AIR TEMPERATURE ANOMALIES IN THE NORTHERN HEMISPHERE UNDER DIFFERENT CONDITIONS IN SPACE

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The anomalies in temperature annual behavior are considered in the paper as a function of solar activity, the sign of its total magnetic field, orbital position of planets and the Earth's position relative to the Sun equatorial plane. The results obtained provide derivation of integral background characteristics of long-term variations of the atmospheric optical state over large regions as well as estimates of trends in such variations.

INTRODUCTION

When solving the problem on describing long-term variations of the atmospheric optical state over large regions, like northern region of the Earth, under the lack of direct data, extended continuous series of fundamental atmospheric parameters correlating with the optical state can appear to be quite useful. Optical parameters of the atmosphere in polar and sub-polar regions essentially depend on the varying thermal state of the atmosphere and on the accompanying meteorological phenomena.

In statistical terms, polar regions are distinguished for an increased variance of all meteorological quantities. Polar atmosphere is always considered to be the most responsive to the solar activity since charged particles are easy penetrating the atmosphere just in the northern latitudes. In this paper, analysis of external factors of large-scale temperature transformations in the atmosphere is presented. Results of this analysis can be used in the interpretation of the long-term variations of optical parameters in the northern latitudes in the past and in the future.

Also, in this paper, a hypothesis that near-equatorial neutral layer of the Sun influences the atmosphere of the Earth is further developed. That point was first considered in Refs. 6–9 and in other our papers. The most important parameter of space influence on the Earth was shown to be northern–southern position of the latter relative to near-equatorial neutral layer which divides two magnetic hemispheres of the Sun. Inclined orbital motion of the Earth with respect to that layer and perturbations of neutral layer under the action of asymmetric development of the solar activity, as well as under the action of planets passing in the vicinity of the layer in their orbital motion are also considered.

In this paper, we use monthly mean data on the near-surface temperature anomalies of air in the northern region of the Earth (between the latitudes from 60° to 90°, see Ref. 10) obtained in 1881–1992 years. Data on temperature anomalies for every day were obtained by the method of linear interpolation. Daily values are required to smooth curves when analyzing cycles that are not multiple to one month or one year duration. Heliographic latitudes and heliographic longitudes of orbital motion of Mercury, Venus, Earth, Mars, Jupiter, Saturn, and Uranus were calculated. All astrodynamical magnitudes of the planets were calculated for every day of the years from 1881 to 1992 using data presented in Ref. 1 from average orbital elements. Polarity of total magnetic field of the Sun (SMF) was calculated from data on phases of eleven-year cycle of solar activity over the same period of time. It is well known that the polarity retains its sign over a period of about ten years. A change of sign occurs in the year of maximum activity of the Sun or one or two years later. Besides, it can be said that sign of the Sun magnetic field is not changed in the vicinity of a minimum in the eleven-year cycle and two years before and after that moment. Polarity of magnetic field of the Sun is opposite in its northern and southern hemispheres. It was assumed in the analysis, that in the northern hemisphere of the Sun the sign was negative (SMF^-) during the following time intervals: from 1899 to 1903, from 1921 to 1925, from 1942 to 1946, from 1962 to 1966, from 1984 to 1988. Sign of total solar magnetic field was considered to be positive (SMF^+) in the northern hemisphere of the Sun during the following time intervals: from 1887 to 1891, from 1911 to 1915, from 1931 to 1935, from 1952 to 1956 and from 1974 to 1978. Below the sign of magnetic field in designation of samples is related to the northern hemisphere.

Time scale for one year period was transformed to degrees of heliocentric longitude of the Earth orbital motion around the Sun (0–360°).

Northern–southern asymmetry of solar hemisphere activity (A) was calculated based on the data on integrated areas of solar spots in the northern (N) and

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southern (S) hemispheres according to the following expression: $A = (N - S)/(N + S)$. Positive values of A are observed when the activity in the northern hemisphere is higher than that in the southern hemisphere and vice versa.

