Oscillations of the Solar Irradiation of the Earth Caused by Secular Changes in the Elements of the Earth' s Orbit

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Abstract

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Oscillations of the Solar Irradiation of the Earth Caused by Secular Changes in the Elements of the Earth' s Orbit

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In the 1930s M. Milanković ([1]), generalizing and developing the ideas of his predecessors, created an astronomical theory of climatic oscillations, in which he considered the Earth' s climate to be determined only by solar radiation and by changes in the position of the Earth relative to the Sun. The solar constant J_0 and the period of the Earth' s revolution around the Sun T, as quantities having insignificant secular oscillations, are taken to be constant quantities. In his works M. Milanković divides the year into two equal summer and winter ("caloric") half-years in such a way that the amount of heat received by the Earth' s surface on any day of the summer half of the year exceeds the amount of heat on any day of the winter half.

The change in the amount of heat received by a given latitude during the caloric half-years will depend on the secular changes in the eccentricity of the Earth' s orbit e, the longitude of perihelion Π, and the inclination of the ecliptic to the equator ε, in the following way:

$$\Delta Q_s = \Delta W_s \Delta\varepsilon \pm m\Delta(e\sin\Pi), \qquad \Delta Q_w = \Delta W_w \Delta\varepsilon \mp m\Delta(e\sin\Pi).$$

Here ΔW_s, ΔW_w, m, under the assumptions made regarding J_0 and T, are quantities constant for a given latitude. The lower sign in the formulas refers to northern latitude, the upper to southern latitude.

Comparison of the summer or winter sums of radiation received by a given latitude at different dates of the geological past with the sum of radiation received by the same latitude during the same caloric half-year at the present time makes it possible to judge climatic oscillations over this interval of time. From the point of view of geologists, the course of the summer sums of radiation is of particular interest.

M. Milanković constructed tables and graphs of changes in the solar irradiation of the Earth for a time interval of 600 thousand years before 1800, on the basis

Fig. 1. Insolation during the summer (solid lines) and winter (dashed lines) at equivalent latitude. The abscissa axis shows

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of the secular perturbations of the elements of the Earth' s orbit calculated by V. Mišković ([2]).

The results of M. Milanković were recently recalculated by Wurkom ([3]), using new data on the secular perturbations of the elements of the Earth' s orbit ([4]). He constructed insolation curves during the summer half-year for latitude 65° in both hemispheres for a time interval of 1 million years before 1950.

Further development of the astronomical theory of climate, undertaken at the Institute of Theoretical Astronomy of the Academy of Sciences of the USSR on the initiative of geological organizations, required the calculation of insolation for a longer interval of time in the geological past. For this purpose we carried out work on revising the trigonometric formulas of precession,

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the determination of constants and coefficients of the obtained trigonometric series and the calculation of the secular variations of the elements of the Earth' s orbit over a time interval of 30 million years before 1950 (5). On the basis of the results of these studies and of the recalculated and expanded tables of the values ΔW_s, ΔW_w, m, Q_s^0, Q_w^0, tables of summer and winter insolation were computed for latitude 65° in both hemispheres, and graphs were constructed of the secular course of the radiation sums (reduced to the equivalent latitude) for the same data over a time interval of 30 million years before 1950.

Comparison of our results with those of M. Milanković and A. Wurm showed fairly good agreement among the three studies.

In the present article only part of the graphs obtained is presented, namely the graphs of summer and winter insolation for 65° latitude in both hemispheres over a time interval of 3 million years ago. The insolation curves for

semesters for 65° north latitude (a) and 65° south latitude (b), reduced to the equinox; time in millennia before 1950.

30 million years ago, and a general discussion of the results obtained will be published in editions of the Institute of Theoretical Astronomy of the Academy of Sciences of the USSR.

Institute of Theoretical Astronomy
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Note: Figure translations are in progress. See original paper for figures.