Russian Journal of Earth Sciences, Vol. 22, ES01SI07
https://doi.org/10.2205/2022ES01SI07

Russian Journal *of* Earth Sciences

Special Issue: "Fundamental and Applied Aspects of Geology, Geophysics and Geoecology"

Arctic anticyclone and its influence on the North Atlantic Oscillation

S. V. Morozova*[,1], K. E. Denisov[2], E. A. Polyanskaya[1], M. Yu. Chervyakov[1], N. V. Semenova[1], and E. I. Ormeli[1]

[1] *Saratov State University, Saratov, Russia*
[2] *Saratov State Vavilov Agrarian University, Saratov, Russia*

Received 1 July 2021; accepted 10 August 2022; published 20 October 2022.

This article examines the influence of the permanent center of atmospheric action – the Arctic anticyclone (Arctic High) – on the dynamics of adjacent circulating oscillatory structures – the North Atlantic. Analysis of variance was used to estimate the degree of influence of the Arctic anticyclone on the state of the centers of action of the atmosphere in the North Atlantic. The influence of the Arctic High on the change in the pressure in the Icelandic minimum and Azores maximum is estimated at 48%. This influence showed not statistical significance, confirmed by Fisher's test. The impact of the circulation systems of the North Atlantic on the Arctic anticyclone is estimated at 7%, and is not statistically significant. A statistically significant correlation was found between the intensity of the Arctic High and the intensity of the Icelandic center of atmospheric action. With the strengthening of the Arctic anticyclone, the Icelandic depression deepen. The correlation coefficient were −0.39. This coefficient is statistically significant.

Keywords: Arctic High, climate change, north Atlantic oscillation, the second wave of global warming , stabilization period.

Citation: Morozova, S. V., K. E. Denisov, E. A. Polyanskaya, M. Yu. Chervyakov, N. V. Semenova, and E. I. Ormeli (2022), Arctic anticyclone and its influence on the North Atlantic Oscillation, *Russian Journal of Earth Sciences*, Vol. 22, ES01SI07, doi: 10.2205/2022ES01SI07.

1 Introduction

The Arctic anticyclone is a permanent center of atmospheric action, which is located in the northern polar region. Like all permanent centers of action of the atmosphere, it is located above the ocean. However, unlike other permanent centers of atmospheric action in the Northern Hemisphere, it exists separately. The Arctic anticyclone does not form a pair system, as the centers of action of the atmosphere of the North Atlantic [*Smirnov et al.*, 1998] and the northern part of the Pacific Ocean [*Smirnov and Vorobiev*, 2002]. According to [*Vorobiev and Smirnov*, 2003], this is not related to the absence of this center of action in winter. It's just that in winter, against the background of the Siberian maximum pressure and the Canadian anticyclone, the Arctic center of atmospheric action is weakly expressed and is not always identified on average maps. We point out that the Arctic anticyclone as an independent center of atmospheric action is rarely studied. The so-called arctic oscillation (AO) is usually considered. The Arctic Oscillation is the average difference in pressure values around 37°N–45°N and the polar region [*IPCC*, 2013; *Roshydromet*, 2014]. The Arctic anticyclone is an independent baric system, an object of general atmospheric circulation.

The Arctic anticyclone plays an important role in shaping the hydrometeorological regime of the Arctic. This was pointed out back in the 40s of the last century by V. Yu. Vize [*Vize*, 1944]. In the present publications, for example, in [*Deser et al.*, 2000; *Alekseev et al.*, 2000; *Vinje*, 2001; *Alekseev*, 2003], the enormous role of this center of action of the atmosphere in the meteorological and hydrological processes of the Northern Polar region is also emphasized. According to the above and taking into account the fact that climate changes are most pronounced in the Arctic region [*IPCC*, 2013; *Roshydromet*, 2014], further study of this center of action is very important.

2 Objects, data and methods

The object of the study was the Arctic anticyclone (Arctic High). For the Arctic anticyclone, the

*Corresponding author: swetwl@yandex.ru

geographic coordinates of the center (latitude and longitude) were considered, as well as the value of pressure in this center of action. The time interval of the study was the period from 1950 to 1020. Required data for the period from 1950 to 2010 taken from Reference monograph [*Neushkin et al.*, 2013]. For a later series of years (2011–2020), the values of latitude, longitude and intensity of this center of action were taken from the average monthly sea level pressure maps issued by the Hydrometeorological Center of the Russian Federation (`https://meteoinfo.ru/pogoda`).

