Variability of seasonal characteristics of climate in Siberia during the twentieth century

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This paper continues analysis of the intrasecular variability of hydrometeorological measurement series for Western Siberia. The emphasis is on the climatic variability of the seasonal values of temperature, precipitation, and circulation index. Seasonal climatic characteristics have some specific features. For example, the most pronounced warming of the climate occurred in winter and spring in the south. The fall season drops out of the overall picture of a positive trend. The overall picture of the behavior of precipitation remains the same as for the annual behavior: increase for northern regions and decrease for southern regions, except for the summer season when there is no a distinct trend.

In accordance with the data of the World Meteorological Organization (WMO), the global Earth's temperature has increased by 0.5°C for the last 135 years. The temperature rise has taken place during two periods: 30-year period from 1910 to 1940 and the last 15 years. The positive anomalies are observed in the lower troposphere, while the stratosphere continues to cool down. These facts correspond to the model estimates the greenhouse effect. Now it is well understood that this can lead to the change of the Earth's radiative budget and the further increase of the global surface temperature. By the model estimates, if warming keeps up the pace, then the global temperature will increase by 1.0–1.5°C by the end of the XX century and by 3–4°C during the first half of the XXI century.

A regional distribution of this warming, which is a response to a larger-scale climate change, is hard to predict so far because of the complexity of the climatic system.

This problem is so urgent that investigations have been carrying out since 1979 under the auspices of the WMO. Of particular importance in this regard is development of investigations aimed at detection of regional responses to climate change on a larger scale.

In Western Siberia investigations in this field were made over the period from 1993 to 1995. Based on the analysis of measurement series on temperature, precipitation, and river runoff, changes of regional climate were evaluated over the entire set of considered problems (Refs. 1, 2, 3, 5, 6).

The aim of this research is to analyze in depth the behavior of climatic series using the data of measurement stations of Western Siberia for the last 100 years, to coordinate the climatic changes with the peculiarities of circulation in the Northern Hemisphere, and to reveal regularities.

Data

For climatic analysis, we used the data on the monthly mean temperature, net monthly precipitation, and circulation parameters for the period from 1901 to 1996.

The monthly mean temperature and the net monthly precipitation were measured at the following stations of Western Siberia:

– northern territories: Salekhard, Khanty-Mansiisk, Tarko-Sale, Surgut, Tobol'sk, Aleksandrovo, Kolpashevo;

– southern territories: Omsk, Tomsk, Novosibirsk, Barabinsk, Kemerovo, Barnaul.

Besides, for analysis we used a series of observations of the Wangenheim – Girs circulation indices as well as the data on the number of days with Whittles anticyclonic circulation in the third region (the northern part of Western Siberia) and the eighth region (the southern part of Western Siberia together with the northern part of Kazakhstan).

According to the WMO resolution, the concept of climate implies a 30-year period of averaging. The three periods of averaging, namely, 1901–1930, 1931–1960, and 1960 until now are universally accepted. The climatic data are those obtained during the period of 1961–1990. For our analysis we used the values averaged 30 years by moving averaging.

Analysis of surface air temperature

The temperature (climate) smoothed over 30 years separately for the northern and southern parts of Siberia is shown in Figs. 1*a*–*d*.

On the annual scale of averaging, the climate of the southern part of Western Siberia got warmer by 0.9°C.[2] The highest rise in temperature is observed in

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the spring and winter seasons: by 1.6°C and 1.0°C, respectively (Figs. 1*a* and *b*). The 0.5°C rise is observed in summer and fall.

