Title

NABOS II – Seawater macronutrient observations in the eastern Eurasian and Makarov Basins, Arctic Ocean, 2021.

Abstract

The cruise was conducted from September 10 – October 13, 2021 aboard the Research Vessel Akademik Tryoshnikov as a part of the Nansen and Amundsen Basins Observational System II (NABOS-II) project. A total of 102 stations were occupied during the cruise; profiles were made at roughly alternating stations (n = 80) and surface samples were collected for all stations. Macronutrient measurements include nitrate, nitrite, nitrate+nitrite (as "nitrogen"), phosphate, and silicate. Additional details are included in the readme file.

Macronutrient and Bottle Data
NABOS 2021 Cruise – R/V Academik Tryoshnikov
September 10 – October 13, 2021

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Data within this spreadsheet includes sample metadata (Cruise, Event, Station, Cast, Sample ID, Latitude, Longitude, Pressure, and Depth), CTD data from the time the bottle was tripped (temperature, salinity, oxygen, fluorescence, and turbidity), and macronutrients from frozen samples (phosphate, silicic acid, nitrate, nitrite, nitrate + nitrite, and ammonium). Column numbers, headers, and parameters are itemized in Appendix Table 1.

CTD Data are QC'd prior to extraction for this file and data are of good quality – except for CTD oxygen, which had sensor issues during this cruise. **Thus, oxygen data should be used for profile shape, rather than quantitative metrics.**

1. Sample Collection and Analysis

Nutrient analysis occurred at the University of Alaska's Nutrient Analytical Facility (https://nutrients.alaska.edu). Samples were collected from the niskin bottles into plastic (HDPE) 20 mL vials. Vials were rinsed 3 times with the sample prior to collection. Samples were unfiltered for stations 0 – 63 and stations 90 – 102. Samples were filtered for stations 64 – 89; these samples were collected into a syringe – rinsed 3x – and filtered through a 0.45 µm cellulose acetate filter into the 20 mL HDPE vial (also rinsed 3x with filtrate). Stations 64 – 89 were part of a transect that extended from the basin (bottom depths > 2000) to the shelf (bottom depths ~30 m). All other stations were along the slope or in the basins (bottom depths >1400 m). A few samples were collected as both filtered and unfiltered samples for station 0 – 64 (basin and slope stations). When compared, these samples have minimal deviation for nitrate and silicate (Figure 1). Phosphate has more scatter, but still is scattered around the 1:1 trendline. Thus, we don't consider filtered/unfiltered to be a source of issue in our dataset.

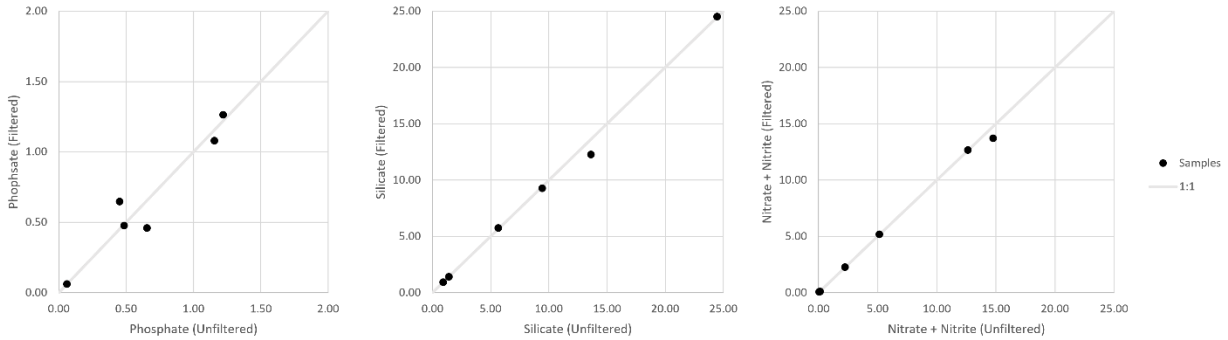

Figure 1. Comparison of filtered samples vs unfiltered samples.

All samples were stored frozen until analysis. Nutrient analyses (nitrate plus nitrite, nitrite, phosphate, and silicate,) were performed on a Seal Analytical continuous-flow QuAAtro39 AutoAnalyzer. Analyses were conducted following Becker et al. (2020). Final concentrations are determined using a standard curve fit using Seal Analytical AACE 7.07 software, with blank subtraction. Primary standards were made from high purity compounds/stocks/reagents (KNO_3; 99.999%; Acros Organics), nitrite ($NaNO_2$; 99.999%; Alfa Aesar), phosphate (KH_2PO_4; >99%; Acros Organics), silicate (Na_2SiF_6; 99%; Strem Chemicals).