STATEMENT OF THE PROBLEM AND METHODS OF ANALYSIS

The sign of solar-terrestrial relationships as a function of the sign of total solar magnetic field at different positions of the Earth relative to equatorial neutral layer in the magnetosphere of the Sun was described in Ref. 9. Let us consider this problem in more detail.

Interplanetary space is filled with nonisotropic magnetic field generated by solar and galactic magnetic fields. Neutral layer separating two magnetic hemispheres of the Sun and different concentrations of charged particles is located in the vicinity of equatorial plane of the Sun. The Earth follows its orbit which makes an angle of 7.3° with equatorial plane of the Sun. Therefore, heliographic longitude of the Earth (angular distance between the Earth and the Sun equatorial plane) varies in the range from −7.3° to +7.3° during a year. The Earth crosses this plane two times per year. Motion .of the Earth in the ecliptic is analyzed in heliocentric longitudes.

According to Ref. 1, terrestrial longitude is about 100° on the 1st of January, whereas in December the Earth intersects solar equatorial plane in the direction from northern hemisphere to the southern one (N → S) and in June in the opposite direction (S → N) at the longitude of 76° and 253°, respectively·. The Earth is in the northern hemisphere in fall and in the southern one in spring.

One should take into account that near-equatorial layer (dividing line between the magnetic hemispheres) does not always coincide with the equatorial plane. The layer can move in the north-to-south direction or twist in accordance with the development of solar activity in one or another hemisphere. Surface of the layer is wavy almost without exceptions due to nonuniformity of the evolution of active centers on the Sun and, probably, some perturbations of solar plasma streams on its motion to the Earth.

Temperature anomalies are assumed to depend on the sign of that magnetic hemisphere of the Sun where the Earth is located under the action of the following geometric factors:

1) heliographic latitude of the Earth;

2) north-to-south displacement of dividing line between magnetic hemispheres of the Sun (neutral near-equatorial layer) under the action of asymmetry of the activity of solar hemispheres (hemisphere with high activity removes neutral layer to hemisphere with low activity);

3) north-to-south displacement of dividing line under the action of planets of solar system.

Methods of calculation of the conventional means and variances, correlative method of analysis and one-factor variance analysis were used to test these hypotheses. Calculations in variance analysis were performed according to procedure described in Ref. 5 on the basis of conventional means and variances which were obtained from data of physically justified year samples. Percentage of a factor studied in the total variance of the series was determined from ratio of interlevel sum of squares to the total sum of squares. A pair of sets of statistics of temperature anomalies obtained under hypothetically different conditions was considered in the variance analysis. Every set of the statistics represents 36 means and variances of temperature anomalies obtained from 36 uniform parts of annual period, years with uniform conditions of the factor to be investigated were taken into account. Pair of sets with opposite conditions of the factor under investigations was chosen. The difference between corresponding pairs of conventional means gives distinctions resulting from the influence itself.

Thirty six differences were obtained using every pair of sets, variances of the differences were calculated as a sum of corresponding pair variances. Moreover, one-factor variance analysis on 36 levels was made. Statistical significance of obtained estimations was defined on the basis of correlation between Fisher F-criterion and the ratio of the square average value of the interlevel deviations to the square average value of deviations inside the levels. In the present paper, only quantitative estimations with the reliability no less than 95% are presented.

ANALYSIS OF THE ASYMMETRY IN THE HEMISPHERE ACTIVITY OF THE SUN

The aim of our analysis is to find a way of describing variations of temperature anomalies at different positions of the Earth relative to the Sun's near-equatorial layer. Therefore, comparative analysis of annual behavior of temperature anomalies obtained from specially chosen annual data samples was performed. Distinctions between annual behavior of the anomalies in these samples will describe the significance of the differences in the conditions under which these samples were taken.

Consider next the effect of asymmetry of the Sun activity at the same sign of solar magnetic field (SMF). Let us take years from 1881–1992 interval when polarity in the northern hemisphere of the Sun was positive (northern) and designate these years as SMF^+. Then, these years are separated into two groups. Years with the asymmetry index $A < -0.35$ are included in the first group and years with $A > 0.45$ are included in the second group.

