The generalization of electron density at 200 km into model on the base of Irkutsk incoherent scatter data

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ABSTRACT

The generalized results of electron density (N_e) measurements collected by the incoherent scatter method in Institute of Solar-Terrestrial Physics (Irkutsk, Russia) at height range 200 km are studying. The approach based on the generalization of N with help of semi-empirical model describing the connection of N_e with the thermosphere characteristic is used. The lasts are derived from MSIS-86 thermosphere model. The received model allows to calculate N_e for the Millstone-Hill coordinates and compare the results with the Local Model developed on the base of 30-year measurements for this incoherent scatter radar. The conclusion are made about the representativity of N_e (200) measurements in Irkutsk and validity of these data for generalization into the semi-empirical model.

Keywords: ionosphere, semi-empirical model, incoherent scatter data.

1. INTRODUCTION

The systematic measurements of the ionospheric parameters by the incoherent scatter method are in progress near Irkutsk. The measurements of N_e are made by using the Faraday rotation[1] at currying frequency 158 MHz. The length of sounding pulse varies from 50 to 100 microseconds that provides spatial resolution of electron density data better then 15 km. The last circumstance allows us to make the detail investigation of N_e behavior at relatively low heights (below the F2 layer maximum).

Due to presents of ground clutter in IS radar signal, the low altitude, where measurements are possible is limited by 170 km. In connection with the peculiarity of data processing, it is more reliable to say about the height level of 200 km as low height of analysis during the years 1998-2003. At the present time the works for extending down range of measurements are carried out. These permits us to have the reliable set of data from the range 160-200 km where condition of photochemical equilibrium is well fulfilled in daytime hours. The level of 200 km can be considered as the upper boundary of the mentioned ionosphere region. The investigation of correctness level for N_e measurements at level 200 km and its using for the scientific analysis is of particular interest. The resolution of the formulated problems is the required condition of IS measurements for their geophysical analysis.

The generalized result of N_e measurements at 200 km in Irkutsk during the years 1998-2003 are investigated in the paper. The data of measurements over 134 days are used for the generalization. As the height level 200 km belong to the region where the condition of photochemical equilibrium is fulfilled we may generalize N_e into semi-empirical model (SEM) which describes the connection of N_e with thermosphere neutral gas characteristics. The later studying is proceeded with help of calculation making by SEM. The main content of the work is the comparison of these data with the other model and some experimental data.

As result we have evidence showing that received data of N(200) are suitable for the purpose of their scientifical using and that they can be used for reducing into SEM.

At the same time it should be remarked that the derived SEM has the prior character since the measurements in period of low solar activity are lacking.

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2. THE INITIAL DATA

We have chosen for analysis 134 days of regular measurements including the five year period of N_e measurements (1998-2003). In choosing data procedure we do not include the days when the measurements carried out during short period (1-3 hours) of light day. Several days were rejected for the reason of large departure of measured N_e from expected ones. The range of reality was estimated by using the IRI-2000 model[2] and SEM[3]. The next step is the evaluation of the coefficients of regression equation over all array of selected data. For this purpose the averaged value of N_e were received over one hour interval LT centered in every integer hour. As result the table of the data was collected in which the dates of experiments averaged for every light hours (6,7,8,...12,...18) values of N_e were presented. The initial data were taken from the incoherent scatter database ORDA (http://hawk.iszf.irk.ru).

The values of indexes F10.7 for every selected days, for every previous day and its average value over 81 days, as well as Ap indexes for day of experiment and for days ago were assembled in the individual file. On the base of described data the first approximation of SEM were calculated. The root-mean square departures was calculated for every hour. Those values of N_e for which the departure from calculated with the SEM exceeded 2s were eliminated from consideration. 60 values of N_e were eliminated so as. So, for the final version of regression equation its coefficients were calculated over set of 134 day data, including 1230 values.

