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Climate Change and Fluctuations in the Karelian-Kola Region

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***Abstract.* In this work we consider the regularities of changes of climate and assessed the potential impact of these changes on some of the characteristics of the hydrological regime and biota water bodies of the North of the European territory of Russia from temperate latitudes to the Arctic. Within the annual course, variation of monthly air temperature values is irregular for different seasons, with most intensive warming in January and March. In summer, variations in air temperature are multidirectional. Variations in the thermal regime led, in its turn, to later ice cover formation and earlier ice-breakup resulted in the longer ice-free period. Data analysis revealed variations in the course of precipitation of warm and cold periods. Under distinguished increase of precipitation sums, a total number of days with precipitation was revealed to be equal to or lower than its climatic norm. The total precipitation amount increase occurred due to increasing frequency of rainfalls of 10 mm and more. In winter, the snow cover height exceeded the climatic norm. As the increase of annual sums of precipitation is compensated by a rise of evapotranspiration, any trend in the total river inflow into Lake Onego is absent.**

***Keywords* – air temperature, linear trend, precipitation, climate change.**

I INTRODUCTION

Long-term data from weather observations suggest that the global climate system has been changing since the beginning of the 20th century. Patterns in the ongoing change in the late 20th – early 21st centuries appear the most interesting. Detailed analysis of the regional climatic characteristics and study of the way natural systems respond to climate change based on representative observations would contribute to climate change mitigation efforts. In this paper, the climate of the Karelian-Kola region is characterized with regard to latest observation data. Multiyear means of meteorological elements were computed through year 2010.

II MATERIALS AND METHODS

The climatic system can be studied by a variety of methods and at various angles, for instance, using statistical methods, long-term observations data, by studying the physical processes that shape the climate, or through modeling. Identification of climate change is a process meant to demonstrate that the climate fluctuations we observe are statistically unusual or statistically significant. Hence, the first task for any climate change study would be a statistical description of available long-term series of observations, first of all instrument-based observations.

The source data for this study were series of mean daily and mean monthly values of the main meteorological indices according to observations at the weather stations in Karelia and the Murmansk Region in 1951-2011.

III RESULTS AND DISCUSSION

Mean annual air temperature in the Murmansk Region had a gradient from 0°C on the Barents Sea and White Sea coasts through -2°C in the central part of the Kola Peninsula and to -3-4°C in mountainous areas. The long-term mean annual air temperature in Karelia ranged from 0°C in northern districts to + 2.6…+ 2.8°C in the south of the Republic. Normal annual air temperature means were the highest at Lake Ladoga (+3.0°C at the Sortavala weather station and +3.3°C at the Valaam WS). The overall trend of mean annual air temperature throughout the Karelian-Kola region over the 20th century and in the first decade of the 21st century has been upward. Yet, the mean annual air temperature has not been growing consistently throughout the century: a temperature rise continuing since the beginning of the century was superseded in the 1950s by a cooling, which was followed in the 1980s by a new wave of warming. In nearly all years since 1989, annual air temperature means have been higher than the climatic norm as computed for the 1961-1990 period.

Mean annual air temperature has been rising unevenly across the territory. The highest linear trend coefficients for the period of 1951-2010 in Karelia came from the weather stations in southern parts of the republic, along Lake Ladoga shore: Olonets WS +0.34^{0}C/10 yrs., Sortavala WS +0.3^{0}C/10 yrs. In the central parts of Karelia the upward trend in mean annual air temperature was not so explicit: +0.26…+0.27^{0}C/10 yrs. The mean annual air temperature linear trend coefficients describing warming in the northern districts of Karelia were the lowest: ca. + 0.2^{0}C/10 yrs. Thus, the rate of rise in mean annual air temperature in the region in question increases gradually from higher to lower latitudes.

In the Murmansk Region, the linear trend coefficients in the period of 1951-2010 were +0.13^{0}C/10 in Kandalaksha, +0.17^{0}C/10 in Krasnoshchelje and Murmansk, +0.19^{0}C/10 in Lovozero, + 0.25^{0}C/10 in

Nickel'. According to the Finnish Meteorological Institute, mean annual air temperature deviations observed in Finland in 1990-2010 were also only positive. They were 0.5-1.5°C.

