimizing the least-squares-error:

$$\varepsilon^2 = \int_0^1 [h - h_{|R|}]^2 dg \quad (10)$$

B1 is incremented from 1.0 to 5.0 in steps of 0.1 and the B1 value producing the smallest error in (10) is selected. Once B1 is known, the coefficients Ci in Equation (8) can be calculated by a least-squares fit:

$$\varepsilon^2 = \int_0^1 [X - X']^2 dg \quad (11)$$

Once C_i and D_i are determined, B0 is obtained from $B0 = D_i/C_i$, or

$$B0 = \frac{\Sigma\Sigma A_i S_{ij} C_j}{\Sigma\Sigma C_i S_{ij} C_j} \quad (12)$$

where

$$S_{ij} = \int_0^1 g T_i^*(g) T_j^*(g) dg \quad (13)$$

Figure 5 illustrates the improvement that can be obtained when the best B0 and B1 parameters are used in the IRI F2 profile function. The figure shows the ARP profile at 20 UT for August 1993 calculated from the 30 individual profiles at Jicamarca, together with the adjusted IRI 90 profile and the best IRI profile using best B0 and B1.

4. Conclusion

Comparison with profile data from ionosondes shows that the IRI bottomside F2-profiles can be improved by using better B0 and B1 parameters. The best (in a least-squares sense) parameters can be easily calculated in a numerical procedure from measured profiles presented as a sum of Chebyshev polynomials. Although the procedure is applicable to individual as well as monthly average representative profiles, it is recommended to use the latter when calculating the best B0, B1.

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References

Bilitza, D., The International Reference Ionosphere, 1990, National Space Science Data Center, NSSDC/WDC-A-R&S Report 90-22, Greenbelt, Maryland, November 1990.

Gulyaeva, T.L., Adv. Space Res., 7(6), 39-48, 1987.

Gulyaeva, T.L., K.K. Mahajan, and N.K. Sethi, Modification of IRI half-density option for low latitudes, Adv. Space Res., 18, 2, 1996.

Huang, X. and B.W. Reinisch, Vertical electron density profiles from the Digisonde network, Adv. Space Res., Vol. 18, 6, 121-129, 1996.

Huang, X. and B. W. Reinisch, Calculating the best parameters B0 and B1 for The IRI profile from ionograms, this issue, 1997.

Ramakrishnan, S., and K. Rawer, Space Research XII, 1253-1259, Akademie-Verlag, Berlin, 1972.

Reinisch, B.W., and X. Huang, Low latitude Digisonde measurements and comparison with IRI, Adv. Space Res., Vol. 18, 6, 5-12, 1996.

