Chapter III. Climatic regime and its changes in the region of the Barents and Kara seas

(E.I. Alexandrov, V.F. Radionov, P.N. Svyaschennikov)

Introduction

The observation data of the main meteorological parameters (temperature, pressure, air humidity, wind speed, precipitation and snow cover depth) were generalized climatilogically at the network of stations, which are adjacent or located in the water areas of the Barents and Kara seas, for the period, as a rule, 1951-1992. Therewith, the spato-temporal characteristics of the snow cover parameters and precipitation, which make a significant influence on its formation, were considered, because precisely the snow cover on ice of freezing seas makes direct influence on formation and destruction of ice cover in the Arctic seas. A significant volume of fresh water penetrates rather rapidly into the above layers of the ocean during the melting of snow cover in spring. The long-term tendencies of changes of temperature, precipitation and snow cover depth for the investigated region were analyzed.

1. Meteorological observations in the region of the Barents and Kara seas

Systematic meteorological observations in the region of the Barents and Kara seas are carried out from the end of last century. However, the main network of meteorological stations was established in 30-40s. An observation program at stations was described in the manuals (8, 9) and consists of measurements (observations) of more than 20 various atmosphere characteristics near the Earth surface. Among them are the following parameters: temperature and air humidity, speed and direction of wind, atmospheric pressure, cloudiness, precipitation, snow cover, duration period of the shine of the sun, different atmospheric phenomena - snow storms, fogs, glaze, rime, visibility etc. Starting from 1966 the observations are performed 8 times a day, before 1966 they were carried out 3-4 times a day.

The network of meteorological stations is non-uniform in the investigated region. Figure 1 demonstrates the meteorological polar station network in the Arctic zone of the Barents and Kara seas basins. Table 1 presents their titles, the height above mean sea level, H, and coordinates. In the Barents Sea region the stations are located, mostly, on coasts. There are no stations in the internal sea regions. In the Kara Sea region some stations are located on islands.

Table 1

Meteorological stations in the region of the Barents and Kara seas

№	Station	$h_м$	Latitude, N	Longitude, E	№	Station	$h_м$	Latitude, N	Longitude, E
1.	Barentsburg	70	78.04	14.13	20.	Russkaya Gavan	18	76.11	63.34
2.	Medvezhy Island		74.31	19.01	21.	Harasavey Cape	10	71.08	66.49
3.	Vayda-Guba	8	69.56	31.59	22.	Marresalya	24	69.43	66.49
4.	Murmansk	51	68.58	33.03	23.	Zhelaniya Cape	8	76.57	68.34
5.	Tsyp-Navolok	24	69.43	33.08	24.	Popov Island	4	73.20	70.02
6.	Viktoria Island	8	80.09	36.46	25.	Vilkitsky Island	3	73.31	75.46
7.	Tersko-Orlovsky light	72	67.12	41.20	26.	Vize Island	10	79.30	76.59
8.	Kanin Nos Cape	48	68.39	43.18	27.	Ushakov Island	47	80.49	79.33
9.	Shoyna	16	67.53	44.08	28.	Leskin Island	10	72.21	79.33

10.	Naguskaya	15	80.49	47.38	29.	Dikson Island	42	73.30	80.14
11.	Indiga	4	67.42	48.46	30.	Uedineniya Island	22	77.30	82.14
12.	Kolguev Island	12	69.30	49.05	31.	Isvestuya Tsyk Island	11	75.32	83.05
13.	Bugrino	11	68.47	49.21	32.	Sterligov Cape	10	75.25	88.54
14.	Malye Karmakuly	16	72.23	52.44	33.	Isachenko Island	10	77.09	89.12
15.	Narjan-Mar	7	67.39	53.01	34.	Golomyanny Island	7	79.33	90.37
16.	Menshikov Cape	12	70.43	57.36	35.	Pravdy Island	10	76.16	94.17
17.	Rudolpha Island	52	80.48	57.58	36.	Russky Island	9	77.10	96.26
18	Bolvanskiy Nos	13	70.27	59.04	37.	Krasnoflotskiye Islands	8	78.38	98.43
19.	Amderma	53	69.46	61.41	38.	Geiberg Island	6	77.36	101.31

Meteorological conditions in the Arctic zone of the Barents and Kara seas basins are described on the base of observation data using the data archived at AARI and, particularly, from publications (10, 12). The period 1951-1980, which describes the climatic regime of the second half of 20th century, was selected as the basic one to calculate the average monthly standards. It consists of branch of cold snap of climate in the region after 1940s and that of the warm spell of climate from the mid 1960s. Extreme values of the investigated meteorological elements were selected from the data for the whole observation period at the stations.

2. Climatic conditions in the Barents and Kara seas region

Climatic conditions in the region are characterized by geographic position of the region in the Arctic, non-uniform incoming solar radiation within a year, atmospheric circulation. The Atlantic air mass penetrating into this region with the cyclones makes the significant influence on its climate. At that time the extensions of the Arctic high and the Siberian one make a significant influence too.

Underlying surface plays an important role in the climate formation in the region. In the western area of the region the Barents Sea is not completely ice covered. In the central and south-eastern areas ice is the first-year one and is of local formation. Ice formed during the cold year period melts completely during the warm period. Open water is observed in the south-eastern Barents Sea from July through October. During the other eight months ice cover with snow is observed. Multi-year ice transported by wind and currents from the Arctic basin and the Kara Sea is observed in the extreme north and the north-eastern sea area. In the eastern area of the region the Kara Sea is ice-covered within the major part of the year period. Compacted ice cover slightly smoothes the climatic contrasts of some areas. Ice impedes the heat exchange between ocean and atmosphere, but does not completely excludes it. That is why climate over the Kara Sea in winter is warmer than that over the adjacent continental areas.

In total, the region climate is rather severe: long duration period of winter, long duration of snow cover in the eastern area, short intermediate seasons (spring and autumn), short and cold summer, early frosts in autumn and the late ones in spring, absence of the period without frosts in some years in the eastern area of the region. Climate becomes more severe, in total, from west to east.

2.1. Circulation conditions and air pressure

The cyclone circulation makes the significant influence on the region climate within cold period and gradually weakens in the northern and eastern areas of the region.

Intensive cyclone activity is observed over the south-western and the southern areas in winter. The southern Barents Sea is the main track of the Atlantic cyclones displacing from the Greenland and Norwegian seas and, particularly, of the Mediterranean seas. In January 7-8 cyclones overpass the Barents Sea. Their amount increases last years. Periodically, cold Arctic and polar air mass penetrates into this region.

Low pressure trough, which occupies an area from Iceland through the Norwegian and Barents seas to Severnaya Zemlya, is shown up in charts of ground pressure. Novaya Zemlya elongated almost meridionally is a barrier for the cyclones. As a result, there are two cyclone branches with high-pressure gradients directed to the north-east to the Franz Josef Land and the south-eastern Barents Sea. High horizontal temperature gradients are fixed over the western coast of Novaya Zemlya. At that time, they abruptly are decreased over the eastern coast and the southern Kara Sea. Novaya Zemlya also impedes the penetration of warm water of the Barents Sea. Anticyclone circulation connected with the Siberian and Arctic winter highs makes influence on the eastern region area, near Severnaya Zemlya archipelago. As a result, the cyclone circulation over the Kara Sea sharply weakens, and the significant pressure variability, high frequency of South-West high winds (15 m/s and higher) (in the northern area – the South winds), small cloudiness, frequent, but not intensive, precipitation are observed.

Interannual variability of average monthly pressure is the maximum one in the central and eastern area of the Kara Sea (Table 2). In total, it is increased from west to east in the region, and interannual variability maximum is fixed in February. Standard deviation of average monthly values of air pressure is increased from 8.2 mbar near Rudolph Island to 9.8 mbar on Dikson Island and 10.1 mbar on Isachenko Island.

Table 2

Standard deviations of average monthly values of air pressure, mbar

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Rudolpha Island	7.4	8.2	8.0	6.0	4.8	3.9	3.4	4.5	4.6	5.0	5.9	6.7
Malye Karmakuly	7.1	8.3	8.1	4.9	3.9	3.2	2.8	3.7	4.8	5.3	7.4	7.9
Zhelaniya Cape	7.6	8.7	8.2	5.8	4.6	3.6	3.1	4.8	5.1	5.4	6.7	6.9
Amderma	7.0	8.8	7.6	4.7	3.2	2.9	2.8	3.7	4.3	5.0	7.6	8.3
Dikson Island	7.6	9.8	8.2	5.3	4.2	3.3	2.4	3.6	4.5	5.3	7.2	7.3
Golomyanny Island	8.4	9.5	8.7	6.7	5.5	3.7	3.3	4.7	5.3	6.0	6.6	7.1
Russky Island	8.1	9.6	8.5	6.3	4.8	3.6	2.9	4.2	5.1	5.8	6.7	6.8
Isachenko Island	8.3	10.1	8.6	6.9	5.2	3.7	2.9	4.5	4.9	6.0	6.6	6.8

In spring the circulation has a winter character, but pressure gradients are decreased. Trough of Iceland low weakens, decreases in April in the Kara Sea keeping in the Barents Sea and completely disappears by May. Temperature contrasts are decreased. That is why the cyclone intensity (speed of cyclone displacement and the cyclone depth) is decreased also. Cyclone tracks displace to the south, their frequency decreases. In April, in the average, not more than 3-4 cyclones overpass the region. The Siberian low decays. Extensive low area (not deep) takes its place. Variability of monthly pressure decreases in spring. In April it is equal to, in the average, 5-6 mbar, in May 3-4 mbar.

In summer the cyclone activity continues to decrease. In July, in the average, 3 cyclones overpass the southern circumscription of the region, 2 cyclones overpass the northern one. Anticyclones of small intensity are formed over the Barents Sea. Amount of anticyclones (very small in winter and spring) increases up to 3 within a month in July. Differences of the meteorological conditions in the region are smoothed due to weakening and changing of the circulation processes. The diffused area of increased pressure is formed over the region. Pressure gradients are small. In the extensive area of Asia low the North winds become to be prevailing over the Kara Sea. In spring and summer not deep cyclones move to the Kara Sea region from the continent.

Average variability of monthly pressure in July is equal to not more than 2.5-3.0 mbar.

In autumn the cyclone activity increases, pressure field distribution becomes that of winter type. In September continually deepening lows are formed over the Barents Sea (from October over the Kara Sea), which then interfuse with developing Iceland trough. In October the Iceland low trough is the distinct one. In October about 5 cyclones displace over the Barents Sea region, about 4 cyclones over the southern Kara Sea. Stable high pressure center is formed over Siberia. The pressure field distribution becomes that of winter type over the region by November. Interannual variability of monthly pressure increases up to 5-6 mbar.

The years with the minimum, average and the most possible sea ice transport from the Kara Sea were defined by the analysis of fields of average monthly air pressure at sea level for the period 1951-1990. For this purpose the average difference between air pressure at the Zhelaniya Cape station and that at Golomyanny Cape was used for the period from July through September. It clearly demonstrates the sea ice transport from the Kara Sea (Figure 2). As it is demonstrated on Figure 2, the 1985, 1987 and 1988 years, within which the meteorological conditions cause the maximum, average and minimum fast ice transport from the Kara Sea, are the specific ones for the period 1981-1990.

Circulation conditions, for which the fast ice transport from the Kara Sea was maximum, average and minimum, are demonstrated on Fgs. 3-5. In June-July, 1985 the baric field in the Kara Sea region was characterized by positive pressure anomaly (Figure 3). It was equal to 1 mbar in June in the center, which was located over the Franz Josef Land region. In July it was equal to 8 mbar. Stable North-East winds, which caused the drift of the major volume of sea ice from the Kara Sea region to the north of Novaya Zemlya, became to be prevailing. In August the positive pressure anomaly displaced to the north-east to the Central Arctic basin. The center of negative pressure anomalies was located over the major area of the region. However, still there were the conditions for the sea ice transport.

Circulation atmospheric conditions for the average ice transport from the Kara Sea can be demonstrated on the example of the warm season 1987 (Figure 4). An area of positive pressure anomalies was located over the sea in June. In the southern area the anomalies were equal to 1-2 mbar, in the northern one 2-4 mbar. In July the Kara Sea region was on the periphery of extensive low pressure center. In August pressure was slightly higher than the standard one over the sea region. There are no stable wind conditions, which cause or impede the sea ice transport from the Kara Sea region, due to this pressure field distribution.

In summer 1988 (Figure 5) the circulation atmospheric conditions were those that the ice transport from the Kara Sea region was impeded. In June-July the Kara Sea was always in the low-pressure area. Therewith, the center of negative pressure anomalies in June was located to the west from the Kara Sea in the northern Greenland Sea. Anomaly in the center was equal to −14 mbar. In the eastern Kara Sea the center of negative pressure anomaly was developed. Anomaly in the center was equal to −4 mbar. The area of small positive anomalies was located over the Barents Sea and the south-eastern Kara Sea. Stable West and North-West winds prevailed due to this pressure field distribution. In August the area of positive pressure anomalies extended over the whole Kara Sea region. The center was located in the north-eastern Barents Sea between the Franz Josef Land and Novaya Zemlya. The anomaly in the center was equal to 4 mbar.

2.2. Air temperature and humidity

Annual variability of air temperature, in total, in the region is characterized by temperature minimum in February and the temperature maximum in July-August. Air temperature at the stations located in the western area of the region is always higher than at these in the eastern one. However, in summer this difference is smoothed, the latitudinal direction of isotherms is observed, the local peculiarities are shown up more clearly.

Average annual air temperature in the region of Franz Josef Land is equal to 10-12 °C below zero, near the Severnaya Zemlya archipelago it decreases to 14-15 °C below zero and lower (Table 3). Air temperature in February is equal, in the average, to 18-20 °C in the western area of the region, 26-29 °C below zero in the eastern one. July is the warmest month, when the average temperature is equal to 4-7 °C in the southern and western area of the region. It lowers to 1-3 °C in the east.

Table 3

Average monthly and annual air temperature, °C

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	–22.7	–22.3	–23.2	–18.6	–10.0	–1.9	0.9	–0.1	–4.6	–12.5	–17.7	–20.7	–12.8
Malye Karmakuly	–14.4	–14.9	–14.8	–10.1	–4.2	1.7	6.8	6.4	3.0	–2.6	–8.4	–11.6	–5.3
Zhelaniya Cape	–19.6	–20.0	–20.7	–15.8	–8.1	–1.1	1.8	2.3	0.0	–5.6	–12.8	–16.1	–9.6
Amderma	–18.1	–19.3	–17.5	–10.8	–4.5	1.6	6.4	6.7	3.4	–3.2	–9.8	–14.3	–6.6
Dikson Island	–25.6	–25.7	–24.3	–17.2	–8.1	0.2	4.6	5.0	1.6	–7.3	–17.6	–22.3	–11.4
Golomyanny Island	–27.9	–28.1	–28.1	–21.2	–10.3	–1.4	0.7	0.0	–3.3	–12.0	–20.7	–24.6	–14.7
Russky Island	–28.2	–28.9	–28.5	–21.2	–10.5	–1.3	1.4	0.8	–1.7	–10.0	–20.0	–24.2	–14.4

Air temperature has significant short-term and long-term interannual variability. Standard deviation of annual air temperature is equal to 1.4-1.5 °C, in January temperature is equal to 3.5 °C, in July 2-3 °C.

Absolute air temperature maximum at the stations located in the north-western area is equal to 21 °C, in the north-eastern area 13 °C, in the southern one 31 °C. Absolute minimum of air temperature in this region is accordingly equal to 50 °C, 51 °C and 48 °C below zero.

Table 11 presents the average and extreme (the first and the latest) dates of the first frost (air temperature below zero measured by minimum thermometer) in autumn and the latest frost in spring and also the average, minimum and maximum duration period without frosts. As it is demonstrated in Table 4, there is no period without frost in the northern area of the region. In the southern area of the region the duration period with positive air temperature is from June through September, and in the average, is equal to 50-70 days.