In the years from the first group the southern hemisphere of the Sun was observed to be much more active than the northern one. Besides, the neutral near-equatorial layer is displaced to the north and the Earth is typically in south magnetic hemisphere of the Sun throughout the year, that is, in negative field.

In the years from the second group the northern hemisphere of the Sun was observed to be much more active than the southern one. Neutral near-equatorial layer of the Sun therewith is displaced to the south and the Earth throughout the year is typically in the southern magnetic hemisphere of the Sun or in positive field.

Amount of charged particles entering the atmosphere depends on the sign of that interplanetary magnetic field, where the Earth is located at every instant in time. The above data samples of years allow temperature anomalies to be compared under various external conditions.

Averaged curves of annual behavior of temperature anomalies (T) in the northern hemisphere were obtained using these data arrays. These curves are presented in Fig. 1. Abscissa is heliocentric longitude of the Earth in its orbital motion. Vertical dashed lines depict longitudes, where the Earth intersects equatorial plane of the Sun. Figure 1 shows that in the years from the first group, when the Earth is far inside the negative magnetic hemisphere (see curve *1*), negative temperature anomalies throughout the year are observed. In the years of the second group, when the Earth is far inside the positive magnetic hemisphere (see curve *2*), positive temperature anomalies throughout the year are observed. Variance analysis reveals the fact that under selected "pure" conditions north-to-south asymmetry of the Sun hemisphere activity represents 40% of the total variance of temperature anomalies. Once similar samples are formed using "soft" conditions with $A<-0.25$ and $A > 0.25$, asymmetry describes only 9.3% of the total variance of the anomalies.

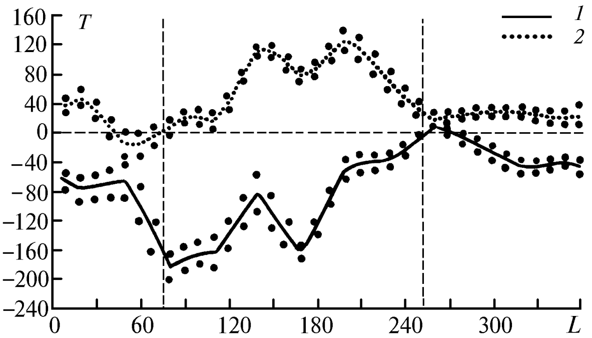

FIG. 1. Temperature anomalies T (°C·100) in arctic region in years with SMF⁺ as a function of heliocentric longitude of the Earth L. Curves 1 and 2 correspond to $A < -0.35$ *and* $A > 0.45$*, respectively.*

The same analysis can be repeated using independent data in the case of negative (south) polarity of total magnetic field in the northern hemisphere of the Sun. Calculations were performed for $A < -0.25$ and $A > 0.25$. Under these conditions asymmetry of the Sun activity provides only 10.1% of the total variance. As in the previous cases, during these years negative temperature anomalies are observed when the Earth enters negative magnetic hemisphere and positive temperature anomalies occur when the Earth enters positive magnetic hemisphere. These results are mutually confirmed by independent data.

So, influence of the total magnetic field orientation of the Sun on near-surface temperature of air in northern regions of the Earth is demonstrated with only one factor. It is also shown that transition of the Earth across the dividing line between solar hemispheres is accompanied by the change of the sign of temperature anomalies.

As the change of SMF sign results in the change of air temperature anomaly, changes of interplanetary magnetic field (IMF) in the vicinity of the Earth have to be observed. Unfortunately, duration of the IMF observations is insufficient to make the complete analysis. Reliable data on IMF polarity are available only since 1957. During these years, SMF was positive over a period of time from 1973 to 1979, whereas A value was lower than -0.25 only in 1974 and in other years A was close but higher than zero. Therefore, only two "pure" subsequent years (1974 and 1975) with SMF^+ were chosen for comparison. In 1974 A was as low as -0.27 and in 1975 A was as high as 0.46. Time dependences of IMF in 1974 (curve *1*) and in 1975 (curve *2*) are presented in Fig. 2. These curves were calculated using everyday data on IMF polarity presented in Ref. 4 by the extension to ten-degrees intervals of the Earth orbit according to following expression:

$$(\text{IMF}) = (n - s)/(n + s) ,$$

where n and s are the numbers of days with positive and negative polarity in ten-degrees orbital intervals, respectively.

