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Insolation Periods of Climate Change as a Means of Solving Long-Term Climatic Puzzles

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Abstract: The results of the new Astronomical theory of climate change are considered. Earth insolation depends on the eccentricity of the Earth's orbit, the position of the perihelion and the inclination of the equator to the orbit. Changes in these three parameters are shown for time of 5 million years ago. A change in the insolation of the Earth over 1 million years is considered, and the results are compared with the previous theory. It is shown that the change in insolation in high latitudes from the cold to the warm epoch changes in twice. Insolation periods of climate change have been introduced. They coincide with the known warming and cooling of the paleoclimate. The geography of the onset and end of polar days and nights in different epochs is considered. The presented results are a reliable means of solving the paleoclimate puzzles associated with its long-period changes.

Key words: earth, orbit, axis, evolution, insolation, paleoclimate, periods

1. Introduction

Many processes on Earth, including weather and climate, are determined by the heat of the Sun. Day is replaced at night due to the rotation of the Earth around its axis. Winter comes to replace summer, because the Earth is orbiting around the Sun and its axis inclines to the orbit's axis of the angle 23.4°. Because of these movements, the length of the day along the latitude of the Earth varies from 24 hours to the polar night.

The orbital and rotational movements of the Earth create the contemporary climate on the Earth. However, the parameters of these movements change over the times of tens thousands years and the climate becomes other. For example, the angle of inclination between Earth's equator and its orbit, i.e., obliquity, varies from 14.4° to 32.4°. With a small angle of obliquity it is observed a cooling at high latitudes, and with a large angle the warming occurs. For example, 32.28 thousand years ago (ka) with an angle of 32.1° the heat per year at high latitudes is twice more than 46.44 ka at the angle of 14.8°. In these two epochs, in the summer half of the year also doubles the heat more at high latitudes.

However, in equatorial latitudes, the changes are completely different and even reverse in direction. For example, in the warm epoch of 32.28 ka the annual heat is less by a quarter than in the cold epoch of 46.44 ka. In such cold epochs, as 46.44 ka, at latitudes of 53.4° and more the heat in the summer half year is less than now at the pole. Therefore, the snow does not melt over the summer, and in such cold epoch the ice cover forms in high latitudes, i.e., the ice age comes.

What are interesting are the winters in the Ice Ages. They are warmer around the globe than during the warm period. The warm winters, the warm oceans in winter it is lead to an increase in snow precipitation, which further contributes to the growth of ice caps.

And in the warm epochs, for example 32.28 ka in the summer half year, even at a latitude of 80°, there is more heat than now at the equator. Therefore, all ice

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sheets on the continents are disappearing, and in Greenland and Antarctica they are greatly reduced. At the same time, winters are cold, so little falls during the winters, and glaciers are not restored.

What is interesting is the polar circle. In the warm epoch, it descends to the latitude of the Tyumen, i.e. polar days and polar nights come here, and at the same time it is warmer in summer than at the equator. That is, the Earth's climates are becoming others, and such that no one could even imagine.

Therefore, it becomes clear why the past of the Earth consisted of a number of puzzles, for the solution of which the researchers put forward as many presumptions and hypotheses as there were the researchers. New Astronomical Theory puts an end to these hypotheses [1-2]. All extremums of insolation are timed to within a few minutes and for 200 ka numbered. Insolation periods of climate change are defined. They coincide with paleoclimate changes according to its study for 50 thousand years. Therefore, the insolation periods are a reliable means for solving long-term climatic puzzles.

The results of the new Astronomical theory of climate change are mentioned above. The former Astronomical theory was developed by the Yugoslav scientist Milutin Milankovich almost 100 years ago [3-4]. It is also called the Milankovitch's theory or the Orbital theory of the paleoclimate. Over the years, this theory has been repeated by many researchers [5-9], but they were based on the same principles as M. Milankovich.

Astronomical theory of climate change includes a number of complex problems: the evolution of the Earth's orbital motion, the evolution of the Earth's rotational motion, changes in solar heat on the Earth's surface depending on these movements, and other problems. In our works [1, 10-18], all these problems were solved in a new way, starting with the derivation of equations, the creation of new methods for solving differential equations, and the analysis of the solution results. This led to new results that are consistent with a change in the paleoclimate.

Next, we consider some of these results.

2. Earth's Motions and Their Variations

The Earth moves along an elliptical orbit around the Sun, which is located at the focus of the ellipse (Fig. 1). The shortest Earth-Sun distance in perihelion is denoted as R_p, and the largest distance in aphelion, as R_a. The period of Earth's motion with respect to the motionless space connected with the Solar system is $P_{sd} = 365.25636042$ days. The quantity P_{sd} is called the sidereal orbital period of the Earth's motion around the Sun. The Earth's orbital motion proceeds in anticlockwise direction on the condition that the orbit is viewed from the Earth's North Pole *N*. The normal to the orbital plane is denoted as $\vec{S}$, and it is called the orbital axis.

