Peculiarities of the global climate tendencies in the south-east Russian plains

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Abstract. The paper discusses seasonal changes in the surface temperature of the Northern Hemisphere during various climatic periods - the first wave of global warming, the second wave of global warming, and stabilization. The statistical significance of the changes was estimated. The features of the activity of global climatic trends in the Southeast of the Russian Plain in an arid climate are studied. It is shown that climatic changes in the region have their own characteristics. The degree of climate continentality in different climatic periods is estimated. The change in the continentality degree was statistically significant at the transition from stabilization period to the second wave of global warming. It has been revealed that in the current climate changes in the Southeast of the Russian Plain the main factor in winter is advective, and in summer the main factor is transformational. Climatically meaningful conclusion about the role of transformation in possible further development of global warming is formulated, especially in continental types of climate.

1. Introduction

Global climate tendencies on the planet affected almost all parts of the Earth's climate system (ECS). The changes affected even the ice-sphere – the most conservative element, which has the longest relaxation time comparing to all the other components of ECS. Changes are absolutely identified with the average global and average hemispheric surface air temperature. Graphs of surface temperature are regularly submitted to the IPCC [1, 2]. According to the reference [3, 4] and the authors [5-9], during the global near-surface temperature, at least the last 120 years, one can distinguish such climatic periods as the first and second waves of global warming, between which there is a short stabilization period. Relatively low temperature before global warming is called Little Ice Age in Europe.

An important and integral feature of climate is seasonality, especially in high and moderate latitudes. Global climatic trends in the two contrasting seasons – summer and winter were identified. The statistical significance of the changes was rated. It is known that global climatic trends are different in various regions. It turns out to be interesting to study the peculiarities of global climate trends in the Southeast of the Russian Plain in the conditions of arid climate.

2. Material and methods

Anomalies of the surface air temperature of the Northern hemisphere for January and July were investigated. Data was taken from the website http://www.cru.uea.ac.uk/cru/data/temperature/#dat
dow. Sharp fluctuations in the level of the series were determined by the method of step trend [10]. The significance of changes (95%) was estimated by the method of confidence intervals [10]. Each time interval was determined by the statistical characteristics (average, variance). Within each climatic period the tendency of changes of meteorological quantities or characteristics was determined using a linear trend. For each time interval, the equations of the trend line are obtained (graphs in this article not given).

Researches of the regional climate have been carried out for several weather stations of the region (Samara, Penza, Voronezh, Elista, Astrakhan, and Orenburg). Data was taken from (http://www.pogodaiklimat.ru/archive.php) and from climate reference books.

The climate continentality degree was evaluated by the value of the annual amplitude of temperature. The annual amplitude of temperature (A) was defined as the temperature difference between the warmest (T July) and the coldest months (T January) (A=T July – T January).

Regional climate changes are conditioned to the regime of the General atmospheric circulation. We investigated the impact of the circulation on the development of the climatic variability. The impact of the circulation was determined on the basis of the number of warm and cold intrusions in the region, in different climatic periods. Warm and cold invasion seemed to be waves of heat or cold. A wave of heat (cold) was an increase (decrease) in air temperature by 5°C or more for at least two days. In each climatic period, the number of warm and cold waves in winter and summer was counted.

The duration of the main and transitional seasons of the year was determined by the dates of a stable transition of the average daily air temperature through certain limits. The boundary between winter and spring is the date of a steady transition through 0°C upward, between spring and summer – through 10 °C upward, between summer and autumn – through 10°C downward, between autumn and winter – through 0 °C downward, respectively.

3. Results and discussion
Using the method of stepwise trend for series of anomalies of near-surface air temperature in the Northern Hemisphere for January and July, periods of dehomogenization are identified. As a result, the following time intervals (climatic periods) are determined:

- 1850-1907 - from the Little Ice Age in Europe;
- 1908 – 1943– the first wave of global warming;
- 1944 – 1974 – the period of stabilization (relative cooling);
- 1975 – 2016 - the second wave of global warming.

