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Arctic Ocean data in CARINA

S. Jutterström[1], L. G. Anderson[1], N. R. Bates[2], R. Bellerby[3,4], T. Johannessen[4,3], E. P. Jones[5], R. M. Key[6], X. Lin[6], A. Olsen[4,3,1], and A. M. Omar[3,4]

[1]Department of Chemistry, University of Gothenburg, Gothenburg, Sweden
[2]Bermuda Biological Station for Research Inc., St. George's GE01, Bermuda
[3]Bjerknes Centre for Climate Research, UNIFOB AS, Bergen, Norway
[4]Geophysical Institute, University of Bergen, Bergen, Norway
[5]Bedford Institute of Oceanography, Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada
[6]Atmospheric and Oceanic Sciences Program, Princeton Univ., Princeton, NJ 08544, USA

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Correspondence to: S. Jutterström (sara.jutterstrom@chem.gu.se)

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Abstract

The paper describes the steps taken for quality controlling chosen parameters within the Arctic Ocean data included in the CARINA data set and checking for offsets between the individual cruises. The evaluated parameters are the inorganic carbon parameters (total dissolved inorganic carbon, total alkalinity and pH), oxygen and nutrients: nitrate, phosphate and silicate. More parameters can be found in the CARINA data product, but were not subject to a secondary quality control. The main method in determining offsets between cruises was regional multi-linear regression, after a first rough basin-wide deep-water estimate of each parameter. Lastly, the results of the secondary quality control are discussed as well as suggested adjustments.

Data coverage and parameter measured

Repository-Reference: doi: Will be provided
Available at: http://cdiac.ornl.gov/oceans/CARINA/Carina_inv.html
Coverage: 60 N to 90 N and 180 E to 180 W
Location Name: Arctic Ocean
Date/Time Start: 1980-08-11
Date/Time End: 2005-05-20

1 Introduction and instrumentation

The CARINA data set contains 28 cruises collected in the Arctic Ocean, in the Arctic Ocean shelf seas including the Barents Sea and in the Canadian Arctic Archipelago (Table 1).

The oldest data is from 1980 (77YM19800811) with the Swedish icebreaker Ymer and the latest is a Barents Sea cruise in 2005 (58JM20050520) with a Norwegian ship Jan Mayen. The locations of all stations included can be seen in Fig. 1. The parameters

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discussed in this paper include the carbon parameters (total dissolved inorganic carbon (TCO_2), total alkalinity (TA) and pH), oxygen (O_2), nutrients (nitrate (NO_3), phosphate (PO_4) and silicate (Si)) (Tables 2 and 3). However more parameters may be included in the data product itself. For the CFCs the reader is referred to the paper of Jeansson et al. (2009) describing the analyses of the Nordic Seas CFCs.

2 Determining offsets between cruises

The difficulty of investigating the Arctic data is that the cruises are quite few and spread out both in time and location. Also, the separate basins show differences in the N/P ratios, Si concentrations, and oxygen saturation in the deep-water etc. Therefore, the investigations have been done for each individual basin of the Arctic Ocean (Fig. 2). The disadvantage of this is of course that the scarcity of data makes it very difficult to quickly see which cruise is offset when there are only two or three others for comparison.

All cruises were investigated in a repeated primary QC, which included examination of depth profiles, property-property plots etc. However, only cruises with station depths deeper than 2500 m were involved in the secondary QC (Fig. 3). This unfortunately excluded all except 8 cruises and left out many of the shelf cruises that did not have a section extending into the central basin, but these shallower waters show too much variability to make it possible to determine reliable offsets.

As a first step, deep-water averages of each parameter were calculated for every separate basin in the Arctic Ocean for each of the 8 cruises included in the secondary QC (Table 4). This was also done to look at the spread of each parameter in the deep-water. The results show that there likely existed an offset between some of the parameters in different cruises. However, deep-water averages do not take into consideration the natural variability of water masses and other processes and is not sufficient on its own to determine offsets.

Crossovers between the Arctic cruises were carried out using the manual approach described by Tanhua et al. (2009c), with modifications according to Olsen et al. (2009).

Unfortunately, it was difficult to control which stations were included in the crossover so that all stations chosen were in the same basin. Also, keeping the crossover radius not too large often made the number of stations so few that no standard deviation could be calculated. Due to this the crossover results will not be discussed. It is noteworthy that the crossover results did not contradict the basin average results.

Trying another approach for the investigations, a regional multi-linear regression (MLR) is applied for each parameter (the MLR is applied to data deeper than 2500). If the MLR support the evidence from the basin averages we assume that there is an offset and the magnitude then determines if a correction is needed. However, care must be taken when choosing the predictor variables of the MLR so that none of these are biased. A number of different MLRs were used and tested for the TCO_2 and TA predictions. The following gave the best fits to the data, but other MLRs were run for every test to check that there was no bias in the results due to an offset in a predictor variable:

$$TCO_2 = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 NO_3 + \alpha_5 \text{Si} + \alpha_6 \text{AOU}$$

$$TCO_2 = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 PO_4 + \alpha_5 \text{Si} + \alpha_6 \text{AOU}$$

$$TA = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 PO_4 + \alpha_5 \text{Si}$$

$$TA = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 NO_3 + \alpha_5 \text{Si}$$

Examples of MLRs for oxygen and nutrients
(here also other sets of parameters were used):

$$O_2 = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 NO_3 + \alpha_5 \text{Si}$$

$$O_2 = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 PO_4$$

$$\text{Si} = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 PO_4 + \alpha_5 \text{AOU}$$

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$NO_3 = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 \text{Si} + \alpha_5 \text{AOU}$

$PO_4 = \alpha_1 + \alpha_2 \text{Salinity} + \alpha_3 \text{Theta} + \alpha_4 NO_3 + \alpha_5 \text{Si}$

3 MLR-results

For an adjustment to be made, it was determined that the offset should be greater than 4 μmol for TCO_2, 6 μmol for TA, 2% for nutrients and oxygen and 0.01 for salinity. For salinity none of the deep-water averages showed any differences larger than 0.01 for any of the cruises in the same basin and salinity was not run with MLRs. The figures in this section showing the MLR results has the offset on the y-axis and the number on the x-axis corresponds to the Cruise # (see Table 1) for each cruise involved in the MLR.

3.1 TCO_2

3.1.1 The Canada Basin

The cruises that were part of the MLR in the Canada Basin were: 18SN19970924 (Cruise #54) and 32H120020718 (73). Both cruises used Certified Reference Materials (CRMs), however the TCO_2 samples for 32H120020718 were poisoned and stored for analyses at shore. The deep-water averages of TCO_2 show a 5 μmol offset. The results from the MLR also show an offset between the cruises, although slightly smaller (Fig. 4).

Runs without AOU were also made since the deep-water averages of oxygen showed a discrepancy. Those results also showed a potential offset of TCO_2 for 32H120020718 of ∼3 μmol. As a whole the 32H120020718 cruise seems to have an offset, but since this cruise only had three stations in deep-water as well as the offset being just on the limit, no adjustment is advised.

