Collaborative Research on the Northeast Water Polynya: NEWP92
Hydrographic Data Report
USCGC *Polar Sea* Cruise, July 15 - August 15, 1992

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Introduction

The Northeast Water Polynya (NEW) off the northeast coast of Greenland was the focus of two cruises aboard the USCGC *Polar Sea* during the summers of 1992 and 1993. The cruises were supported by the National Science Foundation Arctic Systems Science (ARCSS) program and were part of the Arctic Ocean Science Board's International Arctic Polynya Program. The Polar Sea cruises were designed as multidisciplinary studies to test hypotheses about the mechanisms of heat, water and carbon flow within and beyond the boundaries of the polynya. Preliminary results of the 1992 study have been described elsewhere (NEWATER, 1993). A collection of papers arising from the 1992 cruise have been published in a Special Section of the Journal of Geophysical Research (Overland et al., 1995).

This data report presents the hydrographic and basic chemical observations made from CTD/Rosette casts during the 1992 cruise. The station positions cruise are plotted in Figure 1. Also included in the report are selected section plots and vertical profiles. A total of 130 CTD casts were made during the cruise, measuring pressure, temperature, conductivity, dissolved oxygen, fluorescence and light transmission. Discrete samples were collected in 10-liter, rosette-mounted, Niskin bottles and analyzed, from most casts, for: salinity, dissolved nutrients, dissolved oxygen, anthropogenic halocarbons (e.g., Freon gases), pigments, particulate organic carbon and nitrogen. Suspended particulate matter was analyzed at selected stations and these data were used to calibrate the CTD-transmissometer. Samples were collected from selected stations and depths for tritium and helium analyses, carbonate chemistry, as well as for measurements of bacterial abundance.

All the data listed in this report are currently stored in a remotely-accessible database at Brookhaven National Laboratory, access to which can be arranged on request (contact: D. Wallace). In addition, the entire NEWP92 and NEWP93 dataset is to be published in CD-ROM format by the National Snow and Ice Data Center, University of Colorado, Boulder, CO. The hydrographic data will also be submitted to NOAA's National Oceanographic Data Center.

Description of Methods:

Header Data:

Ice cover refers to bridge observations made by Coast Guard personnel at or close to the time of sampling. Specifically, ice cover at any particular station has been estimated from linear interpolation of the hourly bridge observations which were initially recorded in tenths. It should be noted that the ice cover in this region was often highly variable in time, as well as in space.

CTD Data:

<u>CTD/Rosette Sampling.</u> CTD data were collected using a Neil Brown Instrument Systems Mark III CTD underwater unit with a model 1150 deck data terminal. The CTD was equipped with a Beckman oxygen sensor and interfaced with a SeaTech fluorometer, and a 25cm path-length SeaTech transmissometer.

All underwater instrumentation was mounted on a General Oceanics rosette multi-bottle sampler, model 1015-12. The rosette was equipped with 11 x 10-liter Niskin bottles, and a single 5-liter bottom-tripped bottle. The bottom-trip switch was triggered when a weight suspende from a lanyard one meter beneath the rosette contacted the bottom.

CTD data were collected and displayed in real-time on a PC-486 computer using Oceansoft I software from EG&G Marine Instruments.

CTD Data Processing. The raw CTD data were transferred to a MicroVAX for processing. Large spikes were removed using a gradient check and 0.1 dbar averages were calculated. For each cast, data were extrapolated to the bottom depth. Any obvious large-amplitude spikes that remained in the raw data variables (pressure, temperature, conductivity, oxygen current, oxygen temperature, fluorometer and transmissometer) were edited and replaced by interpolation. Additionally, any missing values were filled in by linear interpolation.