Statistical characteristics are calculated for each interval (table 1). The coefficients of linear trends (α) change a sign from one period to another, indicating the opposite of climate change. The smallest temperature variability in winter was during the first wave of global warming, in summer – during stabilization period. In summer, the temperature variability in the second wave of global warming is greater than in all other periods, in winter it is second only to the period before global warming.

| Periods, years | January | July |
|----------------|---------|------|
|                | Statistical characteristics | Confidence intervals | Statistical characteristics | Confidence intervals |
|                | α       | χ     | σ     | [-0.4029;-0.2053] | -0.034 | -0.09 | 0.23 | [-0.1438;-0.0444] |
| 1)             | -0.0002 | -0.30 | 0.45  |                  |        |      |      |                    |
| 2)             | 0.0097  | -0.19 | 0.27  | [-0.2688;-0.1162] | 0.0165 | -0.12 | 0.20 | [-0.1763;-0.0641] |
| 3)             | -0.018  | 0.01  | 0.31  | [-0.0475;0.0645]  | -0.0025 | -0.01 | 0.12 | [-0.0486;0.0260] |
| 4)             | 0.028   | 0.4   | 0.36  | [0.3037; 0.4899]  | 0.0249 | 0.35  | 0.33 | [0.2612; 0.4338]  |

Table 1. The statistical significance estimation of changes in mean anomalies. Near-surface air temperature in the Northern Hemisphere in January and July.
Changes of surface air temperature in Northern hemisphere in winter are significant during the transition from the first wave of global warming to the stabilization period and during the transition from stabilization period for the second wave of global warming (table 1). Changes in summer temperatures were important only during the transition from stabilization period for the second wave of global warming (table 1).

Global climate trends differ in various regions. For the study, we selected the Southeast of the Russian plain, characterized by a high degree of climate continentality (Gorchinskii index 63-67). As it was mentioned, the studies were carried out in several weather stations in the region. However, the results were identical; therefore, this article presents the results for the Saratov Southeast weather station. In addition, this station has the longest and most complete series of observations – since 1912.

The purpose was to determine the global climatic periods in the Southeast of the Russian plain. That is why we divided the examined time series (1912-2016) for the same time intervals. For each time interval we determined the trend of the meteorological values and got the equation of the trend line (figure 1).

![Figure 1](image1.png)

Figure 1. Changes of average monthly air temperature in the Southeast of the Russian plain in January (a) and July (b) according to the Saratov Southeast weather station.
Global climate trends in the Southeast of the Russian plain are very peculiar. The first wave of global warming in the region is characterized only by the increase in summer temperatures. Winter temperatures in this period, on the contrary, significantly decreased – by 2.2°C in 10 years. The first wave of global warming is known as the “Arctic warming”. This warming is not evident in continental areas [2]. Continental climate areas were cold. Cold was in the southeast of the Russian plain.

A similar trend is typical for the stabilization period. During this period, summer temperatures have been increasing and winter ones have been decreasing. Changes were much slower than in the first wave (figure 1).

In the second wave of the global warming changes in winter and summer temperatures in the region are very peculiar. It is known that the second wave of the global warming is characterized by the increase in temperature during the cold part of the year. However, both winter and summer temperatures increased in the region. While the summer temperatures increased faster than in winter (figure 1).

Changes in winter and summer temperatures influence the degree of climate continentality. The main indicator of continentality is the annual amplitude of temperature. Figure 2 shows the annual amplitude of temperature in different climatic periods in the southeast of the Russian plain. We see that in the first wave of global warming, annual amplitude of temperatures increases as well as the degree of climate continentality. In the stabilization period, the increase in annual amplitude of temperature decreased. The absolute value of the annual amplitude of temperature in the first wave of global warming was 33.2°C, in the period of stabilization it was 32.6°C. The comparison of the coefficients of the linear trends in the first wave of global warming and a period of stabilization in summer and winter (figure 1) showed that the increase of continentality degree within these periods was due to a decrease in winter temperatures.

![Figure 2. Changes in the annual amplitude of air temperature.](image)

In the second wave of global warming, there is a cessation of increase in the degree of the climate continentality. The increase in annual temperature amplitude is very small ($\alpha=0.032$) (figure 2). Over this time interval, the average absolute value of the annual temperature amplitude was 30.0°C. It should be noted that during the second wave of global warming, a slight increase in the degree of continentality is caused not by the decrease in winter temperatures, but by an increase in summer ones. This phenomenon is not characteristic of the Earth’s climate system, at least in the era of regular
meteorological observations; there is an increase in the degree of the climate continentality with the increase in winter temperatures.

Thus, the peculiarity of the second wave of warming in the region is the increase in winter and summer temperatures in the continental southeast. At the same time, summer temperatures rise faster than winter ones. Thus, their influence on the change in the degree of continental climate increases.

