Pronounced anomalies of air, water, ice conditions in area of the Barents, Kara and Azov Seas

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Abstract
Results of analysis of the anomalous hydrometeorological situation, which emerged in the beginning of 2012 year in the seas of Russian Arctic and Central Europe, are given. It is showed that as a result of western transfer blocking in temperate zone, branch of Siberian anticyclone formed marked positive anomaly of air temperature and ice cover in the Barents and Kara seas. At the same time in the Central and Southern Europe protracted negative anomaly of air temperature was noticed. Winter hydrological situation in the Pechora and Kara seas is depicted with unique set of observations, made with the usage of expendable bathythermosalinographs.

1. Introduction
Problems of thermal regime and sea ice cover changes are discussed for a long time in the recent scientific literature on a global and local scale (Matishov & Dzhenyuk 2012; Levermann et al. 2012; Matishov et al. 2012). The subjects of analysis are usually displacement of climatic norms and hydrometeorological characteristics' trends of many years, which often do not go beyond the bounds of statistical errors. Meanwhile conduct of economical activity in seas and coastal areas, stability of land and sea ecosystems first of all depend on large and protracted oceanological anomalies, which do not always coincide with the sign of long-term trends (Matishov 2008).

Strong warming was recorded in Arctic Ocean and its shelf seas since the beginning of XXI century (Matishov et al. 2009; Alekseev et al. 2010; Katsov & Porfirjev 2011). Positive anomaly of water temperature in Atlantic water masses remains for not less then ten years in the Barents Sea (Matishov et al. 2009, 2012).

Arctic ice area in summer and autumn months decrease significantly and because of that transportation on the Northern Sea Route could be organized without icebreaking. Absence of ice of Pechora and Kara seas was noticed in winter 2011/12, when the probability of that condition was close to zero according to many years' data. Meanwhile at the beginning of 2012 (January and February) air temperature at Franz Josef Land reached values, which were close to absolute maximum (+1-2°). Condition of ice edge on the Barents Sea was close to its climatic minimum with degree probability 1%. In Kara Sea significant ice-free areas remained in February. That was not recorded according to previous climatic data (Atlas …, 1980).

Some researchers suppose that decrease of ice cover in Arctic basin in summer and autumn is caused by alteration of large-scale atmospheric circulation (Overland & Wang 2010), which causes increase of blocking situations and precipitations in Europe in winter (Liua et al. 2012).

At the same time anomalous cold weather, which was set in the second half of the winter, became the typical phenomenon on the territory of Central and Southern Europe and water areas of adjacent seas (the Sea of Azov, northern-east of the Black Sea, northern Caspian Sea) (Matishov et al. 2012; Moore & Renfrew 2012; Tourpali & Zanis 2013). Anomalies in January and February of 2006 and 2012 were especially pronounced. Air temperature in January 2006 on the south of European Russia decreased to -32-33°, its average monthly values were about -15°, and that is 12-15° lower than climatic norms. Similar conditions were recorded in January and February of 2012. At that period of time the influence of Siberian anticyclone spread down to English Channel and Portugal. It is the first time in 30 years when northern part of the Black Sea was frozen, the first time in 80 years when channels of Venice was iced, piers of Geneva Lake was covered by ice.

On the Sea of Azov and the Caspian Sea ice complicated navigation seriously, which typically does not meet obstacles all the year round. Duration of the ice period reached 50-80 days on the Caspian Sea and the Sea of Azov. About 100 vessels were locked in ice on the water area and in ports of the Sea of Azov and The Kerch Strait in February and March 2012 (Matishov et al. 2012). On the Caspian Sea drifts of ice spread along the west coast down to the Apsheron Peninsula.

At the end of XIX century climatologist A.I. Voeikov was analyzing the connection between wind and pressure and came to the basic conclusions about the development of "big axis of European-Asian continent" (Voeikov 1884). Siberian anticyclone with branch oblong to Europe began to call the axis of Voeikov. This climatic axis appears as wind divide, which separates winds with southern component (to the north from the axis) from winds with northern component (to the south from the axis). As a result anomalous advection of Siberian anticyclone to Pyrenees and Gulf Stream warmth to the Arctic towards Franz Josef Land happens in winter (Figure 1).

