ISSN: 0975-766X
CODEN: IJPTFI
Available Online through ***Research Article***
www.ijptonline.com

THE INTERANNUAL CHANGEABILITY OF ATMOSPHERIC PRESSURE AND NEAR-SURFACE AIR TEMPERATURE IN THE EXTRATROPICAL LATITUDES OF THE NORTHEN HEMISPHERE

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Received on 10-08-2016 *Accepted on 06-09-2016*

Abstract

The spatial and temporal changes of atmospheric pressure fields (P) and near-surface air temperature (T) in extratropical latitudes of the Northern Hemisphere (NH) over the period 1900-2014 are considered in the article.

For the estimation of reorganization in meteorological values in the latitudinal zone 20-90°N., it were determined the differences fields of atmospheric pressure and near-surface temperature, averaged according to the following time periods: 1900-1929, 1930-1959, 1960-1987, 1988-2000 for the pressure, and 1900-1929, 1930-1959, 1960-1987, 1988-2000 1988-2014 for the temperature. The degree of conformity between the obtained maps of differences was determined using the analogousness criterion ρ. It was found out that the greatest similarity between the differences fields was during the two adjacent periods 1988-2000 and 1988-2014. The long-term run of low-frequency components (LFC) of air temperature and atmospheric pressure at the atmosphere action centers (AAC) in the Volga Federal District was considered in the article. This has allowed to establish their antipodal character, specified by the influence of circulating factors. The climatic maps of air temperature and atmospheric pressure distribution in January and in July in the extratropical latitudes of the Northern Hemisphere (20-90°N) were constructed. The monitoring of air temperature and atmospheric pressure changing, averaged in the latitudinal zone 32,5-67,5°N in January, in July, and for the whole year during the period of 1900-2014 was carried out.

Keywords: atmospheric pressure, air temperature, differences of the average values, atmosphere action centers, low-frequency component.

Introduction

This article focuses on the analysis of spatial and temporal distribution of near-surface air temperature and atmospheric pressure during 1900-2014 in latitudinal zone 20-90 ° N in conditions of today's global warming.

Generalizing materials on climate changes are contained in works [1, 2] and other scientific journals. Of course, the issues related to the causes of climate change and the expected consequences for the environment and society, come to the fore. In particular, the works [3, 4] considered the question about existing alternative to the scenario of accelerating climate warming due to increased concentrations of greenhouse gases, where 180-year cycle of solar rotation around the solar system center of mass is considered as environmental loads to the climate system.

The role of natural factors in the current climate changes specified in works [5, 6], according to which during the winter period in temperate latitudes, powerful circulation processes, associated with the interaction of the ocean and the atmosphere, cause significant temperature fluctuations with scales from interannual to several decades, superimposing on the overall process of global warming and significantly altering its expression. Earlier studies of the authors [7, 8] also discuss the role of natural factors in the ongoing climate change.

Materials and Methods

As the raw materials, it were used the time series of near-surface air temperature and atmospheric pressure at the points of a regular latitude-longitude grid over the period 1900-2014, prepared by the Department of Climate Researches of the University of East Anglia (series CRU) [9, 10, 11]. The authors had data on air temperature during 1900-2014, and on atmospheric pressure over the period 1900-2000.

Due to the fact that the series CRU for the pressure ends in 2000, the research on the restoration of the pressure field to 2014 was conducted, using reanalysis data. This has been possible owing to the high correlation (r≈0.9) between considered series of atmospheric pressure.

At the beginning, long-term average values for January and July, over the specified period, were calculated in every grid point, as for the temperature (T), as for the pressure (P). Then the maps of distribution of average long-term P and T values were built, as for the whole period, and for shorter times: 1900-1929, 1930-1959, 1960-1987, 1988-2000 and 1988-2014. Then the differences maps were constructed by subtracting the data of the earlier period from the later period. The similarity of fields was determined both visually and according to the calculated analogousness criterion ρ .

Long-term fluctuations of air temperature and atmospheric pressure, obtained by smoothing the basic data, using the low-frequency filter of Potter were considered in the atmosphere action centers and on the territory of the Volga Federal District (VFD). In order to determine the general trend of air temperature and pressure changes in the temperate zone of the Northern Hemisphere (32,5-67,5°N) over the period 1900-2014, the basic data in the grid points were averaged across all the latitudinal zone for January, July and the whole year. Obtained time series were subjected to statistical analysis. In addition, they were smoothed, using the low-frequency filter of Potter to assess the long-period fluidity, i.e. the waves with a period of less than 20 years were filtered (Figure 1).

