Knowledge E
enriching | engaging | empowering

Conference Paper

Applying the δ^{18}O Parameter for Evaluating of Organic Matter Production-destruction Processes in the Barents Sea

Alexey Namyatov[1,2], Ivan Pastukhov[1], and Irina Semeruk[2]

[1]Murmansk Marine Biological Institute, Kola Scientific Centre of Russian Academy of Sciences
[2]OOO"FERTOING"

Abstract

The authors present the determination method of nutrient's background concentration in the sea water.

In this work, as a basis for the proposed method, we use a three-component system [1-6, 10, 11, 12, 13] for mixing water masses in the Barents Sea based on the parameter δ^{18}O. Simple mixing of purely Atlantic water masses and purely river water masses as well as ice formation and melting processes were taken into account. The authors suppose that the background concentration is a concentration that changes only as a result of water transformation, such as melting and freezing. The authors consider background concentration of phosphates, nitrates and silicates for the Barents Sea calculated from previously collected data. The difference between measured and background concentrations indicates production or destruction process of organic matters. If the results are positive - there is destruction; if negative, there is - production. The data for δ^{18}O, salinity, phosphates, nitrates, and silicates that were used in this study were taken from an open source database published on the NASA website and in our own collection. Samples were taken in the summer.

Keywords: oxygen isotope fractionation, Atlantic water, river water, sea water, nutrients, phosphorus, nitrogen, silicon, destruction-production process, plankton.

1. Introduction

All the elements of sea water can be divided into two groups: conservative and non-conservative. Concentration of conservative components changes only in a result of water transformation, such as melting and freezing, for example, salinity. Non-conservative element's concentration, in addition, depends on the chemical and biological processes in sea water, for example, nutrients.

2. Methods and Equipment

In present study we used a model assuming that there are only two basic water masses in the Barents sea - pure "Atlantic" and pure "river" water. Another one masses is product

OPEN ACCESS

of these two basic masses mixing [12]. In this case, when we say ``sea waters'', we mean real waters, which are formed by mixing of Atlantic and river waters in any proportion and are transformed as a result of melting or freezing.

Total amount of Atlantic, river and ice water is described by a system of mixing equations:

$$fa \times Sa + fr \times Sr + fi \times Si = Smean$$

$$fa \times Oa + fr \times Or + fi \times Oi = Omean \tag{1}$$

$$fa + fr + fi = 1$$

where a -- Atlantic waters; r -- river waters; i -- ice waters; S -- salinity (psu); O -- value of δ18O (‰); f -- amount of different types of water (%); Smean and O mean -- result (measured) salinity and value of δ18O (‰) sea water resp.

In order to calculate the values of fa, fr, and fi in the system of equations (1), it is necessary to know the value of salinity and δ18O in the initial waters (Atlantic, river and ice). For these purposes, we take the value of this parameter, which was used in other studies, but was specified for the Barents Sea (Table 1).

TABLE 1: Calculated value of salinity and $\Delta^{18}O$ (‰).

Sa	Oa	Sr	Or	[1]Si	Oi
35.04	0.3	0	-15	5.86	[2]Surface value + 2.6

[1] determined from 288 samples [14]; [2] [6]

Thus, if we assume that sea water is the result of mixing and transformation of two basic waters, the concentration of any conservative component of this water will be determined by the following equation:

$$fa \times Ca + fr \times Cr + fi \times Ci = Cf \tag{2}$$

where *Ca*, *Cr*, and *Ci* are the concentrations of the studied component in the ``pure'' Atlantic, river, and ice waters (Table 2); *Cf* is the background concentration of the studied components.

Then the difference between the measured and background value will determine the ``non-conservative'' value. In case of nutrients, value will determine the total amount of the nutrient involved in production or destruction process.

$$\Delta C_j = C_j - C_{fj} \tag{3}$$

where ΔCj < 0 -- consumption (during photosynthesis); ΔCj > 0 -- admission (mineralization due to oxidation of organic matter); j - consider parameter (phosphorus, nitrogen, silicon or anything else).

TABLE 2: Values of the studied parameters in the basic water masses [14, 16, 17].

Water masse	Salinity, psu	P-PO$_4$, µg/l	N-NO$_3$, µg/l	Si-SiO$_3$, µg/l
Atlantic, *Ca*	35.00	21.4	102	129
River, *Cr*	0.0	26.1	80.6	3050
Ice, *Ci*	5.86	11.1	24.8	30.9

Ca -- average values of the presented parameters for the 0-200m layer, from January to February in the western part of the sea. We choose the mentioned period of the year to ensure maximum values of the average concentration of nutrients, which will decrease in spring, when the process of photosynthesis in sea water begins to intensify [16].