Table 4

Date of the first and the latest frost and duration period without frosts

Station	Date of frost						Duration period without frost		
	Latest frost			First frost					
	average	earliest	latest	average	earliest	latest	Average	Shortest	Longest
Rudolpha Island	Absence of the period without frost								
Malye Karmakuly	26.06	10.06	28.07	08.09	11.08	13.10	72	33	103

		1952	1946		1978	1923		980	1938
Zhelaniya Cape	Absence of the period without frost								
Amderma	09.07	15.06 1943	12.08 1940	04.09	30.07 1969	27.09 1950	55	20 1942	91 1977
Dikson Island	10.07	18.06 1941	11.08 1944	02.09	12.08 1943	04.10 1919	53	32 1947	97 932
Golomyanny Island	Absence of the period without frost								
Russky Island	Absence of the period without frost								

Partial pressure of water vapour in atmosphere over the investigated area is equal to 1-2 mbar in winter and 6-9 mbar in summer within the whole year due to low temperature background (Table 5). In winter in the eastern Barents Sea it is equal to about 2 mbar, in the south-western Kara Sea about 1-2 mbar, in the north-eastern one about 1 mbar. In summer the vapour pressure increases, and in August it is equal to 8-9 mbar in the south-western area of the region, about 6 mbar in the north-eastern one. Interannual variability of partial pressure of water vapour is the maximum one in July-August. In the southern area of the region the standard deviation is equal to 1.0-1.2 mbar, in the northern one 0.7-0.9 mbar. Within autumn period it slightly decreases (0,7-0,8 mbar) and in February-March it is equal to 0.4-0.5 mbar (minimum).

Table 5

Average monthly and annual value of partial pressure of water vapour, mbar

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	1.1	1.2	1.0	1.4	2.6	4.8	6.0	5.7	4.2	2.4	1.7	1.4	2.8
Malye Karmakuly	2.1	1.9	2.0	2.7	3.8	5.8	8.2	8.2	6.6	4.4	3.2	2.7	4.3
Zhelaniya Cape	1.4	1.3	1.2	1.8	3.0	5.2	6.4	6.6	5.5	3.6	2.3	1.9	3.4
Amderma	1.5	1.4	1.7	2.7	4.0	6.2	8.5	9.0	7.1	4.5	2.9	2.1	4.3
Dikson Island	0.9	0.8	0.9	1.7	3.1	5.8	7.8	8.0	6.2	3.3	1.6	1.2	3.4
Golomyanny Island	0.6	0.6	0.6	1.1	2.5	5.0	6.1	5.8	4.5	2.3	1.2	0.9	2.6
Russky Island	0.6	0.6	0.6	1.1	2.6	5.2	6.5	6.3	5.1	2.7	1.3	0.9	2.8

Relative air humidity is characterized by rather high values within the whole year (Table 6). Average annual values in the region are more than 80 %. In the north and east of the region they are equal to 87-88 %. In summer relative air humidity is equal to 90 % and more in the region. Interannual variability of relative air humidity is small. Standard deviation within some months changes in the range from 2 % to 5%. Maximum standard deviation is fixed within cold months and the minimum one within the summer months.

Table 6

Average monthly and annual relative air humidity, %

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	84	84	83	85	87	90	92	93	91	87	85	84	87
Malye Karmakuly	79	78	78	79	80	83	82	84	84	82	81	81	81
Zhelaniya Cape	84	83	84	85	86	91	92	92	89	85	85	83	87
Amderma	83	83	84	86	88	90	88	89	89	88	88	85	87
Dikson Island	85	84	85	86	87	91	91	90	89	87	87	86	87
Golomyanny Island	83	83	82	84	86	90	94	95	92	86	84	84	87
Russky Island	84	84	84	85	88	92	95	96	92	87	85	84	88

2.3. Wind and the conditions for high speed wind

Wind regime over the Barents and Kara seas is specified by the position of atmospheric pressure fields and has the monsoon character.

Table 7 presents the frequency of the directions of wind and calms. Frequency of wind directions is calculated using the total amount of observations without calms for each month and year. Frequency of calms is calculated by total amount of observations. When the table was developed, observation data sets for the period 1951-1980 were used. In November-March the winds with the south component prevailed. Therewith, in the south-western sea area winds are the South-West and South, in the north-eastern the South-East and South. In June-August the winds with the north component prevailed, mostly, the North and North-West. Wind changed its direction in spring and autumn. Wind regime in the coastal zone, in straits, bays and narrow places differs from that in the open sea. Frequency of calms varies from 2 % to 11 %.

Table 7

Frequency (%) of wind direction and calms

	N	NE	E	SE	S	SW	W	NW	Calm
					Zhelaniya Cape				
I	7	3	7	29	18	6	17	13	9
II	5	2	7	31	17	6	21	11	10
III	6	3	8	32	13	3	20	15	11
IV	7	3	9	29	10	2	22	18	9
V	11	4	10	21	7	2	23	22	8
VI	8	3	12	19	4	1	28	25	8
VII	6	2	13	18	2	1	29	29	9
VIII	9	4	10	19	6	2	25	25	10
IX	13	6	11	20	11	5	19	15	6
X	14	7	12	15	16	8	16	12	5
XI	9	4	10	23	20	6	17	11	7
XII	7	3	7	23	21	7	20	12	8
Year	8	4	10	23	12	4	21	18	8
					Amderma				
I	6	8	10	9	29	25	8	5	3
II	5	7	15	9	28	24	7	5	4
III	8	9	14	9	24	20	10	6	4
IV	7	10	14	8	18	20	14	9	3
V	11	13	13	6	10	16	17	14	2
VI	12	15	15	5	8	11	17	17	3
VII	12	17	20	5	8	9	13	16	3
VIII	12	15	17	6	10	12	14	14	3
IX	10	10	14	10	16	17	13	10	3
X	11	10	10	11	20	20	11	7	2
XI	9	8	9	10	24	24	10	6	2
XII	6	7	10	11	29	25	8	4	2
Year	9	11	13	8	19	19	12	9	3
					Golomyanny Island				
I	6	12	18	32	18	6	2	6	9
II	6	9	15	32	20	7	5	6	6
III	8	13	17	34	14	3	5	6	7

IV	11	17	21	23	10	6	4	8	6
V	14	20	16	18	9	7	6	10	5
VI	17	13	14	16	11	9	8	12	5
VII	19	8	7	13	14	10	13	16	5
VIII	18	10	11	13	13	10	11	13	6
IX	15	15	14	18	14	9	7	8	5
X	11	17	22	18	12	7	6	7	5
XI	7	14	24	24	15	5	5	7	5
XII	7	10	14	28	22	7	5	7	6
Year	11	13	16	23	14	7	7	9	6

Average monthly wind speed in the region changes from 4-6 m/s in summer to 6-9 m/s in winter (Table 8). It is explained by the increasing of cyclone activity in winter and its weakening in summer. In the western sea area during cold period the winds of 6-9 m/s are often observed, in the north-eastern these of 5-6 m/s. In summer wind speed decreases by 1-2 m/s in the western area, in the north-eastern one its decrease is almost imperceptible.

Wind speed distribution within all year seasons significantly depends on the relief. Wind of higher speed is observed near the western coast of Novaya Zemlya and in the straits of the Kara Sea (Vilkitsky, Matochkin Shar, Yugorsky Shar, Kara Strait, in the straits of Severnaya Zemlya), near the mountainous capes (Zhelaniya Cape). Wind speed variability slightly changes from year to year. Within the cold months it varies from 1 m/s to 2 m/s in the western sea area and about 1 m/s in the north-east. Within the warm months it flattens and is equal to 1 m/s.

Table 8

Average monthly and annual wind speed (V) and its standard deviation (SD), m/s

Station	Parameter	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	V	7.4	7.2	6.9	6.5	5.4	4.8	4.1	4.4	5.6	6.4	6.8	6.7	6.0
	SD	2.0	2.2	2.4	2.3	1.3	0.8	0.8	1.0	1.1	1.2	1.7	1.5	0.6
Malye Karmakuly	V	9.6	9.6	8.9	7.6	6.7	6.3	6.0	6.2	7.0	7.6	8.9	9.6	7.8
	SD	2.2	2.5	2.0	1.7	1.2	1.2	1.1	1.0	1.3	1.2	1.7	1.8	0.7
Zhelaniya Cape	V	9.0	8.8	8.3	8.0	7.1	7.0	7.0	6.8	7.5	8.3	8.3	8.5	7.9
	SD	1.6	1.8	1.5	1.7	1.2	1.2	1.3	1.4	0.9	1.1	1.3	1.6	0.5
Amderma	V	8.5	8.2	7.7	6.8	6.4	5.6	4.9	5.3	6.3	7.2	8.1	8.7	7.0
	SD	1.8	1.5	1.7	1.3	0.9	1.1	0.9	0.9	0.9	1.1	1.5	1.7	0.8
Dikson Island	V	8.2	8.1	7.4	7.1	6.8	6.8	5.9	6.3	6.9	7.4	6.9	8.3	7.2
	SD	1.3	2.0	1.7	1.5	0.9	0.8	0.5	0.9	0.9	1.2	1.6	2.3	0.7
Golomyanny Island	V	5.9	6.0	5.9	5.9	5.4	5.4	5.1	5.3	6.4	6.4	6.0	6.5	5.9
	SD	1.2	1.2	1.4	1.0	1.0	0.6	0.8	1.0	1.0	1.3	1.0	1.2	0.5
Geiberg Island	V	5.2	5.2	5.8	6.3	5.8	6.0	5.7	5.8	6.1	6.0	5.7	5.7	5.8
	SD	1.0	1.2	1.1	1.4	1.0	1.1	0.8	1.0	0.9	1.1	1.2	1.1	0.5

The highest wind speeds observed by wind vane at the coastal and island stations within their operating period up to 1980 are presented in Table 9. Wind speed is equal to 34-

40 m/s over the Kara Sea within the cold period. Sometimes it is higher than 40 m/s. It, as a rule, does not exceed 23 m/s within the summer period over the sea area without ice In the straits it does not exceed 34 m/s. However, in some coastal regions even in simmer wind speed may increase up to 40 m/s.

Table 9

The highest wind speed measured by wind vane, m/s

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	>40	>40	>40	>40	34	34	30	34	34	40	40	>40	>40
Zhelaniya Cape	>40	>40	>40	37	28	34	40	34	40	34	40	40	>40
Amderma	40	37	38	40	28	34	24	24	32	40	40	40	40
Dikson Island	40	40	34	40	40	28	24	34	28	>40	40	>40	>40
Golomyanny Island	28	31	28		23		23		30		29	31	
Russky Island	34	40	30	36	34	34	24	28	40	40	34	34	40

Table 10 presents the highest wind speeds, which can be observed one time within 1, 5, 15 and 20 years. They were calculated by a method described in the publication (5). The data of wind vane observations for the period 1936-1965 were assumed to be the initial ones to carry out the calculation.

Comparing the tables 9 and 10 a conclusion is made that the calculated and observed highest wind speeds are similar. Table 10 also presents the data of possible wind speeds and the their probability in the region.

Table 10

The highest wind speed (m/s) possible one time within the concrete amount of years

Station	Wind speed possible one time within				
	1 year	5 years	10 years	15 years	20 years
Rudolpha Island	42	50	54	55	56
Malye Karmakuly	51	59	63	65	67
Zhelaniya Cape	39	44	46	48	49
Amderma	36	42	44	45	46
Dikson Island	39	46	49	50	52
Russky Island	34	41	44	46	47

Data of stormy winds frequency (>15 m/s) are of the practical interest (Table 11). The high winds are the West and South ones. The day amount with storms is the maximum one within the cold year period. Day amount with storms is equal to 10-14 in the western area in November-March, 3-5 in the north-eastern area for a month. Within summer period the stormy wind frequency is imperceptible and equal to 1-2 days in the northern area, 2-4 days in the southern sea areas. In November-March high winds are observed from west, south-west and south and are accompanied by air temperature increase and snow storms. In June-August they are observed, mostly, from north, north-east and are accompanied by air temperature decrease.

Table 11

Average monthly and annual day amount with high wind (>15 m/s)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	12	10	9	9	6	3	2	3	5	8	8	10	85
Malye Karmakuly	16	14	14	11	8	7	6	5	7	10	12	14	124
Zhelaniya Cape	13	10	10	10	6	8	8	9	8	10	12	14	118
Amderma	14	10	10	8	6	4	2	3	5	10	12	12	96
Dikson Island	12	9	9	7	6	4	2	4	5	8	8	10	84
Golomyanny Island	3	3	5	4	2	2	2	2	4	5	4	5	41
Russky Island	4	2	3	3	2	2	1	2	4	6	4	4	37

Amount of days with storm within a year is equal to, in the average, 80-100 in the south-western sea area, about 40 days in the north-eastern one, up to 100 days and more in the straits and near the mountainous capes (Zhelaniya Cape). Table 12 presents wind speed of 25 m/s and higher at Zhelaniya Cape station within some years. Amount of days with this wind speed can change from year to year.

Table 12

Amount of days with wind speed of 25 m/s and higher at the Zhelaniya Cape station

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1985		1	1						2	2	6	1	13
1987										2			2
1988		1										1	2

Duration period of wind of 15 m/s and higher is short. Their continuous duration period is not more than 6 hours within a year in 35-45 % of all cases. In some cases it can be more than 3 days. These winds with duration of 5-6 days were observed in winter in Yugorsky Shar strait and near the western coast of Yamal peninsula, 7 days – near the entrance of Matochkin Shar strait. In some cases high winds were observed within several days. Wind of 25 m/s speed and higher was observed on Dikson Island within 6 days (with breaks) from December 23 through December 29, 1976. On Zhelaniya Cape wind of 25 m/s speed was observed within 3 days (November 14-17, 1985). High gusty wind named as "Novozemelskaya bora" is characteristic for the Novaya Zemlya islands. Speed of the gusts reaches sometimes 60 m/s. Bora is observed from north-west on the eastern coast of the Novaya Zemlya islands, from north-east in the eastern entrance of Matochkin Shar strait. This wind propagates to the sea direction at a short distance. Usually its speed significantly lowers at 15-20 miles distance from the coast. Bora is frequently observed in October-March. In July-September it is observed rarely. In the average, the duration period of bora is about a day, but sometimes it can continue up to 5 days.

High winds occur in the Kara Sea region in the almost all cases due to pressure field of the same type. High winds are caused by cyclone circulation. Cyclones of depth from 960 mbar to 1000 mbar displace to the Kara Sea region from the North Atlantic. They can displace over the Barents Sea and Novaya Zemlya or over the Spitsbergen to the north of Novaya Zemlya. Then they are blocked by anticyclone located over Siberia or the extensive anticyclone over the East Europe. That is why, the isobars become more concentrated in the atmospheric pressure field, and wind speed increases. Such situation was observed on November 2, 1980. Cyclone of 978 mbar depth displaced along the northern track to the Kara Sea region. At that time an extensive anticyclone with crest directed to Novaya Zemlya was located over the European area of the continent. As a result, the North winds of 14-20 m/s prevailed over the whole south-western Kara Sea, due to which water level increased and ice was transported to the Barents Sea.

2.4. Precipitation

2.4.1. Processing of observation data of precipitation totals for the polar regions

The characteristic climate features in the northern polar area are frequent precipitation and long duration of the snow cover. However, it was difficult to obtain the accurate numerical precipitation characteristics because different equipment was used to measure them. Rain gauge with Nipher shield was used to carry out the measurements in the Arctic before 1954. The main error of the rain gauge is connected with blowing of solid precipitation out of it. The precipitation gauge of Tretyakov (O-1) was used starting from 1952. The main error of new precipitation gauge is connected with the blowing the snow into the precipitation gauge bucket from the snow cover surface by strong wind. The heterogeneity of data was shown up, which is, especially, obvious within the winter period (Table 13), due to change of the instruments.

Table 13

Monthly precipitation totals in January on Dikson Island measured by rain gauge (1945-1952) and Tretyakov's precipitation gauge (1953-1960), mm

Year	1945	1946	1947	1948	1949	1950	1951	1952
Total	4	4	3	3	4	3	8	5
Year	1953	1954	1955	1956	1957	1958	1959	1960
Total precipitation	49	168	86	49	32	39	18	13

A method to reduce the precipitation monthly totals measured by rain gauge with Nipher shield to the observation data of Tretyakov's precipitation gauge for the polar regions was developed on the base of comparing the measurement results by rain gauge with Nipher shield and these by O-1 Tretyakov's precipitation gauge, which were obtained at the Arctic stations in 1950-1954. As a result, the conclusions were made that the value of systematic differences between precipitation monthly totals measured by Tretyakov's precipitation gauge and these measured by rain gauge with Nipher shield:

1) is always positive;
2) depends on precipitation type (solid, mixed, liquid);
3) depends on the precipitation amount for the solid precipitation.

But always this difference increases when wind speed increases independently of precipitation type and their amount. It is connected with constructive features of the used instruments.

To recalculate the monthly precipitation totals measured by rain gauge with Nipher shield to these measured by Tretyakov's precipitation gauge the coefficients were used, which are presented in Table 14.