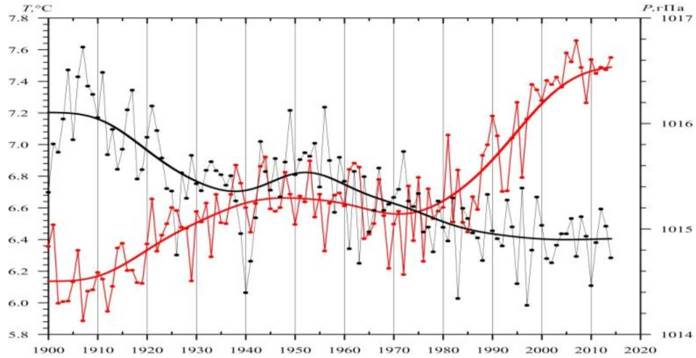

Fig. 1. The long-term run of the average annual values (basic data and low-frequency components with a period of more than 20 years) of the pressure, reduced to the sea level (black line) and near-surface air temperature (red line).

The spatial and temporal changes of atmospheric pressure and air temperature fields

The analysis of Figure 1 showed that the long-term run of average annual temperature (AAT) over the 115-year period (1900-2014) had some fluctuations. Thus, from 1900 to 1945, the temperature increase was observed by 0.52°C, and then average annual temperature gradually decreased to 1970 by 0,1°C, due to a slight cooling of the climate, and, since the beginning of the 1970s, there has been an active phase of warming. The temperature growth was about 0.9°C. At the same time, the curve of atmospheric pressure pointed to the falling tendency, except for a small period of 1935-1952, when it increased. Thus, over the periods 1900-1935 and 1975-2014 the antiphase run of atmospheric pressure and air temperature in the temperate latitude zone was observed, that indicated about increase of cyclone activity during the periods of climate warming in the early twentieth century and in recent decades, at the turn of XX-XXI centuries. In general, the similar principle was observed in January and July.

The maps of average temperature and near-surface pressure fields were built for January and July in the extra-tropical zone from 20°N to the North Pole, according to the previously calculated average values in the grids points over a long period (for the temperature from 1900 to 2014, for the pressure from 1900 to 2000).

The structure of the fields, shown on these maps is generally reproduced well-known climatic patterns of spatial distribution of considered meteorological values. In particular, the Icelandic and the Aleutian Lows, the Siberian High in January, the Honolulu and the Azores Highs, and an extensive Asian depression in July are notable in the climate pressure maps.

For the research of climate processes development over the period 1900-2014, we analyzed the differences of atmospheric pressure and near-surface air temperature during the selected periods. As can be seen from Figure 2, January during 1930-1959 was significantly warmer compared to 1900-1929 in the polar region, in the north of Eurasia ΔT reached 3 ° C, in the extreme north-east of Siberia in the region of Chukotka ΔT = 3-4 ° C. In the Western Hemisphere, on the territory of Greenland and the Canadian Archipelago, it was also noticeably warmer (by 2-3°C). However, in Europe and in most parts of the Asian continent, the temperature decreased by 1°C.

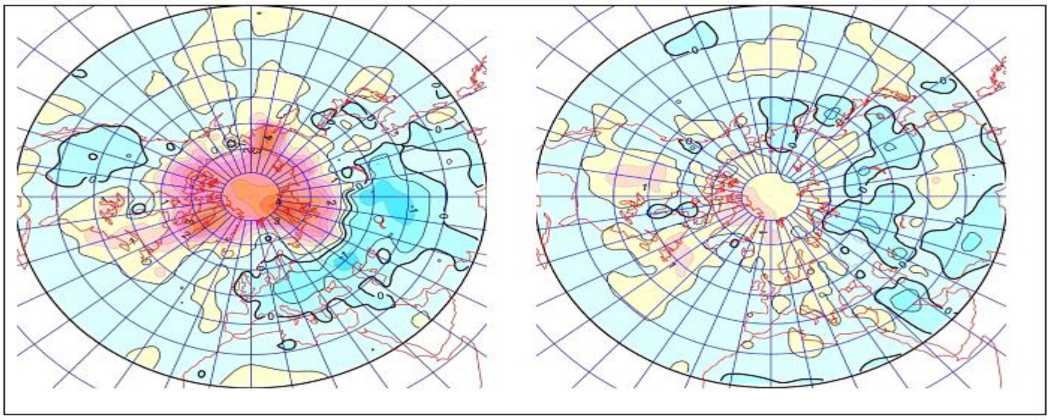

Fig. 2. The differences between average temperature values over the periods 1930-1959 and 1900-1929 in January (left) and in July (right).