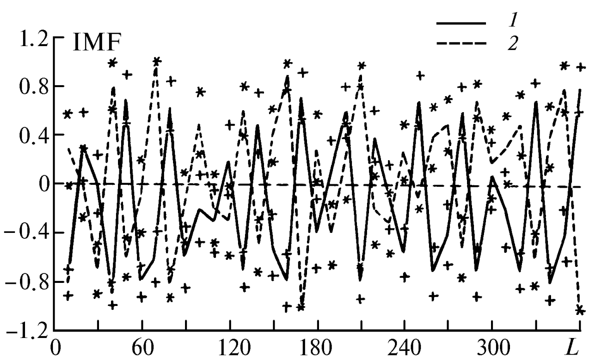

FIG. 2. Interplanetary magnetic field in years with SMF⁺ versus L at $A < -0.25$ *(curve 1) and* $A > 0.25$ *(curve 2).*

Coefficient of correlation between the curves is equal to -0.79. Highly variable IMF curve for 1974 was found to be a mirror reflection of IMF for 1975. In the first case the southern solar hemisphere with negative magnetic polarity was more active than the northern one. In the second case the situation observed was the opposite. Dependences presented in Fig. 2 well confirm the importance of asymmetry of solar hemisphere activity for generation of magnetic field (IMF) in the vicinity of the Earth. In its turn, IMF controls penetration of charged particles into the atmosphere. It is important to remember that observation of mirror reflection of the curves shown in Fig. 2 was only possible because of the same position of active magnetic longitudes on the Sun within the years under consideration. That event was observed once again in "pure" state due to appropriate selection of time interval, otherwise it will be eroded because of the displacement of active longitudes.

ANALYSIS OF THE EFFECT OF ORBITAL POSITION OF PLANETS ON TEMPERATURE

The problem on the influence of planetary positions on temperature and climate on the Earth still remains unresolved. The data available are contradictory. Let us consider the problem based on the hypothesis that planets have effect on near-equatorial layer of the Sun, which, as was indicated above, can control the action of space forces on IMF and atmosphere of the Earth. The role of planets can not be examined using direct data because reliable data on IMF are available only for short period. Therefore, our analysis was performed using data on temperature anomalies in the northern region.

Data for heliographic latitudes of six planets from Mercury to Uranus were used in the analysis. Revolution periods of the planets being far from the Sun exceed duration the series of observations available. So, these planets were not taken into account. Inclination of planetary orbits with respect to ecliptic varies in the range from 46° (Uranus) to 7° (Mercury). Besides, ecliptic itself is inclined relative to equatorial plane of the Sun by 7.3°. Therefore, heliographic latitudes of the planets can vary from 7° to 14° to the north and to the south with respect to the solar equatorial plane. The latter is placed close to dividing line between magnetic hemispheres of the Sun. As earlier, year samples with the same sign of SMF and different position of the planets can be prepared.

Annual behavior of temperature anomalies obtained using the following four specialized temporal samples were considered:

a) years when total magnetic field of the Sun in its northern hemisphere was negative (SMF^-) and heliographic latitude of a planet (f) was lower than 0° (south position);

b) years when SMF was the same, but f was higher than 0° (northern position);

c) years when total magnetic field of the Sun in its northern hemisphere was positive (SMF^+) and heliographic latitude of a planet (f) was lower than 0° (south position);

d) years when SMF was the same but f was higher than 0° (northern position).

The above-mentioned samples were compiled individually for each planet. A total of 24 samples was obtained. Everyday values of temperature anomalies in each sample were averaged over ten-degrees longitude intervals of orbital motion of the Earth. For every sample 36 averaged values of temperature anomalies characteristic for annual behavior of temperature anomalies under certain internal conditions were obtained. Standard deviations were calculated for every average value.