When the average monthly air temperature is higher than +2°C within the month the precipitation were considered to be the liquid ones. In the western Arctic the duration of this period is from July through September. The period with mixed precipitation includes the months with average monthly air temperature from +2 ^{o}C to -2 ^{o}C. The period with solid precipitation is that with average monthly air temperature below -2 ^{o}C.

Table 14

Correction factors for recalculation of precipitation monthly totals measured by rain gauge to these measured by precipitation gauge for liquid (Cl), mixed (Cm) and solid (Cs) precipitation

Mean monthly wind speed m/s	Cl	Cm	Amount of solid precipitation measured by rain gauge, mm		
			0-10	11-20	>21
1	1.02	1.15	1.4	1.3	1.2
2	1.03	1.26	1.9	1.7	1.3
3	1.05	1.37	2.5	2.0	1.4
4	1.07	1.48	3.2	2.3	1.5
5	1.09	1.55	3.9	2.5	1.6
6	1.12	1.66	4.2	2.7	1.8
7	1.15	1.71	4.4	2.9	1.9
8	1.17	1.85	4.6	3.1	2.1
9	2.00	1.93	4.8	3.3	2.2
10	2.24	2.00	5.0	3.5	2.3
11	2.27	2.10	5.2	3.6	2.4
12	3.30	2.20	5.4	3.8	2.6
13	-	-	5.6	4.0	2.7
14	-	-	5.8	4.1	2.9
15	-	-	6.2	4.3	3.0

So, the monthly totals of precipitation obtained before 1954 by rain gauge with Nipher shield were corrected on the base of data of average monthly values of wind speed, temperature and monthly totals of precipitation for each station.

The method of measuring the precipitation amount, which is used at the stations, shows up the systematic corrections of moisture loss due to moistening of sides and bottom of the precipitation gauge bucket, when precipitation are transvased to the precipitation measurement glass (9). This error is equal to 0,2 mm for liquid and mixed precipitation and 0,1 mm for the solid ones for each measurement. From 1966 this correction is introduced directly by observers at the stations and is accounted in calculation of monthly totals of precipitation.

A method described in publications (6, 13, 19) was used to correct the sets of monthly totals of precipitation obtained before 1966. According to these publications the corrections for moistening were calculated by the following formula:

$$\Delta P_{w}=q\cdot n \ ,$$

where n is amount of days with 0.1 mm precipitation and more in a month; q-coefficient of moisture loss for moistening (It is calculated using Table 15).

Table 15

Coefficient (q) of precipitation loss for moistening to introduce the errors into monthly precipitation totals, mm

Prevailing precipitation type and average monthly air temperature	Coefficient q
Liquid precipitation and air temperature higher than +2 ^{o}C	0.30
Mixed precipitation, air temperature from +2 up to –2 ^{o}C	0.20
Solid precipitation, air temperature below -2 ^{o}C	0.15

In principle, it is necessary to account the moisture loss because of evaporating from precipitation gauge between the observation periods. Systematic error connected with it is accounted by the evaporation correction (6). Its value depends on wind speed and the deficit of air humidity. Evaporation correction is calculated by the following formula:

$$\Delta P_E = b \cdot d \cdot 0{,}75 \cdot v \cdot n,$$

where b is empiric coefficient (Table 16); d is average monthly deficit of saturation, mbar; v is average monthly wind speed for wind vane of 10 m height, m/s; n is amount of days with precipitation of 0.1 mm and more.

Table 16

Empiric coefficient b for evaporation correction of monthly totals of precipitation

Prevailing precipitation type, average monthly air temperature	b
Liquid precipitation, air temperature higher than +2 ^{o}C	0.004
Mixed precipitation, air temperature from +2 up to -2 ^{o}C	0.012
Solid precipitation, air temperature below -2 ^{o}C	0.020

Its long-term average value is equal to 1-2 mm in a month and, thereafter, it was not accounted.

Maximum errors of precipitation measuring observations are connected with the influence of wind, especially, in winter.

In summer or in winter without snow storms the error caused by wind is not accounted. Speed of air flow increases with that flows round the gauge. That is why a precipitation rate is skimmed over the receiving hole of precipitation measuring bucket. In winter during the snow storms the «assumed» precipitation fall into precipitation measuring bucket.

Comparing the different types of precipitation gauges the Russian precipitation gauge mounted in double fence shield is assumed now by WMO as the world standard (3, 17). However, this shield can not be used in the Arctic, fences are drifted by snow during the first hard snow storm. A method for wind correction was developed using the results of the performed investigations (15).

The correction factors for calculation of the corrected monthly totals of precipitation are presented in Table 17. Monthly totals, which were corrected accounting the wind influence, are calculated by the following formula

$$P_3 = P \cdot K,$$

where P is amount of precipitation measured by precipitation gauge, mm, К is correction factor (Cl – for liquid precipitation, Cm for mixed, Cs for solid).

Correcting the monthly totals of solid precipitation (selecting the correction factor) it is necessary to have the additional information whether snow storms were observed within the specified month or not. These data are presented in tables in Meteorological Monthly.

Table 17

Wind correction factors

Mean monthly wind speed m/s	Cl	Cm	Amount of measured solid precipitation, mm							
			During snow storms				Without snow storms			
			0-10	11-20	21-50	>50	0-10	11-20	21-50	>50
0.0	-	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.5	1.00	1.03	1.08	1.07	1.06	1.05	1.10	1.08	1.06	1.04
1.0	1.02	1.05	1.16	1.14	1.12	1.08	1.18	1.16	1.14	1.12
1.5	1.04	1.07	1.23	1.20	1.17	1.12	1.27	1.20	1.17	1.15
2.0	1.06	1.10	1.30	1.27	1.22	1.16	1.36	1.25	1.20	1.19
2.5	1.08	1.12	1.37	1.35	1.28	1.17	1.45	1.32	1.27	1.24
3.0	1.10	1.14	1.48	1.42	1.24	1.18	1.51	1.40	1.35	1.29
3.5	1.12	1.17	1.39	1.31	1.22	1.12	1.63	1.50	1.42	1.38
4.0	1.14	1.20	1.30	1.26	1.18	1.06	1.70	1.60	1.49	1.42
4.5	1.16	1.24	1.22	1.29	1.15	1.00	1.75	1.65	1.54	1.46
5.0	1.18	1.27	1.19	1.16	1.08	0.86	1.80	1.70	1.60	1.50
5.5	1.20	1.31	1.17	1.12	1.00	0.80	1.86	1.76	1.67	1.55
6.0	1.22	1.36	1.13	1.00	0.90	0.74	1.93	1.85	1.75	1.60
6.5	1.25	1.39	1.10	0.96	0.86	0.68	-	-	-	-
7.0	1.27	1.42	1.05	0.90	0.78	0.62	-	-	-	-
7.5	1.30	1.46	1.00	0.88	0.73	0.56	-	-	-	-
8.0	1.33	1.50	0.96	0.85	0.70	0.52		-	-	-
8.5	1.35	1.52	0.86	0.82	0.66	0.48	-	-	-	-
9.0	1.37	1.57	0.82	0.76	0.63	0.44	-	-	-	-
9.5	1.40	1.60	0.78	0.72	0.61	0.40	-	-	-	-
1.0	1.43	1.64	0.75	0.68	0.58	0.37	-		-	-
1.5	1.47	1.66	0.71	0.66	0.54	0.32	-	-	-	-
1.0	1.53	1.72	0.68	0.63	0.50	0.28	-	-	-	-

11.5	1.8	1.76	0.64	0.60	0.47	0.24	-	-	-	-
120	1.4	1.80	0.60	0.58	0.44	0.22	-	-	-	-
12.5	1,1	1.86	0.57	0.55	0.40	0.20	-	-	-	-
13.0	1.77	1.95	0.53	0.50	0.34	0.19	-	-	-	-
13.5	1.84	2.00	0.49	0.45	0.30	0.18	-	-		-
14.0	1.91	2.06	0.46	0.40	0.25	0.17	-	-	-	-
14.5	1.95	2.13	0.43	0.35	0,21	0.15	-	-	-	-
15.0	2.05	2.18	0.40	0.30	0.18	0.14	-	-	-	-
15.5	-	-	0.36	0.26	0.16	0.13	-	-	-	-
16.0	-	-	0.32	0.22	0.14	0.12	-	-	-	-
16.5	-	-	0.28	0.18	0.12	0.10	-	-	-	-
17.0	-	-	0.26	0.14	0.11	0.08	-	-	-	-

The monthly precipitation totals used for the analysis of features of precipitation regime in the region of the Barents and Kara seas were corrected accounting all types of errors using the above method.

2.4.2. Climatology of precipitation

Amount and distribution of precipitation for the considered area of the region is specified, mostly, by the peculiarities of total atmosphere circulation and by the relief character. Table 18 presents the average long-term day amount with precipitation for some stations.

Table 18

Amount of days with precipitation >0.1 mm

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	13	12	14	13	17	16	18	19	19	19	14	16	190
Malye Karmakuly	19	15	17	16	16	15	14	16	18	18	17	19	200
Zhelaniya Cape	16	13	15	15	17	14	14	17	19	20	16	17	193
Amderma	20	17	17	16	16	15	12	17	21	23	22	21	217
Dikson Island	20	16	17	16	18	18	15	18	22	22	19	20	221
Golomyanny Island	12	12	13	10	14	13	14	16	17	17	14	15	167
Russky Island	12	11	11	10	14	12	14	14	17	17	12	14	158

High precipitation frequency in the Arctic is significantly connected with high relative humidity, with which the small air temperature decrease can cause the condensation processes and precipitation. But, despite the fact that precipitation frequency at the coastal stations in the Barents and Kara seas is high, their annual totals are small.

Table 19 presents the average monthly, seasonal and annual precipitation totals for the period 1951-1980 with moistening and wind correction as it is described above.

Table 19

Monthly and annual precipitation amount, mm

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	X-V	VI-IX	Year
Rudolpha Island	16	15	14	12	20	16	24	28	22	22	19	20	138	90	228
Malye Karmakuly	30	22	24	23	28	29	44	46	43	42	30	24	223	162	385
Zhelaniya Cape	15	15	16	17	23	22	28	38	31	30	14	18	148	119	267
Amderma	22	19	19	19	28	37	42	43	50	45	24	25	201	172	373

Dikson Island	21	17	20	17	26	32	40	46	45	34	20	20	175	163	338
Golomyanny Island	11	11	11	7	13	13	27	28	23	18	12	12	95	91	186
Russky Island	14	15	14	14	15	16	34	33	24	19	15	14	120	107	227

The maximum annual precipitation amount (about 500 mm) is fixed in the southern Barents Sea, along the coast of Kola Peninsula. The increase of precipitation amount in this region is connected with high cyclone activity. The precipitation amount decreases to the north and east from this zone and is, accordingly, equal to 380-230 mm in the south-eastern and northern sea areas. In the Kara Sea precipitation amount decreases from 370 mm in the south-western sea area to 180-200 mm in the north-eastern one. Decrease of precipitation amount in the northern areas of the Barents and Kara seas is connected with low moisture level of the prevailing Arctic air, and in the eastern Kara Sea additionally with the influence of Asian and Arctic anticyclones.

Considering the data of Tables 18 and 19 a conclusion can be made that despite of the fact that the amount of days with precipitation is great, the precipitation intensity is small. According to publication (12) the precipitation intensity is equal to 0.06-0.15 mm/h in January and April, 0.22-0.34 mm/h in June and 0.6-0.25 mm/h in October depending on the year season. Figure 6 demonstrates the interannual variability of monthly precipitation totals.

Table 20 presents the distribution of the monthly precipitation amount by their type: solid (S), liquid (L) and mixed (M).

Table 20

Monthly and annual amount of liquid (L), solid (S) and mixed (M) precipitation, mm

Station		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Barentsburg	L					2	12	23	25	12	2			76
	S	57	55	52	37	19	8	2	10	25	52	55	68	450
	M					4	4	10	17	13	2			50
Rudolpha Island	L						2	8	11	3	2			27
	S	16	15	14	12	19	9	5	5	14	16	17	18	157
	M					1	5	11	12	5	4	2	2	44
Malye Karmakuly	L				1	3	19	40	44	33	14	3		157
	S	28	21	23	18	19	2			2	12	18	21	164
	M	2	1	1	4	6	8	4	2	8	16	9	3	64
Zhelaniya Cape	L						6	19	26	10				61
	S	15	15	16	16	21	5	1	4	7	26	12	17	155
	M				1	2	11	8	8	14	4	2	1	51
Amderma	L				1	4	26	37	41	37	7			153
	S	22	19	19	14	16	2			2	20	21	24	159
	M				4	8	9	5	2	11	18	3	1	61
Dikson Island	L					1	14	38	43	23	2			121
	S	21	17	20	17	19	5			6	24	19	20	168
	M					6	13	2	3	16	8	1		49
Golomyanny Island	L						4	18	19	7				48
	S	11	11	11	7	12	3	1	3	6	15	11	11	102
	M					1	6	8	6	10	3	1	1	36
Russky Island	L						5	25	16	6				52
	S	14	15	14	14	15	5	2	2	10	17	15	14	137
	M						6	7	15	8	2			38

Selecting the rate of precipitation of each type is of the main importance for the intermediate seasons, when the formation and destruction of snow cover occurs. In the northern and north-eastern area of the region 50-70 % of solid, 12-20 % of liquid and 17-19 % of mixed precipitation of the annual amount are fixed within a year. A solid precipitation rate decreases to the south and is equal to 35-43 % in the south of the region. A rate of liquid precipitation increases to 40-50%. The maximum rate of liquid precipitation in annual variability is observed in August, in total, for a region. The maximum rate of solid precipitation in the north-east of the region is fixed in October, in the south – in December-January. A proportion between the precipitation types in the region changes from south-west to the north-east. Mixed and liquid precipitation are observed in April in the southern area of the region. In May mixed precipitation are observed in the north and north-east of the region, in June in the east of the region. In the southern Barents Sea (Malye Karmakuly) mixed precipitation are observed all year round. A rate of mixed precipitation in the annual total for the region is higher by 9-10 % than that in the adjacent south continental regions. Liquid precipitation in the north and east of the region are observed only from June through September.

Coefficients of variation characterize the interannual variability of monthly and annual precipitation totals (Table 21). Coefficient of variation is a proportion between standard deviation and the average value.

Table 21

Coefficient of variation of monthly and annual precipitation amount

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Rudolpha Island	0.68	0.84	0.64	0.52	0.39	0.52	0.48	0.43	0.34	0.46	0.56	0.54	0.24
Malye Karmakuly	0.95	0.75	0.60	0.54	0.61	0.55	0.64	0.56	0.51	0.41	0.57	0.66	0.22
Zhelaniya Cape	0.78	0.78	0.87	0.73	0.85	0.47	0.66	0.51	0.48	0.51	0.62	0.70	0.29
Amderma	0.45	0.60	0.36	0.53	0.39	0.52	0.64	0.46	0.36	0.30	0.37	0.62	0.17
Dikson Island	0.67	0.65	0.62	0.61	0.50	0.54	0.42	0.45	0.40	0.44	0.54	0.53	0.23
Golomyanny Island	0.69	0.56	0.70	0.57	0.39	0.55	0.52	0.40	0.43	0.59	0.61	0.70	0.22
Russky Island	0.61	0.63	0.64	0.87	0.52	0.71	0.52	0.54	0.42	0.40	0.76	0.74	0.28

The interannual variability of the annual precipitation totals is small. Coefficient of variation changes in the range from 0.2 to 0.3. It testifies that annual precipitation totals in the region are stable. However, within a year the coefficients of variation significantly change. Within cold period their values almost in the whole region are more than 0.60. Maximum interannual precipitation variability is observed within cold period in the north-eastern Barents Sea. Minimum interannual precipitation variability is observed in September-October, when thermobaric fields of winter type are formed due to radiation and circulation factors.

2.5. Snow cover

2.5.1. Obtaining of the snow cover data in the region of the Barents and Kara seas

Data of standard snow measuring observations at a meteorological site and data of snow line measurements for the period 1951-1992 were used as the initial ones to describe the snow cover characteristics. Beside, data of solid precipitation amount for this period were used also.

The observations were carried out according to manual (9). The methods of observations are briefly described in publication (20) too.

Table 22 presents the average long-term (for 1951-1992) characteristics of the interannual variability of snow cover depth according to the measurement results at the meteorological site and snow line measurements and their standard deviation. The measurements of snow cover depth are different. In some cases the measurement results at meteorological site are understated. Beside, the analysis of long-term observation data sets showed up that interannual variability of snow cover depths, which were obtained by snow line measurements, in the most cases is less than that at the meteorological site. That is why, developing the charts of snow cover depth the preference is given to observation data of snow line measurements, by which the snow cover density was measured. Data of snow depth at meteorological site were used, mostly, in the region of the south coast of the Barents Sea (Kola Peninsula).

