EARTH'S CRYOSPHERE
SCIENTIFIC JOURNAL

*Earth`s Cryosphere*, 2018, vol. XXII, No. 2, pp. 71–79 **http://earthcryosphere.ru/**

*ATMOSPHERIC PHENOMENA AND CLIMATE*

DOI: 10.21782/EC2541-9994-2018-2(71-79)

# THE CONTRIBUTION OF ANOMALOUS VALUES OF METEOROLOGICAL CHARACTERISTICS TO WINTER CLIMATE VARIABILITY IN NORTHERN EURASIA

**L.M. Kitaev**

*Institute of Geography, RAS, 29, Staromonetniy per., 109017, Moscow, Russia; lkitaev@mail.ru*

The spatial and temporal changes in the air temperature, precipitation and snow cover have been quantitatively illustrated for the main regions of northern Eurasia for the period of 1966–2011. Steady warming is registered widely, regional variability of precipitation and snow cover have low trend values – with the exception of the territory of the Russian Far East. Values of regional anomalies of the characteristics under study have been calculated and categorized. The contribution of the cumulative values of anomalies to the total variability of the amount of sample values has been defined for all the characteristics. As a result, statistical distribution of the property values and the type of long-term trends have been refined, particularly for cases with not significant coefficients of the linear trend. The largest contribution of the total values of air temperature anomalies has been observed for Western and Eastern Siberia, and the largest contribution of cumulative values of anomalies for precipitation and snow cover has been obtained for the region of Eastern Siberia and the Russian Far East.

*Air temperature, precipitation, snow storage, frequency of anomaly events, values of the anomalies, spatial and temporal variability*

## INTRODUCTION

The specific features of the meteorological regime of the cold period of the middle and high latitudes of Eurasia (primarily the surface air temperature, precipitation, and snow storage) account for shortage or excess of soil moisture, for extremely low or catastrophically high volumes of the spring floods, the condition of the biota and, hence, the character of the economic activities. Currently, the studies of the variability of climatic parameters are being conducted in many areas. Significant spatial variability of the surface albedo in the winter period related to landscape conditions and snow accumulation [*Kopanev, 1978; Kotlyakov, 2004; Rubinshtein et al., 2006; Kitaev and Titkova, 2011; Trofimova, 2014*] cannot but exert influence on the nature of heat and moisture exchange between the land surface and the atmosphere. Long-term rise of the surface air temperature causes variability of the snow cover parameters. In particular, dependence of the snow cover period on the character of warming and the specifics of atmospheric circulation have been revealed [*Popova and Polyakova, 2013*]; data on variability of the snow storage and of the snow cover depth over the recent decades due to regional inhomogeneity of the surface air temperature are shown in the works by A.N. Krenke [*Krenke et al., 2000, 2009*] and V.M. Kotlyakov [*Kotlyakov, 2004*]. During the second half of the 20$^{th}$ century, the regional trends of the increase in the share of liquid precipitation did not affect the variability of snow accumulation [*Kitaev et al., 2010*], and the limit of the snow storage growth due to climate warming has not yet been reached in most of the northern regions [*Kitaev et al., 2004; Krenke et al., 2009*]. Changes in the meteorological characteristics under modern conditions have ambiguous spatial and temporal manifestations – both positive and negative trends are possible, which do not agree in the local and regional scales [*Kitaev et al., 2002; Brown and Mote, 2009; Bulygina et al., 2011; Kitaev et al., 2012; Second Evaluative Report..., 2014*].

The above characteristics are well illustrated by mean values and the standard deviation of meteorological characteristics, and the contribution of their anomalous values to climate variability must also be considered. The main objective of this work is to reveal spatial-temporal meteorological characteristics and their contribution to formation of the climate of the winter period. The object of the study is the north of Eurasia within the borders of Russia for the period of 1966–2011.

## OBSERVATION DATA AND THE METHODS OF THEIR PROCESSING

The study is based on analysis of observation data from 800 meteorological stations of the Hydrometeorological Service of Russia for the period of 1966–2011 (http://meteo.ru): daily values of the surface air temperatures, precipitation, and snow storage based on the data of decadal traverse snow surveys. The technology of making regime observations by meteorological stations is regulated by respective rules [*Instructions..., 1985*]. Long-term variability of snow storage has been examined for the end of February in combination with variability of mean values of surface air temperature and precipitation in November–May. The specific features of the large physico-geographical regions of the north of Eurasia within the borders of Russia have been investigated by sectors – the Russian Plain (30–60° E), Western Siberia (60–90° E), Middle Siberia (90–125° E), Eastern Siberia and the Russian Far East (125–180° E). In the south, the territory was limited by the 50$^{th}$ parallel, as in the lower latitudes of Russia quantitative assessment of small values of the snow storage of plain territories and of the snow storage of alpine regions is not quite valid statistically.