To reduce the spikes caused in the calculation of salinity, a three-point moving average was first performed on conductivity to create a smooth signal. A lag of .4 was then applied to conductivity to better match the conductivity sensor with the temperature sensor. After final calibrations were applied to the CTD data, derived variables (depth, potential temp, salinity, oxygen in %-saturation and µmole kg^{-1}, c_p, SPM, sigma-t, sigma-p, sigma-1000, sigma-theta, Brunt-Vaisalla frequency, integrated density, steric height and freezing point) were calculate and then averaged using a pressure-centering procedure.

CTD Data Calibration. CTD data were calibrated solely with in situ methods and did not employ the use of pre- or post-cruise laboratory calibrations.

1. Pressure. A pressure offset of -0.5 dbar was applied to each CTD cast in its entirety. This correction accounted for the difference between the true and actual distance measured by the CTD pressure sensor at the surface of the water.
2. Temperature. CTD temperature was calibrated based on a linear regression with two in situ SIS reversing thermometers. A reiterative procedure produced the following relationship:

$$\text{Corr T} = .996306 * \text{CTD T} + .002380,$$

which had a standard deviation of 0.007°C.

3. Conductivity. Final conductivity corrections were derived from a reiterative linear regression of upcast CTD conductivity and in situ bottle conductivity (inverted from salinity using corrected pressure and temperature). A pressure edit greater than 30 was used to eliminate bottles taken in the chlorophyll max layer. Time-series plots of water sample data minus CTD upcast conductivity differences were constructed to determine station subgroups. Three groups were identified, giving the following slope and bias terms, and their respective standard deviations:

CTD 1 - 89	Corr C =	.998553 * CTD C + .063721	Std. dev. 0.007
CTD 90 - 97	Corr C =	.953416 * CTD C + .032105	Std. dev. 0.011
CTD 98 - 130	Corr C =	.933751 * CTD C + .033966	Std. dev. 0.005

4. Oxygen. Using the corrected pressure, salinity and temperature values, CTD values of oxygen were calculated from the upcast oxygen current and oxygen temperature sensors, following the algorithm of Owens and Millard (1985). Final oxygen coefficients were derived from reiterative linear regression of CTD upcast oxygen and in situ water sample oxygen, both in units of percent saturation. The same pressure edit criterion (P > 30) was used as stated above. Time-series plots yielded two groups, giving the following terms:

CTD 1-100 Corr Ox % = .991460 * CTD Ox % + .068328 Std. dev. 0.0099

CTD 101-130 Corr Ox % = .851967 * CTD Ox % + .139818 Std. dev. 0.0097

5. Transmissometer. Transmissometer data were calibrated by correlation with gravimetric analysis of suspended particulate loads. Between 1 and 10 liters of water were vacuum-filtered in-line from 10l water bottles through pre-weighed 0.4 µm Poretics PCTE membrane filters. The filters were rinsed in a laminar flow hood ten times with distilled, deionized and 0.4 µm filtered water, then air dried in the hood. At least one filter was put through this process during each cast without exposing it to seawater to establish an average blank value for methodological corrections. On deck transmissometer voltages were monitored throughout the cruise to assure clear optical pathways. Air calibrations of the transmissometer used were made in the lab at the beginning and end of the cruise to correct for any decay of the LED beam intensity. Readings with the light path blocked and unblocked were made through the CTD electronics prior to several casts to test for any voltage losses through the CTD. Percent transmission was recorded through the CTD and converted to a total beam attenuation coefficient (c) using the equation:

$$V/5 = T = e^{-cz}, \qquad (1)$$

where V is the instrument voltage output, 5 is the maximum voltage of the transmissometer output, T is percent transmission, c is the beam attenuation coefficients with units of m^{-1}, and z is the optical pathlength in meters. Thermal hysteresis was not corrected for because the thermal variability was small (<5°C) between the on-deck temperature and through the water column, and little or no hysteresis was apparent from comparison of up and down traces.

