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Prediction of Solar Activity on the basis of Redistribution of Masses of the Solar System

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ABSTRACT. The article is devoted to the construction of a mathematical model for forecasting the indicator "the number of sunspots", which is one of the characteristics describing the activity of the Sun. The sun is the basis of life on Earth and, accordingly, its activity is of paramount importance for us. A reliable relationship between the activity of the Sun and natural and natural disasters is established, which cause great economic damage. A technique for constructing mathematical models based on taking into account the redistribution of the gravitational forces of the solar system as a result of the motion of the planets is proposed, which makes it possible to substantially increase the homogeneity of the primary material.

I. INTRODUCTION

Solar activity (SA) has a huge impact on the natural processes of the Earth. A reliable correlation dependence of SA with natural cataclysms and biological processes was revealed. It is proved that SA can lead to very serious economic and social consequences, which violate the stability of the development of civilization. In this context, the task of forecasting the SA acquires particular urgency.

To date, there is no unified theory for SA prediction. This is due to the fact that SA indices, as a rule, it does not have a certain physical meaning, there is no homogeneity and continuity of their series. Their characteristics undergo cyclic and random oscillations, which lead to the variability of their averages over large time intervals. The prediction of SA is also complicated by a number of atmospheric factors: air quality, location and type of clouds, relative humidity and other atmospheric conditions. Therefore, the methods of forecasting are sometimes purely empirical-statistical, based solely on all possible statistical relationships between different characteristics of the SA.

Many of the researchers concluded that the long-term prediction of the SA is impossible, since it is associated with the physic-chemical processes of the Sun itself. There is also the opinion that, in addition to internal causes, there are also external factors - the dependence of the Sun's activity on its position in the Galaxy and on the position of the planets relative to the Sun. Wolf's first dependence on the motion of the Sun in the Galaxy from the position of the planets was proposed (1841). Recall that even Newton in the "Principles of Mathematics" assumed the effect of the position of the planets on oscillations in the motion of the Sun in its orbit. E. Brown in 1900 noted that the planet by the force of its attraction still should cause the influx in the gaseous matter of the Sun. In 1936 Stetson suggested that a resonance effect from planets that can create tides up to 5 km on the Sun [1, 2, 3] can trigger.

In this paper, we propose a statistical technique for constructing a dynamic regression based on the use of the values of the gravitational forces of the solar system instead of the time parameter. The concept of modeling natural processes based on the forces of gravity is not new. In 1889 I.O. Yarkovsky published the work: "World-wide gravity as a consequence of the formation of weighty matter". V.A. Bishop-Kalpeper in his report before the Astrological Society in London, he noted the influence of the location of the planets on the weather. We will outline the technique for predicting SA based on the gravitational forces that arise from the redistribution of masses in the solar system relative to the Earth.

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II. FORMULATION OF THE PROBLEM

According to the above, SA depends on atmospheric factors: air quality, location and type of clouds, relative humidity, etc., which in turn are determined by the nature of the underlying surface of the site, the geographical latitude and altitude of the location above sea level, features Terrain and vegetation cover, and the degree of air pollution. In this case, the rotation of the Earth around its axis and the rotation of the Earth around the Sun determine daily and annual variations of the SA.
All these factors can be conditionally divided into the following categories:
1. The Category **"Place of observation".** The intensity and nature of atmospheric phenomena depends on the specific characteristics of the geographical point of observation $M(i)$.
2. The category of**"Time"**. SA changes during the day t.
3. The category of **"Date".** The SA depends on the time of the year Data.
4. The Category of **"Gravitational forces".** The SA depends on the mass distribution in the solar system relative to the observation point $F(k)$

Thus, in order to obtain effective predictions on the dynamics of the SA, it is necessary to construct a regression equation in the form of:

$$SA = f(M(i), t, Data, F(k)) \qquad (1)$$

In this case, the mathematical model of the SA forecast will depend on many factors, which in turn continuously vary in time and space. This leads to violations of the requirements of the method of least squares [4]. To increase the homogeneity of the initial data sample, the following procedures are proposed for solving the SA prediction problem.

