The issue of the change of the climatic conditions of the Rostov region of the Russian Federation

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Abstract. The study raises an urgent and important problem of the climate change. The research area is the Rostov region of the Russian Federation. The paper considers the features of the change of the climatic conditions of the region and assesses the consequences. The dynamics of the average monthly temperature in January and July in Rostov-on-Don, as well as its average annual precipitation from 1970 to 2019, is analyzed. The research is based on the weather chronicle of the Rostov region. Over the past 60 years, there had been a steady increase in the average monthly temperatures. The work also considers the issue of desertification processes in the study area, its impact on human life activity.

1. Introduction

The climate of the south of the European territory of the Russian Federation is formed under the influence of the circulation processes in the southern zone of temperate latitudes. The territory is accessible for the free invasion of the cold masses from the Antarctic [1].

The Rostov region covers an area of 100.9 thousand square kilometers. The territory stretches from north to south for almost 476 km and from west to east - to 456 km. The water surface of numerous rivers, lakes and reservoirs is 285 thousand hectare [2].

The territory of the study region is characterized by the insufficient moisture, hot and dry summers and relatively warm winters. Thus, the main factors determining the climatic conditions are solar radiation and atmospheric circulation. Relief has no significant effect on climate, since it is represented by a plain with small elevations. The Sea of Azov and the Caspian Sea also have no significant impact on the climate of the region: the first because of its small size, the second because of its remoteness.

The region’s territory is characterized by a huge transfer of the air masses from the Atlantic Ocean, the meridional north and south transfers, as well as the processes of air transformation in the direction of its cooling or warming over the underlying surface. The plain relief favors the free flow of air masses of various origin [1].

Accordingly, the aim of the study is to identify changes in the climate of the Rostov region of the Russian Federation over the past half century.

2. Methodology

The study was based on the weather chronicle [3] of the Rostov region, the analysis of scientific literature corresponding to the topic. The study was based on the study and analysis of the monthly
average temperatures and precipitation in January and July in Rostov-on-Don during the period from 1970-2019.

The urgency of the work is in the complex study the problem of the climate change in the Rostov region of the Russian Federation, because of the importance of the problem at this stage of human life and the global warming.

The object of study is the Rostov region of the Russian Federation.

The subject of the study is the climatic indicators (the average monthly temperature in January and July and its average annual precipitation) of the Rostov region in the period from 1970-2019.

The work included the following steps:
1. The determination of the changes in temperature and precipitation during the study period.
2. The determination of the effects of the climate change characteristic of the Rostov region.
3. The prediction of the further climate change in the Rostov region.
4. The prediction of the impact of the climate change on the environment and human life.

3. Results

The most detailed data are available on the changes in the air temperature obtained both from the instrumental observations and from the indirect methods. These data show that in the northern hemisphere since 1990 there had been a steady increase in the air temperature. This was especially noticeable over the past 60 years. Based on this, to determine the trends in the sum of the average annual air temperature and precipitation indicators, the authors analyzed the series of the corresponding station observations from 1971 to 2019 [1].

The diagram (figure 1) shows the average annual temperature in Rostov-on-Don during the period from 1970 to 2019.

![Diagram showing the average annual temperature in Rostov-on-Don from 1970 to 2019.]

Figure 1. The average annual temperature in Rostov-on-Don during the period from 1970 to 2019.

The diagram shows that:

- the temperature of January was -8.6 °C, and of July - 19.3 °C in 1970;
- the temperature of the first winter month was -4.6 °C, and the summer one - 20.2 °C in 1980;
- the average annual air temperature in January was -2.4 °C, and of July - 20.6 °C in 1990;
• the January temperature was -2.1 °C, and of July -23.3°C in 2000;
• the January temperature was -1.6 °C, and of July -24.7 °C in 2010;
• the average annual temperature in January was -1.2 °C, and of July 26.2 °C in 2019 [3].

Based on the data, the temperature increase in January is 7.4 °C, and in July is 6.9 °C during the last fifty years. The analyzed data indicate a steady trend towards the increase in the average annual temperature of the region.

The diagram (figure 2) shows the average annual precipitation of Rostov-on-Don from 1970 to 2019.

![Figure 2. The average annual precipitation of Rostov-on-Don during the period from 1970 to 2019.](image)

Based on the data presented in the diagram, it can be concluded that the average annual precipitation was independent of each other and varied greatly from year to year. However, there was a tendency to reduce their number with the exception of the year 1980 [3].

