Doklady Earth Sciences, Vol. 377, No. 2, 2001, pp. 190–194. Translated from Doklady Akademii Nauk, Vol. 376, No. 5, 2001, pp. 679–683.

GEOGRAPHY

Climate Changes in Western European Russia in the Late Holocene

V. V. Klimenko[1], V. A. Klimanov[2], A. A. Sirin[3], and A. M. Sleptsov[1]

Presented by Academician G.S. Golitsyn September 14, 2000

Received September 19, 2000

Data on past climate changes can serve as the basis for the analysis of its modern trends and the forecast of future ones. A large number of studies were dedicated to the reconstruction of climate changes. Nonetheless, some spatial and temporal aspects of this problem still remain crucial. For instance, chronological boundaries of many paleoclimatic events during the last millennium remain unclear. Data on some climatically and historically important areas such as the western European part of Russia (EPR) are still insufficient. The peat section in the central part of the Usvyatskii Mokh bog serves as one of the objects for long-term stationary studies of the western Dvina forest–bog station of the Institute of Forest Science, Russian Academy of Sciences (western Dvina area of the Tver district, (56° N, 32° E). The study of this section provided data for the adequate reconstruction of climatic conditions of the western part of the EPR. Simultaneously, they made possible more accurate estimates of temporal boundaries of main paleoclimatic events in the Late Holocene.

Favorable conditions in January 1999 for peat excavation (extremely low temperature and absence of snow) allowed us to penetrate the peat section to a depth of 80 cm by making a prospecting pit and then to a depth of 2 m using the TBO peat corer. The section was sampled for a palynological study with steps of 1 and 2.5 cm. In total, 128 samples were studied. Paleoclimatic reconstructions were performed based on palynological data (determinations by E.S. Malyasova) and using the information statistical method. Radiocarbon dates for 20 samples of peat and buried wood were obtained at the Geological Institute of the RAS in the laboratory headed by L.D. Sulerzhitskii. Calendar dates were obtained using the last version of the CALIB program [1]. Data from instrumental meteorological observations at the Riga, St. Petersburg, Moscow, and Vilnius stations, as well as paleoclimatic materials provided by historical sources for the western part of Eastern Europe [2], were used for calibration and verification of the results.

The reconstructed pattern of climate change (Fig. 1) is considered based on the Blitt–Sernander Holocene Scale modified by Khotinskii [3]. The values of climatic parameters are given as deviations from their modern values determined here as a norm for the 1951–1980 period: the average temperature for July and January was about 16.5°C and –8°C, respectively: the annual average temperature was about 4.5°C, and total precipitation was about 700 mm.

A large number of radiocarbon dates and additional information from neighboring sections allowed us to obtain an adequate record of Late Holocene climate changes.

The calendar age of peat layers at a depth of 80 cm is estimated to be about 600 yr. Thus, every sample from this interval collected at a spacing of 1 cm characterizes a time interval of approximately 8 yr. In total, 35 warming and cooling peaks with average durations of 20 yr were recorded during the last 600 yr. Owing to such high resolution, climate changes at the century and decade scales were registered. In the domestic practice of palynological studies, this accuracy is obtained for the first time.

Below 80 cm, where the peat accumulation rate is lower and samples were taken at a step of 2.5 cm, the paleoclimatic data appeared to be less accurate. Therefore, paleoclimatic data derived from neighboring boreholes and adjacent areas, particularly from the Novgorod district [4], were also used. The results are shown in Fig. 1.

