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ON MODELING OF THE DIURNAL VARIATION OF THE COEFFICIENT OF COMPUTATION OF TILT SOUNDING FROM VERTICAL SOUNDING OF IONOSPHERE

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ABSTRACT. A method of modeling of the diurnal variation of parameter M (3000) F2 has been developed. The method has been tested by the use of the data of Ionospheric Digital Database of the National Geophysical Data Center (NGDC), Boulder, Colorado, USA, namely, the data of Juliusruh - (φ=54.5^0 *N*). The type of the parameter dependence on solar activity has been studied and a model of diurnal variation of the median values in January has been made. The model is uniquely dependent on F10.7 allowing prediction of M (3000) F2. The method permits to make models for any point of the Earth (where the measurements are carried out during several cycles of solar activity) for every month.

INTRODUCTION.

Due to peculiarities of propagation of short waves the problem of computation and projection of radio-communication line is different for short waves compared to the problem posed for long and medium waves. For computations within the diapason of long and medium waves the problem is to define the length of the most advantageous wave, necessary transmitting power and necessary type of transmitting antenna. In many cases the sought values are found by means of solution of one mathematical problem as the above-said values are in a certain relation with one another.

Working within the diapason of short waves, first of all, it should be taken into consideration that it is necessary to use several waves for diurnal communication. Besides, due to absorption of radio waves independently of the transmitter power there exists the most advantageous wave for any diurnal period. On the one hand this factor makes computations easier, since the most advantageous wave is defined independently from the transmitting power, and on the other hand, it is necessary to choose several waves while only one operating wave is enough to work on long and medium waves. Besides, it is necessary to know the time of change from one wave to another. Situation is complicated as annual minimal number of total waves is necessary to be taken into consideration. Besides, the reserve waves are necessary because of variation of solar activity.

Thus, for designing the short-wave radio-communication line it is necessary to define the most advantageous annual number of total waves and the time of change from one wave to another to have a diurnal communication [1].

Ionosphere layers E and F2 have special functions in propagation of spatial short waves in normal conditions: in such a case layer E is an absorber, and layer F2 – the reflector. The diagram of propagation of radio waves is given in Fig.1.

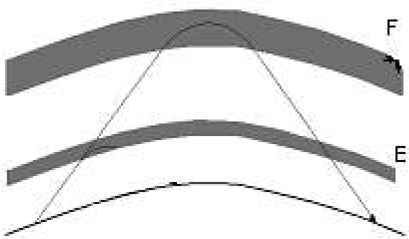

Fig.1. The trajectory of radio waves while propagation of short radio waves in normal conditions

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Analysis of Fig. 1 gives ground to conclude that in normal conditions concentration of electrons in the E layer is not enough to reflect the short waves. Besides, absorption of short waves while reflection from the F2 is less than while penetration E layer: on the ground of a well-known experimental fact daytime concentration of electrons in F2 is about 10-times more than in E layer [1].

It should be noted that while propagation in real conditions short waves are absorbed not only in E layer but also in lower part of the ionosphere - in D area. In such conditions the absorption coefficient does not change inversely proportional of frequency square but frequency increase causes reduction of absorption coefficient.
Absorption of radio waves in ionosphere must be taken into account to choose the working frequency. The more the frequency the less the absorption, but we are limited from above by critical frequency of the reflective layer. For prognosis (while reflection from F2 layer) of maximum applicable frequency (MAF) it is necessary to predict two parameters: critical frequency of F2-layer - f_0F2 and the coefficient of computation of tilt sounding M (3000) F2 = M3.

It is necessary to know two values to compute MAF in reflection from F2-layer: MAF of F2-0 and MAF of F2-4000 defining MAF on routes 0 and 4000, respectively (4000 km – maximum distance of one reflection).

$$\text{F2–0–MAF} = f_0\,\text{F2} + 1/2 f_H \qquad (1)$$

$$\text{F2-4 000 MAF} = 17.8\,[(\text{F2–3000-MAF})–(\text{F2–0-MAF})]\,/14.75 + +(\text{F2-0-MAF}), \qquad (2)$$

where (F2-3000-MAF)=f_0F2 $*$ M(3000)F2 and f_H is a Larmor frequency [2].

