Regional tendencies in air temperature at the southwestern Pribaikalie

O V Vasilenko¹, N N Voropay¹,²

¹Sochava Institute of Geography SB RAS, Russia, Irkutsk
²Institute of Monitoring of Climatic and Ecological Systems SB RAS, Russia, Tomsk

E-mail: oksa_na85@mail.ru, voropay_nn@mail.ru

Abstract. The regional features of long-term changes in air temperature at the south-western Baikal region on the background of global climate changes were studied. To estimate changes in air temperature in the basins of the south-western Pribaikalie, the long-term series of air temperature were used for the Tunka weather station. The correlation coefficients between the series of air temperature at the Tunka weather station and the temperature averaged for the temperate latitudes, the Northern Hemisphere, and the Globe were analyzed. Analysis of the variations in the anomalies of the mean annual temperature averaged for different zones, have shown a pronounced increase in the growth rate of the annual air temperature since the beginning of the 1970s for all the series of data. To estimate the relationship between the change in the surface air temperature in south-western Pribaikalie and large-scale atmospheric circulation mechanisms, correlation coefficients between the series of temperature and the characteristics of the atmospheric circulation have been calculated. The results of the analysis showed that the closest relationship between air temperature in the basins of the south-western Pribaikalie exists with the Scandinavian index (SCAND), the western type of atmospheric circulation of Wangengeym-Girs (W) in winter, the pressure in the center of the Siberian High in December.

1. Introduction

The current climate change is characterized by continuing warming, the main indicator of which is the near-surface air temperature, calculated as the average surface air temperature (at 2 m above the surface) over the continents and the water surface temperature of the ocean surface [1, 2].

According to the results of the Intergovernmental Panel on Climate Change (IPCC) from 1880 to 2012, the increase in global near-surface air temperature on the continents and oceans was 0.85°C (0.65 to 1.06°C). Since 1951, the rate of growth of surface air temperature was 0.12°C per 10 years (from 0.08 to 0.14), and for 1998-2012 it was only 0.05°C / 10 years (from 0.05 to 0.15). The slowdown in temperature growth was due to natural fluctuations in the climate system and can not serve as evidence of the cessation of the global warming [3].

It is known, that the change in the near-surface air temperature for the Northern Hemisphere in the XX and early XXI centuries was also not homogeneous. The anomaly of the mean annual near-surface temperature averaged for the Northern Hemisphere varied unevenly during the period 1850-2014 [4]. Until 1945, there was a temperature increase, then until 1970 the average annual air temperature of the...
Northern Hemisphere was lowered. Since 1970, the phase of active growth of near-surface air temperature has been observed, with a maximum (0.719°C) in 2005 \[5\]. The most intensive is considered warming, which began after 1976. At the same time, interest in research on the problem of climate change has grown \[6\].

A large number of works have been devoted to the analysis of the ongoing climate changes on the territory of Russia \[1, 4, 5, 7-11\]. According to the IPCC Fifth Assessment Report, climate change in Russia as a whole (on average for the year and for the territory) should be characterized as continuing warming, noting that the trend towards slowing down of warming is traced only in winter \[3\]. At the same time, many authors emphasize the very important role of the natural variability of the climate system over the decades, especially for individual regions.

2. Objects, data and methods
The territory of the southwestern Pribaikalye is represented by mountain-hollow landscapes. Local conditions are imposed on the zonal features of the climate of this region due to a combination of high-mountainous terrain and relatively low intermountain depressions, latitudinal orientation of the main orographic elements, regional peculiarities of the atmospheric circulation. In addition, the complex terrain and individual geomorphological conditions contribute to the formation of a unique microclimate of different landscapes, due to the interaction of the circulation and radiation factors and the properties of the underlying surface. The description of the main meteorological parameters and their changes is based on the data of meteorological stations located on the territory of the southwestern Pribaikalye. As it was shown, the data of the Tunka weather station are the most representative for the study area \[12\]. To assess the changes in air temperature in the basins of the south-western Baikal region, against the backdrop of current climate changes, long-term series of temperatures at the weather station Tunka \[13\]. In addition, the anomalies of the mean annual near-surface air temperature averaged for the globe, the Northern Hemisphere and the temperate latitude zone from 1888 to 2014 \[14\] were studied.