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3.1.2 The Makarov Basin

The following cruises were part of the MLR in the Makarov Basin: 06AQ19969712 (3), 18SN19940724 (47) and 77DN19910726 (177). Of these 77DN19910726 did not have CRMs. From the deep averages the 06AQ19969712 cruise seems quite a bit lower than the others (∼10 μmol). However, this is not supported in the MLRs (Fig. 5). Using other predictor variables did not give a larger offset for 06AQ19969712. Since the offset for the 06AQ19969712 cruise is not supported in the MLRs and it also has stations in other basins and does not show an offset in these, no correction is suggested.

3.1.3 The Amundsen Basin

Cruises included in the Amundsen Basin MLR: 06AQ19969712 (3), 18SN19940724 (47) and 77DN19910726 (177) (no CRMs). The results show no significant offsets in the MLRs.

3.1.4 The Nansen Basin

Cruises included in the Nansen Basin MLRs were: 06AQ19930806 (2), 18SN19940724 (47), 77DN19910726 (177) and 77DN20020420 (179). The deep-water averages for 77DN20020420 and 06AQ19930806 suggested that these cruises had lower TCO_2 than the others; this is only in part shown in the MLR (Fig. 6) with the 77DN20020420 cruise being lower than the others. For this cruise CRMs were used and it also had stations in the deep Greenland Sea, so any corrections would also have to take into account how it fits the other Nordic Seas cruises. Therefore the TCO_2 data from this cruise will not be recommended for adjustments in this paper.

06AQ19930806 was also excluded in a test run to see the impact on the other cruises (O_2 and NO_3 seemed to be off when considering the deep-water averages), but only small differences resulted from this. The offset suggested by the deep-water averages for 18SN19940724 is not evident in any of the regional MLRs.

3.2 TA

3.2.1 The Canada Basin

The deep-water averages of TA in the Canada Basin only contain 18SN19970924. CRMs were used on this cruise and the value seems reasonable. No correction of TA is suggested.

3.2.2 The Makarov Basin

Included cruises in the Makarov Basin: 06AQ19960712 (3), 18SN19940724 (47) and 77DN19910726 (177). Deep-water averages show a large discrepancy in alkalinity. The different MLRs support this (e.g. Fig. 7), however not always to the same magnitude. These cruises are also included in other basins so the correction must also depend on the results from the Amundsen and the Nansen Basin and will be discussed at the end of the TA results.

3.2.3 The Amundsen Basin

Cruises included in the Amundsen Basin: 06AQ19969712 (3), 18SN19940724 (47) and 77DN19910726 (177). 18SN19940724 is suggested to have ∼22 μmol offset from the salinity regression (Fig. 8).

3.2.4 The Nansen Basin

Cruises included in the Nansen Basin: 18SN19940724 (47), 77DN19910726 (177) and 77DN20020420 (179). 06AQ19969712 had a breakdown of the TA system and did not have TA data in the deep Nansen Basin. The MLRs suggest offsets for 18SN19940724 of $\sim 15\,\mu\text{mol kg}^{-1}$.

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3.2.5 Discussion

TA data for 77DN19910726 seem lower than the other cruises in the Makarov and Amundsen Basins when looking at the deep-water averages. No CRMs were used on this cruise which suggests that a correction is not surprising. The MLRs do support the differences found in the deep-water averages in the Makarov Basin (as seen in Fig. 7), but not in the Nansen Basin or the Amundsen Basin (Fig. 8). Considering that most of the stations of this cruise were located in the Amundsen and Nansen Basin and only a few stations in the Makarov Basin it makes more sense to trust the Eurasian Basin results. Also, TA data were quite scattered in the deep-waters in the Makarov Basin and running a MLR from 100 m did not show the same offset as the deep-water MLR did. In conclusion, no correction to TA data is suggested for this cruise.

For the 18SN19940724 cruise deep-water averages suggest that this cruise is almost 30 μmol higher than e.g. 06AQ19969712. This is supported by all the MLRs using only salinity as predictor variable (giving a positive offset of over 20 $\mu mol\,kg^{-1}$), except the one from the Nansen Basin showing an offset of about 15 $\mu mol\,kg^{-1}$. Since this basin has only a few stations from the 18SN19940724 cruise it seems best to rely on the results of the others. However, increasing the number of predictive parameters in the MLRs seems to reduce the offset. In conclusion it is most likely that 18SN19940724 has a positive offset in TA of about 24 $\mu mol\,kg^{-1}$.

3.3 pH

Only two cruises had measured pH (and, since they also measured TA and TCO_2 on the same cruise, over determined the carbonate system): 77DN20020420 and 06AQ19969712. By doing "round-calculations", i.e. using TA and TCO_2 to calculate pH, TCO_2 and pH to calculate TA and TA and pH to calculate TCO_2 and then comparing the measured parameter to the calculated, it is possible to get an idea of whether any of the parameters are offset. This was done for the cruises mentioned above (using CO_2SYS by Lewis and Wallace, with the constants from Mehrbach et al. (1973) refit by

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Dickson and Millero, 1987). The results show a difference in TA of about 3 μmol kg^{-1} between measured and calculated and the same for DIC. ΔpH has an average of 0.008 and in view of this no corrections of pH is suggested. Velo et al. (2009) evaluated the pH data in the CARINA data set, but since there were only three cross-overs for pH in the Arctic Ocean data, the authors drew no conclusions regarding possible adjustments.

3.4 O_2

For oxygen a clear offset in the deep-water averages (>2% from the average) was seen in one cruise in the Nansen Basin (06AQ19930806) and a smaller offset of just about 2% in the Canada Basin (18SN19970924).

3.4.1 The Canada Basin

The following cruises were part of the MLR in the Canada Basin: 18SN19970924 (54) and 32H120020718 (73). The results did not differ substantially between different predictor variables; the largest offset between the cruises was only about 2%. Since the deep-water averages and the MLR are on the limit, the suggestion is not to adjust.

3.4.2 The Makarov and Amundsen Basins

Oxygen MLRs for the Makarov Basin and Amundsen Basin were run, although no results diverged from the conclusions of the deep-water averages.

3.4.3 The Nansen Basin

The following cruises were part of the MLR in the Nansen Basin: 06AQ19930806 (1), 18SN19940724 (47), 77DN19910726 (177), 77DN20020420 (179) and 77YM19800811 (180).

Figure 9 shows an offset for 06AQ19930806, which was also indicated in the deep-water averages. However, 77YM19800811 is also clearly offset. Looking closer at 06AQ19930806 and 77YM19800811 and the predictor variables, the 06AQ19930806 cruise seems to have a lower deep-water average in NO_3 as well as oxygen and 77YM19800811 seem to be low in NO_3 and PO_4, while the deep-water average for oxygen is not far off from the other cruises. Changing the predictor variables to exclude NO_3 and also other nutrients was done. The results were similar in the sense that the 06AQ19930806 cruise showed an offset of 14–20 μmol. 77YM19800811 varies between having a small offset (>2%) to having no offset. Excluding NO_3 keeps 77YM19800811 within the limits and it is likely that this seems to be a question about the NO_3 being too low rather than the oxygen being too high for this cruise.