The layer located slightly below the date of 4630 ± 120 yr B.P. reflects a cooling, which can be correlated with the beginning of the Subboreal period (SB) that was observed in some other regions of Northern Eurasia about 4600 yr B.P. During this period, probably maximal Late Holocene cooling, the average annual

[1] *Moscow Energy Institute, Krasnoznamennaya ul. 14, Moscow, 111250 Russia*

[2] *Institute of Geography, Russian Academy of Sciences, Staromonetnyi per. 29, Moscow, 109017 Russia*

[3] *Institute of the Forest Science, Russian Academy of Sciences, Uspenskoe, Moscow district, 143030 Russia*

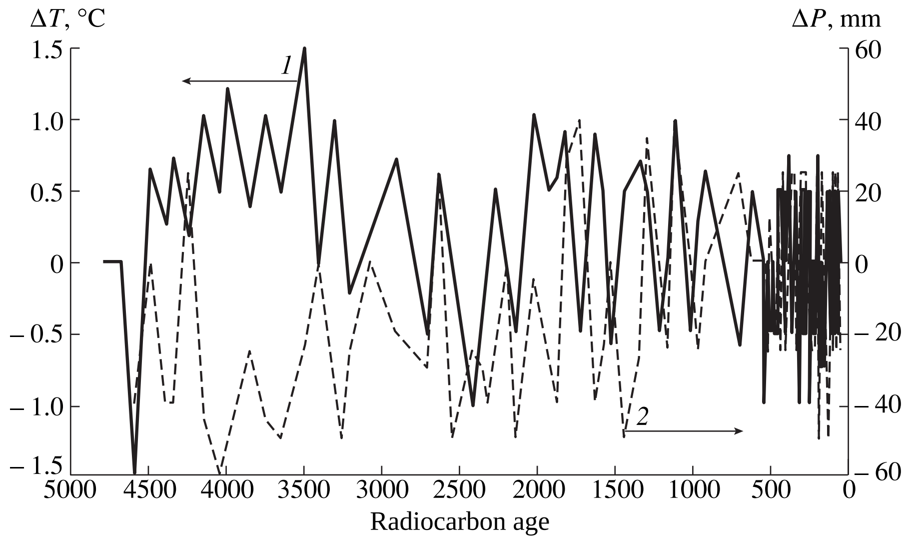

Fig. 1. Deviations of (*1*) average annual temperatures and (*2*) total annual precipitation from the 1951–1980 norm during the Late Holocene reconstructed using data from the Usvyatskii Mokh peat bog.

and July temperatures were 1.5–2.0°C lower and the average January temperature was 2–3°C lower compared to their modern values, whereas precipitation was 25–50 mm lower than today. At the beginning of the SB period, the peat accumulation rate was relatively high, which provided a sufficiently high resolution of the paleoclimatic record. For the period from the beginning of the SB to 4040 ± 40 yr B.P., four warming episodes were recorded. The strongest of them is registered at about 4000 yr B.P.: average July, January, and annual temperatures were approximately 1, 1.5, and 1.0–1.5°C lower, respectively, compared to the present-day temperature, while the precipitation was 40–50 mm lower. The temperature during cooling events between warming episodes never dropped below modern values. As in other regions of Russia, the maximum warming of the Subboreal period registered in the layer located above the date of 3760 ± 60 yr B.P. probably occurred approximately 3500 yr B.P. Preceding cooling episodes were probably dominated about 3850 and 3650 yr B.P. During the maximum SB warming, all temperature parameters were approximately 1.5°C higher compared to the modern ones, whereas precipitation was approximately 25 mm lower. Three additional warming episodes with successively lower amplitudes occurred before the termination of the SB period. In contrast, each successive cooling was stronger than the preceding one and temperatures sometimes dropped below values characteristic of modern times at the end of the SB period. The times of the cooling episodes were about 3400, 3200, and 2700 yr B.P., and the cooling events were approximately 3300, 2900, and 2600 yr B.P. The end of the SB period was marked by a cooling, the maximum of which corresponds to the Subatlantic period (SA).