3. MODEL

The regression equation of SEM, describing the dependence of N_e from thermosphere parameters, of two types is used. The first of them given in the early paper[4] is:

$$N_e / N_{av} = X1 + X2.[n_1/(5n_2+n_3)]^{1,5} + X3(n_1/n_3)^{0,5}.(\cos\chi)^{0,5} + X4.\exp[-(T_{ex} - 600)/600] +$$

$$+ X5.(F - F_{av}) + X6.(F_{av} - 150) + X7.(F_{av} - 150)^2. \quad (1)$$

Here N_{av} is the averaged over whole data set value of N_e, X_j are the required coefficients of the model, n_1, n_2, n_3 are the densities of atomic oxygen, molecular oxygen and nitrogen respectively at 120 km; T_{ex} is the exosphere temperature or asimptotic temperature of atmosphere; χ is the solar zenith angle; F, F_{av} is the values of indexes F10.7 and its average value. The last three members in (1) give direct dependence of N_e from the ionizing solar flux.

In the second type of regression equation of SEM[3] the dependence of N_e from the solar activity level described with help of member $X_5 \cdot (E_s/E_{s0})$. It gives the relative value of ionizing solar flux. Here E_s – is the integrated solar flux energy over the range 5.0-105.0 nm[5,6]; E_{s0} is the value of E_s at the maximum of solar activity when $F=F_{av}=250$ in the noon of June 21. For the calculation of E_s, F and F_{av} are used as input parameters.

$$N/N_{av} = X1 + X2.[n_1/(5n_2+n_3)]^{1,5} + X3(n_1/n_3)^{0,5}.(\cos\chi)^{0,5} + X4.\exp[-(T_{ex} - 600)/600] + X5.(Es/Es0) \quad (2)$$

In the paper the data about the flux of E_s were calculated by using the model of spectral distribution of ionizing solar flux[6] $E(\lambda)$. In the present work the E_s data were calculated on the base of model $E(\lambda)$[6] . It is noted that using the model of $E(\lambda)$[6] that gives the result of calculation N by SEM differ from above mentioned variant less then from other models.

The thermosphere characteristics are calculated by using Hedin's[7] model for F in every previous day. At the same time in the terms 5, 6 and 7 in equation (1) and in the 5-th term in equation (2) values of F for current day are used.

Table 1. The coefficient of equation (1) and (2).

Number of equation	*Coefficients*						
	X1	X2	X3	X4	X5	X6	X7
1	-1,258	22,060	2,088	0,3949	-0,001767	0,1313	-0,000008845
2	-1,362	22,83	2,113	0,4579	0,5121		

We emphasize that the derived coefficients X_j and any calculation with the SEM are justify in the frame of obeying the thermosphere condition described by MSIS-86 model. It is necessary to note that coefficient X_4 is calculated by using the semi-empirical model[4]. It is necessary to obviate the receiving of negative values of X_5 in equation (2). The derived coefficients are shown in Table 1.

4. RESULTS

Let us firstly compare the results of calculation with version of the SEM based on equations (1) and (2). When $F_{10.7}$=150 these results of calculations are agreeing with each other. When $F_{10.7}$=200 the calculated values of N higher on 1-2% that equation (1). The most distinctions between the two variants of the SEM are when solar activity is near the minimum. The calculation by using equation (1) gives values of N_e on 20% lower than for equation (2). Notice that the calculation with equation (1) for the cases when all seven coefficients were derived and when X_4 is given and fixed are with agree each other.

The distinction between the average velocities of midday N_e (dN_e/dF) changing is a result of differences between the equations. It should be noted that the discussed dependences are close to linear. The version of SEM based on equation (1) give higher values of dN_e/dF compared with equation (2) (see table 2).

Table 2. Ratio d N_e /dF (10^7 sm^{-3} on unit of $F_{10,7}$).

Number of SEM equation	*Day of the year*			
	15	74	166	258
1	216	196	146	181
2	166	146	95	131

Let us examine the validity of the SEM by comparing the calculation for geographical coordinates of Millstone-Hill with the Local model (LM) developed on the base of 30-year set of observation data[8]. The equation (2) is used for calculations. The diurnal variation of N_e in January and June for $F_{10.7}$ =150 and A_p=10 are shown on Fig. 1. The variations of N_e calculated with IRI-95[9] are shown also. The dominant feature of the curves shown in Fig.1 is the general similarity both in their shape and in the absolute values of N_e.

