Features of the climate of Tuva in connection with physical and geographical conditions

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Abstract. The paper studies the climatic features of Tuva in their causal relationship with physical and geographical conditions. It was revealed that against the background of these common factors, the climatic conditions of individual parts of Tuva are formed under the direct influence of physical and geographical features and, above all, relief. The 30-year climatic norms of average annual and average seasonal air temperatures are highlighted. The ongoing climate changes affect socio-economic development, food and energy security, crop yields, quality of life, population migration, etc. Taking into account climate change is important for developing an adaptation strategy in the mountainous regions of Russia for sustainable development.

1 Introduction

Located in the center of the Asian part of the Eurasian continent, Tuva in its natural appearance reflects the influence of neighboring territories: from the north and northeast - taiga Eastern Siberia, from the south and southeast – the desert-steppe regions of Mongolia, from the west – the mountainous taiga Altai. Due to this geographical location and the sharp dissection of the relief, the natural features of Tuva, including its climate, are distinguished by significant contrast. Cold winters with little snow, warm summers, low rainfall and a large amplitude of absolute and daily temperatures are characteristic features of the climate of Tuva.

The climate of Tuva was studied in different years by a number of authors [1-2], some agro-climatic characteristics of the basins were generalized by N.P. Bakhtin [3] and V.P. Filimonov [4]. The remoteness from the oceans and the barrier role of mountain ranges determines the first of the main general features of the climate of Tuva – a sharp continentality – the most pronounced feature of the climate, the stamp of which is more or less manifested in all parts of the territory of the republic. In winter, Tuva is located in the sphere of an extensive and stable Central Asian anticyclone created by strongly cooled low-moving air masses. The air temperature in the large basins of Tuva at this time can drop to -50 ° C. During the warm period, Tuva falls under the influence mainly of cyclonic currents coming from the northwest, and only partially under the influence of strongly heated and dry air masses forming over the nearby desert areas of Central Asia.

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Tuva as a whole is a mountainous country with altitude fluctuations from 520 to 4000 m, as a result of which the vertical zonation of physical and geographical components, including climate, is particularly clearly manifested in it. Due to the alternation of ridges and basins, the climate-forming role of the relief in Tuva is extremely great; thus, according to some climatic indicators, certain parts of the region do not have their own counterparts in neighboring areas close in latitude. The absolute height of the terrain, the degree of isolation, the orientation of mountain ranges in relation to moisture–bearing air currents, the exposure of slopes, the nature of the underlying surface - all this determines the diversity of climatic features of individual parts of Tuva in mutual connection and conditionality [5].

2 Materials and Methods

The contrast of extreme temperatures and especially monthly averages is more typical for the basins. This is due to the fact that in winter, cold air (as heavier) descends into the basins, where additional radiation cooling of its lower layers occurs, causing a temperature inversion. For this reason, it is much colder in the hollows in winter than in the mountains (up to about 2000 m) and than in neighboring areas close in latitude. In summer, on the contrary, a positive temperature gradient is established in Tuva – the temperature decreases with altitude. This peculiarity of the temperature regime leads to the fact that the amplitude of the average monthly temperatures per year in neighboring territories close in latitude, nowhere reaches such a magnitude as in some basins of Tuva (about 54 °C).

Fenced off from the west and north by ridges above 2000 m above sea level, the territory of Tuva falls directly into the sphere of domination of the west-east circulation of the middle layers of the troposphere. Therefore, during the entire warm season in Tuva, westerly and northwesterly winds prevail. This direction of air currents is also associated with the main amount of precipitation, most of which falls in summer in cyclones coming from the northwest. However, air masses come to Tuva heavily depleted of moisture, which they leave mainly on the windward slopes of such significant mountain barriers as Altai and Western Sayan, where up to 1000 mm or more of precipitation falls per year. In this regard, the leeward slopes of the Tuva ridges and basins receive the least amount of precipitation, amounting to 200-230 mm per year. In the hollows, in addition, thermal conditions strongly contribute to a decrease in precipitation in summer.