The amount of precipitation in 1980 was due to such a term as “The Cyclonic Depression” or “the extreme weather events”. This weather condition is called one of the consequences of the global warming. It also includes periods of abnormal heat in winter or cold in summer, heat waves and sudden droughts. This is because the area is dominated by the region of low (as in the Rostov region in 1980) or high pressure. According to scientists today [3], in the future, as global warming continues to develop, the frequency of such phenomena will only increase, and they will cover more and more territories.

These climate changes will have both positive and negative impacts not only on the environment (vegetation, soils, glaciers, waters eutrophication [4] etc.), but also quite significantly on the main sectors of the economy, especially agriculture.

The heating period can be related to the positive effects of the climate change in the region. In the Rostov region, the heat deficit is 50-100 degree-months (the standard unit for measuring the excess of the average daily temperature over the set minimum), and the duration of the heating period is 168-190 days [5]. If the climate continues to develop according to the trend shown in Figure 1, then by 2050 the heat deficit will decrease by 20-25%, and the duration of the heating season by 30 days. This situation will allow for the significant fuel economy [5].

The climate warming will also lead to the improvement in the thermal regime of buildings, since the heat resistance of the walls of buildings will increase, which will allow maintaining a predetermined temperature inside the buildings with the lower fuel consumption.
In the Rostov region, as in most of the European territory of the Russian Federation, the decrease in the wind speed should be expected, which will reduce the wind loads on the power lines and the high-rise buildings. At the same time, the decrease in the wind speeds will lead to the reduction in the wind energy potential, which in a number of regions will be almost halved.

The climate warming will lead to the change in the amount of the atmospheric precipitation, and for the Don river basin it will increase in some scenarios and decrease in others [6]. Therefore, there is the reason to assume that both the increase and decrease in the average annual inflow of water into the Tsimlyansk reservoir will be from 5% to 15%.

According to the scientists, the increase in the water content of the Don River is more likely. Accordingly, flooding and flooding of settlements, deterioration of the climatic conditions along the riverbanks (increased air humidity, frequency of fogs, decreased visibility, etc.), increased formation of sludge, and mash phenomena in river sections, the appearance of cracks and streaks on the ice of reservoirs can be expected in the region’s territory.

It is worth noting that the modern climate changes have led to a significant intensification of the channel processes that complicate navigation. However, the increase in the low-water runoff and the reduction in the freezing period on the rivers of the region, predicted by 2050, are potentially favorable for the development of the river shipping and the increase in the volume of the freight traffic.

A number of oil pipelines and gas pipelines pass through the region territory. They were built until the 1980s and for the stationary climate conditions. In the context of the projected increase in the annual and seasonal river flow in the Don river basin, the loads on the underwater sections of pipelines will increase. Therefore, today it is necessary:

- to revise in the direction of the decreasing of the «life» of the underwater crossings of pipelines built before 1980;
- organize an effective system for monitoring the status of pipelines in order to avoid emergency situations on them;
- take into account the forecast of the changes in the climatic conditions and water regime for the coming decades when designing new pipe-line crossings.

It should be noted that changes in the climatic conditions lead to the deterioration in the comfort of living. Throughout the region, there will be an increase in the number of days with high air temperature. At the same time, the probability of extremely long periods with critical values of air temperature, the so-called “heat waves”, significantly increase.

The climate warming will have a very significant impact on the landscape structure of the region, agro-climatic resources and agricultural productivity.

The climatic conditions are one of the main landscape-forming factors. Changes in the climatic conditions, respectively, will cause the re-structuring of the landscape structure in the region. First, this will affect the soils and vegetation. Thus, first, on the vegetation and much later on the soils.

Therefore, for example, because of the steady increase in the average annual temperature and the decrease in the amount of the precipitation, scientists distinguish such a phenomenon as “desertification”. By B.G. Rozanov [7], the desertification is a process of the irreversible soil change and vegetation and the decrease in the biological productivity, which in the extreme cases can lead to the complete destruction of the biosphere potential and the transformation of the territory into a desert.

The desertification is one of the important environmental and social problems of the Rostov region. The total area of lands subjected to desertification processes in the region is about 50,800 km2 (as of February 2019), which is 57% of the territory of the entire region.