During the maximum cooling of the initial SA period dated back to 2400 ± 40 yr B.P., all temperature parameters were lower than their modern values by approximately 1°C and precipitation was lower by 25 mm. Slightly later, this cooling is also registered in the entire territory of Russia, Canada, Scandinavia, California, Alaska, and in other regions of the world [5, 6]. It was followed by a warming about 2250 yr B.P. During the subsequent warming period, which was maximum approximately 2000 yr B.P., all temperature parameters were higher than the modern ones by approximately 1°C and precipitation was close to the modern level. A preceding cooling event probably occurred about 2100 yr B.P. Two warming episodes corresponding to 1800 and 1600 yr B.P. occurred before the cooling episode that is registered in the middle SA period at 1500 yr B.P. These events had climatic characteristics similar to those specific to the preceding warming episode. During the cooling event, which separated these warming episodes by about 1700 yr B.P., temperatures were 0.5°C lower compared to their modern values and precipitation was 25–50 mm higher. During the cooling episode in the middle of the SA period at about 1500 yr B.P., the average July and annual temperatures were lower by 0.5–1.0°C and the average January temperature was by 1.0–1.5°C lower, whereas precipitation was close to the modern amount. The next cooling events occurred about 1300 and 1200 yr B.P.

During the Medieval Climatic Optimum about 1100 yr B.P., all temperature characteristics were approximately 1°C higher compared to modern values and precipitation was 25–50 mm higher. The cooling episode between the two warming phases of the Medieval Optimum (about 1000 yr B.P.) was characterized by temperatures and precipitation values approximately 0.5°C and 25 mm, respectively, lower compared to their present-day values. The following period, up to 530 ± 70 yr B.P., was marked by two warming episodes