With respect to the motionless space, the Earth rotates around its axis $\vec{N}$ at an angular velocity $\omega_E = 7.292115 \cdot 10^{-5}$ 1/sec in anticlockwise direction coincident with the direction of the Earth's orbital motion. The value of ω_E corresponds to a full revolution performed by the Earth in 0.99726968 day. The Earth's rotation axis $\vec{N}$ is inclined to the orbital axis $\vec{S}$ at an angle equal in the contemporary epoch to $\varepsilon = 23.44°$. This inclination is called obliquity. During the orbital motion of the Earth, the orientation of its rotation axis $\vec{N}$ remains unchanged in space (Fig. 1). That is why at two points of the orbit at times March, 20 (20.03) and September, 22 (22.09) the axis $\vec{N}$ turns out to be normal to the Earth-Sun direction, so that with respect to the Earth the Sun is in the equatorial plane of the Earth. That is why the southern and northern hemispheres receive identical amounts of solar radiation and, in its duration, the day appears to be equal to the night. These points are called the day of vernal equinox (20.03) and the day of autumnal equinox (22.09). At the time of June, 21 (21.06), the axis $\vec{N}$ is least inclined to the Earth-Sun line, and the northern hemisphere at that time is therefore illuminated with solar radiation to a largest degree. At the time of December, 21 (21.12), the axis $\vec{N}$ is most inclined to the Earth-Sun line; that is why the southern hemisphere at that time is the most illuminated one, and at the high latitudes of the northern hemisphere there comes a polar night. Since the two situations of extreme angles, with the times spent on reaching and leaving the extreme angles, last for several days, those points are called respectively the summer solstice day (21.06) and the winter solstice day (21.12).

The inclination of the Earth axis $\vec{N}$ to the orbital axis $\vec{S}$ leads to the variation of sunshine duration both during the year and on one and the same day at different latitudes. On summer solstice day (Fig. 1, 21.06), we have a polar day in the whole region between the North Pole and the Arctic Circle. Then, as the latitude decreases, the day gets shorter to reach 12-hour duration at the equator, and we have a polar night established below the Antarctic Circle. On the contrary, on the winter solstice day (21.12), on the territory between the North Pole and the Arctic Circle we have a polar night; then, the day starts increasing in duration. At the equator, the day lasts for 12 hours, and a polar day sets in below the Antarctic Circle. As we approach the equinoctial points of 20.03 and 22.09, the difference between the days in latitude decreases in value, the day's duration along all latitudes becomes identical, equal to 12 hours.

As the Earth moves along its orbit, the alteration of seasons occurs. The duration of the seasons is defined by the Earth's motion along its orbit over certain orbital segments. Over the segment from the vernal equinox day, 20.03, till the summer solstice day, 21.06, the duration of spring is 92.7 days. Over the *summer* segment, the summer duration is 93.7 days. Over the *autumnal* segment, the autumn duration is 89.9 days. Over the *winter* segment, the duration of winter is 89.0 days.

The Earth's orbital and rotational motions define the variation of the Earth's climate in the contemporary epoch. However, those motions vary in time, and the Earth's climate therefore undergoes changes. The position of Earth's orbit precesses in space. The Earth orbit's axis $\vec{S}$ (Fig. 1) rotates or, in other words, it precesses about the direction of $\vec{M}$, which is motionless in space. The precession proceeds clockwise with a period of 68.7 thousand years. Also in clockwise direction, the Earth's axis $\vec{N}$ precesses about the direction of $\vec{M}_2$, also motionless in space. The precession period here is 25.74 thousand years. Besides, the axes $\vec{S}$ and $\vec{N}$ execute oscillations, each with respect to its own precession axis, $\vec{M}$ and $\vec{M}_2$, respectively. In addition to those motions, the shape of the orbit, that is, its eccentricity $e = (R_a\text{-} R_p)/(R_a\text{-} R_p)$, whose value varies from 0 to 0.064 at the current value being equal to e = 0.016 and, also, the perihelion position, both undergo variations. Today, the perihelion is over the *winter* segment (Fig. 1), when the winter sets in the Northern hemisphere. Since the Earth orbit' perihelion rotates in anticlockwise direction at a mean period of T_p = 147 thousand years, its position in other epochs can be at any point of the Earth's orbit. Here, T_p is a period of the perihelion rotation relative to the motionless space.

3. Evolution of the Parameters of the Orbit and the Axis of the Earth

The amount of heat coming from the Sun to Earth, i.e., the Earth's insolation depends on the three parameters of its orbital and rotational motions, e, $\varphi_{p\gamma}$, and ε. The evolution of those parameters is shown in Fig. 2. Over this time interval, the eccentricity e oscillates within the range from 0.0022 to 0.0629 with oscillation periods of 94.5 thousand years, 413 thousand years, and 2.31 million years. The perihelion angle $\varphi_{p\gamma}$ varies from 1.776 radian in the epoch of 12.30.1949 to (-1445.7) radian in the epoch of five million years ago. This change is due to the rotation of perihelion in the direction of Earth's orbital motion.

Fig. 2 shows the moving average values of the periods $T_{p\gamma t}$ of perihelion rotation over intervals of 20 thousand years. Evidently, the rotation periods are distributed unevenly, they vary from 13.8 to 41.8