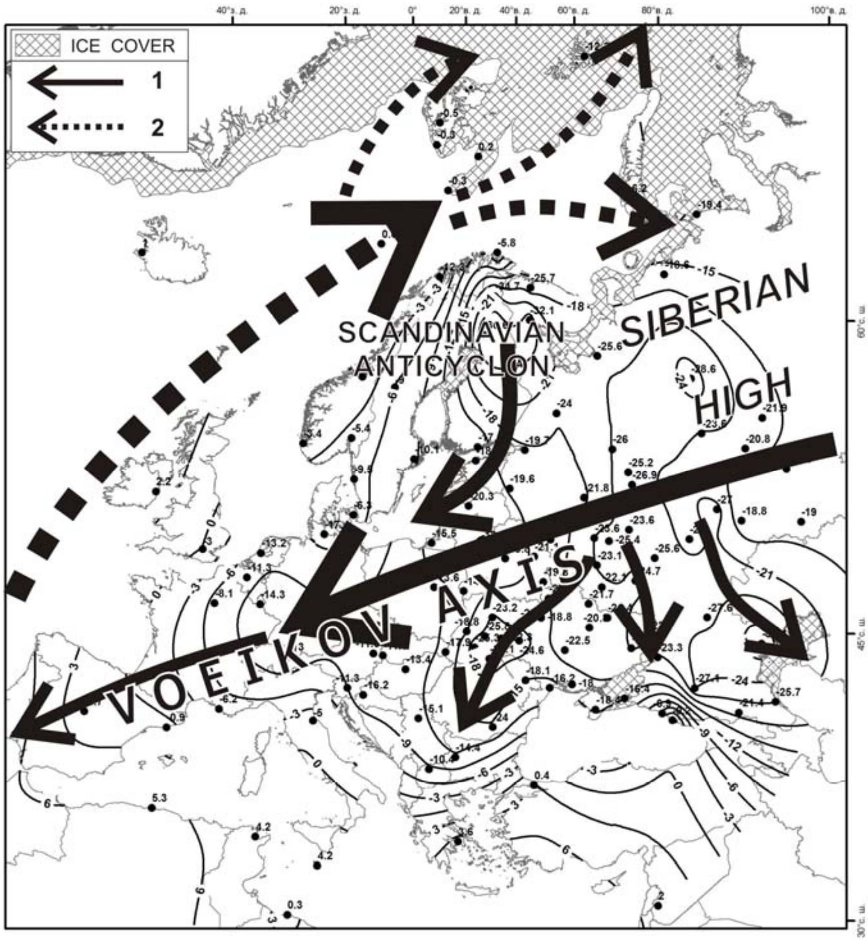


Figure 1. Anomalous spreading of Siberian anticyclone branch: 1-cold atmospheric inflow; 2-warm atmospheric and hydrospheric inflows. Contours are drawn according to mean values of air temperature for a coldest period of 1-4 February 2012. Minimum ground air temperatures are shown by digits near every point of observations.

In the sequel conditions of atmospheric circulation above northern hemisphere were studied in detail by B.L. Dzerdzeyevskiy (Dzerdzeyevskiy et al. 1946; Kononova 2009), G.Y. Vangengeym (Vangengeym 1940), A.A. Girs (Girs 1971). Several sets of macrosynoptical processes types were developed on similar methodic basis (zonal and meridional transfers with subtypes). Persisting of blocking anticyclone leads to cooling of atmosphere surface layer above continent and eastern transfer impede warming effect of southern seas.

In our opinion intensification of these processes in the atmosphere favours weather anomalies development, as well as anomalies of hydrological and ice conditions, which have different signs depended on season and geographical localization of atmospheric transfers. To estimate such anomalies we use database of climate and biology of the arctic and southern seas, which was created as a result of many years' cooperation with NOAA and World Ocean Database of the USA. Further it will be considered marked anomalous situation in January-March 2012, which is elucidated by unique set of meteorological and oceanological data.

2. Materials and methods

For creating schematic map of average surface temperature we used data from the Internet resource "The weather of Russia" (http://meteo.infospace.ru). Final schematic map is done in GIS-programme ArcGIS and based on data of more than 130 weather stations. Contours are drawn according to average values of surface air temperatures in the coldest period 1-4 February. Minimal temperature values for the same period are shown (Figure 1).

Information about salinity and water was got in the course of passing observations of MMBI at the Northern Sea Route from the board of diesel-electric ship "Talnakh" in March of 2012. Two sections were done in the Barents (st. 1-10) and Kara (st. 11-16) seas (Figure 2). Extendable bathythermosalinographs XCTD-3 production of Tsurumi Seiki (Japan) were used for conducting of hydrological profiling. This method was firstly tested during passing observations at the Northern Sea Route in ice period. Measurement results of expendable bathythermosalinographs were interpolated every 1 m and marked on bottom profiles, which were made according to bathymetric data (Matishov 1997).

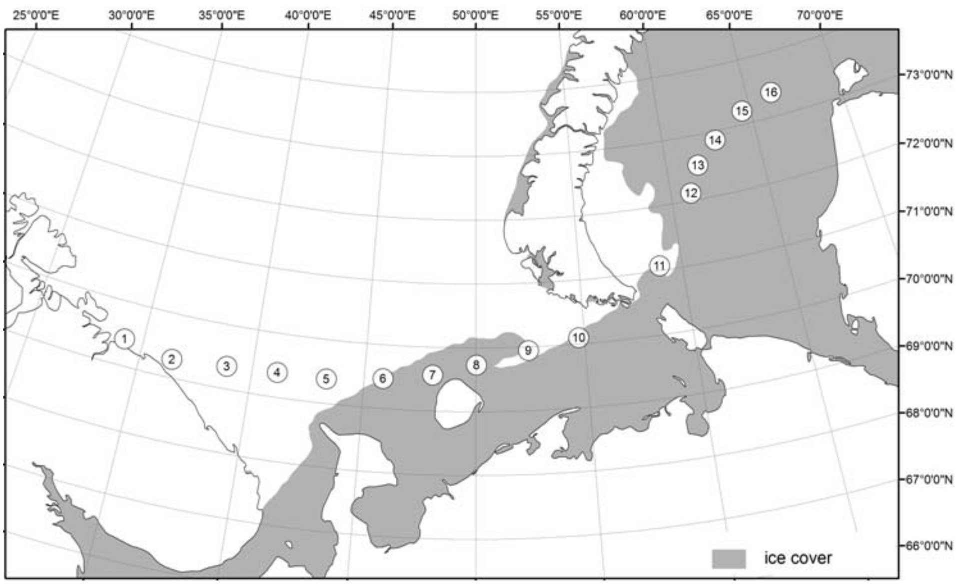


Figure 2. Position of XCTD stations 11 – 13 March 2012; ice cover (according to ice analysis of AARI on 11 – 13 March).

