Original Russian Text © The Authors, 2022,
published in MORSKOY GIDROFIZICHESKIY ZHURNAL, Vol. 38, Iss. 3 (2022)

Processes Determining Synchronous Interdecadal Variability of Surface Temperature in the Barents and Black Seas

A. A. Sizov ✉, T. M. Bayankina, V. L. Pososhkov, A. E. Anisimov

Marine Hydrophysical Institute of RAS , Sevastopol, Russian Federation
✉ *sizov_anatoliy@mail.ru*

Abstract
Purpose. The work is devoted to considering the phase correspondence between the interdecadal variability of the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation indices, and their influence on the mechanism of synchronous formation of the surface temperature anomalies in the Barents and Black seas.
Methods and Results. The surface temperature anomaly values in the Barents and Black seas selected from the Hadley Centre for Climate Prediction and Research arrays, namely the sea ice and sea surface temperature data set, were used. To assess the atmospheric circulation in the Atlantic-European sector, the North Atlantic Oscillation and Atlantic Multidecadal Oscillation indices, as well as the position of the tropospheric frontal zone were applied. The correlation between the position of the tropospheric frontal zone and the values of the North Atlantic Oscillation index was analyzed using the initial series smoothed by a filter of a moving average, and spatial distribution of the surface temperature anomalies – by the composite maps. At the negative values of the Atlantic Multidecadal Oscillation (1950–1970), the processes characteristic of the negative values of the North Atlantic Oscillation index were predominant, whereas at the positive values of the Atlantic Multidecadal Oscillation index (1970–1990), the processes characteristic of the positive values of the North Atlantic Oscillation index prevailed.
Conclusions. The atmospheric circulation in the Atlantic-European sector constitutes the basic mechanism regulating the sea surface temperature anomalies in the North Atlantic, as well as in the Barents and Black seas. At the positive values of the North Atlantic Oscillation index, the sea surface temperature in the Barents Sea became higher, and that of the Black Sea – lower than the climate mean. At the negative values of the North Atlantic Oscillation index, the sea surface temperature in the Barents Sea became lower, and that of the Black Sea – higher relative to the climate mean.
Keywords: Barents Sea, Black Sea, surface temperature anomaly, Atlantic Multidecadal Oscillation, North Atlantic Oscillation
Acknowledgments: the work was carried out within the framework of the state assignment on theme No. 0555-2021-0002 “Fundamental research on the interaction processes in the ocean-atmosphere system determining regional spatial and temporal variability of the natural environment and climate”.
For citation: Sizov, A.A., Bayankina, T.M., Pososhkov, V.L. and Anisimov, A.E., 2022. Processes Determining Synchronous Interdecadal Variability of Surface Temperature in the Barents and Black Seas. *Physical Oceanography*, 29(3), pp. 257-270. doi:10.22449/1573-160X-2022-3-257-270

DOI: 10.22449/1573-160X-2022-3-257-270

Introduction

The Barents and Black Sea surface temperature changes in winter under the influence of atmospheric circulation in the Atlantic-European sector and the inflow of Atlantic waters into the western sector of the Arctic Ocean. Atmospheric circulation, determined by the North Atlantic Oscillation (NAO) index [1–3], regulates the warm Atlantic air inflow into the middle and high latitudes of the Atlantic-European sector. This regulation is carried out through cyclonic activity, manifested in the displacement of the cyclone trajectory in different NAO phases. In the positive NAO phase, cyclones move to the north; in the negative – to the south [1, 2].

Besides, the temperature variability of the Barents Sea is affected by the Atlantic water inflow [4–6]. At the same time, on the interannual and interdecadal scales, the inflow of these waters into the North European seas, including the Barents Sea, is also regulated by atmospheric circulation (NAO index) [7–9]. According to [8, 9], the maximum inflow of Atlantic waters into the North European seas is noted in the negative NAO phase.

Thermal state of the North Atlantic, represented by the Atlantic Multidecadal Oscillation (AMO), varies over a wide range of scales [4, 10, 11]. According to some estimates [12, 13], the multidecadal NAO mode corresponds to AMO in a way that the positive (negative) NAO phase corresponds to the negative (positive) AMO phase.

Unlike the Barents Sea, the Black Sea surface temperature changes mainly under the influence of air masses carried in the process of atmospheric circulation, determined by the NAO index. Thus, the winter surface temperature variability (sea surface temperature anomalies (SSTA) of the Barents and Black seas) is due to the combined effect of atmospheric circulation (NAO index) and interdecadal surface temperature variability of the North Atlantic (AMO index). In the present paper, the authors studied the processes affecting the surface temperature variability of the Barents and Black seas in more detail, briefly described in a previously published paper [14].

