Long-term variations in the atmospheric circulation and climate over Siberia

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Long-term variations of circulation and temperature regime in the atmosphere over Siberia have been studied against the background of the global climate variations. General atmospheric circulation is presented by B.L. Dzerdzeevskii typification. It is shown that the intensification of cyclogenesis above Arctic in the second half of the 20th century is accompanied by an increase of temperature in the Northern hemisphere, especially, starting from the 80s. The change of atmospheric processes in the Arctic manifests itself in variations of the regional climate as well. In the past decade, most noticeable growth of the near ground air temperature is observed in winter.

Introduction

At present, much attention is paid to the problem of climate changes. The data of observations in recent decades have revealed a growth of the globally mean surface air temperature, as well as the mean temperature in both hemispheres and in the majority of big regions overland.[1] The results obtained in Ref. 2 allow us to assume that one of possible causes of the global warming can be variation in the general atmospheric circulation (GAC).

Different typifications of atmospheric processes, along with the circulation indices, can be a helpful tool in investigating the long-term variations in GAC. Although this method is only rarely used, it possesses certain advantages over the traditional ways of analyzing averaged meteorological fields. First, it is much easier to analyze one complex characteristic of circulation (recurrence of macroprocesses), than a set of plots of meteorological elements in different geographical locations. Second, the use of typification of atmospheric processes makes it possible to reveal changes in the spatial structure of the circulation, when recurrence of the processes changes. This method is best developed for the Northern hemisphere.

To investigate the long-term variations in the atmospheric circulation on both the global and regional scales, we use typical Dzerdzeevskii schemes of elementary circulation mechanisms (ECM). Dzerdzeevskii typification has been developed with regard to directions of the mainstreams, the latter being in agreement with the position and orientation of the upper-level troughs and ridges. This system of typifying synoptic processes covers the whole hemisphere, is better detailed, and has clear morphological characteristics, which allow us to determine the periods of different circulation regimes more reliably.

In his system, Dzerdzeevskii has distinguished 13 main typical ECM schemes in the Northern hemisphere. By the extent of irregularity in the mid-latitude zonal transfer, the ECMs are divided into four groups: zonal group, break of zonality, meridional northern, and meridional southern group.

In their turn, the groups are divided into subtypes. The total number of subtypes is 41. However, with the same ECM, the character of atmospheric processes and the directions of the main transfer in different parts (sectors) of the hemisphere are different. To characterize the circulation, in each sector the same (41) schemes of the ECM designed for the whole hemisphere are used. They are divided into six groups by the characteristics that show the character of a macroprocess in the form it manifests itself in different parts of the hemisphere. Correctness of the ECM types was the subject of many investigations. It was established via tests that the probability that the successive change of an ECM is not random is rather high. For different sectors and seasons in the Northern hemisphere, it does not drop down below 95%.[3]

Results of analysis

The macrocirculation is characterized by zonal and meridional transfer in the atmosphere. Collecting the Dzerdzeevskii ECMs in zonal and meridional circulation groups allows us to distinguish among three long-term periods of different circulation. Early in the 20th century (until the end of the second decade) and in its second half the meridional circulation prevailed. In the interim, the role of zonal transfer is greater.[4] Along with this the research described in Ref. 5 has demonstrated that in the past decades, the uncertainty of circulation has grown up, which manifests itself in a more frequent changes of the types of atmospheric processes. This agrees with the changes in dynamics of the circulation index and in the behavior of the centers of atmospheric processes.[6,7]

To thoroughly investigate GAC at global warming, we used the calendar of the ECM type

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change composed at the Institute of Geography, RAS. To statistically characterize the time series of typical schemes, we used the frequency of occurrence of each process, which determines the structure of atmospheric circulation and gives a good understanding of the dynamics of temporal development of atmospheric processes.

Figure 1 illustrates changes in the occurrence of the 13th ECM and in the near-surface air temperature in winter and summer in the Northern hemisphere during the period from 1900 to 2002. The analysis performed shows that starting from the eighties, the circulation of the 13th type (polar cyclonicity) has become more intense both in summer and winter.