Sea ice data were downloaded from the AARI site (www.aari.ru). Database, which was formed by MMBI, was used for calculation of ice anomalies. Ice conditions anomalies of the Sea of Azov were estimated with the usage of SSC RAS database. Data was obtained during winter expeditions 2005-2012 on research vessels "Professor Panov", "Deneb", and on icebreaker "Captain Demidov" and other passing vessels.

3. Results and discussion

Meteorological situation

Anomalous situation in January-February 2012 was caused by Siberian anticyclone spreading on Central and Southern Europe (down to English Channel and Portugal) and anomalous advection of Atlantic waters on Siberian shelf (Figure 1). Trajectories of Atlantic cyclones displaced northward, forming warm anomaly in the Western Arctic. Intensification of west atmospheric transfer to high latitudes caused the increase of air temperature and surface layer of sea, slowdown of ice formation processes and drifts of ice edge to the north-east. Transfer of cold air masses from Siberia and Central Asia to southern Europe and the Mediterranean happened to the south of the axis of Vojeikov in anticyclonical pressure field.

Blocking situation began to form in the middle of January 2012. Anticyclone with the centre above North Ural at the end of the second decade began to cover European part of Russia, and at the third decade – Karelia and Finland. At the same time surface pressure in the centre of anticyclone zone increased and got closer to its climatic records: up to 1055 mb 27 January and up to 1060 mb from 31 January to 4 February. By this time homogenous zone of high pressure covered European area of Russia. Location of anticyclonical ridge above Southern and Central Europe stabilized, trajectories of cyclones displaced far to the north and south from the usual location (Figure 3).

Starting from 5 February homogeneity of high pressure zone was broken by pressure trough, which spread from Central Europe to the White Sea. At the same time high pressure ridge remained above Scandinavian and British islands till 12 February. It displaced in Central Europe 13 – 14 February, and from 15 February irruption of deep cyclone from the north destroyed the blocking situation completely. Thus, duration of that situation was 30 days.

