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VALIDATION OF THE MODEL IRI - 2007 BY THE LATEST EXPERIMENTAL DATA IN AURORAL IONOSPHERE

L.N. Makarova, A.V. Shirochkov, A.V. Frank-Kamenetsky, V.D. Nikolaeva
Arctic and Antarctic Research Institute, 38 Bering Street, 198397 Saint-Petersburg, RussianFederation
e-mail: lumak@aari.nw.ru, phone: 7-812-3373157

Abstract. Numerical calculations of ionospheric parameters by means of the model IRI-2007 were compared with the corresponding experimental data of vertical ionospheric sounding made at the auroral station Tromse (φ = 69°40' N; λ = 18°56' E) during September of 2009 – February 2010. Experimental and calculated parameters of the ionograms as well as of vertical profiles of electron density were compared for the same periods of time.
It was found that the model values of the heights of electron density maximum during noontime exceed the corresponding experimental values. The same effect was obtained in comparison of the model and experimental foF2 values.
This difference could be explained by the fact that empirical model IRI-2007 is compiled by the data of the epoch before 2008 and could not contain the data of the year 2009. However epoch of 2009 is characterized by extremely low level of the solar activity which was expressed in complete absence of the sunspots as well as by very low values of parameters of the solar wind (its magnetic field, density and velocity). Such very low level of the solar activity was responsible for comparatively low intensity of the ionospheric electric fields which in its turn resulted in the low values of h_{max} F2 and foF2. Our conclusion is that the model IRI-2007 could not adequately describe a real situation in the auroral ionosphere in the periods of very low solar activity.

Results of comparison numerical calculations and experimental ionospheric parameters

The main goal of this work is validation of the model IRI - 2007 by the latest experimental data in auroral ionosphere. We choose the ionospheric model IRI because of several reasons:
1. IRI – is a global empirical model. We may use it in high latitudes.
2. IRI is based on the real ionospheric data from 1994 to 2007 year. IRI is persistently updating and has several versions. In current work we use the latest modification IRI 2007.
3. Model IRI covers all kinds of ionospheric observations (incoherent scatter, vertical sounding and satellite data)
4. Using this model we can plot the vertical electron density profile from 50 to 1500 km.

Sun spot number, AP and F10.7 indexes are used in IRI as input parameters of magnetic and solar activity. For the correct simulation data file AP.dat was supplement with real data of AP and F10.7 indexes from 2007 till 2010. For the investigated period Wolf numbers were entered manually. For the model accuracy estimation was made the comparison with the real data from the ionosonde Tromso. Tromso station is situated in Norway at 69°40'n.l. and 18°56'e.l. – in the middle of the auroral zone. Sounding data are located in the Internet in real time with 15 minutes resolution in graphical form (ionograms).
From the ionograms we obtained the following parameters:
f_0F2 – critical frequency of F2 layer
hmF2 – maximal altitude of F2 layer
f_0E – critical frequency of E layer
hmE – maximal altitude of E layer
In the following analyses we used near-noon hourly data from 10 to 15 hours LT from September 2009 till February 2010.
Table 1 represents the comparison results of simulation data with real sounding parameters of high-latitude ionosphere in values of standard deviation (σ). Also in this table one can see mean monthly values of σ.

Table 1 Difference between real data and simulation results

	σ HmF2 [km]	HmF2 difference [σ]	σ NmF2 [cm-3]	NmF2 difference [σ]	σ HmE [km]	HmE difference [σ]	σ NmE [cm-3]	NmE difference [σ]
September 2009	10.88	-2.66	36409	2.58	9.68	-1.12	9825	-0.05
October 2009	10.66	-3.61	63677	1.64	6.79	-0.60	8992	0.46
November 2009	10.24	-3.08	68151	1.70	3.30	-0.34	5764	0.87
December 2009	13.29	-2.18	22955	-0.65	0.00	0.00	1213	1.39
January 2010	12.14	-2.49	54463	0.29	3.18	-0.23	3679	1.11
February 2010	11.06	-2.35	73005	1.33	4.47	-0.43	8669	0.73

The comparison of simulation data with real sounding parameters of high-latitude ionosphere shows that there is rather good agreement a significant both in maximal altitude and maximal electron density of E layer. Figure 1 shows behavior of simulation results (red line) and real sounding data (blue line) of maximal electron density of E layer (NmE). Green line characterizes magnitude of magnetic field (Ap index). Model and real curves have practically similar shape during all investigated period. So one can see that ionosphere model IRI-2007 can exactly describe E layer in concrete geophysical conditions.

