Impact of climate changes on population vital activities in Russia in the early 21st century

A N Zolotokrylin, V V Vinogradova, T B Titkova, E A Cherenkova, D D Bokuchava, I A Sokolov, A V Vinogradov, E D Babina

Institute of Geography, Russian Academy of Sciences, Staromonetnyy per., 29, Moscow, 119017, Russia

E-mail: vvvinog@yandex.ru

Abstract. The study substantiates the approach to the assessment of impact of climate change on vital activities of population in Russia in the face of increasing climate extremes. The obtained results reveal the occurrence of the essential climate extreme events over the period 1991–2013 in Russia that are vital for population activities. Annual amounts of interdiurnal temperature differences and pressure were calculated. Propagation of heat and cold waves, trends and frequencies of daily precipitation extremes were evaluated. The map “Zoning the territory of the Russian Federation by natural living conditions of the population” adapted for modern climate (2001–2010), illustrates the climate changes in the early 21st century. The modern warming of climate has led to a significant easing of discomfort in the territory of Russia. The steady decline of the absolutely unfavorable zone resulted from the expansion of less unfavorable areas is observed, especially in the Northern and Arctic regions. In the south the boundary of unfavorable territories shifts toward the north. It results in the expansion of the conditionally unfavorable area in West Siberia and in the south of East Siberia. In European Russia the favorable area expands and shifts far to the northern regions.

1. Introduction

The continuous global warming and growing climate extremes have an ambiguous impact on various areas of population life. Climate change is a significant threat for the population vital activities and especially for population health. Since the mid-1970s the average surface air temperature in Russia has been increasing at an average rate of 0.43 °C per decade that excesses the global warming rate more than twofold [1]. The most significant climate changes are observed in the Arctic regions and subarctic areas of permafrost. According to the observation data the tendency to slowdown in the climate warming has not yet been traced (except for winter). The main contribution to the observed temperature rise in Russia is caused by changes in the concentration of greenhouse gases. The surface pressure in the significant part of Russia decreased in the second half of 20th century. At the same time almost everywhere in the territory the wind speed became less [1].

This study presents new results indicating the geographical distribution of extreme climate events with a significant impact on the population vital activity in Russia over the period 1991–2013. For the first time, the annual amounts of the average daily temperature differences and pressure were calculated. There were also obtained the evaluations of heat and cold wave propagation, trends and the frequency of daily precipitation extremes.
2. Material and methods
The available observations over the average daily maximum and minimum temperatures and daily precipitation total from the VNIIGMI (All-Russian Research Institute of Hydrometeorological Information – Worldwide data centre) [2] (http://meteo.ru/) for the whole territory of Russia (458 weather stations) and surface pressure values from the NCEP/NCAR reanalysis archive with a spatial resolution of 2.5° × 2.5° were used in this study [3]. The study covered the peculiarities of the geographical distribution of heat and cold waves with characteristics significant for population activities, the maximum precipitation totals and the average daily temperature and pressure differences (swings) in the late 20th – early 21st century. The maximum (or minimum) daily temperatures exceeding the 95th percentile value (or below the 5th percentile) of maximum (or minimum) temperature distribution over the base period were considered as a threshold value to identify the heat and cold waves. Trends in daily total precipitation and frequency of precipitation extremes for the various periods of the year were calculated. The assessment was performed for the whole territory of Russia and for the most sensitive regions with a high density of population where precipitation extremes lead to the negative outcome for environment and human life activities. The results of numerous foreign and domestic studies indicate the impact of the average daily temperature and pressure differences on the amount of hospitalization and mortality caused by circulatory system diseases [4−6]. In this regard, the changes in average annual number of events with critical temperature and pressure differences were analyzed. The annual total of the critical average daily temperature and pressure differences exceeding 6 °C and 8 hPa, respectively was calculated. The significance of changes was estimated using the Student’s t test.

3. Results and discussion

3.1. Weather climatic anomalies in Russia
In the early 21st century, the number of days with extremely hot weather increased non-uniformly both over time and through territories [7−11]. In the late 20th century, the growth of positive temperature anomalies was observed mainly in the south of European Russia, in the south of Eastern Siberia and in the Far East. In the north of European Russia, in Western and Eastern Siberia the number of such days decreased. The number of heat waves with a duration exceeding three days increased and the temperature growth of heat waves reached 4−8 °C. The most significant duration of lengthening of heat waves was registered in European Russia, in Transbaikalia and in the northeast of Russia. The growth of the average maximum temperature in the heat wave speeded up, especially in European Russia, where it reached 10−12 °C in eastern and southern areas. The maximal heat wave duration increased almost throughout Russia, with the exception of the Kola Peninsula, Taimyr and the south of Western Siberia. Within the European territory, southward of 60° North latitude it increased by 10−15 days, and in Central Black Soil Regions – by 20 days.