The beam attenuation coefficient in natural seawater is a summation of the beam attenuation coefficients for seawater (c_w, "yellow matter" (c_y), and particles (c_p) (Pak et al. 1988):

$$c = c_w + c_y + c_p. \qquad (2)$$

The contribution of c_w is constant and is set at the factory to equal 0.364 m^{-1} in particle-free water for this instrument. At 660 nm, c_y is assumed constant and negligible (Bricaud et al., 1981; Gardner et al., 1993). To obtain c_p, c was calculated from the transmission values. The minimum value, c_{min}, for the cruise was subtracted from all c values to yield a pre-adjusted c_p (beam attenuation due to particles alone). Linear fits were performed between the pre-adjusted c_p values and the suspended particulate matter (SPM) concentrations obtained from the water filtered from the rosette water bottles. The data were split at a c_p = 0.25, essentially dividing the near surface data from the rest of the water-column. The x-intercept value from the c_p < 25 relationship was subtracted from the pre-adjusted c_p to obtain a c_p that was zero for a particle mass

concentration of zero. The two linear fits were then equilibrated at c_p = 0.453 to yield a single relationship between c_p and SPM concentration for the entire range of transmissometer data.

Bottle Data

BNL_ID: Each Niskin bottle closed during the cruise was assigned a unique identifier number that was incremented throughout the cruise; this same number was used to identify all sub-samples collected from that particular Niskin. This 'BNL_ID' number was subsequently used to merge data arising from various analytical procedures into a single database.

Dissolved Oxygen: Sub-samples for Winkler titrations were drawn into ~125 ml flasks immediately after the rosette was brought on deck and samples had been withdrawn for chlorofluorocarbon analyses. These samples were analyzed following the methodology described by Carpenter (1965). Subtle changes to methodology and calibration as described by Culberson (1991) were implemented, so that the oxygen data meet the precision and accuracy guidelines of the World Ocean Circulation Experiment (WOCE, 1991): namely accuracy <1% and precision ~0.1%.

Dissolved Nutrients: Sub-samples of ~60 ml were drawn from the Niskin bottles within 10-20 minutes of the cast being complete. Phosphate, silicate, nitrate, nitrite and ammonium were measured as soon as possible after sample collection (usually within a few hours) using a Technicon Autoanalyzer II, following standard colorimetric methods. The methods used have been described in Whitledge et al. (1981) with the exception of the phosphate determination which used the hydrazine reductant method described in Gordon et al. (1992). Standards were analyzed with each batch of samples in order to compensate for instrument response drift. Standards were prepared in both distilled, deionized water and low-nutrient surface seawater to determine the salt-effect on colorimeter response. The wash water was distilled, deionized water.

Total Dissolved Inorganic Carbon and Total Alkalinity: Samples were collected in 500 ml ground-glass stoppered bottles, to which 200 µl of 50%-saturated $HgCl_2$, was added. A headspace was introduced to allow for expansion, and the bottle was then tightly stoppered. The stopper was coated with Apiezon grease, and held firmly in place with elastic-bands. Samples were kept cool (~5°C) following collection and prior to analysis. Subsequently they were analyzed in the laboratory at Brookhaven National Laboratory for total dissolved inorganic carbon by coulometric titration (using a SOMMA system: Johnson and Wallace, 1992; Johnson et al., 1993). Small corrections were applied to account for the loss of CO_2 gas to the headspace, and for the dilution of the sample due to addition of $HgCl_2$. Total alkalinity analyses were performed subsequently on the same samples at the Woods Hole Oceanographic Institution (Dr. Catherine Goyet's laboratory) using potentiometric titration in a closed, glass cell.

Pigments: Subsamples (~280 ml) were filtered through Gelman GF/F glass fiber filters (~0.7 µm nominal pore size). The filters were sonicated (on ice, in darkness) for 10 minutes in glass 15 ml centrifuge tubes together with 10 ml of 90% acetone. The samples were extracted in the dark for an additional 15 minutes and read using a Turner Designs Model 10 fluorometer before and after acidification (Smith and Nelson, 1990). The fluorometer was calibrated at the beginning and end

of the cruise using a commercially prepared chlorophyll standard.

