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PREDICTION THE PARAMETERS OF SOLAR ACTIVITY ON THE BASIS OF TAKING INTO ACCOUNT THE REDISTRIBUTION OF GRAVITATIONAL FORCES IN THE SOLAR SYSTEM

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ABSTRACT

In the paper a forecasting technique based on taking into account the redistribution of gravitational forces in the solar system is presented. Proposed procedures increase the homogeneity of the initial choice of data. This technique used to predict one of the characteristics of solar activity - declination (D) of the Earth's magnetic field. The forecast D for 2018 is given allowingfor estimating the effectiveness of the obtained model values.

Keyword*:* Solar activity, Earth, Place of observation, Gravitational forces, Dudson constant.

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1. INTRODUCTION

Solar activity is of great practical importance, because it affects the biosphere of the Earth, generating a response of all systems of the Earth. In particular, a high degree of synchronization of cycles of solar activity (CA) with climatic, seismic, hydrological, biological cycles occurring on the Earth has been established. Therefore, the parameters of the long-term dynamics of CA are of great interest for specialists in various industries.

1.1. Overview of methods

When the predicting the parameters of the CA, as a rule, use the statistical method, the analogy method and the cause-effect [2].

The disadvantage of the statistical method is the existence of ex-trepidation procedures, which allows only a short-term forecast. The accuracy of the predictions of the statistical method is less than 70%. The method of analogies takes into account the movement of sunspots over the disk of the Sun and allows us to implement CA predictions with an accuracy of 80-90%. Both these approaches do not provide an explanation of the reasons for the change in the CA and do not allowsto prediction for longer periods. The causal method implies that the CA is due to the internal physic-chemical processes of the Sun itself, which are not available for observation. This circumstance leads some researchers to conclude that it is impossible to determine the causes of CA.

Along with that, a number of researchers are of the opinion that on CA, apart from internal causes, external factors influence the position of the Sun in the Galaxy and the position of the planets relative to the Sun. It is, noted that the impact of planets on the Sun causes significant stresses, leading to a change in electromagnetic and other processes inside the luminary. In particular, it established that the change in the distance of the planets affects the change in the gravitational, and the change in their velocity - on the electromagnetic field of the Sun.

When the planets move around the Sun and interact their gravitational fields, synchronous oscillations of solar and planetary processes occur. The periods of oscillations depend on the time of revolution of the planets and the Sun around the center of gravity of the solar system, and the amplitudes of these oscillations depend on the masses of the planets and their distances to the Sun. This leads to a change in the speed of the orbital motions of the Sun and the planets and affects their internal processes. Because of these forces, the Sun extends and decreases its rotation speed around the axis. Because of this, solar activity fluctuates [1].

These gravitational interactions also stretch the atmosphere, the hydrosphere and the lithosphere of the Earth and are one of the main causes of synchronic climate fluctuations, earthquake activity and volcanoes.

2. WORKING HYPOTHESIS

When solving the problem of long-term prediction of CA, it is necessary to include cycles of different duration, due to the motions of the planets. In this context, the most acceptable is the use of gravitational forces, which have a number of advantages. In particular, they are:

- is a property of mass and affect any object that has mass;
- fully describe the terrestrial, solar and other cosmic cycles;
- allow to take into account the influence of any planet of the solar system relative to the place of observation;
- can be calculated with a high degree of accuracy for any point of the globe and at any time [4];

- give a one-to-one correspondence for any point of the globe taking into account the year, season, day, hour.

By now, the opinion has been formed that before solving the problem of magnetism for the Sun, this problem should be solved for the Earth (dynamo theory). All of the various effects of the Sun's impact on the Earth, magnetic storms are the most accessible and informative manifestation of them, allowing us to evaluate the state of near-Earth space [2].

As is known, the Earth's magnetic field at any point is described by the parameters of the direction and intensity of the field. The direction of the magnetic field is characterized by the declination (D) and the inclination (I), and the intensity of the common field (F) by the horizontal (H), vertical (Z) components.

As is known, the accuracy of our observations of the Earth's magnetic field depends on many factors that can be conditionally divided into the following categories:

1. Category «Place of observation». This is the geographical latitude, altitude above sea level and specific features of the place of observation.