A characteristic feature of nonstationary processes, such as air temperature change, is a continuing change of the mean. Hence, the mean (norm) should be regarded as a function of time. Table 1 shows the climatic norms of mean annual air temperature in Karelia for two standard climatic periods: 1931-1960 and 1961-1990, and the 1991-2010 means at different weather stations. Analyzing the values one can see that there has been no or very little deviation from the climatic norms in the former two climatic periods, whereas the mean annual air temperatures averaged over the late 20th – early 21st century period were 0.9-1.2°C higher than the norm.

TABLE 1.
MEAN ANNUAL AIR TEMPERATURE

Weather station	Averaging time		
	1931-1960	1961-1990	1991-2010
Kalevala	0.5	0.3	1.3
Reboly	1.2	1.1	2.1
Padany	1.4	1.6	2.4
Segezha	1.4	1.3	2.2
Medvezhjegorsk	1.5	1.5	2.5
Petrozavodsk	2.2	2.4	3.3
Pudozh	2.2	2.1	2.9
Sortavala	3.0	3.0	4.0
Olonets	2.5	2.7	3.9

Within a year, the following patterns can be discerned in the change of mean monthly air temperatures (1951-2010) in Karelia. Warming has been the most intensive in March (+0.5 …+0.6 ^{0}C/10 yrs.) and January (from +0.3^{0}C/10 yrs. in northern to +0.6^{0}C/10 yrs. in southern districts). The temperature rise in February has also been significant, 0.4^{0}C/10 years, throughout the republic. In the period from May to December, July and August excluded, warming has evenly covered the whole study region. The August trend in northern and central Karelia has been for a cooling.

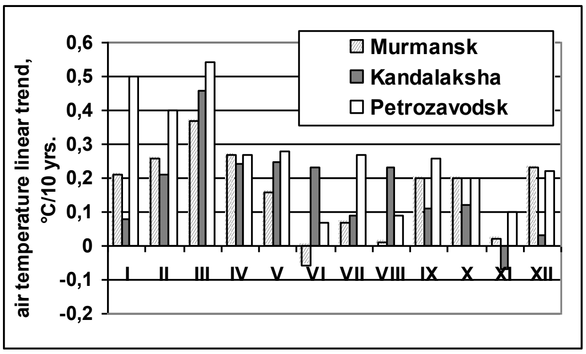

Fig.1. Coefficient of linear trend of air temperature (°C/10 year) in the Karelian-Kola region, 1950-2010 y.

Similar trends have been observed in the Murmansk Region. The air temperature rise has been the most significant in March (+0.37…+0.54^{0}C/10 yrs.). For August, the mean monthly air temperature trend has also been negative. Also, negative linear trend coefficients have been obtained for the November air temperature series (Fig,1).

Changes in the temperature regime in the territory have caused a shift in the dates on which the climatic seasons begin and end. Computations show that the dates on which the air temperature steadied above or below 0, 5 and 10°C in years 2000 - 2010 shifted relative to the multiyear means. The greatest deviation from the climatic norms is seen in the dates when the warm part of the year (above 0°C) begins and ends. The cold period of the year began 5-23 days later than the long-term average date in Karelia, and 9-15 days later in the Murmansk Region. In years 2000-2010 the cold period ended 10-20 and 6-10 days earlier than the long-term average date in Karelia and the Kola Peninsula, respectively. With these deviations in the dates of the air temperature steady transition across 0°C the duration of the warm period averaged over the stated time interval was 215- 225 days instead of the climatically normal 192-210 days in Karelia, and 180-200 days instead of 160-180 days in the Murmansk Region.

An essential meteorological element is precipitation. The estimates of change in precipitation volumes are however far less reliable than such estimates for the air temperature.