Factor "Place of observation": Any geographical point is characterized by the following characteristics: geographical latitude and longitude, altitude above sea level, the nature of the underlying surface of the observation site, its remoteness from the sea coasts, the features of the terrain and vegetation cover, the presence of glaciers and snow cover, the degree of air pollution.
If from the initial statistical array of data to select observations fixed at a single geographic point, the resulting data array will be homogeneous with respect to the specific features of the observation site. In this case, we can assume that the observed changes in the values of SA are due to factors of other categories.

Thus, the factors of the category **"Place of observation**" from the category of variables pass into the category of constant values $M(i) = const$ and the original model (2) is transformed to the form:

$$SA = f(t, Data, F(k)) \qquad (2)$$

Using this procedure, we increase the homogeneity of the original data set by eliminating characteristics that describe the specific features of the observation site. At the same time, we implicitly agree with the fact that for each geographic point our prognostic SA model will be built.

Factor "Time of day" and "Time of the year": As it 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 an astronomical point of view, Time and Date are clearly separated (Figure 1.1).

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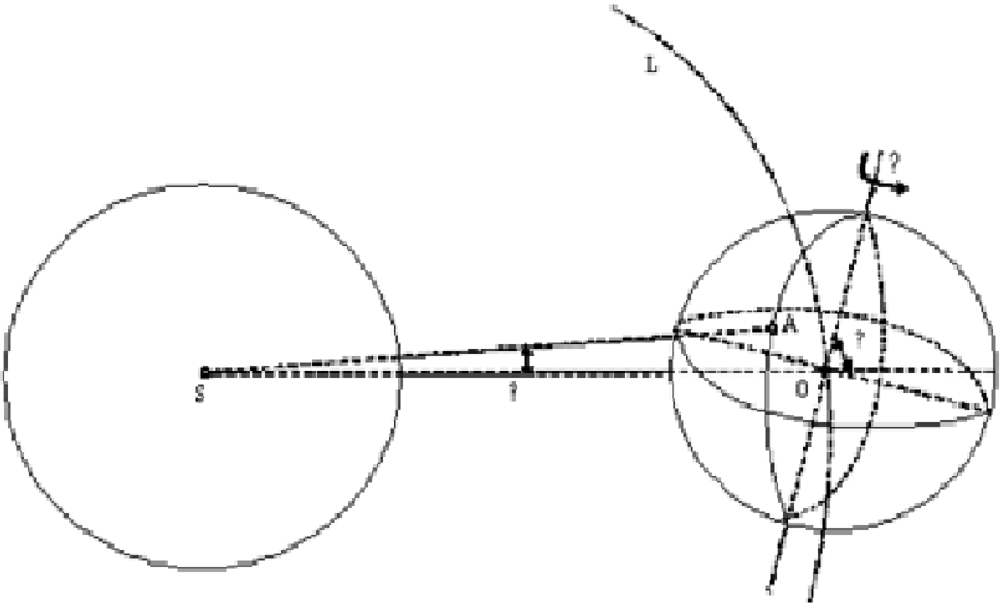

Fig.1.1. Movement of the Earth around the Sun.

The time of day t is determined by the rotation of the Earth Oaround its axis ω, and Data - by the coordinates (x, y) of the location of the center of the Earth O in its orbit L with respect to the Sun. In this case seasonality is described by the angle of inclination of the axis of rotation of the Earth to the ecliptic γ.The problem is complicated by the fact that the parameters ω, γ and $O\ (x, y)$ vary continuously and simultaneously. This leads to a change in the angle of incidence of the sun's rays α and the change in the distance of the geographical point A relative to the center of the sun S.

Let the position of the Earth relative to the Sun, shown in Table 1.1 corresponds to January 1, 1952. One year corresponds to one revolution of the Earth in its orbit relative to the Sun. Hence it follows that this particular position of the Earth in relation to the Sun it will be celebrated every year on January 1. We will create an array of data corresponding to this position by years for a specific geographic point (Table 1.1):

Table 1.1: The values of SA, recorded at the Pulkovo Observatory on January 1.