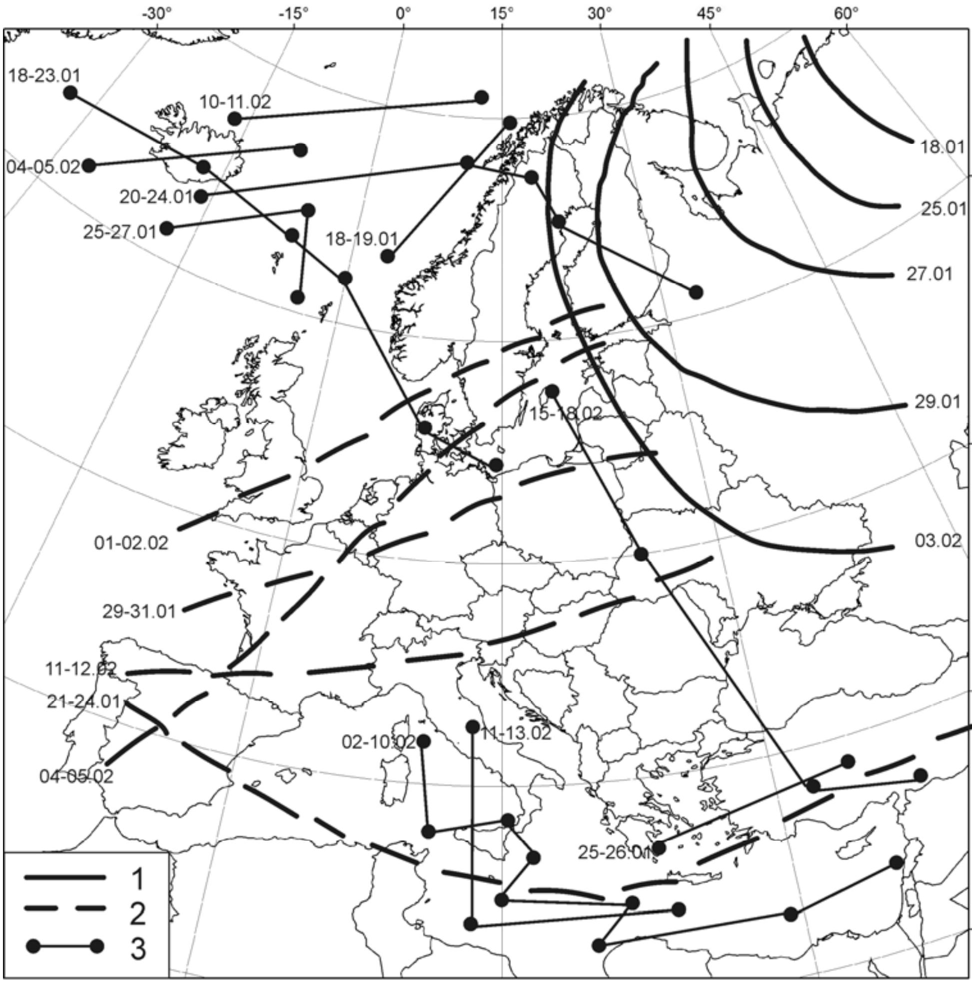


Figure 3. Composite map of surface atmospheric processes over a period of time 18.01 – 18.02.2012 (solid line 1 – position of western border of anticyclone, broken line 2 – position of pressure ridge axis, lines with circles 3 – cyclones trajectories)

On the south of Europe during the first days high pressure ridge spread from stationary anticyclone along the Mediterranean Sea. Western transfer stayed above Central Europe. After passing by cyclone away from Iceland to the south of the Barents Sea and its filling on 23 January, anticyclone branch placed above Eastern and Central Europe. Cyclonic activity resumed in this region only on 15 February. Exactly in that period large anomalies of air temperature were recorded: in the third decade of January on the south of Russia, where diurnal minimum exceeded -20°, and in the first half of February on the whole territory of Western Europe up to British Isles. Temperature records were not exceeded but duration and stability of anomalous frost did not have analogues in the last two decade, which were characterized be warming on the whole.

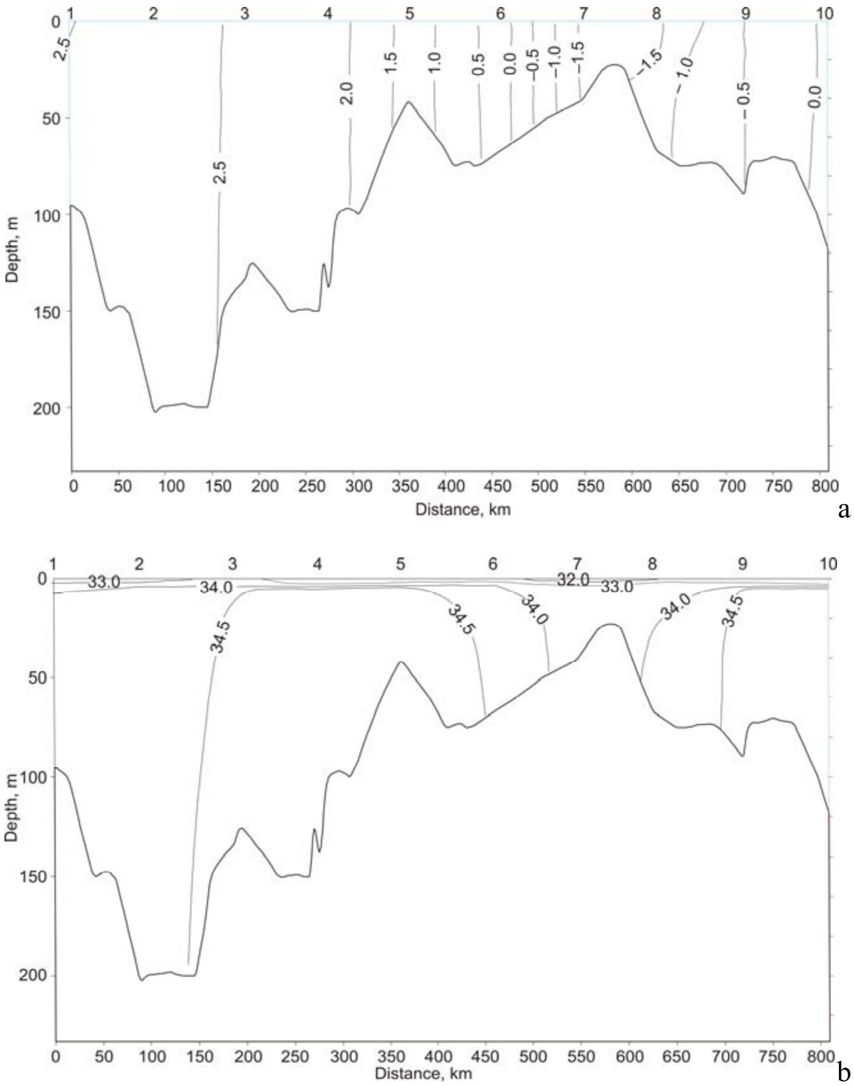
According to B.L. Dzerdzeevsky typification examined situation corresponds to winter subtype of longitudal southern circulation. Recurrence of this type increased significantly in the period 1986-1997, and then began to decrease (Matskovsky & Kononova, 2011). Nevertheless, during the last decade it is much above the norm, which was calculated for the whole period in accordance with synoptical information (from 1899 to the present time).