One of the leading climate-forming factors that affect the fluctuations of the regional climate is the large-scale mechanisms of atmospheric circulation. The connection between the circulation systems and the temperature regime of the Northern Hemisphere has been confirmed by many authors \[1, 4, 5, 15, 16\]. When the relationship between large-scale atmospheric circulation mechanisms and components of the climate system is identified, scientists use long-term series of atmospheric circulation indices that are linked to specific geographic sectors. According to the results of modern studies for the territory of Siberia, the most informative are the indices SCAND (Scandinavian Index), NAO (North Atlantic Oscillation Index), as well as the frequency of Wangenheim-Girs atmospheric circulation types (W - western, E - east, C - meridional) and elementary circulation mechanisms according to the classification of Dzerdzievsy. In addition, the Siberian anticyclone (Siberian High) has a significant influence on the climate of Eastern Siberia \[17-19\]. In the present paper, to determine the relationship of regional changes in the surface temperature in the south-western Pribaikalye with large-scale atmospheric circulation mechanisms, the monthly and annual values of the atmospheric circulation indices, the frequency of atmospheric circulation types according to the Wangenheim-Girs and Dzerdzievsy classifications, and the position of the center of the Siberian High were used. To estimate the relationship between the change in the surface air temperature of the basins of the southwestern Baikal region (according to the data of the Tunka weather station) and large-scale atmospheric circulation mechanisms, the coefficients of correlation between the series of temperature and the characteristics of the atmospheric circulation were studied.

3. Results and discussion
To estimate changes in air temperature in the basins of the south-western Pribaikalya, against the background of modern climate changes, long-term series of temperatures were used for the Tunka meteorological station. As it was shown, that the data of the Tunka weather station are the most representative for the investigated territory. Long-term changes in the temperature regime in the basin
area correspond to global trends in air temperature. The coefficient of correlation between the series of air temperature at the Tunka weather station and the temperature averaged for the temperate latitude zone (44-64 N) is 0.72, for the Northern Hemisphere is 0.65, for the globe is 0.49. Correlation coefficients are statistically significant (at p <0.05). When analyzing the graph of the variation in the anomalies of the mean annual temperature averaged for different zones, there is a pronounced increase in the growth rate of the average annual air temperature since the beginning of the 1970s for all the series of data (figure 1).

When analyzing trends in air temperature, special attention has been paid to the period since 1976, because during this interval the most intensive warming is observed. During the period of instrumental observations at the Tunka weather station, positive trends in temperature were noted during the whole period of observations (1939-2015 – 0.28°C/10 yr). During the period 1976-2015 trend of air temperature was higher (0.34°C/10 yr), than for the base period (1961-1990 – 0.08°C/10 yr) and for the whole period of instrumental observations (1939-2015), which is generally consistent with the global trends of long-term changes in air temperature.

In order to analyze the features of regional climate change on the territory of the Russian Federation we investigate the standard physiographic regions [20]. The territory of the southwestern Pribaikalie is a part of the Pribaikalie and Transbaikalia regions, the main area of the region is represented by the Altai-Sayan and Baikal Mountain countries. Comparison of the linear trend coefficients for 1976-2006 and 1976-2012 showed that the annual trend values on the territory of Russia have not changed. In the Baikal region and Transbaikalia and at Tunka station, the rate of increase in the average annual temperature became less (table 1).

| Table 1. The values of the linear trend coefficient (°C/10 years) of air temperature. |
|--------------------------------------|---------------------|---------------------|---------------------|---------------------|
|                                     | Winter 1976 – 2006  | Summer 1976 – 2012  | Year 1976 – 2012    | Year 1976 – 2012    |
| Russia                              | 0.35                | 0.52                | 0.41                | 0.43                |
| Pribaikal and Transbaikalie         | 0.39                | 0.66                | 0.58                | 0.21                |
| Weather station Tunka               | 0.74                | 0.59                | 0.29                | 0.46                |
|                                     | 1976 – 2012         |                     |                     |                     |
| Russia                              | 0.18                | 0.56                | 0.44                | 0.54                |
| Pribaikal and Transbaikalie         | 0.06                | 0.53                | 0.52                | 0.26                |
| Weather station Tunka               | 0.50                | 0.41                | 0.24                | 0.46                |

Note: significant coefficients of the linear trend are marked in bold (p <0.05).