Cr -- average values for 10 years (2006--2016 y.) [17]

Ci -- The average values of salinity and nutrient concentrations were calculated based on the materials published in the book ``Seas of the USSR: Barents Sea'' [14] Which were collected on the cruise of the scientific icebreaker ``Otto Schimdt'' in the 80s of the 20th century.

Cj and Mean are directly measured values of salinity and concentration of several nutrients, derived from field research.

A joint determination of only salinity and nutrients is quite common, but a joint determination of salinity, δ^{18}O and nutrients is very rare in available databases. But, as was shown [9, 6 and other], there is a rather close correlation between salinity and δ^{18}O. For the Barents sea this correlation is shown in the paper [7]. We obtained the equation of relationship between these parameters for the Barents Sea based on NASA's publicly [15] available database (2150 definitions at 215 stations). The correlation coefficient was about 1 (R^2 = 0.9422):

$$y = 0,0011x^2 + 0,3815x - 14,338 \qquad (4)$$

Using this equation it is possible to calculate the value of δ^{18}O for each salinity value. To use this equation, we hypothesize that it applies to the entire salinity series. We tested this hypothesis and it was shown in our other works [9].

3. Results

As a result, we had calculated the background concentrations of some nutrients in the Barents Sea. Then the value of their changes was calculated due to the consumption by photosynthesis and mineralization of organic matter both in two layers (bottom and surface) and in the Kola Meridian section (R.V. Otto Schimdt, April 1982).

Distribution of obtained phosphate phosphorus value over "the Kola Meridian" section is shown on Figure 2, background concentrations and values of their difference, that is, the values of ``non-conservatism''. The position of the section is shown on Figure 1.

Negative values of up to 10 µg/L were obtained in the surface layer - that is, were real values of the reduction of mineral phosphorus during photosynthesis obtained. At the bottom level, on the contrary, positive values of up to 11 µg / L were received, which indicates the real values of the process of mineralization of organic matter. Figure 1 clearly shows the zones of nutrient intake from the water column, that is, the active photosynthetic activity of plankton occurs in these zones. Also on the map are visible areas where the accumulation of mineral forms of nutrients occurs. Production processes prevail in the surface waters of the northwestern Barents Sea from June to September, and destruction processes prevail at the bottom layer of the Central Basin region.

The obtained values of the consumption of nutrients allow considering jointly the results of hydrochemical and phytoplankton researches. Below is the P: N: Si ratio in the surface layer during the summer in the western, northern and southeastern parts of the Barents Sea, which was calculated according to materials in Figure 1 and the ratio of these elements to mass groups of phytoplankton. [8]

The presented results (Table 3) show that the ratio of ``non-conservatism'' of some nutrients in the

southeastern part of the Barents Sea coincides with the same ratio for diatoms, and this ratio is relatively close to the peridine algae in Atlantic waters in the western part of the sea.

TABLE 3: Ratio of some types of nutrients in different areas of the Barents Sea and the plankton groups in it.

Area	N/P	Si/P	Group of plankton [8]	N/P	Si/P
West	6,4	6,3	Diatoms algae	4	30,8
Nord	4,4	15,0	Peridinian algae	8	4
South-East	5,4	33,1	Blue-green algae	9	1