Table 22

Average long-term (1951-1992) snow cover depth (a) and their standard deviations (b) according to measurements at meteorological site (Ms) and snow line (Sl), cm

Type of observation		VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII
Rudolpha Island													
Sl	a	1.1	6.6	12.1	14.3	14.8	15.2	16.7	17.4	18.3	20.2	16.8	
	b	2.1	5.1	6.5	6.5	6.9	7.4	8.0	7.4	7.8	8.5	8.0	
Ms	a	3.3	6.3	11.9	13.2	14.0	14.3	16.0	17.4	17.9	20.8	17.8	5.0
	b	2.8	5.8	7.1	7.1	7.2	7.6	8.4	9.1	8.7	9.7	12.1	7.6
Amderma													
Sl	a		16.1	23.0	26.6	32.6	34.2	38.1	40.8	36.3	18.3		
	b		7.7	8.8	8.2	8.3	8.9	12.2	11.6	16.9	7.6		
Ms	a	2.1	13.3	19.4	25.0	27.6	29.8	31.3	30.2	18.8	8.3		
	b	2.6	8.0	8.3	13.4	11.0	10.6	12.1	13.0	13.5	12.3		
Popova Island													
Sl	a			12.2	20.5	27.3	32.3	37.3	42.6	47.2	51.8	31.3	
	b			4.5	5.1	7.1	8.6	10.3	8.5	7.7	10.5	16.8	
Site	a		1.8	10.3	17.5	22.9	26.8	32.1	38.5	44.3	46.4	20.6	3.8
	b		1.9	5.7	7.2	9.9	12.1	14.2	16.4	17.6	19.7	18.3	7.1
Vize Island													
Sl	a		2.6	14.7	21.0	26.1	30.2	34.4	38.9	42.0	47.5	27.0	
	b		3.5	4.9	6.0	6.8	7.4	8.8	9.4	11.5	12.5	20.6	
Ms	a	1.0	5.0	11.7	15.1	18.0	20.4	24.0	26.3	28.7	32.4	13.7	
	б	2.1	3.7	6.2	7.3	7.6	8.8	15.9	11.5	11.6	13.3	18.6	
Isachenko Island													
Sl	a		2.5	9.5	14.8	17.7	19.6	21.4	23.6	26.7	30.2	25.0	
	b		2.1	4.0	6.0	6.5	6.5	6.7	7.8	8.4	10.3	11.6	
Ms	a		2.6	9.8	14.4	18.7	20.5	22.3	24.4	27.9	31.0	16.1	
	b		2.3	5.9	7.1	7.2	8.7	9.2	9.8	10.0	10.2	11.4	

As the direct measurements of the snow cover parameters on ice in the Arctic seas were carried out very rarely, not systematically and, as a rule, only in late winter - early spring and in different points (10), it is, practically, impossible to obtain any characteristic of long-term, interannual and annual variability. That is why the following method was used to create long-term data sets of snow cover depths of monthly discreteness in the points of 250x250 km regular grid:

1. It was assumed that a period of formation and retention of steady snow cover coincides with that, when the average monthly temperature does not exceed –2 °C. These periods were defined for each from these points with 1-month discreteness interpolating long-term data of average monthly temperature at each station into grid points.

2. For each of the months of this period the average long-term values (norms) of monthly precipitation totals at each station, which were interpolated into the grid points, were calculated. The norms of monthly precipitation were defined in each point.

3. Relative anomalies of monthly precipitation totals (a proportion between monthly precipitation total and its long-term norm) were calculated for each month of this period (1952-1992) at all stations for each year. The relative anomalies of monthly precipitation totals in each point of the regular grid were defined by interpolation of these values.

4. Monthly precipitation totals for each specific month for the period 1951-1992 were calculated in each point by data of the foregoing calculations (items 2, 3).

5. Interpolation of long-term norms of average monthly density of snow cover ρ (g/cm^3) into the points of regular grid allowed to create the archive of average monthly snow densities for each point. These data and the data of monthly precipitation totals (conceptually, snow water equivalent (SWE) Q, mm) were used to calculate the snow cover depth H, cm (20):

$$H=Q/10\rho$$

in each month for the whole observation period (1951-1992).

Three-stage method of the definition of average monthly precipitation totals in the points of regular grid is of preference than the direct formal interpolation of the measured values at each station into the selected points. Moreover, formal interpolation will be not correct because of essential spatial and temporal precipitation heterogeneity. Therewith, there is a dominance of temporal variability over the spatial one (16). This problem is essentially solved using the long-term norms and relative anomalies of the measured parameters with interpolation. But it does not solve a problem connected with spatial heterogeneity of parameters of snow cover, which is formed on ice of the Arctic seas (16). Table 23 presents an example of calculation of snow cover parameters in the points of coordinate grid.

Table 23

Snow cover parameters in a point 80.973N 90.000E of coordinate grid

Parameter	VIII	IX	X	XI	XII	I	II	III	IV	V	VI
Density, g/cm^3	-	0.00	0.20	0.24	0.25	0.25	0.26	0.26	0.28	0.30	0.00
Monthly tot	-	10	14	14	12	5	5	7	10	10	-
SWE, mm	-	-	24	38	50	55	60	67	77	87	-
Depth, cm	-	-	12	15	20	22	23	26	28	29	-

The snow cover depths were calculated in the points of coordinate grid with 250 km step by longitude and latitude using this method. The coordinate grid was taken from publication (14). To combine the charts of the snow cover in the region and the continental area the charts of snow cover from Atlas of snow-ice world resources (1) were used.

2.5.2. Snow cover depth

Snow cover depth depends on the amount of solid precipitation. In the previous section the annual variability of solid, mixed and liquid precipitation was described. In the region of the Barents and Kara seas the distribution of a rate of solid precipitation has its own features. A rate of solid precipitation in annual precipitation total increases to the north-east. Spitsbergen archipelago, Franz Josef Land and Severnaya Zemlya archipelago are in the zone, for which a rate of solid precipitation is mire than 60 % of annual precipitation total. A boundary of the zone with a rate of solid precipitation of more than 50 % for a year passes southerly from Spitsbergen archipelago to the north-west of the coast of Novaya Zemlya. Then it lowers along its western coast approximately to 74 N, rounds Novaya Zemlya from the eastern coast and goes to Taimyr Peninsula across the central Kara Sea. The zone boundary with 40 % rate of solid precipitation is located along the divide of the Pechora and Kara seas. So, in the southern Kara Sea solid precipitation are equal to 40-50 % in annual total, in the northern one – more than 50 %. In the central Barents Sea the rate of solid precipitation is equal to 30-40 %. Isolines of snow cover depths are distributed according to the rates of solid precipitation in the annual precipitation totals.

Figure 7 demonstrates the fields of snow cover depths in the region of the Barents and Kara seas from October through June. Table 24 presents the values of snow cover depth at some stations and in some points of coordinate grid.

In the region of the Barents and Kara seas the basic snow accumulation starts from late August and ends up in March-May. According to annual variability of snow cover depth (Table 24) the maximum snow cover depth in the western area of the region (the Barents Sea) is observed in March-May. Snow cover is the most extensive in the northern and north-eastern Barents Sea, and its depth in May can reach 30 cm (Rudolph Island) and more. On the south-western coast of the Barents Sea (Vayda-Guba) the maximum snow cover depth (32 cm) is observed in March. On the western coast of Novaya Zemlya the North Atlantic cyclones lose moisture and decay, when they are impeded by mountainous ridge. The maximum snow cover depth (24 cm) in the annual variability on the coast is observed in April (Malye Karmakuly). Snow cover depth of 60 cm and more can be observed on the glaciers of Novaya Zemlya (Severny Island). On the eastern coast of Novaya Zemlya the snow depth in April is equal to from 25 cm (Severny Island, Opasny Cape) to 23 cm (Yuzhny Island, Menshikov Cape).

In the western region of the Kara Sea the maximum snow cover depth (34 cm) is fixed in March-April (Amderma), in the eastern one (31 cm) – in May (Geiberg Island). In the central Kara Sea the snow cover depth is equal to 20-25 cm. It is connected with the weaker cyclone activity in winter, and the main cyclone tracks pass to the south over the coast.

Calculated values of snow cover depth in the points of coordinate grid well agree with the data obtained at the nearest stations. Spatial distribution of snow cover depth in the region is characterized by depth increase in the direction from north-east and south-east from the central sea areas.

Table 24

Seasonal variability of snow cover depth in the region of the Barents and Kara seas at some stations and in the points of coordinate grid, cm

Station, Grid points	Month											
	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Vayda-Guba	0	5	9	15	25	29	32	27	8	0	0	0
Malye Karmakuly	0	3	6	12	14	19	24	23	19	1	0	0
Rugolpha Island	6	12	15	14	14	16	17	18	21	18	7	3
Golomyanny Island	5	12	15	14	15	15	18	20	23	15	0	1
Amderma	2	12	19	26	30	32	34	34	21	10	0	0
Geiberg Island	4	14	19	21	22	26	29	30	31	21	1	1
80.70N 76.00E	2	10	15	20	22	24	25	27	28	14	-	-
78.70N 36.90E	1	7	12	18	21	24	26	28	25	6	-	-
78.70N 90.00E	3	10	13	16	20	23	25	28	29	14	-	-
73.30N 56.00E	5	8	10	15	20	25	35	40	40	35	-	

74.80N 63.40E	0	2	10	13	15	20	22	25	22	5	-	-
71.80N 60.30E	0	3	5	9	15	20	22	25	25	5	-	-

Table 25 presents maximum and minimum snow cover depths according to the snow measurement observations for the period 1951-1992.

Table 25

Maximum and minimum snow cover depth according to snow line measurements, cm

	Month																			
	9	10	11	12	1	2	3	4	5	6	9	10	11	12	1	2	3	4	5	6
Station	Maximum snow cover depth										Minimum snow cover depth									
Rudolpha Island	16	28	29	33	37	40	37	38	46	34	-	4	6	6	6	6	9	9	9	-
Bolvansky Nos	27	37	43	46	55	56	64	58	68	66	-	3	6	10	9	12	12	17	20	-
Amderma	-	38	48	45	47	55	68	74	72	14	-	7	7	15	15	18	16	15	3	-
Marresalya	-	21	27	30	31	33	40	41	41	7	-	2	3	6	5	8	6	7	5	-
Zhelaniya Cape	6	22	24	25	28	34	32	36	40	52	-	2	3	4	3	4	4	5	8	-
Bely Island	5	29	34	44	51	73	63	66	72	66	-	3	9	16	15	17	22	31	3	-
Vilkitsky Island	-	19	27	41	41	46	50	61	66	57	-	4	7	14	19	23	25	29	28	7
Vize Island	10	21	38	46	47	48	55	64	70	60	-	5	10	13	16	20	23	19	16	-
Leskin Island	-	20	31	33	40	44	47	54	65	62	-	6	5	7	15	16	18	22	29	0
Dikson Island	8	22	17	22	26	27	27	28	38	16	-	5	6	9	7	7	6	8	8	-
Cterligov Cape	13	25	27	32	33	32	38	43	48	37	0	1	2	3	2	3	7	9	9	4
Isachenko Island	6	16	32	35	35	35	46	48	54	45	0	2	3	4	5	5	6	7	7	0
Golomyanny Island	14	22	27	36	32	31	34	39	47	39	-	4	5	5	3	5	7	5	4	-
Russky Island	24	27	33	33	45	53	48	50	63	48	-	3	7	7	10	9	10	14	18	-

Interannual variability of this parameter is significant due to essential difference between the extreme depths and is defined by interannual variability of atmospheric circulation parameters.

2.5.3. Formation and destruction of snow cover

The first steady snow cover starts to form in the northern area of the region in late August and completely covers all islands in late September. On glaciers of Severnaya Zemlya, Novaya Zemlya, Franz Josef Land and Spitsbergen snow cover is not destructed, it transforms into firn snow and glacier ice (1). When ice begins to cover the Barents and Kara seas region, the formation of snow cover is observed there. Young ice begins to form in late September in the Spitsbergen-Franz Josef Land region. In October young ice is formed in the central area (near Novaya Zemlya), in November – in the south-eastern Barents Sea (the Pechora Sea). At that time, ice of different age is transported there from the Arctic basin and the Kara Sea (4).

In December and January near the western coast of Novaya Zemlya the area of compacted first-year ice with snow cover and low-height hummocks increases. The first-year thick ice and that of middle thickness is observed there from February.

Average long-term boundary of floating ice in the western sea area is at 350-500 km distance from Kola Peninsula (2, 4). Near 45^{o} E ice edge sharply lowers to the south and in the region of Svyatoy Nos Cape bears against the peninsula. Ice edge is the most northerly located in September, is the most southerly located in April-May.

In mid September ice begins to form in the north-eastern Kara Sea. Ice cover is formed even in the eastern Kara Sea by mid October, forms in November in the region of

Kara Strait. So, in late November within the region, excluding the area of the Barents Sea, which is not ice covered, snow cover is formed.

The duration of snow cover is specified by dates, when 50 % and more of visible area is covered by snow (snow cover is the steady one) and 50 % and less of visible area is covered by snow (snow cover is destructed). The steady snow cover is that is kept within the whole winter or with the breaks not more than 3 days within each month of the duration of snow cover. Therewith, the 1 day break in the beginning of winter is not accounted if snow cover age is not less that 5 days. If the break is 2-3 days, it is not accounted if snow cover age is not less than 10 days. If in late winter snow cover is formed after 3 days of its destruction again and is kept within not less than 10 days, snow cover is considered to be the continuous one (20). Average long-term dates of formation and destruction of steady snow cover were defined only at the stations, where the observations of steady snow cover were carried out within more than a half of the total period 1951-1992. They are presented in Table 26.

According to the analysis of the data of Table 26 the latitudinal distribution of snow cover duration is pointed out. The period of snow cover accumulation is longer than that of its destruction. According to data of this table a conclusion can be made that the average duration of snow cover a year in the Barents and Kara seas decreases from north to the south.

Dates of formation and destruction of snow cover on sea ice are different. Steady snow cover on ice near the southern coast of the Kara Sea is formed after the fast ice formation and after the covering of the sea by drifting ice in late October. It is kept within the whole ice a period. In some years steady snow cover can be formed in mid November. Duration of snow cover is equal to 250 days and longer within a year.

Table 26

Amount of days with snow cover, dates of its formation and destruction, formation and destruction of steady snow cover

Station	Amount of days with snow	Dates, when snow cover is formed			Dates of the formation of steady snow cover			Dates of the destruction of steady snow cover			Dates of the destruction of snow cover		
		Average	Earliest	Latest	Average	Earliest	Latest	Average	Earliest	Latest	Average	Earliest	Latest
Rudolpha	306	23.08	29.07	18.09	7.09	13.08	18.10	1.07	12.06	18.07	4.07	12.06	1.08
Nagurskaya	293	23.08			13.09			13.07			14.07		
Malye Karmakuly	243				18.10	24.09	27.11	10.06	11.05	30.06			
Bolvansky Nos	298	24.08	1.08	1.10	16.09	18.08	11.10	4.07	12.06	18.07	7.07	12.06	29.07
Amderma	243	28.09	25.08	26.10	12.10	21.09	21.11	4.06	26.06	22.06	15.06	18.05	14.07
Russkaya Gavan	272	5.09	1.08	1.10	25.09	1.08	31.10	16.06	15.05	31.07	27.06	24.05	31.07
Harasavey	239	29.09			14.10			9.06			12.06		
Marresalya	243	26.09	1.08	20.10	11.10	18.09	13.11	2.06	30.06	22.06	15.06	16.05	26.07
Zhelaniya Cape	287	5.09	4.08	15.10	29.09	22.08	26.10	3.07	9.06	3.08	9.07	10.06	3.08
Popov Island	273	22.09	25.08	16.10	4.10	10.09	28.10	28.06	10.06	16.07	29.06	10.06	19.07
Vilkitsky Island	264	26.09			1.10			26.06			28.06		
Vize Island	292	18.08	29.07	12.09	12.09	18.08	3.10	23.06	9.06	6.07	25.06	13.06	21.07
Dikson lsand	261	18.09	28.07	20.10	1.10	11.09	20.10	14.06	22.05	2.07	18.06	22.05	11.07
Uedineniya	279	28.08	3.08	22.09	20.09	24.08	9.09	20.06	8.06	12.07	25.06	8.06	25.07
Sterligov	269	14.09	3.08	11.10	27.09	27.08	15.10	17.06	20.05	17.08	22.06	5.06	17.07
Golomyanny Is.	293	28.08	28.07	1.10	12.09	16.08	11.10	28.06	4.06	24.07	29.06	4.06	24.07
Pravdy Island	279	2.09			18.09			25.06			28.06		
Russky Island	292	2.09	4.08	16.10	20.09	16.08	16.10	1.07	12.06	20.07	3.07	12.06	26.07
Krasnoflotskiye Is.	290	29.08			19.09			28.06			28.06		
Geiberg Island	288	3.09			15.09			24.06			26.06		

Snow cover begins to decay when air temperature is negative under the influence of solar radiation (Figure 8) (20). When the intensity of total solar radiation becomes to be equal to 600 W/m^2, snow begins to melt with air temperature of – 4 ^{o}C. However, the main snow melting process occurs, when air temperature is positive with advection of warm air mass. Snow completely melts when ice cover begins to decay (early June) (4).