The situation has fundamentally changed during 1960-1987 compared with 1930-1959 (Figure 3): in the Arctic, in the north of Europe and Asia, the temperature dropped by 3 °C, but the South regions of Asia were occupied by the positive temperature anomaly (ΔT = 2 ° C). There is the center of cold to -2°C in the southeastern United States, in the most parts of the Northern Hemisphere, the differences between the compared periods are small, dominated by a cold snap.

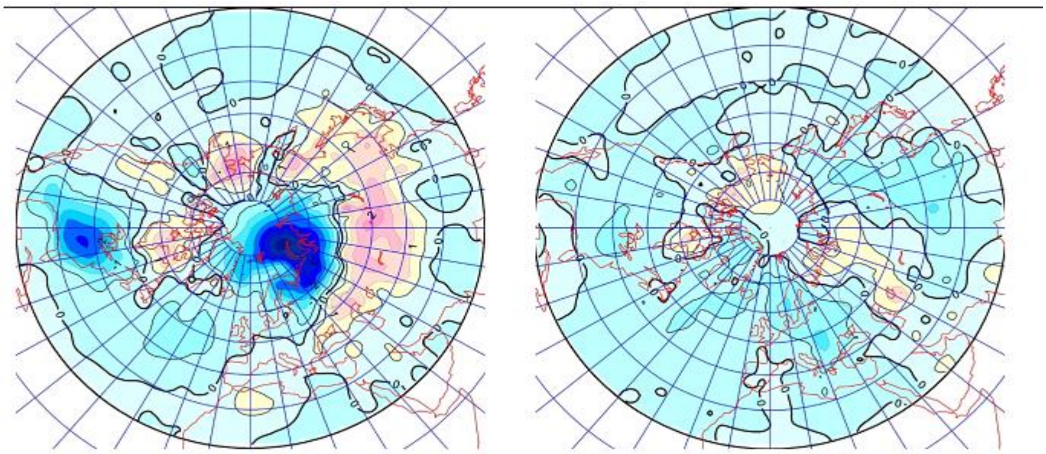

Fig. 3. The differences between average temperature values over the periods 1960-1987 and 1930-1959 in January (left) and in July (right).

Over the period 1988-2000 compared with the period 1960-1987 in the north-eastern North America and in the region of the Aleutian depression it is observed a decrease in temperature (Δ T = -2°C) (Figure 4). Eurasia and the greater part of the North American continent by the end of the century significantly warmed up to 4°C. In the final period 1988-2014 t is observed warming of the continents to 2-3 °C and cooling in the North Atlantic waters, especially in the region of the Aleutian depression, where Δ T = -2 ° C.

In July, the tuning processes are less expressed; there is a mosaic structure of temperature anomalies distribution in the early period of warming in the Arctic and North America and only the period 1988-2014 relatively to 1960-1987 is characterized by a marked temperature increase on the European continent, in the United States, in the east of Eurasia. The temperature on the surface of the Pacific Ocean decreased.