4. Discussion

The results of calculations by the described method are presented in Figure 3. As we see, the minimum consumption of the considered nutrients is observed in the incoming Atlantic water. Maximum consumption is viewed in the southern and southeastern parts of the Barents Sea, as well as at the northern border of the sea. The ΔCj value for
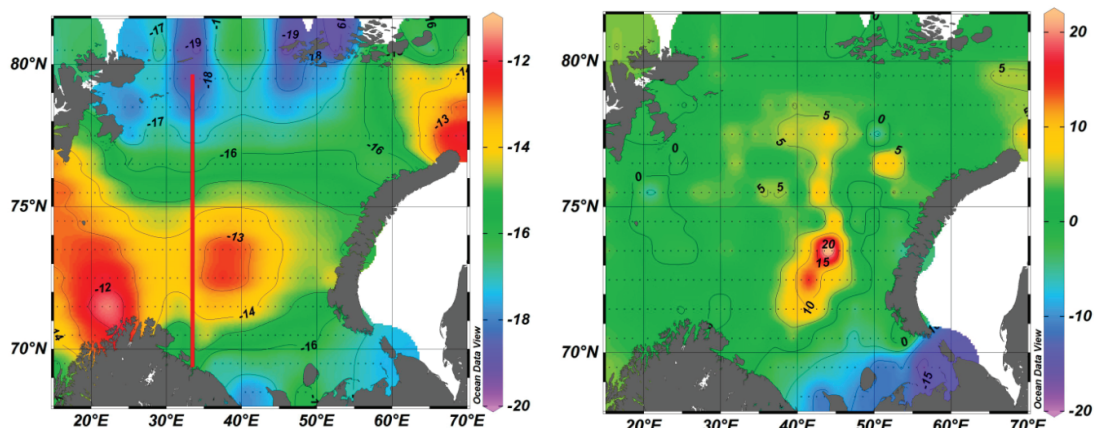
Figure 1: Distribution of ``non-conservative'' values of phosphate phosphorus in the Barents Sea from June to September (on the left - the surface layer, on the right - bottom). The red line on the map is the Kola Meridian section. The data for the graph constructing were taken from the NOAA database for the summer months (July - September) and divided into squares with a side of 1 degree [16].

mineral phosphorus (calculated from the NODC atlas) in the western part of the sea, where Atlantic waters flow, is about minus 12 µg / l, in the northern and southeastern part - minus 18-19 µg / l.

The same value for silicon ranges from minus 50 µg / L near the western border of the sea, up to -300 µg / L near the northern border of the sea and up to 450 µg / L in the southeastern part of the sea. Similar values for nitrogen are minus 80 µg / L, minus 100 µg / L and - 95 µg / L, respectively.

The distribution of the ratio of the values of Si / P and N / P (Figure 4) is of interest. As shown above, the Si / P ratio of about 30.8 characterizes the dominance of diatom groups of phytoplankton. In Fig 4 it can be seen that the values of this ratio are observed in the southeastern part of the Barents Sea, located in the zone of distribution of the Pechora river flow. N/P ratios about 8 characterize the predominance of the peridine group of phytoplankton, and close to such values (Figure 4) are observed in the Atlantic water masses of the western and central parts of the sea.