Analysis was performed using standard methods of mathematical statistics and geoinformation technologies, for which the data from meteorological stations were recalculated into the nodes of a regular 1 × 1° grid, which allowed the use of long-term series of observation data without additional consideration of gaps in them. The interpolation method applied (kriging) is one of the kinds of generalized linear regression used for simulating surfaces, in the calculation of which standard deviation is minimized [*Baikov et al., 2010*]. The error of spatial averaging may reach 7–15 mm per year for precipitation [*Gruza et al., 2013*] and –0.007...–0.003 °C for surface air temperature of January [*Zhiltsova and Anisimov, 2009*]. For the snow storage of the Russian Plain, the error is taken not exceeding 10 mm [*Kislov et al., 2001*], for the other regions, it is 7–15 mm (it seems to be equal to the error for precipitation).

Table 1. **Variability of meteorological characteristics of the cold period (October–May)**

| Parameter | Surface air temperature, °C | Precipitation, mm | Snow storage, mm |
|---|---|---|---|
| *Russian Plain* | | | |
| Mean deviation | –8.7 | 142 | 92 |
| Standard deviation | 1.69 | 13.66 | 10.76 |
| Linear trend factor | 0.046 | *0.280* | *0.165* |
| *Western Siberia* | | | |
| Mean deviation | –16.6 | 108 | 107 |
| Standard deviation | 2.27 | 11.15 | 12.53 |
| Linear trend factor | 0.050 | *0.086* | *0.268* |
| *Middle Siberia* | | | |
| Mean deviation | –27.1 | 59.8 | 88.4 |
| Standard deviation | 1.90 | 5.23 | 10.13 |
| Linear trend factor | 0.047 | *0.045* | *0.149* |
| *Eastern Siberia and the Russian Far East* | | | |
| Mean deviation | –24.7 | 86 | 99 |
| Standard deviation | 1.25 | 13.79 | 15.52 |
| Linear trend factor | –0.054 | 0.487 | 0.549 |

Note. The figures in italics stand for the values of insignificant linear trend factors.

The main object of the study was winter anomalies of the surface air temperature, precipitation and snow storage. Characteristics are considered anomalous if they exceed a single and double value of standard deviation for long-term series with a remote trend.

## VARIABILITY OF METEOROLOGICAL CHARACTERISTICS

The results of investigating the variability of meteorological characteristics have been repeatedly published and summarized, in particular, in the Second Evaluative Report of Rosgidromet on Climate Changes... [*Second Evaluative Report..., 2014*]. Therefore, the information concerned is provided in brief – to illustrate the general situation with the climate of the recent decades. The values of meteorological characteristics which are mean for the regions considered and the standard deviation of the series of values correspond to the climatic features of the northern regions of Eurasia (Table 1). Significant regional coefficients of the linear trend are characteristic only of long-term variations of the surface air temperature: with the negative sign for Eastern Siberia and the Russian Far East (–0.054 °C/year) and with the positive sign for the remaining territory, with the maximum coefficient found for Western Siberia (0.050 °C/year).

The most significant long-term increment of the surface air temperature is observed in the northwest of the Russian Plain (Kola Peninsula, Karelia) and in the north of Western and Middle Siberia (the lower reaches of the Ob and Yenissei Rivers). Long-term reduction of the surface air temperature is characteristic of the northern regions of the Russian Far East and of the south of Western Siberia. Areas with significant precipitation and snow storage increment are situated in Western Siberia above the 60$^{th}$ parallel, in the territories of Chukotka and of the Kamchatka Peninsula, as well as in the lower reaches of the Amur River. Areas with a significant negative trend for snow storage are found in the center and in the north of Middle Siberia.

## DISTRIBUTION OF THE ANOMALIES OF METEOROLOGICAL CHARACTERISTICS

As already mentioned, values exceeding the single and double value of standard deviation are taken to be anomalous values in the behavior of surface air temperature, precipitation and snow storage (accord-

Table 2. **The manifestation rate of anomalous years**

| Region | Characteristic | Anomalies – single standard deviation | | Anomalies – double standard deviation | |
|---|---|---|---|---|---|
| | | Positive | Negative | Positive | Negative |
| Russian Plain | Surface air temperature, °C | 1971, 1981, 1983, 2004 | 1969, 1979, 1985, 1987, 1994, 1998 | 1983 | 1969, 1985 |
| | Precipitation, mm | 1966, 1968, 1976, 1977, 1985, 1987, 1993, 2000, 2003 | 1967, 1972, 1974, 1978, 1983, 1984, 1991, 2008 | 2003 | – |
| | Snow storage, mm | 1968, 1976, 1979, 1986, 1993, 1994, 1995, 2000 | 1969, 1972, 1975, 2003, 2009 | 1993 | 2003 |
| Western Siberia | Surface air temperature, °C | 1968, 1981, 1983, 1984, 1995, 2002, 2007 | 1969, 1977, 1985, 1993, 1998, 2001, 2010 | 1983 | 1969, 2010 |
| | Precipitation, mm | 1966, 1974, 1979, 1983, 1994, 2000, 2007, 2010 | 1967, 1969, 1971, 1972, 1984, 1987, 2003 | 1966 | 2003 |
| | Snow storage, mm | 1973, 1979, 1992, 1993, 1998, 2007 | 1968, 1986, 2000, 2003, 2010 | 1993 | 1992 |
| Middle Siberia | Surface air temperature, °C | 1968, 1976, 1984, 1989, 1992, 1995, 2002 | 1966, 1969, 1977, 1985, 2010 | 1989 | 1969, 2001 |
| | Precipitation, mm | 1974, 1978, 1982, 1991, 1993, 2007 | 1968, 1969, 1977, 1985, 1986, 1987, 1988, 2003 | – | 2003 |
| | Snow storage, mm | 1975, 1981, 1982, 1993, 2007 | 1966, 1977, 1985, 1986, 1987, 2003, 2010 | 2000 | 2003 |
| Eastern Siberia and the Russian Far East | Surface air temperature, °C | 1968, 1976, 1986, 1996, 2011 | 1966, 1983, 1998, 1999, 2000 | 1996, 2011 | 1982 |
| | Precipitation, mm | 1967, 1978, 1982, 1992, 1993, 2007 | 1966, 1977, 1984, 1985, 1986, 1987, 1988, 2003, 2010 | 1967, 1982 | 2003 |
| | Snow storage, mm | 1966, 1974, 1978, 1982, 1991, 2003, 2010 | 1977, 1984, 1986, 1987, 1988, 1992, 1996, 2006 | 1982, 2010 | – |

