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Changes in Snowpack Density over Northern Eurasia since 1966

Olga N. Bulygina,[1] Vyacheslav N. Razuvaev,[1] Natalya N. Korshunova,[1] Pavel Ya. Groisman[2]

1 – All-Russia Research Institute of Hydrometeorological Information – World Data Center, 6, Korolev Str., Obninsk, Russia
2 - UCAR at NOAA National Climatic Data Center, Asheville, NC, USA

E-mail: bulygina@meteo.ru, razuvaev@meteo.ru, nnk@meteo.ru and, Pasha.Groisman@noaa.gov

INTRODUCTION

Current snowpack density state description and estimates of density changes (spatial and temporary) up to 2010 are given from 958 meteorological stations of Russia. Apart from the description of long-term averages of snowpack density, the estimates of it change that are averaged over quasi-homogeneous climatic regions are derived and regional differences in the change of snow characteristics are studied.

During the period of widespread instrumental observations in Northern Eurasia (since 1881), the annual surface air temperature has increased by 1.5 °C (in the winter season by 3 °C (Groisman and Soja 2009). Close to the north in the Arctic Ocean, the late summer sea ice extent has decreased by 40% (Serreze et al 2007, Levinson and Lawrimore 2008, Groisman and Soja 2009) providing a near-infinite source of water vapor for the dry Arctic atmosphere in the early cold season months. There is also evidence of more frequent thaw days over northern latitudes of western Eurasia (Groisman et al 2003, McBean et al 2005). For example, in Fennoscandia in the second half of the 20th century, the number of days with winter thaw increased by six days in 50 years, or by 35% (Groisman et al. 2011). All these factors affect the state of snow cover.

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DATA

Regular snow observations have been conducted at Russian meteorological stations since 1882. Daily snow observations at meteorological stations include snow depth measurements, determination of the amount of snow covering the area around a meteorological station and determination of the snow cover character. In addition to daily snow observations, snow course surveys are performed at meteorological stations. The course length is 2000 m or 1000 m in the field and 500 m in the forest. The snow cover depth is measured every ten meters in the forest and every twenty meters in the field. Snow density at the 1000-m and 500-m courses is measured every one hundred meters and at the 2000-m course, every two hundred meters. Snow course surveys determine snow depth and density, snow water equivalent, ice crust and saturated snow thickness, the amount of snow and ice crust covering the course, and the state of the underlying ground. Snow surveys are conducted every ten days, when no less than half the visible area around the station is covered with snow. In 1966, the measurement procedure changed substantially and at present, only snow survey data obtained no earlier than 1966 can be used.

The snowpack densite is analyzed from snow course survey data at 958 meteorological stations, The period 1966 –2010 was used in the study. The snow year was defined from July of the previous year to June of the current year. Regional analysis of snow cover data was carried out using quasi-homogeneous climatic regions, The Alisov classification (1956) was used in determining quasi-homogeneous climatic regions.

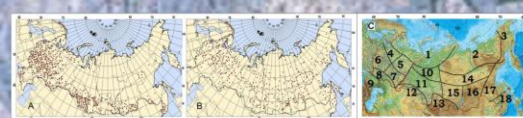

Figure 1. Locations of 958 meteorological stations with long-term snow survey information for the past five decades for surveys (A) in field (open terrain) (665 stations) and (B) forested (425 stations) environments.
(C)- The quasi-homogeneous climatic regions based on the Alisov (1956) classification

CHANGE IN SNOW CHARACTERISTICS

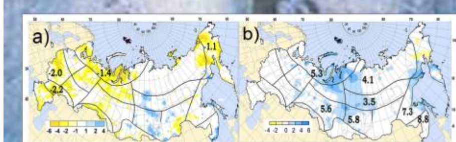

Figure 2. a) Linear trend estimates in the time series of the number of days with snow covering more than 50% of the area around a meteorological station (SCD) at meteorological stations (days/decade) (indicated by color) and SCD averaged (indicated by numerals) over quasi-homogeneous regions (%/decade), b) Linear trend estimates in the time series of the mean winter snow depth (SD) at meteorological stations (cm/decade) (indicated by color) and SD averaged over quasi-homogeneous regions (%/decade) (indicated numerals) (1966-2010).

