Variability of snow cover characteristics in the southern Rostov region (on the example of the Gigant settlement)

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Abstract. Snow cover affects many natural processes, including determining and regulating the water balance, determining spring runoff. The aridity of the climate in the southern Rostov region causes water scarcity in the region. The purpose of this work is to study the variability of snow cover in the settlement Gigant for the period from 1961 to 2019. The main task is to determine the changes in the dynamics of snow cover, analyze the number of days with snow and the average snow height for the study period. The analysis included the height of the snow cover, the number of days with snow, and the average annual temperatures. The data of route snow-measuring surveys were statistically analyzed. A decrease in the number of days with snow was revealed, which is explained by frequent thaws and instability of negative temperatures. There is a tendency to decrease the snow cover in winter and an increase in the number of thaws.

1. Introduction
Snow cover plays an important role in the formation of the water balance, carrying out long-term regulation of the components of the balance. The thickness of the snow cover determines the degree of soil freezing and their infiltration properties. Currently, there are negative trends in the duration of snow cover and its area in recent decades [1 - 8].

The impact of climate change on the environment is one of the most pressing problems of the present time, cause hydrological changes, changing ecosystems. As a result, ecosystems of lower economic value and low productivity are formed [3, 4]. Therefore, the analysis of climate change is an important and urgent task. An increase in precipitation during the cold season and warming of the winter period is a sign of global climate changes in the southern European part of Russia [9 - 14]. The flat area, the high arrival of solar radiation and insufficient precipitation influence meteorological peculiarities of the area [11 - 14].

The south of the Rostov region is located in the arid climate zone, this area is characterized by insufficient moisture, hot and dry summers and relatively warm winters [12]. This area is experiencing a significant water shortage. The rivers of the region have been transformed significantly. The main source of recharge is snowmelt water [13, 14]. Winter precipitation plays a significant role in the humidification of the area; the study of distribution dynamics of snow reserves is relevant.

2. Data and Methods
Steppe, dry-steppe and semi-desert are three types of landscape in the Rostov region [14]. Steppe landscapes predominate in the area. The average air temperature in the steppe zone varies from 6.7 (north) to 9.4°C (south). Similarly, the sum of active temperatures varies from 2919 to 3432°C [11-13]. According to the degree of moisture, arid and very arid areas are represented, which are formed under conditions of changing moisture [13-18]. This paper focuses on the arid steppe.
The arid steppe is considered on the example of the settlement Gigant (Rostov region), latitude 46.52, longitude 41.35, altitude 79 m above sea level. It is located in the south of the Rostov region, founded in 1928 as the first grain collective farm in the USSR, the largest in the country.

The analysis of long-term climate changes shows that there was an increase in the average annual temperature from 9.0 (1939-1960) to 10.2°C (1961-2017). The average temperature in January changed significantly from -5.5 to -3.6°C in similar periods. Summer temperatures have not changed so significantly [18].

The analysis of changes in snow cover in the area of the weather station is based on [19, 20]. This array contains the characteristics of the snow cover according to the route snow measurement surveys. Observations of snow cover according to the regulations of route snow surveys are carried out every 10 days during the cold period (every five days during the period of intense snowmelt).

Table 1. Number of days with snow.

| Year | January | February | March | November | December | Sum |
|------|---------|----------|-------|----------|----------|-----|
| 1961-1965 | 16.95 | 15.19 | 6.00 | 2.86 | 10.1 | 51.10 |
| 1966-1970 | 21.8 | 21.8 | 8.6 | 3.0 | 8.2 | 63.4 |
| 1971-1975 | 13.4 | 10.4 | 2.6 | 0.4 | 4.4 | 31.2 |
| 1976-1980 | 19.2 | 21.4 | 10.0 | 3.2 | 10.4 | 64.2 |
| 1981-1985 | 13.2 | 12.6 | 9.0 | 2.2 | 9.6 | 46.6 |
| 1986-1990 | 18.4 | 16.4 | 11.2 | 5.0 | 15.2 | 66.2 |
| 1991-1995 | 15.0 | 15.4 | 5.6 | 6.2 | 14.2 | 56.4 |
| 1996-2000 | 19.6 | 14.8 | 4.2 | 4.2 | 7.8 | 50.6 |
| 2001-2005 | 10.8 | 13.8 | 4.2 | 0.8 | 11.6 | 41.2 |
| 2006-2010 | 18.0 | 13.0 | 4.6 | 1.0 | 5.8 | 42.4 |
| 2011-2015 | 15.0 | 14.8 | 2.2 | 2.2 | 9.2 | 43.4 |
| 2016-2019 | 15.8 | 9.5 | 2.5 | 9.7 | 13.0 | 44.8 |

