Collaborative Research on the Northeast Water Polynya: NEWP92 Hydrographic Data Report

USCGC *Polar Sea* Cruise, July 18 - August 20, 1993

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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 hydrographic data report presents a summary of the water property observations made from CTD/Rosette casts during the 1993 cruise. A total of 103 Stations (181 CTD casts) were occupied along the cruise track shown in Fig. 1. The sampling strategy was intended to resolve both the proposed physical objectives and to support the biological/chemical sampling and the current meter/modelling efforts of the collaborating scientists. The sampling of NEWP93 included some refinements, relative to that of NEWP92, in particular an extended coverage of the EGC over the slope and a complete crossing of Belgica Bank.

Physical objectives were met mostly by synoptic transects through dynamically important regions of the Polynya. These were focused on determining the volume and mass fluxes in the Northern and Southern Trough systems and in the East Greenland Current region and in characterizing the water mass structure in a distributed fashion. Some additional physical casts were dedicated to time-series information for internal-wave studies and to moored current-meter calibrations. Chemical and biological objectives were met by analyses of bottle samples during the synoptic transects and some time-seriessampling. Chemical and biological sampling was focussed primarily in the top 70m of the water column with lower density sampling beneath this, in order to allow inventories of biogeochemically active constituents to be assessed for the euphotic zone.

This data report presents the hydrographic and basic chemical observations made from CTD casts during the 1993 cruise. The CTD casts included measurements of 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, total dissolved in organic carbon, the partial pressure of carbon dioxide, pigments, particulate organic carbon and nitrogen, oxygen isotopes of water. Samples were collected from selected stations and depths for measurements of tritium/helium, and bacterial abundance. A few special casts were conducted for radon sampling. Suspended particulate matter was analyzed at selected stations and these data were used to calibrate the CTD-transmissometer.

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 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:

CTD/Rosette Sampling. A SeaBird Electronics, Inc. 911 plus CTD system was used which was equipped with standard temperature, conductivity and pressure sensors along with an optional dissolved oxygen sensor. The temperature, conductivity and oxygen sensors were configured within SeaBird's pumped TC Duct system. Additionally, the CTD was equipped to provide power and twelve-bit analog to digital conversion to as many as eight ancillary sensors and instruments. The water sample package consisted of General Oceanics, Inc. twelve position rosette sampler and ten-liter Niskin bottles. Two Sensoren Instrumente Systeme reversing thermometers were mounted on the second deepest sample bottle as a means for temperature comparison with the CTD. Control of the water sampler was provided by the CTD deck unit and underwater fish along with the acquisition software. A Sea Tech fluorometer and transmissometer, a Biospherical PAR sensor and a Datasonics altimeter complete the suite of equipment utilized in the instrument package. The altimeter provided package distance from the bottom in meters, to a resolution of ten centimeters. Together with the CTD was a mechanical device (rosette) that permitted the closure of water bottles at selected depths. The standard CTD/Rosette Casts involved the lowering the CTD at about 1/2 m s^{-1} in continuous data acquisition from the surface to within several meters of the bottom; and then while returning to the surface, it involved the triggering of the Rosette sampler at a set of standard depths. Normally one of these bottle depths was selected from the downcast data in order to sample certain features, for example, at the depth of the chlorophyll maximum, the salinity maximum, etc.

CTD Data Acquisition. The electrical connection from the underwater unit to the CTD deck unit in the vessel's laboratory passed through a slip ring at the winch. The data were acquired in real- time at a rate of 24 Hz. The Sea-Bird acquisition software SEASOFT, version 4.024 (1993) allowed for real-time plots and parameter monitoring during the actual cast. After the cast, the data were backed up to compressed files, a downcast acquisition plot was made, and an upcast bottle file was printed. Also, the raw data were concurrently archived to audio cassette tape in the form of an exact replica of the CTD telemetry audio signal. Pre-cruise sensor calibration information from the manufacturer was entered in the SEACON routine for all sensors. A header was created for each station with such information as the navigational position, the wind and the sonic depth. The station position corresponded to the vessel's GPS position at the time of the end of the down cast. This information is displayed with the upcast data summaries.

CTD Data Processing. The initial portions of the data processing were done using the Sea-Bird Software (version 4.2) routines.