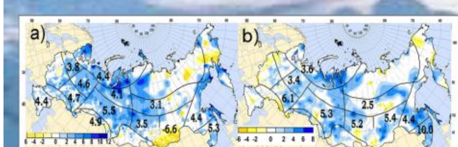

Figure 3. Same as Figure 2, but for maximum winter snow depth (a) and number of days with snow depth above 20 cm (b)

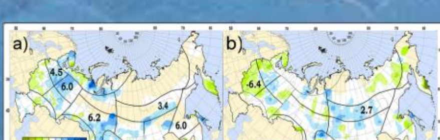

Figure 4. Same as Figure 2, but for maximum snow water equivalent in the field (a) and in the forest (b).

SNOWPACK DENSITY CLIMATOLOGY

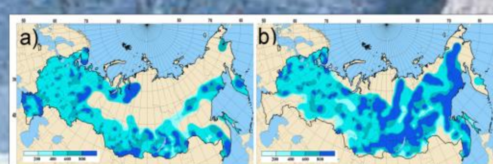

Figure 5. Mfximum values (kg/m^3) of snowpack density in the field (a) and in the forest (b) (1966-2010).

Table 1.

Long-term mean values of snowpack density averaged over quasi-homogeneous regions (Fig1(C)) (kg/m^3) (1966-2010).

№ Region	Field		Forest	
	max	mean	Max	mean
1	357.13	257.86	326.35	225.35
2			279.11	183.86
3			308.41	194.34
4	347.35	231.37	334.81	234.86
5	348.33	234.54	335.48	231.74
6	346.36	244.15	335.80	234.15
7	350.86	252.15	316.73	222.03
8	329.44	240.20		
9	253.19	184.14		
10			336.60	228.75
11	320.98	229.46	312.18	213.56
12	319.29	234.00		
13	275.90	192.74	311.25	216.84
14			277.50	181.44
15	276.97	195.56	291.62	186.01
16	223.08	162.52	255.44	164.38
17			302.14	202.22
18	272.16	188.26	291.96	200.61

CHANGE IN SNOWPACK DENSITY

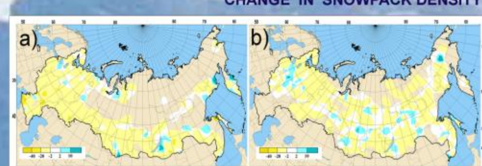

Figure 6. Linear trend estimates in the time series of the mean winter snowpack density at meteorological stations (kg/m^3 / decade) in the field (a) and in the forest (b)

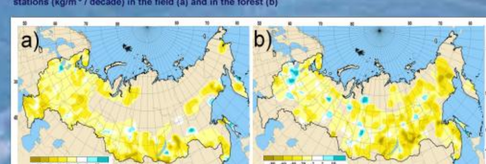

Figure 7. Linear trend estimates in the time series of the maximum winter snowpack density at meteorological stations (kg/m^3/ decade) in the field (a) and in the forest (b)

Table 2.

Linear trend estimates in the time series of the max / mean winter snowpack density averaged over quasi-homogeneous regions (Fig1(C)) (%/decade)

№ Region	Field		Forest	
	max	mean	max	mean
1	-4.48	-2.02	-4.01	-2.53
2			-10.25	-2.23
3			-15.95	-3.65
4	-2.82	-1.12	-1.88	-0.51
5	-4.74	-2.43	-3.25	-1.55
6	-3.87	-4.18	-2.20	-0.68
7	-4.13	-4.60	-5.05	-3.11
8	-5.80	-5.08		
9	-12.64	-7.55		
10			-4.10	-1.84
11	-3.68	-3.49	-2.72	-0.84
12	-6.20	-4.40		
13	-10.76	-4.41	-6.55	-1.66
14			-7.42	-1.60
15	-8.56	-3.07	-11.01	-2.10
16	-11.34	-3.38	-14.56	-2.31
17			-8.80	-1.48
18	-8.71	-3.72	-4.86	-0.20

Among the two competing factors that can cause a systematic change in the maximum and mean snowpack density over Northern Eurasia, increase in max snow depth and a decrease in number of days with snow cover, the second factor appeared to be more significant during the past 43 years. However, at a few stations in European Russia, Siberia, and Yakutia, the tendencies for the increase in snowpack density are found. But these tendencies are not now characteristic of quasi-homogeneous climatic regions.