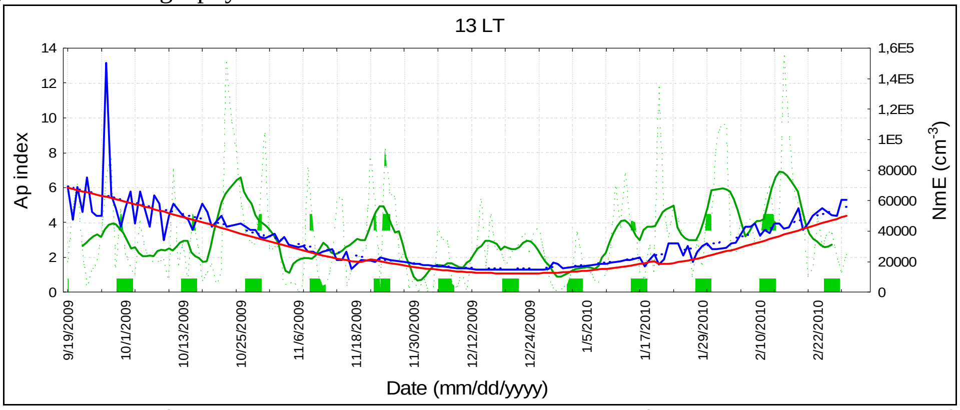

***Figure 1** Variations of simulation results and real sounding data of maximal electron density of E layer*

Talking about maximal altitude of F2 layer (HmF2) (Figure 2) we can mention that simulation results are overrated real values. Also there are no fluctuations in simulation results.

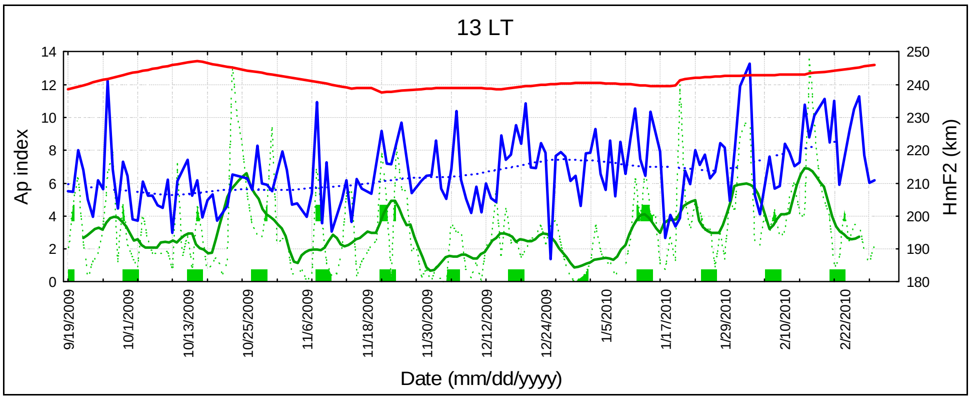

***Figure 2** Variations of simulation results and real sounding data for the maximal height of F2 layer*

In variations of maximal electron density of F2 ionosphere layer we can allocate 3 periods (Figure 3):
I – September - November 2009 (autumn)
II – December 2009 and January 2010 (winter)
III – February 2010 (spring)

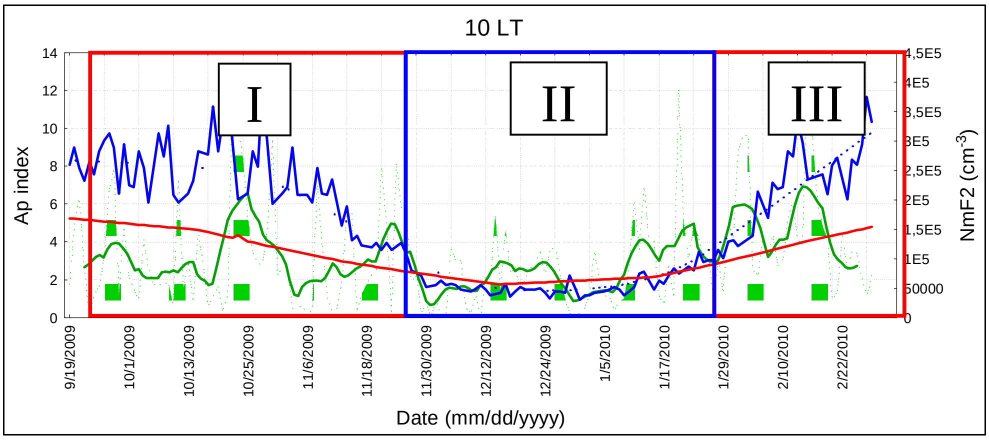

***Figure 3** Variations and periods of simulation results and real sounding data for the maximal electron density of F2 layer*

In winter season there is rather good agreement between IRI-2007 and ionosonde data. But in autumn and spring, when photochemical processes takes place, we get worse results.

For the numerical estimation of differences between IRI-2007 simulation results and real ionospheric sounding data was calculated Spearman rank correlation coefficients (Table 2).

Table 2 Spearman rank correlation coefficients between model and real for maximal altitude of F2 layer (HmF2), maximal electron density of F2 layer (NmF2) and maximal electron density of E layer (NmE)

	10 LT	**11 LT**	**12 LT**	**13 LT**	**14 LT**	**15 LT**
HmF2	0.49	0.31	0.44	0.33	0.23	0.46
NmF2	0.83	0.67	0.64	0.66	0.76	0.80
NmE	0.95	0.96	0.96	0.97	0.97	0.98

Correlation analysis also shows good agreement in maximal electron density of E layer and worse in maximal altitude and electron density of complicated F2 layer. This difference can be explained by the unrecorded values of electric field in IRI.