3.5 Nutrients

3.5.1 The Canada Basin

For the Canada Basin the deep-water averages for NO_3, PO_4 and Si are not significantly (>2%) offset between the different cruises, as can be seen in Table 4. MLRs in this basin support this. Testing different sets of predictor variables such as AOU/PO4, AOU/Si or Si/PO4 or running MLRs of the other nutrients yielded the same results.

3.5.2 The Makarov Basin

In the Makarov Basin deep-water averages, the NO_3 concentration for 06AQ19960712 is quite a bit lower than the other cruises in this basin. This is also seen in the Amundsen and Nansen Basin, often with slightly lower PO4 concentrations. In the MLR it is instead 18SN19940724 that shows up a little bit on the high side (Fig. 10). Using other predictor variables does not give evidence either for a large enough negative offset for 06AQ19960712 or positive offset for 18SN19940724 to justify a correction of data. The P:N ratios for these cruises are the same: 1:14. The Si concentrations in the deep-water differ quite a bit, however when running MLRs, only small offsets are found.

3.5.3 The Amundsen Basin

In the Amundsen Basin again the 06AQ19960712 cruise has a lower deep-water average of NO_3 than the others and the Si values are quite varied. The results are quite similar to the Makarov runs. No conclusive offsets.

3.5.4 The Nansen Basin

In the Nansen Basin the clearest offsets in the deep-water nutrient averages are the NO_3 average of the 06AQ19930806 cruise, the Si average of the 18SN19940724 cruise and the NO_3 and PO4 averages of the 77YM19800811 cruise. The latter cruise also has rather low Si concentrations. Although this can be explained by the fact that the deep stations are close to Fram Strait and the deep-water concentrations of Si seem to decrease in this area this does not explain the very low NO_3 values. In Fig. 11 the offset in NO_3 for 77YM19800811 is quite clear and changing the predictor variables does not change the offset significantly.

Since 77YM19800811 does not contain any carbon parameters in the CARINA data product, has few deep stations in the Arctic Ocean proper and is clearly offset in NO_3 and PO_4, the suggestion is to exclude this cruise. Figure 11 does not however show an offset for NO_3 from the 06AQ19930806 cruise. However, when removing AOU as a predictor variable, since it was earlier determined to be offset for 06AQ19930806, the result show a clear negative offset of NO_3 for 06AQ19930806. Changing predictor variables between PO4 and Si does not change this result. Therefore the suggestion is to adjust NO_3 for the 06AQ19930806 cruise. The high Si in the deep-water average for 18SN19940724 does show up to some extent in the MLR, but since this is not the case for the other basins and there are only a few stations for 18SN19940724 in the Nansen Basin there is no suggestion to adjust.

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4 Suggestions for adjustments

TCO_2: No adjustments suggested.

TA: 18SN19940724 is offset by 24 μmol kg^{-1} and should be adjusted downwards by this amount.

pH: No adjustments suggested.

O_2: 06AQ19930806 needs to be adjusted upwards by 7%.

Nutrients: Excluded 77YM19800811 from the synthesis, and NO_3 concentrations for 06AQ19930806 needs to be adjusted upwards by 5%.

Salinity: No corrections suggested based on deep water averages and primary QC.

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Table 1. Cruises included in the Arctic Ocean synthesis in CARINA.

Cruise #	EXPOCODE	AREA	Country, Institution	Chief Scientist	# stations, (# samples)
2	06AQ19930806	Arctic Ocean	Germany, AWI	D. K. Fütterer	63, (506)
3	06AQ19960712	Arctic Ocean	Germany, AWI	E. Augstein	102, (2481)
45	18RD19980404[a]	North Water Polynya	Canada, IOS	L. Fortier H. Melling	348, (6757)
46	18RD19990827	Arctic Ocean	Canada, IOS	L. Fortier, H. Melling	40, (464)
47	18SN19940724	Arctic Ocean	Canada, SIO	K. Aagaard	39, (1269)
48	18SN19970803	Arctic Ocean	Canada, IOS	F. McLaughlin, K. Faulkner	24, (424)
49	18SN19970831	Arctic Ocean	Canada, IOS	F. McLaughlin, K. Faulkner	26, (379)
50	18SN19970924	Arctic Ocean	Canada, IOS	F. McLaughlin, K. Faulkner	16, (475)
72	32H120020505[a]	Arctic Ocean	USA		36, (1579)
73	32H120020718	Arctic Ocean	USA	J. M. Grebmeier, L. W. Cooper	44, (1857)
74	32H120030911[a]	Arctic Ocean	USA		186, (1197)
75	32H120040515[a]	Arctic Ocean	USA	J. Swift, L. Codispoti	35, (1116)
76	32H120040718[a]	Arctic Ocean	USA	J. Swift, L. Codispoti	60, (2155)
77	32H120040910	Arctic Ocean	USA	J. Swift, L. Codispoti	117, (1555)
82	32PZ20020715	Arctic Ocean	USA	J. Swift, L. Codispoti	63, (506)
83	320620030705	Arctic Ocean	USA, Scripps	J. Swift, L. Codispoti	326, (3642)
123	58AA19991003[a]	Storfjorden	Norway, UIB	A. Omar, A. Olsen	71, (374)
124	58AA20000923[a]	Storfjorden	Norway, UIB	S. Osterhus	168, (502)
126	58AA20010822[a]	Storfjorden	Norway, UIB	R. Skogseth	69, (266)
145	58JM20030710[a]	Barents Sea	Norway	P. Wassmann	4, (258)
146	58JM20040724[a]	Barents Sea	Norway	P. Wassmann	7, (79)
147	58JM20050520[a]	Barents Sea	Norway	P. Wassmann	9, (106)
148	58LA19860719[a]	Barents Sea			11, (55)
177	77DN19910726	Arctic Ocean	Sweden, UGOT	L. Anderson, J.-E. Hellsvik	54, (1618)
178	77DN20010717	Arctic Ocean	Sweden	G. Björk	30, (360)
179	77DN20020420[b]	Nordic Seas	Sweden, UGOT	L. Anderson	92, (1569)
180	77YM19800811	Arctic Ocean			63, (1072)
181	90AQ19940706	Arctic Ocean			75, (137)

[a] These cruises have been through primary QC and are in the data product, but they have not been through the repeated primary QC or the secondary QC.
[b] One section in the Fram Strait was used for comparisons, for more details of this cruise see the Nordic Seas papers.

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Table 2. Overview of the inorganic carbon parameters.