Destruction of snow cover in the region of the Barents and Kara seas begins in the south-western region and extends to the north-east. According to the average long-term data snow cover decays on the coast of the Kola Peninsula in the beginning of the second half of May. In the southern Kara Sea snow cover decays in early June. In the northern and north-eastern area of the region it does not melt completely on drifting ice and is kept within the summer period transforming into firn ice.

3. Seasonal, interannual and long-term variability of the climate in the region of the Barents and Kara seas

To estimate the parameters of climate variability in the region for the period 1951-1992, the changes of air temperature in January (the middle of cold season) and July (the middle of warm season), changes of precipitation totals within the cold season and snow cover depths for a month with maximum snow accumulation (in total, for the region in April) were defined. The field expansion by empirical orthogonal functions (EOF) was used as the main investigation method (7). The average monthly air temperature for January and July, precipitation totals for the cold period (October-May) and snow cover depth in April (the month of maximum snow accumulation, in total, for the region) at 38 stations (Table 1) for the period 1951-1992 were used as the initial data.

Analysis of the field expansion results showed up (Table 27) that the percentage of variance explained by the three modes of EOF expansion of the solid precipitation and snow cover depth is 47 % and that of temperature - 68-83 %. High temperature convergence in comparison with precipitation and snow depth is specified by spatial heterogeneity of temperature fields. According to Table 27, a contribution of components into total dispersion significantly depends on the season (for air temperature). Contribution of the first components of temperature field expansion decreases from the cold period to the warm one. It well agrees with general climatic regularity of decreasing the role of large-scale processes during transition period from winter to summer.

The convergence in precipitation data sets is rather high for the element, which is characterized by significant spatial heterogeneity. However, it is specified by relative small sizes of the region. It brings to significant connectedness in correlation matrix.

Figure 9 demonstrates spatial distribution of the first leading mode of EOF expansion of air temperature for January and July, totals of solid precipitation for October-May and snow cover depths for April. The percentage of variance explained by the first mode of EOF expansion of temperature is 30-50 % and that for solid precipitation is 26 % within mid months of warm and cold seasons. Values of the first temperature mode for January are positive only. There are two areas of contrary sign in spatial distribution of the first mode for precipitation: area with negative values – over the north-eastern Barents Sea and, almost the whole Kara Sea; area with positive values– over the central area of the Barents Sea and the south-eastern Kara Sea and also over the southern coast of the seas.

Table 27

Contribution of expansion in total field dispersion of air temperature, precipitation and snow cover depth, %

Month	λ_1/D	λ_2/D	λ_3/D	$\sum_{1}^{3}\lambda_j/D$
Air temperature				
January	49.6	19.0	14.0	82.6
July	30.5	25.0	12.4	67.9
Precipitation				
October-May	26.0	12.0	9.0	47.0
Snow cover depth				
April	22.0	15.0	10.4	47.4

Note: λ_j – proper values of correlation matrix of j-order; D – total dispersion.

The first mode characterizes the influence of the main large-scale factor in the investigated region for the considered meteorological elements (7). The succeeding modes describe the influence of other factors of less scale. The cyclogenesis is the main factor, its influence is more significant on the thermal field formation than that on the precipitation fields. The North Atlantic cyclones, which displace across the Barents Sea to the Kara Sea, transport the warm air mass to the east and north-east. Warm sea and air currents make influence on air temperature in the most distant areas of the region. In total, the variability of sign of the first mode of EOF expansion of air temperature fields shows that the change of air temperature in the region within the mid months of both warm and cold seasons has the same sign. If precipitation are solid, the large-scale change in the region consists of the changes of different directions for the northern and southern areas of the region. Spatial distribution of the first mode of snow cover depth of solid precipitation also shows the contrary character of snow cover depth change in the sea water areas and adjacent continental area of the region.

Considering the long-term variability of the first coefficient of EOF expansion of air temperature in the region for January and July (Figure 10 and Figure 11), the tendency of temperature decrease by mid 60s in January and early 70s in July and its further increase in the both seasons is shown up. However, in some areas of the region the character of the temperature changes can be different. As Figure 10 demonstrates, at the stations in the northern area of the region (Rudolpha Island, Golomanny Island) the transition period from the decrease of air temperature to its increase is observed some years earlier than that in the southern region area (Murmansk, Narjan-Mar). The contrary character in air temperature changes at the stations located in the western (Murmansk) and eastern areas of the region (Dikson Island) can be pointed out. In July the character of temperature change at the stations is more different (Figure 11). But the general tendency of temperature decrease in July is more clearly shown up than that in January (Table 28).

Table 28

Coefficients of linear regression of meteorological characteristics for the period 1951-1992

Station	Air temperature in January, °C/10 years	Air temperature in July, °C/10 years	Precipitation for X-V, mm/10 years	Snow cover depth, cm/10 years
Rudolpha Island	0.37	-0.00	-13.6	-7.8
Golomyanny Island	0.25	-0.00	-5.9	-0.1
Sterlegova Cape	0.24	-0.12	-3.0	-8.9
Dikson Island	0.01	-0.28	1.0	-4.5
Murmansk	-0.48	-0.01	17.9	4.4
Narjan-Mar	-1.08	-0.14	25.1	2.8

Long-term variability of coefficient of EOF expansion of solid precipitation field shows the precipitation decrease by the end of 80s and the tendency of their increase in the beginning of 90s (Figure 12). It describes the prevailing processes of precipitation over the major area of the region. In the selected areas of the contrary sign of spatial distribution of the first mode components the contrary precipitation changing in time in the region is observed. In total, the amount of solid precipitation decrease is observed in the northern (Rudolph Island, Golomyanny Island) and eastern (Sterlegova Cape) areas of the region for the period 1951-1992. In the south-western (Murmansk) and southern (Narjan-Mar) the amount of solid precipitation increase and weakly increases in the south-eastern (Dikson Island) (Figure 12).

Temporal changes of snow cover depth are the same as these of air temperature and totals of solid precipitation. Figure 13 demonstrates the interannual changes of the first coefficient of expansion of snow cover depth in April. The changes of snow depth at some stations for the month with maximum snow accumulation are presented there: in the northern and eastern area of the region – for May; in the southern one – for April. In long-term variability of snow cover depth for each station has its own peculiarities. However, in total, the decrease of snow cover depth in the northern Barents Sea and the eastern Kara Sea and its increase on the southern coast of the Barents Sea (Kola Peninsula and the Pechora Sea) are pointed out.

Conclusion

In this article the characteristic of climatic regime for the period 1951-1992 is given using the empiric observation data of the main meteorological elements for the region of the Barents and Kara seas. The method of introducing the measurement errors into data of monthly precipitation totals is described. The method was elaborated to develop the charts of snow cover depths for the region including the distribution of snow cover depth on sea ice.

The obtained working results testify about the change of climatic regime in the region of the Barents and Kara seas for the 1951-1992. Changes of thermal regime within the cold period from mid 60s brought to changes of precipitation regime and snow accumulation in the region. The increase of air temperature over the major area of the region caused the decrease of the solid precipitation amount and accordingly the snow cover depth.

The increase of global temperature, which is forecasted in succeeding years (17), can bring to more evident climate changes in the region amplifying the tendencies of its change.

References

1. Atlas of snow-ice world resources. Moscow, Institute of Georgaphy RAS, 1997, p. 352

2. Borodachev V.E. Comparative analysis of probability and statistical characteristics of ice concentration and its measurements. Trudy AANII, V. 401, 1988, pp. 103-120

3. Golubev V.S., D.A. Konovalov, A.Yu. Siminenko, Yu.V. Tovmatch Correction of precipitation measurements and their qualitative estimation according to the data of Valdayskaya hydrological station. Meteorologia i gidrologia, № 1, 1999, pp. 108-116

4. Zubakin G.K. Large-scale variability of ice cover of the North-European basin seas. Leningrad, Gidrometeoizdat, 1987, p. 160

5. Koshinsky S.D. Regime characteristics of high winds for the seas of the Soviet Union. Part 2, Leningrad, Gidrometeoizdat, 1978, p. 392

6. Methodical instructions for correction of monthly precipitation totals at the observation location. Addition to methodical instructions for the Hydrometeorological authorities. № 89, Leningrad, GGI, 1985, p. 22

7. Mescherskaya A.V. et.al. Intrinsic components of meteorological fields. Leningrad, Gidrometeoizdat, 1970, p. 199

8. Observations carried out by hydrometeorological network of the USSR. Definition of notions of hydrometeorological elements and estimation of observation accuracy. Leningrad, Gidrometizdat, 1970, p. 92

9. Manual for hydrometeorological stations and posts. Iss. 3, Leningrad, Gidrometeoizdat, 1985, p. 300

10. Technology handbook of the climate of the USSR . Series 3, Iss. 1, 2, 17, 21, Leningrad, Gidrometeoizdat, 1988-1990

11. Romanov I.P. Ice cover of the Arctic basin. St.Petersburg, AARI, 1992, p. 212

12. Handbook of the climate of the USSR. Iss. 1, 17, 21, Leningrad, Gidrometeoizdat, 1966-1968

13. Instructions for hydrometeorological stations how to introduce the corrections into the measured atmospheric precipitation. Leningrad, Gidrometeoizdat, 1969, p. 31

14. Armstrong, R., and M.J. Brodzik, An earth-gridded SSM/I data set for cryospheric studies and global change monitoring, Advances in Space Research,16,155-163,1995.

15. Briazgin N.N. Method of measurement and correction of solid precipitation in the Russian Arctic.- World climate research programme. Proceeding of the workshop on the AC SIs solid precipitation climatology projekt. Reston, VA USA, 1995, pp. 30-32

16. Colony R., V. Radionov and F.J. Tanis, 1988: Measurements of precipitation and snow pack at Russian North Pole drifting stations. Polar Rec., v.34, 3-14.

17. International Organizing Committee for WMO solid precipitation measurement intercomparision/ Final report of first session, WMO/ CIMO, 1985.

18. Nicholls N., Grusa G. V. el al. Observed climate variability and change. /In: Climate Change 1995. Houghlon J. T., Meira, Filho L. G. et al, eds.), - Cambridge, Cambridge University Press, 1996, 572 pp.

19. Recommendations for preparation of uniform long-term data of monthly preparation totals. Leningrad, AANII, 1980, p. 36

20. Radionov V.F., Bryazgin N.N., Aleksandrov Y.I. The Snow Cover of the Arctic Basin. – SPb.: Gidrometeoizdat, 1996. - 124 pp. [English translation available from Polar Science Center, University of Washington, Seattle, WA98195; Tech.Rep. APLUW TR 9701].

21. Warren S. G., Rigor I. G., Untersteiner N., Radionov V.F., Bryazgin N.N., Aleksandrov Y.I., Colony R. 1999: Snow Depth on Arctic Sea Ice. Journal of Climate, Vol.12, 1814-1829.

Figures

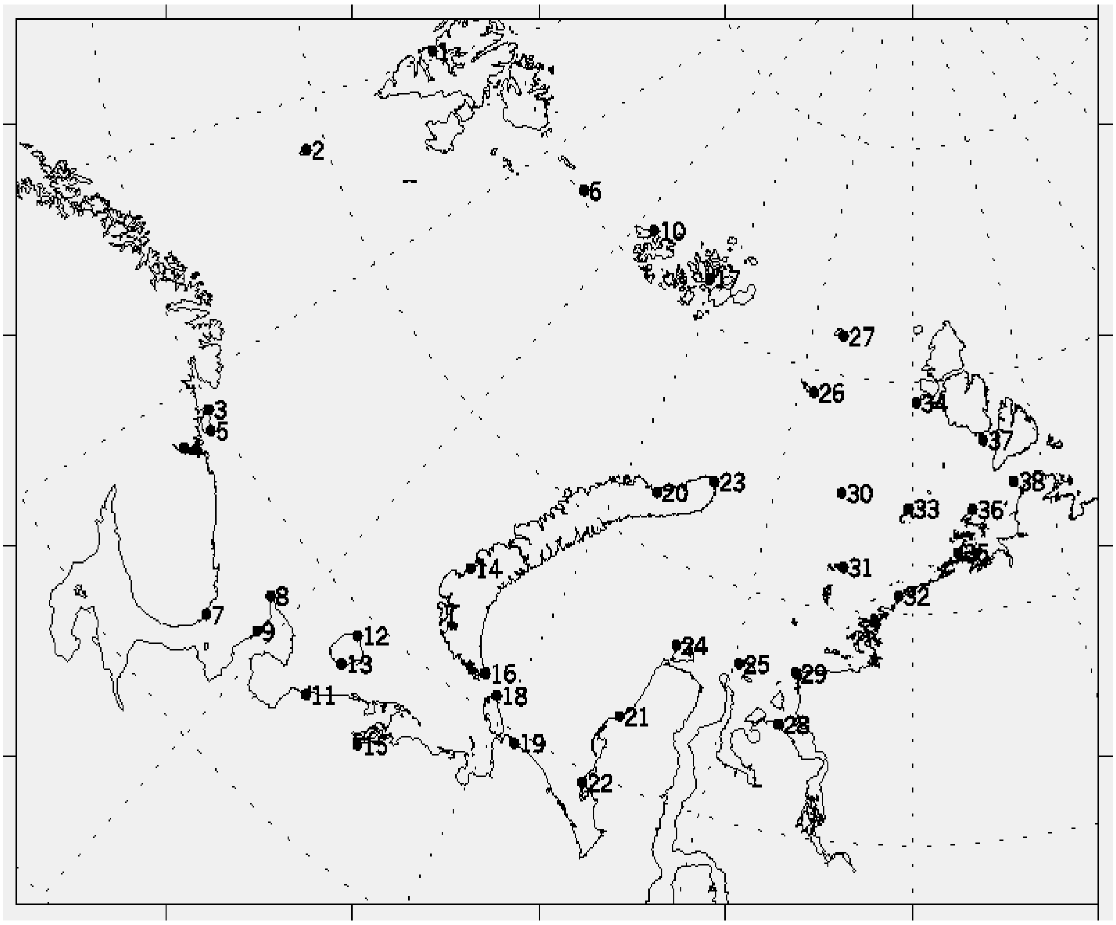


Figure 1.