Prior to analysis frozen samples were heated to 50°C for 30 minutes in a water bath to ensure depolymerization of reactive silicate. Samples were allowed to cool to room temperature before proceeding. For each run, standardizations were performed at the beginning and Certified Reference Materials for Nutrients in Seawater (RMNS; KANSO CO., LTD.), drift standards, and blanks were measured throughout. Reagent solutions and primary and secondary standards were prepared with Milli-Q water and working standards were prepared daily with low nutrient artificial seawater. Limit of Detection for each parameter was determined by multiply the standard deviation of the blank values (across all analytical runs) by three. Precision is reported as the standard deviation of the certified reference material (ran 5 times during each analytical run).

Nitrate was determined by reducing nitrate to nitrite at pH 8 in a copperized cadmium reaction coil (following Armstrong et al., 1967). Nitrite reacts with sulfanilamide and produces a red dye that is measured at 550 nm. Nitrite analysis is conducted similarly, but without the cadmium column, and nitrate is determined by subtracting the total nitrate + nitrite analysis with the nitrite only analysis. The nitrate + nitrite method has a detection limit of 0.03 µmol/L and nitrite has a detection limit of 0.02 µmol/L. Precision was determined to be 0.24 µmol/L for nitrate+nitrite and 0.02 µmol/L for nitrite.

Phosphate was analyzed using a modification of Murphy and Riley (1962) where a blue color is formed when phosphate reacts with molybdate ion and antimony ion followed by reduction with ascorbic acid. The reduced blue phosphor-molybdenum complex is read at 880 nm. Phosphate had a detection limit of 0.02 µmol/L. Precision was determined to be 0.04 µmol/L.

Silicate was measured following Armstrong et al. (1967); silicomolybdate was reduced in acid to molybdenum blue by ascorbic acid and oxalic acid was added to inhibit phosphate interference. Absorbance was measured at 820 nm. Silicate detection limit was 0.02 µmol/L. Precision was determined to be 0.41 µmol/L.

2. Quality Control

2.1 Visual Inspection of profiles

Profile shapes and concentrations are within expected ranges. Expected ranges were originally defined by Matthew Alkire for a pan-arctic nutrient data compilation (Appendix Table 2). Uncertainty in the analytical processes for determining nitrate and nitrite can lead to slightly negative numbers (near zero); any negative values for these parameters are set to zero.

Profiles were examined and any uncharacteristic data points were flagged. Data points were flagged initially with values of 2 (good), 3 (questionable), or 4 (bad), following the WOCE Bottle Flag scheme. Reanalysis of bad and questionable data points was conducted, with good samples included throughout. The reanalysis data was either averaged (where both data points were reasonable) and flagged with a 6 (mean of replicate values) or the first or second analysis was accepted as a good value (and flagged with a 2). Values that were flagged "6" are reported in appendix table X, all averages have an n = 2. Values that were flagged 3 or 4 are in appendix table X with an explanation of the flag. Once flags were made on profiles, the sections were also plotted in Ocean Data View and any anomalous points were revisited – no additional changes were made at this point.

2.2 Deep Data Comparison

In this step, 2021 profiles were compared to previous NABOS cruises. Deep water from 2021 aligns well with 2018 but is offset from 2015. Matt Alkire and Rob Rember, data creators for the 2018 and 2015 datasets indicate that 2018 is the highest quality and can be used as a standard. The data produced in 2021 are well aligned with the previous cruises, nitrate and phosphate have the greatest variability between years, but are still consistent.