EXPOCODE	Country, Institution	P.I. Carbon data	# TCO_2 stat., (# samples)	# TA stat., (# samples)	CRMs used:	# pH stat, (# samples)
06AQ19930806	Sweden, UGOT	L. Anderson	NA	NA		NA
06AQ19960712	Sweden, UGOT	L. Anderson	78, (1221)	62, (918)	Yes	82, (1277)
18RD19980404	Canada, IOS?	L. Miller, D. Wallace, T. Yager	72, (737)	63, (567)	Yes	NA
18RD19990827	Canada, IOS	L. Miller, D. Wallace, T. Yager	40, (389)	40, (319)	Yes	NA
18SN19940724	Canada, SIO	E. P. Jones, K. Azetsu-Scott	39, (1234)	38, (917)	Yes	NA
18SN19970803		E. P. Jones, K. Azetsu-Scott	24, (328)	24, (328)	Yes	NA
18SN19970831	Canada, SIO	E. P. Jones, K. Azetsu-Scott	26, (328)	26, (303)	Yes	NA
18SN19970924	Canada, SIO	E. P. Jones, K. Azetsu-Scott	16, (352)	16, (319)	Yes	NA
32H120020505		N. Bates	28, (330)	28, (328)	Yes	NA
32H120020718[a]		N. Bates	42, (475)	NA	Yes	NA
32H120030911			NA	NA		NA
32H120040515		N. Bates	31, (308)	31, (305)	Yes	NA
32H120040718		N. Bates	56, (467)	55, (453)	Yes	NA
32H120040910			NA	NA		NA
32PZ20020715			NA	NA		NA
320620030705			NA	NA		NA
58AA19991003	Norway, UIB	A. Omar	61, (286)	59, (275)	Yes	NA
58AA20000923	Norway, UIB	A. Omar	168, (500)	168, (493)	Yes	NA
58AA20010822	Norway, UIB	A. Omar	68, (261)	68, (256)	Yes	NA
58JM20030710	Norway, UIB	R. Bellerby, C. Kivimäe	4, (253)	4, (203)	Yes	NA
58JM20040724	Norway, UIB	R. Bellerby, C. Kivimäe	7, (79)	5, (56)	Yes	NA
58JM20050520	Norway, UIB	R. Bellerby, C. Kivimäe	9, (104)	9, (101)		NA
58LA19860719	Sweden, UGOT	L. Anderson	7, (33)	7, (33)	No	11, (53) Titrated
77DN19910726	Sweden, UGOT	L. Anderson	45, (1105)	44, (1127)	No	NA
77DN20010717	Sweden, UGOT	L. Anderson	NA	30, (355) stored!	Yes	NA
77DN20020420	Sweden, UGOT	L. Anderson	91, (1386)	92, (1498)	Yes	92, (1503)
77YM19800811			NA	NA		NA
90AQ19940706	Sweden, UGOT	L. Anderson	22, (77)	74, (136)		NA

[a] Samples were stored and analysed on shore.

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Table 3. Overview of the nutrient and oxygen data.

EXPOCODE	Country, Institution	P.I Nutrients/Oxygen	# NO_3 stat., (# samples)	# PO4 stat., (# samples)	# Si stat., (# samples)	# O_2 stat., (# samples)
06AQ19930806	Germany, AWI		63, (474)	63, (494)	63, (495)	NA
06AQ19960712	Germany, AWI		102, (2410)	102, (2421)	102, (2359)	102, (2431)
18RD19980404	Canada, IOS?	J.-E. Tremblay, K. Cochran	133, (1365)	123, (1275)	129, (1182)	64, (661)
18RD19990827	Canada, IOS?	J.-E. Tremblay	NA	NA	NA	NA
18SN19940724	Canada, SIO		38, (1084)	39, (1090)	38, (1037)	39, (1059)
18SN19970803			24, (360)	24, (357)	24, (357)	24, (354)
18SN19970831			NA	NA	NA	NA
18SN19970924	Canada, IOS	F. McLaughlin, K. Faulkner	16, (452)	16, (452)	16, (452)	16, (475)
32H120020505	USA		35, (1495)	35, (1498)	35, (1498)	34, (1429)
32H120020718	USA	L. Codispoti	44, (861)	44, (861)	44, (861)	44, (721)
32H120030911	USA		162, (938)	167, (968)	167, (967)	152, (833)
32H120040515	USA	L. Codispoti	35, (590)	35, (588)	35, (590)	35, (455)
32H120040718	USA	L. Codispoti	60, (1309)	60, (1310)	60, (1311)	60, (972)
32H120040910	USA	J. Swift	113, (833)	113, (833)	113, (833)	113, (783)
32PZ20020715	USA	J. Swift	59, (474)	63, (494)	63, (495)	NA
320620030705	USA	L. Codispoti	326, (3447)	326, (3446)	326, (3447)	326, (3434)
58AA19991003	Norway, IMR		71, (370)	71, (372)	71, (367)	NA
58AA20000923	Norway, IMR	A. Omar, A. Olsen	168, (492)	167, (496)	168, (499)	168, (492)
58AA20010822		A. Omar	NA	NA	NA	69, (259)
58JM20030710	Norway, UIB	R. Bellerby	4, (246)	4, (244)	4, (245)	NA
58JM20040724	Norway, UIB	R. Bellerby	7, (76)	7, (78)	7, (78)	NA
58JM20050520	Norway, UIB	R. Bellerby	9, (104)	9, (104)	9, (105)	NA
58LA19860719			11, (55)	8, (41)	11, (55)	11, (55)
77DN19910726		G. Kattner, L. Anderson	54, (1601)	49, (1483)	54, (1602)	54, (1502)
77DN20010717			NA	NA	NA	NA
77DN20020420	USA, Scripps	J. Swift/E. Falck	92, (1566)	92, (1564)	92, (1565)	92, (1546)
77YM19800811	Sweden, UGOT	L. Anderson	23, (262)	22, (250)	22, (249)	22, (242)
90AQ19940706			NA	NA	68, (130)	21, (83)

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Table 4. Deep-water averages (depth >2500 m).

