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GEOGRAPHY

Changes in the Duration of Stable Cold and Warm Seasons at the Beginning of the 21st Century in Russia

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Abstract—This paper reports on changes in the dates of the beginning, end, and duration of the stable cold and warm seasons in Russia in the second half of the 20th century and the beginning of the 21st century. For 2001–2015, the duration of the cold period was significantly reduced by 30 days almost throughout the country. In the eastern European part of Russia, Southern Urals, these changes were caused by a later beginning of the winter; on the remaining territory, this happened because of the date shifting for both the beginning and the end of the stable cold season. The duration of the warm period increases everywhere due to the earlier end of the spring, except for south of the European part of Russia, Southern Yakutia, and the northern part of Western Siberia.

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The global-mean surface temperature of air rose by 0.5°C in 2001–2010 and by 0.2°C in 1991–2000 as related to the temperature for the basic climatic period from 1961 to 1990 [1]. According to the data in [2], 2015 and 2016 were the warmest years on the record of meteorological observations. It should be noted that the growth rates of temperatures in Russia almost double the global growth rates [3].

For the territory of Russia, warming is accompanied by significant changes in the seasonal temperature trends with a nonuniform spatial structure that are associated with the climatological boundary of the snow cover [4, 5]. Generally, the duration of the cold season is reduced, and the term with steady snow cover becomes shorter [6, 7]. This factor encourages development of many sectors of the economy, especially agricultural sectors. The winter period is characterized by more complex conditions for vehicle traffic [8, 9]; in addition, there is the need to heat residential and nonresidential buildings. The reduction of the heating season in different regions of Russia has been discussed over recent decades in many works [10, 11, 12]. Professionals in the field of energy are aware of the need to update the standards of the applied climatology because the current climatic settings in Russia differ drastically from the settings described in the effective standard technical documents. According to the calculations of V.V. Klimenko [12], these differences will be even more evident in the coming decades under the milder conditions of the cold season of the year, affecting the energy supply system, especially in designing new objects and planning the loads for the heating supply. However, some works make the point that a number of abnormally cold winters were registered in Russia over the last 15 years [13].

In this work we consider the changes in the duration of the stable warm and cold seasons in Russia in 2001–2015 as related to the base climatic period of 1961–1990.

There are different criteria to determine the beginning and the end of climatic seasons depending on the goal of research and the field of science. Publication [14] provides an overview of the various methods to determine the boundaries of conditional seasons of the year and considers the changes in their duration for St. Petersburg. One of the criteria is the beginning and the end of the heating period accepted by the Regulation of the Russian Federation [15]. This criterion has an important application for different sectors of the economy and for the population. It was this one that was used in our work. The dates of the consistent transition of the air temperature over the defined boundaries (0°C for the cold season and +8°C for the warm season) were designated as the boundaries of the seasons of the year. When the daily mean air temperatures stay higher or lower than the specified values for 5 days, the temperature transition is considered as stable; the date when the next season begins is the 5th day of this transition. Therefore, the cold season of the year, accepted in our work, is the period with a stable

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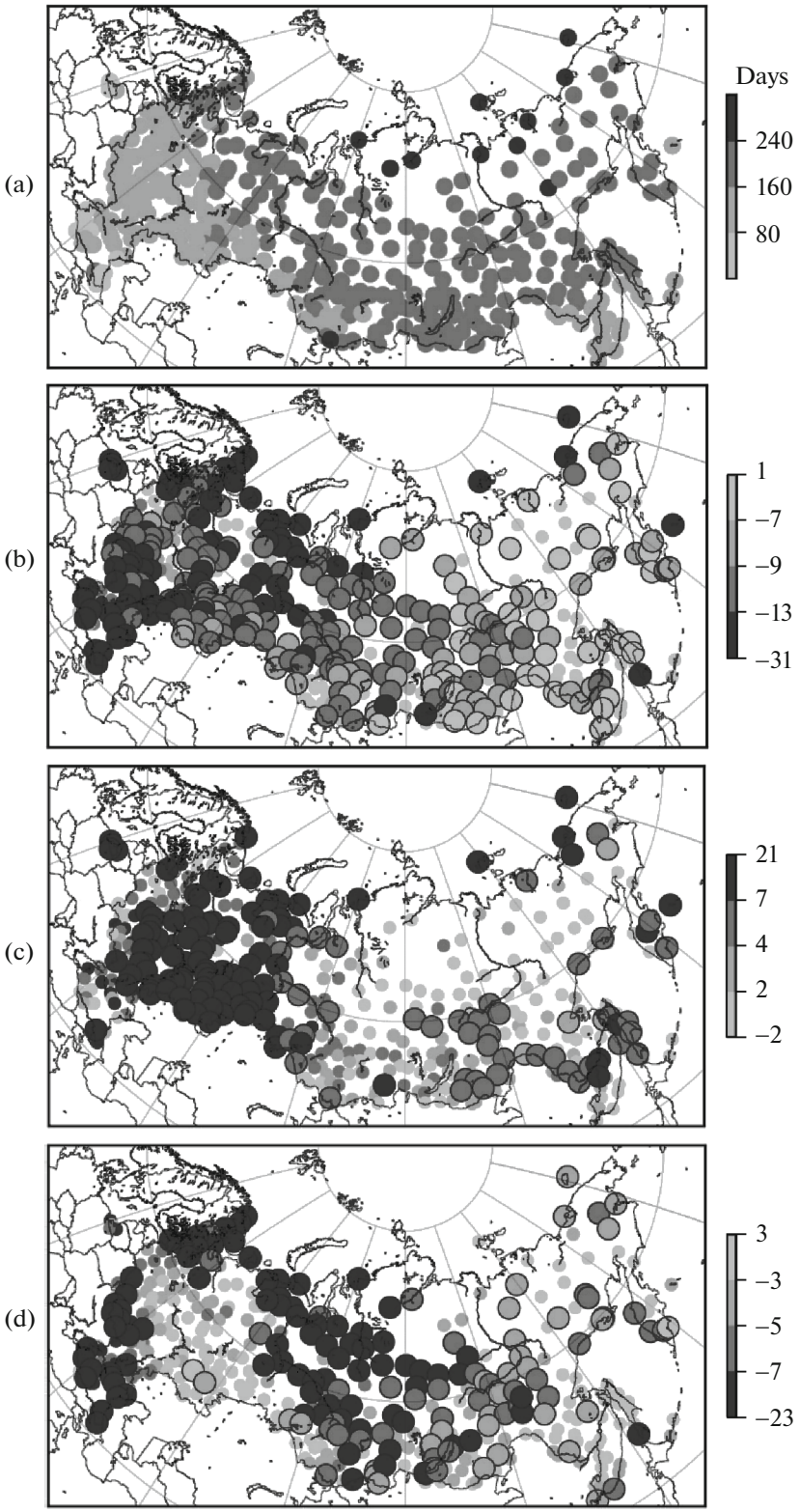