ingly, the mean value and the sum of values for November–February). To obtain them in the long-term course of characteristics, for each year, the values of the respective parameter were averaged for all the 1 × 1° cells of each region. Then for thus obtained long-term series (1966–2011), the values of the single and double standard deviation were calculated; to sum up, a sample of values exceeding that single and double standard deviation was taken (for positive and negative ranges of the characteristics' distribution). Table 2 demonstrates manifestations of anomalies, in which for each region anomalous years in the positive and negative ranges of values' distribution are indicated. The total number of anomalies is 5–9 cases (years), indicating 12–22 % of the total duration of the period under study.

The difference between the number of positive and negative anomalies reaches the maximum of three cases, thus not violating the symmetry in the characteristics' distribution. This may be illustrated by the asymmetry factor, which for the random value $X$ with $E[X] < \infty$ is set by the formula

$$\eta = \mu_3/\sigma^3,$$

where $\mu_3 = E\left[\left(X - EX^3\right)\right]$ is the central moment of the third order; $\sigma = \sqrt{D\left[X\right]}$ is the standard deviation. The asymmetry factor is positive, if the right distribution "tail" is longer than the left one, and is negative if the opposite is true. If the distribution is symmetrical in relation to the mathematical expectation, the asymmetry factor is equal to zero. Significance of the asymmetry factors was evaluated by calculating the mean-root-square error

$$\sigma_\eta = \sqrt{6(n-1)/\left((n-1)(n+1)\right)},$$

where $n$ is the number of the set members.

The ratio between the calculated asymmetry factors and their error does not exceed three in this case: $\eta/\sigma_\eta < 3$ (Table 3), and then the factors are considered insignificant [*Lukasevich, 1998*]. Thus, the distribution of the studied characteristics is normal, and all the statistical estimates, including analysis of anomalies, may be considered correct.

Table 3. **Regional values of the asymmetry factor values**

| Region | Surface air temperature, °C | Precipitation, mm | Snow storage, mm |
|---|---|---|---|
| Russian Plain | 0.205 | 0.282 | 0.375 |
| Western Siberia | 0.692 | –0.221 | 0.029 |
| Middle Siberia | 0.275 | 0.534 | 0.008 |
| Eastern Siberia and the Russian Far East | 0.430 | 0.630 | 1.066 |

## THE VALUES OF THE ANOMALIES OF METEOROLOGICAL CHARACTERISTICS

Revealing the cases of anomalies and their number in the positive and negative ranges of the distribution of values is important for illustrating the long-term variability of meteorological characteristics (Fig. 1). In this regard, determining specific anomalous values allows more precise presentation of the inter-annual variation of climatic conditions.

For all the anomalies, concrete values of the surface air temperature, precipitation and snow storage for the positive and negative distribution ranges have been obtained (Table 2). The long-term behavior of the values exceeding the standard deviation for the surface air temperature is shown in Fig. 2, *A*, for precipitation, in Fig. 2, *B*, and for snow storage, in Fig. 2, *C*. It can be seen from Fig. 2 that the numbers of anomalous cases in the positive and negative ranges of the samples do not match, and the sums of their values for the period under study differ, too. For instance, the ratio between the sum of positive values and the sum of negative values for the anomalies of the characteristics for the entire period is:

– The Russian Plain: for surface air temperature anomalies – 2.6, for precipitation anomalies – 0.9, for snow storage anomalies – 0.8;

– Western Siberia: for surface air temperature anomalies – 2.7, for precipitation anomalies – 1.2, for snow storage anomalies – 1.0;

– Middle Siberia: for surface air temperature anomalies – 1.5, for precipitation anomalies – 0.8, for snow storage anomalies – 0.4;

– Eastern Siberia and the Russian Far East: for surface air temperature anomalies – 0.7, for precipitation anomalies – 1.3, for snow storage anomalies – 1.6.