The parameters of F2-layer have a very complex spatial and time distribution, which cannot be given by a simple formula. Therefore, until the recent time the prognosis of F2 and M3 was done by means of handwork of numerous graphical materials. Development of the methods of computational mathematics and wide use of computers allows automation of this labor-consuming work. On this purpose it has become necessary to develop a method of analytical description of complex spatial variations allowing computation of the values of parameters of F2-layer for any point of the Earth for any period of time. One of such methods was developed in USA in 1962 [3]. In 1973 Chernishev and Vasileva in the USSR developed an analogous method. This method of analytical description of planetary distribution of ionosphere parameters is based on the spherical harmonics method of analysis, where solar activity is considered as follows: in the first volume the prognosis is made for solar activity, when Wolf's number W=10, in the next three volumes W=50, 100 and 150, respectively [2].

The main goal of the study of the structure of upper atmosphere is to define variation of atmosphere parameters according to height and time. To find the causes of variation of the upper atmosphere it is necessary to describe it by model. Therefore, one of the main directions of investigations by means of rockets and satellites is to make its model [4].

An empirical and statistical planetary model of monthly median values used at present for long-term prognosis of radio communication conditions (e.g. CCIR [5] and "MAF prognosis" [2]) is based on the dependence of 12-month smoothed value (R_{12}) of sunspots and f_0F2. But some works [6-8] show that application of ionospheres permits to obtain more exact approximation of f_0F2 dependence on solar activity. In [9] it is shown that application of GSSN (global sunspot number) instead of R_{12} permits to increase the exactness of prognosis: six month earlier – by 11%, a year earlier – by 18%. According to the authors of [7] it is quite prospective to turn to ionosphere indices for long-term prognosis.

In the USSR the "MAF prognosis" [2] was used for long-term prognosis, which differs from the international CCIR in the volume of used experimental material as well as in the method of its construction. Therefore, direct application of a "strange" ionosphere index for the model might be ineffective, though in [10] it is partially shown, that the change of R by GSSN permits to increase the precision of modeled description of median values of f_0F2. Standard method of R prognostication is given in [11]. Besides, deviation of f_0F2 prognosis in daytime is ~20% [12].

The method of modeling of the diurnal variation of f_0F2 described in [13] is quite different from the previous methods. It is uniquely dependent on the solar activity parameter (F10.7). By means of this method the dependence of the values of f_0F2 on F10.7 changes according to zenith angle of the Sun and it is necessary to solve an equation for every hour, but computer can do it easily. As shown in [13], precision of f_0F2 prognostication a few years earlier is lesser than 10% for any hour of the day.

In the present work a model of M3 diurnal variation has been made in analogous method. These two models allow the prediction of f_0F2 and M3, which is necessary for MAF prognosis.

EXPERIMENTAL RESULTS

Data obtained by German station (Julruh, $\varphi = 54.38^0$ N) in 1958-1986 have been used as in [13].

Table 1.

Monthly median values of M(3 000)F2 and F10.7
Julruh. January.

	Hour								F10.7
Year	0	1	2	*	*	*	22	23	
1958	235	235	230				248	240	243
1959	250	245	245				260	258	266
*									
*									
*									
1986	295	300	305				310	300	71

Parameter M3 in a fixed point of current month depends on the solar activity as well as on the Sun's zenith angle i.e. on local time T – M3(F10.7;T). To study the M3 dependence on F10.7 it is necessary to fix T in current month. On this purpose all the data should be arranged as given in Table 1. The terminal column of the Table represents the relevant value of F10.7. Each line of the Table shows diurnal variation of median values of M3 in January of the given year. The Sun's zenith angle for each column of the Table is constant permitting to study mutual relation between M3 and solar activity. This relation is given by the function

$$M3 = A + B * F10.7 \qquad (3)$$

Fig. 2 shows the graph of M3 dependence on F10.7 for $12^{h}UT$. Linear analysis is carried out in the program of "Origin 6.1". Correlation parameter R appears to be rather high. Fig.2 shows that increasing the solar activity, M3 decreases, which maybe caused by enerease of the height of reflected layer [14]. Only two points are at F10.7>200 and at low activity there are comparatively more points. Therefore, deviation in M3 prognostication will be more for the year of high solar activity. Using the data of the period as longer as possible for modeling provides more precise prognosis. Dependence for each hour is linear but the parameters of the line are different. Fig. 3 shows diurnal variation of R (coefficient correlation between (3) line and experimental points). Great changes in that variation coincide with the moments of sunrise and sunset in that latitude. Collection of statistical data will allow in-depth study of this effect.