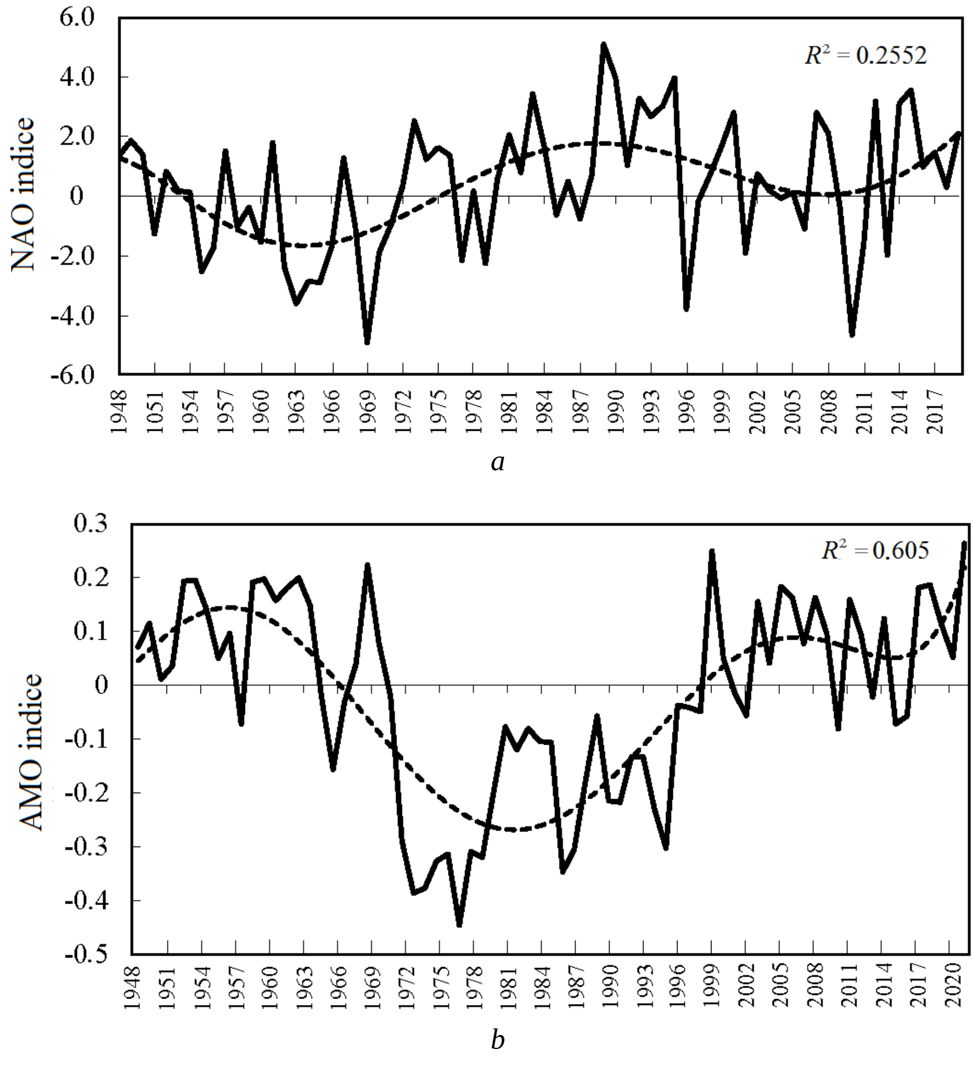
The present paper aims to consider the phase correspondence between the interdecadal variability of the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation indices, and their influence on the mechanism of synchronous formation of the surface temperature anomalies in the Barents and Black seas.

Research data and methods

Surface temperature anomaly values in the Barents and Black seas were selected from the arrays of the Hadley Center for Climate Prediction and Research (https://www.metoffice.gov.uk/hadobs/hadisst/). NAO index values (December–March averages) were selected from the Climate Prediction Center archive (https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml). The AMO index is available at http://www.esrl.noaa.gov/psd/data/timeseries/AMO/. Latitudinal position of the isohypse is 540 dkm (tropospheric frontal zone – TFZ) on 0° and 30°E meridians calculated from NOAA Extended Reconstructed Sea Surface Temperature (ERSST) data (https://psl.noaa.gov/cgi-bin/data/composites/printpage.pl). The correlation analysis between TFZ position and NAO index values was carried out using the smoothed moving average filter of the original series. The spatial distribution of surface temperature anomalies was analyzed using composite maps. The Barents and Black Sea water areas were limited by the coordinates 28°–43°E, 72°–77°N and 28°–42°E, 41°–47°N, respectively. The processes developed during 1950–2020 were studied.

Results and discussion

According to our estimates, the interdecadal variability of the AMO and NAO indices over the 1948–2020 period was observed with a phase shift (Fig. 1). Fig. 1 shows the mean for December – March NAO index values and the mean AMO index values for January – March.



F i g. 1. Interannual variability of the NAO (*a*) and AMO (*b*) indices

With polynomial smoothing of the curves Fig. 1 shows that the maximum NAO index values are observed 8–10 years earlier than the maximum AMO index values. Thus, negative NAO index values were specific for the mid-1960s, while negative AMO index values – for the mid-1970s. Positive NAO index values were peculiar to the early 1990s, while positive values of the AMO index – of the early 2000s.

According to [3], when processes with extreme positive or negative NAO index values prevail for several years, the upper layer circulation of the North Atlantic changes. Therefore, the ocean surface temperature should change, which is shown in numerous works (see, for example, [15–17]. The process of the formation of a large-scale SSTA in the North Atlantic in different phases of the NAO requires a separate study, but our estimates of the variability shift in the AMO index relative to the NAO index confirm results of works [18, 19].

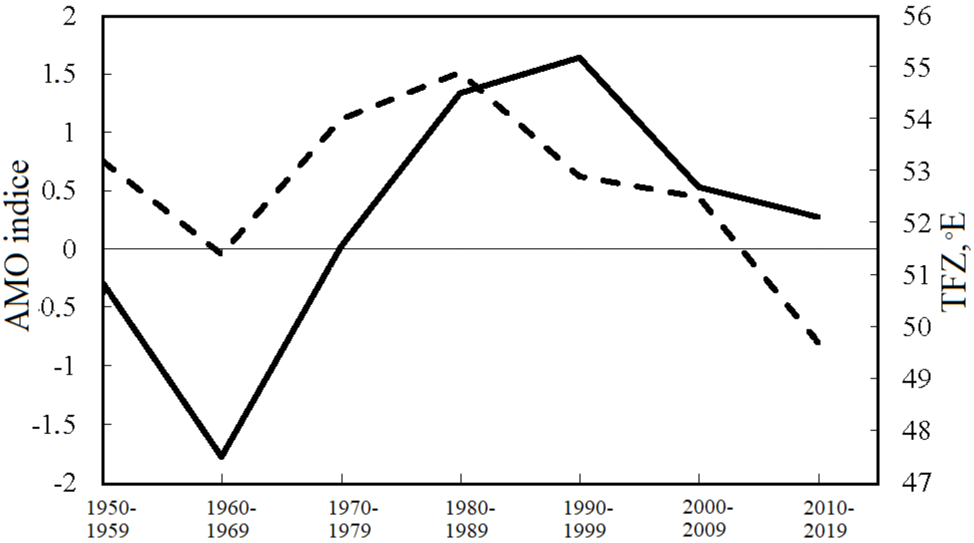
Taking into account the phase shift of the interannual variability of the NAO and AMO indices, which affect the formation of SSTA in the Barents and Black Seas, two temporal intervals were chosen. The first temporal period (1957–1994) was characterized by the predominance of negative AMO index values and was conditionally defined as the "cold" North Atlantic period. The second temporal period (1995–2020), characterized by positive AMO index values, was conditionally called the "warm" North Atlantic period. At the negative AMO index values (1950–1970), the processes specific for negative NAO index values prevailed, and at the positive AMO index values (1970–1990), the processes specific for positive NAO index values prevailed [3].