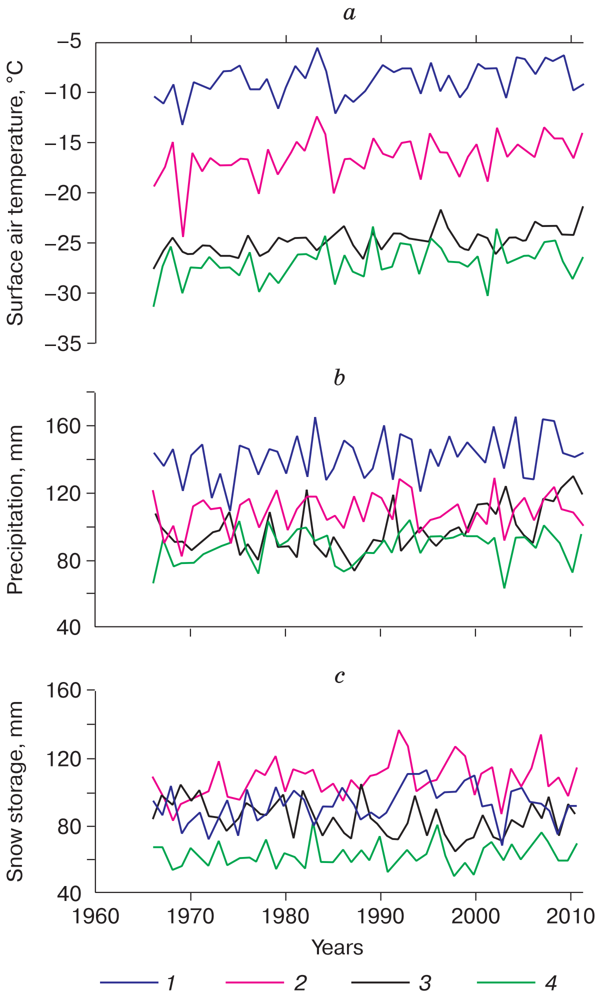


**Fig. 1. Long-term behavior of the surface air temperature (*a*), precipitation (*b*) and snow storage (*c*) in the territory of the Russian Plain (*1*), Western Siberia (*2*), Middle Siberia (*3*), Western Siberia and the Russian Far East (*4*).**

The values of the anomalies and their ratio in the negative and positive distribution ranges are a good qualitative indicator of the contribution of the extreme values to the inter-annual behavior of the values, which specifies the character of the long-term trends in climate changes. To take an example, regional warming is accompanied by essential prevalence of positive values of anomalies in the surface air temperatures over the negative ones (with asymmetry factors $\eta = 0.20–0.69$), except for Eastern Siberia and the Russian Far East, where the sum of negative values of temperature prevails, and the linear trend factor is significant and negative (with $\eta = -0.430$). The values of precipitation and snow storage anomalies on the Russian Plain and in Western Siberia are characterized by close to unity ratios between the sums of positive and negative anomalous values (for precipitation $\eta = 0.282$ and $-0.221$, for snow storage $\eta = 0.375$ and $-0.029$), which agrees with the linear trend factors significant here. In Middle Siberia, prevalence of the negative values of precipitation and snow storage anomalies is observed (with $\eta = 0.534$ and 0.008) also in the absence of significant trends in long-term variations. The territory of Eastern Siberia and of the Russian Far East is characterized by essential prevalence of positive values of precipitation and snow storage anomalies (with $\eta = -0.630$ and 1.066) in combination with significant positive factors of their linear trends.

The greater than 1.3 ratio between the positive and negative values of anomalies is typical of the cases with a positive asymmetry factor, and that less than 1.3 characterizes the cases with the negative asymmetry factor. The ratio equal to 1.3 is boundary in terms of the presence of significant and insignificant linear trends.

To illustrate the spatial distribution of the anomalous values of characteristics, for the time series with a remote trend of each 1 × 1° cell, the mean and standard deviations were calculated, the prevalence of the single value of standard deviation in the positive and