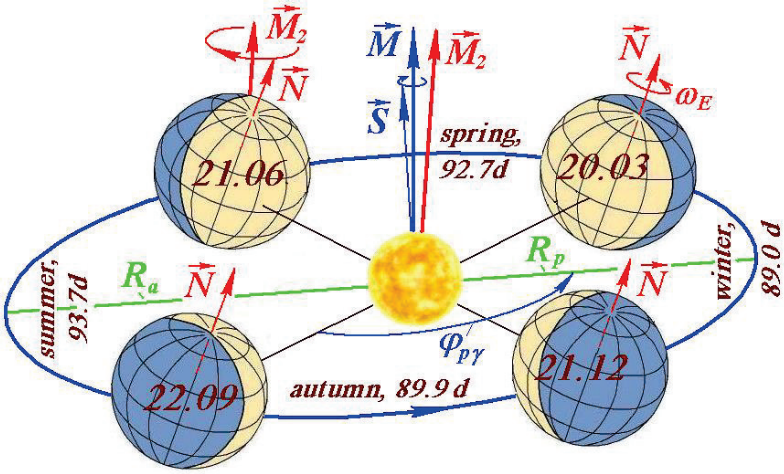

Fig. 1 The Earth's position in its orbit in 2025 at the days of vernal equinox (*20.03*), summer solstice (*21.06*), autumnal equinox (*22.09*), and winter solstice (*21.12*), and the time expressed in the Earth motion's days in spring (*92.7 d*), in summer (*93.7 d*), in autumn (*89.9 d*), and in winter (*89.0 d*): $\vec{N}$ is the Earth's rotation axis; $\vec{M}_2$ is a vector relative to which the axis $\vec{N}$ precesses at a period of 25.74 thousand years; $\vec{S}$ is the Earth's orbit axis; and $\vec{M}$ is a vector relative to which the axis $\vec{S}$ precesses at a period of 68.7 thousand years; obliquity is an angle between axes $\vec{N}$ and $\vec{S}$; $\varphi_{p\gamma}$ is an angle between autumnal equinox and perihelion [1, 18].

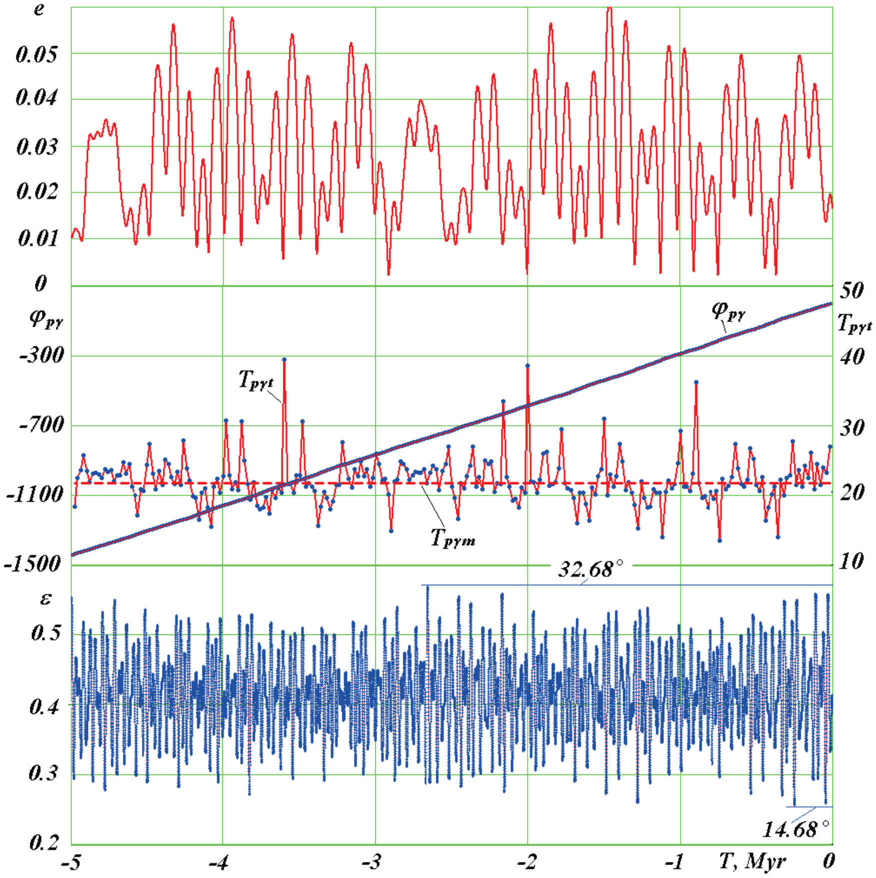

Fig. 2 Evolution of eccentricity *e*, perihelion angle $\varphi_{p\gamma}$, and obliquity ε over the last five million years: $T_{p\gamma t}$, in thousand years, is the moving average value of the period of perihelion rotation over 20-thousand-year time intervals; $T_{p\gamma m}$ = 21.7 thousand years is the mean period of perihelion rotation.

thousand years. On the average, those changes occur once in a time interval of 19 to 25 thousand years. The average period of perihelion rotation over five million years is $T_{p\gamma m}$ = 21.7 thousand years.

The oscillations of the obliquity ε proceed irregularly and with different amplitudes (Fig. 2). The main oscillation period, the average one over the time interval of five million years, is $T_{\varepsilon m}$ = 25.73 thousand years. Taking into account the use of different averaging algorithms, this period is equal to the period of Earth-axis precession P_{pr} = 25.74 thousand years. The period of oscillation in a particular epoch may differ from the mean oscillation period by a thousand years. Also, there may be more significant differences. For example, in the epoch of 4.6 million years ago one minimum of ε turned degenerated, and two oscillations occurred over the three intervals of $T_{\varepsilon m}$, i.e., the oscillation period here becomes equal to 38.6 thousand years. The amplitude of the oscillations of ε is variable; it varies from zero to a maximum value equal to 9°. On the average, the oscillation amplitude of ε is 2.74°, and the average value of the obliquity is 23.8°, with its current value being equal to 23.44°.

Over the interval of five million years, there are no time intervals with repeating behavior of the changes in angle ε. The distribution of large fluctuation amplitudes is also irregular. There are two time intervals with very large amplitudes: 0 to 0.25 and 2.2 to 2.8 million years ago. Also, there are time intervals with very small fluctuation amplitudes, for example, in the epochs of $T \approx 3.3$ million years ago and $T \approx 4.2$ million years ago. The largest value $\varepsilon = 32.68°$ is shown in Fig. 2 in degrees during the epoch $T = 2.6582$ million years ago, and the smallest one, $\varepsilon = 14.68°$, in the epoch $T = 0.2508$ million years ago. Thus, the largest amplitude of Earth-axis oscillations over the last five million years amounts to $\Delta\varepsilon_{Amx} = 9°$.