1. Downcast. The raw data were first converted to engineering units using the routine DATCNV. The ALIGNCTD allows for an alignment of the conductivity and oxygen sensors to that of pressure to insure simultaneous sampling of the same water and to minimize spikes created by the inherent differences in the sensor response times. The conductivity was advanced 0.073 sec in the deck unit and the oxygen 10 sec in the AUGNCTD routine. The appropriateness of these values was checked by experimenting with deviations in these advance times. The FILTER routine was then applied; a 0.03 sec time constant was used for the temperature and conductivity and 0.15 sec time constant was used on the pressure. The CELLTM program was used to compensate for differences in thermal-mass effects between the conductivity cell's glass housing and the water. The raw data were then used to compute other parameters, using the DERIVE routine, and were pressure-bin averaged to 0.1-dbar intervals using the BINAVG routine. An ASCIIOUT program was used to produce an ASCII version of the averaged data for transferring them to a VAX system.

2. Upcast. On receiving the command to close a bottle, the Sea-Bird underwater unit tags 36 scans immediately prior to the bottle closure. The routine DATCNV writes these scans, in oceanographic units, to an output file. The ROSSUM routine computes the parameter averages for each bottle closure from its 36-scan data group and then writes them to an output bottle file. The statistics of the bottle file are checked to prevent the inclusion of spikes or large pressure variations.

CTD Data Calibration.

1. Pressure. The Paroscientific Digiquartz pressure sensor on the CTD has a stated accuracy of 0.015 of full range (6885 dbar). The sensor pressure plus the altimeter (Datasonics) readings were routinely compared with the ship's precision depth recorder (Ocean Data Equipment Corporation). All downcasts were begun at 2.5 dbar to uniformly eliminate electrical spikes in the data caused by the initiation of the pump motor. No further adjustments were made to the pressure parameter.

2. Temperature. Normally the SIS thermometers were used on the next to deepest sample depth, where the temperature gradients are minimal. The quoted accuracy of the SIS thermometers is about ±0.005°C and that of the Sea-Bird thermistor is about ±0.002°C. Scatter plots of the differences between the CTD and SIS temperatures were formed based on envelopes of 2 standard deviations. The final results of this procedure (on a subgroup of 137 out of 275 total observations) revealed a temperature offset of 0.0011°C, with a standard deviation of 0.0017°C. However, the pre-and post-cruise calibrations of the CTD sensor by Sea-Bird showed a change of 0.001°C. Given that the accuracy of the reversing thermometers is less than that of the CTD thermistor, that the standard error of the linear regression was greater than the bias, and that both the laboratory and in situ comparisons were within the accuracy of the stated temperature thermistor of 0.002°C, it was decided not to apply any additional calibration correction to the CTD temperature data.

3. Salinity. Water samples for salinity analysis were taken from one or more depths of each cast for comparison/control with the CTD salinity values. The bottle salinities were analyzed in March 1994 on an AutoSal Guildline Model 8004B salinometer having an accuracy of ±0.003 psu. The Sea-Bird's stated accuracy for salinity is ±0.003 psu. Pre- and post-checks by Sea-Bird of the conductivity sensor indicated a negligible drift of 0.00033 mmho/cm. To compare the CTD and bottle salinities, a scatter plot of their difference was first made with station number to check for any trends or discontinuities in time. There were none. However, the entire set, and even a subset from depths >30 m, showed unacceptably large standard deviations. The variabilities of the bottle CTD data were determined individually, and it was clear that bottle data was the more noisy. For example: the sample standard deviation for the CTD and water sample data was 0.017 psu and 0.026 psu, respectively for P>500 dbar and 0.0077 psu and 0.018 psu, respectively, for P>1000 dbar. The deviations from the bottle data mean value was strongly biased towards higher salinities, which suggested an evaporation error in the bottle samples. Further, comparisons with the HUDSON 1982 salinities from the deep slope water revealed agreement to within ~0.01 psu with the CTD sensor whereas the bottle values were as much as ~0.06 psu higher. Therefore, no additional calibration adjustment to the CTD conductivities was applied.