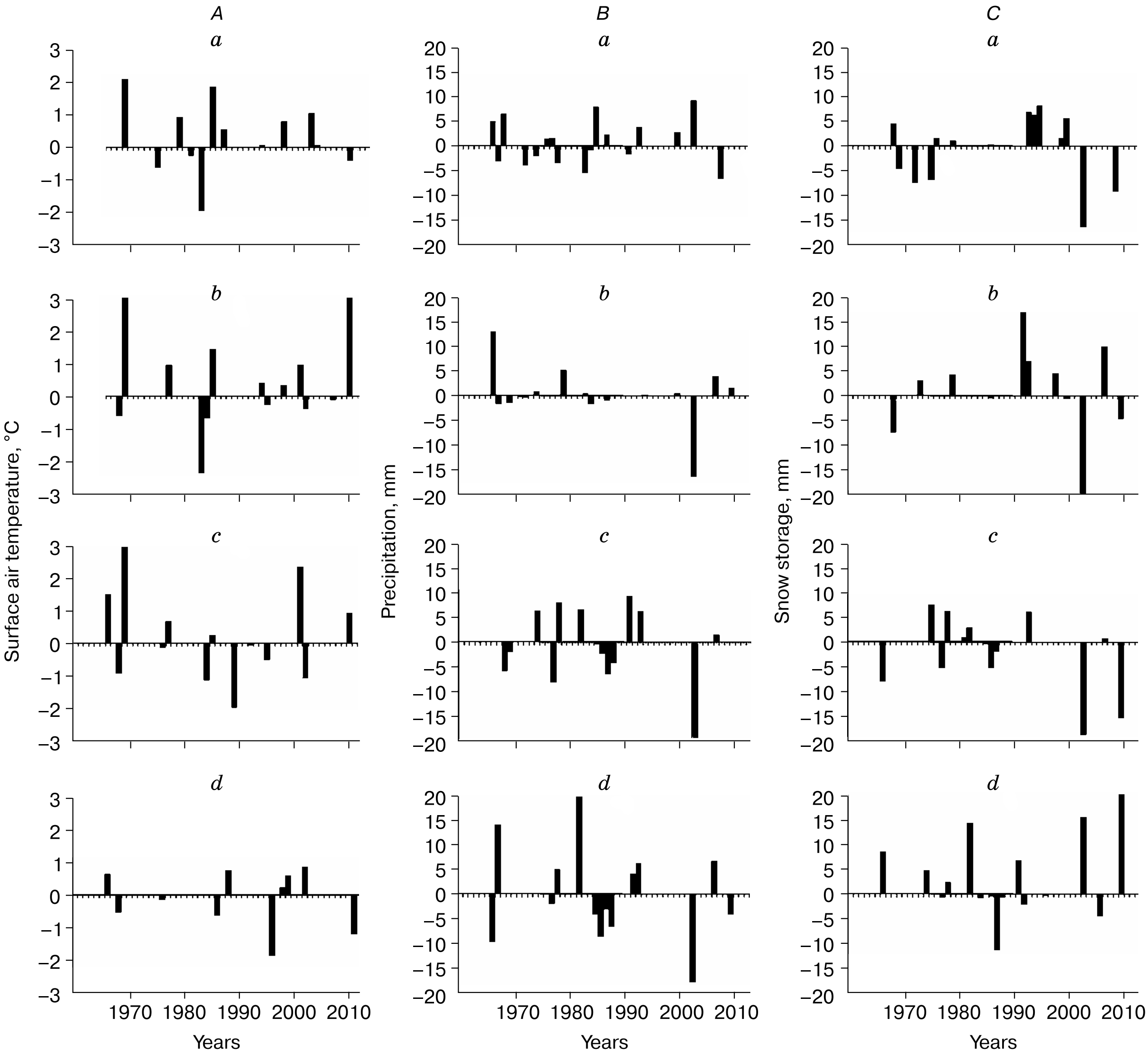


**Fig. 2. Long-term behavior of anomaly values:**

*A* – surface air temperature; *B* – precipitation; *C* – snow storage; *a* – the Russian Plain; *b* – Western Siberia; *c* – Middle Siberia; *d* – Eastern Siberia and the Russian Far East.

negative ranges of the sample was found, the values of which were summed for the period under study. Fig. 3 demonstrates the location of anomaly areas; the territories with the sums of anomalies greater than +20 °C and less than –20 °C for the surface air temperature, and the values exceeding the double value of standard deviation correspond to more than +200 mm and less than –200 mm for precipitation and snow storage.

The north of the Russian Plain, Eastern and Middle Siberia may be considered territories manifesting significant positive sums of anomalies in the surface air temperatures. Significant values of the sums of negative temperature anomalies are manifested in the Russian Far East. There are no essential positive and negative sums of precipitation and snow storage anomalies in Middle and Eastern Siberia. Significant positive anomalies in snow storage were observed in the west of the Russian Plain, in the north of Western Siberia and the Russian Far East, and negative anomalies were recorded in the east of the Russian Plain, in the south of Western Siberia and in the center of Siberia.

The contribution of anomalies to the trends in changes of the meteorological characteristics under study may be assessed by the ratio between the sum of