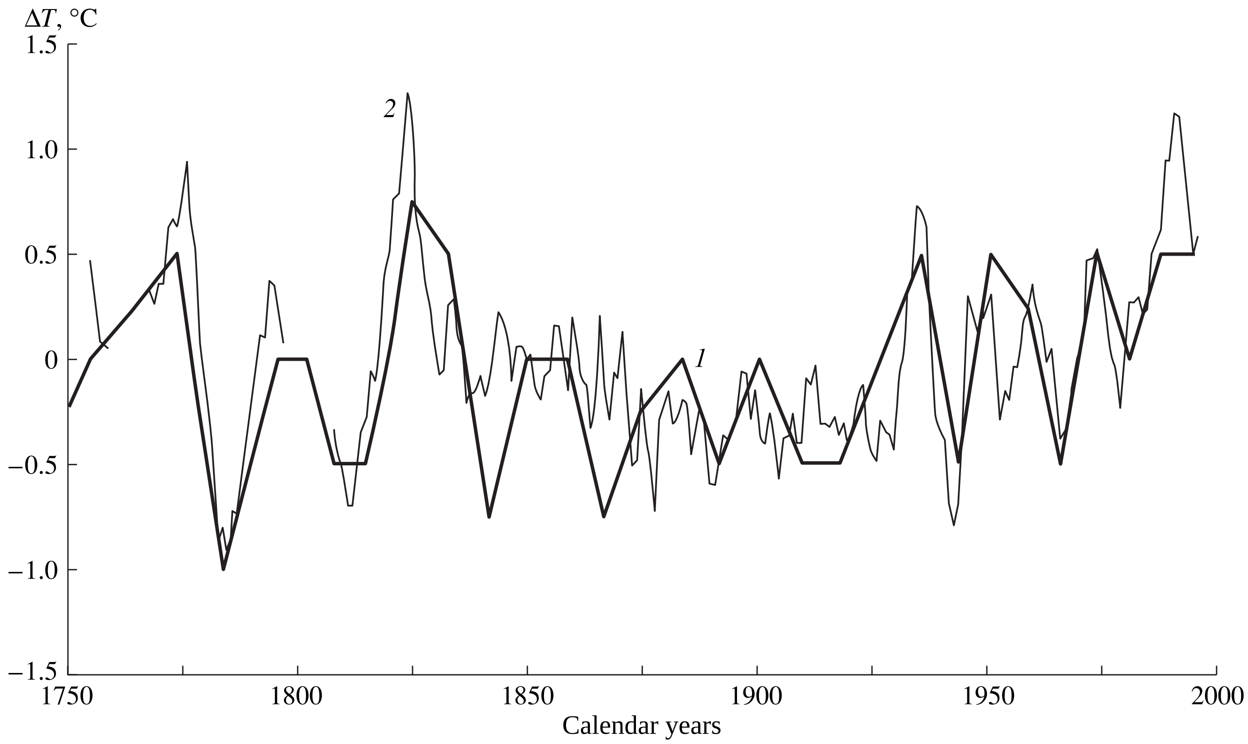

Fig. 2. Comparison between deviations of the (*1*) average annual temperature and (*2*) observation data (7-yr-long moving averages) from the Riga, St. Petersburg, Moscow, and Vilnius meteorological stations.

corresponding to about 900 and 600 yr B.P. The intervening cooling could have occurred about 650 yr B.P. The date slightly younger than 530 ± 70 (about 500 yr B.P.) was marked by strong cooling with temperatures 1°C lower than modern ones. Precipitation was also lower by about 25 mm. The date of 470 ± 40 yr B.P. corresponds to a brief warming, when the warmest average July, January, and annual temperatures were 0.5, 1, and 0.5°C higher, respectively, than their modern values, and precipitation exceeded that of the present day by about 25 mm.

These materials suggest that variations in the annual January temperatures during the considered period were characterized by a greater amplitude than those established for July. No distinct correlation is observed between temperature and precipitation variations. It can be only noted that, in most cases, precipitation peaks are located between temperature maximums. This peculiarity was previously noted in Estonia, the Yaroslavl district, and other midlatitude areas [7, 8]. Beginning from the maximum warming of the Subboreal period up to today, natural climate changes show a slight cooling trend, which is an order of magnitude lower than that registered for the warming trend during the 20th century. Chronological boundaries and quantitative estimates of past climate changes in the study area generally correspond to those previously established for Northern Eurasia [9].

A large number of palynological samples and significant peat accumulation rates after 530 ± 70 yr B.P. made it possible to reconstruct climatic parameters with high resolution and to compare their values with long-term meteorological observations at stations located in the same climatic zone. The unique feature of the selected area is that four such stations (Riga, St. Petersburg, Moscow, and Vilnius), each of which has over 200 years of observation records, are located relatively close to the study area.

A comparison of this paleoclimatic data with the smoothed series (7-yr moving averages) of averaged observations from the four stations (Fig. 2) demonstrates their agreement with respect to the dates, signs, and amplitude of climate changes. The data were calibrated in such a way to allow us to compile detailed paleoclimatic curves for the last 600 calendar years. In doing so, the dates were mainly based on measured peat accumulation rates, which were estimated to be 1.3 mm/yr during the considered period (Fig. 3). Data presented in Fig. 3 demonstrate that, the warming episode that occurred in this area during the 20th century is not a unique phenomenon. Such warming events occurred repeatedly in the past period, for instance, in the 1820s, which is also confirmed by observations (Fig. 2), or around 1720.

For older paleoclimatic data, radiocarbon ages were transformed into calendar dates using the standard procedure described in [1].