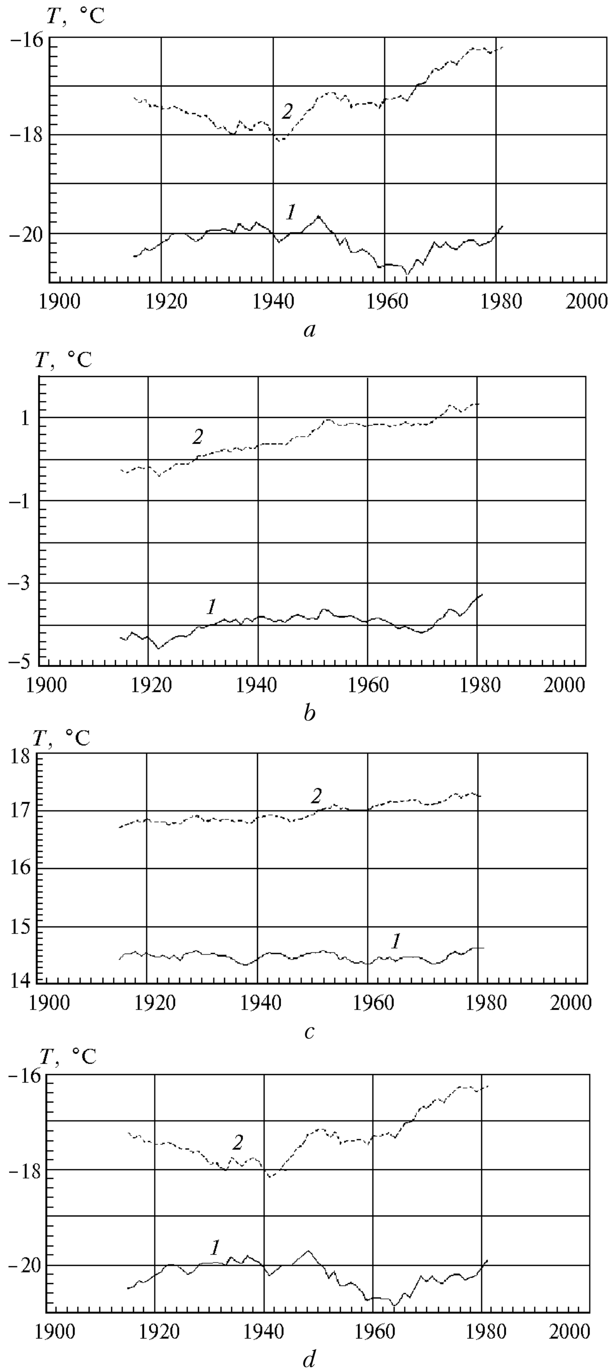

Fig. 1. Regionally mean air temperature smoothed over 30 years (1901–1996): winter (*a*), spring (*b*), summer (*c*), and fall (*d*). Curve *1* corresponds to the northern part of Western Siberia, and curve *2* corresponds to the southern part of Western Siberia.

As to the northern part of the Siberian territory, the annual trend is not so pronounced. The rise in temperature was observed during two periods: in 1910–1940 (slight increase) and in the last 20 years (marked rise of temperature) (see Fig. 1*a*). A positive trend of temperature (by 1°C) is most clearly seen in the spring season, as in the southern part of the territory. However, in spite of the overall positive trend, in some periods the classical picture of the positive trend was broken (for example, in cold winters of 1965–1975).

It should be noted that the fall season drops out of the overall picture (see Fig. 1*d*).

Thus, as far as concerned the surface air temperature, we can conclude that the climate of Western Siberia got warmer. Warming is more pronounced in the southern part of the territory than in the northern part. The principal contribution to climate warming is made by the winter and spring seasons.

Climatic variability of atmospheric precipitation

The technique of processing of data series for atmospheric precipitation is the same as for the temperature. We calculated regionally mean total precipitation smoothed over 30 years. The northern and southern parts of the territory were considered separately. The annual and seasonal precipitations smoothed over 30 years are shown in Figs. 2*a*–*d*.

First of all, it should be noted that the pattern of moisture variation is different in the northern and southern parts of the territory. In the north, the annual precipitation increases, on the average, by 60 mm, while in the south it, on the contrary, decreases by 50 mm (Ref. 2).

However, it should be noted that these trends are clearly seen up to 1980; for the last 15 years the increase of precipitation in the north and the decrease in the south have been stopped. In the last 15 years, the atmospheric precipitation in the north is within the normal range, and even a slight growth is observed in the south.

Let us now consider the behavior of the net precipitation for every season.

Winter. The regionally mean net precipitation smoothed over 30 years for the winter period is shown in Fig. 2*a*. The overall picture of the behavior of precipitation during the winter period is similar to the annual picture but more pronounced. Curve *1* in Fig. 2*a* indicates that in the northern part of Western Siberia the climatic norm of winter precipitation increased during the studied period from 62 mm to 77 mm, i.e., by 15 mm for a season. In the southern part, the climatic norm decreased until the 1950's and then became to grow.

Spring. Although the spring precipitation in the north and in the south follows roughly the behavior of the annual precipitation, there are no distinct trends in the overall picture. Thus, in the northern part of the territory, the period of 1940–1964 stands out, because during it the climatic norms decreased, although being higher than the mean ones calculated for the entire observation period.