Comparison of estimates of the linear trend coefficient over two periods (1976-2006 and 1976-2012) in the territory of the Russian Federation, Pribaikalie and Transbaikalie and the weather station Tunka showed that the annual trend values in the territory of the Russian Federation did not change. In
the region Pribaikalie and Transbaikalie and at the weather station Tunka, the rate of increase in the average annual temperature, taking into account recent years, become less. However, with the addition of the series for 6 years, the magnitude of the trend of air temperature in Russia in all seasons, except in winter, has increased. In the region Pribaikalie and Transbaikalie, the average annual temperature trend, with the addition of a series of observations for 6 years, became smaller (0.32°C/10 years). In addition, the trend for the winter period has significantly changed - the trend values have decreased to 0.06°C/10 years. In the other seasons of the year, the change is insignificant, mainly indicators have become lower, but still remained positive. The maximum rate of warming in the territory of the Russian Federation and in the region is observed in the spring. The values of the linear trend are 0.56°C/10 years in Russia and 0.53°C/10 years in the Pribaikalie and Transbaikalie region.

In the territory of the southwestern Baikal region, the values of the linear trend, with the addition of a time series of air temperatures for 6 years, as well as in the region, have changed in the smaller values. The rate of change in the average annual temperature from 1976 to 2006 were 0.52°C/10 years, for the period 1976 to 2012, the trend value is lower (0.43°C/10 years). According to the weather station Tunka data, the maximum values of the long-term trend are recorded in the winter period, and the minimum values are recorded in the summer. In the Pribaikalie and Transbaikalie region, as well as on the territory of the Russian Federation, the maximum trend values fall on the spring months.

Correlation coefficients between the series of temperature and the characteristics of atmospheric circulation have been calculated to estimate the relationship between the change in the surface air temperature and the southwestern Pribaikalie (according to the data of the Tunka weather station) and large-scale atmospheric circulation mechanisms (figure 2).

![Figure 2](image-url)

**Figure 2.** Correlation coefficients of mean monthly and mean annual air temperature values at the Tunka weather station and atmospheric circulation indices (NAO is the index of the North Atlantic Oscillation, SCAND is the Scandinavian index, PCA is the pressure in the center of the Siberian High, SLaWLoS, SLoN, SLaW are the elementary circulation mechanisms according to the Dzerziyevsky classification, W, E, C are the types of atmospheric circulation of Wangengeym-Girs, red line - a significance level for p < 0.05).
The results of the analysis showed that the closest relationship between air temperatures in the basins of the southwestern Pribaikaliya exists with the Scandinavian index (SCAND), the western type of atmospheric circulation of Wangengeym-Girs (W) in winter (table 2). The pressure in the center of the Siberian High in December (-0.41).

Table 2. Correlation coefficients between air temperature series at Tunka weather station and atmospheric circulation characteristics (1940-2014).

| Months | I   | II  | III  | IV  | V   | VI  | VII | VIII | IX  | X   | XI  | XII | Год |
|--------|-----|-----|------|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|
| SCAND  | -0.35 a | -0.25 a | -0.60 a | -0.41 a | -0.11 | -0.32 a | -0.09 | -0.19 | -0.35 a | -0.24 a | -0.57 a | -0.66 a | -0.49 a |
| W      | 0.37 a | 0.24 a | 0.40 a | 0.25 a | 0.21 | 0.01 | 0.11 | 0.13 | 0.30 a | 0.27 a | 0.30 a | 0.41 a | 0.41 a |

Note: Significant coefficients are marked in bold (p <0.05).

4. Conclusions

Thus, long-term changes in the air temperature of the basins of the southwestern Baikal region occur synchronously with the global changes. However, a high variety of types of underlying surface and a significant difference in the heights of the mountain-hollow landscape affect regional climate change. The winter months make the main contribution to the increase in the average annual air temperature in the basins of the south-western Pribaikaliya during the period from 1976 to 2012, while in the territory of the Russian Federation and the Pribaikaliya and Transbaikaliya region - spring and summer.

Circulation processes play a significant role in the formation of the climate of the basins of the southwestern Pribaikaliya, especially in the winter season, when the solar radiation incoming the territory is minimal. In the cold period of the year, the influence of Western transport on the territory of Eastern Siberia is weakened as a result of the formation of the Siberian anticyclone, which leads to a violation of zoning in the temperature distribution. The effect of global circulation, as a climate-forming factor, is manifested in air temperature relationships with SCAND index and the frequency of western circulation in the winter months. In addition, an increase in the linear trend coefficient of the average annual air temperature at the Tunka weather station from 1976 to 2012 is due to the temperature increase during the winter months, during the formation and development of the maximum capacity of the Siberian High. This may indicate the influence of the power of the Siberian anticyclone on the formation and trends in the thermal regime of the basins of the southwestern Pribaikaliya.