5. Conclusion

A method for studying the hydrochemical variability of water masses is presented, where a new definition of the background concentration of any elements of sea water proposed. Unlike the other definitions of this value, our method allows estimating this parameter by the ratio of water masses at a given point. The background concentration at one point will not be constant and depend on the ratio of Atlantic, river and ice water. This is especially important for seas with large temporary changes in salinity.
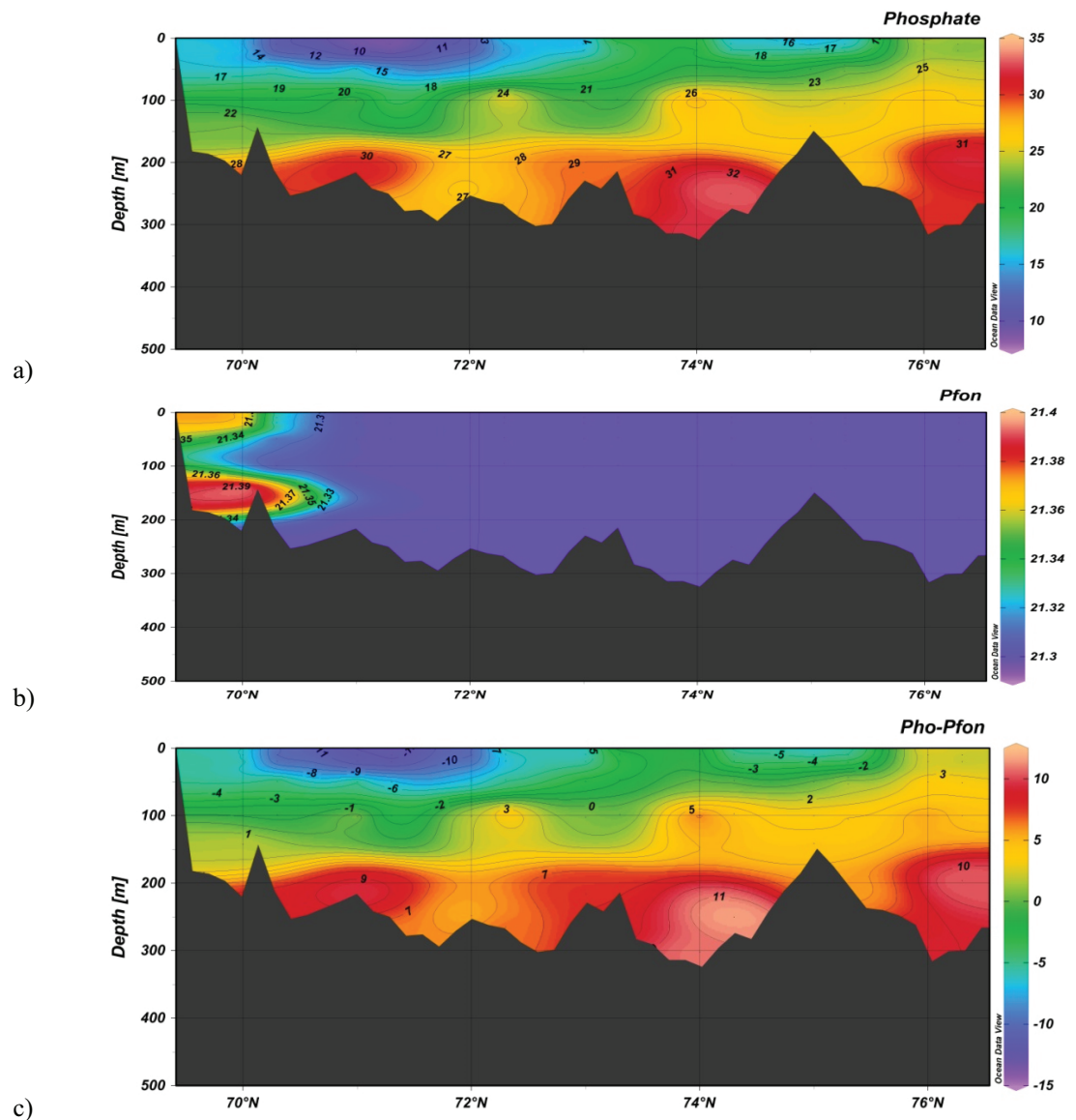
Figure 2: Distribution of phosphate phosphorus concentration: (a) measured values, (b) background values, (c) ``non-conservatism'' values (μg / L) at the «Kola meridian» section (R.V. Otto Schimdt, April 1982) [16].

The presented method allows dividing the total concentration of an element into a ``hydrobiological'' one, which is determined by the production and destruction of organic matter (due to the activity of phytoplankton), and terrigenous. This allows connecting the hydrological, hydrochemical and hydrobiological processes at a quantitative level.