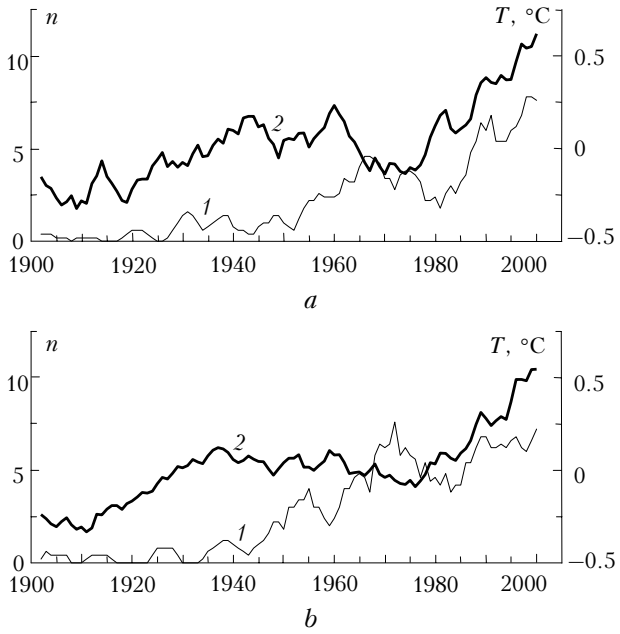

Fig. 1. Changes in the frequency of occurrence of the 13th ECM type (*1*) and in variations of the near-surface air temperature (*2*) in the Northern hemisphere in winter (*a*) and summer (*b*) during the period from 1900 to 2002 (a five-year sliding average).

The highest growth of the frequency of occurrence of the 13th ECM type is observed in winter. It is accompanied by the increase in the near-surface air temperature in the Northern hemisphere. In case of 13th ECM occurrence invasion of cyclones takes place from south in several directions. These cyclones reach the highest latitudes and can even cross the polar basin. As a result, in winter, we observe outbreak of southern air masses to a strongly cooled surface of mainland, which prevents any noticeable anomalies in the air temperature behavior.

Of a special interest are variations in the near-surface air temperature in the Northern hemisphere in the years from 1940 until 1970 known by a decrease in the global near-surface air temperature and a more frequent occurrence of the 13th ECM, i.e., cyclonic activity developed more intensely in high latitudes and, consequently, in winter air temperature must increase. A seeming contradiction vanishes in further analysis, which shows that the considered period is characterized by a more frequent occurrence of circulations of the 11th and 12th types, when invasions of polar anticyclones are more frequent (Fig. 2).

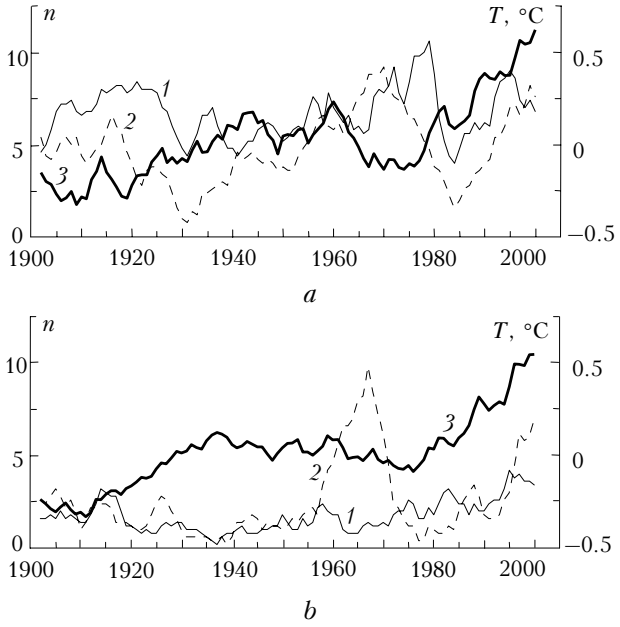

Fig. 2. Changes in the frequency of occurrence of the ECM types and near-surface air temperature in the Northern hemisphere in the period from 1900 to 2002: winter (*a*): occurrences of the 11th and 12th types of the ECM (*1*, *2*); deviations of the near-surface air temperature (*3*); summer (*b*): occurrence of the 9th and 12th ECM types (*1*, *2*); deviations of the near-surface air temperature (a five-year sliding average has been applied to all the curves).