The dynamics of the Arctic anticyclone was considered in the natural climatic periods of the state of the earth's climate system. The term "natural climatic period" was introduced by S. V. Morozova. She also gave a statistical justification for the selected intervals [*Morozova*, 2019; *Morozova et al.*, 2018].

Two permanent centers of atmospheric action – the Icelandic minimum and the Azores maximum – were considered as the North Atlantic oscillatory structure. Data on the state of these action centers for 2010 are taken from the Reference monograph [*Neushkin et al.*, 2013]. Information about the state of the AAC from 2011 to 2020 was taken from average monthly maps regularly compiled at the Hydrometeorological Center of the Russian Federation (`https://meteoinfo.ru/pogoda`).

Standard statistical techniques (calculation of average statistical characteristics, as well as correlation analysis) were used as research methods [*Gmurman*, 2003].

To assess the degree of influence of one quantity on another, the method of variance analysis was used. The essence of this analysis is to compare the "factorial" variance generated by the influence of a factor and the "residual" variance due to other reasons. If the difference between these variances is significant, then the factor has a significant impact on the investigated value [*Kolemajev et al.*, 1991; *Morozova et al.*, 2019].

The main technique of variance analysis is the calculation of the total σ_x, factorial σ_f and residual variances σ_z. In practice, sometimes, instead of variances, the sums of squares of deviations are calculated: S_x – total sum of squares, S_f – factorial sum of squares, S_z – residual sum of squares [*Alekseev et al.*, 2000; *Vinje*, 2001]. The peculiarities of using the variance analysis in order to assess the mutual influence of circulating objects are detailed in [*Morozova et al.*, 2019].

3 Results and discussion

The real climatic changes, against the background of which the dynamics of the Arctic High was studied, were considered during the natural climatic periods of the state of the Earth's climate system (ECS) – the period of stabilization and during the second wave of global warming. The physical and statistical justification for the identification of these periods is presented in [*Morozova*, 2019; *Morozova et al.*, 2018].

Table 1 shows the characteristics of the state of the Arctic High in two natural climatic periods of the state of the ECS – the period of stabilization (1950–1974) and the second wave of global warming (1975–2020).

According to Table 1, in two natural climatic periods of the state of the earth's climate system near the Arctic anticyclone, the geographic location of the center changed, and its intensity changed. Thus, during the second wave of global warming, the Arctic anticyclone became more powerful. The average pressure at its center during the second wave of global warming increased by 3 hPa compared to the stabilization period. At the same time, the center of the Arctic High during the period of stabilization was located to the north than during the second wave of global warming. Also, from the period of stabilization to the second wave of global warming, the Arctic anticyclone began to be located to the west (by four degrees).

In Table 2 shows the average monthly characteristics of the Arctic anticyclone in two natural climatic periods of the state of the earth's climate system. According to Table 2, the strengthening of the Arctic anticyclone from the period of stabilization to the second wave of global warming is observed in all months. The change in geographical position from one natural climatic period to another shows no noticeable trend.

Let us consider whether the Arctic High influences the state of the adjacent circulation structures – atmospheric action centers of the North Atlantic. To do this, we will plot the average monthly pressure values of the selected atmospheric action centers on the graph. **??** shows the change in pressure in the atmospheric action centers of the North Atlantic and the Arctic High.

According Figure 1 the change in the intensity of the considered atmospheric action centers during the year occurs in a very peculiar way. The following feature should be noted. The change in the intensity of the Arctic High is opposite to the change in the intensity of the Azores High. In those months when the Azores anticyclone is most intense (from May to August), the pressure in the center of the Arctic anticyclone is minimal. At the same time, one can notice a consistent course of pressure in the North Atlantic action centers in the months from April to October. It is at this time that the Arctic anticyclone has the lowest power. When the Arctic anticyclone intensifies (months from December to March), the dis-