The Atlantic waters are directly involved in the formation of the upper layer temperature of the Barents Sea [20]. Therefore, our estimates show that the interdecadal variability values of the AMO and SSTA index of the Barents Sea have a significant positive correlation (R = 0.82) in the 1950–2020 temporal interval.

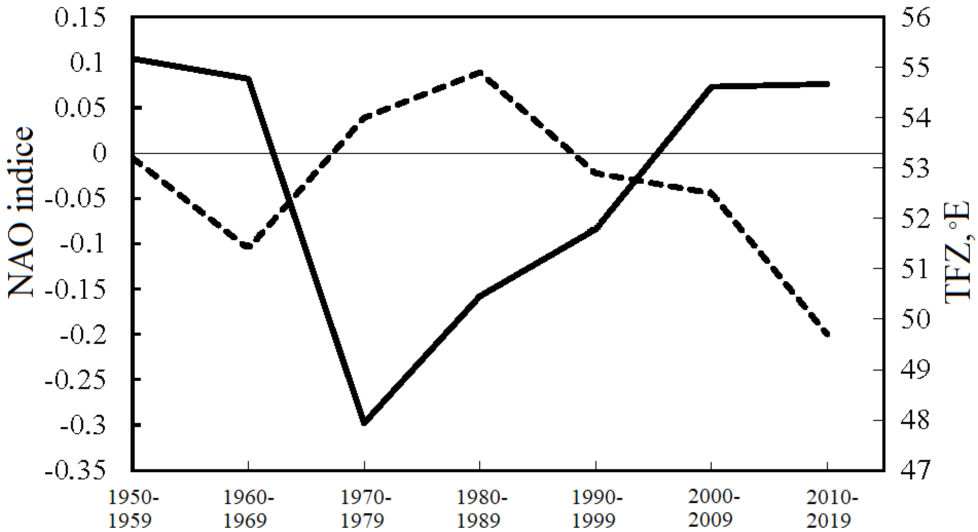
At the same time, the Black Sea SSTA formation apparently occurs under the weak influence of the long-term (climatic) change in the AMO. Therefore, the interdecadal variability of the Black Sea SSTA does not significantly correlate with the AMO index (R = 0.29), but it is significantly negatively correlated with the NAO index (R = −0.71). This indicates that the interdecadal variability of the Black Sea SSTA is largely determined by the atmospheric circulation in the Atlantic-European sector. The estimates obtained are consistent with the conclusions of [21] and give reason to believe that, apparently, the trajectories of cyclones transporting air masses to the Black Sea region are determined not only by the NAO index, but also by the TFZ position (Fig. 2).

Baric systems in the Atlantic-European region are known to be transferred in the direction of the leading flow in accordance with the position of isohypses in the TFZ. It can be expected that the thermal state of the North Atlantic affects the baric field state both at the surface and on the H_{500} surface. Therefore, we are to consider the interdecadal variability of the 540 dkm isohypse (TFZ) position depending on AMO and NAO.

Fig. 2 shows that the low-frequency TFZ component over Eastern Europe changes in antiphase with the AMO index (R = −0.70) (Fig. 2, *a*) and in phase with the NAO index (R = 0.40) (Fig. 2, *b*). This may mean that the interdecadal variability of cyclone trajectories in the Black Sea region is formed under the influence of the thermal state of the North Atlantic and TFZ the atmospheric circulation determined by the NAO index. The low-frequency variability of the North Atlantic SSTA influences the TFZ position over Eastern Europe so that during the negative AMO index phase, TFZ shifts to the north, and in the positive phase it occupies a more southerly position. On the contrary, in the positive NAO TFZ index phase, it shifts to the north, and in the negative phase – to the south. There are noticeable features in the change in the latitudinal TFZ position over Eastern and Western Europe during the years of negative and positive AMO index values. These features stand out well in the series smoothed by the 5-year moving filter. The table below shows the correlation coefficients between the latitudinal TFZ position in February and the mean NAO index values for December – March.



a



b

F i g. 2. Interdecadal variability of the latitudinal position of the 540 dcm isohypse (TFZ) in February at the meridian 30°E (dashed line), and the AMO (*a*) and NAO (*b*) indices (solid lines)

Correlation coefficients between the latitudinal position of TFZ at 0° and 30°E, and NAO index during different phases of AMO index