2. The category «Time». The Earth's magnetic field has diurnal variations that are caused by the rotation of the Earth around its Time axis.

3. The category «Date». The Earth's magnetic field is characterized by annual variations due to the motion of the Earth in its orbit relative to the Sun and the change in the angle of inclination of the Earth's rotation axis with respect to the Data eclipse [9].

4. The category «Sun». The intensity of the processes taking place on the Sun is influenced by the Earth's magnetic field.

5. Category «Gravitational forces». The magnetic field of the Earth depends on the location of the planets in the solar system relative to the observation point.

Thus, in order to obtain adequate forecasts of the dynamics of the parameter of declination D in a mathematical model (equation or system of equations), it is necessary to include all these factors as independent variables:

In the study of such problems, the mathematical apparatus of the theory of time series, differential and integral equations are often used. In this case, the parameters of the process under investigation invariably turn out to be dependent on others, which in turn are also dynamical. The inclusion of these parameters in the consideration leads to an increase in the order of the system, significantly complicating the process of solving the initial problem in analytical form and obtaining effective forecasts.

In this paper, we will outline the method of forecasting based on the influence of gravitational forces arising from the redistribution of masses in the solar system relative to the Earth. The technique is implemented at an approximate measure of the declination (D) of the direction of the earth's magnetic field.

In view of the fact that the original data array has a statistical character, the least squares (LOS) method was used in constructing forecast models. The main advantages of estimating are that they possess the smallest possible variance in the class of all linear unbiased estimators and are therefore the best linear unbiased estimators of unknown parameters.

It should be noted here that these advantages of LOS estimates are achieved when assumptions are made that are advanced with respect to the initial data set. The fulfillment of these conditions ensures homogeneity of the initial sample of data and, accordingly allows obtain effective estimates.

The above dependence of the investigated process on many factors leads to violations of the requirements and, accordingly, does not allow obtaining effective estimates. To improve the homogeneity of the initial sample of data when solving the prediction problem, we propose the following procedures.

1. «Place of observation». Any geographical point is characterized by the following characteristics: geographical latitude and longitude, altitude above sea level, remoteness from seacoasts, features of relief and degree of air pollution.

We propose from the initial data array on declination D to select observations recorded only at one geographic point. Then the received data array will be homogeneous in relation to the specific features of the observation site. As a result, it will be possible to conclude that the variations of the values of D noted for these data are due to factors of other categories.

Thus, the factors of the category «Place of observation» from the category of variables will go into the category of constant values.

Using this procedure, we increase the homogeneity of the original mass of data by eliminating characteristics that describe the specific features of the place of observation. At the same time, we implicitly agree with the circumstance that for each geographic point, a prognostic model will be built for declining D.

2. «Time» and «Date». As is known, in mathematics the unit of time is equivalent, and minutes are added in hours, hours - in days, days - in weeks, months, years. Here, the transition of the «Time» parameter to the «Date» parameter is noted. From the astronomical point of view, Time and Date are clearly separated. Time of day Time is determined by the rotation of the Earth around its axis ω, and Data - coordinates (x*, y*) of the location of the center of the Earth in its orbit relative to the Sun, moving along which changes the angle of inclination of the Earth's rotation axis to the ecliptic γ.

The problem is complicated by the fact that the parameters ω, γ and coordinates (x*, y *) vary continuously and simultaneously. This leads to a change in the distance of the observation point relative to the object of the study.

Let us choose the specific position of the Earth relative to the Sun, for example, at 3 pm on January 1,1958. Since one year corresponds to one revolution of the Earth in its orbit relative to the Sun, it can be concluded that the Earth's position in relation to the Sun will be observed every year on January 1 at 3 pm. We form an array of data corresponding to this position by years for a particular geo-graphical point (see Table 1).

Table 1 The values of D, recorded in the observatory «Moscow»January 1 at 3 pm

№	D	Time (t)	Day	Year
1	7050,7'	15	1 January	1958
2	7048,6'	15	1 January	1959
- -	- - -	- - -	- - -	- - -
- -	- - -	- - -	- - -	- - -
k	10033,8'	15	1January	2018

A feature of the data array formed in this way is the fact that the Earth is in one position with respect to the Sun. This means that such factors as the rotation of the Earth around its axis ω, the coordinates of the Earth in orbit relative to the Sun(x*,y*), the slope of the Earth's rotation axis to the plane of the ecliptic γ are constant. Note that the parameter «Year» is a parameter-a counter that describes the number of revolutions that the Earth made around the Sun from the moment taken as the initial one.