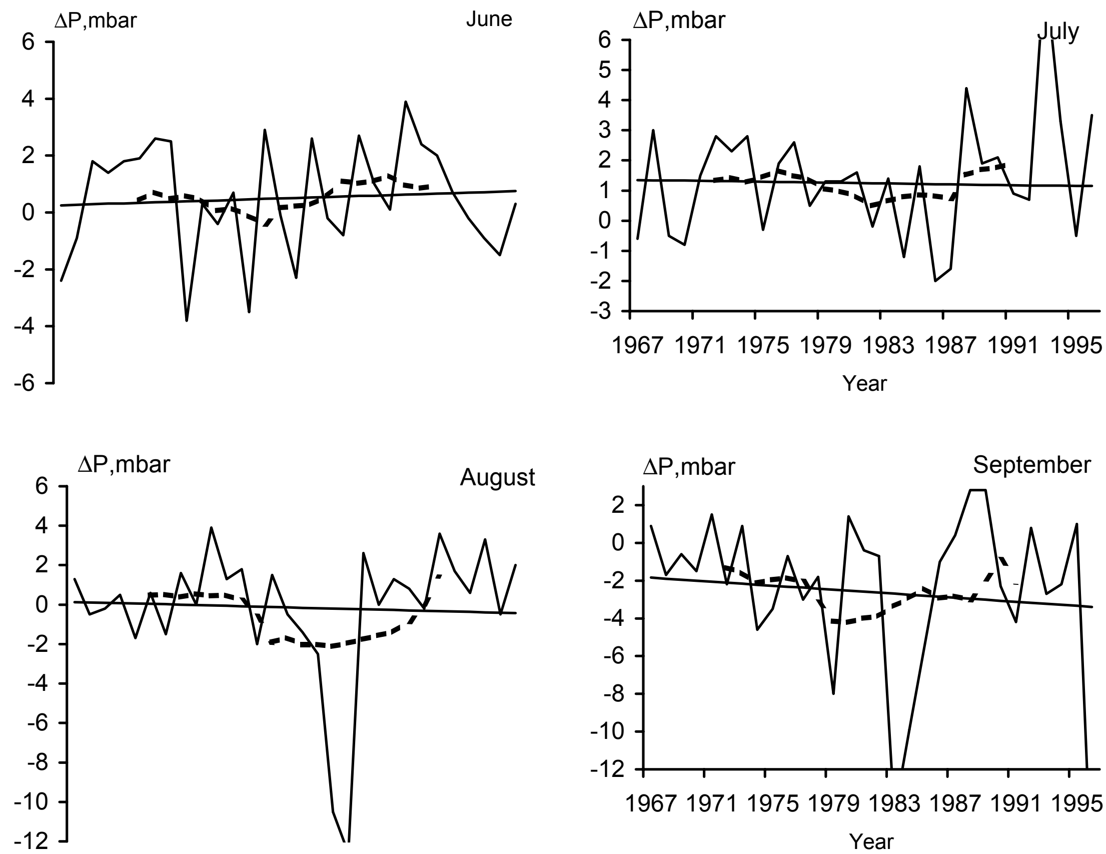

ΔP,mbar
June
6
4
2
0
-2
-4
-6
ΔP,mbar
July
6
5
4
3
2
1
0
-1
-2
-3
1967 1971 1975 1979 1983 1987 1991 1995
Year
ΔP,mbar
August
6
4
2
0
-2
-4
-6
-8
-10
-12
ΔP,mbar
September
2
0
-2
-4
-6
-8
-10
-12
1967 1971 1975 1979 1983 1987 1991 1995
Year

Figure 2

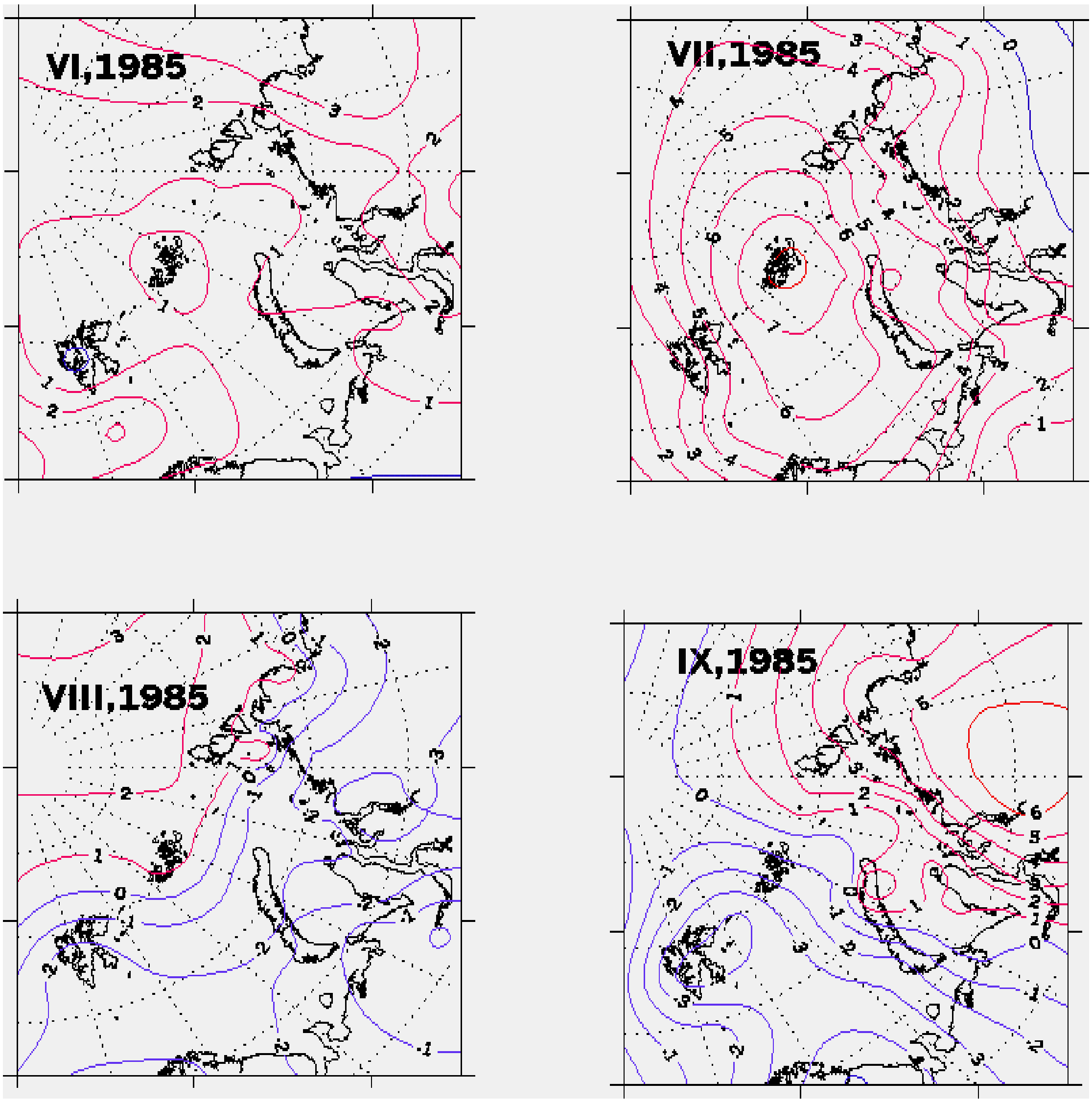


Figure 3. Spatial distribution of anomalies of air ground pressure in the region of the Barents and Kara seas in June-September, 1985

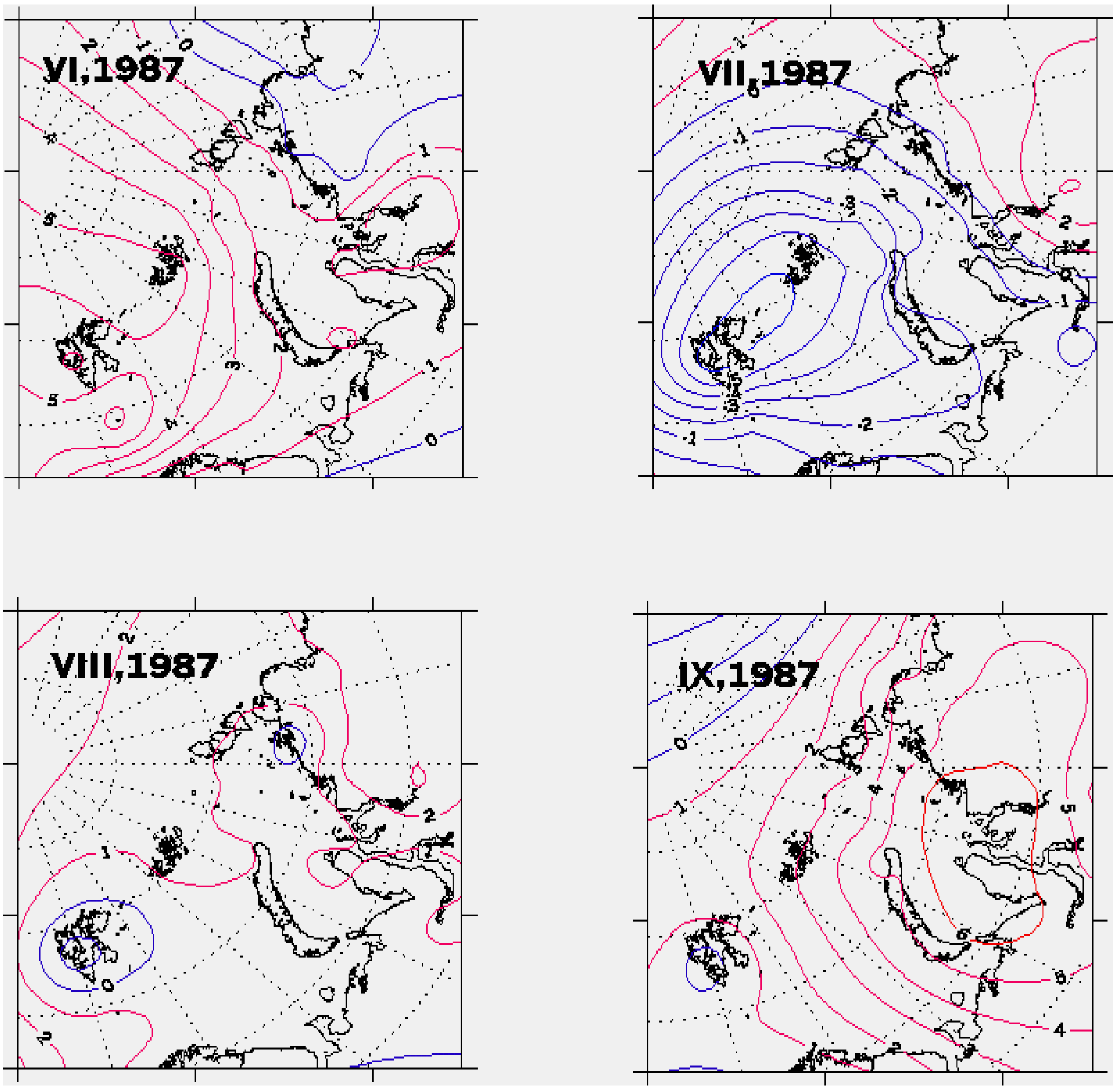


Figure 4. Spatial distribution of anomalies of air ground pressure in the region of the Barents and Kara seas in June-September, 1987

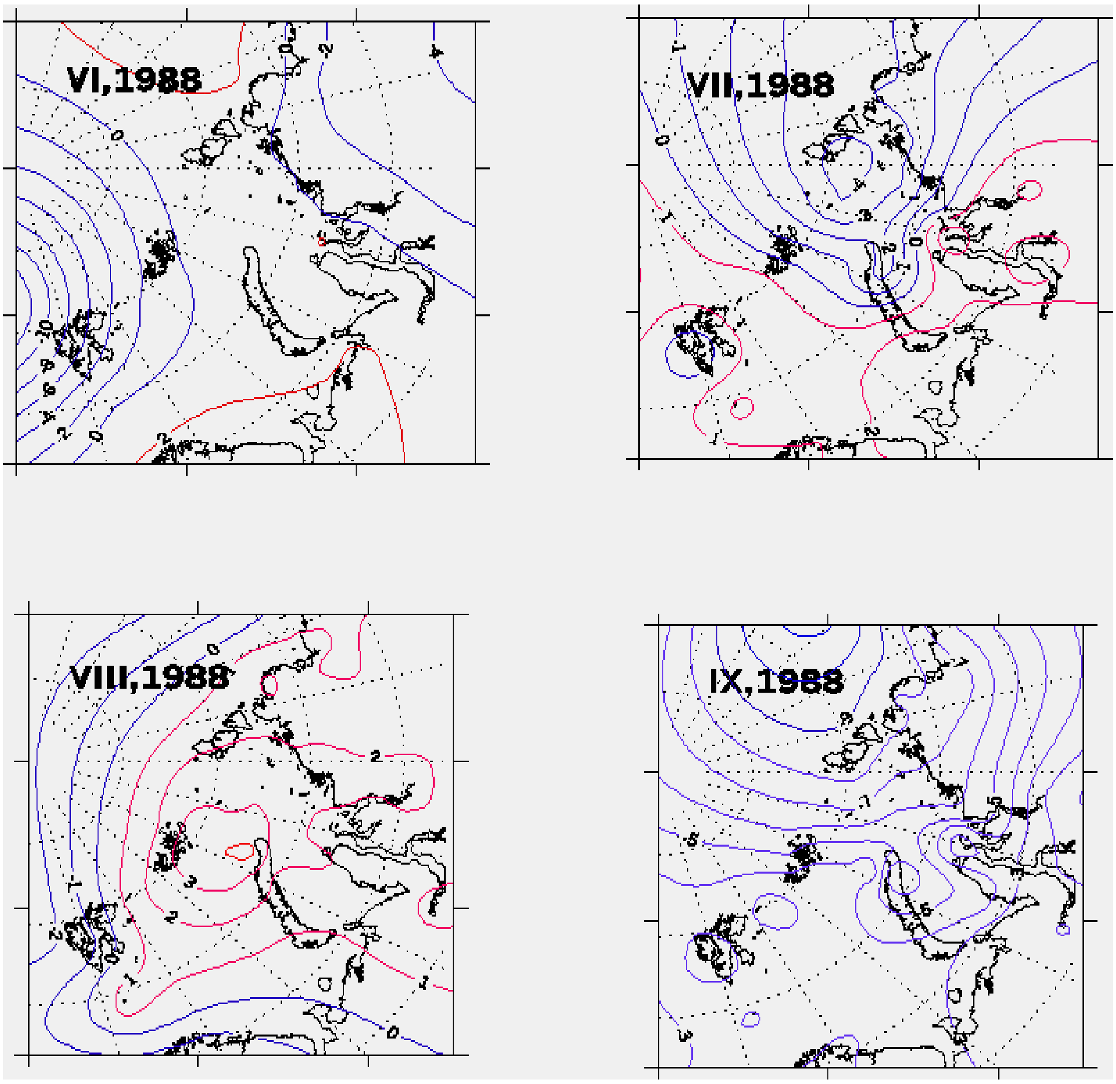


Figure 5. Spatial distribution of anomalies of air ground pressure in the region of the Barents and Kara seas in June-September, 1988

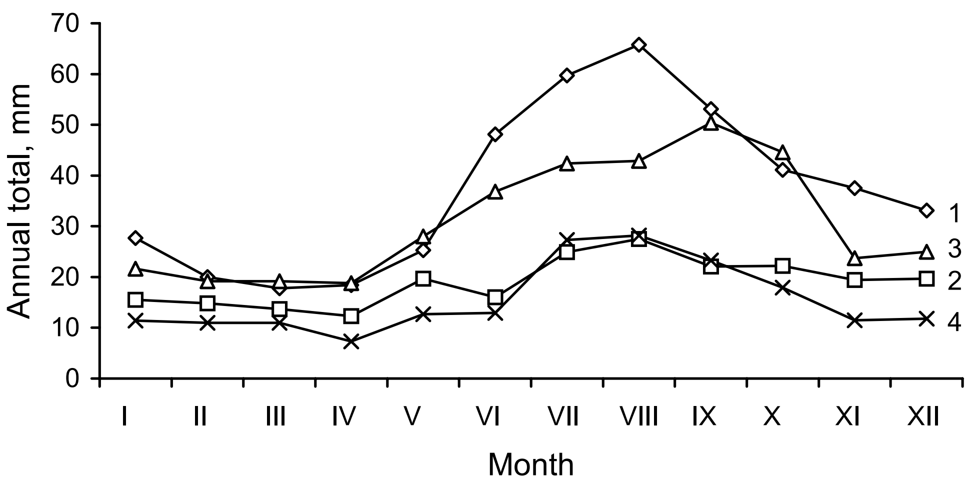


Figure 6.