4. Oxygen. Water samples were analyzed for dissolved oxygen content by Winkler titrations throughout the cruise. CTD values of dissolved oxygen concentration 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 a reiterative linear regression (cf. Millard, 1982) of CTD upcast oxygen and in situ water sample oxygen, both in units of percent saturation. Water samples taken at depths less than 30 dbar were eliminated from the oxygen calibration analysis. This was to eliminate those samples from the euphotic zone that are characteristically more noisy due to photosynthetic production. Time-series plots of water sample data minus CTD upcast oxygen differences were constructed to determine station subgroups. Four subgroups were identified, giving the following slopes, bias terms and their respective standard deviations:

CTD 1- 22	Corrected Ox % = 1.133215 * CTD Ox % - 0.033451;	st. dev. = 0.0047
CTD 23- 53	Corrected Ox % = 1.050866 * CTD Ox % + 0.021588;	st. dev. = 0.0065
CTD 54- 72	Corrected Ox % = 1.128162 * CTD Ox % - 0.090587;	st. dev. = 0.0117
CTD 73-181	Corrected Ox % = 1.030166 * CTD Ox % + 0.006027;	st. dev. = 0.0103

Similar regressions were made with the downcast data, to check the sensor's repeatability under the differing conditions of the down- and upcasts. The fits were slightly noisier (twice the standard deviation) as one might expect due to natural variability. All CTD oxygen (up- and downcasts) values were corrected according to the above relationships.

5. Transmissometer. The beam attenuation of 660 nm light due to particulate matter in seawater

(c_p) was calculated in units of per meter from output transmissometer volts, using the following two equations:

CTD 1- 39 & 87-181 $c_p = (((-\log((tr*1.044)*0.2))/0.25)-0.388)$

CTD 40- 86 $c_p = (((-\log((tr*1.044)*0.2))/0.25)-0.442)$

Linearly related to c_p is the mass concentration of the suspended particulate matter, [SPM], calculated in units of micrograms per kilogram:

$$[SPM] = (c_p *661)/1.025\ \mu g\ kg^{-1}$$

6. For the other sensors (fluorometer, PAR and altimeter) no additional calibrations or treatments were made.

CTD Data Formatting. The processed and calibrated CTD data were archived into the following formats.

1. Raw Data File. The raw data as acquired on board is archived in PKZIP files on diskettes.

2. Calibrated Averaged Files. The calibrations were performed on the 0.1-dbar center-averaged files. These files were transported to a VAX where an extrapolation routine was run to complete the casts in the vertical, i.e. from the first sample (2.5 dbar) to the surface and from the last sample to the bottom (if less than 30 dbar from the bottom). Any edited-out values were filled in by linear interpolation. This is done to permit complete water-column integrations. Those secondary parameters depending on calibrated parameters were re-derived in the 0.1 dbar files. The algorithms for the computation of salinity, density, potential temperature and freezing point were obtained from Fofonoff and Millard (1983). Depth was computed from pressure and the density profiles by inverting the hydrostatic equation i.e. instead of that of the standard ocean (i.e. Saunders and Fofonoff, 1976). The Brunt-Vaisala frequency was also computed from the density profiles (as a function of the calculated depth), as well as integrated density.

Finally, using integrated density, steric height was computed with a reference density of 1.0282 taken to be slightly greater than the maximum for the Greenland Sea Basin, so as to insure positive values for the steric heights.

The data were then pressure-averaged into 1-dbar averages and depth-averaged into 1-m averages. The values were centered averaged except for depth (or pressure), integrated density and steric height which were all equal to their value at the address value (from 0.1-dbar file).

CTD Data Presentation.

1. CTD Downcast Tables. The downcast values presented in the CTD data listings, were from the 1-dbar average file. These list numeric values of parameters as function of pressure. The listed values are spaced every 2 dbar from 0 to 40 dbar, every 5 dbar from 40 to 125 dbar, every 25 dbar from 125 to 400 dbar and every 100 dbar thereafter. Finally, the last 1 dbar record is also listed to give insight into near-bottom values.

Notes on these Tables:

a) Oxygen values at surface should be ignored if O_2 %-saturation is lower than their immediate subsurface values. The fact that the first 10 dbar often display low values is probably due to slow circulation in the TC duct during pump warm-up or to air bubbles not having been completely eliminated.

b) CTD 48 began at 25 dbar, so no surface extrapolation has been made. Depth could not be computed and therefore there are no Brunt-Vaisala, integrated density or steric height values given for that cast.