References

[1] Perevedentsev Y P, Vereshchagin M A, Naumov E P, Shantalinsky K M and Nikolaev A A 2005 Modern climate change in the Northern Hemisphere of the Earth Scientific Notes of Kazan State University 1 91-106

[2] Evaluation Report on Climate Change and its Consequences on the Territory of the Russian Federation: Climate change 2008 vol I (Moscow: Roshydromet) p 277

[3] Stocker T F, Qin D, Plattner G-K, Tignor M, Allen S K, Boschung J, Nauels A, Xia Y, Bex V and Midgley P M 2013 Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge: Cambridge University Press and NY, USA) p 1535

[4] Perevedentsev Yu P and Shantalinsky K M 2014 Estimation of current changes in air temperature and wind speed in the troposphere of the Northern Hemisphere Meteorology and hydrology 10 19-31

[5] Perevedentsev Y P, Wilfand R M and Shantalinsky K M 2016 Low-frequency changes in atmospheric pressure and near-surface air temperature in the extratropical latitudes of the Northern Hemisphere Proceedings of the Hydrometeorological Research Center of the Russian Federation 360 5-25
[6] Gruz V, Rankova E Ya and Rocheva E V 1989 Analysis of global data on changes in surface air temperature during the period of instrumental observations Meteorology and Hydrology 1 22-31

[7] Ippolitov I I, Kabanov M V, Komarov A I and Kuskov A I 2004 Modern natural and climatic changes in Siberia: the course of average annual surface temperatures and pressure Geography and Natural Resources 3 90-6

[8] Izrael Y A, Pavlov A V, Anokhin Y A, Ball L T and Sherstyukov B G 2006 Statistical estimates of the dynamics of changes in climate elements in permafrost areas on the territory of the Russian Federation Russian Meteorology and Hydrology 5 27-38

[9] Voropay N N and Kichigina N V 2018 Long-term changes in the hydroclimatic characteristics in the Baikal region IOP Conference Series: Earth and Environmental Science 107(1) 012042

[10] Voropay N N, Maksyutova E V and Riazanova A A 2016 Hydrothermal conditions at the south of East Siberia during the ongoing warming IOP Conference Series: Earth and Environmental Science 48 doi:10.1088/1755-1315/48/1/012003

[11] Ryazanova A A and Voropay N N 2017 Droughts and Excessive Moisture Events in Southern Siberia in the Late XXth - Early XXIst Centuries IOP Conference Series: Earth and Environmental Science 96(1)

[12] Vasilenko O V and Voropay N N 2015 Features of formation of the climate of the depressions of the southwestern Baikal region Izvestiya RAS, Geographic Series 2 104-11

[13] Bulygina O N, Veselov V M, Razuvaev V N and Aleksandrova T M 2014 Description of the array of urgent data on the main meteorological parameters at Russian stations Certificate of State Registration of the Database 2014620549 (in Russian) Income accessed online on 18th July 2018 via http://meteo.ru/data/163-basic-parameters#description of the mass-data

[14] Climatic Research Unit University of East Anglia (UK) 2017 Income accessed online on 10th May 2018 via https://crudata.uea.ac.uk/cru/data/temperature/HadCRUT4-nh.dat

[15] Groysman P Y 1983 About changing of some characteristics of atmospheric circulation in global warming and cooling processes Russian Meteorology and Hydrology 11 26-9

[16] Gorbatenko V P, Ippolitov I I, Kabanov M V, Loginov S V, Podnebesnykh N V and Kharyutkina E V 2011 Influence of atmospheric circulation on the temperature regime of Siberia Atmospheric and Ocean Optics 1 15-21

[17] Ippolitov I I, Kabanov M V, Loginov S V, Podnebesnykh N V and Kharyutkina E V 2012 Variability of the temperature regime in the Asian territory of Russia during the period of global warming Atmospheric and Ocean Optics 2 122-31

[18] Kabanov M V 2015 Regional climate-forming factors in western Siberia Geography and Natural Resources 3 107-13

[19] Borzenkova A V and Shmakin A B 2013 Modern changes of climate characteristics of heating period in Russia and their communication with the atmospheric circulation Izvestiya RAS, Geographic Series 4 59-69

[20] Second Assessment Report of Roshydromet on Climate Change and its Consequences on the Territory of the Russian Federation 2014 vol I (Moscow: Roshydromet) pp 18-235