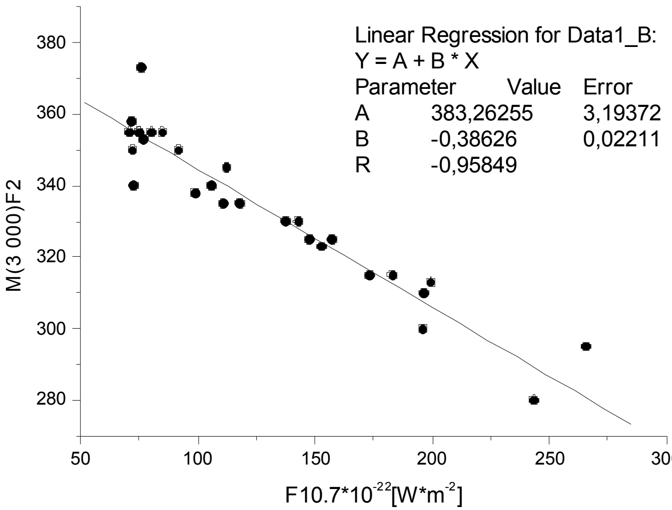

Fig. 2. Dependence between M3 and F10.7 for January, 12^h. Julruh.

For modeling it is necessary to compute M3 for every i-th hour by means of the following formula:

$$M3_i = A_i + B_i * F10.7$$

Fig.4 shows the model of diurnal variation of M3 for quiet (B,F10.7=70) and active (C, F 10.7 =250) Sun.

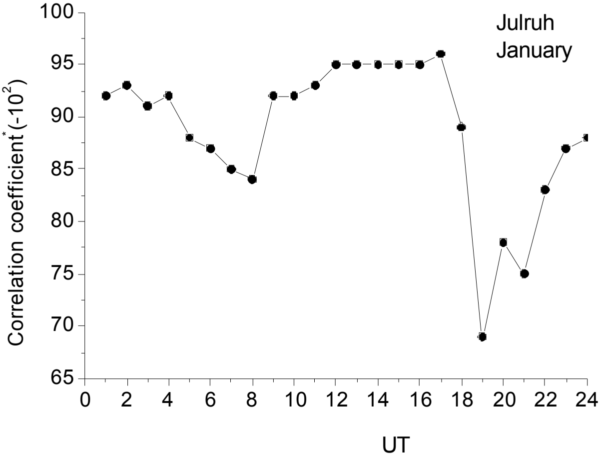

Fig.3. Diurnal variation of correlation coefficient

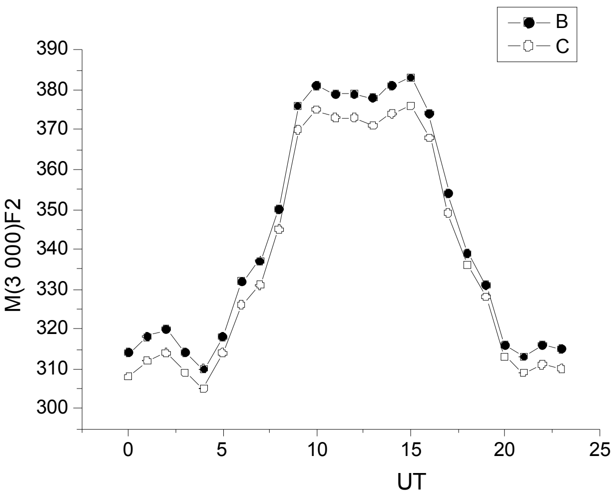

Fig. 4 Diurnal variation M3 for quiet (F10.7=70; (B)) and active (F10.7=250; (C)) sun. Julruh, January.

As noted above, the material collected up to 1986 have been used to make a model. Prognosis can be done for 1987(i.e. a year earlier). Deviation of predicted values of M3 from the real one does no exceed 5% for any hour.

Fig.5 shows real (B) and predicted (C) diurnal variation of M3 for January 1987. The variations are found to be rather similar and Fig.6 shows how precise they are.

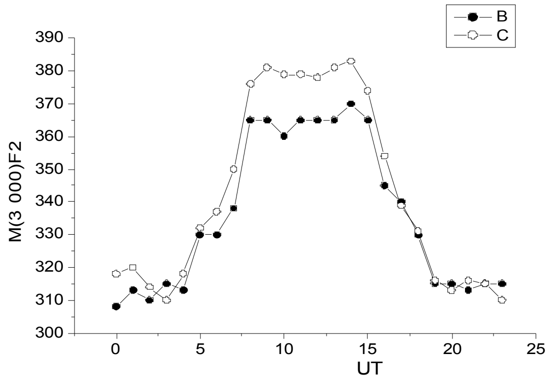

Fig. 5. Diurnal variation of M3 for 1987 year (experimental (B) and prognosis (C) values). Julruh, January.