We can determine whether changes in the annual temperature amplitude are statistically significant. Figure 3 presents confidence intervals of changes in the annual temperature amplitude. Obviously, that the changes in the degree of continentality are insignificant in the transition from the first wave of global warming to the stabilization period and are significant in the transition from the stabilization period to the second wave of global warming.

![Figure 3. The statistical significance of changes in the annual amplitude of temperature in the Southeast of the Russian plain. Confidence intervals.](image)

It should be noted that from one climatic period to another, the average values of the annual temperature amplitude in the interval decrease; while within each period there is a tendency to their increase; the growth in annual amplitude slows down from period to period.

It is generally accepted that the cause of climate change during time intervals within decades is the general circulation of the atmosphere. It determines the temperature background and its changes. Let us consider the role of atmospheric circulation by calculating the number of warm and cold intrusions in the region. To do this, we calculate the number of waves of heat and cold in various climatic periods in winter and summer (table 2).

In all climatic periods the number of waves is more in winter than in summer (table 2). Thus, advective processes have a greater impact on the formation of the background temperature in winter than in summer.

In the region in winter, the maximum cold waves were during the first wave of global warming. In the stabilization period and in the second wave they were of the same number. It is also interesting that in the first two climatic periods the number of cold waves is greater than that of heat ones. In the second wave of global warming, heat waves prevail over cold ones. In the winter season, regional cooling during the first wave of global warming was determined by the cold air masses. During the second wave of global warming, the regional increase in winter temperatures was determined by the warm air masses in the region. Thus, in winter, the advective factor in regional climatic changes was pronounced.

### Table 2. Average seasonal number of heat and cold waves in different natural climatic periods of ECS.

| Periods                     | Winter |       | Summer |       |
|-----------------------------|--------|-------|--------|-------|
|                             | heat waves | cold waves | heat waves | cold waves |
| First wave of global warming| 8.1    | 9.6   | 6.0    | 5.9   |
| Stabilization               | 7.5    | 8.1   | 6.1    | 6.1   |
| Second wave of global warming| 9.0    | 8.1   | 5.9    | 5.9   |
| Average                     | 8.2    | 8.6   | 6.0    | 6.0   |

In summer during all three climatic period the number of heat and cold waves was the equal. We conclude that in summer the role of the advective factor in regional climate changes is not pronounced. The research [11, 12] shows growing precipitation of the Arctic anticyclone in the region.
in summer. The transformation of dry Arctic air in the local rain occurs within 1-1.5 days. This process leads to the formation of intense and prolonged heat waves.

Thus, advective factor has significant value in regional climate changes, while in summer it belongs to transformation processes. According to this fact we can formulate a climatically significant result: with a further possible development of global warming, we can expect the increasing role of the transformational factor in global climate processes. Such development of the processes in the Earth's climate system involves the weakening of the inter-latitudinal air exchange.

The complete characterizations of regional climate, the length of the seasons are represented in Table 3, it shows the climatic dates of the transition of average daily temperature through certain limits.

Table 3. Long-term Average dates of transition of average daily air temperature in certain limits.

| Temperature | Spring | Autumn |
|-------------|--------|--------|
|             | 40th - 60th years XX | 1975 – 2010 years |
|             | 1975 – 2010 years | 40th - 60th years XX |
| 0 °C        | 29.III | 24.III |
| 5 °C        | 11.IV | 9.IV |
| 10 °C       | 24.IV | 23.IV |
|             |         | 9. XI |
|             |         | 18. X |
|             |         | 11.XI |
|             |         | 20.X |
|             |         | 1.X |

Thus, the manifestation of global climate trends in specific in different climatic periods.

4. Conclusion
During the first wave of global warming and stabilization period, winter temperatures decreased and summer temperatures increased.

During the second wave of global warming, winter and summer temperatures increased. During this climatic period, the growth rate of summer temperatures is faster than the growth rate of winter ones.

The average annual temperature amplitudes decreased from one climatic period to another. However, within each climatic period, there is a noticeable tendency towards an increase in annual temperature amplitudes.

Advective processes play an important role in the formation of climate variability in the region in winter. In summer, the transformation factor plays the main role in climate change.

The consequence of regional climatic changes was a shift in the timing of meteorological and agrometeorological seasons of the year.

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