2. CTD Downcast Plots. The vertical structure of eight principal parameters is presented in 4-panel format for each cast: Salinity & Temperature; Oxygen Saturation & Oxygen Concentration; Sigma-0 & Fluorescence; Steric Height & Suspended Particulate Matter. The parameters are plotted against pressure from the 0.1-dbar averaged files. All casts were cut at 400 dbar in order to have a uniform scale and have adequate vertical resolution.

3. CTD Upcast Data. The CTD parameters which are included in the bottle data tables were taken from the calibrated ROSSUM bottle file.

Bottle Data

Dissolved Oxygen: Sub-samples for Winkler titrations were drawn into ~125 ml flasks immediately after the rosette was brought on deck. 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, filtered, surface seawater to determine the salt-effect on colorimeter response. The wash water was distilled, deionized water.

Total Dissolved Inorganic Carbon and pCO_2: Samples for total dissolved inorganic carbon were collected in 250 ml ground-glass stoppered bottles, to which 100 µl of 50%-saturated $HgCl_2$ was added. Samples were stored on-deck and in-the-dark prior to analysis. These were analyzed on-board ship for total dissolved inorganic carbon by coulometric titration (using a SOMMA system; Johnson and Wallace, 1992; Johnson et al., 1993). A small correction was applied to account for the dilution of the sample due to addition of $HgCl_2$. Accuracy was checked by regular analyses of Certified Reference Materials prepared and distributed by Dr. Andrew Dickson, Scripps Institute of Oceanography, and is estimated to be <1.5 µmol kg^{-1}.
Analyses of pCO_2 were performed on almost all samples that were separately analyzed for T CO_2. Samples were collected in 60ml glass serum bottles which were promptly sealed with a teflon faced butyl rubber septa and aluminum crimp seal. A headspace with known volume (~6 ml) and CO_2 partial pressure was subsequently introduced into the sample, and the serum bottle was placed on its side in a shaking water bath (-15°C) and equilibrated for 3-4 hours prior to headspace analysis. After the headspace had been equilibrated with the water sample, the headspace pressure was measured using a needle-probe attached to a Paroscience digital pressure sensor. The headspace was subsequently displaced into a 0.45 ml sample loop attached to a gas-sampling valve. The atmospheric pressure and loop temperature was recorded and the loop contents injected onto a chromatographic column (10' x 1/16" (o.d.) Hayesep N), operated at a constant temperature of 60°C with a carrier gas flow rate of high-purity N_2 at ~20 ml/min. After separation on the column, the CO_2 was converted to methane on a heated nickel catalyst under a flow of H_2 and the methane was detected by flame-ionization detection. Gas standards with CO_2 partial pressures ranging from 200 to 1500 µatm were injected through the sample loop as standards. Full details of the method and calculation are being prepared for publication (Neill, Wallace and Johnson, In Prep.)The pCO_2 of the equilibrated samples was calculated for the (measured) temperature of equilibration after corrections were applied for the CO_2 exchanged with the headspace, by assuming that the total alkalinity of the sample was held constant during the equilibration. Calculation of the alkalinity was made knowing the TCO_2 of the sample (analyzed separately), the pCO_2 after equilibration and the apparent dissociation constants for CO_2 in seawater (Roy et al., 1993a,b). The pCO_2 together with the temperature of equilibration at which it was determined are reported. Precision of this quantity is estimated at <2 µatm. Also reported is the CALCULATED total alkalinity value; precision of this quantity is estimated at 1-2 µmol kg^{-1}. Results of a recent intercalibration exercise (Dickson, unpubl. data) suggest an accuracy (relative to potentiometric titration) of <5-10 µmol kg^{-1}. This accuracy estimate includes the effects of uncertainty in the thermodynamic constants required for the calculation of the total alkalinity from pCO_2 and TCO_2 data, together with analytical uncertainty.

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.

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 ^3He 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 ^3He / 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, ^3He and ^4He beams were measured separately, and calibrated with standard air aliquots. The ^3He ratio anomaly was expressed as:

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

where sx and std refer to the sample and the atmospheric standard, respectively. ^4He measurements were converted to concentrations by peak height comparison, and were expressed in units of nanomoles per kg (seawater). The precision in δ^3He is ±0.2%; in ^4He 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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References

Bricaud, A., A. Morel and L. Prieur (1981) Absorption by dissolved organic matter of the sea (yellow substance) in the UV and visible domains. Limnol. Oceanogr. 26: 43-53.

