Comparison of the first long-duration IS experiment measurements over Millstone Hill and EISCAT Svalbard radar with IRI2001

Jiuhou Lei [a,b,c,*], Libo Liu [a], Weixing Wan [a], Shun-Rong Zhang [d], A.P. Van Eyken [e]

[a] . . . .f . . . . , A , B . . . 100029, ...
[b] . . . . . .f . . . , A , . . 430071, ...
[c] . . . . .f . . A . .f . . , ...
[d] . . . , ...f . . . . , f. . . , , A
[e] A . . . A . . . . , ... , . . . , . .

Received 10 August 2004; received in revised form 25 January 2005; accepted 26 January 2005

A

The first long-duration incoherent scatter (IS) radar observations over Millstone Hill (42.6°N, 288.5°E) and EISCAT Svalbard radar (ESR, 78.15°N, 16.05°E) from October 4 to November 4, 2002 are compared with the newly updated version of the IRI model (IRI2001). The present study showed that: (1) For the peak parameters $_mF_2$ and f_oF_2, the IRI results are in good agreement with the observations over Millstone Hill, but there are large discrepancies over ESR. For the B parameters, the table option of IRI produces closer values to the observed ones with respect to the Gulyaeva's option. (2) When the observed F_2 peak parameters are used as input of IRI, the IRI model produces the reasonably results for the bottomside profiles during daytime over Millstone Hill, while it gives a lower bottomside density during nighttime over Millstone Hill and the whole day over ESR than what is observed experimentally. Moreover, IRI tends to overestimate the topside $_e$ profiles at both locations. (3) The $_i$ profiles of IRI can generally reproduce the observed values, whereas the IRI-produced $_e$ profiles show large discrepancies with the observations. Overall comparative studies reveal that the agreement between the IRI predictions and experimental values is better over Millstone Hill than that over ESR.

. . . : Ionosphere; Incoherent scatter radar; Modelling and forecasting; International reference ionosphere

1. I d

The International Reference Ionosphere (IRI) model is the mo.

this campaign, this paper makes a comparative study between the ISR observations at these two sites and the IRI2001 model. As ISR can probe the whole ionospheric information from bottomside to topside, rather than ground ionosondes can only see the ionosphere up to the point of highest density (the F_2 peak), the measurements are used to assess the whole electron density profiles also the plasma temperature profiles predicted by the IRI model.

2. D d d

A long-duration incoherent scatter radar experiments were carried out at Millstone Hill and ESR from October 4 to November 4, 2002. Over Millstone Hill, these experiments included the 410 and 480 μs single-pulse (S/P) and the alternating code (A/C) measurements. In this study, the A/C data with higher height resolution ~5 km are used to deduce the peak parameters and *B* parameters, while the S/P data with higher upper height boundary are used to compare the IRI height profiles. Over ESR, the vertical measurements, with the variable height space from 3 to 36 km over the height range of 90–772 km, are used to analyze.

First, the peak electron density ($_mF_2$) and its height ($_mF_2$) are obtained with a least-squares fitting for the observed profiles from the Chapman function (Rishbeth and Garriott, 1969),

$$N_e(h) = N_m F_2 \exp[0.5(1 - z - e^{-z})],\quad z = (h - h_m F_2)/H(h). \qquad (1)$$

Here, the scale height is taken to be ( ) = A_1(− $_mF_2$) + $_m$ in the bottomside, and ( ) = A_2(− $_mF_2$) + $_m$ in the topside (see Lei et al., 2004, 2005). Thus, $_mF_2$, $_mF_2$, $_m$, A_1, and A_2 are set as adjustable variables to bring in the best match with the observed electron profiles $_e$( ). As for the fit analysis, the electron height profiles between 160 and 600 km are employed. We consider that the derived peak parameters $_mF_2$ and $_mF_2$ are reliable, given that most profiles can reach quite good agreement.