Particulate Organic Carbon and Nitrogen: POC and PON were quantified by filtering samples onto precombusted (450°C for 2 hours) GF/F Whatman glass fiber filters, placing them in combusted glass vials, drying the filters at 60° C, and analyzing them on a Carlo-Erba model EA1108 elemental analyzer after high-temperature pyrolysis.

Tritium and Helium: For tritium analysis, 1-liter water samples were drawn from the Niskins into glass bottles, which had been previously filled with argon gas. These bottles were capped with a minimum of head-space and transferred to the laboratory. In the laboratory the samples were transferred to 1-liter Corning 1724 glass flasks in a vacuum line, degassed, sealed, and placed in a storage freezer at -20°C. After about 8 months, accumulated ^{3}He in the flask was measured in a MAP215-50 mass-spectrometer and the tritium concentration was calculated using calibrated air aliquots as standards, and appropriate correction factors. In addition, a set of NBS standards prepared to have 1 - 2 TU were measured as a check on accuracy. The reproducibility of the NBS standards and duplicate samples was 0.007 TU. Analytical precision was ~2.5% of the measurement or ~0.007 TU, whichever was greater (1 TU = 1 $^{3}He/10^{18}H$). Measurements were decay-corrected to the time of sampling.

For helium analysis, 50 g water samples were sealed in refrigeration-grade copper tubes by clamping, and transferred to the laboratory. In the laboratory, water samples were processed in a vacuum line to seal the helium-neon fraction of the dissolved gas into Corning 1724 glass ampoules. These were then re-processed in the mass-spectrometer inlet line to separate helium from neon, and the helium fraction was admitted into the MAP 215-50 mass-spectrometer. ^{3}He and ^{4}He beams were measured separately, and calibrated with standard air aliquots. The ^{3}He ratio anomaly was expressed as:

$$\delta^{3}He = [\ [(^{3}He/^{4}He)_{sx} / (^{3}He/^{4}He)_{std}\ ] -1] \times 100,$$

where sx and std refer to the sample and the atmospheric standard, respectively. ^{4}He measurements were converted to concentrations by peak height comparison, and were expressed in units of nanomoles per kg (seawater). The precision in $\delta^{3}He$ is ±0.2%; in ^{4}He concentration, it was ±1.0%.

Bacterial Abundance. Water samples were collected aseptically directly from the Niskin bottles immediately after arrival of the CTD on deck. Volumes of 10 ml were fixed in 0.2-µm filtered 2% formaldehyde and stored at 4°C in the dark until processed for counting. We used a dual staining procedure, reported by Deming et al. (1995), to enumerate bacteria. Samples were stained with acridine orange (AO), according to Hobbie et al. (1977), and gently filtered onto a 0.2-µm black Nucleopore filter, followed by DAPI stain (0.001%) according to Porter and Feig (1980). The slide preparations were viewed using a Zeiss epifluorescence microscope. Individual bacteria in 20 randomly selected fields (a minimum of 200 bacteria per slide) were counted routinely using standard optical filters for AO; switching to optical filters for DAPI allowed confirmation that AO-fluorescing particles were microorganisms.

Units: All concentration data are reported in units of per kg (seawater), with the exception of bacterial abundance which is in units of cells per ml.