Carpenter, J.H. (1965) The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method. Limnol. Oceanogr. 10: 141-143.

Culberson, C.H. (1991) WHP Operations and Methods: Dissolved Oxygen. In WOCE Operations Manual, Volume 3: The Observational Programme. Part 3.1.3. WHP Operations and Methods. WHP Office Report WHPO 91-1; WOCE Report No. 68/91. Woods Hole, MA. July 1991.

Deming, J.W., A.-L. Reysenbach, S.A. Macko, and C.R. Smith (1995) Evidence for the microbial basis of a chemoautotrophic invertebrate community at a whale fall on the deep seafloor: bone-colonizing bacteria and invertebrate endosymbionts. J. Microscopy Res. Tech. (in press).

Gardner, W.D., I.D. Walsh and M.J. Richardson (1993) Biophysical forcing of particle production and distribution during a spring bloom in the North Atlantic. Deep-Sea Res. 40: 171-195.

Gordon, L.I., J.C. Jennings, A.A. Ross and J.M. Krest (1992) A suggested protocol for continuous flow automated analysis of seawater nutrients. WOCE Hydrographic Program Office, Methods Manual (In Prep.), Woods Hole, MA

Hobbie, J.E., R.J. Daley, and S. Jasper (1977) Use ofNuclepore filters for counting bacteria by fluorescence microscopy. Appl. Environ. Microbiol. 33, 1225-1228.

Johnson, K.M. and D.W.R. Wallace (1992) The Single-Operator Multiparameter Metabolic Analyzer for Total Carbon Dioxide with Coulometric Detection. DOE Research Summary No. 19, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory.

Johnson, K.M., K.D. Wills, D.B. Butler, W.K. Johnson and C.S. Wong (1993) Coulometric total carbon dioxide analysis for marine studies: maximizing the performance of an automated gas extraction system and coulometric detector. Mar. Chem., 44, 167-187.

Millard, R.C., Jr., (1982) CTD calibration and data processing techniques at WHOI using the 1978 practical salinity scale, in Proc. Int. STD Conference and Workshop, LaJolla, Mar. Tech. Soc., 19 pp.

NEWATER Science Steering Committee and Principal Investigators (1993) Northeast Water Polynya: Polar Sea Cruise Results. EOS 74(16), 185, 195-196.

Owens, W.B. and R.C. Millard Jr. (1985) A new algorithm for CTD oxygen calibration, J. Phys. Oc., 15, 621-631.

Pak, H., D.A. Kiefer and J.C. Kitchen (1988) Meridional variations in the concentration of chlorophyll and microparticles in the North Pacific Ocean. Deep-Sea Res. 35: 1151-1171.

Porter, K.G. and Y.S. Feig (1980) The use of DAPI for identifying and counting aquatic microflora. Limnol. Oceanogr. 25, 943-948.

Roy, R.R., L.N. Roy, M. Lawson, K.M. Vogel, C.P. Moore, W. Davis, and F.J. Millero (1993a) Thermodynamics of the dissociation of boric acid in seawater at S=35 from 0 to 55 C. Mar. Chem., 44, 243-248.

Roy, R.R., L.N. Roy, M. Lawson, K.M. Vogel, C.P. Moore, T. Pearson, C.E. Good, F.J. Millero and D.M. Campbell (1993b) The dissociation constants of carbonic acid in seawater at salinities 5 to 45 and temperatures 0 to 45 C. Mar. Chem., 44, 249-267.

Saunders, P.M. and N.P. Fofonoff (1976) Conversion of pressure to depth in the ocean. Deep- Sea Res., 23, 109-111.

Sea-Bird Electronics, Inc. (1993) CTD data acquisition software SEASOFT version 4.2, 99pp.

Smith, W.O., Jr. and D.M. Nelson (1990) Primary productivity and new production in the Weddell Sea marginal ice zone during austral spring and autumn, Limnol. Oceanogr., 35, 809-821.

Whitledge, T., S. Malloy, C. Patton and C.D. Wirick (1981) Automated nutrient analysis in seawater. Brookhaven National Laboratory Technical Report, BNL 51398.