Next, the thickness parameter B0 and the shape parameter B1 are obtained by best fitting individual observational profile from the peak height $_mF_2$ down to the 0.24 $_mF_2$ height ($_{0.24}$) if no F_1-layer exists or to the F_1 peak if F_1-layer occurs, using the least-squares-fitting approach, with the formula used in the IRI model,

$$N_e(h) = N_m F_2 \exp(-x^{B1})/\cosh(x),\quad x = (h_m F_2 - h)/B0. \qquad (2)$$

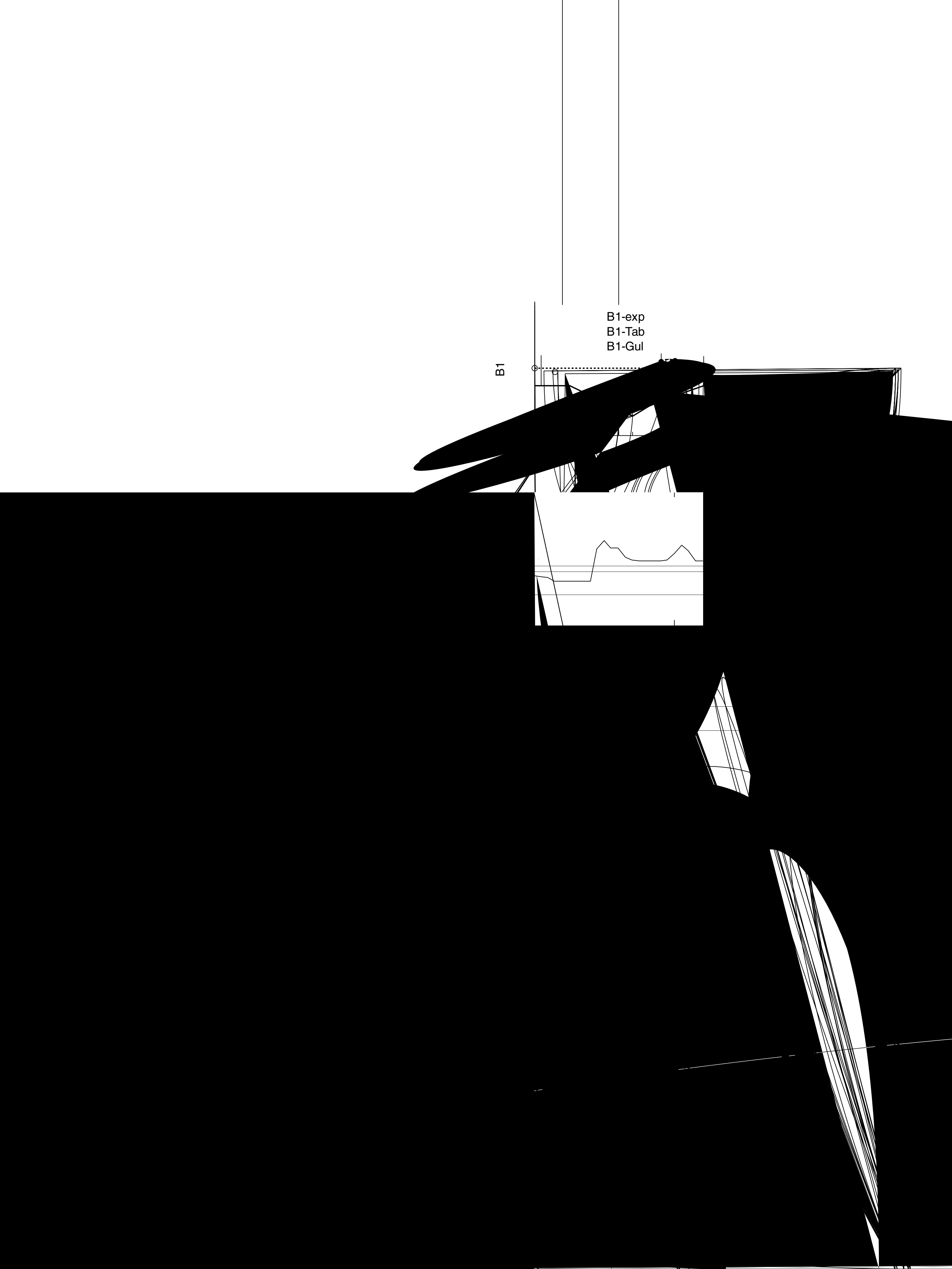
We also compare the observations with those of the IRI2001 to validate the prediction capacity of the empirical model. Given that the IRI model profiles represent the monthly mean ionosphere, the monthly average representative results are obtained by using all the data in this experiment to compare with IRI results. The model values are calculated under F_{107} = 166.8 as well as with the day number 290, as representative of October 2002. Note that the observed $_mF_2$, $_mF_2$ are used as input parameters of IRI2001 to compute the model B parameters and density profiles $_e$( ). The $_e$( ) profiles are calculated with IRI using its standard option, but $_i$, $_e$ profiles are calculated using the option of Truhlik et al. (2000).