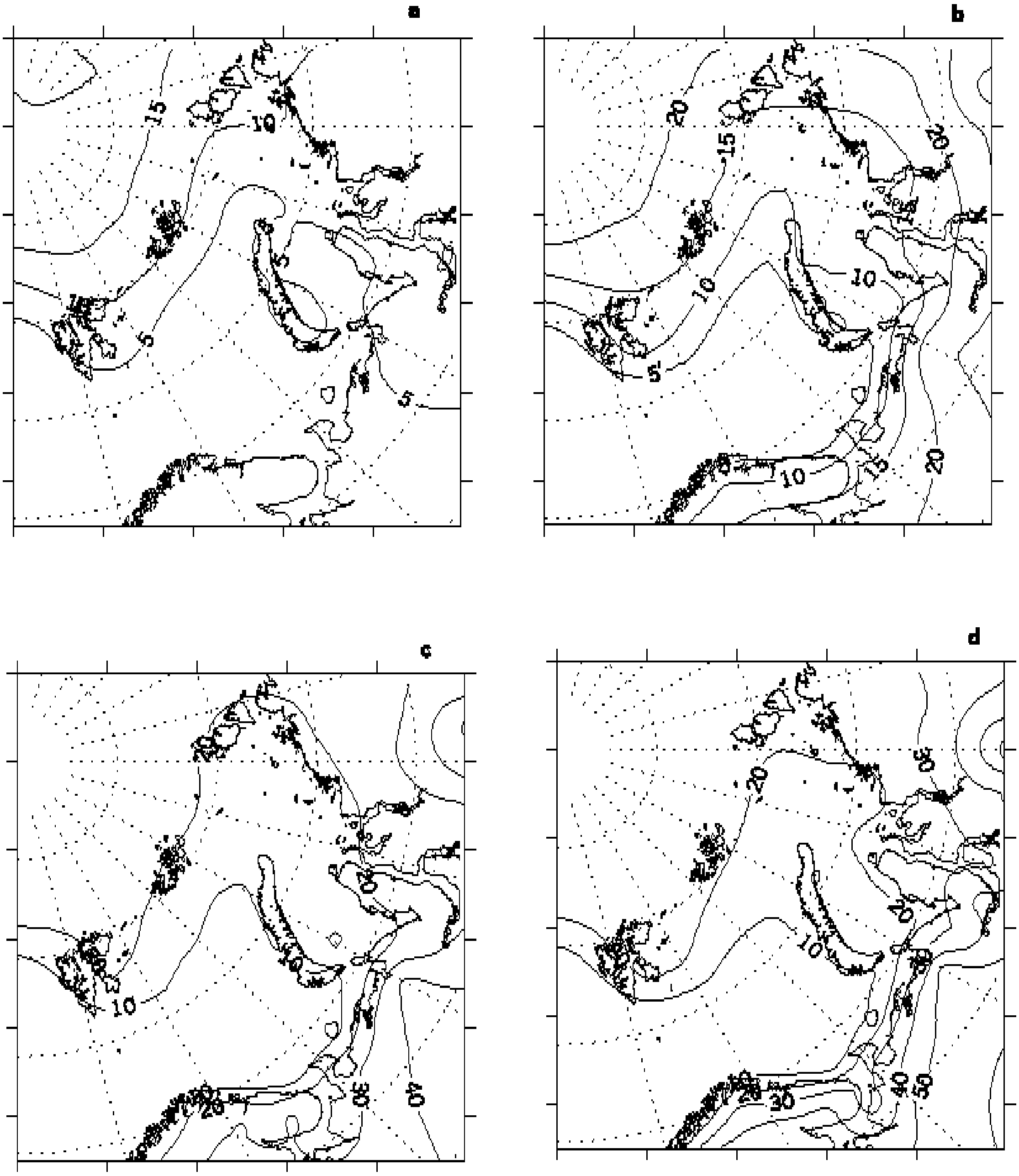

a
15
10
5
5
5
b
20
15
20
10
10
5
5
10
15
20
c
10
40
20
20
30
40
d
20
30
20
10
30
20
30
40
50

Figure 7.1

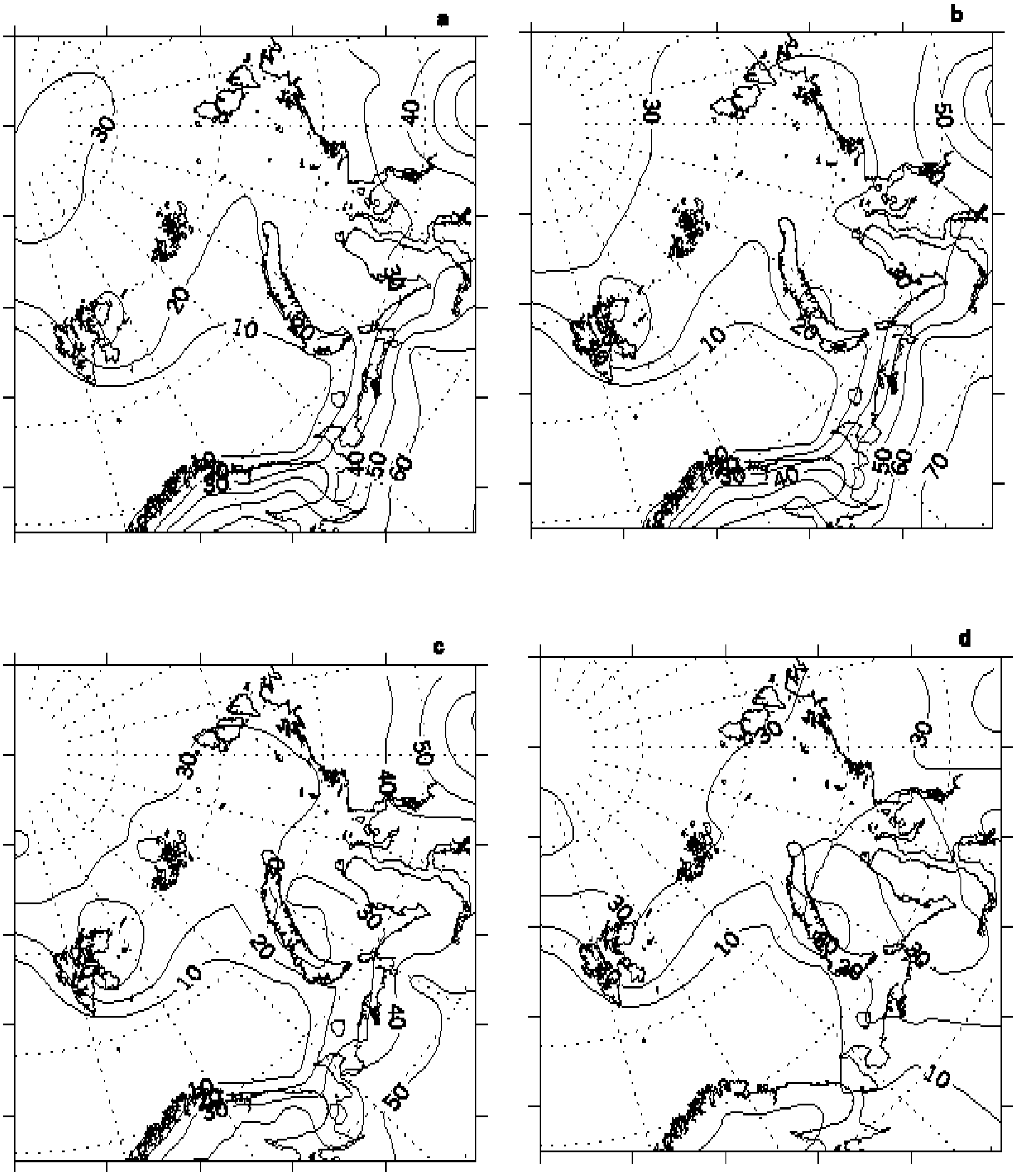


Figure 7.2.

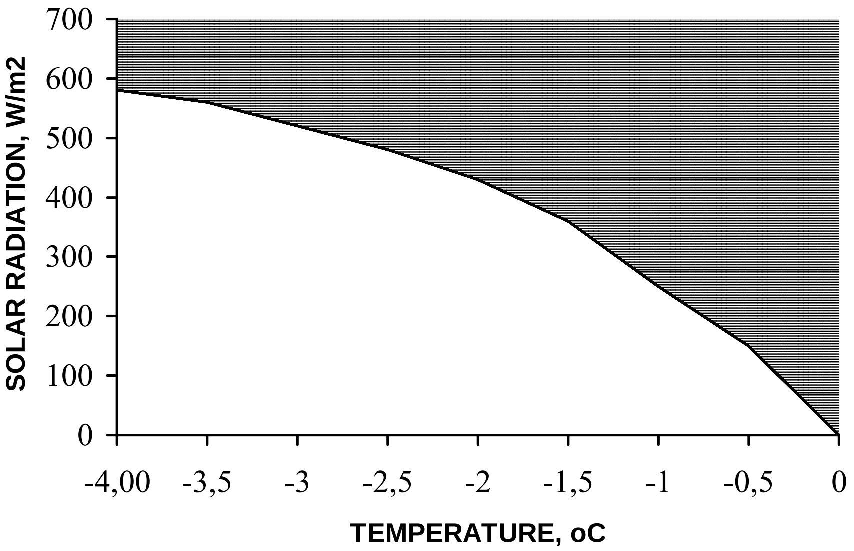

700
600
500
400
300
200
100
0
SOLAR RADIATION, W/m2
-4,00
-3,5
-3
-2,5
-2
-1,5
-1
-0,5
0
TEMPERATURE, oC

Figure 8.

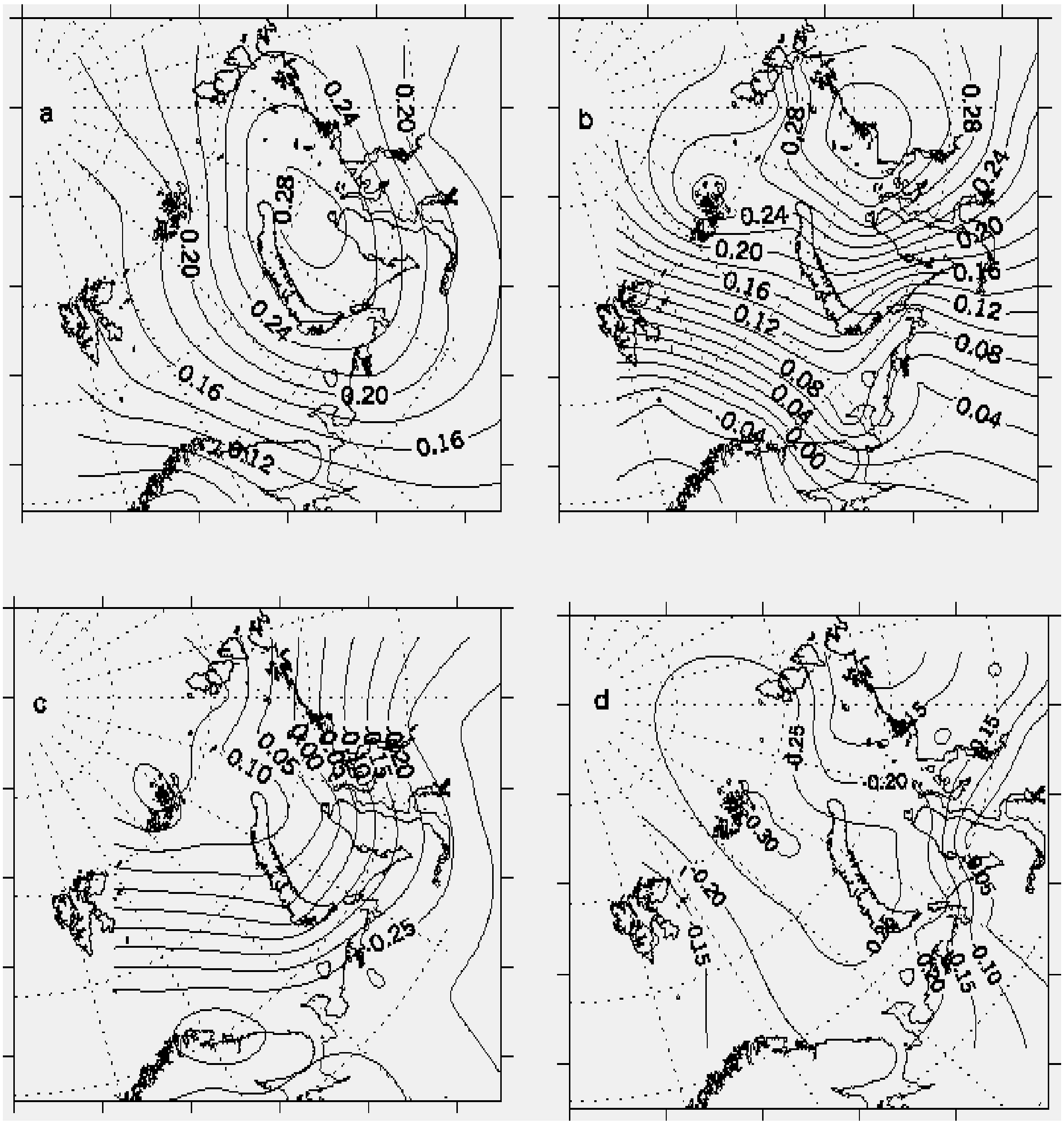
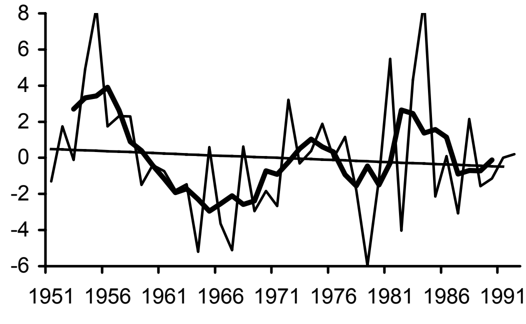
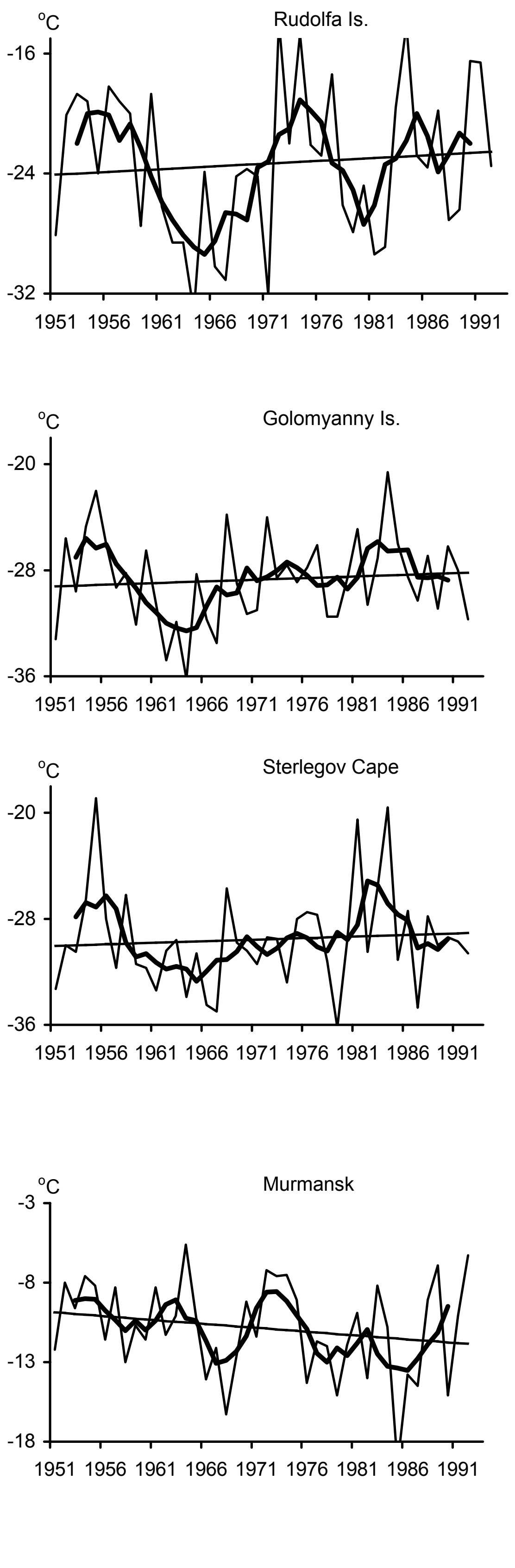
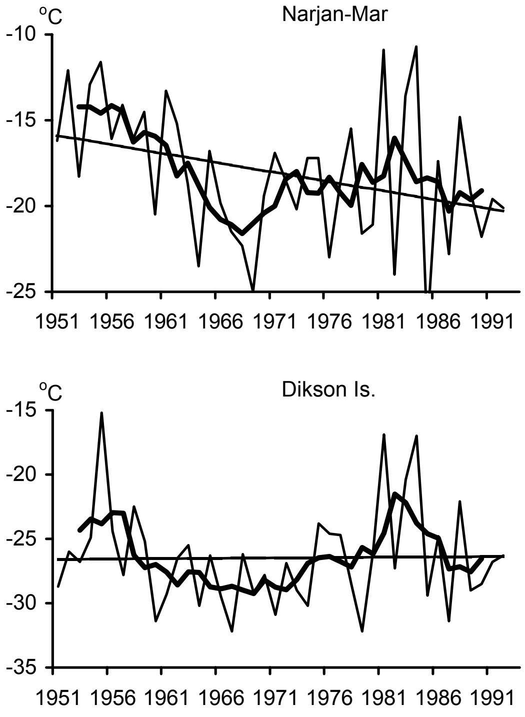