WOCE (1991) WOCE Operations Manual, Volume 3: The Observational Programme. Part 3.1.2. Requirements for WHP Data Reporting. WHP Office Report WHPO 90-1; WOCE Report No. 67/91. Woods Hole, MA. July 1991.

NEWP93 STATION LIST

STATION	CAST	CTD-NO	DATE GMT	TIME GMT	LATITUDE DEG.	LONGITUDE DEG.	SONIC DEPTH METERS
1	1	1	7/22/93	20:09	80.293	-9.405	313
1	2	2	7/22/93	22:06	80.313	-9.679	311
1	3	3	7/22/93	23:24	80.311	-9.734	310
1	4	4	7/23/93	01:09	80.323	-9.756	307
2	5	5	7/23/93	16:48	80.476	-13.255	296
2	6	6	7/23/93	19:22	80.438	-13.003	283
2	7	7	7/23/93	20:45	80.440	-13.343	290
2	8	8	7/24/93	05:16	80.452	-13.288	300
3	9	9	7/24/93	10:34	80.273	-13.657	228
4	10	10	7/24/93	11:26	80.275	-13.822	269
5	11	11	7/24/93	12:18	80.301	-13.761	280
6	12	12	7/24/93	21:49	80.140	-13.255	111
7	13	13	7/24/93	23:08	80.222	-13.571	142
8	14	14	7/25/93	01:05	80.306	-13.963	289
9	15	15	7/25/93	02:20	80.387	-14.115	342
10	16	16	7/25/93	04:15	80.468	-14.510	327
11	17	17	7/25/93	05:18	80.560	-14.759	159
12	18	18	7/25/93	07:07	80.642	-15.091	73
13	19	19	7/25/93	08:44	80.668	-15.197	72
14	20	20	7/25/93	11:33	80.531	-14.703	205
15	21	21	7/25/93	12:45	80.494	-14.648	288
16	22	22	7/25/93	13:35	80.511	-14.515	245
17	23	23	7/25/93	19:32	80.488	-13.209	299
18	24	24	7/26/93	06:38	80.301	-11.222	232
19	25	25	7/26/93	09:09	80.356	-11.022	285
19	26	26	7/26/93	09:28	80.355	-11.024	288
20	27	27	7/26/93	11:18	80.407	-11.044	310
21	28	28	7/26/93	12:12	80.473	-11.064	293
22	29	29	7/26/93	13:48	80.530	-11.087	250
23	30	30	7/26/93	14:42	80.587	-11.101	253
24	31	31	7/26/93	15:46	80.659	-11.119	215
25	32	32	7/26/93	16:48	80.663	-11.132	119
26	33	33	7/26/93	18:02	80.784	-11.141	225
27	34	34	7/26/93	19:05	80.864	-11.186	269
28	35	35	7/26/93	20:21	80.925	-11.185	118
29	36	36	7/26/93	21:20	80.973	-11.143	68
30	37	37	7/27/93	00:41	80.573	-11.155	251