4. Evolution of the Earth's Obliquity and Insolation Over A Span of 1 Million Years

In Fig. 3, the results of the new Astronomical theory of climate change *1* are compared with the results of the previous theory *2* [9], for obliquity ε and summer insolations: Q_s^{65N} and *I*. Over the time interval of 1 million years the oscillations of ε as yielded by the new theory *1* proceed in the range from 14.7º to 32.1º, whereas the range in the previous theory was from 22.08º to 24.45º; in other words, the range of oscillations in the new theory proves to be seven times greater.

This difference is due to the fact that, in the new Astronomical theory, the Earth's rotation problem was treated in full, without simplifications. The solution of this problem and various checks of obtained data were analyzed at length in publications [1, 15, 19].

The astronomic summer and winter half-years measured from the vernal equinox day to the autumnal equinox day and vice versa differ in duration for different epochs. That is why it is caloric half-years, equal in duration, that are considered here. The summer insolation Q_s^{65N} occurring during the summer caloric half-year at the 65-deg northern latitude is a characteristic of the Earth's climate when considering climate change over time. Fig. 3 gives a comparison of the insolation changes Q_s^{65N} in the new theory (line *1*) [1] with the changes as calculated by the previous theory (line *2*) [9]. As it is seen, the amplitude of insolation oscillations is also seven times greater than that in the previous theory. Besides, the insolation extremes occur at other times, and the oscillation periods are different. Therefore, the previous theory could not explain the significant changes in the Earth's climate that had been occurring in the past.

In order to compare climates in other epochs with the contemporary climate, we consider the insolations in equivalent latitudes *I*. For calculating of *I*, we consider the Earth's latitude φ in contemporary epoch characterized by the admission of the same amount of summer solar radiation Q_s at the latitude 65°*N* in other epoch. Fig. 3 shows the summer insolation in equivalent latitudes *I* over a time interval of 1 million years. The lowest values $I \approx 90°$ indicate that at the latitude 65°*N* in summertime there was less solar radiation than now on the pole. The highest values such as $I \approx 23°$ at time -0.031 million years denote epoch in which in summertime the amount of the solar radiation having reached the Earth at the latitude 65°*N* exceeds the amount of solar radiation having fallen onto it presently at tropics, i.e., in the equatorial area. Such profound insolation oscillations lead to substantial climate oscillations. As it is seen from graph *2*, the oscillations of *I* in the previous theory were less significant. That is why the previous theory could not explain the paleoclimate fluctuations.