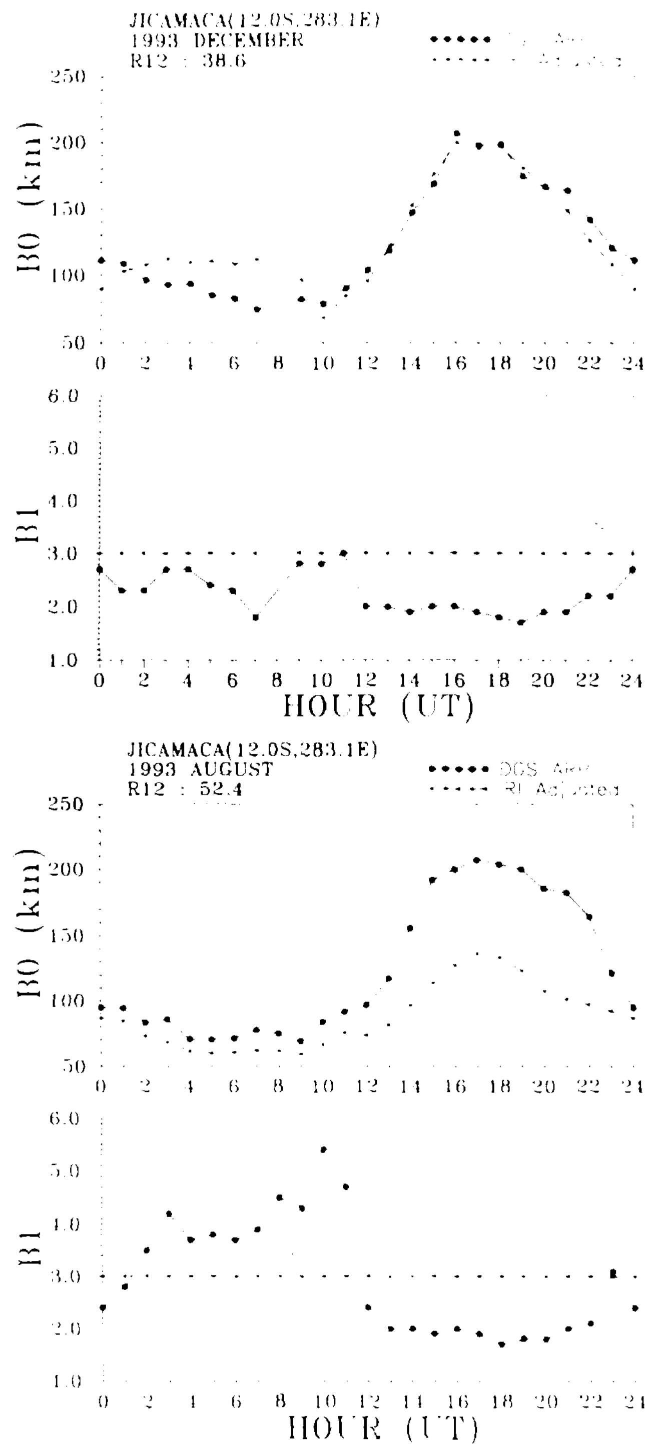

Figure 1. Jicamarca. IRI (dashed) and best B0 and B1 parameters for August and December 1993.

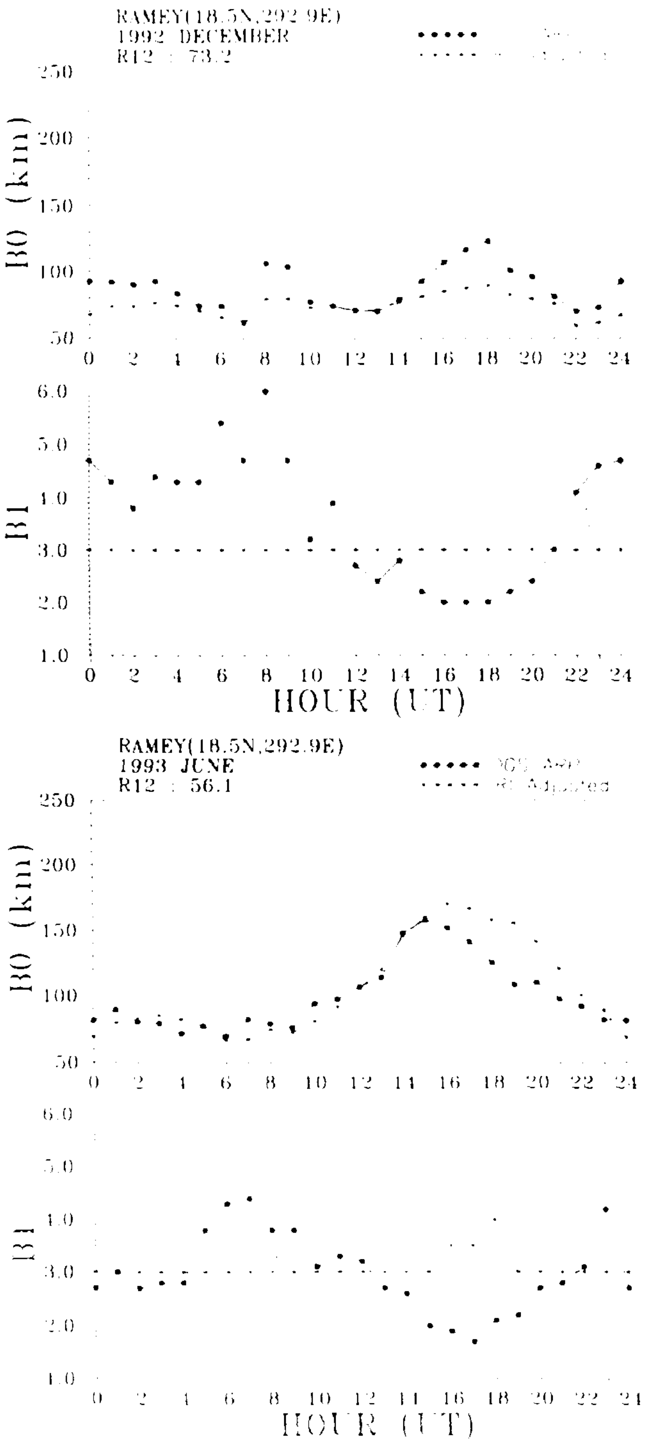

Figure 2. Ramey. IRI (dashed) and best B0 and B1 parameters for December 1992 and June 1993.