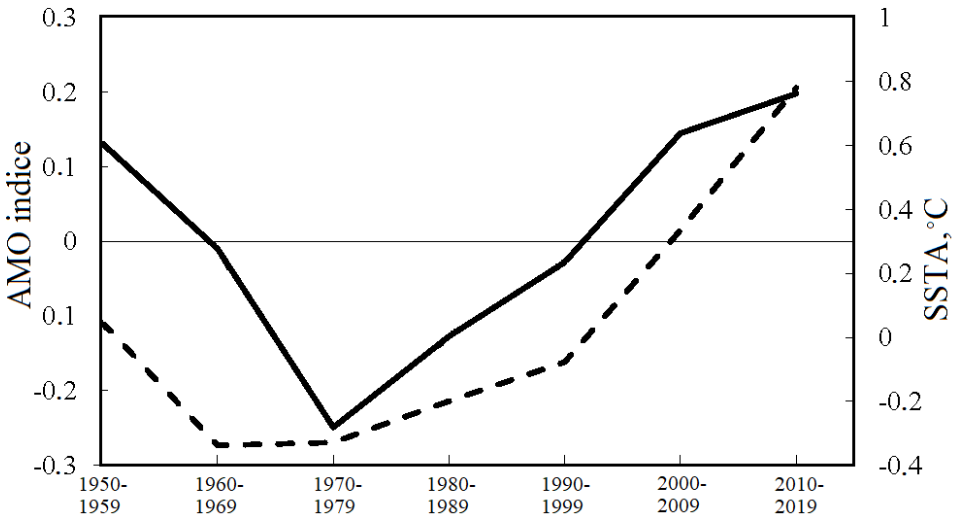
Parameters	Latitudinal position of TFZ at 0°E	Latitudinal position of TFZ at 30°E	NAO index
	Negative phase of AMO index		
Latitudinal position of TFZ at 0°E		**0.49**	0.26
Latitudinal position of TFZ at 30°E	**0.49**		**0.60**
NAO index	0.26	**0.60**	
	Positive phase of AMO index		
Latitudinal position of TFZ at 0°E		**-0.53**	**-0.57**
Latitudinal position of TFZ at 30°E	**-0.53**		**0.49**
NAO index	**-0.57**	**0.49**	

N o t e. Bold type indicates the correlation coefficients significant at the 95% confidence level

It follows from the table that in years of negative AMO index values, the latitudinal position of TFZ both over Western and Eastern Europe changes in phase. At the same time, TFZ at 0° and 30°E shows a tendency to shift to the north in years with the maximum NAO index values, and to the south – in years with its minimum values. This is especially noticeable in TFZ with a longitude of 30°E (the correlation coefficient between the latitudinal position of the TFZ and the NAO index is 0.60).

In years of positive AMO index values, the latitudinal position of TFZ over Western and Eastern Europe changes in antiphase with the NAO index. In periods with maximum of the NAO TFZ index over Western Europe it shifts to the south ($R = -0.57$), and over Eastern Europe it shifts to the north ($R = 0.49$). Consequently, the trajectories of cyclones over Europe are aligned so that in years of negative AMO index, zonal transport of air masses prevails, and the further north it occurs, the higher the NAO index is. In years of positive AMO index, the process of air mass transfer becomes more complicated. In this case, at high NAO index, the trajectories of cyclones over Western Europe take a more southern position, and over Eastern Europe – more northern. At low NAO index, the trajectories of cyclones over Western Europe shift to the north, and over Eastern Europe – to the south.

The noted features of the Atlantic water transport and the interdecadal variability of the winter atmosphere circulation in the regions of the Barents and Black seas create characteristic conditions for the SSTA formation of these seas in years of negative and positive values of the AMO and NAO indices (Fig. 3).



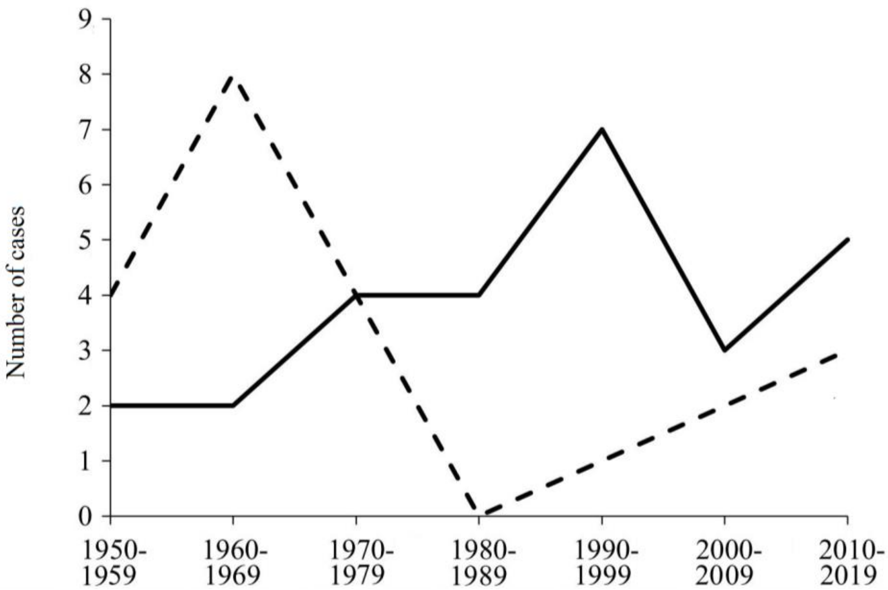
a

b

F i g. 3. Interdecadal variability of the AMO index (solid line) and SSTA (dashed line) of the Barents Sea (*a*), and the NAO index (solid line) and SSTA (dashed line) of the Black Sea (*b*)

Fig. 3 clearly shows that the inflow of Atlantic waters into the Arctic Basin (AMO index) significantly changes the surface temperature of the Barents Sea (R = 0.82). At the same time, the correlation between the interdecadal variability of the Barents Sea SSTA and the NAO index is insignificant. This is due to the fact that the interdecadal SSTA variability in the Barents Sea (Fig. 3, *a*) was observed in phase with the NAO index during the decades of negative AMO index values (1960–1999). During the decades of positive AMO index values and minimum NAO index values (2000–2019), the surface temperature of the Barents Sea began to rise rapidly due to the warmer Atlantic water inflow. The weakening of cyclonic activity, observed at the minimum NAO index values [3, 20], could not lead to a significant decrease in surface temperature; therefore, the temperature of the Barents Sea increased in these decades (Fig. 3, *a*).