Figure 9. Distribution of the components of the 1st eigenvector of average monthly air temperature in January (a) and July (b), precipitation amount within the cold season (October-May) (c), snow cover depth (d) for the period 1951-1998



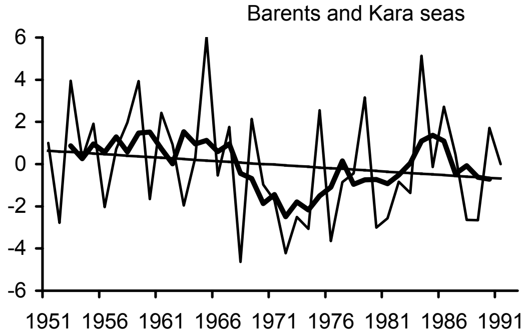


Rudolfa Is.
°C
-16
-24
-32
1951 1956 1961 1966 1971 1976 1981 1986 1991
Golomyanny Is.
°C
-20
-28
-36
1951 1956 1961 1966 1971 1976 1981 1986 1991
Sterlegov Cape
°C
-20
-28
-36
1951 1956 1961 1966 1971 1976 1981 1986 1991
Murmansk
°C
-3
-8
-13
-18
1951 1956 1961 1966 1971 1976 1981 1986 1991

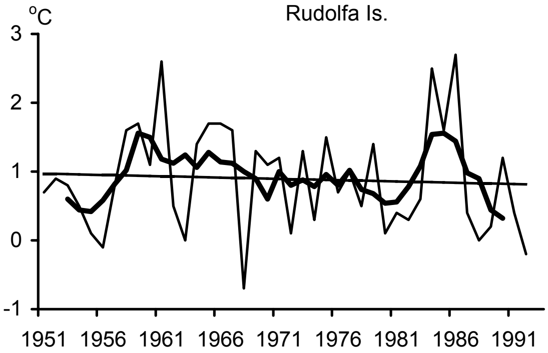


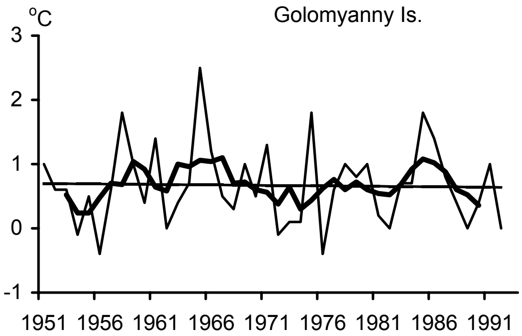
Narjan-Mar
°C
-10
-15
-20
-25
1951 1956 1961 1966 1971 1976 1981 1986 1991
Dikson Is.
°C
-15
-20
-25
-30
-35
1951 1956 1961 1966 1971 1976 1981 1986 1991

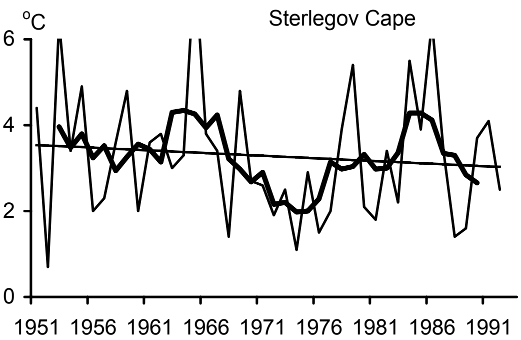
Figure 10

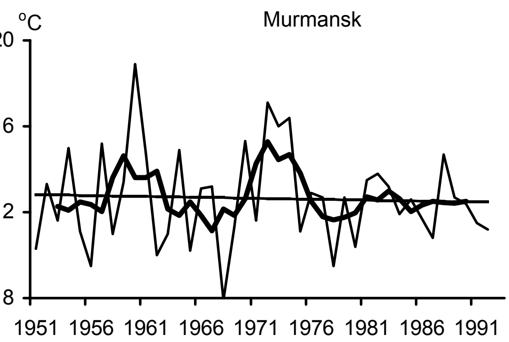


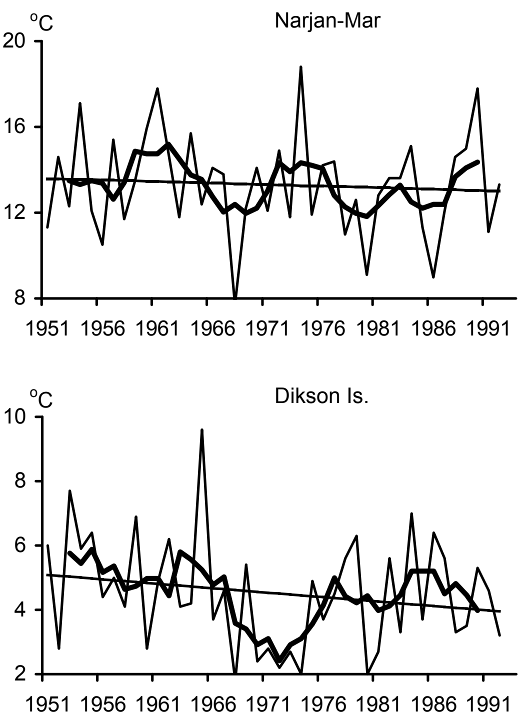
Barents and Kara seas
6
4
2
0
-2
-4
-6
1951
1956
1961
1966
1971
1976
1981
1986
1991


Rudolfa Is.
°C
3
2
1
0
-1
1951 1956 1961 1966 1971 1976 1981 1986 1991


Golomyanny Is.
°C
3
2
1
0
-1
1951 1956 1961 1966 1971 1976 1981 1986 1991

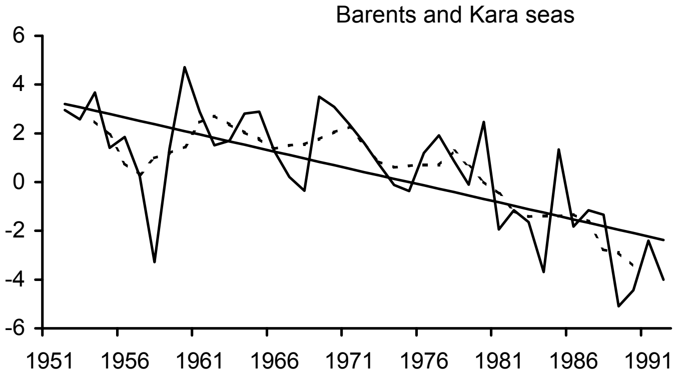

Sterlegov Cape
°C
6
4
2
0
1951 1956 1961 1966 1971 1976 1981 1986 1991

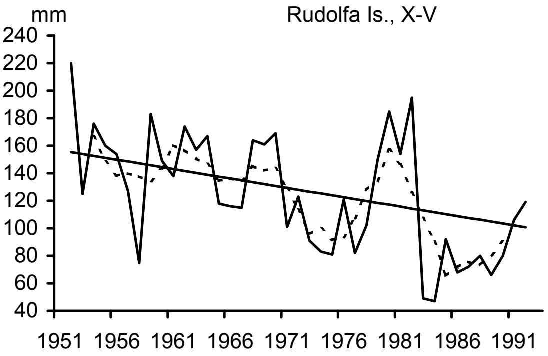

Murmansk
°C
20
16
12
8
1951 1956 1961 1966 1971 1976 1981 1986 1991

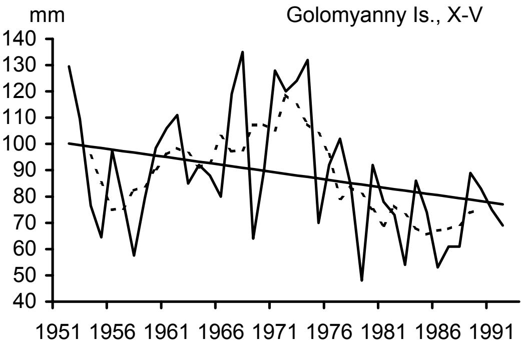


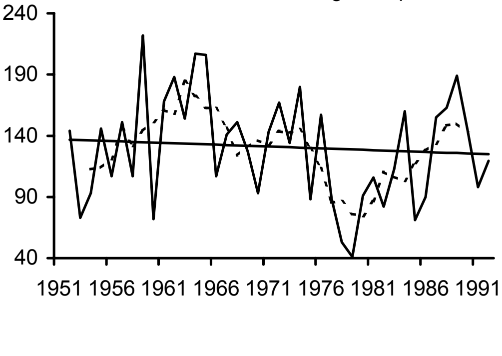
°C
Narjan-Mar
20
16
12
8
1951 1956 1961 1966 1971 1976 1981 1986 1991
°C
Dikson Is.
10
8
6
4
2
1951 1956 1961 1966 1971 1976 1981 1986 1991

Figure 11


Barents and Kara seas
6
4
2
0
-2
-4
-6
1951 1956 1961 1966 1971 1976 1981 1986 1991


mm
Rudolfa Is., X-V
240 220 200 180 160 140 120 100 80 60 40
1951 1956 1961 1966 1971 1976 1981 1986 1991


mm
Golomyanny Is., X-V
140 130 120 110 100 90 80 70 60 50 40
1951 1956 1961 1966 1971 1976 1981 1986 1991


mm
Sterlegov Cape, X-V
240 190 140 90 40
1951 1956 1961 1966 1971 1976 1981 1986 1991

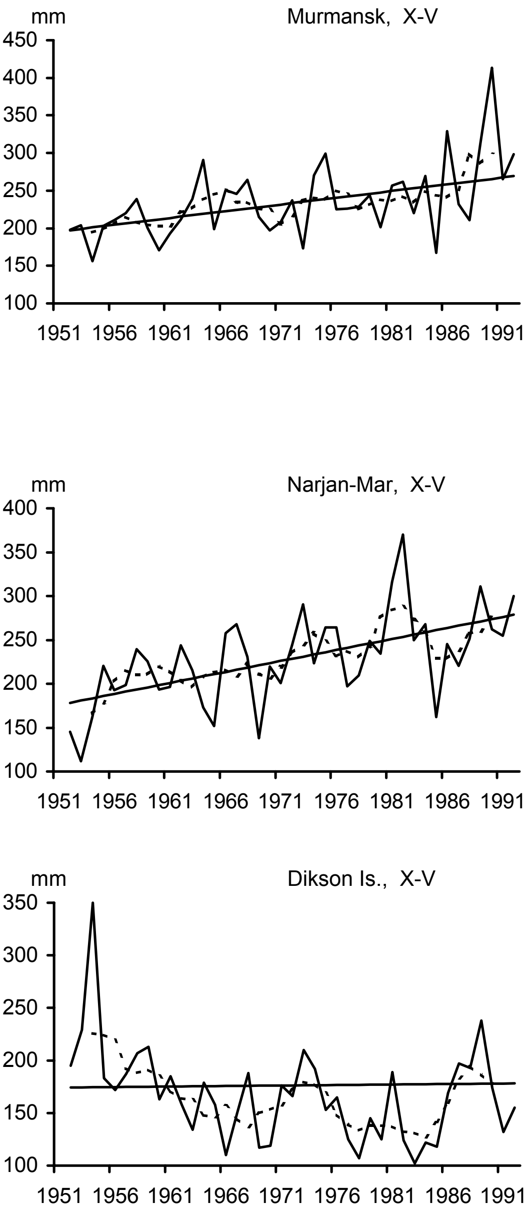
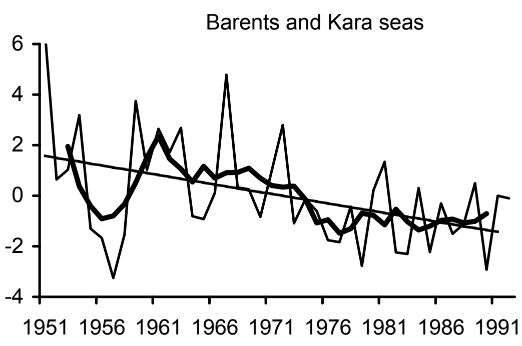
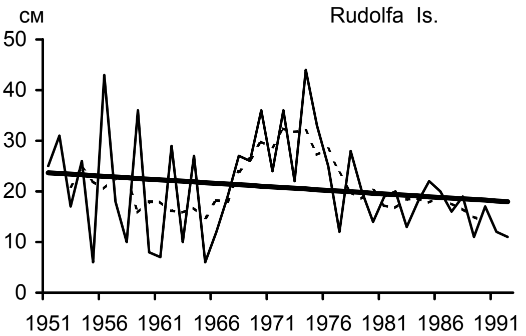
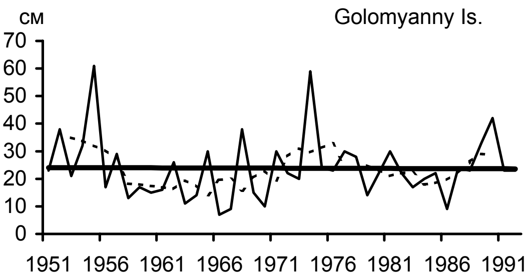
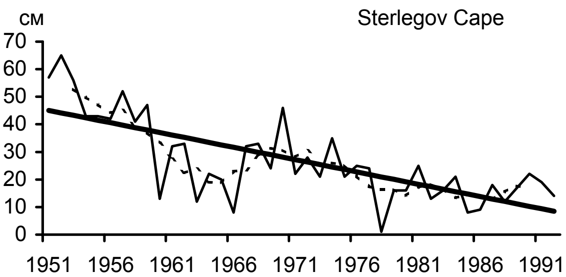

mm
Murmansk, X-V
450
400
350
300
250
200
150
100
1951 1956 1961 1966 1971 1976 1981 1986 1991
mm
Narjan-Mar, X-V
400
350
300
250
200
150
100
1951 1956 1961 1966 1971 1976 1981 1986 1991
mm
Dikson Is., X-V
350
300
250
200
150
100
1951 1956 1961 1966 1971 1976 1981 1986 1991

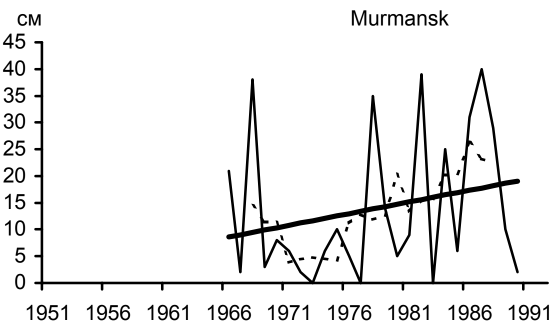
Figure 12


Barents and Kara seas
6
4
2
0
-2
-4
1951 1956 1961 1966 1971 1976 1981 1986 1991


Rudolfa Is.
см
50
40
30
20
10
0
1951 1956 1961 1966 1971 1976 1981 1986 1991


Golomyanny Is.
см
70
60
50
40
30
20
10
0
1951 1956 1961 1966 1971 1976 1981 1986 1991


Sterlegov Cape
см
70
60
50
40
30
20
10
0
1951 1956 1961 1966 1971 1976 1981 1986 1991


Murmansk
см
45
40
35
30
25
20
15
10
5
0
1951 1956 1961 1966 1971 1976 1981 1986 1991

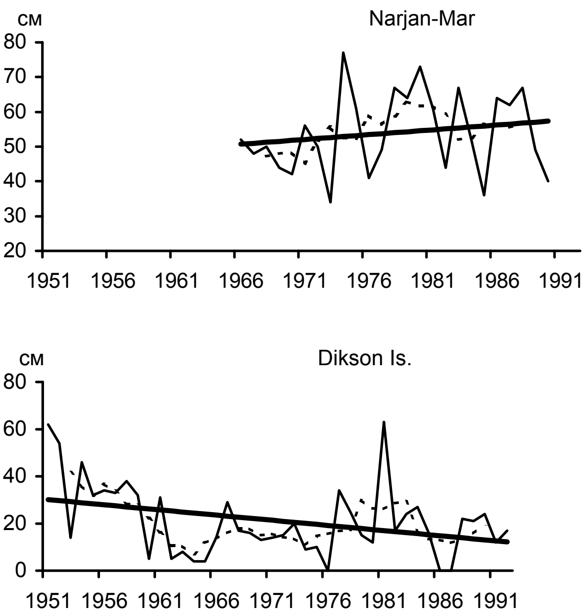

см
Narjan-Mar
80
70
60
50
40
30
20
1951
1956
1961
1966
1971
1976
1981
1986
1991
см
Dikson Is.
80
60
40
20
0
1951
1956
1961
1966
1971
1976
1981
1986
1991

Figure 13