It can be seen from Table 1 that although the parameters Time = const, Data = const, but nevertheless, there are variations of the parameter D with respect to which, we can assume that they are due to the parameters of the categories «Sun» and «Gravitational forces».

At the same time, we implicitly agree with the circumstance that for each hour and every day of the year of the corresponding geographic point, a prognostic model will be built for declining D.

Here we should say a few words about such factor as the intensity of solar processes β. With this method of data formation, the Earth is in one position in relation to the Sun and this ensures a constant angle of observation of the object of investigation. However, in different years there may be a differentintensity of solar processesβ, which, in turn, have a significant influence on the parameters of the magnetic field of the Earth.

If we adhere to the point of view [5, 7, 8], then it turns out that in our case, the influence of the solar activityβ on D has already been taken into account by the gravitational forces of the planets included in our analysis as independent variables.
Thus, it can be stated that the use of procedure 2 allows the parameters of the categories «Time», «Date» and «Sun» to be translated into the category of constants.

As a result, it can be stated that the changes in the values of D noted in Table 1 is due only to the gravitationalin fluence of other planets on the Earth.

The proposed procedure makes it possible to increase the homogeneity of the initial sample of data, but at the same time, it forces us to construct a prognostic model for each moment of time and every day of the year in isolation. If you operate with hourly data measurements, then the total number of models will reach 8760 (365 days a year * 24 measurement sperday).

3. «Gravitational forces». In the previous stages, with the help of the procedure, the parameters of the categories «Observation», «Time» and «Date» were reduced to a constant level, which allowed the original problem to be transformed that is, from the gravitational forces of the solar system.

It is known that, the tide-generating potential is the result of a cumulative effect of waves of different length [4]. Dudsonin 1921 a harmonic expansion of this function was carried out over spherical harmonics. Its decomposition contained 386 waves. In 1971, a more complete expansion of the tidal potential was published, containing 550 waves [11].

At this stage, it is proposed to construct predictive models based on the waves that make up the tide-generating potential.

In the study, we looked at the projections for the parallel, meridian and vertical of 550 waves of all objects of the solar system (except Pluto). In the final model, only those of them that had a reliable correlation relationship at the level ($p < 0.05$) with the Earth's magnetic field parameter D were included as independent variables. The rest were excluded from consideration as factors creating «white noise».

Based on the selected waves, the resultant «pure signal» was formed in the form of sums of their values. Summation for each projection was carried out separately. In order to prevent mutual compensation of positively and negatively correlated waves, the separate summation was also performed taking into account the nature of the correlation coupling. As a result, six characteristics were formed, having a reliable correlation relationship with the studied indicator D:

Mer-P, Par-P, Wer-P - the sum of the projections of waves along the meridian, parallel, vertical, respectively, having a reliable positive correlation with D;

Mer-M, Par-M, Wer-M - the sum of the projections of the waves along the meridian, parallel, vertical, respectively, with a significant negative correlation with D.

This procedure allows you to take into account the effect of synchronization of solar and planetary oscillations that arise because of the motion of planets around the Sun and the interaction of their gravitational fields.

3. ALGORITHM FOR THE CALCULATION OF GRAVITATIONAL FORCES

It is known that the tidal potential consists of waves of different length.

$$F = F^{d} + F^{S} + F^{P} + F^{t}$$

where

F^{d} − long-period (zonal) wave

F^{S} − diurnal (tesseral) wave

F^{P} − half-day (sectorial) wave

F^{t} − third-wave wave

$$F^{d} = D(c/r)^{3}\left[3\left(\sin^{2}\phi - 1/3\right)\left(\sin^{2}\delta - 1/3\right)\right]$$

$$F^{S} = D(c/r)^{3}\left[\sin 2\phi \sin 2\delta \cos H\right]$$

$$F^{p} = D(c/r)^{3}\left[\cos^{2}\phi \cos^{2}\delta \cos 2H\right]$$

$$F^{t} = D(c/r)^{3}\frac{1}{2}\left[5\cos^{3}\phi - 3\cos\varphi\right]$$

To calculate the tidal forces in the projections along the vertical, meridian and parallel components, we take the partial derivatives with respect to r and φ, and by performing the transformations, we obtain:

Long-period (zone) wave

vertical $F^{d}_{w} = D(c/r)^{3}\left[3\left(\sin^{2}\phi - 1/3\right)\left(\sin^{2}\delta - 1/3\right)\right]$

meridian $F^{d}_{m} = D(c/r)^{3}\left[-3\sin 2\phi\left(\sin^{2}\delta - 1/3\right)\right]$

parallel $F^{d}_{p} = 0$

The daily (tesseral) wave

vertical $F^{s}_{w} = D(c/r)^{3}\left[2\sin 2\phi \cos H \sin\delta\sqrt{1-\sin^{2}\delta}\right]$

meridian $F^{s}_{m} = D(c/r)^{3}\left[-4\cos 2\phi \cos H \sin\delta\sqrt{1-\sin^{2}\delta}\right]$

parallel $F^{s}_{p} = D(c/r)^{3}\left[4\sin\phi \sin H \sin\delta\sqrt{1-\sin^{2}\delta}\right]$

Semi-daily (sectorial) wave

vertical $F^{p}_{w} = D(c/r)^{3}\left[\cos^{2}\phi \cos 2H\sqrt{1-\sin^{2}\delta}\right]$

meridian $F^{p}_{m} = D(c/r)^{3}\left[\sin 2\phi \cos 2H\sqrt{1-\sin^{2}\delta}\right]$

parallel $F^{p}_{p} = D(c/r)^{3}\left[2\cos\phi \sin 2H\sqrt{1-\sin^{2}\delta}\right]$

The Third Wave

vertical $F_w^t = D(c/r)^3 \frac{3}{2}\left[(5\cos^2 z - 1)\sqrt{1-\cos^2 z}\right]$

meridian $F_m^t = D(c/r)^3 \frac{1}{2}\left[-\cos z(10\sqrt{1-\cos^2 z}+1)(\cos\phi\sin\delta - \sin\phi\cos H\sqrt{1-\sin^2\delta})\right]$ parallel

$F_p^t = D(c/r)^3 \frac{1}{2}\left[\cos z(10\sqrt{1-\cos^2 z}+1)\cos\phi\sin H\sqrt{1-\sin^2\delta})\right]$

F_B^A - superscript A means wave type: d - long-period; s – daily; p - semidiurnal; t – The Third Wave; and the subscript B denotes the projection of w to the vertical; m - on the meridian; p is parallel.

$D' = 12100,82127 \text{ cm}^2/s^2$ - Dudson constant for the Sun

The calculation of the Dudson constant for planetsmade by the formula

$D = 3mg_1a_1^2(a_1 + r_0)^2/4c^3$

here

$g_1(\text{cm/s}^2)$ – acceleration of gravity

$a_1(m)$ – average radius of the planet

$m = m_{ob}/m_z$ - the ratio of the object's mass to the mass of the Earth (Table 2)

Table 2. Characteristics of the celestial bodies of the solar system

Planets	$g_1(\text{cm/s}^2)$	$a_1(m)$	$m = m_{ob}/m_z$	ex – Eccentricity
Sun	27400	696000000		
Mercury	370	2439700	0,005	0,2056307
Venus	887	6051800	0,816	0,0067732
Earth	981	6371000	1	0,0167102
Mars	371	3389500	0,107	0,0934123
Jupiter	2479	69910000	318	0,0483927
Saturn	1044	58232000	95,1	0,0541506
Neptune	1115	24622000	17,2	0,0085859
Uranus	887	25362000	14,6	0,0471677

r_0 - elevation above sea level

$c = 60,27\,a_1$

ϕ - geographical latitude of the place of observation on Earth

δ – Declination of the Celestial Body

$\sin\delta = 0{,}406\sin\alpha + 0{,}008\sin 3\alpha + 0{,}090\sin(\alpha - N) + 0{,}006\sin(3\alpha - N)$

for Sun $\sin\delta = 0{,}406\sin\alpha + 0{,}003\sin 3\alpha$

α – where the ascent for the Heavenly body

$\alpha = s - 0{,}043\sin 2s + 0{,}019\sin N - 0{,}019\sin(2s - N)$

for Sun $\alpha = h - 0{,}0435\sin 2h$

c/r – radius vectors are determined from the following relation:

Sun-heavenly body

$c/r = 1 + ex*\cos(s-p) + ex^2*\sin 2(s-p) + 4ex^2*\sin 3(s-p)$

Taking into account the eccentricity values of the planets ex (Table 2), we have Earth - The Sun

$c / r = 1 + 0{,}0167301 \cos(h - p_s) + 0{,}000281 \sin 2(h - p_s) + 0{,}000005 \sin 3(h - p_s)$

The Sun - Mercury

$c / r = 1 + 0{,}2056307 \cos(s - p) + 0{,}042284 \sin 2(s - p) + 0{,}007115174 \sin 3(s - p)$

The Sun – Venus

$c / r = 1 + 0{,}0067732 \cos(s - p) + 0{,}000046 \sin 2(s - p) + 0{,}00000001 \sin 3(s - p)$

The Sun – Mars

$c / r = 1 + 0{,}0934123 \cos(s - p) + 0{,}008726 \sin 2(s - p) + 0{,}00030456 \sin 3(s - p)$

The Sun – Jupiter

$c / r = 1 + 0{,}0483927 \cos(s - p) + 0{,}002342 \sin 2(s - p) + 0{,}00002194 \sin 3(s - p)$

The Sun – Saturn

$c / r = 1 + 0{,}0541506 \cos(s - p) + 0{,}002932 \sin 2(s - p) + 0{,}00003439 \sin 3(s - p)$

The Sun – Uranus

$c / r = 1 + 0{,}0471677 \cos(s - p) + 0{,}002225 \sin 2(s - p) + 0{,}0000198 \sin 3(s - p)$

The Sun – Neptune

$c / r = 1 + 0{,}0085859 \cos(s - p) + 0{,}000074 \sin 2(s - p) + 0{,}00000002 \sin 3(s - p)$

$H = a\tau + bs + ch + dp + eN' + fp_s$ - determines the form of the function from the tables (Table 1 and Table 2),

where

$\tau = 360^0 * T - (s - h) + 180^0$ - indicates the type of wave

s - mean longitude of the Celestial Body for Mercury

$s = 908103{,}26^0 + 538106660{,}097^0 * T + 1{,}0943^0 * T^2 + 0{,}0001^0 * T^3$

for Venus

$s = 655127{,}283^0 + 210669166{,}909^0 * T + 1{,}1182^0 * T^2 + 0{,}0001^0 * T^3$

for Mars

$s = 1279559{,}789^0 + 68910107{,}309^0 * T + 1{,}1195^0 * T^2 + 0{,}0001^0 * T^3$

for Jupiter

$s = 123665{,}342^0 + 10930690{,}04^0 * T + 0{,}8055^0 * T^2 + 0{,}0159^0 * T^3$

for Saturn

$s = 180278{,}897^0 + 4404639{,}651^0 * T + 1{,}8703^0 * T^2$

for Uranus $s = 1130598,018^0 + 1547510,602^0 * T + 1,0956^0 * T^2 + 0,0001^0 * T^3$

for Neptune $s = 1095655,196^0 + 791579,913^0 * T + 1,1133^0 * T^2 + 0,0001^0 * T^3$