EXPOCODE	TCO_2	TCO_2-35	TA	TA-35	pH	O_2	NO_3	PO4	Si	Sal
Canada Basin:										
18SN19970924	2154±3.4	2157±3.4	2299±4.6	2302±4.6	NaN	278.3±2.6	14.3±0.1	1.02±0.01	13.4±0.5	34.9554±0.0013
32H120020718	2149±1.2	2152±1.2	NaN	NaN	NaN	285.0±1.3	14.5±0.1	1.03±0.01	13.2±0.5	34.9549±0.0013
Makarov Basin:										
06AQ19960712	2148±2.4	2150±2.4	2296±2.4	2299±2.4	7.860±0.003	287.6±1.6	13.8±0.1	1.00±0.02	12.6±0.3	34.9519±0.0015
18SN19940724	2159±2.9	2162±2.9	2328±4.3	2331±4.4	NaN	288.7±0.9	14.5±0.04	1.04±0.01	13.4±0.3	34.9531±0.0007
77DN19910726	2157±2.2	2160±2.3	2289±6.5	2292±6.5	NaN	293.2±1.3	14.8±0.07	0.99±0.004	11.9±0.2	34.9544±0.0016
Amundsen Basin:										
06AQ19960712	2153±7.5	2157±7.5	2298±3.4	2302±3.3	7.856±0.004	298.8±0.8	13.7±0.2	0.97±0.02	11.1±0.2	34.9377±0.0054
18SN19940724	2163±1.7	2167±1.8	2326±2.1	2330±2.0	NaN	299.2±0.5	14.5±0.07	1.03±0.007	12.2±0.2	34.9339±0.006
77DN19910726	2149±4.7	2154±4.5	2291±11	2295±12	NaN	302.1±2.0	14.5±0.1	0.97±0.01	10.9±0.2	34.9361±0.0064
Nansen Basin:										
06AQ19930806	2150±3.1	2154±3.2	NaN	NaN	NaN	278.9±1.7	13.6±0.4	0.97±0.06	11.4±0.4	34.9327±0.0052
06AQ19960712	2155±2.8	2159±2.8	NaN	NaN	7.855±0.005	298.5±1.3	14.3±0.3	0.97±0.02	11.3±0.3	34.9381±0.0047
18SN19940724	2159±1.7	2163±1.7	2320±4.0	2324±3.8	NaN	298.9±1.1	14.5±0.04	1.03±0.01	12.9±0.3	34.9374±0.0031
77DN19910726	2153±4.1	2157±4.1	2298±6.7	2302±6.7	NaN	299.3±2.6	14.7±0.2	0.98±0.02	11.1±0.2	34.9399±0.0044
Fram Strait:										
77DN20020420	2149±3.2	2153±3.2	2304±3.5	2308±3.3	7.885±0.005	302.4±2.0	14.7±0.1	0.97±0.02	10.7±0.1	34.9314±0.0074
77YM19800811	NaN	NaN	NaN	NaN	NaN	303.2±4.9	12.3±0.2	0.86±0.03	10.3±0.7	34.9313±0.0111

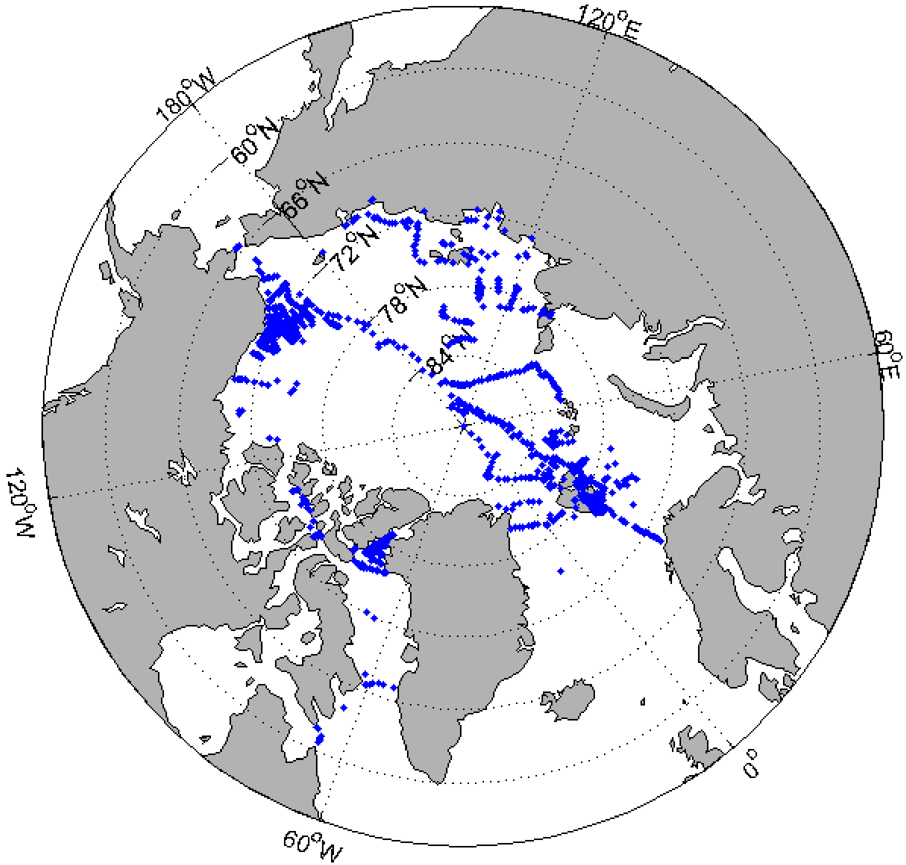

Fig. 1. Map of all station locations of cruises included in Table 1.

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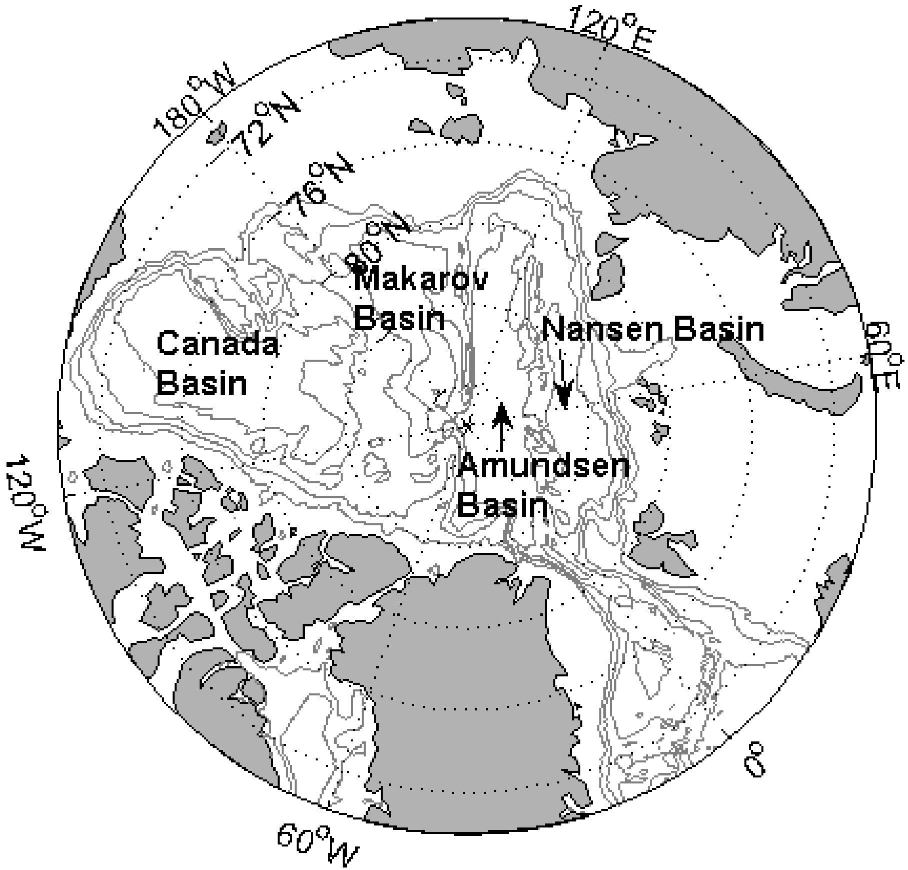

Fig. 2. The basins of the Arctic Ocean.

