Variability of the snow cover and its characteristics on the territory of the Republic of Bashkortostan

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Abstract. This article examines the variability of snow cover characteristics in the territory of the Republic of Bashkortostan (Russia). For analysis, the author used a long-term series of observations of meteorological stations for the period 1961-2010. The main tendencies of variability of snow cover height, water reserve, dates of snow cover establishment and destruction, as well as the duration of occurrence were revealed.

1. Introduction
Snow cover is one of the most important factors of the winter season. Having distinctive properties, the snow cover forms its own "snowy" climate. The greater height of the snow cover increases the temperature of the soil and reduces the depth of its freezing. These factors in a complex increase the absorbing capacity of frozen soils and, thereby, improve the conditions of wintering of plants. Atmospheric precipitation, accumulated during the winter in the snow cover, feeds surface and groundwater [1, 2].

The formation of snow cover is possible under conditions of negative radiation balance and fall of solid precipitation. The territory of Bashkortostan belongs to the region with the annual formation of snow cover throughout the whole winter.

2. Material and methods
The occurrence of the snow cover and further redistribution depends mainly on orography and differences in the hypsometric levels of the surface. On average, snow fall can be observed in October, but with variations in air temperature in the region of 0°C, the snow cover may repeatedly melt throughout the late autumn and pre-winter.

In a changing climate, the snow cover and its characteristics undergo spatiotemporal changes.

To examine the variability of snow cover characteristics, the author uses the average and maximum values of height for winter, snow reserves, dates of establishment and destruction, duration of occurrence.

As data for analysis, the database of the All-Russian Scientific Research Institute of Hydrometeorological Information - World Data Center was used [3].

3. Results and discussion
Throughout the territory of Bashkortostan there is an increase in the average and maximum height of the snow cover. This reflects a direct relationship between the increase in precipitation in the cold period and the thickness of the snow cover [4, 5].
The greatest increase in snow height is recorded along the western periphery of the forest-steppe zone within Bashkortostan. By meteorological stations Sterlitamak, Raevsky, Verkhnejarkevo, the increment for each decade is 5.5, 3.7, 3.4 cm, respectively. The lowest power increase is observed at the meteorological station Aksakovo and Bakaly (figure 1, 2).

Considering the overall trend line in absolute values, the increase is 6-10 cm across the territory. An exception is the meteorological station of Ufa-Dema, where a decrease in the height of the snow cover is noted. This is due to the fact that this meteorological station was built on the outskirts of the city, whereas at the moment it is experiencing the impact of urban infrastructure (because of the intensive urban development).

**Figure 1.** Dynamics of maximum and average height of the snow cover. 1 - maximum height of the snow cover; 2 - average height of the snow cover during the winter; 3 - average multi-year norm; 4 - trend line of maximum height; 5 - trend line of medium height.

The increase in the thickness of the snow cover during the winter is caused by snowfalls. The main causes of snowfall is the frontal precipitation of solid sediments during the passage of cyclones.
Thus, during the passage of Atlantic cyclones in December 1935 and 1947, a record precipitation value for the winter period - 43 and 42 mm per day, respectively. The norm for December is 45 mm per month. At the same time, considering more broadly the entire synoptic situation on December 28, 1935, it should be noted that two days before this date, 30 mm were recorded per day and a powerful thaw was recorded (the air temperature increased by day to +5 °C). More such catastrophic cases were not recorded [6].

**Figure 2.** Coefficients of slope of the linear trend of the maximum height of the snow cover (cm·(10 years))⁻¹.

In the cold period, the highest correlation in atmospheric precipitation is observed with the North Atlantic Oscillation Index. Some authors note that the variability of the pressure field in the winter half-year is related to this index by about 40%. In the work [7] the correlation analysis showed that the greatest relationship was revealed in the cold period in the western forms of circulation. The same authors noted that with the increase in the share of the W circulation form, in accordance with the increase in the index of the North Atlantic Oscillation, the transfer of moist air from the Atlantic increases, which leads to the increase in precipitation during this period in the region under consideration.