h - average longitude of the Sun

$h = 279,69668^0 + 36000,76892^0 * T + 0,00030^0 * T^2$

p - longitude of the perigee of the heavenly body

for Mercury $p = 278842,029^0 + 5603,318^0 * T + 1,0652^0 * T^2 + 0,0002 * T^3$

for Venus $p = 473629,346^0 + 5047,994^0 * T - 3,8618^0 * T^2 - 0,0189 * T^3$

for Mars $p = 1209816,842^0 + 6627,759^0 * T + 0,4864^0 * T^2 + 0,001 * T^3$

for Jupiter $p = 51592,713^0 + 5805,497^0 * T + 3,7132^0 * T^2 - 0,0159 * T^3$

for Saturn $p = 335004,434^0 + 7069,538^0 * T + 3,015^0 * T^2 + 0,0181 * T^3$

for Uranus $p = 622818,573^0 + 5350,965^0 * T + 0,7722^0 * T^2 + 0,0015 * T^3$

for Neptune $p = 173245,286^0 + 5134,572^0 * T + 1,3649^0 * T^2 - 0,0001 * T^3$

p_s - longitude of the perigee of the sun

$p_s = 281,22083^0 + 1,71902^0 * T + 0,00045^0 * T^2 + 0,000003 * T^3$

$N = -N'$ - longitude of the ascending node of the Celestial Body

for Mercury $N = 173991,215^0 + 4270,279^0 * T + 0,6332^0 * T^2 + 0,0008 * T^3$

for Venus $N = 276047,713^0 + 3244,033^0 * T + 1,4639^0 * T^2 - 0,0003 * T^3$

for Mars $N = 178409,136^0 + 2779,544^0 * T + 0,0578^0 * T^2 + 0,0082 * T^3$

for Jupiter $N = 361671,986^0 + 3675,433^0 * T + 1,4440^0 * T^2 + 0,0021 * T^3$

for Saturn $N = 409195{,}885^0 + 3157{,}539^0 * T - 0{,}4347^0 * T^2 - 0{,}0084 * T^3$

for Uranus $N = 266421{,}41^0 + 1876{,}056^0 * T + 4{,}8236^0 * T^2 + 0{,}0666 * T^3$

for Neptune $N = 474422{,}605^0 + 3967{,}929^0 * T + 0{,}9359^0 * T^2 - 0{,}0022 * T^3$

T - the time expressed in the Julian centuries (the first Julian year corresponds to 4713 BC) $T = (T_j - T_{j0}) / 36525$

T_j the number of days that passed from 1 Julian year to the year of the study.

T_{j0} the number of days that passed from the first Julian year to the 1st Julian January of 1899.

The main advantage of this approach is the lack of procedures for extrapolation. Also, note that the orbits of planets (except Pluto) are known, and, consequently, their gravitational forces can be calculated with high accuracy on any point of the Earth and at any time. The proposed procedures are aimed at increasing the homogeneity of the original data set, which in the end will improve the effectiveness of the predictive values of D.

4. BUILDING A MODEL

In view of the fact that the purpose of this paper is to justify the proposed methodology for forecasting and assessing the level of efficiency of its forecasts, we have generated the construction of forecast models for parameter D, corresponding only to 15 hours. The total number of measurements was 20440.

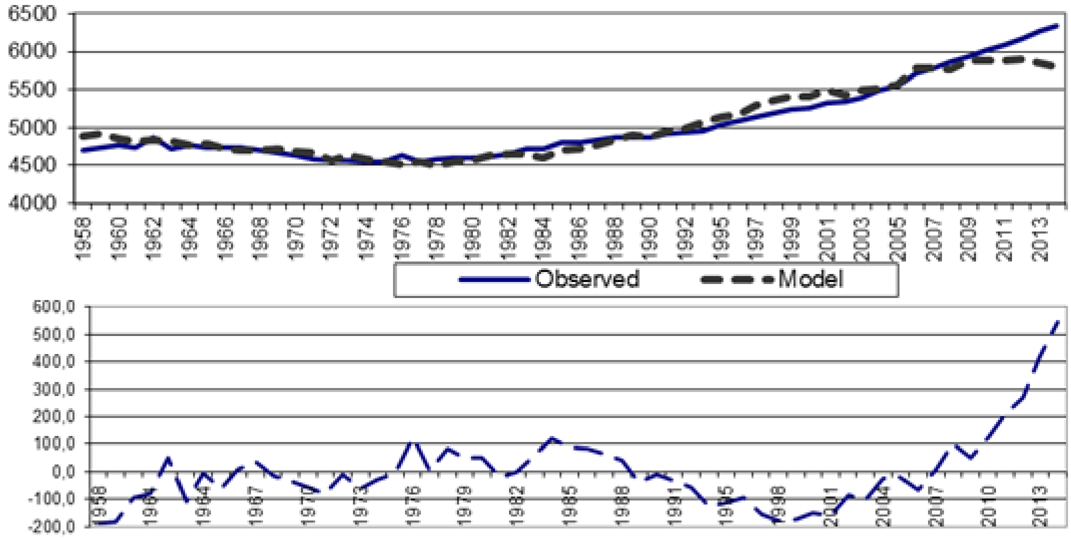

Figure 1 Graph of conformity of predictive model values of the real data of the observatory and their deviations