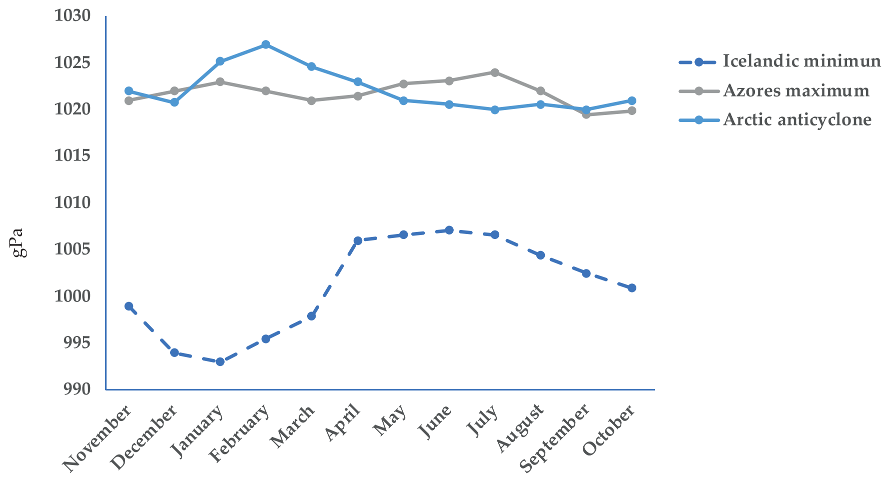

Figure 1: Average seasonal pressure changes in the centers of the Arctic High, Azores maximum and Icelandic minimum (1950–2020)

Table 1: Average annual values of the Arctic High in various natural climatic periods of the state of the ECS

Natural climatic periods of the state of the ECS	Intensity *p, gPa*	Center position φ°N	λ°E
1) stabilization	1019	81	161
2) second wave of global warming	1022	77	165

crepancy between the course of pressure in the Icelandic low and the Azores high is well observed. It is possible that the strengthening of the Arctic anticyclone contributes to the mismatch of the course of pressure in the North Atlantic centers of action.

Since a stronger influence of the Arctic High was noted on the oscillatory system of the North Atlantic, we will estimate the degree of interaction between the circulation system of the North Atlantic and the Arctic High. For this purpose, we use correlation and variance analysis.

Let us calculate the correlation coefficients between the three characteristics (longitude, latitude and pressure in the center) of the indicated atmospheric action centers. Note that the correlation coefficients were calculated for the average annual values and the central month of the winter season. The calculation results are shown in Table 3 and Table 4, respectively.

According to Table 3, for the average annual values, a statistically significant correlation was found between the latitude of the location of the atmospheric action centers of the North Atlantic. As the latitude of the center of the Icelandic minimum increases, the latitude of the center of the Azores maximum increases. No significant correlations have been established between the position of the AAC in the North Atlantic and the position of the center of the Arctic High.

The correlation coefficient (negative relationship) between the pressure in the center of the Arctic High and the Icelandic minimum showed statistical significance. With an increase in the strength of the Arctic High, the Icelandic cyclone deepens ($K_{cor} = -0.39$).

Table 4 shows the calculations of similar dependences between the state of AAC of the North Atlantic and the Arctic High, but only for the central month of the winter season – January.

For January (Table 4) statistically significant relationships were found between the latitude of the Icelandic minimum and the Azores maximum ($K_{cor}= 0.25$). The centers of this oscillatory system are both shifted either to the south or to the north. A negative correlation ($K_{cor}= -0.19$) was marked between the latitude of the location of the centers of the two considered anticyclonic AAC: if the Azores anticyclone moves to the north, then the Arctic High, on the contrary, to the south.

Negative correlation coefficients between the intensity of the considered centers of action confirm the revealed regularities of pressure changes in baric centers (Figure 1).

The small correlation coefficients revealed for the remaining cases (Table 3, Table 4) indicate only the absence of a linear relationship. It is obvious that the structural elements of the AGC are in a complex nonlinear interaction with each other (Figure 1).

Table 2: Average annual values of the Arctic High in various natural climatic periods of the state of the ECS

Month	Intensity, p, gPa		Center position, φ°N		Center position, λ°W	
	stabilization	second wave of global warming	stabilization	second wave of global warming	stabilization	second wave of global warming
January	1022.0	1025.7	75	76	180	50
February	1024.0	1026.1	76	72	170 EL	35
March	1025.0	1027.0	88	77	40	178 EL
April	1022.5	1023.5	85	81	30	196
May	1020.0	1021.2	80	81	35	8
June	1017.5	1017.3	75	76	40	20
July	1012.5	1014.4	81	77	170 EL	171 EL
August	1012.5	1014.8	80	76	40	164 EL
September	1015.0	1017.3	85	77	220	193
October	1015.0	1019.6	85	77	35	23
November	1017.0	1020.5	77	81	180	174 EL
December	1020.0	1020.5	78	78	175 EL	55