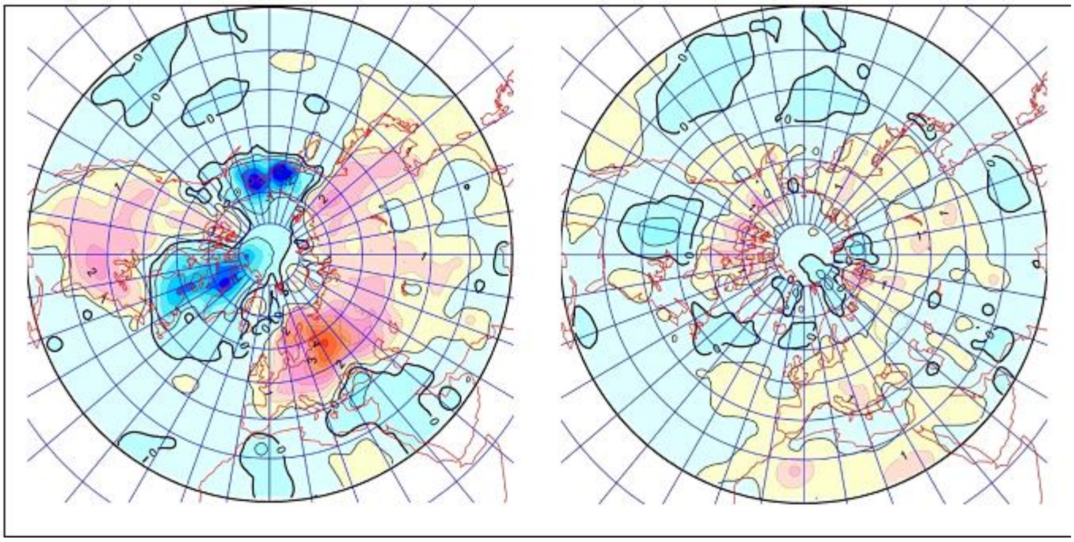

Fig. 4. The differences between average temperature values over the periods 1988-2000 and 1960-1987 in January (left) and in July (right).

The difference in the field of near-surface temperature between the land and the ocean also is come under notice. The difference between temperatures in the periods of 1960-1987 and 1930-1959 identified, generally, weak cooling almost on the entire territory of the Northern Hemisphere. The difference between periods during 1988-2014 and 1960-1987 revealed weak temperature increase (+ 1 °C) over the separate continental regions.

The difference between the pressure fields in January, during the periods 1930-1959 and 1900-1929 (Figure 5) indicates a decrease of the pressure in the central Arctic (Δ P = -5 hPa), in the region of Aleutian depression (Δ P = -3 hPa) and an increase in zone from the west of the North American continent to Chukotka with the centers on Greenland (Δ P = 5 hPa), in Siberia (Δ P = 3 hPa), the rest territory of the Northern Hemisphere is occupied by the weak decrease of the pressure field (by 1 hPa). Particularly sudden changes occurred between the periods of 1988-

2000 and 1960-1987 (Figure 6). The greater part of the North American continent, the entire Arctic region with the adjacent North Atlantic and Asian continent were occupied by negative anomaly of pressure. The centers were observed in the region of the Icelandic depression (-7gPa) and in the region of the Siberian High (-7gPa). At the same time, there has been some weakening of the Aleutian depression (low increase of pressure), intensification of the Azores High (+3 hPa) and the increase of pressure in the Mediterranean Δ P (+3 hPa).

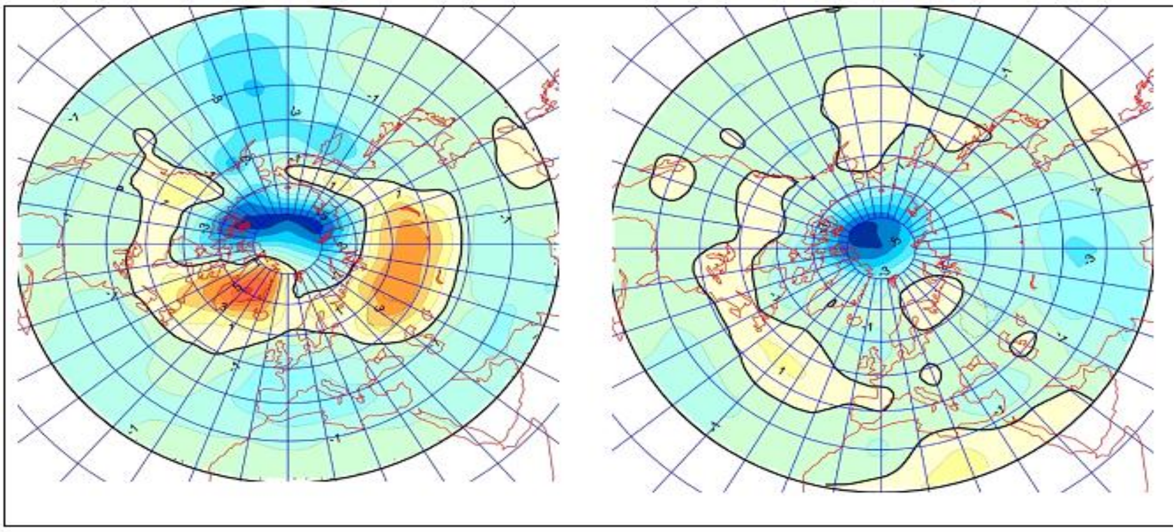

Fig. 5. The differences between average pressure values over the periods 1930-1959 and 1900-1929 in January (left) and in July (right).