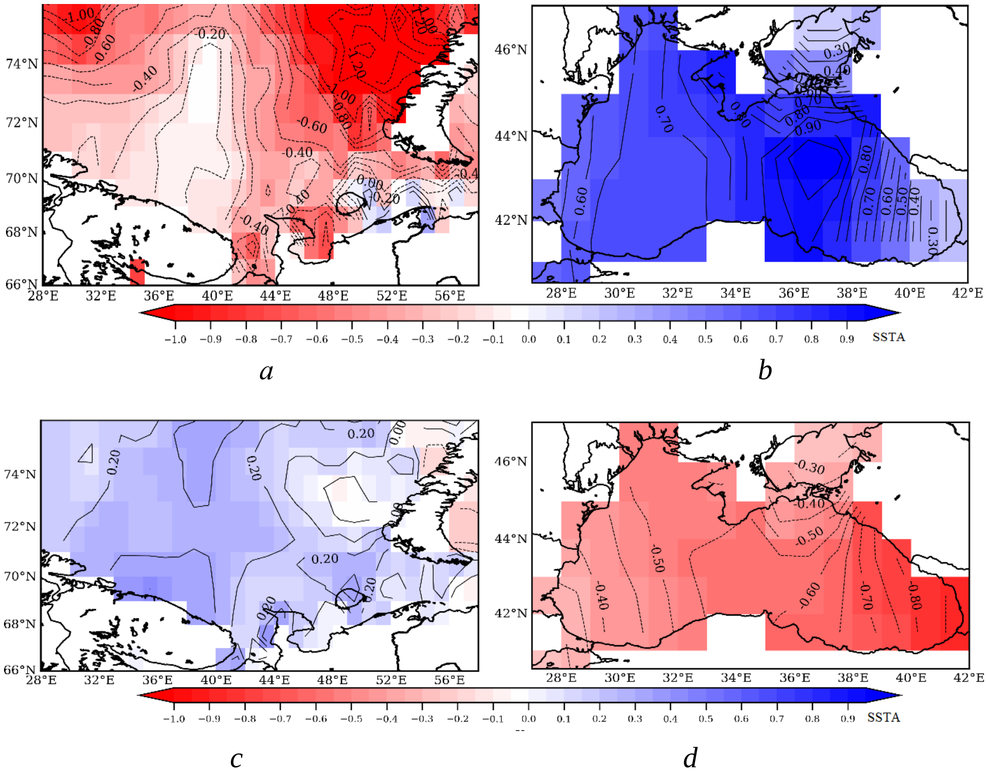
In the Black Sea, the atmospheric circulation, represented by the NAO index, largely forms surface temperature anomalies (R = −0.71). Thus, in the decade of negative NAO index values (1961–1970), the Black Sea was warmer than in the decades of positive values (1981–2000) (Fig. 3, *b*). According to Fig. 3, from 1951 to 2000 (the years of the conditional “cold” North Atlantic), the interdecadal SSTA variability in the Barents and Black seas was in antiphase, and in the years of the “warm” North Atlantic (2001–2020) it was in phase. This result emphasizes the predominant influence of the inflow of Atlantic waters and the relatively weak NAO influence on the interdecadal SSTA variability in the Barents Sea during the decades of the “warm” North Atlantic. On the contrary, the interdecadal variability of the Black Sea SSTA is formed mainly under the influence of the atmospheric circulation in the Atlantic–European sector (NAO index) and, to a lesser extent, under the influence of the North Atlantic SSTA (AMO index) (Fig. 4).



F i g. 4. Number of cases of abnormal values of the NAO index (solid line – NAO index positive, dashed line – NAO index negative)

In the 1961–1970 decade, cases of anomalous negative NAO index values were most often observed. As expected, under these values conditions for the formation of negative SSTA values in the North Atlantic (negative AMO index) and its positive values in the Black Sea) are created (Fig. 4). In the 1991–2000 decade the most frequent situations were with positive values of the NAO index, which form (presumably) positive SSTA values in the North Atlantic (positive AMO index) and negative ones in the Black Sea.

With this in mind, we are to consider how the extreme conditions of atmospheric circulation in the Atlantic-European sector (NAO index) affect the SSTA formation in the Barents and Black seas. This process is well represented on composite maps constructed by SSTA averaged over years of positive and negative values of the NAO index. Fig. 5 shows composite maps for years of negative AMO values.