The analysis of the dynamics of the number of days with snow (figure 1) shows that the greatest number of days with snow was observed in 1967, 1987, 1988, the smallest – 1966, 1970, 1981, 1990, 1999, 2015, 2019.
The thickness of the snow cover varies significantly from year to year (table 2). The average snow cover thickness of up to 10 cm prevails. The highest snow cover is recorded in January – February and is about 6.5 cm.

**Table 2.** Average height of the snow.

| Year-m | January | February | March | November | December | Sum  |
|--------|---------|----------|-------|----------|----------|------|
| 1961-65| 6.5     | 6.8      | 4.1   | 1.9      | 5.1      | 6.9  |
| 1966-70| 9.9     | 11.3     | 5.2   | 1.9      | 6.4      | 5.2  |
| 1971-75| 5.9     | 7.5      | 2.8   | 1.8      | 8.1      | 2.6  |
| 1976-80| 4.6     | 3.9      | 1.7   | 0.4      | 2.4      | 5.8  |
| 1981-85| 5.5     | 12.3     | 4.0   | 2.2      | 5.3      | 3.2  |
| 1986-90| 3.5     | 4.8      | 4.3   | 1.6      | 1.8      | 6.7  |
| 1991-95| 8.3     | 10.0     | 7.7   | 2.0      | 5.5      | 5.0  |
| 1996-2000| 7.3 | 4.6      | 4.7   | 3.4      | 5.0      | 6.6  |
| 2001-2005| 8.0 | 8.2      | 4.9   | 4.3      | 7.6      | 4.4  |
| 2006-2010| 6.5 | 6.6      | 2.5   | 0.6      | 5.7      | 4.2  |
| 2011-2015| 4.5 | 6.3      | 3.9   | 1.9      | 4.3      | 4.2  |
| 2016-2019| 6.0 | 6.0      | 1.7   | 1.0      | 6.0      | 4.7  |
| Average| 5.9     | 4.4      | 4.5   | 5.2      | 4.7      | 6.9  |

Analysis of the average snow height varies from 1 to 14 cm (figure 2). In general, the prevailing snow cover height is up to 10 cm, and the large one is formed quite rarely.
Figure 2. Changes in the average snow height and the number of days with snow.

The correlation values are -0.61 (number of days and average annual temperature) and -0.31 (number of days and temperature in the cold period), -0.29 (average snow height and average annual temperature) and -0.31 (average snow height and temperature in the cold period).

4. Conclusions
Results of the snow cover study in the settlement Gigant area show the following results. There is a gradual reduction in the thickness of the snow cover and the duration of its occurrence. There is a negative trend in the duration of snow occurrence and capacity, which leads to a shortage of water in the region and an increase in water supply problems. The snow cover is unstable, it is formed in mid-January and for a short period. The timing of establishing a stable snow cover varies significantly from year to year. Statistical analysis revealed a decrease in the number of days with snow, which is explained by frequent thaws and instability of negative temperatures. There is a tendency to decrease the snow cover in winter and increase the number of thaws, which confirms the previously identified trends to reduce the amount of precipitation in winter. Thus, the analysis of the time series of precipitation showed a decrease in the amount of precipitation in the winter period with a simultaneous increase in temperature.

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