31	38	38	7/27/93	01:29	80.546	-11.065	249
32	39	39	7/27/93	02:16	80.572	-10.979	256
33	40	40	7/27/93	06:45	80.330	-11.079	254
34	41	41	7/27/93	07:32	80.328	-10.915	248
35	42	42	7/27/93	08:28	80.315	-10.996	231
36	43	43	7/27/93	16:24	80.353	-10.108	328
36	44	44	7/27/93	18:43	80.387	-10.450	324
37	45	45	7/28/93	01:54	80.440	-13.319	287
37	46	46	7/28/93	04:43	80.446	-13.322	291
37	47	47	7/28/93	06:43	80.448	-13.314	291
37	48	48	7/28/93	08:14	80.458	-13.257	295
37	49	49	7/28/93	10:19	80.444	-13.326	290
37	50	50	7/28/93	14:08	80.445	-13.317	289
37	51	51	7/28/93	15:12	80.443	-13.323	281
37	52	52	7/28/93	15:46	80.442	-13.316	281
37	53	53	7/28/93	17:59	80.445	-13.269	290
37	54	54	7/28/93	20:32	80.452	-13.223	301
37	55	55	7/28/93	22:10	80.445	-13.320	291
37	56	56	7/29/93	02:23	80.445	-13.323	289
37	57	57	7/29/93	05:56	80.444	-13.330	291
37	58	58	7/29/93	10:05	80.444	-13.326	292
37	59	59	7/29/93	11:41	80.456	-13.293	289
37	60	60	7/29/93	14:06	80.440	-13.338	291
37	61	61	7/29/93	15:07	80.447	-13.355	296
37	62	62	7/29/93	18:07	80.444	-13.326	289
37	63	63	7/29/93	22:18	80.446	-13.332	291
37	64	64	7/30/93	02:16	80.451	-13.302	301
37	65	65	7/30/93	05:56	80.445	-13.326	292
37	66	66	7/30/93	10:02	80.445	-13.333	209
37	67	67	7/30/93	14:13	80.443	-13.329	281
37	68	68	7/30/93	15:08	80.445	-13.314	291
37	69	69	7/30/93	18:06	80.447	-13.326	289
37	70	70	7/30/93	22:14	80.445	-13.328	290
37	71	71	7/31/93	00:07	80.452	-13.297	299
37	72	72	7/31/93	02:07	80.451	-13.308	301
37	73	73	7/31/93	03:07	80.455	-13.287	300
38	74	74	7/31/93	08:55	80.166	-8.153	324
38	75	75	7/31/93	11:27	80.195	-8.503	328
38	76	76	7/31/93	13:16	80.150	-7.742	304
38	77	77	7/31/93	14:41	80.150	-7.742	308
38	78	78	7/31/93	22:02	80.157	-7.751	290
39	79	79	8/01/93	08:10	79.972	-9.614	154
40	80	80	8/01/93	09:56	80.036	-9.508	144
41	81	81	8/01/93	11:17	80.152	-9.221	292
42	82	82	8/01/93	13:10	80.269	-8.950	303
42	83	83	8/01/93	14:12	80.267	-8.955	301
43	84	84	8/01/93	15:23	80.374	-8.677	261

44	85	85	8/01/93	18:13	80.495	-8.379	256
45	86	86	8/01/93	20:32	80.595	-8.199	195
46	87	87	8/01/93	22:08	80.692	-7.876	89
48	88	88	8/02/93	06:47	80.698	-7.866	87
48	89	89	8/02/93	08:16	80.702	-7.862	92
49	90	90	8/02/93	09:38	80.728	-7.479	217
50	91	91	8/02/93	11:49	80.754	-7.096	502
50	92	92	8/02/93	13:24	80.754	-7.112	487
51	93	93	8/02/93	16:33	80.762	-6.685	801
52	94	94	8/02/93	22:15	80.809	-6.390	1207
52	95	95	8/03/93	00:05	80.809	-6.364	1350
53	96	96	8/03/93	02:16	80.833	-6.008	1805
53	97	97	8/03/93	04:29	80.831	-6.001	1885
53	98	98	8/03/93	06:10	80.834	-6.043	1626
54	99	99	8/03/93	16:17	80.458	-7.333	242
54	100	100	8/03/93	18:13	80.416	-7.332	240
54	101	101	8/03/93	19:24	80.402	-7.321	250
55	102	102	8/04/93	00:17	80.151	-7.746	307
56	103	103	8/04/93	01:50	80.092	-7.828	335
56	104	104	8/04/93	04:13	80.047	-7.658	283
56	105	105	8/04/93	05:29	80.035	-7.635	283
57	106	106	8/04/93	14:35	79.988	-4.733	1502
57	107	107	8/04/93	17:20	79.978	-4.736	1500
58	108	108	8/04/93	19:46	79.946	-5.515	709
59	109	109	8/04/93	21:48	79.932	-6.161	301
60	110	110	8/05/93	00:13	79.918	-6.791	286
61	111	111	8/05/93	01:47	79.899	-7.410	230
62	112	112	8/05/93	03:19	79.883	-8.032	177
62	113	113	8/05/93	04:56	79.893	-7.963	186
62	114	114	8/05/93	08:57	79.883	-7.847	189
62	116	116	8/05/93	20:23	79.882	-8.051	163
63	115	115	8/05/93	12:45	79.768	-8.818	206
63	117	117	8/05/93	22:32	79.769	-8.830	195
64	118	118	8/06/93	04:27	79.671	-9.617	191
64	119	119	8/06/93	05:46	79.673	-9.567	199
65	120	120	8/06/93	09:22	79.587	-10.257	231
65	121	121	8/06/93	10:24	79.598	-10.266	248
65	122	122	8/06/93	15:10	79.586	-10.400	252
66	123	123	8/06/93	21:25	79.464	-11.162	278
66	124	124	8/06/93	21:53	79.462	-11.156	285
67	125	125	8/07/93	01:15	79.364	-11.896	247
67	126	126	8/07/93	01:54	79.363	-11.911	247
67	127	127	8/07/93	03:17	79.363	-11.942	247
68	128	128	8/07/93	07:52	79.261	-12.680	194
69	129	129	8/07/93	10:50	79.181	-13.442	157
70	130	130	8/07/93	15:47	78.983	-14.600	52
70	131	131	8/07/93	16:37	78.984	-14.582	50