Figure 3 shows the dynamics of the forms W, C, E for the period 1900-2009, which shows a significant tendency to increase the form of circulation W. In the work [8] based on the analysis of the constructed trends, the rates of variability in the forms of circulation are described. Thus, the forms of the western circulation W tend to increase 2.5 days for every 10 years in the winter and slightly during the summer period, the eastern circulation of E decreases by 3 days·(10 years)⁻¹ in the winter and increases by 3.9 days·(10 years)⁻¹ in the summer period, meridional circulation C increases slightly in the cold period and decreases significantly in the warm period - by 4.5 days·(10 years)⁻¹.

[9] noted that there is an increase in the tendency of the North Atlantic Oscillation Index, especially in the winter period. This increases the number of days with a positive NAO phase in this season (figure 4).
Figure 3. Dynamics of the forms of circulation W, C, E during the period of instrumental changes [10].

Figure 4. Number of days with index NAO > 1 in the cold period [9].

An increase in the snow mass entails an increase in snow accumulation and, accordingly, water reserves in the snow. In the greater part of Bashkortostan, there is a tendency for an increase in water reserves in the snow (figure 5).

Figure 5. Dynamics of water reserves in the snow cover.
The melting of a larger mass of snow in the spring period, therefore, entails enhanced run-off processes with large snow reserves, this will lead to more intense surface erosion processes and ravine formation.

In addition to the above characteristics of the snow cover, the dates of the establishment and destruction of the snow cover are also important. From these dates will directly depend on the duration of snow occurrence.

A permanent snow cover begins to form with a stable transition of the average daily air temperature below 0 °C (the average multi-year date is November 1-4), but sometimes there are cases of exceptions. So, for example, in 2006 and 2008, the establishment of snow cover in the city of Ufa was noted in mid-December (which, apparently, was the result of the impact of a large city and its infrastructure). In other words, the establishment dates have a very wide spread in time.

Ufa-Dema

Sterlitamak

Figure 6. The dynamics of the establishment dates (blue) and the destruction (red color) of the snow cover.

Considering the dates of establishment in the multi-year profile (50 years), characteristic for this indicator is a wide spread of the timing of the beginning of the occurrence of snow - from October 13 to December 20 (more than two months). The extremely unstable temperature regime and the weather instability during this transitional season (fluctuations in the vicinity of 0 °C and advection of warm air masses) lead to significant variability in the date of snow cover almost every year (figure 6).

Nevertheless, analyzing the graphs of long-term observations, there is a practically homogeneous tendency to shift the dates of snow cover to later dates. If earlier the establishment was observed in the first decade of November, then recently - since the middle of this month (figure 6). The meteorological station Aksakovo is characterized by the greatest variability, where every decade an average snow cover is established later for more than three days.

Regarding the dates of the destruction of the snow cover, it can be noted that they also shift to a later date, but not so much.

The destruction of the snow cover begins even at negative average daily temperatures, but when positive temperatures are observed during the day. The date of destruction of the snow cover in the study area can fluctuate from the third decade of March to the third decade of April. On the basis of the constructed graphs, the displayed displacement of dates is insignificant - on average 1-2 days.
greatest change was in the date at the meteorological station Sterlitamak - for every decade there was a shift of more than two days.

The tendency described above seems to be due to the increase in power, since the largest mass of snow will continue to melt. However, due to the overall increase in average winter and spring temperatures, the shift in the date of total destruction is not so significant.

Almost everywhere there is a tendency to decrease the duration of snow cover. On average, the reduction was 3-6 days. At the Aksakovo meteorological station, there occurred the most significant decrease in duration (for 5-6 days). Exception is the meteorological station Sterlitamak: there is an increase in duration - on average for every 10 years 3 days. So, if at the beginning of the analyzed period the duration of days with snow was about 132, then by the end - along the trend line about 150 (figure 7).

Based on the above mentioned results, it can be stated that at present the winter-spring season is shifting to a later date. This is mainly determined by several reasons:

1) the establishment of a stable snow cover occurs later (approximately from the middle of November);

2) the height of the snow cover noticeably increases both the average and maximum height (by 2-6 cm and up to 10 cm, respectively).

Thus, the shift in climatic seasons that has taken place will affect not only the characteristics of the snow cover, but also the factors that depend on it: surface and underground runoff, the temperature regime of the winter-spring period, humidification, the depth of freezing of the soil and other conditions.

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