Table 3: Correlation coefficients between the average annual characteristics of the Icelandic minimum (IcM), the Azores maximum (AzM) and the Arctic High (AH). (Significant correlation coefficients are highlighted in bold)

Centers actions	Latitude			Longitude			Center pressure		
	IcM	AzM	AH	IcM	AzM	AH	IcM	AzM	AH
IcM	–	**0.26**	−0.01	–	0.07	−0.03	–	−0.17	**−0.39**
AzM	**0.26**	–	0.02	0.07	–	0.11	−0.17	–	0.18
AH	−0.02	0.01	–	−0.03	0.11	–	**−0.39**	0.18	–

Let us estimate the influence of the Arctic anticyclone on the changes in the intensity of the atmospheric action centers of the North Atlantic. The intensity of the North Atlantic AAC was determined as the difference in the pressure values at their centers. The values of the characteristics of the intensity of the studied centers of action in January were taken for the analysis. It is in this month that the Arctic anticyclone reaches its maximum intensity.

Table 5 shows the statistical characteristics of the dependence of the intensity of the North Atlantic AAC on the intensity of the Arctic High.

Based on the data of the Table 5, total, factorial and residual variances and sums of squares were calculated. The total sum of squares (S_x) was 5998.31, the factorial sum of squares (S_f) was 2854.52. The residual sum of squares is 3133.79. The ratio of the factorial and total sum of squares of deviations made it possible to evaluate the influence of the Arctic High on the studied value (the state of the oscillatory system of the North Atlantic). The S_f /$S_x$ratio was 0.4775; therefore, the influence of the Frctic High on the change in the pressure variation in the centers of the Icelandic minimum and Azores maximum is 48%. In addition to the sum of squares, the variances were calculated: σ_x = 86.9; σ_f = 358.10; and σ_z = 49.74. Using the values of the factorial and residual variances, we calculate their ratio ($\sigma^2 f$ / $\sigma^2 z$ = 1.74). Comparison of the obtained value with the Fisher criterion (F_{cr}= 1.97 at a 5% significance level) made it possible to reject the null hypothesis about the equality of factorial and residual variances (F_{fact}<F_{crit}). Consequently, the influence of the selected factor (the intensity of the Arctic High) on the studied value (pressure in the centers of the baric systems of the North Atlantic) is practically no effect.

The study of the influence of the North Atlantic oscillatory system on the state of the Arctic anticyclone was carried out in a similar way. Calculations of the total, factorial and residual sums of squares and variances did not show the statistical

Table 4: Correlation coefficients between the monthly average characteristics of the Icelandic minimum (IcM), Azores maximum (AzM) and the Arctic High (AH) (January) (Significant correlation coefficients are highlighted in bold)

Centers actions	Latitude			Longitude			Center pressure		
	IcM	AzM	AH	IcM	AzM	AH	IcM	AzM	AH
IcM	–	**0.25**	−0.10	–	−0.02	−0.01	–	**−0.40**	**−0.35**
AzM	**0.25**	–	**−0.19**	−0.02	–	0.09	**−0.40**	–	0.15
AH	−0.10	**−0.19**	–	−0.01	0.09	–	**−0.35**	0.15	–

Table 5: Dependence of the intensity of the North Atlantic AAC on the intensity of the Arctic High (January)

Statistical characteristics	Intensity gradations Arctic High						
	1015.0–1016.5	1016.6–1018.0	1018.1–1019.5	1019.6–1021.0	1021.1–1022.5	1022,6–1024.0	1024,1–1025,5
m_i	8	8	18	12	6	10	8
S_f	193.50	316.01	842.72	212.71	415.17	585.11	299.31

significance of the impact of the North Atlantic oscillation on the intensity of the Arctic High. The influence of the AAC of the North Atlantic on the state of the Arctic anticyclone was only 7%.

4 Conclusions

Thus, as a result of the study, the following conclusions can be drawn:

1. In two natural climatic periods – the period of stabilization and the second wave of global warming – the geographic position and intensity of the Arctic anticyclone changed. In the second wave, it began to be located southwest of its position during the period of stabilization and increased its intensity.

2. In all months, there is an increase in the Arctic anticyclone from the period of stabilization to the second wave of global warming. The change in geographical position from one natural climatic period to another in all months of the year does not show a noticeable trend.