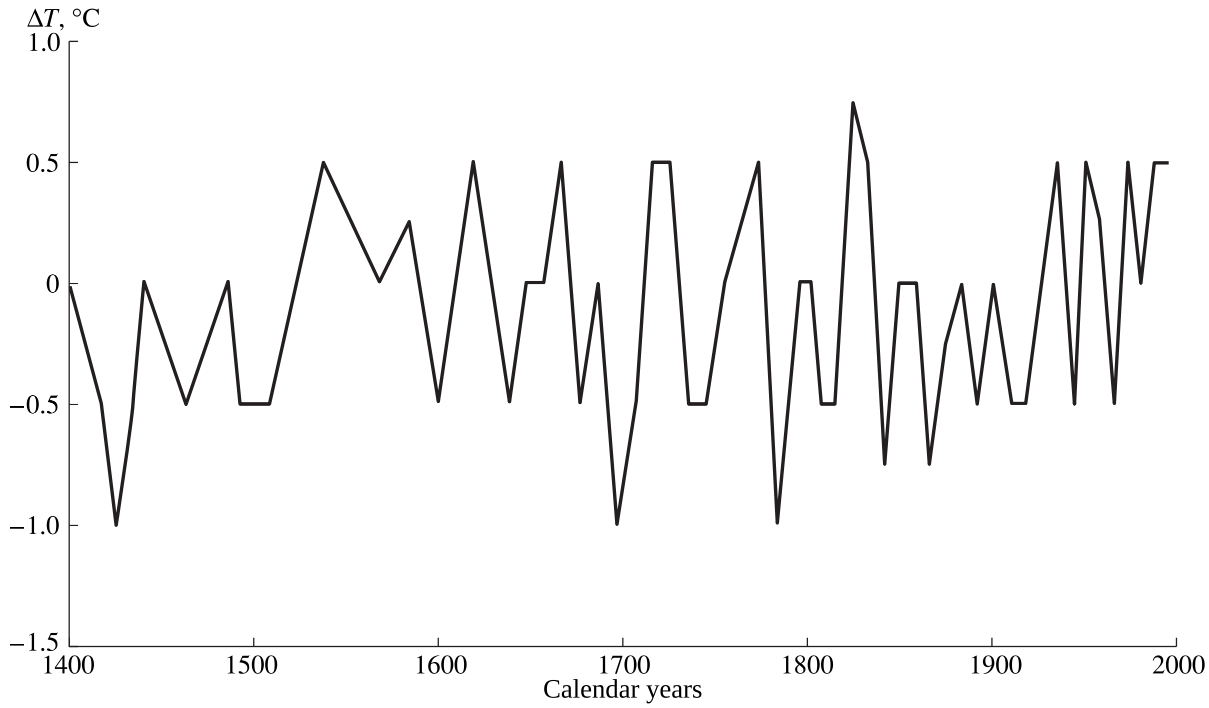

Fig. 3. Deviations of the average annual temperature from the 1951–1980 norm for the study area during the last 600 years.