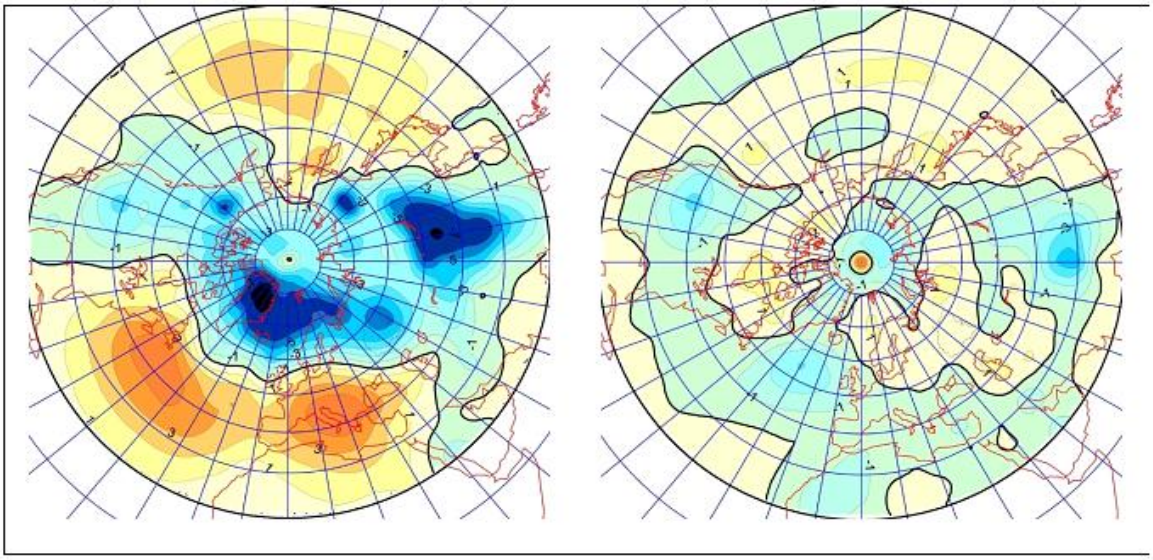

Fig. 6. The differences between average pressure values over the periods 1960-1987 and 1988-2000 in January (left) and in July (right).

In July, there was the most significant decrease of pressure in the center of Arctic by 5hPa during the period 1930-1959 compared to 1900-1929 and, in generally, quite moderate decrease of pressure over the Northern Hemisphere. In the final period of 1988-2000 compared with 1960-1987, the pressure slightly decreased (-1 hPa), and the weak pressure increase (+1hPa) was observed over the waters of the North Pacific Ocean. The center with pressure decrease by 3hPa was formed in China region. So, the alteration of barometric field is more radical in winter than in summer that affects the structure and intensity of the wind velocities.

The similarity of meteorological fields

The well-known analogousness criterion ρ was used for estimation the geometric similarity of anomaly fields of air temperature and atmospheric pressure, obtained during various periods:

$$\rho = \frac{(n_+ - n_-)}{k}, \quad (1)$$

where k – is the total number of the regulatory grid points,

n_+ - is the number of grid points, where the signs of anomalies fields are the same,

n_- - is the number of grid points, where the signs of anomalies fields are opposite.

The values of criteria vary between -1 ≤ ρ ≤1.

Calculated values of ρ over the various periods of XX - XXI centuries for the fields of anomalies temperature and pressure for the latitude zone 27,5 - 67,5 °N is shown in Table 1.

Table 1: The values of analogousness criterion for air temperature and pressure anomalies fields over the various periods (27,5-67,5 ° N).