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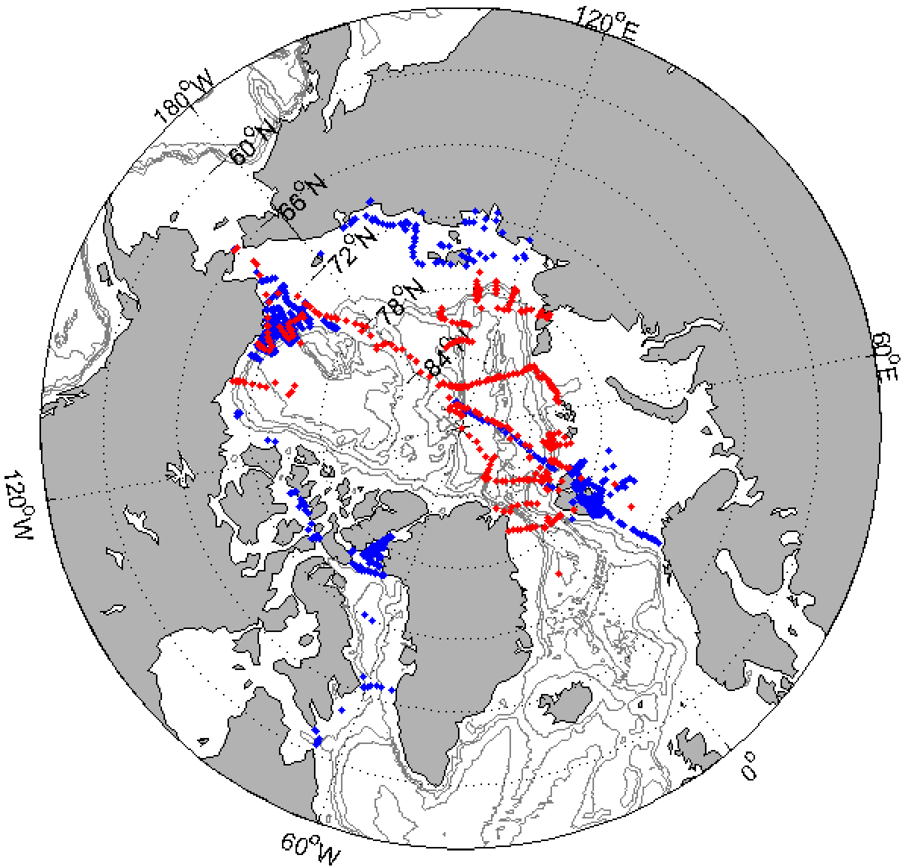

Fig. 3. Map of all station locations of the cruises included in the secondary QC.

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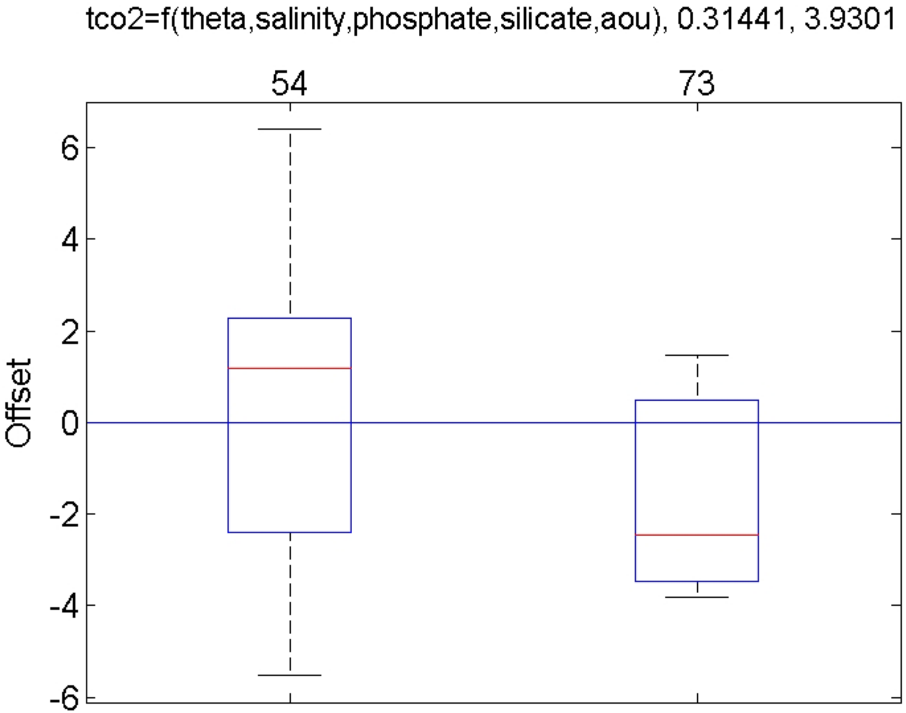

Fig. 4. MLR results for TCO_2 in the Canada Basin (offsets in μmol kg^{-1}).

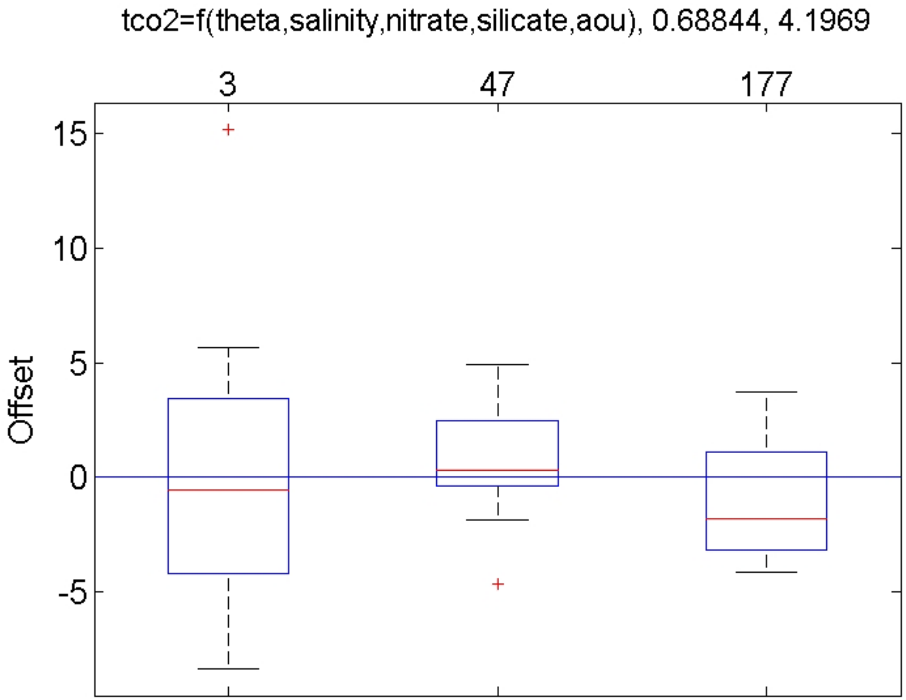

Fig. 5. MLR results for TCO_2 in the Makarov Basin (offsets in μmol kg^{-1}).