Average annual precipitation in Karelia, which belongs to the excessive precipitation zone, is 550-750 mm. Its volumes increase southwards. The distribution of precipitation is however much influenced by the orographic characteristics and the underlying surface, which distort the smooth precipitation trend. The precipitation distribution pattern in the Kola Peninsula is the following: the higher an area is positioned the greater the precipitation volumes there. Precipitation is the lowest (400—500 mm/a) in river valleys and flat areas. In areas with complex relief precipitation is distributed unevenly, amounting to 600—800 mm/a, and precipitation volumes on the tops of the highest mountain ranges (Khibiny and Lovozero tundras, Monche-tundra and Chuna-tundra) exceed 1000 mm/a. The air masses arriving from the mainland during the warm time of the year contain more moisture than in winter, and the precipitation volumes are therefore greater. Total precipitation in the summer months (July—August) is twice higher than that in the winter months (February—March) – a situation not typical of maritime climate.

Analyzing the deviations from the normal values of total annual precipitation (data averaged over the 1961-1990 period were considered the climatic norm) according to the measurements at weather stations in Karelia and the Murmansk Region one can draw the following conclusions. Before 1960, total measured annual precipitation had been much lower than the norm, the reason being measurement faults (Fig.2). Since 1960, the number of years with more precipitation than the norm has been nearly the same as the number of years with less than normal precipitation. Positive deviations from the norm have prevailed in total annual precipitation in the last decade.

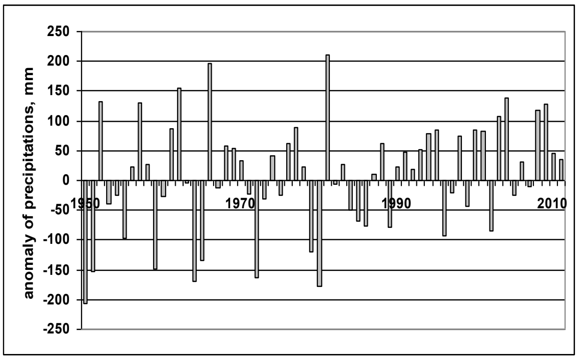

Fig.2. Anomaly of precipitations in Karelia (Petrozavodsk), 1950-2011 y.

In addition to the data about total precipitation, the annual number of days with precipitation can also provide important information. The total annual number of days with precipitation greater than 0.1 mm in Karelia is 193-212 days a year. Thus, precipitation occurs in the territory on more than a half of all days in a year. Comparing this information with averaged long-term data on the annual number of days with precipitation in the 1995-2010 period one can conclude the following. The amount of precipitation during this time period agreed with the norm or was 50-70 mm higher, whereas the total annual number of days with precipitation was mainly below the norm or at the normal level.

The total precipitation volume rose owing to the higher frequency of 10 mm and more of rainfall. Hence, rainfall in Karelia in 1995-2010 was more intensive than the long-term average, and the number of days with heavy rainfall exceeded the norm throughout the study region. More precipitation fell within fewer days.

A question of particular interest is how the snow cover regime may change in connection with the air temperature rise. Analysis of the data on the snow cover is based on the results of snow stake measurements in permanent sample plots. Data on the annual number of snow-covered days and snow depth (10-day averages) were taken into account. The snow cover duration in Karelia was 150-180 days on average. Persistent snow cover in the Murmansk Region usually forms in October, staying for an average of 220 days on the Khibiny and Chuna-tundra tops, and for 180 days in the rest of the territory. The average multiyear snow depth at the end of the winter is 70 cm in flat areas, and 40 cm on the Murman Coast, where snow is blown off by wind. The conclusion from comparing data from 1995-2008 observations in Karelia with the climatic norm is that the snow cover duration in the stated period was somewhat lower or in accord with the multiyear means. As regards 10-day means of the snow depth measured at permanent snow stakes, its values in 1995-2008 were higher than the climatic norm (Fig.3). The snow cover established in the 3rd ten days of October – 1st ten days of November, and its depth increased gradually to reach a maximum in the 1st-2nd ten days of March. By late April/early May the snow cover depth was no more than 1-6 cm.