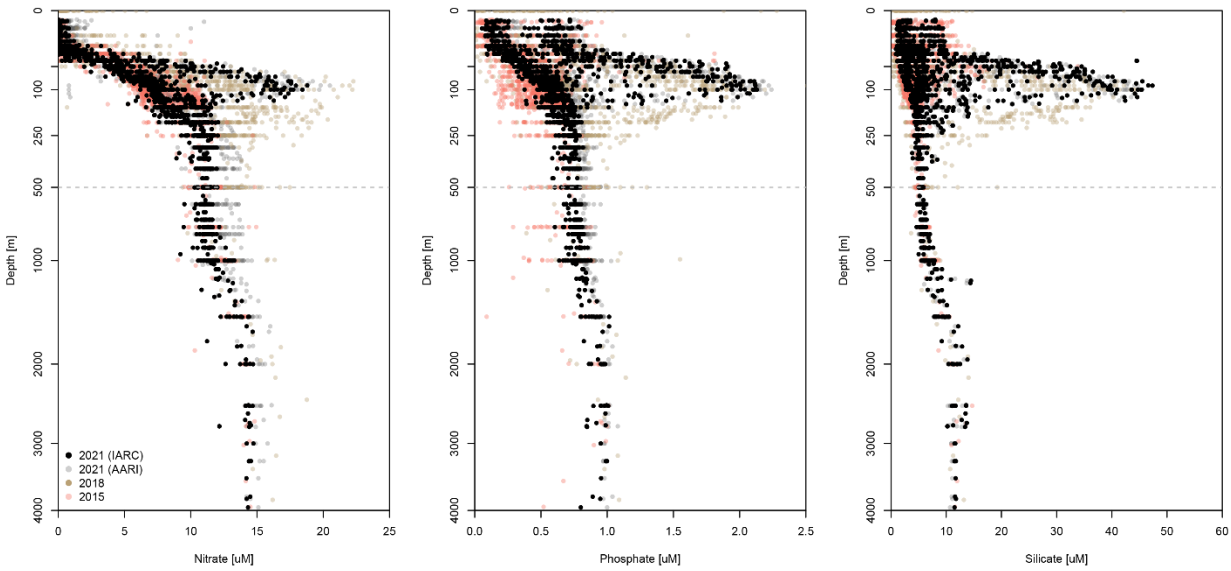

Figure 2. Comparison of nutrient data in the eastern Eurasian and Makarov Basins, all data were produced by IARC's Nutrient Analytical Facility. Generally, throughout QA/QC 500 m has been considered the "deep" data cut-off. All data below this line are compared for consistency.

2.3 Intercalibration with AARI's Shipboard Data

AARI (Arctic and Antarctic Research Institute) collected several of the same stations as UAF on the 2021 cruise – all full depth stations are intercalibration stations. Both datasets are unfiltered with the exception of Stations 64-89, which were filtered and frozen for UAF and were unfiltered and analyzed shipboard (no freezing) by AARI.

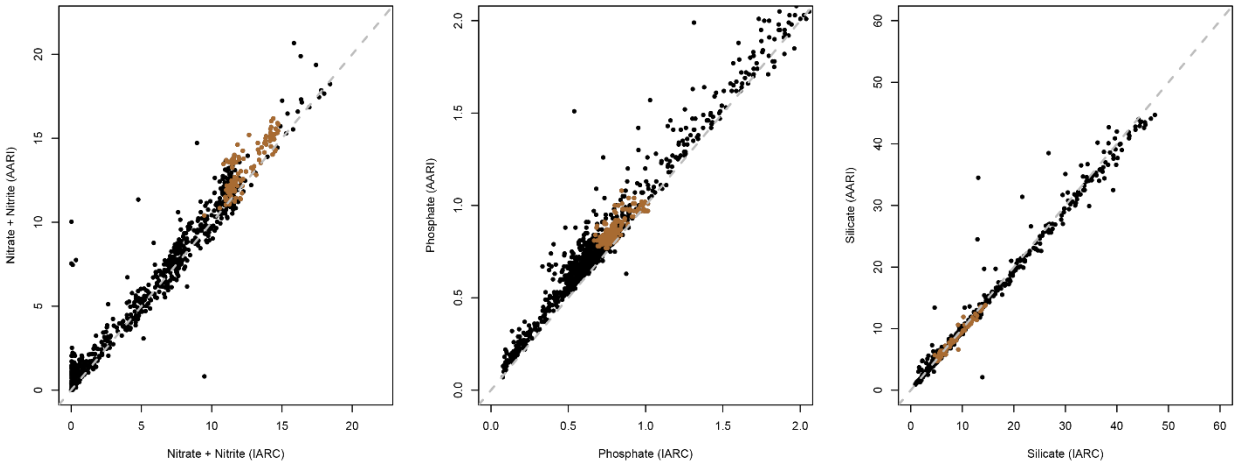

Figure 3. Intercalibration of 2021 NABOS cruise macronutrient data between IARC's Nutrient Analytical Facility and AARI's shipboard AutoAnalyzer. Data betweeen 0 and 500 m are depicted in black dots, and data from depths greater than 500 m are in brown dots. The dashed line represents the 1:1 line. Generally, the Nitrate+Nitrite data are aligned on the 1:1 line, but deviate slightly in deep waters. Phosphate was consistently offset between the two groups, and silicate consistent to the 1:1 line.