Period	January				July			
	Air temperature							
	I	II	III	IV	I	II	III	IV
I	1	-0,19	0,16	0,22	1	-0,39	0,28	0,44
II	-0,19	1	0,15	0,17	-0,39	1	-0,18	-0,19
III	0,16	0,15	1	0,86	0,28	-0,18	1	0,79
IV	0,22	0,17	0,86	1	0,44	-0,19	0,79	1

Period	January			July		
	Pressure					
	I	II	III	I	II	III
I	1	0,26	-0,33	1	-0,02	-0,09
II	0,26	1	-0,35	-0,26	1	0,17
III	-0,33	-0,35	1	-0,09	0,17	1

Note: The differences between the following periods were considered for the temperature: I- (1930-1959) - (1900-1929); II- (1960-1987) - (1930-1959); III- (1988-2000) - (1960-1987); IV- (1988-2014) - (1960-1987); respectively, the following periods were considered for the pressure: I- (1930-1959) - (1900-1929); II- (1960-1987) - (1930-1959); III- (1988-2000) - (1960-1987).

As can be seen from the table, the values of differences, obtained for the two neighboring periods III and IV, ρ = 0,86 in January and in July ρ = 0,79, is the most closely related for the field of temperature. In January overall similarity of these fields is not so large (ρ varies from -0.19 to 0.22). In July, the value of ρ markedly increases and fluctuates in the range from -0.39 to 0.44, indicating more stable processes.

Pressure values of ρ vary in the range from -0.35 to 0.26 in January and from 0.02 to 0.17 in July, i.e. the similarity of the differences in pressure values over the different periods in the grids is not so large.

The long-term fluctuations of atmospheric pressure and air temperature

Let's consider the long-term behavior of smoothed, using the low-frequency filter of Potter, time series of air temperature and atmospheric pressure (low-frequency components with a period of more than 20 years) in the centers of atmospheric activity of the Northern Hemisphere and on the territory of the Volga Federal District (VFD) for the period 1900-2014. In January, in the region of the Icelandic Low, low-frequency components of temperature and pressure met small fluctuations (Figure 7).

Since 1980, the temperature has risen to -6.5 ° C, nearly by 1,2 ° C, and the pressure, after reaching its maximum in 1960-1967 (~ 1004 hPa), has been lowered, dropping by the end of the period to 999 hPa. Of course, the pressure curve reflects the more complex dynamics, than the temperature curve.

In July, from 1990 to the present days, the air temperature is in the active phase of growth (according to low-frequency components), increasing from 5.5 to 7.3 ° C. During the period of 1910-1960, the pressure and air temperature fluctuated in antiphase, but in the final period, the pressure slightly increased and reached 1011 hPa. Minimum pressure value (1008 hPa) is observed in 1925.

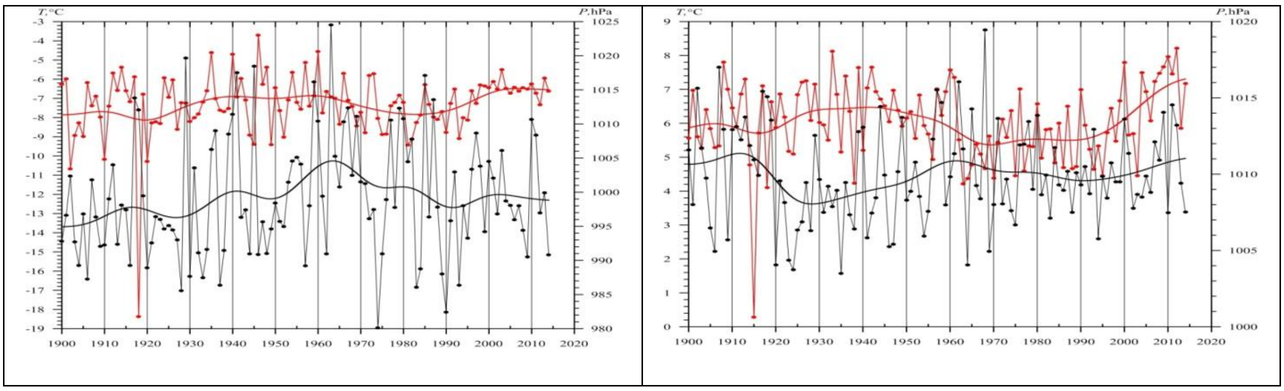

Figure 7. The long-term run of pressure (black line) and air temperature in the region of Icelandic Low in January (left) and in July (right).