№	SA	Days	Years
1	56	1 January	1952
2	18	1 January	1953
3	0	1 January	1954
- -	- - -	- - -	- - -
- -	- - -	- - -	- - -
k	22	1 January	1987

The peculiarity of this data set is that the Earth is in the same 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 O (x, y) are constant. In this case, 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. In our case for the original data table 1 this means that the parameters t = constant, Data =constant and consequently, the original model (2) is transformed to the form (3):

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$$SA = f(F(k)) \qquad (3)$$

Thus, we can state that the use of procedure 2 allows the parameters of the categories "Time", "Date" to be translated into the category of constants and, accordingly, the problem reduces to determining the dynamics of the SA based on the gravitational forces of the solar system.

The proposed procedure makes it possible to increase the homogeneity of the initial sample of data, but at the same time forces us to make the construction of the SA predictive model for each day of the year separately.

Factor "Gravitational forces" In the previous stages, the influence of the parameters of the factors "place of observation", "time of day" and "time of year" were reduced to a constant level by means of procedures, which allowed the original problem (1) to be transformed to the form (3).

It is known that the tide-generating potential is the result of a cumulative effect of waves of different lengths [5].

Long-period (zonal) wave.

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

Meridian $F_m^s = D(c/r)^3\left[-2\cos 2\phi \sin 2\delta \cos H\right]$

Parallel $F_p^d = 0$

Semi-daily (sectorial) wave

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

Meridian $F_m^p = D(c/r)^3\left[\sin 2\phi \cos^2\delta \cos 2H\right]$

Parallel $F_p^p = D(c/r)^3\left[2\cos\phi \cos^2\delta \sin 2H\right]$

Full (sectorial) wave

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

Meridian $F_m^p = D(c/r)^3\left[\sin 2\phi \cos^2\delta \cos 2H\right]$

Parallel $F_p^p = D(c/r)^3\left[2\cos\phi \cos^2\delta \sin 2H\right]$

F_B^A - Superscript A means the type of wave;
d – Long-period;
s- Daily;
p– Semidiurnal;
And the subscript B denotes the projection of w – to the vertical;
M - on the meridian;
P - to the parallel.
$D' = 0{,}46051D$ Dudson constant for the Sun
$D = 26277\ \text{sm}^2/\text{sec}^2$ Dudson constant for the Sun

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The calculation of the Dudson constant for planets is made by the formula:

$D = 3mg_1 a_1^2 (a_1 + r_0)^2 / 4c^3$

Here, $g_1 = 982,04$ sm/sec^2 acceleration of the gravity.

$a_1 = 6378160$ m - Average radius of the earth.

r_0 - Elevation above sea level.

$c = 60,27 a_1$

$m = m_{ob} / m_z$ - The ratio of the mass of the object to the mass of the earth.

For the Mercury, $m = 0,005$; For the Venus, $m = 0,816$; For the Mars, $m = 0,107$;
For the Jupiter, m =318; For the Saturn $m = 95,1$; For the Uranus $m = 14,6$; For the Neptune $m = 17,2$;

c / r – Radius - Vector

The 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 Earth - Celestial object
(The Moon, Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune)

$c / r = 1 + 0,055 \cos(s - p) + 0,010 \cos(s - 2h + p) + 0,008 \cos(2s - 2h) + 0,003 \cos(2s - 2p)$

ϕ - The geographical latitude of the observation site on Earth declination of the Sun

$\sin \delta = 0,406 \sin \alpha + 0,003 \sin 3\alpha$

where the ascent for the sun $\alpha = h - 0,0435 \sin 2h$

Declination of the Celestial object

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

where the ascent to the Celestial object

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

$H = a\tau + bs + ch + dp + eN' + fp_s$

Determines the form of the function from the tables
where,
h – The average longitude of the Sun.

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

s - The average length of the Celestial object.