Appendix

Table 1. Spreadsheet metadata

Column Number	Column Name	Data Type	Unit	Parameter Description	CTD Configuration
1	Cruise	Character			
2	Event	Character			
3	Station	Character			
4	Cast	Numeric			
5	Sample ID	Numeric			
6	Latitude	Numeric	Decimal Degrees		
7	Longitude	Numeric	Decimal Degrees		
8	Pressure	Numeric	dbar		
9	Depth	Numeric	m		
10	Bottle	Numeric	unitless	Niskin bottle number	
11	T1	Numeric	°C	Temperature	Primary Temperature Sensor
12	T2	Numeric	°C	Temperature	Secondary Temperature Sensor
13	Sal1	Numeric	psu	Salinity	Primary Conductivity Sensor
14	Sal2	Numeric	psu	Salinity	Secondary Conductivity Sensor
15	Sigma1	Numeric	kg m^{-3}	Potential Density	Primary T & Conductivity Sensors
16	Sigma2	Numeric	kg m^{-3}	Potential Density	Secondary T & Conductivity Sensors
17	Ox1	Numeric	µmol L^{-1}	Oxygen	Primary Oxygen Sensor
18	Ox2	Numeric	µmol L^{-1}	Oxygen	Secondary Oxygen Sensor
19	Fluor	Numeric		ECO-FLNTUrtd	
20	Turbidity	Numeric		ECO-FLNTUrtd	
21	Silicate	Numeric	µmol L^{-1}		
22	Silicate.Flag	Numeric			
23	Phosphate	Numeric	µmol L^{-1}		
24	Phosphate.Flag	Numeric			
25	Nitrate	Numeric	µmol L^{-1}		
26	Nitrate.Flag	Numeric			
27	Nitrite	Numeric	µmol L^{-1}		
28	Nitrite.Flag	Numeric			
29	Nitrogen	Numeric	µmol L^{-1}	Nitrate + Nitrite	
30	Nitrogen.Flag	Numeric			

Table 2. Reasonable ranges for each parameter in the spreadsheet

Parameter	Minimum	Maximum	Units
Cruise			
Event			
Station	1	102	unitless
Cast	1	3	unitless
Sample ID			
Latitude	60	90	Degrees N
Longitude	0	360	degrees
Pressure*	-0.1	5500	dbar
Depth*	-0.1	5500	m
T1	Freezing point	20	
T2	Freezing point	20	°C
Sal1	0	35.5	psu
Sal2	0	35.5	
Sigma1			
Sigma2			
Ox1	0	500	mmol m^{-3}
Ox2	0	500	mmol m^{-3}
Fluor			
Turbidity			
Phosphate	0	4.5	mmol m^{-3}
Phosphate.Flag			
Silicate	0	150	mmol m^{-3}
Silicate.Flag			
Nitrate*	-0.1	50	mmol m^{-3}
Nitrate.Flag			
Nitrite*	-0.1	10	mmol m^{-3}
Nitrite.Flag			
Nitrogen	-0.1	60	mmol m^{-3}
Nitrogen.Flag			

*Values less than 0 were set to zero.

Table 3. Flag Explanations for flagged samples. All flags = 6 have sample n = 2.

Station	Cast	Sample ID	Silicate Flag	Phosphate Flag	Nitrate Flag	Nitrite Flag	Nitrogen Flag	Comment
17	1	7915	3	3	3	3	3	Reanalysis did not alter data points, this is an average of 2 analyses and zags off the profile shape for all nutrient parameters
22	1	7988	6	6	3	6	3	Reanalysis did not alter nitrate results, this is an average of 2 analyses and zags off the profile shape.
24	1	8009	6	6	3	6	3	Reanalysis did not alter nitrate results, this is an average of 2 analyses and zags off the profile shape.
56	1	8457	2	3	2	2	2	Phosphate is low relative to all other profiles in this region (2021); no reanalysis performed
56	1	8458	2	3	2	2	2	Phosphate is low relative to all other profiles in this region (2021); no reanalysis performed
56	1	8459	2	3	2	2	2	Phosphate is low relative to all other profiles in this region (2021); no reanalysis performed
56	1	8460	2	3	2	2	2	Phosphate is low relative to all other profiles in this region (2021); no reanalysis performed
70	1	8761	3	3	3	3	3	Reanalysis did not alter data points, this is an average of 2 analyses and zags off the profile shape for all nutrient parameters
73	1	8829	3	3	3	2	3	Silicate, Nitrate, and Phosphate all zag off the trendine, surrounding samples were reanalyzed and accurate, but the shape of the subsurface “peak” is a bit odd.
78	1	8962	3	3	3	3	3	Reanalysis did not alter data points, this is an average of 2 analyses and zags off the profile shape for all nutrient parameters
78	1	8964	3	3	3	3	3	Reanalysis did not alter data points, this is an average of 2 analyses and zags off the profile shape for all nutrient parameters
97	1	9361	2	4	2	2	2	No reanalysis performed, phosphate is the only odd result, zags way off the profile.