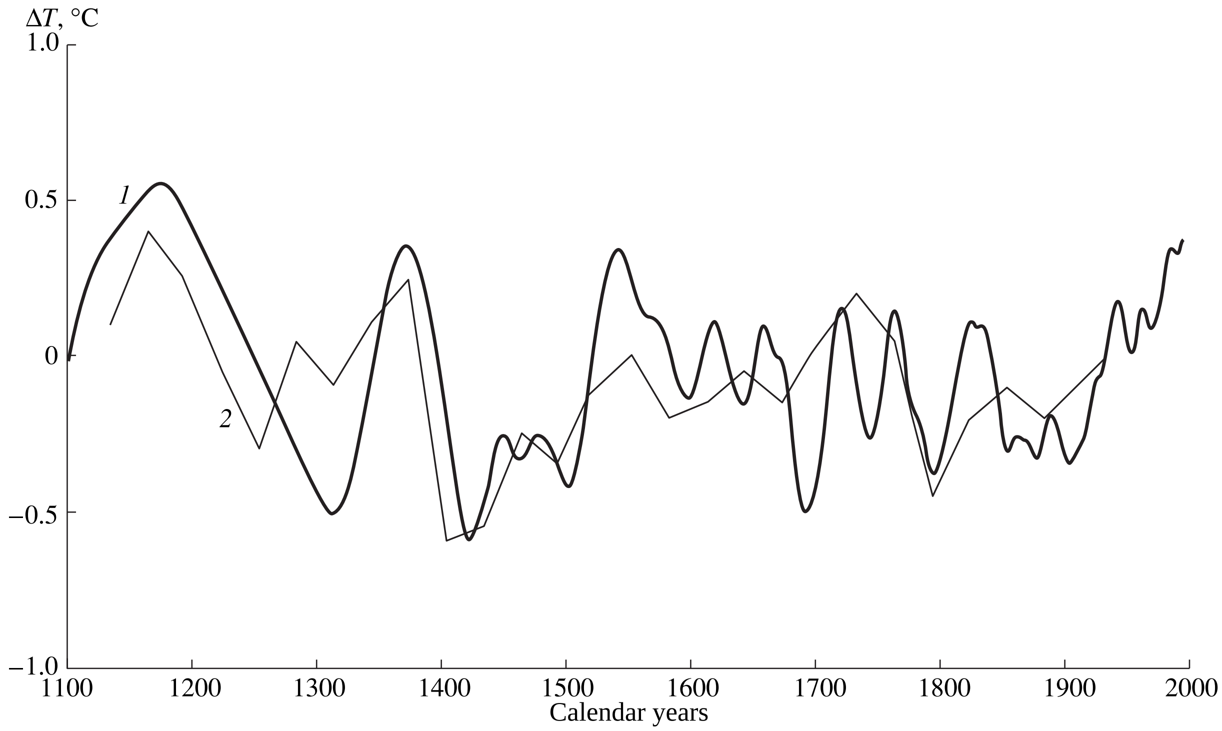

Fig. 4. Comparison between deviations of the (*1*) average annual temperature (300-yr moving averages) and (*2*) historical data (after [2]).

Comparison of palynological data for the last 900 years with historical dates available for northwestern Eastern Europe [2] (Fig. 4) reveals an excellent correspondence. Moreover, both the dates of climatic optimums and their amplitudes coincide. It is noteworthy that during the last millennium, all even centuries in the considered region were warmer compared to the uneven ones. This indicates a distinct, approximately 200-yr-long climatic rhythm closely related, in our opinion, to variations in solar activity [10].

ACKNOWLEDGMENTS

The work was supported by the Open Society Foundation (grant RSS no. 890/1997). V.V. Klimenko also expresses his gratitude to the Alexander von Humbolt Foundation for its assistance.

REFERENCES

1. Stuiver, M. and Reimer, P., *Radiocarbon*, 1993, vol. 35, no. 1, pp. 215–230.
2. Voronov, A.M., *Vodn. Resursy*, 1992, no. 4, pp. 97–105.
3. Khotinskii, N.A., *Golotsen Severnoi Evrazii* (The Holocene in Northern Eurasia), Moscow: Nauka, 1977.
4. Arslanov, Kh.A. *et al.*, *Radiocarbon*, 1999, vol. 41, no. 1, pp. 25–45.
5. Röthlisberger, F., *10 000 Jahre Gletschergeschichte der Erde*, Aarau, 1986.
6. Andrews, J.T., Davis, P.T., *et al.*, *Nature*, 1981, vol. 289, no. 5794, pp. 164–167.
7. Klimanov, V.A., Koff, T.A., and Punning, Ya.M., *Izotopno-geokhimicheskie issledovaniya v Pribaltike i Belorussii* (Isotopic and Geochemical Studies in the Baltic Region and Belorussia), Tallinn, 1986, pp. 117–129.
8. Klimanov, V.A., *Byull. Mosk. O–va Ispyt. Prir., Otd. Geol.*, 1994, vol. 69, issue 1, pp. 58–62.
9. Klimanov, V.A., *Paleoklimaty pozdnelednikov'ya i golotsena* (Paleoclimates of the Late Glaciation and Holocene), Moscow: Nauka, 1989, pp. 29–33.
10. Mikushina, O.V., Klimenko, V.V., and Dovgalyuk, V.V., *Astron. Astrophys. Trans.*, 1997, vol. 12, no. 4, pp. 315–326.