The effectiveness of the jointly operating processes to which the air is exposed, after it passes into Tuva through the ridges of the Western Sayan and Altai, can be so significant that it often leads to the attenuation of frontal processes and the cessation of precipitation. In such cases, the frontal cloud cover is eroded, and rain bands hang in the air, not reaching the ground. A similar result is usually obtained with precipitation due to convective clouds, which makes the role of the latter in the basins very small, whereas in the mid-mountain and high-altitude areas it increases significantly.

The mountains on the territory of Tuva contribute to some exacerbation of frontal processes in cyclones and, in connection with this, an increase in precipitation to 300-400 mm or more on the windward slopes of the Tannu-Ola ridge and the mountains of Eastern Tuva. It should be emphasized that the northeastern and eastern parts of Tuva receive significantly more precipitation, partly because they are more accessible to moisture-bringing northwesterly winds due to lower altitudes and a smaller width in this section of the Western Sayan. The resulting forest cover on the entire territory of Eastern Tuva is currently, in turn, a serious climate-forming factor, determining both the temperature regime and other climatic features here to a large extent.

The degree of protection of the territory from the effects of moisture-bearing air currents is sharply manifested in changes in climatic conditions and the entire appearance of the landscape. The most striking example of such a territory is the Ubsunur basin, separated from the influence of northwestern air currents, except for Altai and Western Sayan, and the Tannu-Ola ridge, exceeding 2000 m. As a result, the climatic conditions of this basin differ significantly from those of the basins north of Tannu-Ola, primarily by pronounced dryness. The amount of precipitation here is almost two times less than in the Ulugh-Khem and Khemchik basins, and the slope of the Ubsunur basin. Western Tannu-Ola is mostly devoid of forest vegetation, replaced here by steppe and dry steppe. The slopes of the mountain ranges of southwestern Tuva – Tsagan–Shibetu and Mongun-Taiga facing the Ubsunur basin also present an almost similar picture of moisture.

3 Results and Discussions

With a small extent of Tuva in latitude (about 4 ° C in the widest part), significant differences are observed in its landscapes and climate from north to south, which some authors [6] tend to explain by the influence of latitudinal zonality. However, these differences are determined not so much by latitudinal zonality as by a complex set of climate-forming factors and, above all, by the role of relief in the stability of the prevailing northwestern air currents.

The influence of absolute height is especially pronounced in Tuva. Based on this, three vertical climatic zones can be distinguished in Tuva: low mountains, middle mountains and highlands (Figure 1).