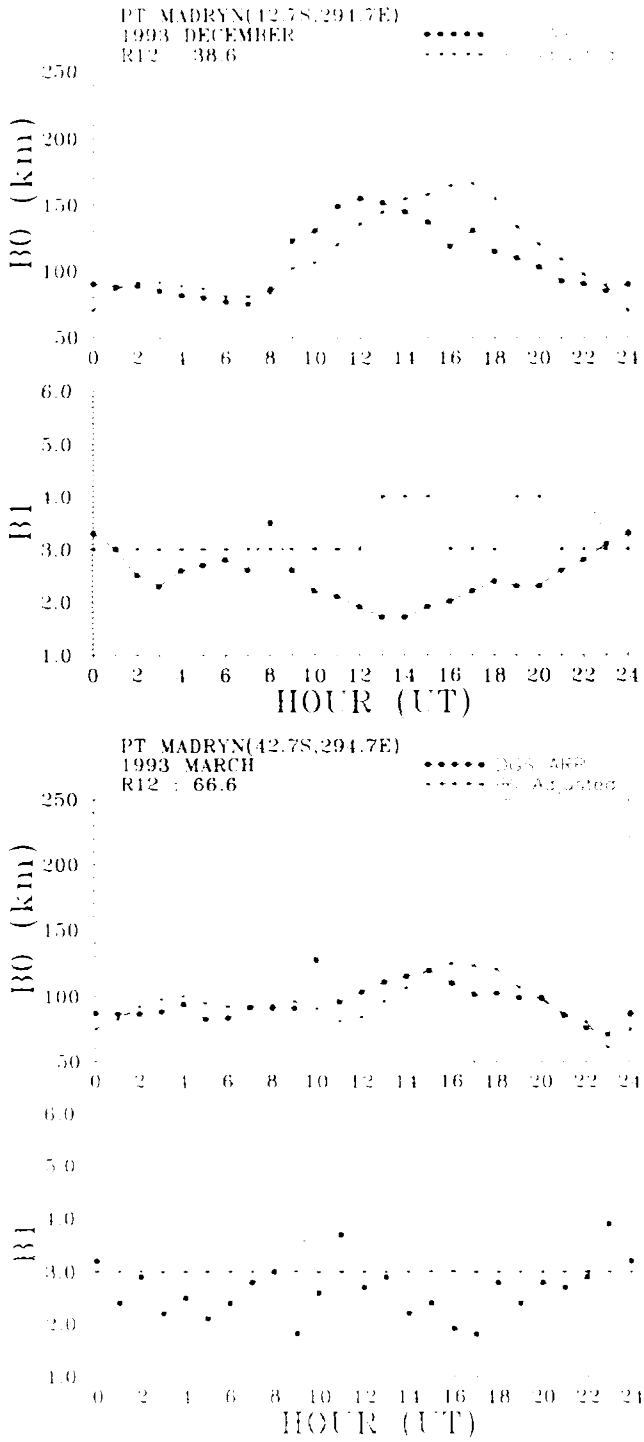

Figure 3. Puerto Madryn. IRI (dashed) and best B0 and B1 parameters for March and December 1993.