The number of days with extremely low temperatures went down almost throughout Russia except the far northeast regions and Chukotka. The maximum decrease of low temperature days was observed in the southern Urals, in the Middle Volga and in the western regions of Russia. The duration of cold waves decreased significantly in many regions of Russia as well except the Kola Peninsula, north of European Russia and the centre of Siberia. But in the early 21st century the number of cold days and the maximal duration of cold waves began to grow in the southern and central regions of European Russia and in the south of Siberia. Absolute minimum temperatures and average minimum temperatures in the cold wave grew and the areas with extremely low temperatures decreased significantly.

The maximum number of the average daily temperature differences (exceeding 30 events per year) was observed in Siberia. On the Arctic coast, it went down to 25 events per year. Geographically the interdiurnal pressure differences in the European Russia territory have the area–based distribution: the maximum totals are observed on the Arctic coast (more than 40 events per year), and the minimum ones – in the south of the territory (less than 10 events per year). The number of pressure differences
in Eastern Siberia increased up to 40 events per year, toward east and south it went down to 10–20 events per year. It should be noted that the maximum number of temperature and pressure differences was observed in the low-populated regions with severe climatic conditions and the minimum ones – in the highly populated regions with mild climatic conditions.

It was established that the frequency of extreme precipitation in winter and spring in the period 1991–2013 increased significantly by an average of 20–40% compared with the climatic norm of 1961–1990 across much of Russia. Against the background of winter and spring positive trends, changes in daily precipitation extremes increase the risks of spring catastrophic floods. In the summer, strong positive trends in precipitation extreme changes were observed in the southern part of the Far Eastern District in the Amur River basin, increasing flood risks in this region.

The consolidation of the results obtained is presented on the integral map of the extreme natural phenomena distribution across the territory of Russia (figure 1).

The map analysis shows that the number of the heat waves increased in European Russia, in the Irkutsk region and Yakutia. The growing heat wave frequency and the decreasing daily precipitation extreme amount caused the higher fire hazard in the forest area of Eastern Siberia. Cold waves were observed in European Russia and in the south of Western and Middle Siberia [5, 9]. Areas of distribution of the maximum daily temperature and pressure differentials are located in the northern part of European Russia and in Western Siberia. The areas with maximum average daily temperature and pressure differences were located in the northern part of European Russia and in Western Siberia. The growing amount of daily precipitation extremes was observed in the Krasnodar Territory, in the

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**Figure 1.** Extreme natural phenomena in Russia for the period 1991–2013. The solid line shows the southern borders between the Far North and the Arctic and the terrains equated to the Far North.
north of European Russia and in Western Siberia. Destructive floods occurred in Krasnodar, Altai, Khabarovsk and Primorye Territories [12]. Severe droughts became more frequent in the Volga region and in the south of Cis-Ural region [13, 14]. Taking into consideration the facts mentioned above, the climate extremes negative for population vital activities have increased almost on the whole territory of the country.

This fact allowed to determine the aspects of adverse environment impact and especially the impact of climate changes on the living conditions of the population and to establish the areas where this impact is stronger.

3.2. Environmental living conditions of population in Russia in the early 21st century

The map “Zoning of the territory of the Russian Federation by natural living conditions of the population” was adapted to the modern day climate conditions (2001–2010) on the base of the meteorological network data [2]. At this stage, the most dangerous and rapidly changing climatic factors, such as thermal, cold and wind, were analyzed.

A brief description of the areas with unfavorable environment conditions emphasized on the map for the modern climate is given below.

I – The area with absolutely unfavorable environment conditions occupies the northern part of Asian Russia from Taimyr to Chukotka. It includes the Taimyr Peninsula where it expands up to 65 parallel north in the Putorana Plateau region and the Arctic ocean coast, mostly northward from 70 parallel north. Territory landscapes are presented by arctic and partly sub–arctic types and by mountains in Subarctic and in the north boreal forest (taiga). This zone is featured by severe winters with little snow in Eastern Siberia. The summer is very cool on the whole arctic coast. With increasing distance from the coast toward the south the summer becomes cold. It is excessively humid in the entire zone territory. According to medical and geographical characteristics an optimal period of residence for the newcomers in this zone is 1–2 years on the plains and up to 1 year in mountainous areas. This zone is not recommended to create residential areas population.

II – The very unfavorable zone covers tundra and forest–tundra landscapes of European Russia and coastal areas of cold seas. It is characterized by the extremely high natural impact on the population with a critical stress of adaptation systems of the incomers and with trends to the health failure decompensation. The prevailing pathology in these areas is determined mainly by climatic conditions – meteorological stresses, cardiovascular pathology, cold poly neuroses, cold injuries, traumatism and decreases in immunity and disorders in biological rhythms. The very unfavorable living conditions take place in the highlands of the Altai Mountains that is characterized by an excess of ultraviolet radiation, drought and extremely high seismic intensity. This territory features extremely intensive impacts on human health, with a critical stress of adaptation systems of the incomers and with trends to the health failure decompensation. With the same prevailing pathologies as in the first zone, the optimal period of residence is slightly longer: 2–3 on the plains and 1–2 years in mountainous areas. The territory is not suitable for mass populating as well.