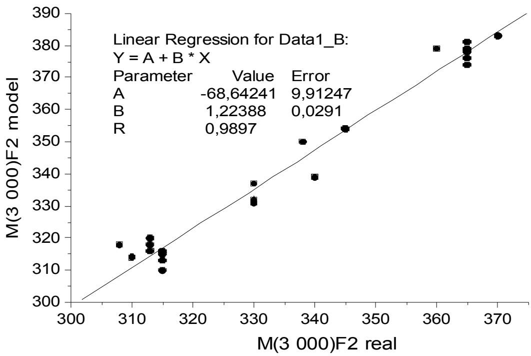

Fig. 6. Comparison of prognosis (model) and experimental (real) values of M3.

The coefficient of correlation between the real and predicted M3 is over 0.98 indicating rather high accuracy.

Fig.7 shows variation of the coefficient of correlation between experimental and predicted values of M3 according to solar activity. The increase of activity causes the decrease of R. As noted above, it is mainly due to insufficient data on high activity while modeling. Only two points are F10.7>200, therefore, it is expectable that the prognosis of high activity will be of low accuracy. In 1989 and 1990 years F10.7>200, therefore, both correlation coefficient and accuracy was low – average deviation was 15% and 17%, respectively. In 1987 and 1988 deviation was 2% and 7%, respectively.

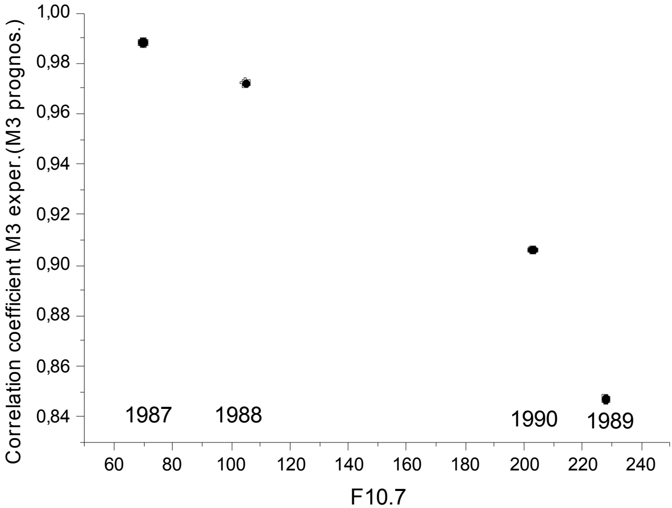

Fig. 7. Dependence of correlation coefficient on the sun's activity. Julruh, January.

THE INFERENCES

A method of modeling of the diurnal variation of parameter M (3000)F2 has been developed. The M(3000)F2 dependence on F10.7 has been studied. It has been established that the increase of F10.7 linearly decreases M(3000)F2, which might be caused by increase of $h_m F2$. Coefficients of the line change according to the Sun's zenith angle. Coefficients of correlation between the line and experimental monthly median data are high in daytime. Deviation of the prognosis for high activity is 15-17%. It is mainly due to insufficient data on high activity while modeling.

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იონოსფეროს ვერტიკალური ზონდირებიდან დახრილ ზონდირებაზე გადასაანგარიშებელი კოეფიციენტის დღეღამური ცვლილების მოდელირების შესახებ

დასკვნა

შემუშავებულია M(3000)F2 პარამეტრის დღეღამური ცვლილების მოდელის შედგენის მეთოდი. მეთოდის შემოწმებისთვის გამოყენებულია Ionospheric Digital Database of the National Geophysical Data Center (NGDC), Boulder, Colorado, USA, კერძოდ, Juliusruh – ($\varphi = 54{,}5^0$ N)-ის მონაცემები. გამოკვლეულია პარამეტრის მზის აქტივობაზე დამოკიდებულების სახე და შედგენილია იანვრის თვის მედიანური მნიშვნელობების დღეღამური ცვლილების მოდელი. მოდელი ცალსახადაა დამოკიდებული F10.7-ზე, რაც საშუალებას იძლევა M(3000)F2-ის წინასწარმეტყველების. ამ მეთოდით შეიძლება მოდელის შედგენა დედამიწის ნებისმიერი პუნქტისათვის (სადაც ჩატარებულია გაზომვები მზის აქტივობის რამდენიმე ციკლის განმავლობაში) ყოველი თვისთვის.