The value of f determines the position of a planet at the moment with respect to the equatorial plane of the Sun. A planet is located to the south when $f < 0°$ and to the north ($f > 0°$) relative to this plane without regard to orbital position of the Earth. If on the average over many years magnetic hemispheres of the Sun are symmetric about its equatorial plane, values $f > 0$ and $f < 0$ correspond to the position of a planet, on the average, to the north and to the south with respect to the dividing line between magnetic hemispheres of the Sun, respectively.

Figure 3 depicts curves for annual behavior of anomalies resulting from annual samples for three major planets. Function of the planets under uniform conditions of solar magnetic field is followed from comparison of curves presented in Figs. 3*a*, *b*, *c*, and *d*.

Let us consider annual behavior of temperature anomalies under conditions in the near-earth space when total magnetic field of the Sun is negative in its northern hemisphere and positive in its southern hemisphere (see Figs. 3*a* and *b*). These conditions are designated by SMF^-.

As illustrated in Fig. 3, under conditions of SMF^- and south position of Jupiter and Saturn with respect to the equatorial plane (see Fig. 3*a*) positive temperature anomalies are mainly observed (curves *1* and *2*), especially in winter when the Earth passes in the vicinity of the equatorial plane in its motion in the direction from the northern hemisphere to the southern one. Uranus also provides an increase of temperature anomalies during that period (see curve *3*).

In contrast, when one of the planets is located to the north with respect to the equatorial plane of the Sun negative temperature anomalies are observed (see Fig. 3*b*, curves *1*, *2*, and *3*). However, the peak of temperature decrease is observed in winter when the Earth is located close to its transition from the northern hemisphere to the southern one. The peak is observed after the Earth crosses the equatorial plane. An exact average position of neutral layer remains unknown for that sample. The layer, probably, is shifted to the south. Then in winter the Earth will cross the layer at a later time, and corresponding negative anomalies will appear later also.

Correlation coefficients between curves corresponding to northern and southern position of the planets are not high due to the shift. But, nearly complete change of sign of anomalies throughout the year depending on conditions clearly shows that in this case the position of the planets determines the sign of temperature anomalies. Shifts of extrema of the curves under different conditions are quite admissible because the dividing line between magnetic hemispheres is located close to equatorial plane of the Sun, on the average, over many years. But the line and the plane in each separate sample can differ in the position resulting in a decrease of the correlation coefficients.

Total magnetic field of the Sun with positive and negative polarities in its northern and southern hemispheres, respectively, provides different conditions in the near-earth space. Let us denote these conditions as SMF^{+}.

Temperature anomalies (T) for years with positive SMF are presented in Figs. 3*c* and *d*. Curves in Figs. 3*c* and *d* are calculated for southern and northern positions of Jupiter, Saturn and Uranus, respectively. Comparison of these curves indicates opposite behavior of corresponding temperature anomalies depending on orbital positions of big planets. Negative (see curves *1* and *3* in Fig. 3*c*) and positive (see curves *1* and *3* in Fig. 3*d*) temperature anomalies are typically observed at southern and northern positions of Saturn or Uranus, respectively. Coefficient of correlation between annual behavior of temperature anomalies over years with northern and southern position of Saturn is equal to $r = -0.80$ and that over years with northern and southern position of Uranus is equal to $r = -0.56$. Variations of temperature anomalies depending on the position of Jupiter are somewhat different, but also opposite for its northern and southern locations. These anomalies are positive (see curve *2* in Fig. 3*c*) or negative (see curve *2* in Fig. 3*d*) for southern or northern positions of Jupiter, respectively. In the latter case, coefficient of correlation is equal to $r = -0.82$. Positions of these planets have the greatest effect on the anomalies in the winter when the Earth is close to its transition from the northern solar hemisphere to the southern one. On the contrary, in the summer the Earth goes from the southern solar hemisphere to the northern one, and temperature anomalies approached zero independently of additional conditions.

Positions of terrestrial planets (Mercury, Venus, and Mars) provide a determined effect on temperature anomalies. Peculiarities of this effect are not discussed in this paper. Only general quantitative estimations are presented below.