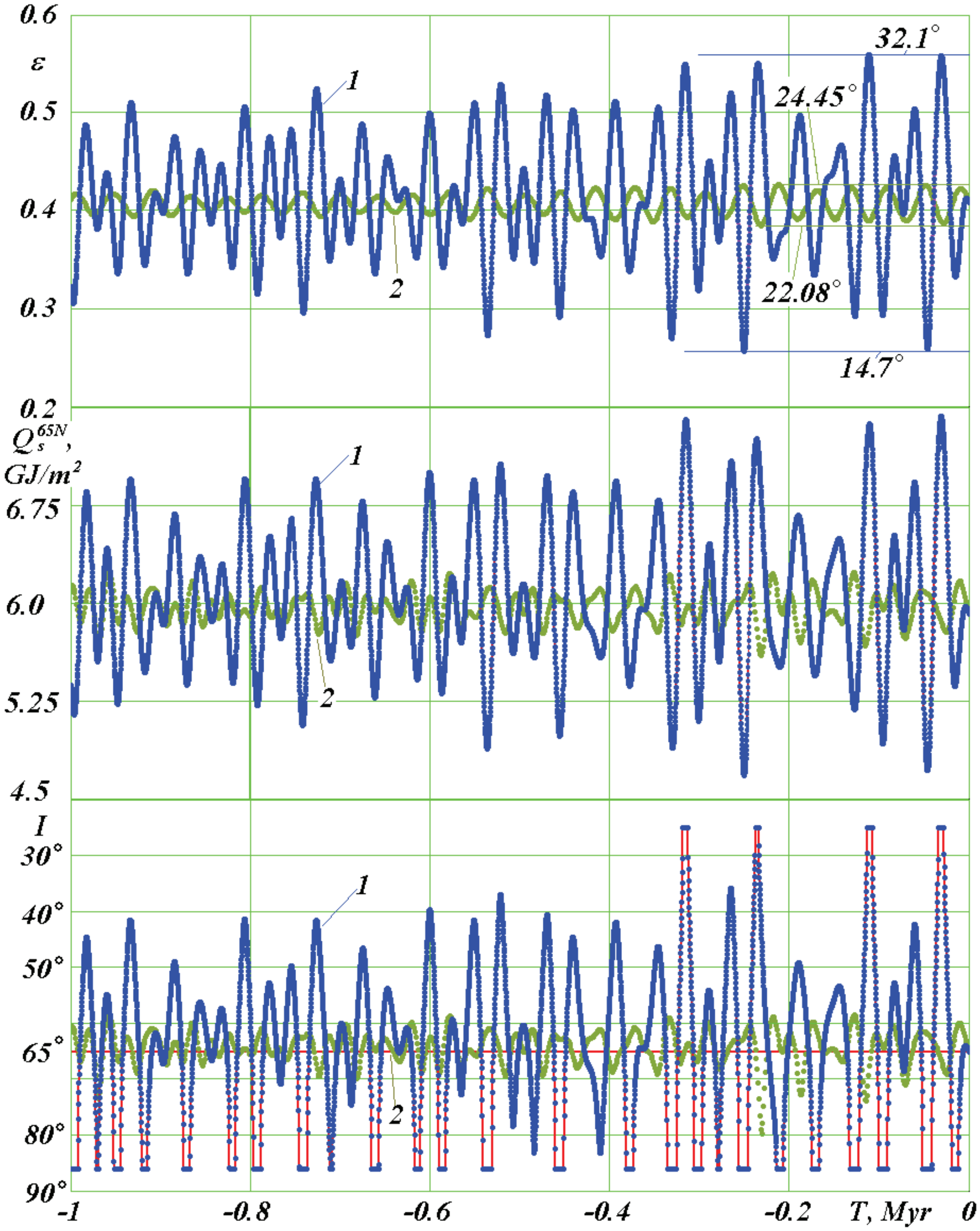

Fig. 3 **Evolution of the obliquity ε, and that of summer half-year insolations Qs^{65N} and *I* over a time interval of 1 million years. Comparison of results yielded by new Astronomical theory of climate change (line *1*) with the results of the previous theory (line *2*) demonstrated using, as an example, the work by J. Laskar *et al.* [9]. Qs^{65N} – insolation in GJ/m² over the summer caloric half-year at 65-deg northern latitude; *I* – insolation in the equivalent latitudes over the summer caloric half-year at 65-deg northern latitude. Indicated in degrees are the maximum and minimum values of ε.**

5. Variation of Insolation Over the Earth's Latitude

Fig. 4 shows the variation of the annual insolation Q_T, and insolations during caloric half-years summer Q_s, and winter Q_w over the latitude φ in three epochs: in contemporary epoch $T = 0$, in the warmest epoch $T = -31.28$ kyr, and in the coldest epoch $T = -46.44$ kyr (the warmest and the coldest epochs over a time interval of 200 thousand years) [1]. Those epochs are characterized by the following values of 65°*N* summer insolation: $Q_s^{65N} = 5.9$, 7.4, and 4.7 GJ/m^2, respectively. In those epochs, the obliquities were $\varepsilon = 23.44°$, 32.10°, and 14.8°, respectively.

Summer insolation Q_s (dashed lines in Fig. 4) in the contemporary epoch (line *1*) has minimum values at the poles, reaches a maximum value at the tropics $\varphi = \varepsilon$, and attains a minimum value near the equator. Summer insolation Q_s at the poles in the warm epoch (line *2*) increases compared with the cold epoch (line *3*) by a factor of 2.07. At 65°N, this insolation changes 1.57 times. Since, on the average, the latitude 65°N adequately represents the change in insolation at high latitudes, it was accepted by M. Milankovitch [4] as a reference one for climate characterization. In the warm epoch *2* insolation Q_s attains an equatorial minimum in Southern Hemisphere, and in cold epoch *3*, in Northern Hemisphere.

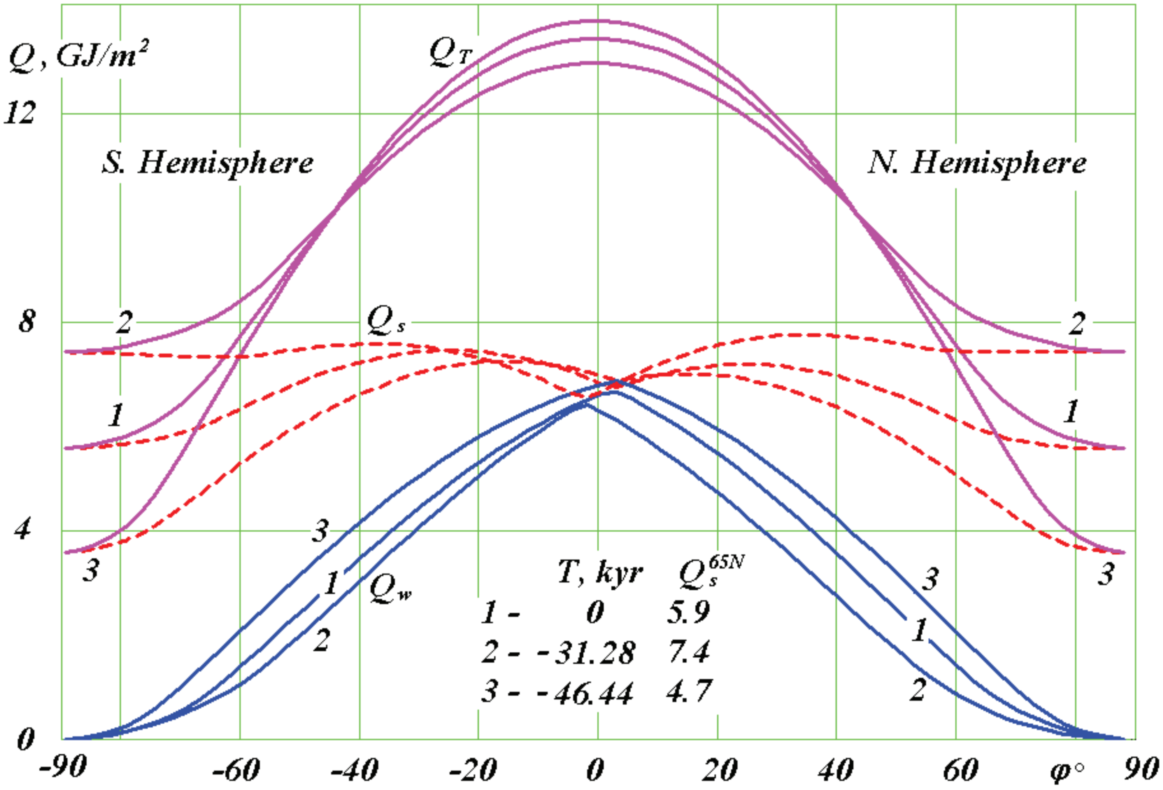

Fig. 4 The distribution over latitude φ of summer Q_s, and winter Q_w half-years, and of annular Q_T insolations for three epochs: *1* – contemporary epoch; *2* – warmest epoch; *3* – coldest epoch over a time interval of 200 thousand years; *T*, kyr – time in thousand years reckoned from December 30, 1949.