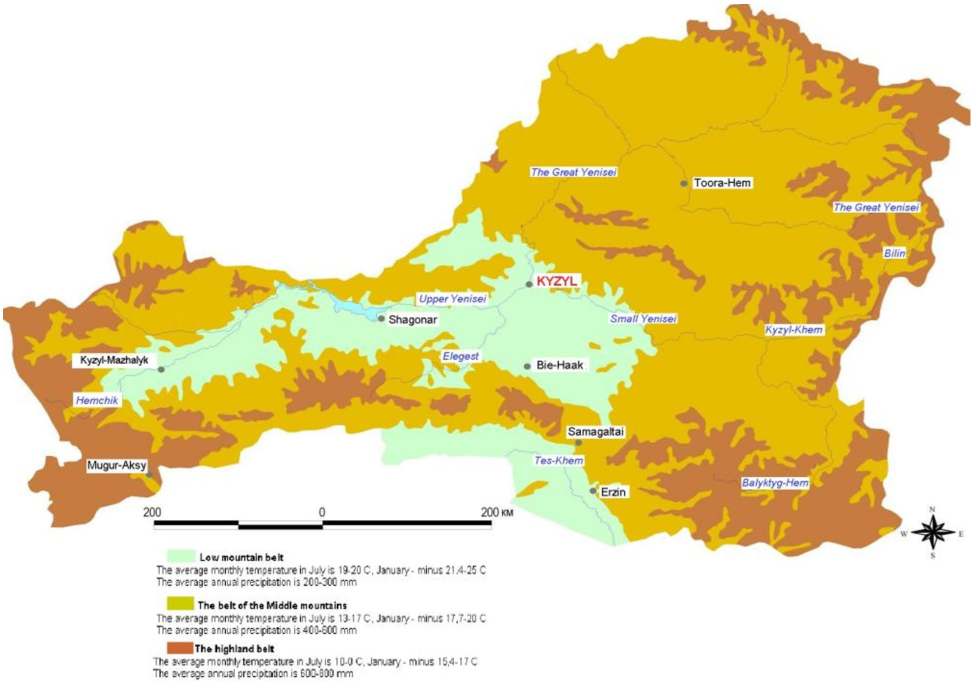

Fig. 1. The scheme of climatic vertical zones of Tuva.

To analyze changes in the surface air temperature of the regime in the Tuva Basin, the entire observation period is divided into 30-year periods, which the World Meteorological Organization recommends using as standard for climatic descriptions. In total, five 30-year climatic periods have been allocated from 1885 to 2020. The first period turned out to be shorter, but this period of meteorological observations of air temperature at the end of the nineteenth century differed very little from the period of the early twentieth century.

With small fluctuations in the temperature regime, temperature trends, even in neighboring months, may have a statistically insignificant opposite direction. In this regard, it is advisable to analyze seasonal changes in surface temperature. The extensive modern scientific literature on the problems of modern climate change provides studies of various scales from global, by hemispheres, by continents, by individual regions of states, etc. At the same time, it is emphasized that the rate of temperature change (linear trend slope coefficients °/10 years) they may differ significantly. For example, in Siberia, when studying climate changes over the past 70 years, five quasi-homogeneous climatic regions have been identified in relation to the rate of temperature change. One of these regions is the Altai-Sayan mountain country. The peculiarity of this region is the complex relief, the presence of large inhabited mountain basins, in which the basin effect is clearly manifested, especially during the cold season.

The analysis of changes in the average annual and average seasonal surface air temperatures showed that from the end of the XIX century to 1930 they changed relatively little.

In the third climatic period of 1931-1960 in Kyzyl, the average annual air temperature decreased by 0.6 °C. In subsequent periods, an increase in temperature was observed. In 1961-1990, the average annual temperature increased by 1.4 °C, and in the subsequent period (1991-2020) it increased by another 1.9 °C. The main contribution to the increase in average annual temperatures over the last two climatic periods was made by winter and spring temperatures of 4.6 °C and 4.4 °C, respectively. In summer and autumn, the temperature growth rates were significantly lower and did not exceed 2.0 °C.

The change in the temperature regime at the Kyzyl station in various climatic 30-year periods is shown in Table 3. During the first and second climatic periods, there was a tendency for air temperature to decrease most of the year, only in the autumn period there was a tendency for climate warming. In the third period, the cooling trend also continued for most of the year, but there was a warming in the summer, which eventually led to a slight cooling.

The highest rates of increase in average annual temperatures were observed in the fourth and fifth climatic periods. Moreover, in the fourth period, the air temperature had a slight tendency to cool down. In the fifth period (1991-2020), a cooling trend was observed in winter. The rest of the year saw an increase in temperature. In general, during this period, a significant increase in air temperature is observed for the Tuvan mountain basin.

4 Conclusion

The global climate changes taking place in recent decades, caused by both natural and anthropogenic factors, lead to an increase in average annual temperatures, uneven distribution of precipitation and an increase in the frequency of catastrophic natural phenomena on the territory of Tuva. The research results show that local hydrothermal conditions, which differ significantly in the intermountain basins of Tuva, and their long-term dynamics are the main factor of effective soil fertility. A long-term increase in precipitation can cause almost the same effect of increasing the content of organic matter in the soil as a single application of organic fertilizers.

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