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NEWP92 STATION LIST

STATION	CAST	CTD-NO	DATE GMT	TIME GMT	LATITUDE DEG.	LONGITUDE DEG.	SONIC DEPTH METERS
1	1	1	7/18/92	08:42	76.526	-6.907	1343
1	2	2	7/18/92	11:15	76.512	-6.966	1304
2	3	3	7/19/92	00:28	77.155	-10.481	488
2	4	4	7/19/92	01:49	77.160	-10.447	476
2	5	5	7/19/92	03:01	77.160	-10.406	472
2	6	6	7/19/92	11:21	77.150	-10.449	487
3	7	7	7/20/92	12:43	78.606	-13.487	142
3	8	8	7/20/92	14:17	78.609	-13.508	139
3	9	9	7/20/92	15:28	78.616	-13.528	137
3	10	10	7/20/92	19:49	78.645	-13.494	168
4	11	11	7/21/92	13:55	80.398	-14.243	337
4	12	12	7/21/92	15:11	80.410	-14.208	333
4	13	13	7/21/92	16:29	80.421	-14.156	330
5	14	14	7/22/92	13:12	80.652	-11.269	238
6	15	15	7/22/92	15:51	80.649	-12.169	260
7	16	16	7/22/92	19:57	80.648	-13.082	222
8	17	17	7/24/92	02:29	80.532	-14.661	208
9	18	18	7/24/92	05:22	80.483	-14.488	324
10	19	19	7/24/92	07:03	80.440	-14.422	301
11	20	20	7/24/92	08:16	80.369	-14.088	314
12	21	21	7/24/92	10:33	80.307	-13.797	286
13	22	22	7/24/92	12:22	80.238	-13.617	175
14	23	23	7/24/92	13:39	80.188	-13.454	185
15	24	24	7/24/92	16:01	80.119	-13.159	75
16	25	25	7/25/92	08:33	80.275	-11.029	199
17	26	26	7/25/92	11:13	80.189	-10.923	121
18	27	27	7/25/92	13:44	80.338	-11.026	253
19	28	28	7/25/92	15:31	80.409	-11.031	315
20	29	29	7/25/92	17:43	80.477	-10.897	290
21	30	30	7/25/92	19:44	80.539	-10.981	257
22	31	31	7/25/92	21:16	80.609	-10.975	267
23	32	32	7/25/92	22:17	80.671	-10.956	181
24	33	33	7/25/92	23:41	80.722	-10.938	111
25	34	34	7/26/92	08:37	80.443	-13.332	288
25	35	35	7/26/92	14:12	80.450	-13.349	306
25	36	36	7/26/92	20:58	80.455	-13.401	305
25	37	37	7/27/92	03:16	80.454	-13.328	301
25	38	38	7/27/92	03:51	80.458	-13.302	301
25	39	39	7/27/92	04:43	80.464	-13.272	302

26	44	44	7/28/92	12:15	80.337	-14.466	344
27	45	45	7/28/92	13:50	80.196	-15.283	271
28	46	46	7/28/92	16:49	80.014	-15.944	418
29	47	47	7/28/72	22:16	80.093	-16.105	187
30	48	48	7/29/92	00:20	80.077	-15.811	350
30	49	49	7/29/92	03:36	80.075	-15.813	354
31	50	50	7/29/92	04:56	80.049	-15.505	275
32	51	51	7/29/92	10:08	80.025	-15.137	234
33	52	52	7/29/92	11:32	79.985	-14.789	149
34	53	53	7/29/92	13:34	79.939	-14.213	85
35	54	54	7/29/92	17:10	80.020	-13.426	83
36	55	55	7/29/92	21:26	80.092	-13.940	154
37	56	56	7/29/92	23:34	80.168	-14.368	248
38	57	57	7/30/92	00:51	80.214	-14.612	332
39	58	58	7/30/92	02:12	80.262	-14.911	380
40	59	59	7/30/92	04:56	80.321	-15.228	272
41	60	60	7/30/92	06:41	80.383	-15.583	93
42	61	61	7/30/92	10:09	80.020	-15.988	437
42	62	62	7/30/92	11:38	80.031	-16.007	388
42	63	63	7/30/92	16:39	80.019	-15.971	450
42	64	64	7/30/92	18:21	80.029	-15.986	450
43	65	65	7/31/92	06:44	80.314	-9.670	313
43	66	66	7/31/92	09:11	80.312	-9.698	312
43	67	67	7/31/92	15:42	80.311	-9.549	308
43	68	68	7/31/92	21:28	80.306	-9.528	309
43	69	69	8/01/92	01:37	80.312	-9.191	305
43	70	70	8/01/92	06:16	80.312	-9.657	312
43	71	71	8/01/92	09:23	80.265	-9.656	303
43	72	72	8/01/92	14:12	80.339	-9.502	306
43	73	73	8/01/92	15:26	80.319	-9.686	315
43	74	74	8/01/92	20:53	80.297	-9.426	314
43	75	75	8/01/92	21:57	80.284	-9.441	310
43	76	76	8/02/92	03:27	80.321	-9.696	316
44	77	77	8/02/92	16:21	80.744	-7.643	175
45	78	78	8/02/92	18:46	80.731	-7.326	276
46	79	79	8/02/92	22:12	80.733	-7.154	356
47	80	80	8/03/92	10:29	80.675	-8.245	69
48	81	81	8/04/92	13:42	80.720	-8.819	58
48	82	82	8/04/92	15:34	80.783	-8.825	61
49	83	83	8/05/92	10:08	80.770	-8.181	76
49	84	84	8/05/92	11:19	80.742	-8.238	75
50	85	85	8/06/92	07:56	80.606	-7.911	101
51	86	86	8/06/92	10:59	80.487	-8.219	249
52	87	87	8/06/92	12:59	80.378	-8.394	255
53	88	88	8/06/92	15:14	80.282	-8.696	292