The winter insolation Q_w (Fig. 4) on the poles is zero, and it monotonically increases in the equatorial region. In the equatorial region, the insolation Q_w exhibits a maximum at a latitude φ at which the summer insolation Q_s shows a minimum. Over the period from cold epoch *3* to warm epoch *2*, the winter insolation Q_w exhibits most pronounced variations at middle latitudes. In the latter situation, for epochs *2* and *3* under consideration, e.g., at the latitude $\varphi = 40°$, the change of the winter insolation is 1.38 times greater in the northern hemisphere in comparison with the southern hemisphere. In cold epoch *3*, the winter insolation at all latitudes is greater than that in warm epoch *2*. In other words, during the cold epochs the winter seasons are warmer than those during the warm epochs.

The annular insolation Q_T (Fig. 4) monotonically increases from the poles toward the equator. At the equator, the annular insolation exhibits a maximum, with the annular insolation being symmetrical with respect to the equator. In other words, the amounts of heat per year are identical in both hemispheres. From cold epoch *3* to warm epoch *2*, the annular insolation Q_T on the poles increases by the same factor the summer insolation Q_s does. With decreasing latitude, the difference between the annular insolations decreases, and at the latitude φ = 45° the annular insolation experiences no changes. In the equatorial region, the changes of Q_T are reciprocal to its changes at the high latitudes: in cold epoch *3*, the amount of heat per year exceed that in the warm epoch. In the latter situation, the change of insolation Q_T is four times smaller than that in the high-latitude region. That is why the main changes of the annular insolation occur at high latitudes.

6. Periods and Gradations of Earth's Climate Changes

Over the previous interval of 200 thousand years (see Fig. 5), 13 climatic periods, O_I, 1_I, 2_I, , , 12_I, were identified [1, 16, 17]. As a result of the comparison of these periods with paleoclimate data for Western Siberia over 50 thousand years, it was found that the periods 3_I, 2_I, 1_I, O_I (see Table 1) refer respectively to the Ermakov ice age, Karginsky warming, Sartan glaciation, and Holocene optimum. They coincide with periods of paleoclimate change in the works of Arkhipov [20], Groswald [21], Svendsen et al. [22] and others. Those evens also correspond to ice ages and interglacial periods in Europe and North America. For example, period 1_I corresponds to Upper Würm, Upper Weichselianan the Ostashkov ice age in Europe and Upper Wisconsinan in North America.

Also, the following gradations of the warm and cold climate were introduced (Fig. 5): moderately warm, warm, and extremely warm climate levels, and moderately cold, cold, and extremely cold climate levels. During the past period of 1 million years (see Fig. 6), the Earth has experienced six extremely cold (e.c.) periods and four extremely warm (e. w.) periods.

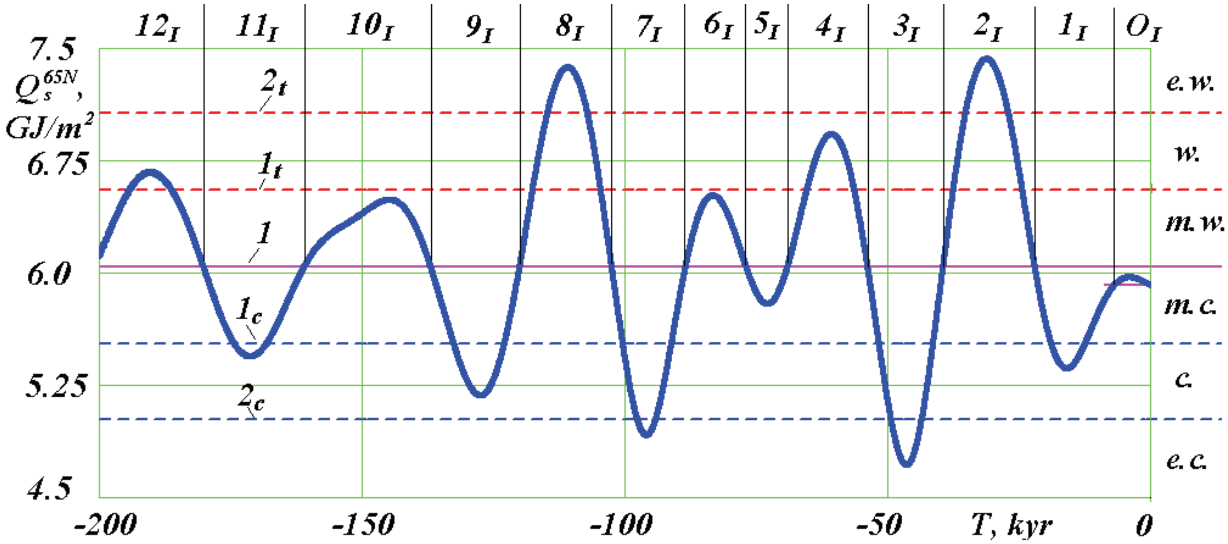

Fig. 5 Insolation periods O_I, 1_I, 2_I,… 12_I over a time interval of 200 thousand years and their boundaries: *1* – mean insolation Q_{sm}; *1t* and *2t* – the first or second boundaries of warm levels; *1c* and *2c* – the first and second boundaries of cold levels; m.w., w., e.w – moderately warm, warm, and extremely warm levels; m.c., c., e.c. – moderately cold, cold, and extremely cold levels.