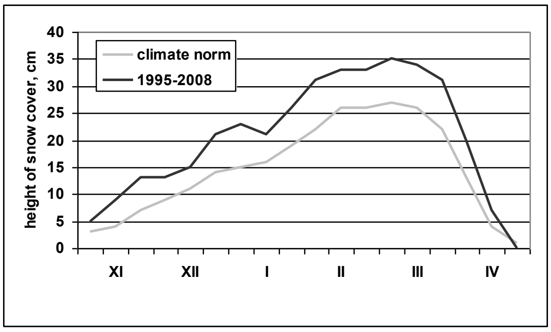

Fig.3. The average decade height of snow cover: climate norm and the average for 1995-2008 y. WS Petrozavodsk.

Under modern varying climatic conditions, evaluation of the water balance components for the river catchment areas is of timely importance. Analysis of variations and variability of the climatic and hydrological processes in the system Lake Onego – its watershed, which occupies a considerable part of Karelia and plays an important role in the socio-economical development of the region, is a strong prerequisite for successful definition of causes and scales of past and future changes in the water system.

Main features of variability and variations of climatic characteristics over and water balance components on the Lake Onego catchment area have been studied. For the period 1951-2010, the increase of annual air temperature, evapotranspiration, and precipitation sums is found to be pronounced. Significant variations in total river inflow are not detected. Intensity of the air temperature increase arises from high to lower latitudes.

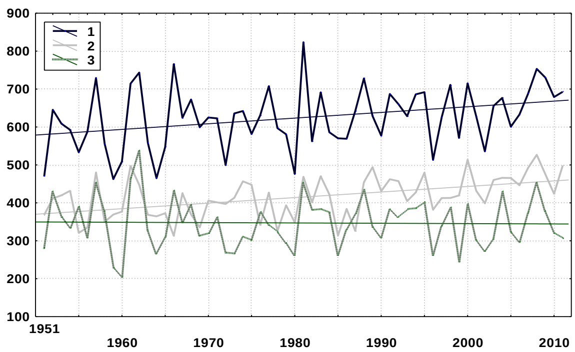

Fig.4. Annual sums of atmospheric precipitation (1), total evaporation from the catchment area (2), and annual depth of runoff from the Lake Onego watershed (3) in 1951-2011.

Within the annual course, variation of monthly air temperature values is irregular for different seasons, with most intensive warming in January and March. In summer, variations in air temperature are multidirectional. Variations in the thermal regime led, in its turn, to later ice cover formation and earlier ice-breakup resulted in the longer ice-free period (from 217 days in 1900`s to 227 days in 2000`s). During 2000-2011, water temperatures in Lake Onego were higher than its long-term value. Data analysis revealed variations in the course of precipitation of warm and cold periods. Under distinguished increase of precipitation sums, a total number of days with precipitation was revealed to be equal to or lower than its climatic norm. The total precipitation amount increase occurred due to increasing frequency of rainfalls of 10 mm and more. In winter, the snow cover height exceeded the climatic norm. As the increase of annual sums of precipitation (60-90 mm/60 years) is compensated by a rise of evapotranspiration (70-80 mm/60 years), any trend in the total river inflow into Lake Onego is absent (Fig. 4).

IV Conclusion

The study of the principal characteristics of the temperature regime in Karelia and the Murmansk Region in the second half of the 20th century and early 21st century using data from meteorological observations has brought about the following conclusions. Since 1989, mean annual air temperature has consistently been 1-2oC higher than the climatic norm. The rate of the mean annual air temperature rise showed a gradual upward trend from higher to lower latitudes. Warming has been the most intensive in the winter months. As the result, the onset dates of seasons shifted relative to the climatic norm. Analysis of changes in the precipitation volumes in the study region revealed an overall increase in total annual precipitation (50-150 mm/50 yrs.). In years 1995-2011, rainfall in Karelia and the Murmansk Region was more intensive than the long-term average, and the number of days with heavy rainfall was greater than the norm throughout the study area. More precipitation fell within fewer days. The above results indicate that the climatic indices of the study area fluctuate significantly.