In the case of occurrence of the eleventh ECM type (typical of winter periods) two strong high-pressure belts are formed in the North America and East Asia that integrate the winter continental centers of atmospheric influence and block the westerly air mass transfer. In this case, intense cyclonicity takes place over oceans. The twelfth type of the ECM forms under intensification of polar anticyclone, which gives rise to formation of an additional high-pressure belt over the East Atlantic and Pacific Ocean, or over one of them.

Analysis of the summer variations of GAC shows that starting from the eighties of the 20th century in the atmosphere the processes of the 9th and 12th ECM types prevail being accompanied by the growth of the near-surface air temperature over the hemisphere. In the case of occurrence of the ninth ECM type, two high-pressure belts develop over the Atlantic and Pacific Oceans. In both cases, they interlock with the ridges of subtropical anticyclones. The cyclones pass across Europe along the Far-Eastern coast of Asia and to the North America while anticyclones are being formed over the East Europe and Siberia.

In summer seasons from 1940 until 1970 the 13th type of circulation occurred more frequently, i.e., an intense development of cyclonic activity resulting in the decrease of the near-surface air temperature in the Northern hemisphere.

In the Arctic basin, changes in the atmospheric processes are expressed as variations of the local climate. Siberian sector (60–119°E) is located in the central part of Eurasia being very far from both the Atlantic and Pacific Oceans and thus it is in the zone of active climatic changes.[1] To estimate climatic variability in this region, we used daily mean data of the NCEP/NCAR reanalysis on air temperature and occurrence of the regional types of Dzerdzeevskii circulations for summer and winter for the period from 1950 to 2002.

The analysis performed shows that the regional variations in atmospheric circulation and air temperature are most pronounced in winter. The observed rise of air temperature occurs against the background of increased occurrence of zonal processes, during which the cyclones frequently move to the territory of Siberia (Fig. 3).

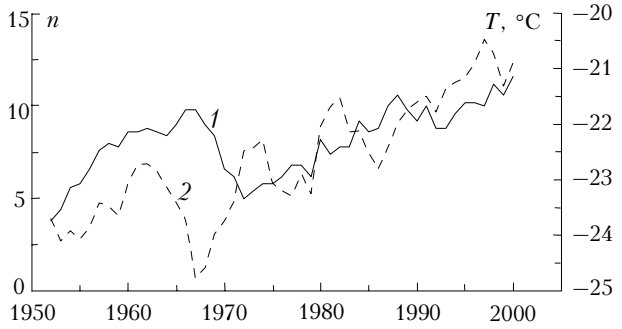

Fig. 3. Changes in frequency of occurrence of the groups of atmospheric circulation: the zonal western and stationary position (*1*) and monthly mean values of the near-surface air temperature in Siberian sector (60–119°E) (*2*) in winter for the period from 1950 until 2002 (a five-year sliding average).

The summer period is characterized by a lower variability of meteorological parameters, as compared to that in winter. It is worthy to be note that in recent years the tendency toward an increase in air temperature in summer has been observed, like in winter being perhaps caused by a more frequent occurrence of meridional circulation types.

Conclusion

The study of circulation peculiarities and long-term variations of air temperature has proved a growing instability of the atmospheric circulation, especially beginning from the eighties of the 20th century, manifested in the increased occurrence of the 13th ECM (polar cyclonicity) of the Dzerdzeevskii typification, which dominates over other circulation types in the Northern hemisphere. Most likely, the growth of the near-surface air temperature, especially in winter, against a steady anticyclone over the mainland is a consequence of this situation.

Most clearly climatic changes are observed in the Siberian sector, which is located at the point of interaction of northern and southern trends. A greater contribution of zonal processes in winter apparently results in the air temperature growth, and, as a consequence, in a weaker manifestation of the continental features in the climate of this region.

Acknowledgments

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