Table 1 The extremes of insolation for 50 ka: 0_I, 1_I, 2_I u 3_I are the insolation periods. The warming is marked as maximum (max), and cooling – as minimum (min).

Parameters	**Values in different epochs**			
Extremes: *T*, ka.	4.16	15.88	31.28	46.44
Type of extremes	**max**	**min**	**max**	**min**
Periods	0_I,	1_I,	2_I	3_I
Boundaries, ka.	0-6.86	6.86-22.08	22.08-39.5	39.5-53.8
Events in the Pleistocene	Holocene optimum	Sartan glaciation	Karghinsky interglacial	Ermakovsky glaciation

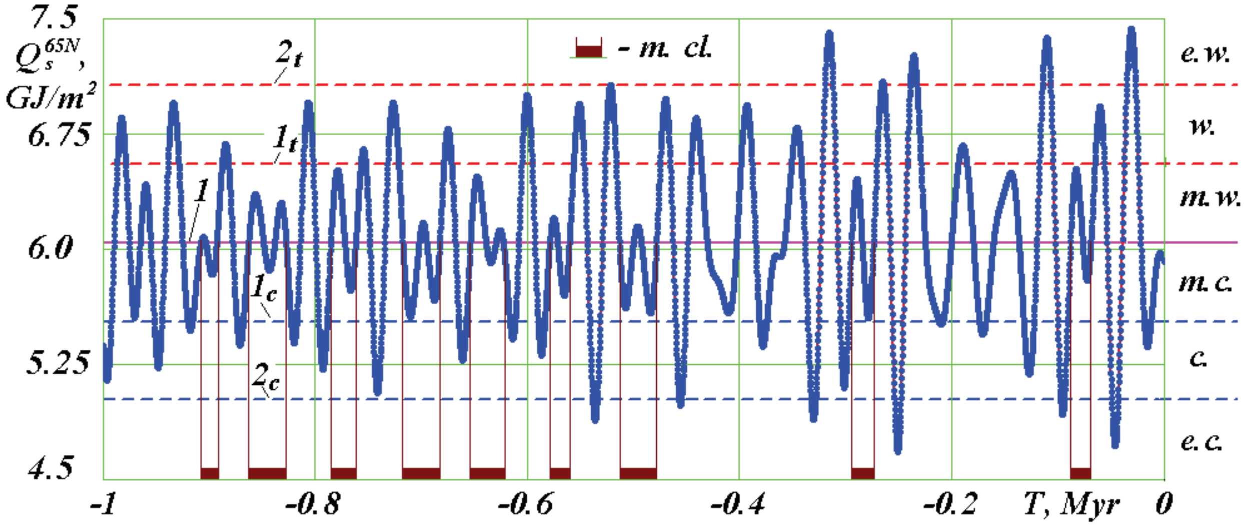

Fig. 6 Climate levels over a time interval of 1 million years: *1* – mean insolation Q_{sm}; *1t* and *2t* – the first or second boundaries of warm levels; *1c* and *2c* – the first and second boundaries of cold levels; m.w., w., e.w – moderately warm, warm, and extremely warm levels; m.c., c., e.c. – moderately cold, cold, and extremely cold levels.

The total number of cold (c.) and warm (w.) periods was 16 periods each. Other periods were moderately cold (m. c.) ones and moderately warm (m. w.) ones. Besides, there were nine moderate-climate (m. cl.) periods, which included both cooling and warming phases.

7. Moments of the Onset and End of Polar Days and Nights

In Fig. 7, the moments of the onset and end of polar days and nights are shown in the form of graphs plotted for various epochs [17, 23-24]. The graphs show the change in the day number T_d over the latitudes φ in Northern Hemisphere. The day number T_d is counted from the moment of vernal equinox, so that the number $T_d = 0$ corresponds to the moment of the equinox. It should be noted that 79 days pass from the beginning of the year to the moment $T_d = 0$. In region *I*, up to approximately $T_d = 90$ days, the onset times of polar days are given versus the latitude φ. Different lines and points show graphs for five epochs. Similarly, in region *II*, at approximately $90 < T_d < 180$ days, the same lines indicate the moments T_d of the end of polar days. In the same way, at approximately $180 < T_d < 270$ and $T_d > 270$ days, respectively the onsets (*III*) and ends (*IV*) of the polar nights are shown.

For example, in the contemporary epoch, $T = 0$, at latitude $\varphi = 70°$, following $T_d = 56.88$ days after the moment of vernal equinox, a polar day sets in. This day ends at $T_d = 128.82$ day. The polar night begins at $T_d = 250.05$ day and ends at $T_d = 302.39$ day. With increasing latitude φ, both polar days and nights begin earlier, and end, begin later. With decreasing latitude φ, the beginning of polar days moves away and approaches T_d = 92.8 days, and the beginning of polar nights approaches T_d = 275.5 days. This occurs at latitudes close to the latitude of the Arctic Circle, which in the present epoch is 66.56°.