Fig. 1. (a) The mean duration of the stable cold season for the period of 2001–2015, (b) the changes of the duration, and the changes of the dates of the (c) beginning and (d) end of the cold season in 2001–2015 in comparison with the period of 1961–1990 (hereinafter, statistically significant changes are shown with large circles). Gradations for the change of the parameters were chosen on the principle of quantiles (roughly the same number of values is in each gradation).

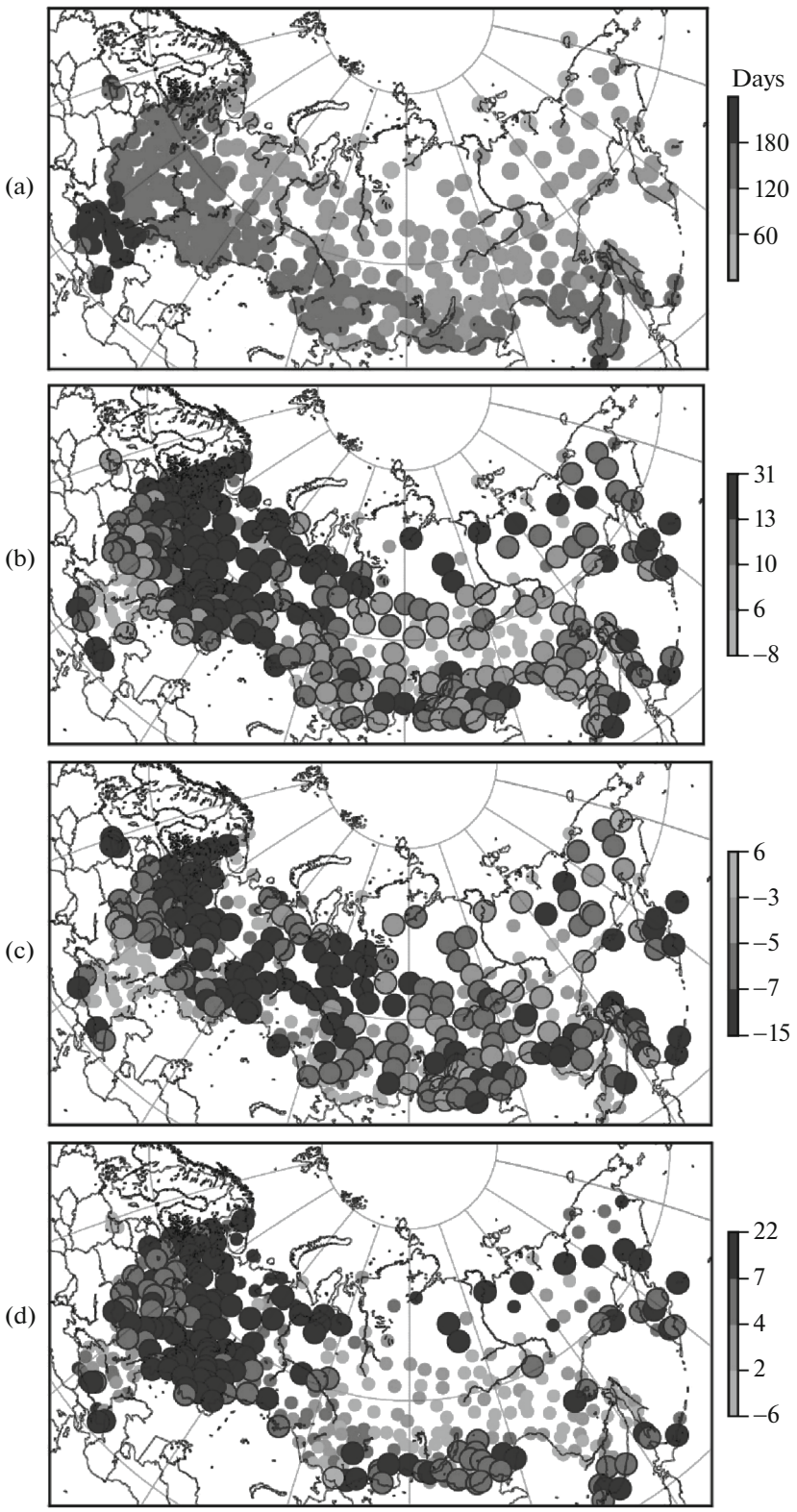

Fig. 2. (a) The mean duration of the stable warm season for the period of 2001—2015, (b) the changes in the duration, and the changes of the dates of the (c) beginning and (d) end of the warm season in 2001–2015 in comparison with the period of 1961–1990.

air temperature that is lower than 0°C, and the warm season is the period with a stable air temperature that is higher than +8°C (the length of time when heating of buildings is discontinued in Russia according to the normative documents). The periods with temperatures ranging from 0 to +8°C are considered as transitional seasons according to this classification.

The dates of the beginning and end of the stable warm and cold seasons were calculated for each year from 1961 to 2015 for 600 stations of Russia. The database of daily mean air temperatures of the All-Russia Research Institute of Hydrometeorological Information–World Data Center (RIHMI-WDC) was used in the calculations (www.meteo.ru). In addition, to assess the quality of the data, the following criterion was introduced: if there were 10 days successively (and/or 20 days not successively) with missing data on the daily mean temperature in a conditional year, this year was not used for the calculations. The stations where 80% and more of years met the quality criteria for the periods of 1961–1990 and 2001–2015 were used for the final analysis. This amounted to 398 stations from the original 600.

The mean values of the study parameters and their mean-square deviations for the base climatic period and the next 25 years were estimated on the basis of these data; Student's *t*-test was used to estimate the statistical significance of the variations. The results are presented in the form of maps for the mean dates of the beginning and the end of the seasons, the season duration, and changes (with an estimation of the significance) for the chosen periods of time.