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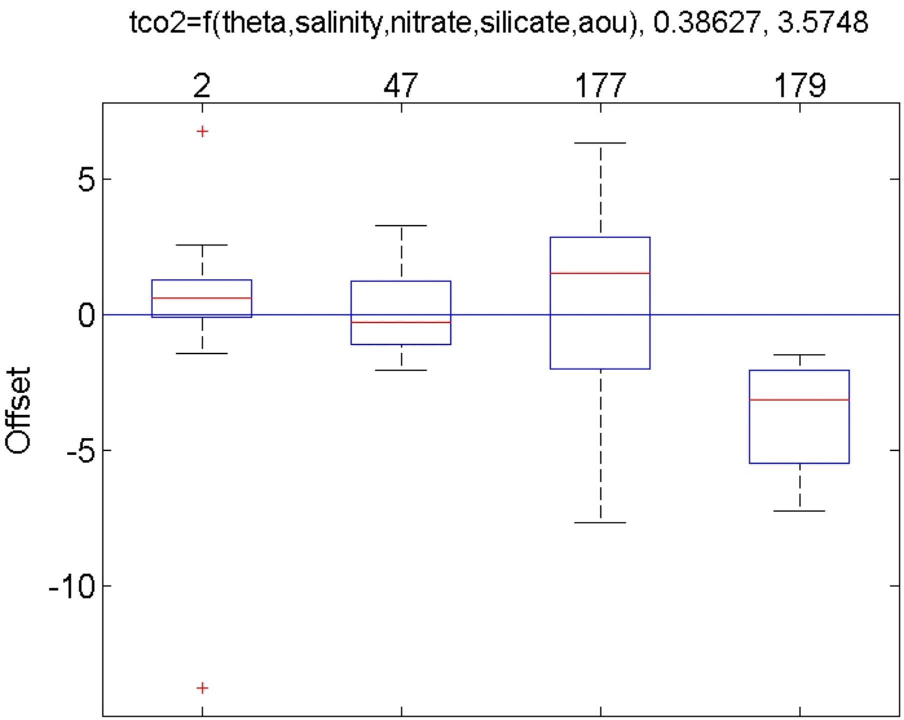

Fig. 6. MLR results for TCO_2 in the Nansen Basin (offsets in μmol kg^{-1}).

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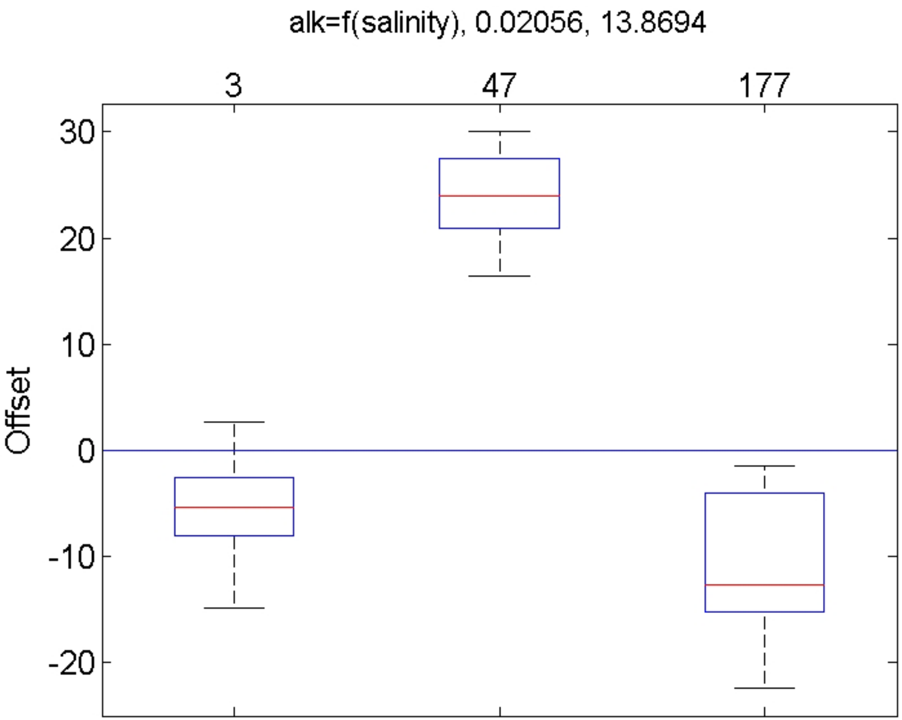

Fig. 7. MLR results for TA in the Makarov Basin (offsets in μmol kg^{-1}).

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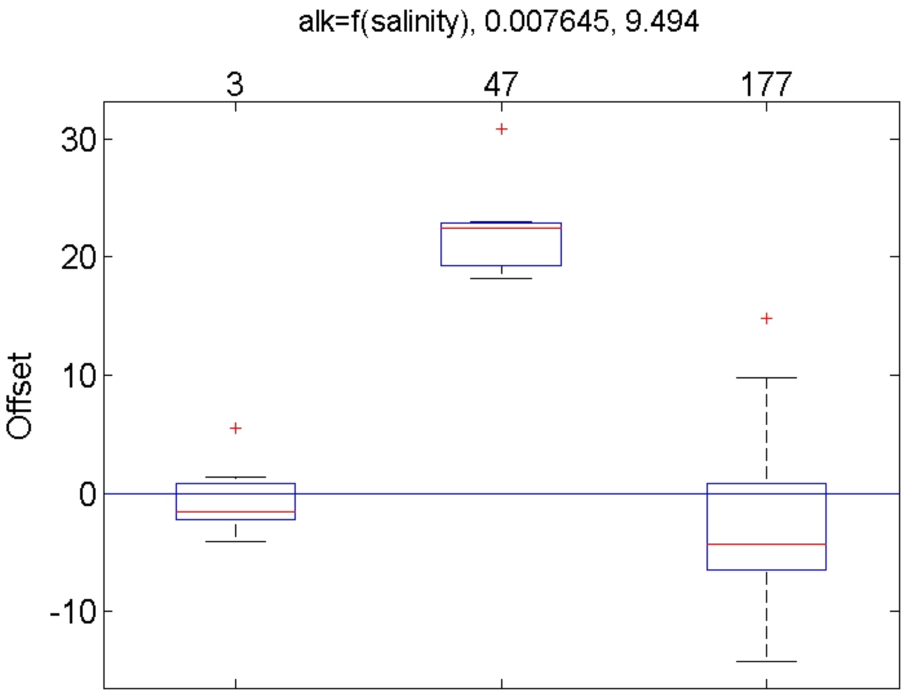

Fig. 8. MLR results for TA in the Amundsen Basin (offsets in μmol kg^{-1}).