3. A negative statistically significant correlation (K_{cor}= −0.19) was marked between the latitude of the location of the centers of the two considered anticyclonic AAC: if the Azores anticyclone moves to the north, then the Arctic High, on the contrary, to the south.

4. A negative statistically significant correlation (K_{cor}= −0.19) was marked between the latitude of the location of the centers of the two considered anticyclonic AAC: if the Azores anticyclone moves to the north, then the Arctic High, on the contrary, to the south.

5. The influence of the Arctic High on the change in the pressure in the Icelandic minimum and Azores maximum is estimated at 48%. This influence showed not statistical significance, confirmed by Fisher's test. The impact of the circulation systems of the North Atlantic on the Arctic anticyclone is estimated at 7%, and is not statistically significant by Fisher's test.

References

Alekseev, G. V. (Ed.), *Formation and dynamics of the modern Arctic climate*, 80 pp., Sankt-Petersburg Hydrometeorological Press, 2003.

Alekseev, G. V., L. V. Bulatov, and V. F. Zakharov, The role of the Arctic anticyclone in fresh water desalination in the Arctic Basin, *Meteorology and Hydrology*, *2*, 61–68, 2000.

Deser, C., J. E. Walsh, and M. S. Timlin, Arctic Sea Ice Variability in the Context of Recent Atmospheric Circulation Trends, *Journal of Climate*, *13*(3), 617–633, doi:10.1175/1520-0442(2000)013<0617:ASIVIT>2.0.CO;2, 2000.

Gmurman, V., *Probability Theory and Mathematical Statistics*, 480 pp., Moscow Higher School Press, 2003.

IPCC, *Intergovernmental Panel on Climate Change, Climate change 2013: The physical science basis*, Cambridge University Press 1535, Cambridge, UK, 2013.

Kolemajev, V., O. Staroverov, and V. Turundajevskyi, *Theory of Probability and Mathematical Statistics*, 480 pp., Moscow Higher School Press, 1991.

Morozova, S. V., *The role of planetary circulation objects in global climate processes*, 132 pp., Saratov University Press, 2019.

Morozova, S. V., E. A. Polyanskaya, G. F. Ivanova, N. G. Levitskaya, K. E. Denisov, and N. P. Molchanova, Variability of the circulation processes in the Lower Volga Region on the background of global climate trends, in *IOP Conference Series: Earth and Environmental Science (EES)*, p. 107, 2018.

Morozova, S. V., E. A. Polyanskaya, N. K. Kononova, N. P. Molchanova, and A. V. Letuchiy, A study of the mutual influence of global circulation objects by a method of dispersive analysis, *IOP Conference Series: Earth and Environmental Science*, *386*(1), 012011, doi:10.1088/1755-1315/386/1/012011, 2019.

Neushkin, A. I., N. S. Sidorenkov, A. T. Sanina, T. B. Ivanova, T. V. Berezhnaya, N. V. Pankratenko, and M. Y. Makarova, *Monitoring obshchey tsirkulyatsii atmosfery. Severnoye polushariye*, 200 pp., Obninsk VNIGMIMTSD Press, 2013.

Roshydromet, *Second Assessment Report of Roshydromet on Climate Change and its Consequences in the Territory of the Russian Federation. General summary*, 60 pp., Moscow: ZAO Gruppa more Press, 2014.

Smirnov, N. P., and V. I. Vorobiev, *North Pacific Oscillation and Climate Dynamics in the North Pacific Ocean*, 121 pp., Russian Hydrometeorological University Press, 2002.

Smirnov, N. P., V. I. Vorobiev, and S. Y. Kachanov, *North Atlantic Oscillation and Climate*, 119 pp., Russian Hydrometeorological UniversityPress, 1998.

Vinje, T., Anomalies and Trends of Sea-Ice Extent and Atmospheric Circulation in the Nordic Seas during the Period 1864–1998, *Journal of Climate*, *14*(3), 255–267, doi:10.1175/1520-0442(2001)014<0255:AATOSI>2.0.CO;2, 2001.

Vize, V. Y., *Fundamentals of long-range ice forecasts for the Arctic seas*, 80 pp., Izdatelstvo Glavsevmorputi, 1944.

Vorobiev, V., and N. Smirnov, *The Arctic High and climate. Dynamics in the northern polar region*, 80 pp., Russian Hydrometeorological University Press, 2003.