5	1	7755	6	6	6	6	6	
5	1	7756	6	6	6	6	6	
5	1	7757	6	6	6	6	6	
5	1	7758	6	6	6	6	6	
5	1	7759	6	6	6	6	6	
5	1	7760	6	6	6	6	6	
5	1	7761	6	6	6	6	6	
5	1	7762	6	6	6	6	6	
5	1	7763	6	6	6	6	6	
5	1	7764	6	6	6	6	6	
5	1	7765	6	6	6	6	6	
5	1	7766	6	6	6	6	6	
5	1	7767	6	6	6	6	6	
5	1	7768	6	6	2	6	2	
5	1	7769	6	2	2	6	2	
5	1	7770	6	6	6	6	6	
5	1	7771	6	2	6	6	6	
5	1	7772	6	2	2	6	2	
5	1	7773	6	2	2	6	2	
5	1	7774	6	6	6	6	6	
5	1	7775	6	6	2	6	2	
5	1	7776	6	6	6	6	6	
5	1	7777	6	2	2	6	2	
5	1	7778	6	6	6	6	6	
9	1	7793	6	6	6	6	6	
9	1	7794	6	6	6	6	6	
9	1	7795	6	6	6	6	6	
9	1	7796	6	6	2	6	2	
9	1	7797	6	6	6	6	6	
9	1	7798	6	6	6	6	6	
9	1	7799	6	6	6	6	6	
9	1	7800	6	6	2	6	2	
9	1	7801	6	6	6	6	6	
9	1	7802	6	6	2	6	2	
9	1	7803	6	6	2	6	2	
9	1	7804	6	6	6	6	6	
9	1	7805	6	2	2	6	2	
9	1	7806	6	2	2	6	2	
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9	1	7809	6	6	6	6	6	
9	1	7810	6	6	6	6	6	

9	1	7811	6	6	2	6	2	
9	1	7812	6	2	2	6	2	
9	1	7813	6	6	2	6	2	
9	1	7814	6	2	2	6	2	
9	1	7815	6	6	2	6	2	
9	1	7816	6	2	6	6	6	
11	1	7838	6	6	6	2	6	
11	1	7840	6	6	6	2	6	
11	1	7846	6	6	6	2	6	
37	1	8181	6	6	6	6	6	
37	1	8186	6	6	6	6	6	
37	1	8188	6	6	6	6	6	
43	1	8247	6	2	6	6	6	
43	1	8255	6	2	6	6	6	
43	1	8258	6	2	6	6	6	
43	1	8261	6	6	6	6	6	
43	1	8262	6	2	6	6	6	
43	1	8263	6	2	6	6	6	
43	1	8264	6	6	6	6	6	
43	1	8265	6	2	6	6	6	
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44	1	8268	6	6	6	6	6	
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44	1	8275	6	6	6	6	6	
44	1	8276	6	6	6	6	6	
44	1	8277	6	6	6	6	6	
44	1	8278	2	2	2	6	2	
44	1	8279	6	6	6	6	6	
44	1	8285	6	2	6	6	6	
44	1	8287	6	2	6	6	6	
45	1	8299	6	2	6	6	6	
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45	1	8301	6	6	6	6	6	
45	1	8302	6	2	6	6	6	
45	1	8303	6	6	6	6	6	
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47	1	8320	6	6	6	6	6	
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75	1	8889	6	6	6	6	6	
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76	1	8904	6	6	6	6	6	
76	1	8916	6	6	6	6	6	
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77	1	8919	6	6	6	6	6	
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77	1	8923	6	6	6	6	6	
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79	1	8982	6	6	6	6	6	
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80	1	9101	6	6	6	6	6	
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81	1	9117	6	2	6	6	6	
82	1	9119	6	6	6	6	6	
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98	1	9383	6	2	6	6	6	
98	1	9391	6	2	6	6	6	
99	1	9414	6	2	6	6	6	
100	1	9450	6	2	6	6	6	

End Table 3