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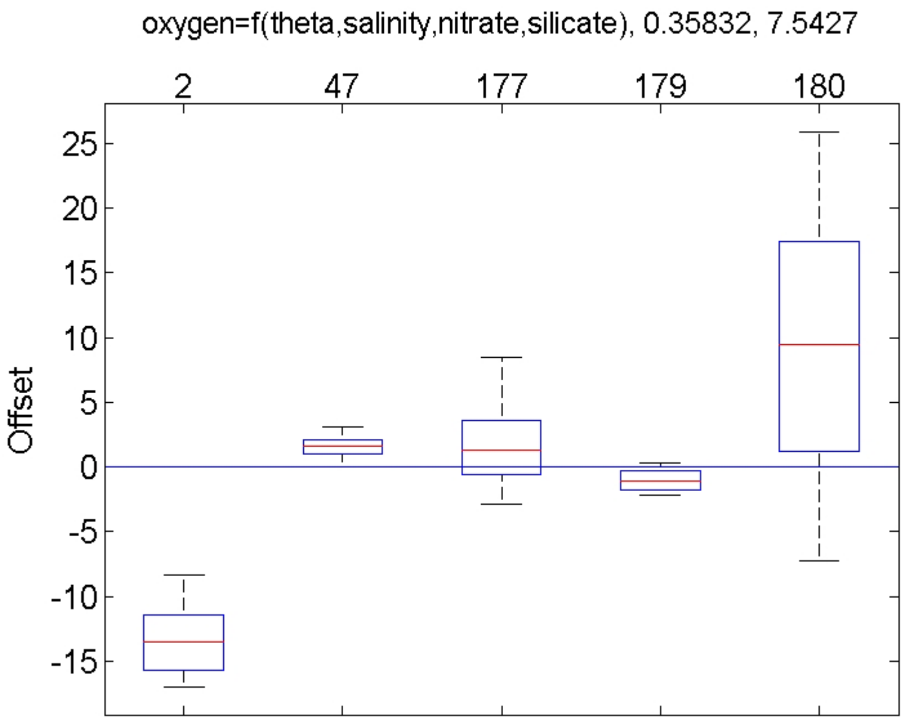

Fig. 9. MLR results for O_2 in the Nansen Basin (offsets in μmol kg^{-1}).

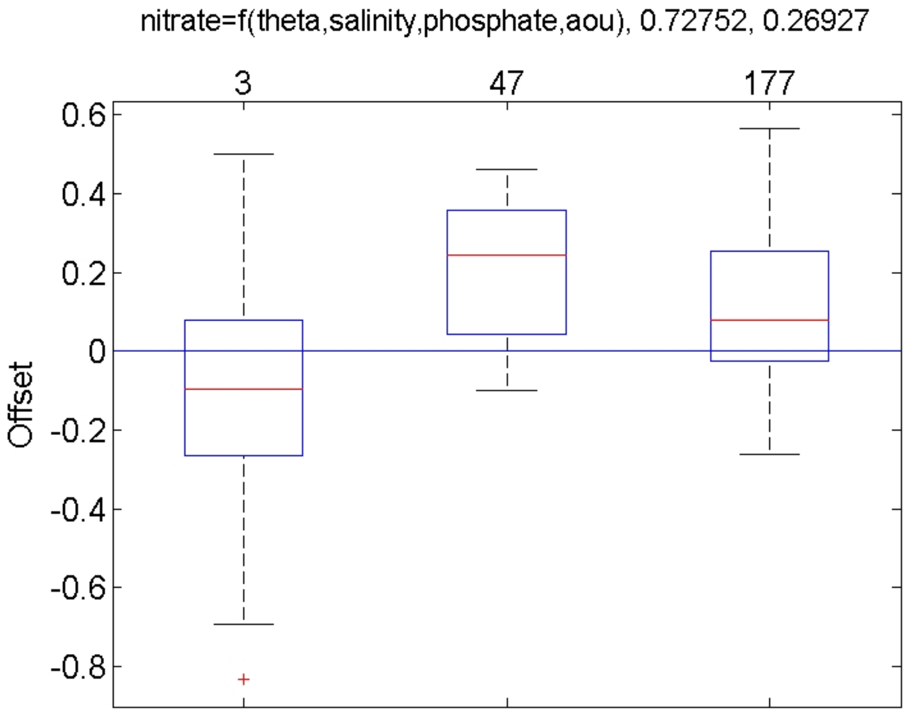

Fig. 10. MLR results for NO_3 in the Makarov Basin (offsets in μmol kg^{-1}).

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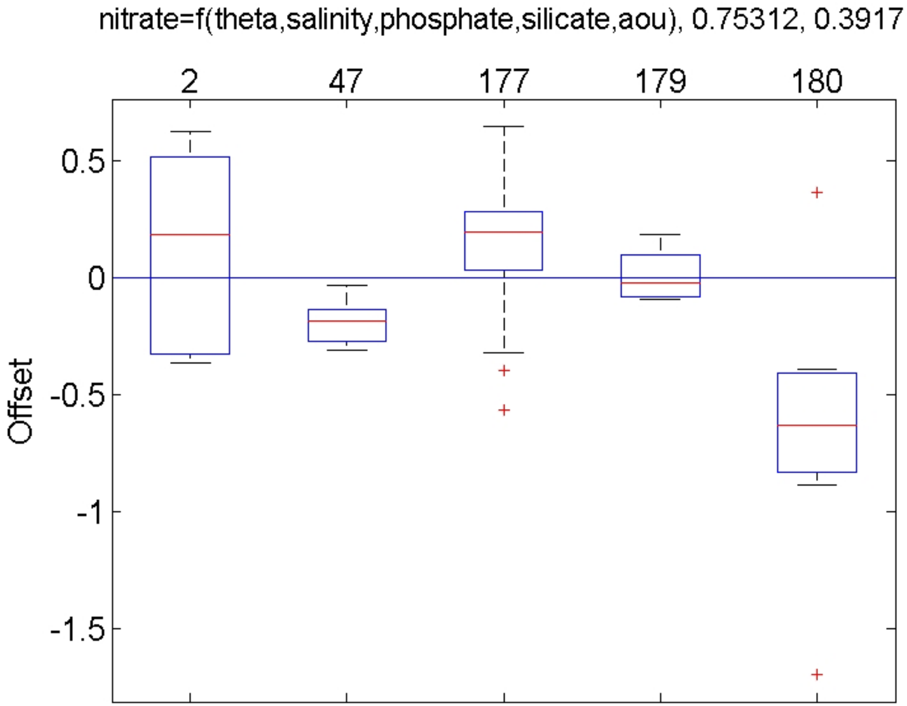

Fig. 11. MLR results for NO_3 in the Nansen Basin (offsets in μmol kg^{-1}).

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