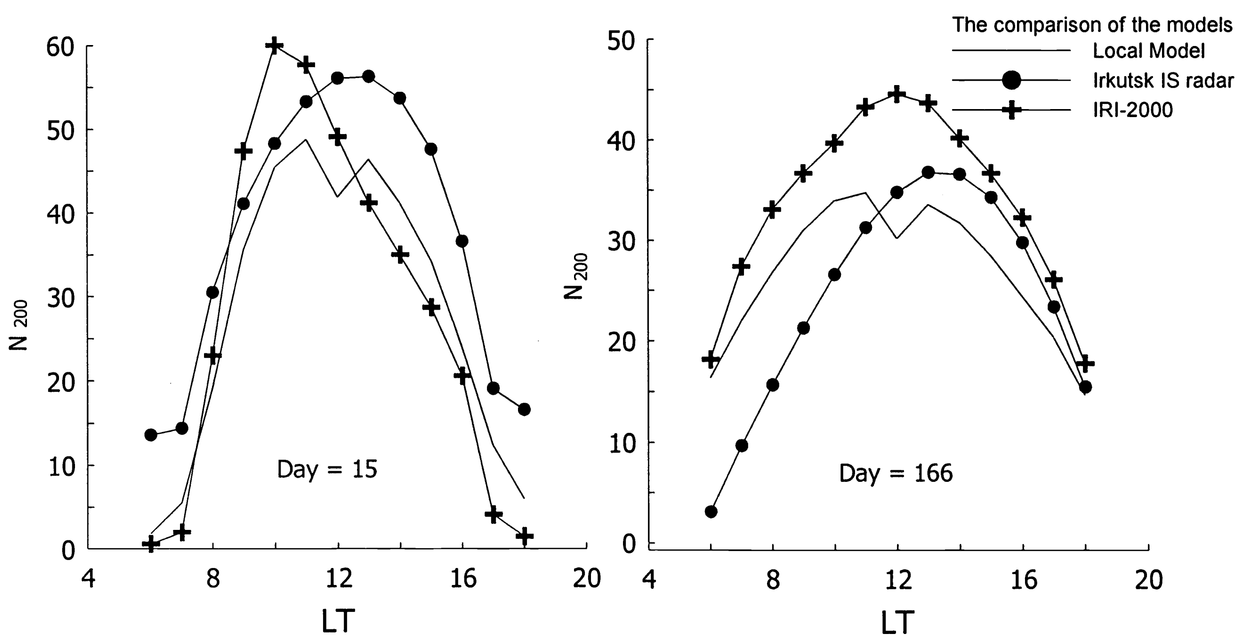

Fig.1. Daily variation of N_e at coordinates of Millstone-Hill (42^0N, 288^0E) in January (Day=15) and in June (Day=166). $F_{10.7}$=150, A_p=10.

This suggest that the developed SEM is realistic enough. At the same time there are some secondary distinctions between the models. These are connected with some shifts between the curves. In January the maximum of N_e in Local Model is in 11 LT. The discussed SEM gives the maximum in 13 LT. The same distinguish has place between SEM and LM in June. The annual variation of noon N_e in 11 LT are shown on Fig. 2 for the same models as on Fig.1. the main similarities between the curves for the discussed models are the summer minimum and winter maximum. The accordance between absolute values of N_e in all considered models is worth noting. The basic distinguish of annual variations in the IRI is the weak secondary maximum in summer months.