Presented method can help to estimate the magnitude of nutrients changes in the annual life cycle of plankton in various parts of the sea and allow evaluating the values of the ratio of consumption of various elements in different parts of the sea with different hydrological and hydrochemical conditions.
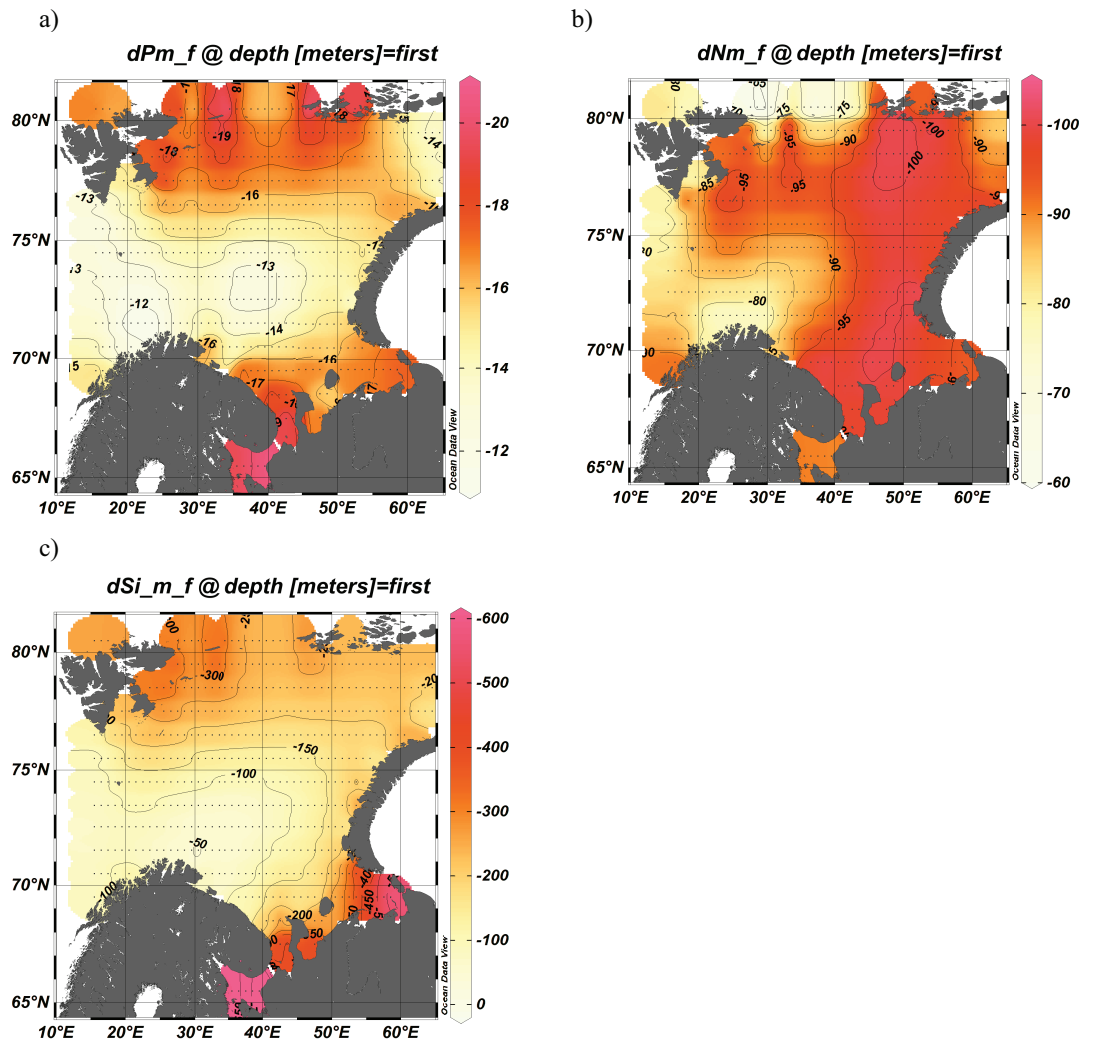
Figure 3: Consumption of (a) mineral phosphorus, (b) nitrogen and (c) silicon in the Barents Sea at summer, surface layer. Calculated from the NODC Atlas.

Acknowledgement

The authors would like to thank their colleague for their contribution and support to the research. They are also thankful to all the reviewers who gave their valuable inputs to the manuscript and helped in completing the paper.

Conflict of Interest

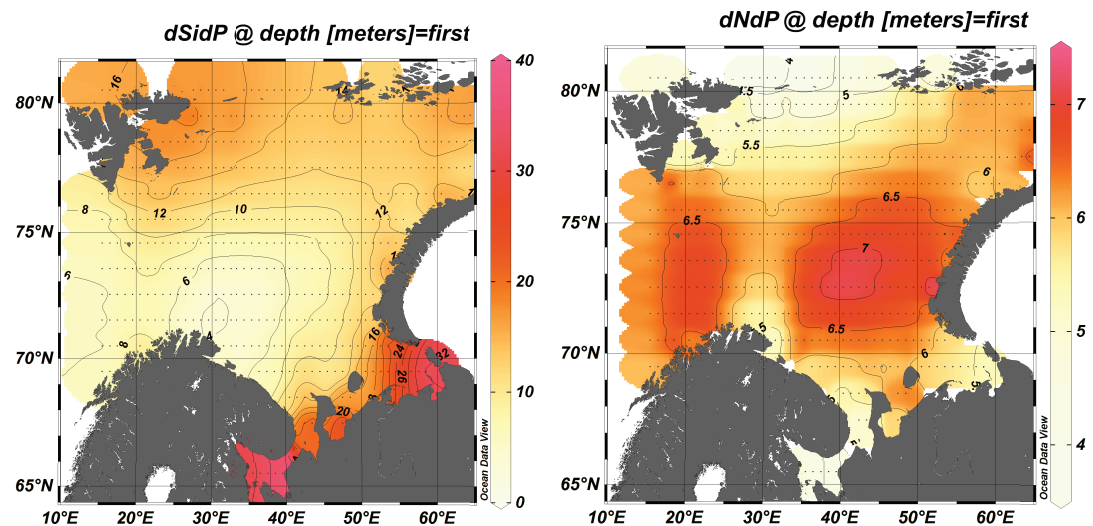The authors have no conflict of interest to declare.