The mean duration of the stable cold season for 2001–2015 varies from 0 days at several stations of the Caucasus's Black Sea coast to 290 days in the Far North. The spatial structure of the cold season is mainly latitudinal excluding the western region, the European part of Russia, where the duration of the cold period is significantly less than in the adjacent eastern areas (Fig. 1a). In 2001–2015, the duration of the conditional winter decreased by 8–31 days for most of the country (Fig. 1b). In the European part of Russia (excluding the western part) and the Urals, this generally happens because of the later beginning of the cold season: in 2001–2015, the data shift was 8–21 days in relation to the base climatic period; most of the stations have statistically significant variations (Fig. 1c). In the western European part of Russia, the Caucasus, and in northern Siberia and the Far East, this parameter either remains unchanged or its variations are negative and statistically insignificant. In the western European part of Russia and in most regions of Siberia, the cold season ends 23 days earlier (Fig. 1d).

There is no stable warm season only for Arctic islands; for the remaining part of the country, it ranges from ten days in the Far North to 270 days in the area of Sochi (Fig. 2a). In 2001–2015, the total duration of the warm season for most of Russia increased by 5–31 days as related to the base climatic period (Fig. 2b). In these years, the warm season began 3–15 days earlier on the entire territory of Russia (excluding Povolzhye, Krasnodar krai, the northeastern European part of Russia, and west of Yakutia) (Fig. 2c) and ended 5–22 days later in the European part of Russia (excluding Povolzhye and Krasnodar krai), south of Siberia, the Far East, and Kamchatka (Fig. 2d).

It can be concluded that the stable cold season in 2001–2015 was reduced almost throughout the country (except for northern Siberia) as compared to the period of 1961–1990. In the eastern European part of Russia and the southern Urals, these changes occur due to the later beginning of winter; for the remaining territory, this is caused by the date shifts for both the beginning and the end of the stable cold period. The duration of the warm season increases everywhere (except for south of the European part of Russia, southern Yakutia, and northwestern Siberia, generally) due to the earlier end of the spring. Subject to further global warming, forecasting by the use of the climate models, the data obtained from the stations allow us to expect a reduction in the duration of the heating season (in a linear extrapolation of the current patterns as a conservative estimate of future changes) by approximately 15 days to the middle of the 21st century.

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