In other epochs, as it is evident from Fig. 7, the graphs of the beginning and end of polar days and nights are identical, but the latitude of their onset can shift substantially. As a result, the duration of polar days and nights varies in length. For example, in the epoch of 31 ka, the latitude of the onset of polar days and nights shifts respectively to 56° and 58°, and in the epoch of 46.44 ka, to 74° and 76°.

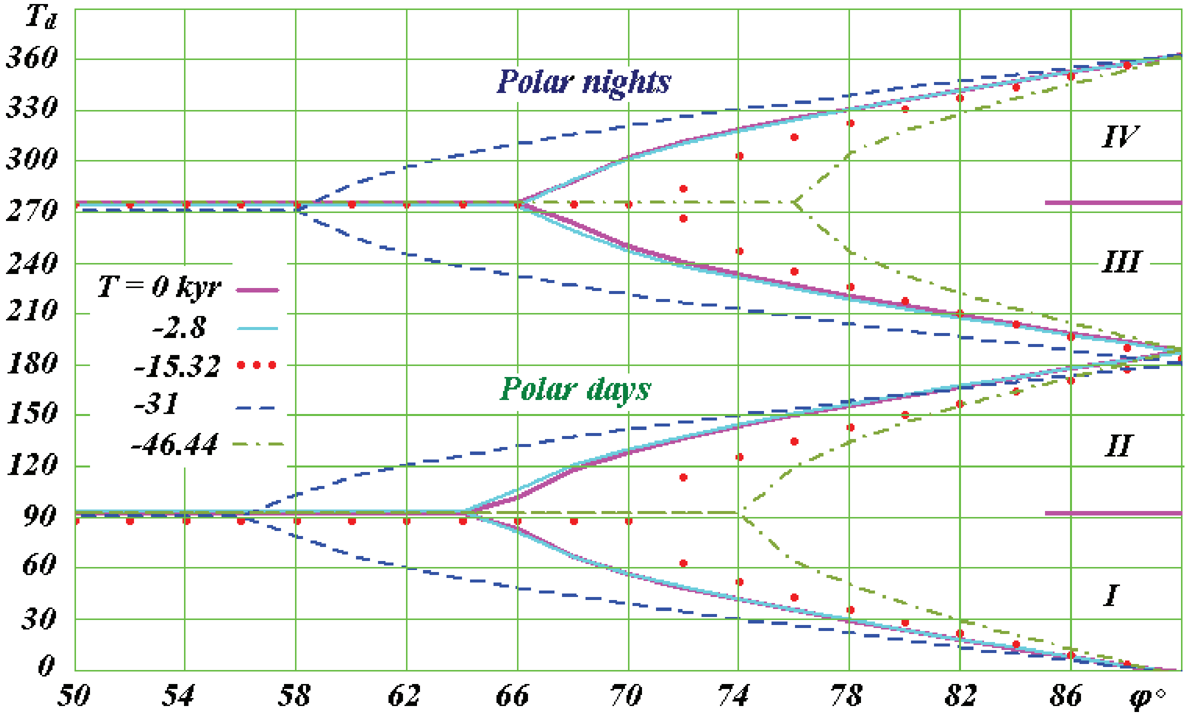

Fig. 7 The times T_d of the onset *I* and end *II* of polar days, and the onset *III* and end *IV* of polar nights at various latitudes in Northern Hemisphere during the extreme epochs over the last 50 thousand years.

It should be noted here that B.G. Tilak [25] studied the texts of the Vedas, Bhagavad-Gita, Avesta and other ancient sources. These texts cite the characteristics of the polar zone, as if the ancient Aryans lived in it. This can only be explained by large angles ε. In this case, the Arctic Circle passes to the south of its present location and, in addition, it becomes warmer at these latitudes. This creates necessary conditions for human life in the polar zone. This could happen in the epoch of -31 kyr. Ancient Aryans could inhabit a territory close in latitude to Tyumen (φ = 57.15°) and observe polar days and nights. With the approach of the last ice age, with a minimum of insolation having occurred 15.88 thousand years ago, Aryans were forced to migrate to southern territories.

The beginnings of polar days T_{dd} and nights T_{dn} and their durations $\Delta T_{dd} = T_{dd1} - T_{dd}$ and $\Delta T_{dn} = T_{dn1} - T_{dn}$, respectively, where T_{dd1} and T_{dn1} are the days of their end, are given in the tables published in [23-24]. These data are given for five different epochs at different latitudes in Northern Hemisphere. The change in latitude φ is given at 2° steps starting from the pole. The latitudes change to values after which no polar day occurs.

The theory and program SunPhnmen.mcd for calculating the total length of daylight hours, the duration of polar days and nights, and other solar phenomena is given in [17, 23-24]. This program and files with data on the evolution of Earth's orbital parameters and rotational motion are freely available at the site http://www.ikz.ru/~smulski//Data/Insol/. Using them, one can determine the solar phenomena for any epoch over a time interval up to 20 million years ago.

8. Conclusions

1) Ice Ages occur at latitudes greater than 50°. At this time in the equatorial latitudes it becomes warmer.
2) Summer in the Ice Ages is colder than the contemporary one and the stronger than the greater a geographic latitude.
3) Winter during the Ice Ages is warmer than today throughout the globe.
4) In warm epochs, polar days and nights come to the south of contemporary places, for example, near the city of Tyumen, and during glacial periods – to the north, for example, north of Bely Island.
5) Ice Ages may recur after 30 thousand years, and may not occur even after three hundred thousand years, i.e. there is no their periodicity.
6) Insolation periods of climate change are defined. They coincide with paleoclimate changes. Therefore, the insolation periods are a reliable means for solving paleoclimate riddles.

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