One-factor variance analysis has been carried out to obtain quantitative estimations of contribution from planetary positions to the total variability of temperature anomalies. Annual behavior of differences in the temperature anomalies in the northern and southern positions of a planet (36 points) was used as this factor. Results of the analysis are given in Table I.

As the variance analysis shows (see Table I), contribution of orbital position of Uranus, Mars and Saturn to annual variation of temperature anomalies with SMF^{-} makes 4.0, 6.9, and 29.7%, respectively. Contributions of Venus, Mercury, and Jupiter are close to that of Saturn. Over the years with SMF^{+} Mercury produces the lowest contribution of 3.8% to the variations. Saturn, Jupiter, and Venus produce the highest contributions of 18.9, 16.6, and 13.4%, respectively. So significant contributions of the planets to variations of temperature anomalies has been revealed as the sign of total solar magnetic field has been taken into account. This fact confirms the statements of many researchers that interplanetary magnetic fields serve as driving agent of planetary effect on the Earth's climate.

To this point the variation of temperature anomalies was studied at different positions of the planets, but at the same sign of total magnetic field of the Sun. Below these variations will be considered as a function of solar field at the same positions of the planets.

Comparisons of Fig. 3*a* with Fig. 3*c* and Fig. 3*b* with Fig. 3*d* are necessary in order to reveal the role of SMF in the formation of temperature anomalies. In the first case, annual behavior of anomalies presented in the figures (see curves *1* and *3*) is completely opposite for similar southern positions of Saturn and Uranus, but at different sign of total magnetic field of the Sun. Coefficients of correlation of annual behavior of temperature anomalies at different sign of SMF for southern positions of Saturn and Uranus are equal to −0.75 and −0.84, respectively. When similar conditions with the southern position of Jupiter are selected (see curve *2* in Figs. 3*a* and 3*c*), temperature anomalies are positive throughout the year ($r = 0.60$) independently of the solar magnetic field.

Comparison of Fig. 3*b* and Fig. 3*d* reveals negative temperature anomalies for SMF^{-} and positive ones for SMF^{+} in the northern position of Saturn and Uranus. Sign of anomalies is observed to be completely opposite throughout the year when sign of the total magnetic field changes. When position of Jupiter is northern, negative anomalies are evident independently of SMF sign.

The results presented are obtained within the time interval of 112 years. Standard deviations for every point on every curve are no more than 0.08°. Statistical significance of extrema of all curves at the level of 95% is undoubted.

Action of latitudinal position of Saturn and Uranus on temperature depends on the direction of the total magnetic field of the Sun. Change in its polarity is accompanied by a change in sign of the effect of the above-mentioned planets position on temperature. Effect of Uranus is slightly lower than that of Saturn, whereas action of longitudinal position of Jupiter is clearly pronounced in temperature variations and is almost independent of the sign of total solar magnetic field.

Terrestrial planets also affect the annual behavior of temperature anomalies. This effect in its magnitude is close to that of big planets.