Desertification is one of the important environmental and social problems of the Rostov region. The total area of lands subjected to desertification processes in the region is about 50,800 km2 (February 2019), which is 57% of the territory of the entire region. Zones of the region for which the problem of desertification is most acute are the Dubovskij, Zavetinskij, Zimovskij, Orlovskij and Rimontenskij ones.
The dry steppes and semi-deserts on the dark and light chestnut soils represent the indicated areas. Desertification here develops because of the degradation of vegetation cover, water erosion, settlement and waterlogging of soils, degumification, as well as in the certain places of the technogenic degradation.

Consequently, it can be concluded that the desertification is a problem that is most acute in the areas of the Rostov Region, whose territories are located in the southeast of the region and border the Republic of Kalmykia.

In the Rostov region, three types of landscapes are observed, namely: steppe, dry-steppe and semi-desert. It makes sense to mention the desert type of landscape, because the Rostov region may acquire them in the future.

In the climatic terms, the boundaries of the landscape types are clearly determined by the average annual air temperatures and annual precipitation; their characteristics are presented in table 1.

Table 1. Characteristics of the landscape types.

| The landscape type | The average annual air temperature, °С | The average annual precipitation, mm |
|--------------------|----------------------------------------|-------------------------------------|
| Steppe             | 6.9-9.4                                | 420-525                             |
| Dry-steppe         | 7.4-8.6                                | 420-320                             |
| Semi-desert        | 7.5-10.0                               | 340-220                             |
| Desert             | 9.3-10.4                               | 220-165                             |

Table 1 shows that the border between the steppe and the forest-steppe landscapes is determined by the average annual air temperature of 6.9 °C and the amount of precipitation is 420 mm. The boundary between the dry-steppe and semi-desert landscapes is determined by 7.4 °C and 320 mm, respectively. In addition, the boundary between semi-desert and desert landscapes is determined by 9.3 °C and 220 mm. The annual values of the air temperature and precipitation are in the good agreement with the types of landscapes. Therefore, based on the data presented above, the hydrothermal coefficient for landscape types can be analyzed [1].

This coefficient is calculated as the ratio of the annual amount of precipitation to the sum of the positive air temperatures during the year.

The hydrothermal coefficient for the different types of landscapes [3] are showed in table 2. The indicator naturally varies from the desert to steppe landscapes, gradually increasing.

Table 2. The hydrothermal coefficient for the different types of landscapes.

| The landscape type | The hydrothermal coefficient |
|--------------------|------------------------------|
| Steppe             | 0.167-0.124                 |
| Dry-steppe         | 0.156-0.102                 |
| Semi-desert        | 0.124-0.093                 |
| Desert             | 0.065-0.043                 |

Table 3 shows that according to the paleoclimatic scenario, both in 2030 and in 2050, steppe, dry-steppe, and semi-desert landscapes advance northward by 25-110 km in 2030 and 10-65 km in 2050,
the desert one retreat by 30-50 km. Thus, in the middle of the XXI century in the Rostov region a desert landscape will not be observed, however, it is worth canceling that the territory of a semi-desert landscape will increase by 10 km.

Table 3. The results of the changes in the hydrothermal coefficient and landscape boundaries according to the paleoclimatic scenario for 1990–2050.

| The landscape type | The hydrothermal coefficient | Years | The boundaries change of the landscape, km |
|--------------------|------------------------------|-------|------------------------------------------|
|                    | 1990                         | 2030  | 2050                                     | 1990-2030 | 1990-2050 |
| Steppe             | 0.146                        | 0.127 | 0.132                                   | 65        | 50        |
| Dry-steppe         | 0.124                        | 0.112 | 0.117                                   | 110       | 65        |
| Semi-desert        | 0.102                        | 0.097 | 0.101                                   | 25        | 10        |
| Desert             | 0.056                        | 0.063 | 0.067                                   | -30       | -50       |

4. Conclusion

Accordingly, the following conclusions were made:
1. Over the past 60 years, there had been a steady increase in the average monthly temperatures. The total increase in the average monthly temperatures was 7.4 °C and 6.9 °C in January and July, respectively.
2. The average annual precipitation varies dynamically year by year.
3. The research showed that the climate of the Rostov region have a tendency to warming.
4. In the middle of the XXI century in the Rostov region a desert landscape will not be observed, however, it is worth canceling that the territory of a semi-desert landscape will increase by 10 km.
5. The question of whether the climate change will positively affect the environment and human life cannot be answered unambiguously, because this is a multifaceted problem with many subtleties. However, in most factors the climate change will adversely affect the agriculture. Economy, on the contrary, will receive a new round of development.

Consequently, based on the study, we can say that the Rostov region of the Russian Federation is a zone of climatic vulnerability.

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