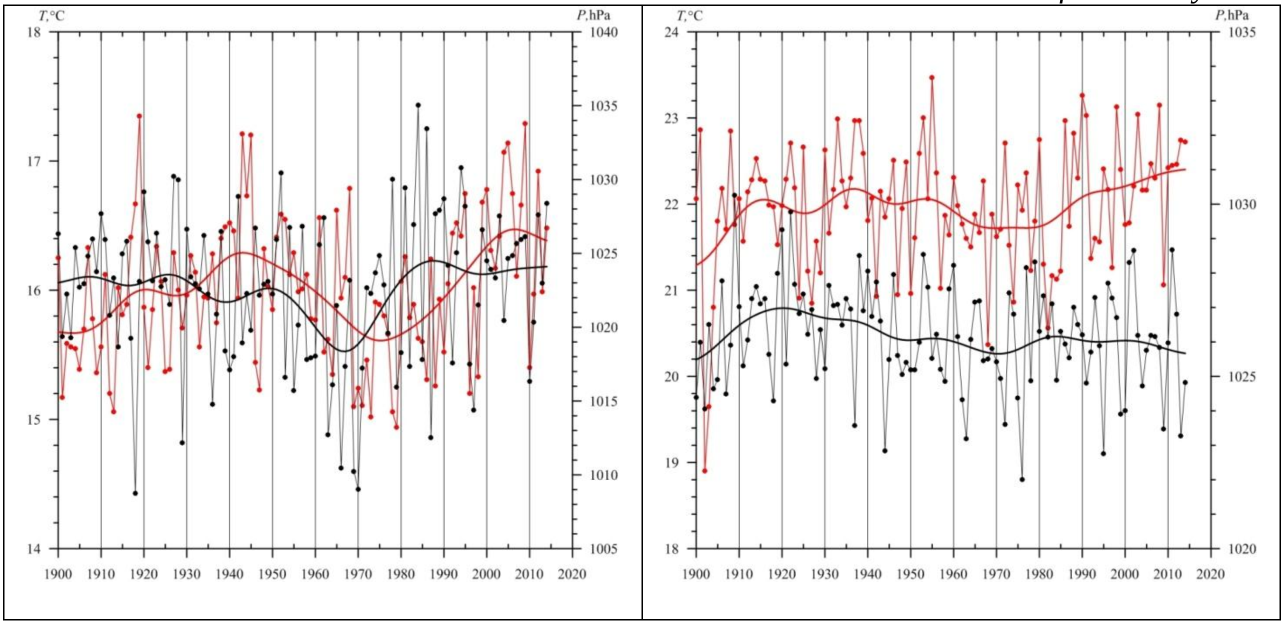

Figure 8. The long-term run of pressure (black line) and air temperature in the region of the Azores High in January (left) and in July (right).

In the region of the Azores High (Figure 8) in January, the situation is more complicated than in the region of the Icelandic Low: there is undulation of pressure and air temperature, upon that since 1965 the pressure value has increased from 1018 hPa to 1024 hPa (1990), and then has slightly decreased, and stabilized at the end of period. Since 1975, the temperature has increased from 15.6° C to 16.5 ° C in 2005 and then slightly began to decrease. Fluent weak changes in the thermodynamic parameters are observed in July, at the same time, since 1980, the temperature has slightly increased and reached 22,4 °C, and the pressure has slightly decreased (to 1025,6hPa).

As for the Siberian High, there is evident a sharp drop of pressure in January, since the end of the 1960s (from 1039 hPa to 1030.5 hPa in 1994). Thereafter, the pressure began to increase, reaching 1036 hPa at the end of the period. The temperature changed in the antiphase with the pressure and had a great increase from the beginning of 1930 to 1995 (from -25.6° C to -22.2 ° C). In the final phase, there is a slight decrease of low-frequency components of temperature.

The European part of Russia, including the Volga Federal District, in winter is often affected by the North Atlantic. According to [12], it is found quite close correlation between circulation modes of North Atlantic Oscillation (NAO) and Arctic oscillation (AO) on the one hand, and the air temperature and the atmospheric pressure of Volga Federal District on the other hand. The long-term run of low-frequency components of the pressure and air temperature is presented in Figure 9. As can be seen from the figure, in January, the pressure and air temperature are changed in antiphase. Therewith, 3 periods in the curves run can be distinguished visually: 1900-1930, 1930-1980 and 1980-2014 years. The middle period is characterized by its instability; during the last period the temperature has rapidly increased from 1970 to 2005 (from -15.8° C to -11.4) (in recent years, there is its decrease); the pressure, since 1990, has increased from 1017 hPa to 1025 hPa. Consequently, the winter process is characterized by its activity on the territory of the Volga Federal District.