Epoch of 2009 is characterized by extremely low level of the solar activity which was expressed in complete absence of the sunspots as well as by very low values of parameters of the solar wind (its magnetic field, density and velocity). Such very low level of the solar activity was responsible for not ordinary changes of neutral atmosphere and for comparatively low intensity of the ionospheric electric fields which results in the low values of HmF2 and NmF2. Influence of the solar activity on the neutral atmosphere is a subject of many studies. It is established that decrease of the solar activity makes the thermosphere denser, while during years of maximum of solar activity the thermosphere becomes to be more rarified [2]. However influence of the electric fields on dynamics of ionosphere was studied only recently.

The distribution of the electric fields in ionosphere depends on the energy of solar wind and its parameters. Experimental data analysis shows that maximal altitude of F2 layer is associated with solar wind total magnetic field magnitude (Bsw).

Availability of long term experimental data of ionosphere were using for study connection HmF2 with full vector of the magnetic field of the solar wind which is connected with large magnetic fields of the Sun. Linkage between full vector IMF and altitude of maximum of F2 layer indicates physical mechanism of these parameters connection. Such physical mechanism can be electric drift of F2 layer under influence of electric field which is connected with IMF.

Average annual values of Bsw were higher than 5 nTl during all the period except of the last few years for period from 1965 year till 2007 years (Figure 4).

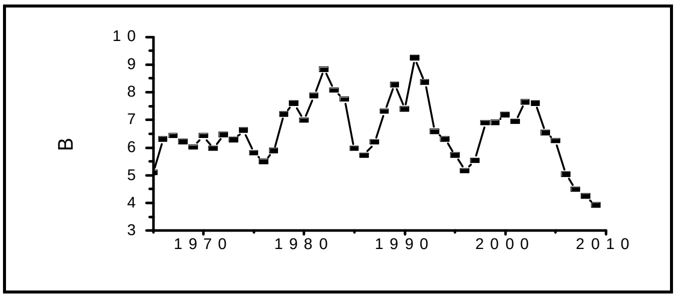

***Figure 4** Variations of solar wind total magnetic field magnitude (Bsw)*

Latest experimental data shows that value of the solar wind of the magnetic field have very low values (Figure 5). Values of the solar wind of the magnetic field in period September – November 2009 year were not more 4 nTl. So, altitude of maximum of F2 layer must very low.

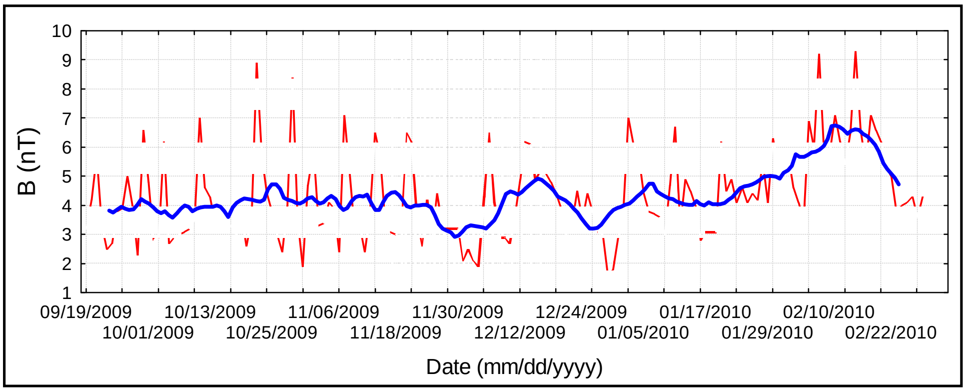

***Figure 5** Variations of solar wind total magnetic-field vector magnitude (B), since 09.2009 till 02.2010. Blue line is moving average with 10 days interval*

Simulation and experimental research demonstrated that maximal electron density of F2 layer decreases descending of F2 layer. But maximal electron density of F2 ionosphere layer can increases during of the low solar activity when the thermosphere is dense from processes of ionization. Obtained results in this research demonstrated it.
Model IRI contains information about the ionosphere state until the year 2007. So the model is not adopted for such a low values of the solar wind parameters and consequently to low values of maximal altitude and electron density in F2 layer. That is an explanation to such a magnificent difference between model results and the real vertical electron concentration distribution.

Summary

Experimental and calculated parameters of the ionograms as well as of vertical profiles of electron density were compared for the same periods of time.
The investigations of experimental and calculated parameters of the ionograms which have been done in this paper allow us to determine that:
a) IRI simulation results describe well both electron density and altitude of ionospheric layer E.
b) Comparison of IRI simulation results with real data shows than in conditions of low solar activity, observed during considered period, model gives disagreement with real values of F2 layer parameters and have to be corrected. But it can be used for overview of ionosphere condition for different purposes which don't need height accuracy.·

References

1. http://iri.gsfc.nasa.gov/
2. O. K. Garriott, H. Rishbet, Introduction to ionosphere physics, New York, London, 1969.