Hydrophysical characteristics

Freezing arctic seas are remarkable for stability of hydrological situation in the period from January to March at standard conditions. As a result of autumn and winter convection at shallow depths of the Pechora Sea water temperature was homogeneous from surface to bottom and becomes close to freezing point of the surface layer. Depending on salinity ice formation starts from 0° (straight in the estuary area of Pechora) to -1.9° on the border of coastal and offshore water masses. Salinity decrease till 32-33‰ on the maximum of summer freshening in open areas of the Pechora Sea area (in latitude 70°), and when river runoff goes down sharply in January-March, salinity increases till 34.0-34.5‰. That is close to typical values of the Barents Sea waters (Hydrometeorology …, 1991; Loeng 1991).

The Kara Sea is remarkable for significant changeability of salinity, because it undergoes river runoff, vastly exceeding that of the Barents Sea river runoff. In summer salinity of surface waters alters from values close to 10 ‰, in areas adjoining to the Ob and Yenisei estuaries outlets, to 32-33‰ (Changeability …, 1994). In autumn and winter months runoffs of those rivers stay significant, because they form on spacious areas of several landscape zones. However, data about straightforward measurements of hydrophysical characteristics in winter period is extremely scanty, because traditional hydrological surveys are impossible in presence of solid ice cover.

Data analysis of hydrophysical probing, which was obtained in voyage of ice class vessel, gives an opportunity to detect features of anomalous processes of winter 2012 in the Barents and Kara seas. Distribution of temperature and salinity on the studied water area is determined by geographical position, bottom topography, ice cover and other factors (Figure 4).



1
2
3
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7
8
9
10
Depth, m
Distance, km
2.5
2.0
1.5
1.0
0.5
0.0
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b

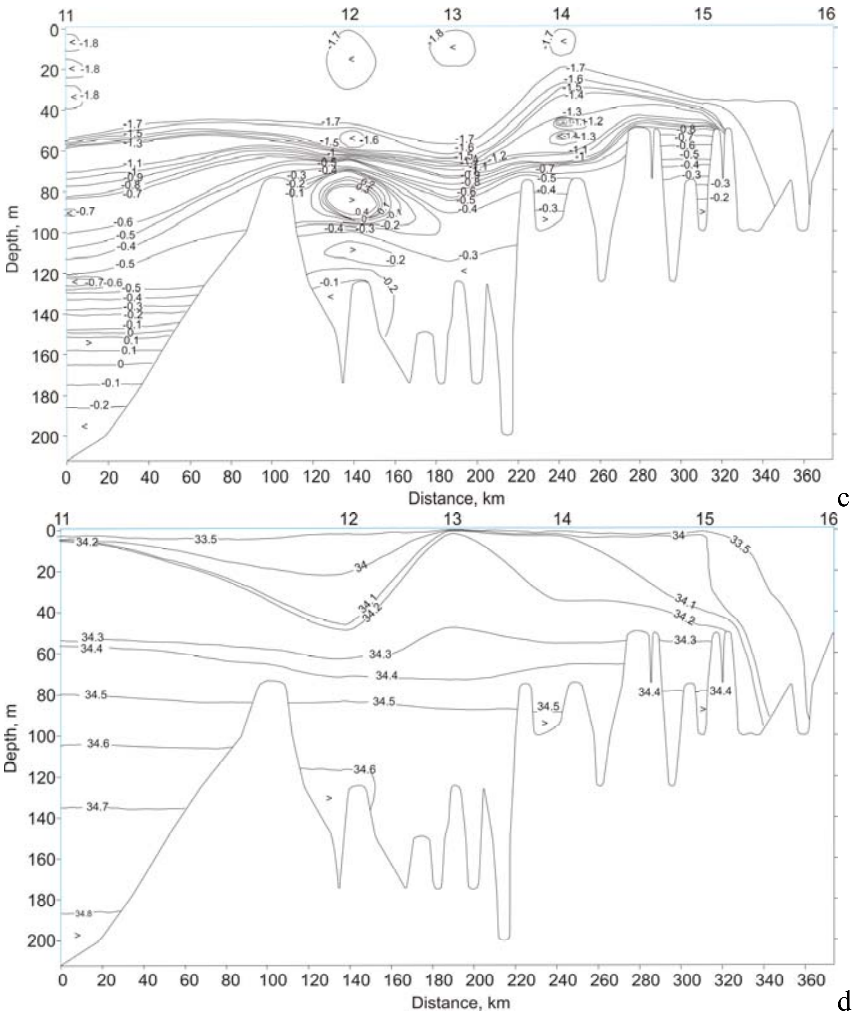

Figure 4. Distribution of temperature (a, b) and salinity (c, d) on sections in the Barents (11 – 12 March) and Kara (13 March) seas. Location of stations is shown in the fig. 2. Bottom profile is made according to Matishov, 1997

Along the section, except a part northwards Kolguyev Island, it was observed quasihomogeneous vertical distribution of water temperature. On the south-west of the Barents Sea temperatures were positive. In the direction from west to east temperature of water column in coastal branch of Murmansk stream decreased from 2.5-2.9 °C to negative values in areas near ice edge. The lowest water temperature on the part of section in the Barents Sea (-1.61 °C) was recorded in shallow water (41 m) to the north of the Kolguyev Island. Eastward, to the south of Novaya Zemlya temperature became positive under the impact of warm waters advection and reached 0.14 °C (Figure 4 a).