III – The unfavorable zone stretches as a narrow strip from the Kola Peninsula to Yakutia. Then it becomes wider due to high seismic ever frozen mountain systems of Eastern Siberia. In the mountainous areas of Tuva and Buryatia the unfavorable zone is placed along the state boundary. Unfavorable living conditions are observed in the west of Kamchatka and on the northern islands of the Kuril Ridge. This territory is presented mostly by north taiga and partly by middle taiga woodlands, as well as by mountain forest lands in the middle taiga in Eastern Siberia. The unfavorable zone is featured by slightly severe and snowy winter in European Russia, severe and high-snowy winter in Western Siberia and very severe and less snowy winter in Eastern Siberia. Cool summer is observed in European Russia and on mountain regions, except of the middle taiga landscapes in Western Siberia, and Central Yakutia, as well as in the basins of Tuva and Buryatia where it is mild. This zone has an intensive environment impact on human health. It manifests itself in very high stress of adaptation systems of incomers’ organisms and hindered compensation. Concerning the environmental conditions the territory is suitable for local populating.
IV – The conditionally unfavorable zone extends considerably and is traced in the middle taiga landscapes of the European Russia plains in Western and Eastern Siberia, as well as in Transbaikalia, the Amur basin and in Primorye. Its natural conditions are specific for Sakhalin and south islands of the Kuril Ridge. In addition, they are specific for the droughty lands. The zone is characterized by semi-severe and snowy winter in European Russia, severe and dry winter in Siberia and semi severe and snowy in the Far East region. Summer over the most zone territory is not quite warm and in the Far East it is cool. There is a high risk of natural stresses in this zone and additional investments are required to maintain normal living conditions.

V – The conditionally favorable zone narrows slightly in European Russia, and spreads out to the southern half of Western Siberia and Krasnoyarsk Territory. This zone is presented as well in the southern part of the Amur basin and in the western part of Primorye. The following climatic conditions are typical for this area: a moderately mild snowy winter in European Russia, a slightly severe snowy winter in Western Siberia and a slightly severe low-snowed winter on the Far East. Summers are usually moderately warm. The conditionally favorable zone is characterized by a slight natural impact on human health with a progressive compensation. Permanent residence of the incomers is possible in these areas, but the costs to maintain vital activities are higher compared to the central part of European Russia.

VI – The favorable zone includes Central European Russia and the adjacent black soil areas. In the West of the European territory it spreads out to the north up to 63–65th parallel north. The environment conditions here are moderately favorable for the population. A winter is moderately mild and a summer is warm. Extreme environment impacts on vital activities are very rare. As a rule, these effects manifest themselves as very cold winters and severe droughts, the frequency of which is increasing at the present time.

VII – The most favorable zone for life activity covers the southern part of European Russia, with the exception of conditionally unfavorable dry-lands, as well as the highlands of the North Caucasus that belong to the conditionally favorable zone. This territory features very mild winters and very warm summers. Extreme natural factors effecting the population living (such as a very cold winter, very severe drought, or very severe flooding, or earthquake) may occur here once in 50 years. It should be noted that there is an increased risk that strong and destructive tornadoes may cause landfall from the Black Sea to the Russian coast of the Caucasus with a frequency of one tornado per decade. At the present time, the risk of extreme precipitation and flooding increases in this zone.

A comparison between the map “Zoning of the territory of the Russian Federation by natural living conditions of the population” for the early 21st century (2001–2010) and the similar map compiled for the long-term average annual conditions (1961–1990) [15, 16] shows that the modern climate warming has led to a significant easing of discomfort in the territory of Russia. It is most noticeable in the northern and Arctic regions where the territories with absolutely unfavorable conditions are significantly collapsed due to expansion of very unfavorable zones (a softer discomfort gradation). The southern boundary of unfavorable territories shifts toward the north. It results in the expansion of the conditionally unfavorable area in West Siberia and in the south of East Siberia. In European Russia the favorable area has expanded and shifts far to the northern regions (approximately to 60° North latitude). The steady decrease of the absolutely unfavorable zone resulted from the expansion of less unfavorable areas is observed. By the beginning of this century the area of absolutely unfavorable zones collapsed by 8% and the area of conditionally unfavorable zones increased by 8%. The unfavorable zone area decreased by 5% and the favorable zone has slightly expanded – by 3%, mainly in the early 21st century.

Changes in the total score of discomfort under the conditions of the modern warming are mainly caused by heat and cold factors. The changes are related to the decrease in the sum of negative temperatures and in the number of days with extremely low temperatures as well as to the rise of sum of active temperatures and the prolongation of the frost-free period.
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