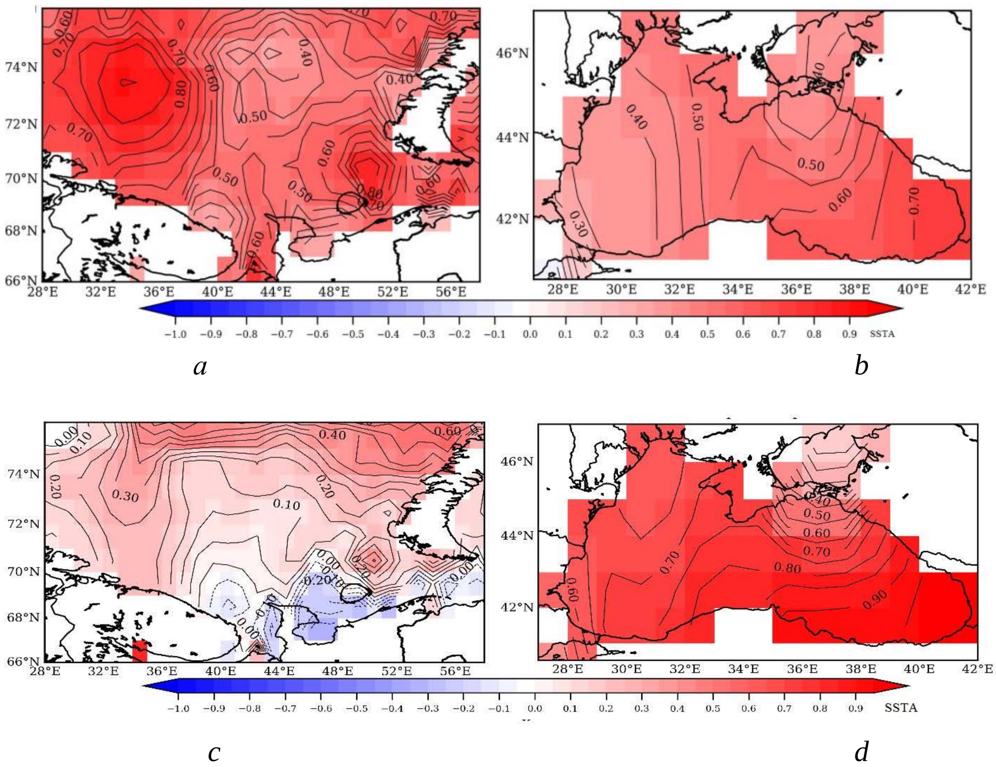


F i g. 5. Surface temperature anomalies during the years of negative values of the AMO index at negative NAO (*a*, *b*) and positive NAO (*c*, *d*) for the Barents (*a*, *c*) and Black (*b*, *d*) seas

Composite SSTA maps (Fig. 5) for negative values of the NAO index were constructed over ten years (1958, 1960, 1962, 1963, 1965, 1966, 1968, 1969, 1970 and 1979), and for positive values – over seven years (1957, 1976, 1983, 1990, 1991, 1992 and 1993). In the years of negative AMO index values with negative NAO index values, due to the weakening of cyclonic activity [1–3, 20], the mean surface temperature for January – March of the Barents Sea was below the climatic norm (Fig. 5, *a*), and that of the Black Sea was above the climatic norm (Fig. 5, *b*).

At the same time, with positive NAO index values, due to the cyclonic activity intensification [1–3, 20], the mean January – March surface temperature of the Barents Sea became higher than the climatic norm, and that of the Black Sea became lower (Fig. 5, *b*). This was due to the fact that with positive values of the NAO TFZ index on the meridian of 30°E shifted to the north and, consequently, the trajectories of the cyclones ran north of the Black Sea. And with negative values of the NAO index, TFZ occupied a southern position over Eastern Europe and, consequently, the Black Sea was in the area of cyclones.

Similar conditions for the SSTA formation in the Barents and Black seas were also observed in years with a positive AMO anomaly (1995–2020). Fig. 6, *a*, 6, *b* show composite maps for positive NAO index values, built for seven years (2000, 2007, 2008, 2012, 2014, 2017 and 2019), and Fig. 6, *c*, 6, *d* – for negative NAO index values for five years (2001, 2006, 2010, 2011 and 2013). The climatic norm was determined for 1981–2010.

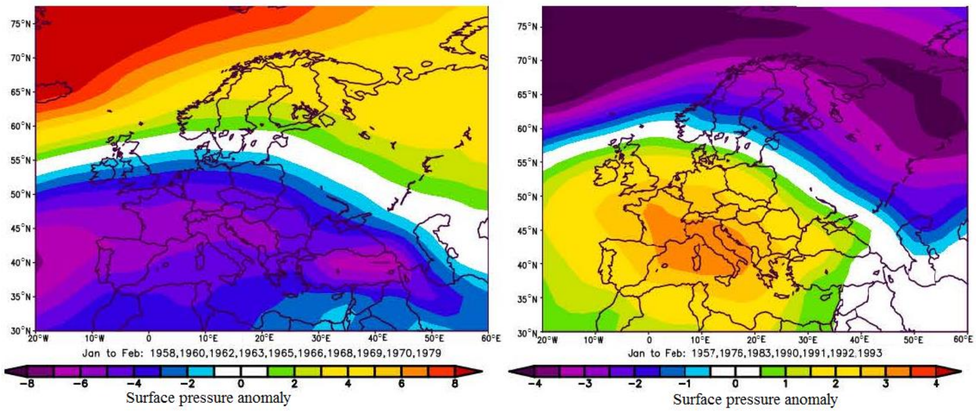


F i g. 6. Surface temperature anomalies during the years of positive values of the AMO index at positive NAO (*a*, *b*) and negative NAO (*c*, *d*) for the Barents (*a*, *c*) and Black (*b*, *d*) seas

The constructed maps (Fig. 6) allowed to obtain the following estimates. With positive NAO index values, the surface temperature anomaly of the Barents Sea is increased (0.53°C), and the anomaly of the Black Sea is lowered (0.59°C) (Fig. 6, *a*, *b*). With negative NAO index values (Fig. 6, *c*, *d*), the surface temperature anomaly of the Barents Sea is lowered (0.10°C), and that of the Black Sea is increased (0.98°C).

Discussion of the results

Large-scale processes of winter surface temperature variability in the Barents and Black seas are regulated by the atmospheric circulation in the Atlantic-European sector. Their interdecadal restructuring takes place under the influence of the Azores and Siberian atmospheric pressure maxima [22, 23]. Preliminary estimates show that the interdecadal variability of atmospheric circulation in the regions of Eastern Europe is mainly influenced by the Azores or Siberian centers of atmospheric action. Below, this process is illustrated by an example of the surface pressure anomaly observed in a number of years with negative AMO index values ("cold" North Atlantic). Composite maps of the surface pressure anomaly were constructed for positive and negative NAO values (Fig. 7). Averaging was carried out over the same years as for the construction of maps in Fig. 5.



a *b*

F i g. 7. Surface pressure anomaly in a number of years with the NAO index negative (*a*) and positive (*b*) values during the decades when the AMO index values are negative

During the years of the weakened Azores High (NAO index ≤ −1), the influence of the Siberian High increases (Fig. 7). This atmospheric circulation restructuration resulted in an expected decrease in the surface temperature of the North Atlantic (see Fig. 1) and an increased inflow of Atlantic waters into the western sector of the Arctic [8, 9]. At the same time, the Siberian High intensification creates conditions for blocking the western transport in the European territory of Russia [22, 23], and the weakening of the Azores High (see Fig. 2) leads to a southward shift of TFZ at the 30°E meridian. Thus, in this interdecadal variability phase of the NAO and AMO indices, cyclone trajectories pass near the Black Sea. Fig. 7 clearly shows that the weakening of the Azores High creates conditions for the low pressure predominance over Central and Southern Europe, contributing to the deepening of cyclones and the formation of an increased winter temperature in the Black Sea.