Water salinity on the section in the Barents Sea altered from 31.55 to 34.81 ‰. Upper freshened layer with 5 m thickness was noted on the all stations. Lower from that layer to the bottom vertical distribution of salinity had quasihomogeneous character. In deep gutters more salt waters of Atlantic origin got its contour with isohaline of 34.5 ‰ (Figure 4 b). Maximal salinity values (above 34.70 ‰) were recorded under the freshened layer on the station 10.

Water temperature on the section between Novaya Zemlya and Yamal had negative values almost everywhere. Only in the area trench (st. 12) in the layer 80-100 m positive temperatures from 0 to 0.48 °C were recorded. Lenses of cold water are characteristic for different layers, especially on the shelf with rugged relief (Figure 4 c).

Freshened surface layer, which is characteristic for the Kara Sea, is recorded. It comes to column with horizontal salinity gradient on the north of the section. On the whole, water salinity on the section in the Kara Sea altered from 31.79 to 34.82 ‰. The highest salinity values were recorded in surface and bottom layers of Novozemelskiy trough (Figure 4 d). Non-typical air temperature of surface layer in winter impeded ice formation in the Kara Sea (Figure 2).

Ice conditions

Peculiarities of atmospheric circulation noticed above, positive anomalies of air and water masses temperature impeded ice formation process and ice accumulation in European sector of the Arctic in winter period of 2012. Edge of floating ices in the Greenland and Barents seas situated much further to the north and to the east of its average annual position (Figure 5). Ice was not noticed almost in all waters of Svalbard and Novaya Zemlya. Vast spaces of clear water noticed in the Kara Sea for the first time in last 30 years in winter months. In February almost whole south-western part of the sea was ice-free (Figure 5). Significant unfrozen patch of water preserved here in March, which is the most glacial month in the Arctic according to average annual data (Figure 5 b).

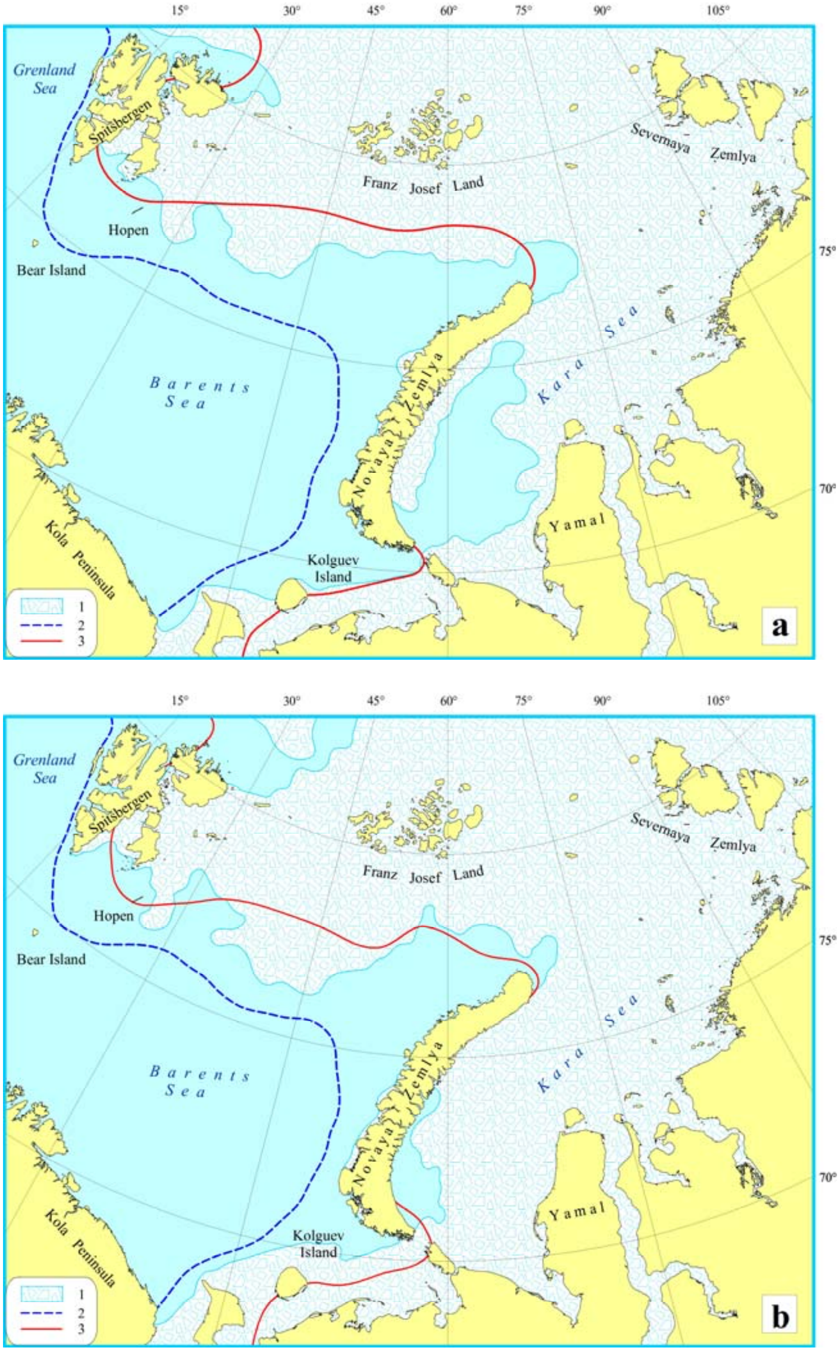

Figure 5. Ice conditions in the seas of the Barents and Kara Seas in February (a) and March (b) 2012
1 – ice cover distribution;

2 – average ice edge position of many years;
3 – minimal position of ice edge of many years.