For the Moon $s = 270,43659^0 + 481267,89057^0 * T + 0,00198^0 * T^2 + 0,000002^0 * T^3$

For the Mercury $s = 908103,26^0 + 538106660,097^0 * T + 1,0943^0 * T^2 + 0,0001^0 * T^3$

For the Venus $s = 655127,283^0 + 210669166,909^0 * T + 1,1182^0 * T^2 + 0,0001^0 * T^3$

For the Mars $s = 1279559,789^0 + 68910107,309^0 * T + 1,1195^0 * T^2 + 0,0001^0 * T^3$

For the Jupiter $s = 123665,342^0 + 10930690,04^0 * T + 0,8055^0 * T^2 + 0,0159^0 * T^3$

For the Saturn $s = 180278,897^0 + 4404639,651^0 * T + 1,8703^0 * T^2$

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

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

p_s - Longitude of the perigee of the sun

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

p - Longitude of the perigee of the Celestial object.

For the Moon $p = 334,32956^0 + 4069,03403^0 * T - 0,01032^0 * T^2 - 0,00001 * T^3$

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

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

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

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

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

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

For the Neptune $p = 1095655,196^0 + 791579,913^0 * T + 1,1133^0 * T^2 + 0,0001 * T^3$

$N = -N'$ - Longitude of the ascending node of the Celestial object

For the Moon($N = -N'$) $N = 259,18328^0 - 1934,14201^0 * T + 0,00208^0 * T^2 + 0,000002 * T^3$

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

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

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

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

For the Saturn $N = 409195,885^0 + 3157,539^0 * T - 0,4347^0 * T^2 - 0,0084 * T^3$

For the Uranus $N = 266421,41^0 + 1876,056^0 * T + 4,8236^0 * T^2 + 0,0666 * T^3$

For the Neptune $N = 474422,605^0 + 3967,929^0 * T + 0,9359^0 * T^2 - 0,0022 * T^3$

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

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 1899.

The parameter H determines the form of the function. It is possible to produce a complete and purely harmonic expansion of this function in spherical harmonics.

This decomposition was first produced by A.T. Dudson in 1921. Dudson's decomposition contains 386 waves. In 1971, D. K. Cartwright published a more complete expansion of the potential, containing 550 waves. Each of the 550 waves can be viewed in the projections on the parallel, meridian and vertical in their kinematic characteristics displacement, velocity and acceleration. In total, 44,550 characteristics can be included in the review (7 planets, the Moon, the Sun * 3 projections * 3 kinematic characteristics * 550 waves).The regression models were constructed on the basis of only those characteristics of the tide-generating potential, which have a reliable correlation with the values of Wolf numbers (p <0.05).In our case, from the kinematic characteristics only displacement (14850 characteristics) was included in the analysis. To exclude the violation of assumptions about the rank of the method of least squares, gravitational waves were combined into 6 groups depending on the project (mer, par, wer) and the character of the correlation relation (r> 0, r <0): S1 (mer, r +) , S2 (mer, r -), S3 (par, r +), S4 (par, r -), S5 (ver, r +), S6 (ver, r -) with parameter SA.

Predictive SA rules were constructed in the form of a simple regression from each of these sums. The final result was taken as the arithmetic average of the values of simple regressions. As the initial data array, the values of Wolf numbers

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recorded at the Pulkovo Observatory from 1 January 1938 to 31 December 1987 were used. The total number of measurements was 1784.

Advantages of the proposed forecasting approach are the absence of extrapolation procedures, i.e. The accuracy of the forecast does not depend on the forecasting period. Based on the models obtained, a software product was implemented, which was used to predict the Wolf numbers (Table 1.2).

Table 1.2: Forecast of the Wolf number in the center of the Sun disc for 2017.

Months	1	2	3	4	5	6	7	8	9	10	11	12
Average	31	33	34	35	35	39	33	38	39	42	37	36
Min	21,7											
Max	42,8											

III. CONCLUSION

Considering natural processes from the viewpoint of the system approach, it can be assumed that the method described can be used for a wide range of tasks. In particular, it was tested in predicting the temperature and atmospheric pressure of air in a number of cities, where it demonstrated its effectiveness.

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