Summer. Trends in the overall picture are absent (Fig. 2*c*). In the northern part of the territory, the climatic norms increased until 1960, then they decreased a little, and since 1976 they have remained almost unchanged. In the southern part, the growth of the climatic norms is observed until 1946, then they decreased until 1976, and since 1976 they acquired the tendency to increase.

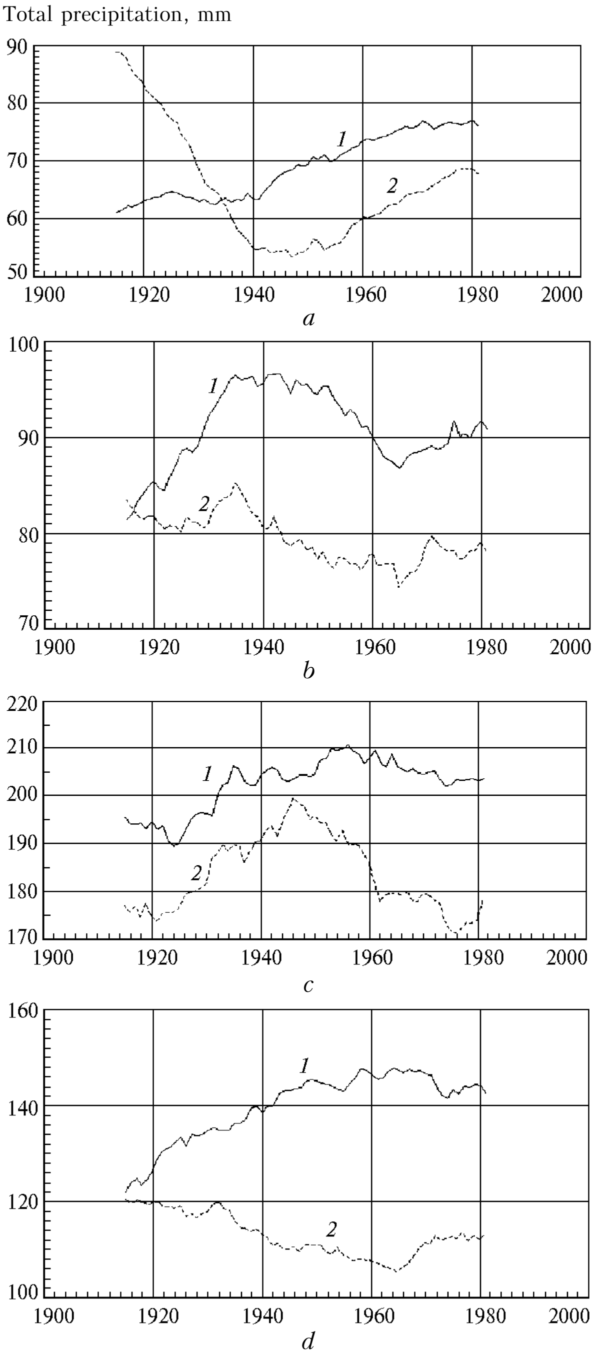

Fig. 2. Regionally mean net precipitation smoothed over 30 years (1901–1996): winter (*a*), spring (*b*), summer (*c*), and fall (*d*). Curve *1* corresponds to the northern part of Western Siberia, and curve *2* corresponds to the southern part of Western Siberia.

Fall. The overall picture follows the annual behavior. The positive trend is observed in the northern part. In the south, the 30-year mean values decreased until 1964, then grew, and stabilized (Fig. 2*d*).

Basic conclusions on the behavior of precipitation during the 100-year period: the precipitation increased in the northern part of Western Siberia; in the southern part, the precipitation decreased until 1980, and after 1980 it stabilized and even increased in winter and summer.

Analysis of circulation

On the whole for the considered period, the number of days with anticyclonic circulation decreased by 20 days an year in both the northern and southern parts of the territory (see Table 1).

Table 1. Number of days with anticyclonic circulation

Region	Year	Winter	Spring	Summer	Fall
8th (southern part of Siberia)	235 – 215 (– 20)	69 – 62 (– 7)	65 – 58 (– 7)	42 – 42 0	62 – 56 (–6)
3rd (northern part of Siberia)	135 – 115 (– 20)	35 – 28 (– 7)	38 – 30 (– 8)	39 – 37 (– 2)	26 – 24 (– 3)

Note. The first number is the number of days with anticyclonic circulation occurred early in the 20th century. The second number is that for the last 30 years of averaging (1967–1996).