Greater interannual and seasonal alteration of ice regime is characteristic for the Barents Sea (Hydrometeorology..., 1990; Zhichkin 2010; Vinje 2001). Analysis of ice anomalous in the Barents Sea in winter period (January – March) during the last decade showed that firstly gradual decrease of ice area to minimal values happened in 2008. After that, growth of ice was recorded during three years, and ice cover area was close to average annual values in winter period of 2011. However, in winter 2012 as in 2008, sharp decrease of icing to minimum values happened (Figure 6).

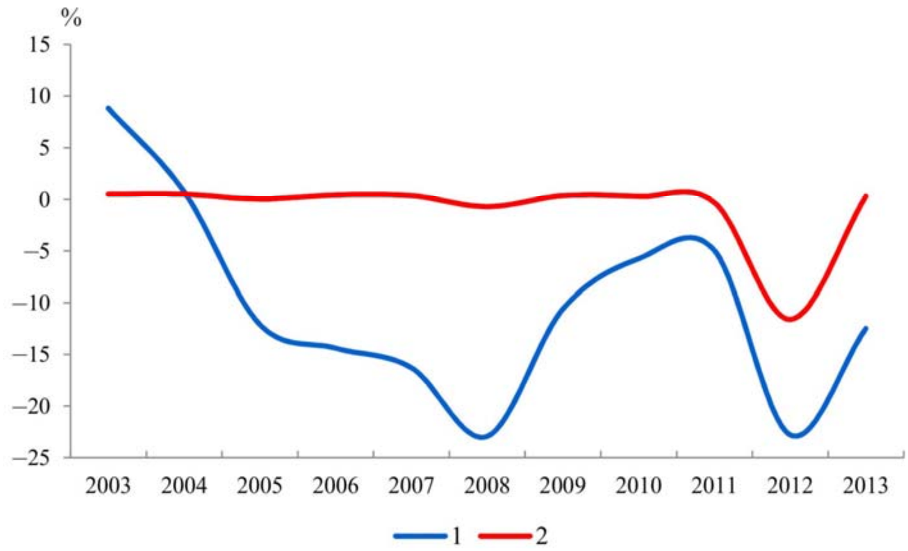

Figure 6. Average anomalies of ice coverage (%) in the Barents (1) and Kara (2) seas in winter period (January – March) 2003-2013

Ice coverage of the Kara Sea in winter months during the last 10 years was stable, anomalies of both signs were insignificant. In the Kara Sea the most anomalous was February among winter months of 2012, when negative ice anomaly increased sharply up to 20% (Figure 7).

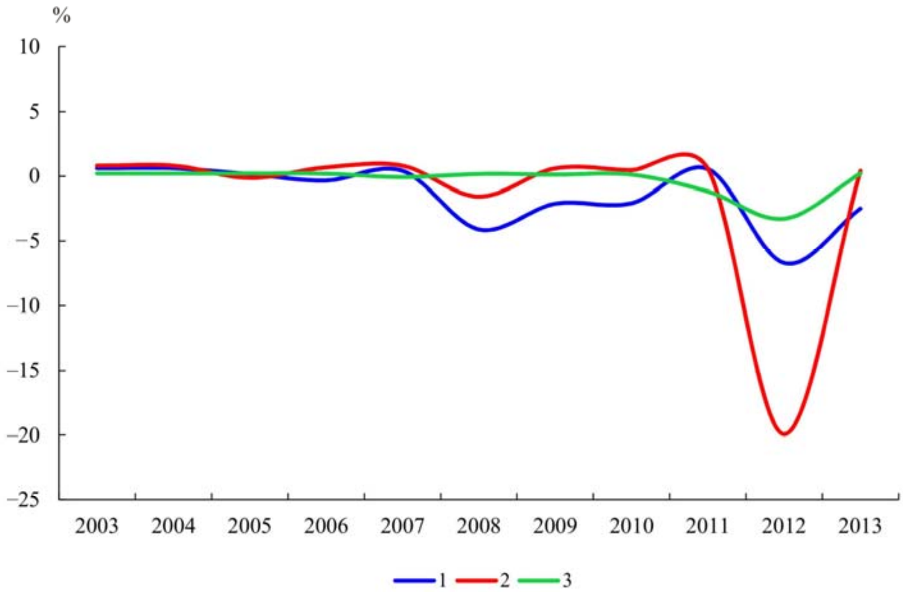

Figure 7. Ice anomalies (%) in the Kara Sea in the winter period 2012-2013 (1 – January, 2 – February, 3 – March)

During a winter time of 2013 under changing conditions of large-scale atmospheric circulation in the northern hemisphere trend of increased ice formation was observed in the Barents and Kara Seas (Figure 6). In the Kara Sea ice concentration in February-March was close to average values (Figure 7).