During the decades of the well-developed Azores High (NAO index ≥ 1) and the weakened Siberian High, an increase in the surface temperature of the North

Atlantic is expected (see Fig. 1). This leads to the inflow of warmer Atlantic waters into the Barents Sea and to the increased cyclonic activity in the region of the Norwegian and Barents seas [20]. During the interdecadal variability phase of the Azores and Siberian highs in the region of the Norwegian and Barents seas, conditions are created for the formation of low atmospheric pressure, which contribute to the deepening of cyclones in this region and an increase in winter surface temperature in the Barents Sea (Fig. 7). At the same time, the NAO index increase leads to a northward shift of TFZ at longitudes of the Black Sea (see Fig. 2), creating conditions for the formation of negative anomalies in its winter surface temperature.

Conclusion

Tentative conclusions may be drawn that the atmospheric circulation in the Atlantic-European sector (NAO index) is the main mechanism that regulates the SSTA of the North Atlantic, Barents and Black seas. At the same time, both in a number of years with negative and in a number of years with positive AMO index values and positive NAO index values, the surface temperature of the Barents Sea became higher, and that of the Black Sea − below the climatic norm. With negative NAO index values, the surface temperature of the Barents Sea became lower, and that of the Black Sea became higher than the climatic mean.

REFERENCES

1. Sorteberg, A., Kvamstø, N.G. and Byrkjedal, Ø., 2005. Wintertime Nordic Seas Cyclone Variability and Its Impact on Oceanic Volume Transports into the Nordic Seas. In: H. Drange, T. Dokken, T. Furevik, R. Gerdes and W. Berger, eds., 2005. *The Nordic Seas: An Integrated Perspective*. Washington, D.C.: American Geophysical Union, pp. 137-156. doi:10.1029/158GM10
2. Hurrell, J.W. and Deser, C., 2009. North Atlantic Climate Variability: The Role of the North Atlantic Oscillation. *Journal of Marine Systems*, 78(1), pp. 28-41. doi:10.1016/j.jmarsys.2008.11.026
3. Nesterov, E.S., 2013. [*The North Atlantic Oscillation: Atmosphere and Ocean*]. Moscow: Triada Ltd, 127 p. (in Russian).
4. Alekseev, G.V., Ivanov, N.E., Pnushkov, A.V. and Balakin, A.A., 2011. Climate Changes in the Marine Arctic in the Early XXI Century. *Problemy Arktiki i Antarktiki = Arctic and Antarctic Research*, (3), pp. 22-34 (in Russian).
5. Alekseev, G.V., Radionov, V.F., Aleksandrov, E.I., Ivanov, N.E. and Kharlanenkova, N.E., 2015. [Arctic Climate Change under Global Warming]. *Problemy Arktiki i Antarktiki = Arctic and Antarctic Research*, (1), pp. 32-41 (in Russian).
6. Smirnov, A.V., Korablev, A.A. and Vyazilova, A.E., 2014. Seasonal and Interannual Variability of Water Thermohaline Properties in the Ows “Mike” Area. *Problemy Arktiki i Antarktiki = Arctic and Antarctic Research*, (2), pp. 25-32 (in Russian).
7. Polyakov, I.V., Alekseev, G.V., Timokhov, L.A., Bhatt, U.S., Colony, R.L., Simmons, H.L., Walsh, D. and Walsh, J.E. and Zakharov, V.F., 2004. Variability of the Intermediate Atlantic Water of the Arctic Ocean over the Last 100 Years. *Journal of Climate*, 17(23), pp. 4485-4497. doi:10.1175/JCLI-3224.1
8. Dvoryaninov, G.S., Kubryakov, A.A., Sizov, A.A., Stanichny, S.V. and Shapiro, N.B., 2016. The North Atlantic Oscillation: A Dominant Factor in the Variations of Oceanic Circulation Systems of the Atlantic Ocean. *Doklady Earth Sciences*, 466(1), pp. 100-104. doi:10.1134/S1028334X16010207
9. Mikhailova, N.V., Bayankina, T.M. and Sizov, A.A., 2021. Two Modes of Atmosphere–Ocean Interaction in the Atlantic Sector of the Arctic Basin. *Oceanology*, 61(4), pp. 443-449. doi:10.1134/S0001437021030097

10. Enfield, D.B. and Cid-Serrano, L., 2010. Secular and Multidecadal Warmings in the North Atlantic and Their Relationships with Major Hurricane Activity. *International Journal of Climatology*, 30(2), pp. 174-184. doi:10.1002/joc.1881

11. Yashayaev, I. and Seidov, D., 2015. The Role of the Atlantic Water in Multidecadal Ocean Variability in the Nordic and Barents Seas. *Progress in Oceanography*, 132, pp. 68-127. doi:10.1016/j.pocean.2014.11.009

12. Semenov, V.A. and Cherenkova, E.A., 2018. Evaluation of the Atlantic Multidecadal Oscillation Impact on Large-Scale Atmospheric Circulation in the Atlantic Region in Summer. *Doklady Earth Sciences*, 478(2), pp. 263-267. doi:10.1134/S1028334X18020290

13. Krasheninnikova, S.B. and Krasheninnikova, M.A., 2019. Causes and Features of Long-Term Variability of the Ice Extent of the Barents Sea. *Ice and Snow*, 59(1), pp. 112-122. doi:10.15356/2076-6734-2019-1-112-122 (in Russian).