Figure 4: Si:P (left) and N:P (right) ratio change in Barents sea at summer, surface layer.

References

[1] Bauch, D., Schlosser P., Fairbanks R.F. (1995). Freshwater balance and the sources of deep and bottom waters in the Arctic Ocean inferred from the distribution of $H_2^{18}O$. *Progress in Oceanography*, vol. 35, p. 53--80.

[2] Bauch, D., Dmitrenko, I. Wegner, C., Hölemann, J. Kirillov, S., Timokhov, L., Kassens, H. (2009). Exchange of Laptev Sea and Arctic Ocean halocline waters in response to atmospheric forcing. *Journal of Geophysical Research,* vol. 114.

[3] Bauch, D., Gröger, M., Dmitrenko, I., Hoölemann, J., Kirillov, S., Mackensen, A., Taldenkova, E., Andersen, N. (2011). Atmospheric controlled freshwater release at the Laptev Sea continental margin. *Polar Research,* vol. 30, p. 14.

[4] Bauch, D., Torres-Valdes, S., Polyakov, I., Novikhin, A., Dmitrenko, I., McKay, J., Mix, A. (2014). Halocline water modification and along-slope advection at the Laptev Sea continental margin. *Ocean Sci.*, vol. 10, pp. 141--154.

[5] Bauch, D., Cherniavskaia, E., Timokhov, L. (2016). Shelf basin exchange along the Siberian continental margin: modification of Atlantic Water and Lower Halocline Water. *Deep-Sea Research,* vol. 1, № 115, p. 188--198.

[6] Bauch, D., Cherniavskaia, E. (2018). Water mass classification on a highly variable arctic shelf region: Origin of Laptev sea water masses and implications for the nutrient budget. *Journal of Geophysical Research: Oceans,* vol. 123.

[7] MacLachlan, E., Cottier, F. R, William, E. N., Austin & John A. Howe. (2007). The salinity: d18O water relationship in Kongsfjorden, western Spitsbergen Suzanne. *Polar Research*, vol. 30, p. 160-167.

[8] Monin, A.S. (1979). *Oceanology. Chemistry of the ocean. T.1: Chemistry of the waters of the ocean.* Moscow: Publishing House "Science".

[9] Namyatov, A.A., Semeryuk, I.A. (2013) Application of the δ^{18}O parameter for the analysis of the origin of mass water in the Laptev Sea. *Problems of the Arctic and Antarctic.* No 4 (98), pp. 35--42.

[10] Semeryuk, I. A., Namyatov, A. A. (2018). ``Using δ^{18}O as a Tracer of the Formation of Water Masses in the Laptev Sea. Part 1. Quantification of Ice Formation and Melting,'' Russian Meteorology and Hydrology, 2018, Vol. 43, No. 9, pp. 591--598. Ó Allerton Press, Inc.

[11] Namyatov, A. A., Semeryuk, I. A. (2019). ``Using δ^{18}O as a Tracer of the Formation of Water Masses in the Laptev Sea. Part 1. Part 2. Quantification of the Volume of Atlantic, River, and Melt Water as well as Water Withdrawn for Ice Formation.'' Russian Meteorology and Hydrology., Vol. 44, No. 7, pp. 467--473.

[12] Nikiforov, E.G., Speicher, A.O. (1980). Patterns of formation of large-scale fluctuations in the hydrological regime of the Arctic Ocean. Leningrad, Gidrometizdat.

[13] Ostlund, H.G., Hut, G. (1984). Arctric Ocaean water mass balance from isotope data. *J. Geophys. Res.*, vol. 89, pp.6373-6381

[14] Ed. Terziev, F.S. (1991). Hydrometeorology and hydrochemistry of the seas. Project Sea of the USSR. Volume 1, Issue 1. Barents Sea. St. Petersburg, Gidrometizdat.

[15] *NASA. Online Version*. Retrieved from http://data.giss.nasa.gov/o18data/ref.html

[16] *NODC. Online Version.* Retrieved from https://www.nodc.noaa.gov/

[17] Surface water quality of the Russian Federation Yearbook. Roshydromet. FGBU "Hydrochemical Institute". Retrieved from http://www.meteorf.ru/product/infomaterials/ezhegodniki/