At the same time in the southern seas ice conditions of February-March 2012 were anomalous severe (Figure 8). Thus, there were hard ice conditions in the Sea of Azov according to data of satellite and icebreaker observations. The total sea area was covered by ice (this state is observed in less than 50% of winter seasons). Ice was barely passable, with marked processes of motions, pressing, hummocking. Fastened ice from 20 cm in Kerch to 50 – 70 cm in Taganrog Bay was formed in offshore zone. In February – March ice thickness to 50 – 80 cm, in hummock – to 4 m, was recorded within Azov-Don Channel.

Figure 8. Ice breaker in the Sea of Azov on 25 March 2012

Discussion

In the first months of 2012 large-scale thermal anomaly, which covered all Europe and adjacent arctic and southern seas, emerged against the background of diverse climatic tendencies. As we showed in the works (Matishov et al 2009; 2011), from the beginning of XXI century prolonged warm anomaly preserved in the Western Arctic. It is comparable in intensity to “the Arctic warming” in the first half of last century. It conforms to viewpoint of AARI specialists (Frolov et al. 2010) about presence of 60-years cycle of arctic seas ice fluctuation, and 200-years cycles of sun radiation incoming to the Earth. Overlay of these cycles gives grounds to consider that it is more likely to be temperature decrease and ice growth then warming development predicted by some results of model calculation (Katsov & Porfiryev 2011) by 2030 – 2040. It is obvious that not taking into account inter-century cycles, it is impossible to analyze climate and condition of large marine ecosystems of the North Atlantic and the Arctic.

Experience of arctic navigation proves the presence of 60-years cycle and caused warm anomalies in the period not covered by regular observations. As is generally known, in 1878-1879 expedition on the “Vega” vessel under the direction of A.E. Nordenskiöld passed the Northern Sea Route and met impassable ice just on the way to the Bering Strait (Nordenskiöld 1887).

Nowadays possibility of open pass of vessels through the Northern Sea Route is interpreted like a feature of irreversible global warming (Stephenson et al. 2013).

Along with that, cycles of shorter duration are singled out in many works, devoted to climate changeability. The most well-known from them is 11-years cycle caused by solar activity alteration. All cases of Kola Bay freezing were documented over a period of time more than 100 years, so it can be considered as one of indicators of processes cyclicity in the arctic seas. In XX century Kola Bay freezing occurs with intervals close to 30 years (Matishov et al. 2011). These situations caused by meteorological and hydrological factors in total. Preserving of stable anticyclone above Scandinavia for a long time (not less than a decade) plays a leading role in this matter.

Certainly, climate cycles do not run like clockwork. The example of its disruption was the situation on the Bering Sea shelf. Ice kept there for a record long time, more than 100 days. During the history of satellite observations (from 1979) it was noticed just for the second time.

The role of macrosynoptical processes in anomalies formation of European climate, as well as hydrological and glacial regime of the arctic seas, requires further research. Warming of 1990 – 2000 years occurred under conditions of intensive western and eastern transfer in middle latitudes. During recent years' recurrence and especially duration of anticyclonic blocking above Eurasia increased, that were conducive to enhancement of continental climate. At the same time trajectories of north Atlantic cyclones displaced to high latitudes, and that is favourable for positive anomalies of water temperatures and ice formation decrease of the arctic seas in warm and cold year periods. In Central and Southern Europe, the Black, Caspian seas and the Sea of Azov such situations cause strong positive anomalies of air and water in summer, and sharp fall of temperature and great ice cover formation in winter.

By opinion of meteorologists (Shakina & Ivanova 2012) nowadays development of blocking situation can be predicted successfully, when it is actually observed. At the current level of knowledge is not possible to predict the emergence of such a situation and especially its duration. Therefore, it is necessary to obtain probabilistic estimate of such anomalies both from synoptic meteorology point of view (frequency and duration of blocking situations, intensity and localization of surface and high pressure-fields) and the usage of climatological criteria.

4. Conclusion

In argues about global climate changes and oceanological regime it is important to expedite development of new technologies and software for climatic norms and anomalies computation, errors recognizing in computational algorithm. For marine climate assessment it should be used not just oceanological but hydrobiological data as well. Thus, according to biomass alteration of some species of polychaetes and crustacean it is stated that fauna reacts to temperature anomalies with 3 – 8 years delay (Matishov et al. 2012).

That is why warm anomaly in the Barents and Kara seas examined above is supposed to affect marine ecosystems till the end of the current decade.

Climate anomalies assessment becomes especially important because of designated activity of oil and gas companies on the Pechora and Kara Seas shelf. Not less important are the ice conditions on the Northern Sea Route. The warming of 2000-2012 already had stimulated the refusal of ice-breaker support from companies participating in arctic shipping. The reverse trend may bring unfavorable sequences for all kinds of economical activity in the Russian Arctic.

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