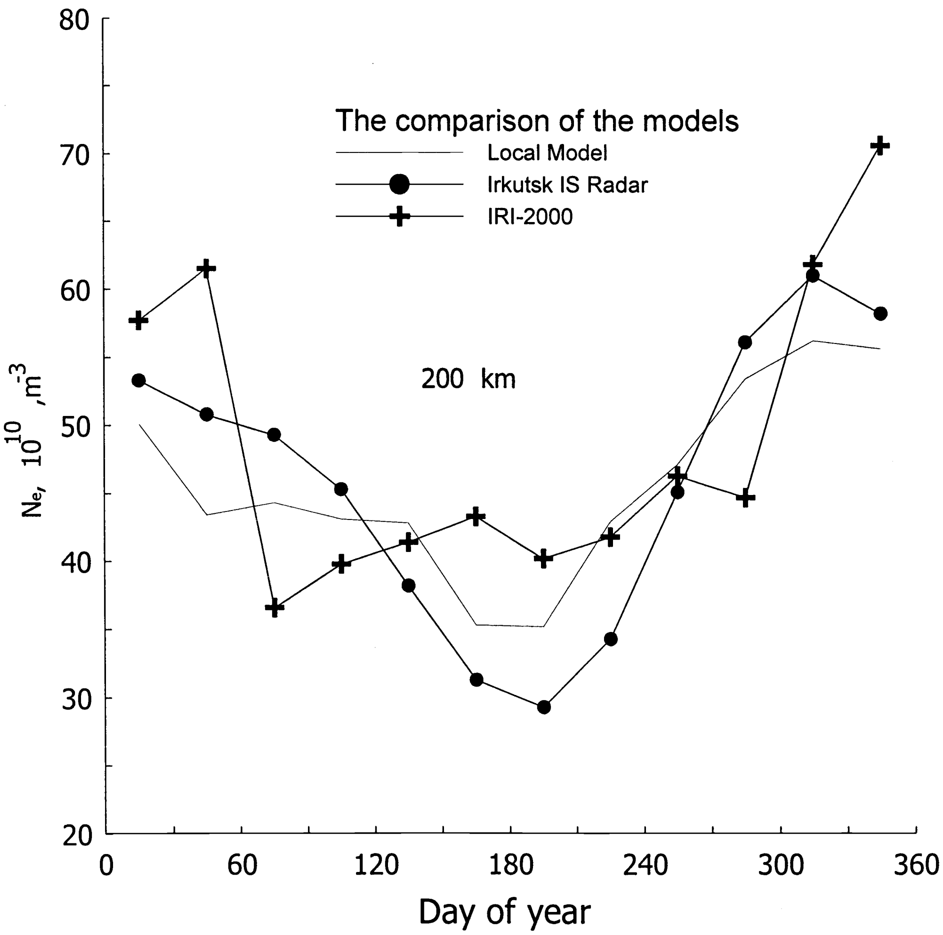

Fig.2. The annual variations of N_e(200) for coordinate of Millstone-Hill. 11 LT; $F_{10.7}$=150; A_p=10.

If we will compare the so called Ionogramm Model[4] with the SEM we fined out the good similarity for summer. The midday values of N_e at low level of solar activity $F_{10.7}$ =75 are practically the same. The difference rises with rising of $F_{10.7}$, and SEM gives higher on 12% values when $F_{10.7}$=100.

The considered differences are more significant in equinoxes and in winter with the same sign of deviation. It is about 15% in the minimum of solar activity and reach 40% when $F_{10.7}$=150. These distinguishes are marked and for annual variations. Being small in the summer time (10%) they differ by factor 1.5 in November at $F_{10.7}$=150. The diurnal variations of N_e in the SEM shows higher amplitude that in IM model.

5. CONCLUSIONS

The model generalization of electron density measurements at 200 km near Irkutsk is made. The received semi-empirical model admit us to make the comparison of measured N(200) with the empirical model worked at Millstone-Hill observatory by using 30-years data set. The satisfactory accordance between the models suggests the validity of the data measured near Irkutsk by incoherent scatter method. The same can be said about diurnal variation of N_e (200). The noted distinctions between models may be due to the departure of real thermosphere state from its describing by MSIS-86 model. The satisfactory accordance between the discussed models confirms that these data are in good stead for its generalization into SEM. At the same time the data of the SEM have prior character as they do not include the minimum solar activity data. The experience of work with data set, used in previous models shows that the distortion of dependence of N_e from $F_{10.7}$ takes place when range of $F_{10.7}$ data constricted with up or down boundary.

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