As is known, natural processes are characterized by a cyclist, which is reflected in models in the form of nonlinear equations. In our case, since the six characteristics of Mer-P, Par-P, Wer-P, Mer-M, Par-M, Wer-M are the sums of the wave projections that take into account this cyclist, we constructed the forecast models in the form of simple regressions for each of the six characteristics formed. The final forecast was determined as the mean-non-arithmetical values of these models. In particular, for the forecast of parameter D on January 10, 15 hours of the day, the following models were obtained:

y1 = -1066,12997235403 + 28,0574686218686 * Mer- P

y2 = 8501,96975037135 -24,9604371675273 * Mer-M

y3 = 5150,95463167591 + 20,4364130134865 * Par- P

y4 = 5143,89670659289 -23,8503260288846 * Par-M

y5 = 5877,30795644784 + 10,9412257953607 * Wer- P

y6 = 3897,1482927835 -12,0676917625328 * Wer-M

The root-mean-square error of the deviations of the model values from the initial values of the variational series was 113.

Note: Hereinafter, the units of measurement D are given according to the international format with the addition of tenths of a minute.

Based on the models obtained, a software product was developed, with the help of which the predictive values of parameter D for 2018 were calculated for 15 hours at the observatory of Moscow (Table 3).

Table 3 Forecast of the dynamics of the parameter D of the direction of the earth's magnetic field at 15-00 o'clock in 2018 for the observatory «Moscow»a

