SOLAR ACTIVITY AND CLIMATE CHANGES OF THE EARTH. V. A. Alexeev, Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow 119991 Russia; e-mail: aval@icp.ac.ru

The solar radiation is the fundamental source of energy that drives the Earth's climate. Climate models show that total solar irradiance variations can account for a considerable part of variations of the temperature of the Earth's atmosphere in the pre-industrial era. Earlier we have considered the correlative connection between some climatic changes on the Earth and the activity of the Sun [1]. In this paper the analysis of data of monthly average and annual average regional variations in the surface air temperature for the last 125 years [2] in comparison with the solar activity variations in the 11-year [3] and secular cycles, is performed.

The variations of the solar activity and surface air temperature are compared in Fig. 1. The solar activity variations are shown for the 11-year (Fig. 1*a*, curve 1) and for the secular (curve 2) cycles in the interval 1700-2004 yrs. The analysis of the entire set of data in this interval has shown that over the background of periodic changes, the solar activity increase is observed on the average at ~0.2%/year. The tendency of solar activity increase in the interval 1880-2004 yrs is much higher: ~1%/year.

The temperature variations of the surface air for the last 125 years are shown in Fig. 1*b*. The well-defined tendency of the temperature increase in time is seen. The parameters of the regression line correspond to the increase of temperature over the analyzed period by 0.61±0.05 ^{o}C. The falls of the temperature (by ~0.1-0.2 ^{o}C) in the intervals ~1900-1920 and 1960-1980 yrs are probably conditioned by the large number of catastrophic volcano eruptions in these periods [4].

Distributions of average annual anomalies of the temperature of land and oceans during different periods of the solar activity in a **secular cycle** (number of a sun-spots $Ri<120$ and $Ri \geq 120$) within the interval 1880-2004 yrs are shown in Fig. 2. One can see, that the range of values of temperature anomalies for the land is almost twice is larger than for the ocean. Such a difference is connected, undoubtedly, with the large thermal inertia of oceanic masses. Median values of distributions for high solar activity years are significantly different from values for years of low solar activity (by ~0.3 ^{o}C).

Distributions of the annual average anomalies of temperature of land and oceans in the different periods of the **11-year solar cycle** within the interval 1880-2004 yrs are shown in Fig. 3. Here, for each 11-year cycle of the solar activity, the years related to a high level of activity of the Sun in this cycle and the years with a low level of activity of the Sun were selected. The obtained data were used for construction of the time dependence of the annual average temperature anomalies for years with high and, separately, low solar activity in the 11-year cycle (analogue of Fig. 1*b* for all years). For each of such dependences, the regression line was calculated and the Δt value was determined (Δt is the increase of temperature for the whole time period). Such a procedure was made for the data related to different regions of the Earth. The obtained results demonstrate the clear-cut distinction between Δt values related to years with different levels of the solar activity. This distinction is most clearly seen for the land, especially for high latitudes of the northern hemisphere (Fig. 3*a*). For example, the Δt values for the range of latitudes 20^{o}*N*-90^{o}*N* for years of high and low solar activity are equal to 1.25±0.11 and 0.79±0.11 ^{o}C, respectively. At transition to the southern hemisphere Δt values decrease, but here higher values of Δt are also peculiar for the periods of high solar activity.

For oceans (Fig. 3*b*) the latitude dependence is practically not seen, though a tendency remains: higher Δt values correspond to the years with high solar activity.

The obtained data testify that the temperature on the Earth "has the time" to react to the changes of the solar radiation in a 11-year cycle. This reacting manifests itself most legibly for the land. The non-uniform distribution of the land and water surface, as well as the small thermal inertia of the land and the large inertia of the oceanic water, are apparently the main causes of the found peculiarities in the distribution of Δt values for different regions of the Earth.