14. Sizov, A.A., Bayankin, T.M., Pososhkov, V.L. and Anisimov, A.E., 2021. Large-Scale Features of Synchronous Variability of the Winter Surface Temperature in the Barents and Black Seas. *Doklady Earth Sciences*, 501(1), pp. 989-993. https://doi.org/10.1134/S1028334X21110143 (in Russian).

15. Carton, J.A., Cao, X., Giese, B.S. and Da Silva, A.M., 1996. Decadal and Interannual SST Variability in the Tropical Atlantic Ocean. *Journal of Physical Oceanography*, 26(7), pp. 1165-1175. doi:10.1175/1520-0485(1996)026<1165:DAISVI>2.0.CO;2

16. Xie, S.-P. and Tanimoto, Y., 1998. A Pan-Atlantic Decadal Climate Oscillation. *Geophysical Research Letters*, 25(12), pp. 2185-2188. doi:10.1029/98GL01525

17. Sizov, A.A. and Chekhlan, A.E., 2010. Anomalies of Hydrometeorological Fields in the Black Sea Area Associated with Sea Surface Temperature Gradients in the North Atlantic. *Russian Meteorology and Hydrology*, 35(7), pp. 476-482. doi:10.3103/S1068373910070071

18. Breeden, M.L. and McKinley, G.A., 2016. Climate Impacts on Multidecadal *p*CO_2 Variability in the North Atlantic: 1948–2009. *Biogeosciences*, 13(11), pp. 3387-3396. doi:10.5194/bg-13-3387-2016

19. Serykh, I.V., 2016. Influence of the North Atlantic Dipole on Climate Changes over Eurasia. In: TSU, 2016. *IOP Conference Series: Earth and Environmental Science*. Tomsk: IOP Publishing Ltd. Vol. 48, 012004. doi:10.1088/1755-1315/48/1/012004

20. Zolotokrylin, A.N., Mikhaylov, A.Yu. and Titkova, T.B., 2015. Effect of Warm Atlantic Waters on the Climate Anomalies in the West Arctic. *Ice and Snow*, 55(3), pp. 73-82 (in Russian).

21. Artamonov, Yu.V., Skripaleva, E.A. and Fedirko, A.V., 2020. Regional Features of the Temperature Field Synoptic Variability on the Black Sea Surface from Satellite Data. *Physical Oceanography*, 27(2), pp. 186-196. doi:10.22449/1573-160X-2020-2-186-196

22. Semenov, E.K., Sokolikhina, N.N. and Sokolikhina, E.V., 2013. Meteorological and Synoptic Aspects of the Formation and Evolution of the Novorossiysk Bora. *Russian Meteorology and Hydrology*, 38(10), pp. 661-668. doi:10.3103/S1068373913100026

23. Semenov, E.K., Sokolikhina, N.N. and Tudrii, K.O., 2013. The Warm Winter in the Russian Arctic and Anomalous Cold in Europe. *Russian Meteorology and Hydrology*, 38(9), pp. 614-621. doi:10.3103/S1068373913090045

About the authors:

Anatoly A. Sizov, Senior Research Associate, Marine Hydrophysical Institute of RAS (2 Kapitanskaya Str., Sevastopol, 299011, Russian Federation), Ph. D. (Phys.-Math.), **ORCID ID: 0000-0001-9055-4768**, sizov_anatoliy@mail.ru

Tatyana M. Bayankina, Research Associate, Marine Hydrophysical Institute of RAS (2 Kapitanskaya Str., Sevastopol, 299011, Russian Federation), Ph. D. (Geogr.), **ResearcherID: G-2535-2019**, bayankina@mhi-ras.ru

Vladimir L. Pososhkov, Research Associate, Marine Hydrophysical Institute of RAS (2 Kapitanskaya Str., Sevastopol, 299011, Russian Federation), **SPIN-code: 7634-9828 AuthorID: 854854, ORCID ID: 0000-0002-3891-2772**, vla_po@mail.ru

Anatoly E. Anisimov, Senior Research Associate, Marine Hydrophysical Institute of RAS (2 Kapitanskaya Str., Sevastopol, 299011, Russian Federation), Ph. D. (Phys.-Math.), **SPIN-code: 1645-7874, AuthorID: 630799**, **WoS ResearcherID: ABA1705-2020, ORCID ID: 0000-0002-5530-5608**, anisimov1@mail.ru

Contribution of the co-authors:

Anatoly A. Sizov – task formulation. Interdecadal variability analysis of the Azores and Siberian highs. Assessment of the influence of atmospheric circulation indices on the structure of winter surface temperature anomalies in the Barents and Black seas

Tatyana M. Bayankina – calculation of interdecadal variability of the surface baric field in the Atlantic-European sector. Analysis of the winter surface temperature of the Barents and Black seas in decades with extreme values of atmospheric circulation characteristics in the Atlantic-European sector

Vladimir L. Pososhkov – calculation of winter surface temperature anomalies in the Barents and Black seas. Calculation and analysis of the position of high-altitude frontal zones in the Atlantic-European sector. Calculation and construction of composite maps of the receiving baric field in the Atlantic-European sector

Anatoly E. Anisimov – calculation and construction of composite maps of surface temperature anomalies in the Barents and Black seas. Analysis of the accuracy of surface temperature anomalies' estimates in the Barents and Black seas in decades of positive and negative values of the Atlantic Multidecadal Oscillation Index

The authors have read and approved the final manuscript.
The authors declare that they have no conflict of interest.