Days	Months											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	9^0 41	9^0 129	9^0 168	9^0 116	9^0 465	9^0 57	9^0 155	8^0 149	9^0 103	9^0 52	*8^0 545*	9^0 116
2	9^0 160	9^0 98	9^0 136	9^0 171	10^0 181	9^0 22	9^0 23	8^0 74	9^0 147	9^0 41	9^0 117	9^0 192
3	9^0 90	9^0 87	*8^0 539*	9^0 120	9^0 66	9^0 57	9^0 214	8^0 75	9^0 62	9^0 212	9^0 144	*9^0 46*
4	9^0 22	9^0 101	9^0 171	9^0 106	9^0 114	9^0 171	9^0 83	8^0 114	9^0 55	*8^0 560*	9^0 127	9^0 119
5	*241*	9^0 114	9^0 9	9^0 67	9^0 139	9^0 23	9^0 147	8^0 75	9^0 223	9^0 83	9^0 81	9^0 120
6	*8^0 529*	9^0 161	9^0 190	9^0 155	9^0 10	9^0 61	9^0 57	8^0 59	9^0 88	9^0 201	9^0 170	9^0 176
7	9^0 52	9^0 77	9^0 45	9^0 109	9^0 64	9^0 31	9^0 1	7^0 583	9^0 180	9^0 118	9^0 254	9^0 113
8	9^0 155	9^0 124	9^0 167	9^0 100	9^0 74	9^0 125	9^0 48	8^0 50	9^0 170	9^0 85	9^0 146	9^0 60
9	9^0 76	9^0 127	9^0 175	9^0 69	9^0 155	9^0 110	9^0 119	7^0 593	9^0 73	9^0 139	9^0 92	9^0 169
10	9^0 89	9^0 34	9^0 115	9^0 149	9^0 63	9^0 83	9^0 124	7^0 545	9^0 92	9^0 156	9^0 167	9^0 59
11	9^0 8	9^0 136	9^0 43	9^0 36	*8^0 561*	*8^0 567*	9^0 231	7^0 579	9^0 131	9^0 77	9^0 186	9^0 61
12	9^0 101	9^0 41	9^0 188	9^0 202	9^0 124	9^0 138	9^0 140	8^0 54	9^0 175	9^0 174	9^0 158	9^0 154
13	9^0 57	9^0 44	9^0 184	9^0 22	9^0 103	9^0 63	9^0 73	*7^0 532*	9^0 123	9^0 103	9^0 151	9^0 177
14	9^0 56	9^0 46	9^0 119	9^0 95	9^0 54	9^0 83	9^0 218	8^0 137	9^0 100	9^0 173	9^0 88	9^0 186
15	9^0 54	*9^0 13*	9^0 58	9^0 84	9^0 162	9^0 75	*8^0 572*	8^0 59	9^0 192	9^0 100	9^0 138	9^0 199
16	9^0 63	9^0 91	9^0 575	9^0 15	9^0 124	8^0 597	9^0 48	8^0 93	9^0 130	9^0 99	9^0 94	9^0 83
17	9^0 56	9^0 24	9^0 95	9^0 107	9^0 65	9^0 43	9^0 100	8^0 61	9^0 161	9^0 179	9^0 98	9^0 186
18	9^0 54	9^0 50	9^0 90	9^0 74	9^0 102	9^0 93	9^0 114	8^0 300	9^0 106	9^0 180	9^0 146	9^0 84
19	9^0 13	9^0 41	9^0 71	9^0 59	9^0 71	9^0 164	9^0 168	8^0 237	9^0 71	9^0 64	9^0 169	9^0 102
20	9^0 75	9^0 61	9^0 166	9^0 151	9^0 63	9^0 104	9^0 52	8^0 143	9^0 174	9^0 78	9^0 147	9^0 152
21	9^0 9	9^0 120	8^0 574	9^0 126	9^0 85	8^0 571	9^0 93	8^0 294	9^0 156	9^0 159	9^0 185	9^0 280
22	9^0 28	9^0 84	9^0 137	9^0 81	9^0 150	9^0 61	9^0 58	8^0 271	9^0 78	9^0 136	9^0 164	9^0 99
23	9^0 133	9^0 209	8^0 561	9^0 87	9^0 5	9^0 156	9^0 161	8^0 565	*9^0 12*	9^0 87	9^0 167	9^0 191
24	9^0 132	9^0 158	9^0 171	9^0 102	9^0 33	9^0 147	9^0 89	8^0 349	9^0 147	9^0 183	9^0 144	9^0 106
25	9^0 54	9^0 115	9^0 93	8^0 590	9^0 163	9^0 125	9^0 136	8^0 333	9^0 105	9^0 177	9^0 62	9^0 58
26	9^0 13	9^0 93	9^0 18	9^0 93	9^0 233	9^0 61	9^0 65	8^0 409	9^0 76	9^0 594	9^0 46	9^0 131
27	9^0 127	9^0 137	9^0 179	9^0 132	9^0 82	9^0 253	9^0 159	8^0 392	9^0 27	9^0 261	9^0 169	9^0 235
28	9^0 42	9^0 89	9^0 77	9^0 159	9^0 114	9^0 126	9^0 41	8^0 553	*9^0 12*	9^0 156	9^0 86	9^0 88
29	9^0 20		9^0 54	9^0 87	9^0 68	9^0 80	9^0 172	9^0 29	9^0 49	9^0 133	9^0 132	9^0 139
30	9^0 56		9^0 23	*8^0 541*	9^0 29	9^0 177	9^0 55	9^0 18	9^0 69	9^0 95	9^0 138	9^0 163
31	9^0 113		9^0 122		9^0 59		9^0 46	8^0 505		9^0 183		9^0 135

Note: In bold italics, the monthly minimum values are marked, and the maximum declination values D

According to our forecasts, the maximum value of D will be observed on May 2 and will be 100 181, and the minimum on August 13 will be 70 532. The conclusion concerns only with respect to measurements corresponding to 15 hours of the day. Concerning other time intervals, it is also possible to obtain a conclusion by building on them the forecast models for the proposed method.

5. CONCLUSIONS

The main advantages of the proposed forecasting approach are:

- the possibility of an hourly forecast;

- the accuracy of the forecast does not depend on the forecasting period, because extrapolation procedures are not used;

- long-term forecasts of the indices can be carried out without averaging the data for the month, quarter and year;

- presence in the prediction rule of such parameters as latitude, longitude and altitude above sea level allows to take into account these parameters and perform numerical experiments with them in order to determine their role and the degree of influence on the process under study.

The above methodology was tested in the prediction of meteorological parameters (temperature and atmospheric air pressure) for the example of different cities. We believe that this technique can also be used to predict various parameters of natural, biological and social phenomena.

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