57	93	93	8/07/92	08:49	80.309	-8.555	283
58	94	94	8/07/92	23:08	80.444	-13.316	285
58	95	95	8/08/92	00:45	80.448	-13.266	292
59	96	96	8/08/92	08:05	80.012	-15.930	425
60	97	97	8/08/92	10:33	79.833	-16.164	236
61	98	98	8/08/92	12:07	79.757	-15.574	211
62	99	99	8/08/92	15:58	79.628	-15.977	200
62	100	100	8/08/92	17:15	79.629	-15.969	196
63	101	101	8/09/92	02:41	79.157	-13.769	126
63	102	102	8/09/92	04:18	79.154	-13.807	123
64	103	103	8/09/92	12:38	79.022	-12.050	216
64	104	104	8/09/92	14:05	79.020	-12.026	219
64	105	105	8/09/92	18:16	79.008	-11.975	220
65	106	106	8/10/92	08:46	78.314	-16.743	525
65	107	107	8/10/92	11:24	78.312	-16.768	512
65	108	108	8/10/92	13:04	78.315	-16.783	515
66	109	109	8/11/92	06:44	77.635	-11.374	271
67	110	110	8/11/92	08:45	77.572	-11.688	440
68	111	111	8/11/92	10:56	77.460	-12.044	490
69	112	112	8/11/92	13:52	77.351	-12.326	321
70	113	113	8/11/92	17:05	77.235	-12.669	261
71	114	114	8/11/92	21:49	77.341	-11.854	414
72	115	115	8/12/92	01:04	77.149	-10.527	486
72	116	116	8/12/92	05:12	77.137	-10.547	490
72	117	117	8/12/92	07:04	77.153	-10.504	490
72	120	120	8/13/92	09:17	77.163	-10.535	478
72	121	121	8/13/92	11:08	77.161	-10.551	485
73	118	118	8/12/92	18:39	77.282	-10.051	350
74	119	119	8/13/92	05:41	77.001	-10.910	385
75	122	122	8/13/92	18:30	76.888	-8.848	363
75	123	123	8/13/92	20:24	76.888	-8.851	363
76	124	124	8/14/92	03:22	77.177	-7.995	287
77	125	125	8/14/92	06:45	77.109	-7.170	266
78	126	126	8/14/92	09:06	76.988	-6.576	273
79	127	127	8/14/92	10:45	76.948	-6.291	697
80	128	128	8/14/92	12:41	76.919	-6.065	1007
81	129	129	8/14/92	15:04	76.850	-5.562	1480
81	130	130	8/14/92	16:50	76.834	-5.561	1490