3. R

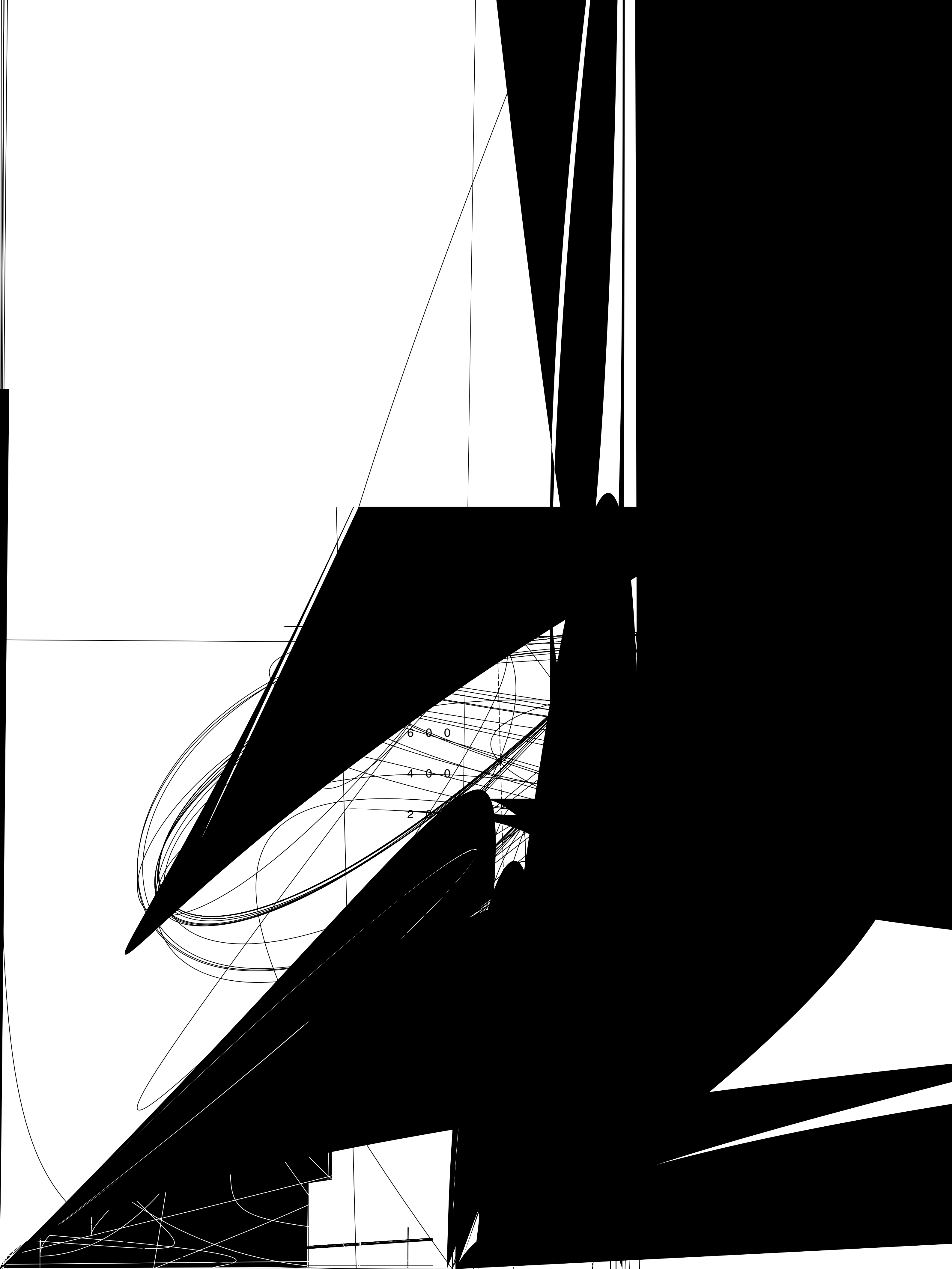
3.1. 2 (2,f 2) ' B (B0, B1)

Fig. 1(a) and (b) show the observations (solid lines with circles) of the F_2 peak parameters ($_mF_2$, f_oF_2) and the thickness and shape parameters (B0, B1) for this campaign over Millstone Hill, and ESR, respectively. The critical frequency f_oF_2 in MHz is equal to ($_mF_2$/ $1.24 \times 10^{10})^{1/2}$ if $_mF_2$ is given in m^{-3}. To compare, the corresponding results predicted by IRI are also presented. For $_mF_2$ and f_oF_2, the model results obtained from the CCIR coefficients are plotted with dashed lines. For the B parameters, the IRI model provides two options, i.e., the table option and Gulyaeva's option (Gulyaeva, 1987) and their results are plotted with solid and dotted lines, respectively.