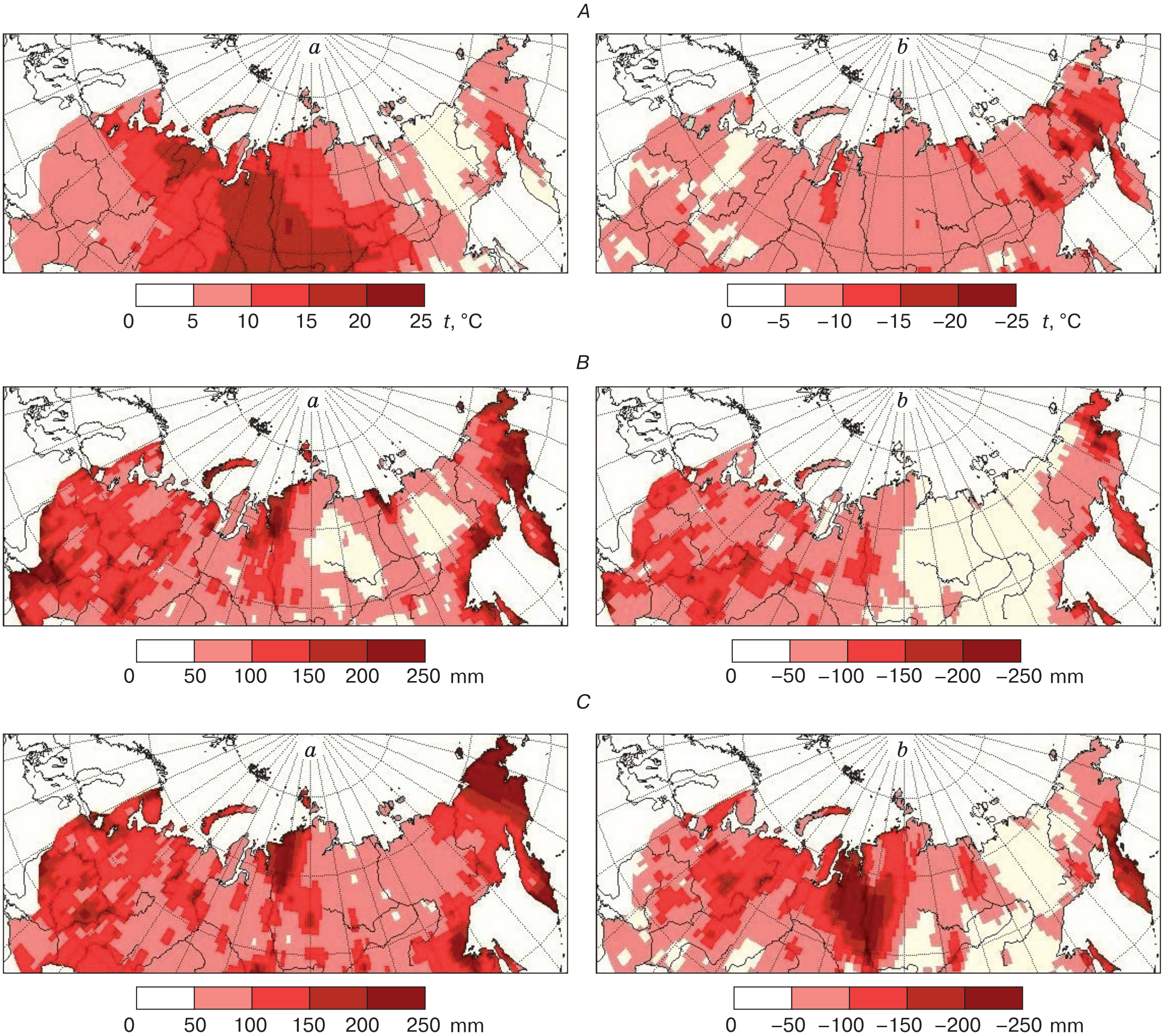


**Fig. 3. Spatial distribution of period-total (1966–2011) positive (*a*) and negative (*b*) anomaly values:**
*A* – surface air temperature; *B* – precipitation; *C* – snow storage.

their values and the sum of the values of these characteristics in the positive and negative distribution ranges for the entire period (Table 4). Thus, for the north of Eurasia, the total contribution of anomalies to the total sum of the sample values is the following:

– For the surface air temperature: 16–46 % in the positive distribution range and 10–26 % in the negative range;

– For precipitation: 20–26 % in the positive distribution range and 18–31 % in the negative range;

– For snow storage: 14–28 % in the positive distribution range and 17–31 % in the negative range.

The result obtained corresponds to the significant trend of climate warming observed over the recent decades: the contribution of positive anomalies to variability of the surface air temperature is nearly two times greater than that of negative anomalies. Essential excess of the negative total values of precipitation and snow storage values over the positive ones (also nearly double) allows certain adjustment of the trends of their change with insignificant linear trend factors (at least, in the negative distribution range the highest "activity" of extreme cases is manifested). The greatest contribution of the total values of anomalies to the mean values of the sample for the surface air temperature is characteristic of Western and Eastern Siberia, for precipitation and snow storage – for the territory of Eastern Siberia and the Russian Far East, primarily due to the situation in the Russian Far East (Fig. 3, *B*, *C*).

Table 4. **The contribution of anomalies to long-term values of meteorological characteristics**

| Distribution range | Contribution of anomalies (%) | | |
|---|---|---|---|
| | Surface air temperature, °C | Precipitation, mm | Snow storage, mm |
| *Russian Plain* | | | |
| Positive | 27 | 26 | 18 |
| Negative | 10 | 18 | 23 |
| *Western Siberia* | | | |
| Positive | 45 | 21 | 23 |
| Negative | 12 | 31 | 21 |
| *Middle Siberia* | | | |
| Positive | 46 | 20 | 14 |
| Negative | 19 | 26 | 31 |
| *Eastern Siberia and the Russian Far East* | | | |
| Positive | 16 | 24 | 28 |
| Negative | 26 | 19 | 17 |

In general, the spatial distribution of the sum of anomalies of the surface air temperature corresponds to zoning of the temperature based on the character if inter-annual variations conducted by *V.V. Popova* [*2009*]. The regions highlighted in the center of Siberia demonstrate an evident trend for warming, which is confirmed by the presence of significant temperature anomalies total for the period (Fig. 3, *A*). The absence of temperature anomalies is characteristic of the interfluve of the Lena River and the Kolyma River – here significant long-term trends in the behavior of the surface air temperature are not observed [*Popova, 2009*]. The western part of the Russian Plain may be considered “calm” from the viewpoint of manifestation of temperature anomalies: it is characterized by a relatively weak trend of long-tern variation in the temperature behavior [*Popova, 2009*].