It is seen from Table 1 that the number of days with anticyclonic circulation decreased both in the north and in the south of the considered territory, on the average, by 20 days per year. The largest change (7–8 days) is observed in winter and spring seasons. In summer the number of days with anticyclonic circulation is practically unchanged. In fall the change (6 days) is more significant in the south than in the north (3 days). The integral curves in Fig. 2 completely confirm these conclusions.

Intrasecular variability of number of days with circulation W, E, and C

The Wangenheim–Girs indices of circulation (W, E, and C) describe, to sufficient degree, the direction of air flow at high altitude and the trajectories of motion of baric formations near the ground in the first synoptic region (Western Siberia, Western Europe, European part of the CIS).

At the western (W) circulation, rapidly shifting small-amplitude waves are observed in the atmospheric thickness. Large-amplitude quasi-stationary waves correspond to meridional circulation: east (E) and meridional (C). At the east circulation, a wedge is over the European part of the CIS (30–60°E), and an upper trough is over the territory of Western Siberia.

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At processes of the circulation E and C, the trajectories of surface baric formations, depending on the direction of a leading flow at high altitudes, acquire a significant meridional component. This essentially differs them from processes of circulation W.

At the processes E, cyclones are shifted toward high latitudes in the regions to the west from the wedge axis and "dive" to the south in the regions to the east from upper wedges.

Jet flows bend around wedges from the north and troughs from the south. Therefore, the active cyclonic activity is different at the places with upper wedges in northern latitudes and at the places with upper troughs in southern latitudes. Just at these places fronts sharpen.

Table 2 shows the annual and seasonal distribution of the number of days with different circulation early and late in the twentieth century.

Table 2. Number of days with different circulation (annual and seasonal distribution)

Circulation index	Year	Winter	Spring	Summer	Fall
W	144 – 89 (– 55)	35 – 24 (– 8)	29 – 18 (– 11)	40 – 17 (– 23)	42 – 29 (– 13)
E	134 – 193 (+ 59)	39 – 43 (+ 4)	38 – 54 (+ 16)	22 – 53 (+ 31)	34 – 42 (+ 8)
C	85 – 81 (– 4)	16 – 20 (+ 4)	25 – 20 (– 5)	30 – 22 (– 8)	15 – 20 (+ 5)

Note. The first number is the number of days with anticyclonic circulation observed early in the twentieth century. The second number is that obtained for the last 30-year period of averaging (1967 to 1996).

The data of Table 2 indicate that for the twentieth century the atmosphere became more meridional according to the Wangenheim – Girs classification. The number of days with circulation W decreased by 55 days an year, and that of days with the meridional circulation E increased by 59, i.e., we observe the tendency of stabilization of the upper wedge over the European part of the CIS and the upper trough over Western Siberia.

The increase of the number of days with circulation E is most pronounced in the spring and summer seasons, namely, by 16 and 31 days, respectively.

The data of Table 2 were obtained during the entire considered period, i.e., from 1901 to 1996. However, if we consider the behavior of circulation in time, it should be noted that the decrease of the number of days with circulation W and the corresponding increase of the number of days with circulation E ceased. In 1984 the tendency to the increase of the west transfer appeared, which is especially marked in the winter season.

References

1. V.I. Kuzin, V.U. Krupchatnikov, and A.A. Fomenko, Atmos. Oceanic Opt. **11**, No. 6, 482–4866 (1998).
2. G.M. Vinogradova, N.N. Zavalishin, V.I. Kuzin, and P.Yu. Pushistov, Atmos. Oceanic Opt. **12**, No. 6, 475–479 (1999).
3. N.A. Bagrov, K.V. Kondratovich, D.A. Ped, and A.I. Ugryumov *Long-term Meteorological Forecasts* (Gidrometeoizdat, Leningrad, 1985), 248 pp.
4. A.A. Girs and K.V. Kondratovich, *Methods of Long-term Weather Forecasting* (Gidrometeoizdat, Leningrad, 1978), 342 pp.
5. N.N. Zavalishin, Trudy ZapsibNIGMI, issue 101, 22 (1995).
6. V.V. Kostyukov, A.A. Lezhenin, V.M. Toporov, and M.I. Chernikova, Agroresursy, `85 (1997).