Over Millstone Hill, $_mF_2$ reaches its peak values at midnight, and then displays two daytime minima at 08 and 16 LT, creating a 'W'-like diurnal variation. The diurnal variation of f_oF_2 displays a simple pattern: higher during daytime and lower during nighttime. The IRI model reproduces the observed $_mF_2$ well during daytime and underestimates its values during nighttime; while for f_oF_2, the IRI values show good agreement with the observed ones. For the parameter B0, its diurnal variation can be characterized by morning and afternoon collapse, with two peaks occurring at midday and midnight. This feature is evident over Millstone Hill in the diurnal variation of B0 for seasons other than summer as reported by Lei et al. (2004). B0-Gulyaeva value of IRI shares quite good agreement in the diurnal tendency with the observational ones, while B0-Table option generates a little closer value. In addition, the experimental B1 has a low value during daytime and a high value during nighttime. B1-Table reproduces the daytime value while overestimates the nighttime value. B1-Gulyaeva values are significantly larger during daytime than those from the measurements, given that the B1-Gulyaeva option takes the constant value of 3, and without changing with seasons and local time.


B1-exp
B1-Tab
B1-Gul
B1

in agreement with the observed topside profiles. This factor generally agrees with that of Bilitza (2004). For $_{i}$, the main difference in magnitude occurs above


600
400

A d

Millstone Hill Madrigal Database is assembled and maintained by members of MIT Haystack Observatory Atmospheric Science Group. EISCAT is an International Association supported by Finland (SA), France (CNRS), the Federal Republic of Germany (MPG), Japan (NIPR), Norway (NFR), Sweden (VR) and the United Kingdom (PPARC). We thank Dr. D. Bilitza for making the IRI model codes available through the Internet. This research was supported by the National Natural Science Foundation of China (40134020), the KIP Pilot Project (kzcx3-sw-144) of CAS, and National Important Basic Research Project (G2000078407).

R

Bilitza, D. International reference ionosphere 2000. Radio Sci. 36 (2), 261–275, 2001.

Bilitza, D. A correction for the IRI topside electron density model based on Alouette/ISIS topside sounder data. Adv. Space Res. 33, 838–843, 2004.

Buonsanto, M.J. Comparison of incoherent scatter observations of electron density, and electron and ion temperature at Millstone Hill with the International Reference Ionosphere. J. Atmos. Terr. Phys. 51 (5), 441–468, 1989.

Gulyaeva, T.L. Progress in ionospheric informatics based on electron density profile analysis of ionograms. Adv. Space Res. 7 (6), 39–48, 1987.

Lei, J., Liu, L., Wan, W., Zhang, S.-R., Holt, J.M. A statistical study of ionospheric profile parameters derived from Millstone Hill incoherent scatter radar measurements. Geophys. Res. Lett. 31, L14804, doi: 10.1029/2004GL020578, 2004.

Lei, J., Liu, L., Wan, W., Zhang, S.-R. Variations of electron density based on long-term incoherent scatter radar and ionosonde measurements over Millstone Hill. Radio Sci. 40, doi:10.1029/2004RS003106, 2005, in press.

Rishbeth, H., Garriott, O.K. Introduction to Ionospheric Physics. Academic Press, New York, 1969.

Truhlik, V., Triskova, L., Smilauer, J., Afonin, V.V. Global empirical model of electron temperatures in the outer ionosphere for period of high solar activity based on data of three Intercosmos satellites. Adv. Space Res. 25 (1), 163–169, 2000.

Zhang, S.-R. et al. October 2002 30-day incoherent scatter radar experiments at Millstone Hill and Svalbard and simultaneous GUVI/TIMED observations. Geophys. Res. Lett. 32, L01108, doi: 10.1029/2004GL020732, 2005.