Spatial distribution of the total anomalies of snow storage for the period also corresponds to their zoning in accordance with the regularities of inter-annual variability [*Popova et al., 2015*]. Yet, there are no significant anomalies in the Russian Far East (Fig. 3), nor are there any significant linear trend factors of the characteristics [*Kitaev et al., 2002; Bulygina et al., 2011; Second Evaluative Report…, 2014*]. The intensity of changes in the surface air temperature, precipitation and snow storage may be in this case related to changes in the PNA (Pacific North American Pattern) [*Van den Dool et al., 2000*]. Frequent occurrences of the negative phase in the pattern changes over the recent years account for the north-western transfer of air masses, accompanied by decrease in the air temperature, increase in precipitation and hence in snow storage. The results of spatial distribution of climatic anomalies in the Siberian mountains should be considered with some caution, as it is necessary to study the nature of climatic variations under conditions of a rugged terrain more thoroughly, considering that the laws of spatial interpolation for alpine regions may disagree with the approaches to interpolation for plain terrains [*Kislov and Surkova, 2009*].

Spatial distribution of the characteristic anomalies generally matches climatic zoning [*Popova, 2009; Second Evaluative Report…, 2014; Popova et al., 2015*], while climatic zoning, in its turn, is related to variability of atmospheric circulation indices; therefore we may suppose the character of atmospheric processes to be the determining factor in the emergence of anomalies. Thus, investigations may continue in the area of the search for the relation between the anomalies of meteorological characteristics and variability of atmospheric circulation.

## CONCLUSIONS

The particular features of spatial and temporal variations in the surface air temperature, precipitation and snow storage have been quantitatively illustrated for large physico-geographical regions of the north of Eurasia. The mean regional values and the standard deviation of the series of values of meteorological characteristics, as well as the long-term trends, correspond to the general climatic features of the territory in question [*Kitaev, 2006; Kitaev et al., 2006; Second Evaluative Report…, 2014*]. Stable warming has been recorded everywhere, the regional variability of precipitation and snow storage has insignificant linear trends, with the exception of the eastern part of Eastern Siberia and the Russian Far East.

Cases of anomaly manifestation have been revealed for the long-term series of the characteristics under study – their excess by single and double values of standard deviation. The number of anomalous years with excess by the single standard deviation is in the range of 5–9, or 12–22 % of the duration of the period in question. The cases of excess of the double value of standard deviation are few – not more than 3, or 6 % for each characteristic for the period in question. The calculated error of the sample asymmetry factor indicates that it is insignificant and that statistical distribution of the characteristics is close to normal, suggesting correctness of the performed statistical calculations.

For all the characteristics, regional values of the anomalies have been calculated – their period-total values for positive and negative distribution ranges. The regional ratios between the period-total values of anomalies and the negative values vary in all the characteristics in the range of 0.4–2.7. The ratio between the period-total positive and negative values of the characteristics by a factor of more than 1.3 is typical of the cases with the positive asymmetry factor, and that by a factor of less than 1.3 relates to the cases with the negative asymmetry factor. The ratio equal to 1.3 is boundary in terms of the presence of significant and insignificant linear trends. Thus, analysis of the total anomaly values may be useful for studying the distribution of the characteristics' values and for specifying the nature of the long-term trends, in particular, in the case of insignificant linear trend factors.

The contribution of the total anomaly values to the total variability of the sum of values in a sample is rather noticeable: for the surface air temperature – up to 46 % in the positive distribution range and up to 26 % in the negative distribution range; for precipitation and snow storage – up to 18 and 28 % in the positive distribution range of values and up to 31 % in the negative distribution range. The greatest contribution of the sums of anomaly values to the mean values of a sample of surface air temperatures is characteristic of Western and Eastern Siberia, and that for the samples of precipitation and snow storage is typical of Eastern Siberia and especially of the Russian Far East.

The proposed approach allows elucidation of the trends of changes in the meteorological characteristics, which is essential, in particular, for insignificant linear trend factors. In addition, in the actual values of the characteristics, regions have been indicated having the highest rate of anomaly manifestation. In the future, we plan to investigate the causes of anomaly emergence and to analyze their quantitative parameters.

*The work has been carried out with the support of program # 01482014-0015 for fundamental data research of RAS (statistical data analysis) and of project # 16-05-00753 A of the Russian Foundation for Basic Research (collecting and processing of primary data).*

## References

Baikov, V.A., Bakirov, N.K., Yakovlev, A.A., 2010. New approaches to the theory of geostatic simulation. Vestnik of UGATU (Ufa State Aviation Technical University) 14, No. 2 (37), 209–215.

Brown, R.D., Mote, P.W., 2009. The response of Northern Hemisphere snow cover to a changing Climate. J. Climate 22 (8), 2124–2145.

Bulygina, O., Groisman, P., Razuvaev, V., Korshunova, N., 2011. Changes in snow cover over Northern Eurasia since 1966. Environ. Research Letters 6, 2045–2051.

Gruza, G.V., Rankova, E.Y, Kleshchenko, L.K., Smirnov, V.D., 2013. On spatial averaging in climate monitoring problems. Problemy Ekologicheskogo Monitoringa i Modelirovaniya Ekosistem XXV, 42–71.