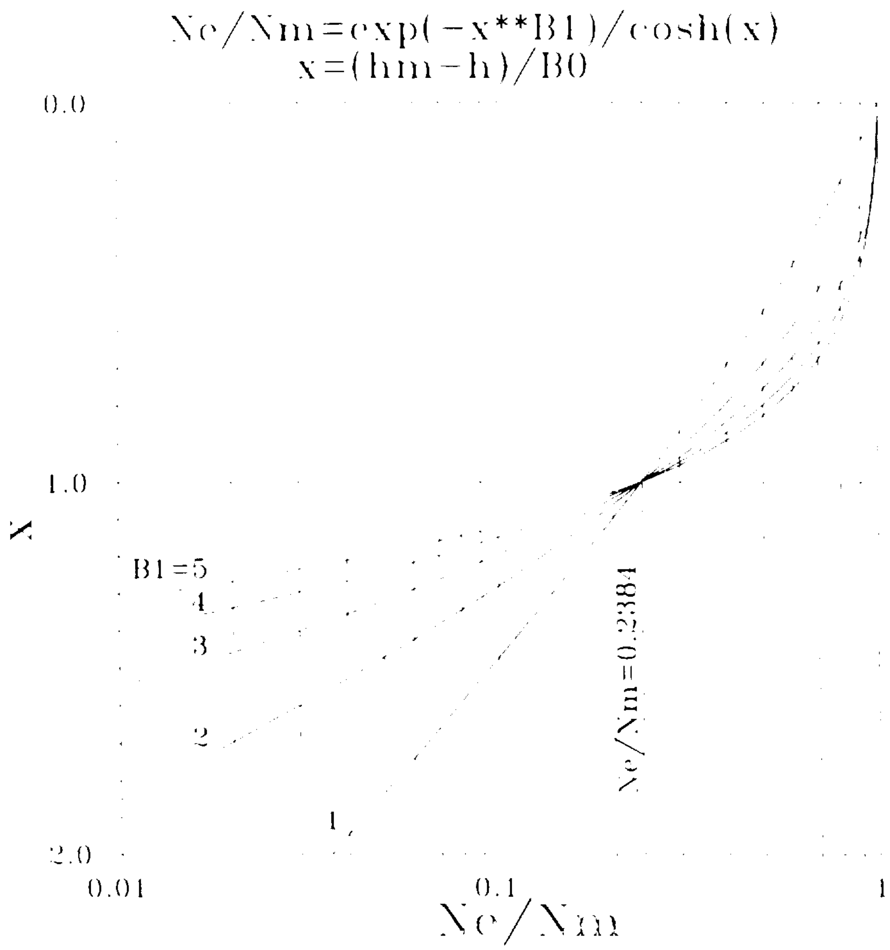

Figure 4. IRI function X for different parameter values B1.

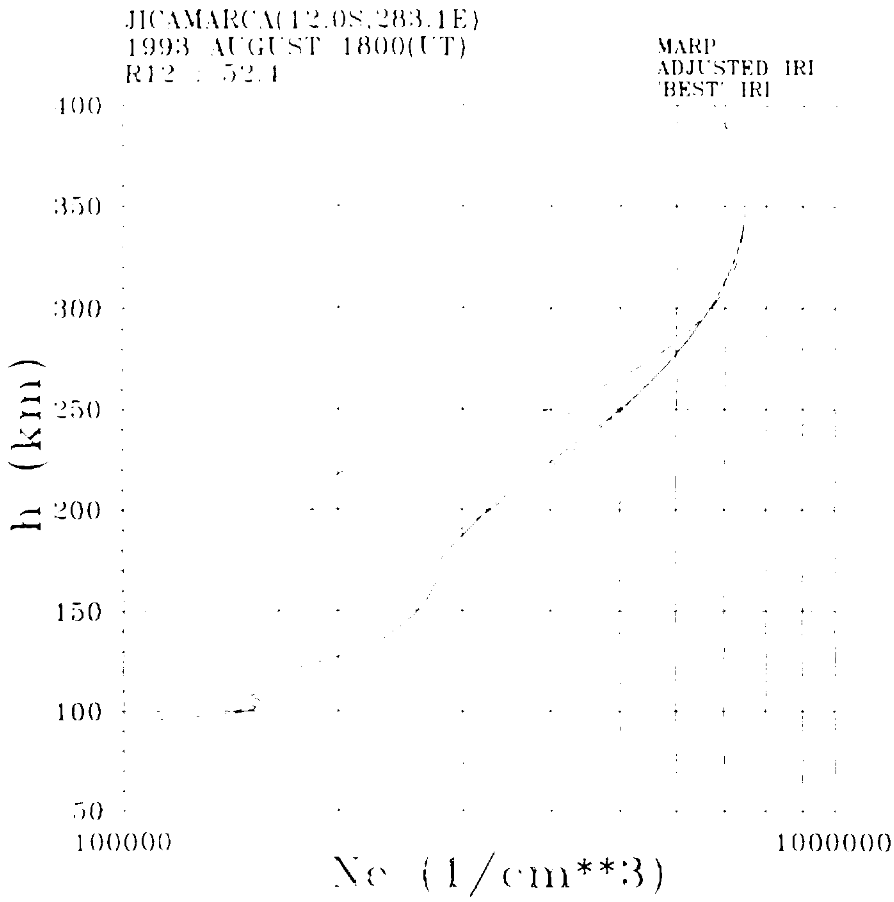

Figure 5. The standard and the "best" IRI profile are compared with the August 1993 ARP profile at Jicamarca for 20 UT (15 LT).