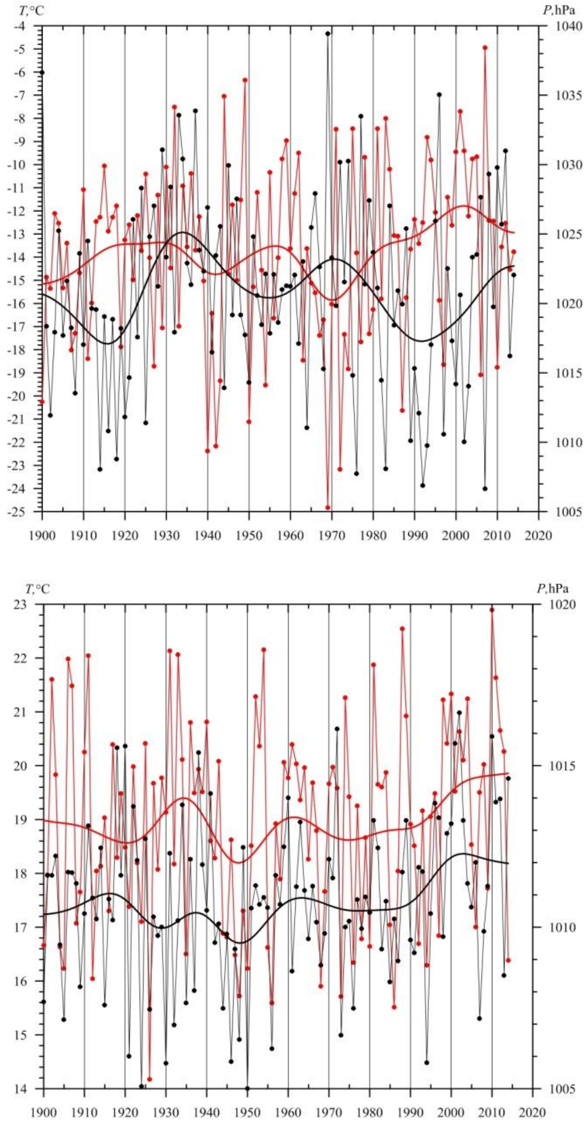

Fig. 9. The long-term run of pressure (black line) and air temperature (red line) on the territory of the Volga Federal District in January (at the top) and in July (at the bottom).

In July, the fluctuations of pressure and air temperature are quite smooth. In recent decades, the temperature increases and the pressure slightly decreases from 2004. The analysis of low-frequency components of the temperature and pressure allows to evaluate the long-term fluctuations, caused by circulating factors.

Deductions

1. The climatic maps of air temperature and atmospheric pressure distribution in January and July in the extratropical latitudes of the Northern Hemisphere (20-90 °N) were constructed.

2. The monitoring of air temperature and atmospheric pressure changes, averaged in the latitudinal zone 32,5-67,5 °N in January, in July and for the whole year, over the period 1900-2014, was carried out.

3. The temporal analysis of air temperature and atmospheric pressure identified antiphase character of their behavior: since the beginning of the century (1900-1929) the pressure tended to increase, and the air temperature tended to decrease. Cooling was at the condition of high pressure. And in contrast, over the period 1988-2000, global warming occurred on the background of decreased atmospheric pressure.

4. Using the low-frequency filter of Potter, it was performed a low-frequency analysis of the average January and July air temperature and atmospheric pressure for a number of territories, such as: the Icelandic Low, the Azores and the Siberian Highs, Volga Federal District.

Conclusion

The description of the spatial and temporal changes of atmospheric pressure and air temperature fields in the troposphere of the Northern Hemisphere (NH) over the period 1900-2014 was given in this work. The low-frequency component (LFC) of average January air temperature, averaged over latitudinal zone 32,5-67,5 °N, since 2005, suspended its 35-year growth, the beginning of which relates to 1970. In July, the low-frequency component of air temperature during 39 years, continues its growth since 1975 until nowadays.

Acknowledgements

The research is carried out at the expense of subsidies, allocated in the framework of the state support of Kazan (Volga) Federal University, in order to improve its competitiveness among the world's leading scientific and educational centers, as well as with financial support of Russian Foundation for Basic Research (grants 15-05-06349).

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