Instructions for Hydrometeorological Stations and Points, 1985, issue 3, part 1. Gidrometeoizdat, Leningrad, 299 pp. (in Russian)

Kislov, A.V., Kitaev, L.M., Konstantinov, I.S., 2001. The statistical structure of large-scale features of the snow cover field. Meteorologia i Gidrologia 8, 98–104.

Kislov, A.V., Surkova, G.V., 2009. Space-detailed climatic forecasting of air temperature and precipitation in Eastern Siberia on the basis of accounting for local features of the underlying surface. Meteorologia i Gidrologia 3, 43–51.

Kitaev, L.M., 2006. Relationship between seasonal changes of air temperature and snow cover in Northern Europe. Kriosfera Zemli X (3), 76–82.

Kitaev, L.M., Krenke, A.N., Titkova, T.B., 2004. Climatic conditions of snow accretion in Northern Eurasia. Led i Sneg 97 (4), 117–126.

Kitaev, L., Krenke, A., Konstantinov, I., Kislov, A., Razuvaev, V., Martuganov, R., 2002. The snow cover characteristics of Northern Eurasia and their relationship to climatic parameters. Boreal Environment Research 7 (4), 437–445.

Kitaev, L.M., Razuvaev, V.N., Heino, P., Førland, T., 2006. Duration of snow cover stay in Northern Europe. Meteorologia i Gidrologia 3, 95–100.

Kitaev, L.M., Titkova, T.B., 2011. Variability of the snow cover albedo – analysis of satellite data. Sovermennye Problemy Distantsionnogo Zondirovania Zemli iz Kosmosa (Modern Problems of Remote Sensing of the Earth from Outer Space) 8 (2), 47–54.

Kitaev, L.M., Titkova, T.B., Korobov, E.D., 2012. Variability of snow accumulation and air temperature variation due to changes in the local meteorological conditions, in: Perennial Processes in the Natural Complexes of Russia's Natural Preserves. Ed. by N.A. Potemkin and A.S. Zheltukhin. Velikiye Luki City Press, Velikiye Luki, pp. 19–26. (in Russian)

Kitaev, L.M., Trofimova, L.B., Komarovskaya, E.V., Danilovich, I.S., Bil'dyuk, A.A., 2010. Long-term variability of precipitation and snow cover formation of the East European plain. Kriosfera Zemli XIV (3), 77–81.

Kopanev, I.D., 1978. Snow Cover in the Territory of the USSR. Gidrometeoizdat, Leningrad, 181 pp. (in Russian)

Kotlyakov, V.M., 2004. The Earth's Snow Cover and Glaciers. Nauka, Moscow, 448 pp. (in Russian)

Krenke, A.N., Kitaev, L.M., Titkova, T.B., 2009. Evaluation of changes in the snow accumulation in the territory of Northern Eurasia at the beginning of the 21st century. Materialy Glyatsiologicheskikh Issled., Moscow, issue 107, 31–37.

Krenke, A.N., Razuvaev, V.N., Kitaev, L.M., Martuganov, R.A., Shakizjanov, R.I., 2000. Snowyness over FSU and its regions territory during the global warming. Kriosfera Zemli IV(4), 97–106.

Lukasevich, I.Ya., 1998. Analysis of Financial Transactions. UNITI, Moscow, 400 pp. (in Russian)

Popova, V.V., 2009. Current changes in the air temperature in Northern Eurasia: regional trends and the role of atmospheric circulation. Bulletin of the Russian Academy of Sciences, geography series, No. 6, 59–69.

Popova, V.V., Morozova, P.A., Titkova, T.B., Cherenkova, E.A., Kitaev, L.M., 2015. Regional features of present winter snow accumulation variability in the North Eurasia from data of observations, reanalysis and satellites. Led i Sneg 55 (4), 73–86.

Popova, V.V., Polyakova, I.A., 2013. Change of stable snow cover destruction dates in Northern Eurasia, 1936–2008: impact of global warming and the role of large-scale atmospheric circulation. Led i Sneg 53 (2), 29–39.

Rubinshtein, K.G., Gromov, S.S., Zoloeva, M.V., 2006. Dynamic classification of the snow cover. Vychslitelnye Tekhnologii 11 (57), 31–37.

Second Evaluative Report of Rosgidromet on Climate Changes and their Effects on the Territory of the Russian Federation, 2014. Rosgidromet, Moscow, 1008 pp. (in Russian)

Trofimova, E.B., 2014. Reflectance of snow cover, in: A University as a regional center of Education, Science, and Culture. Orenburg State University, Orenburg, pp. 1498–1500. (in Russian)

Van den Dool, H.M., Saha, S., Johansson, A., 2000. Empirical Orthogonal Teleconnections. J. Climate 13, 1421–1435.

Zhiltsova, E.L., Anisimov, O.A., 2009. On the accuracy of presentation of air temperature and precipitation in the territory of Russia by global climatic archives. Meteorologia i Gidrologia, No. 9, 66–74.

URL: http://www/meteo.ru (current content – 2017, submittal date: 25.10.2017).

*Received March 6, 2016*