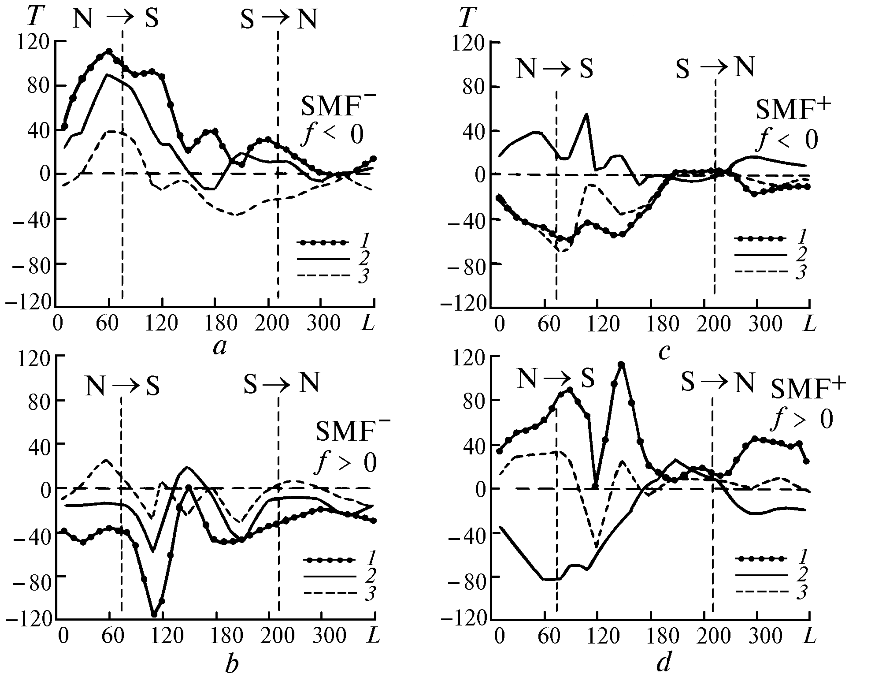

FIG. 3. Temperature anomalies T (°C·100) in the arctic region at different heliographic latitudes f of Saturn (curve 1), Jupiter (curve 2), Uranus (curve 3) versus heliocentric longitude of the Earth L.

TABLE I. Fraction of temperature anomalies (in %) explained to be associated with changes of latitude of major planets.

Planet	Mercury	Venus	Mars	Jupiter	Saturn	Uranus
Years with SMF^+	3.8	13.4	7.5	16.6	18.9	11.0
Years with SMF^-	14.2	20.1	6.9	13.0	29.7	4.0

Annual behavior of temperature anomalies of the air and average annual temperature in the northern regions are mostly determined by the asymmetry of activity of solar hemispheres, latitudinal position of the planets above equatorial plane of the Sun, and the sign of total solar magnetic field. These parameters appear to be large-scale indicators of those conditions in the vicinity of the Earth which are favorable or unfavorable to penetration of charged particles of solar or galactic origin into the atmosphere.

DISCUSSION OF THE RESULTS

The following effect combines all the results obtained from samples for years with different conditions: when the Earth is dipped into the negative or positive magnetic solar hemispheres, correspondingly negative or positive temperature anomalies are observed.

Years with stable sign of magnetic field are also related to the years with low activity of the Sun when conditions in the near space are favorable for penetration of cosmic rays into the atmosphere. Sazonov in his summarizing article[3] reports that cosmic rays can be focused on shock waves arising from interaction of solar wind with a planet. Condition of interaction between solar wind and geomagnetosphere depends on the sign of interplanetary magnetic field. Hence, SMF action on the formation of temperature anomalies is not surprising. However, this well-defined picture of the action has not been understood earlier since conditions of planetary positions were not taken into account. Also, the action of the planets usually has been remained under question because magnetic field being the background of the events described was not considered when manifestations of the action of planetary configuration on the atmosphere were examined.

Changes in latitudes of the planets in their orbital motion are accompanied by temperature variations, but the sign of temperature anomalies is a function of polarity of the total magnetic field of the Sun. This assumes the conclusion that the effect of planets on the Earth's atmosphere is not of gravitational origin.

At the first sight, the action defined only by the heliographic latitude of a planet independently of its distance from the Earth causes perplexity. But it is well known (see Ref. 2) that solar wind appears as solid conducting medium when it acts on a planet, particles of the wind exhibit collective behavior in spite of the lack of collisions. Besides, solar wind in the area of its interaction with a planet apparently retains perturbed state for a certain time. Furthermore, these perturbations are transported for a long distance in the latitude direction by axial rotation of the Sun. As a result, neutral layer is shifted and conditions of the interaction between solar wind and the Earth are changed at a considerable distance from a planet producing the perturbations.

Interaction between solar wind and a planet is determined by electrical conductivity of the planet and its envelope together with the presence or absence of its own planetary magnetic field (see Ref. 2). Solar system exhibits a wide variety of such properties and therefore, many possible kinds of interactions can be realized. This is sufficient to explain the distinctions revealed in action of the planets on temperature variations in arctic regions of the Earth.

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