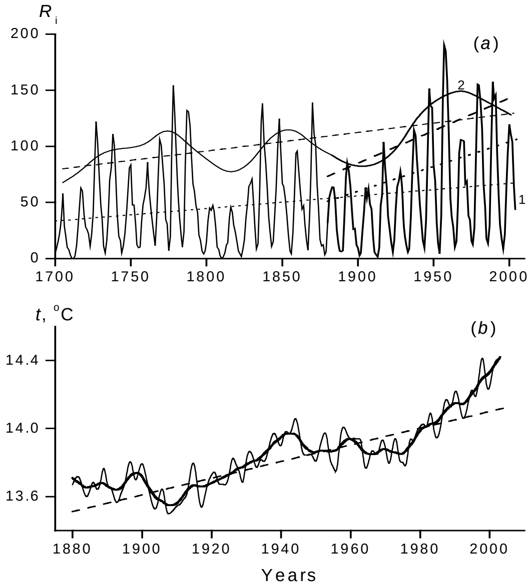

Fig. 1

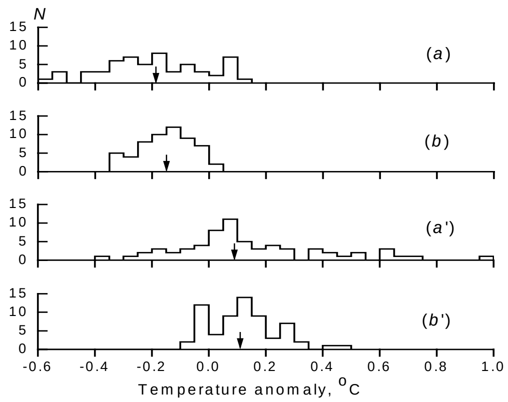

Fig. 2

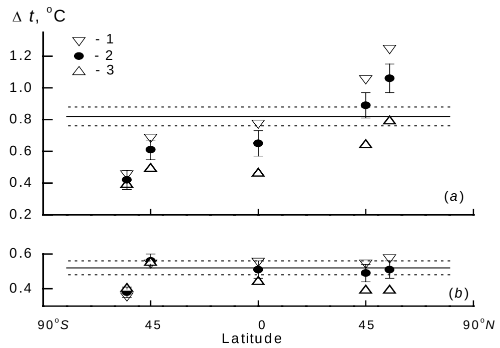

Fig. 3

References

[1] Alexeev V.A., Ustinova G.K. Geokhimiya (in press). **[2]** *http://www1.ncdc.noaa.gov/pub/data/anomalies/* **[3]** *http://www.sunspot.net/cat3sun_r.html* **[4]** Simkin T., Siebert L. Volcanoes of the World. 1994.

Captions

Fig. 1. Comparison of the solar activity variations (*a*) in the 11-year (curve 1) and secular (curve 2) cycles with the temperature variations of the surface air of the land (*b*).

Fig. 2. Distributions of the average annual anomalies of air temperature in 1880-2004 yrs over the surface of land (*a, a′*) and ocean (*b, b′*) for different levels of the solar activity in a secular cycle. *a, b* - number of sun-spots in a secular cycle $R_i < 120$; *a′, b′* - $R_i \geq 120$. The arrows mark median values (°C): -0.19±0.03 (*a*); -0.15±0.03 (*b*); 0.09±0.02 (*a′*); 0.11±0.02 (*b′*).

Fig. 3. The increase of the surface air temperature for 125 years (1880 – 2004) according to the regression line (such as that in Fig. 1*b*) for different regions of the Earth: 90°*N*-20°*N* (mean latitude L_{av}=55°*N*), northern hemisphere (L_{av}=45 °*N*), 20°*N*-20°*S* (L_{av}=0), southern hemisphere (L_{av}=45°*S*) and 20°*S*-90°*S* (L_{av}=55°*S*). The calculation of regression lines is carried out for years of high-level solar activities in a 11-year cycle (1), low-level solar activity (3) and for the entire set of data; *a* and *b* are the data for the land and ocean, respectively.