71	132	132	8/07/93	22:52	79.601	-16.142	186
71	133	133	8/08/93	01:52	79.703	-16.257	324
71	134	134	8/08/93	06:47	79.729	-16.517	213
71	135	135	8/08/93	09:50	79.773	-16.399	209
71	136	136	8/08/93	18:57	79.696	-16.404	279
72	137	137	8/09/93	01:08	80.106	-17.335	117
73	138	138	8/09/93	02:54	80.053	-17.060	111
74	139	139	8/09/93	05:30	79.947	-16.646	128
75	140	140	8/09/93	07:55	79.851	-16.198	212
76	141	141	8/09/93	11:12	79.788	-15.957	345
77	142	142	8/09/93	12:49	79.702	-15.536	131
78	143	143	8/09/93	14:41	79.635	-15.276	98
79	144	144	8/09/93	17:23	79.471	-15.740	112
80	145	145	8/10/93	00:36	80.021	-15.928	420
80	146	146	8/10/93	01:35	80.030	-15.884	419
80	147	147	8/10/93	04:49	80.091	-15.494	395
80	148	148	8/10/93	06:03	80.103	-15.445	399
81	149	149	8/10/93	10:55	80.017	-15.853	433
82	150	150	8/10/93	15:24	79.938	-16.820	250
83	151	151	8/10/93	18:03	80.153	-15.264	403
84	152	152	8/10/93	21:06	80.406	-14.362	339
84	153	153	8/10/93	23:29	80.351	-14.344	328
85	154	154	8/11/93	02:51	80.299	-14.354	316
86	155	155	8/11/93	05:05	80.436	-13.300	277
86	156	156	8/11/93	06:08	80.435	-13.267	282
86	157	157	8/11/93	08:33	80.389	-13.429	279
86	158	158	8/11/93	11:15	80.433	-13.325	272
87	159	159	8/12/93	08:00	79.637	-14.684	383
88	160	160	8/12/93	12:06	79.484	-17.049	361
88	161	161	8/12/93	14:26	79.473	-17.028	373
89	162	162	8/15/93	01:22	79.384	-11.778	246
90	163	163	8/15/93	06:55	78.943	-12.045	260
91	164	164	8/15/93	11:46	78.473	-12.146	176
92	165	165	8/15/93	18:11	78.013	-12.170	153
93	166	166	8/15/93	23:29	77.527	-12.261	502
93	167	167	8/16/93	01:25	77.532	-12.273	502
94	168	168	8/16/93	08:12	77.156	-10.533	480
94	169	169	8/16/93	10:08	77.142	-10.574	498
94	170	170	8/16/93	11:30	77.147	-10.588	495
94	171	171	8/16/93	12:35	77.152	-10.589	498
95	172	172	8/16/93	17:01	77.015	-11.031	416
96	173	173	8/16/93	22:00	77.313	-10.042	326
97	174	174	8/17/93	02:50	76.978	-9.403	392
98	175	175	8/17/93	06:33	76.784	-8.331	353
99	176	176	8/17/93	09:57	76.682	-7.733	323
100	177	177	8/17/93	11:43	76.614	-7.365	530
101	178	178	8/17/93	14:11	76.595	-7.213	767

102	179	179	8/17/93	15:41	76.568	-7.031	1068
103	180	180	8/17/93	19:46	76.519	-6.769	1495
103	181	181	8/17/93	21:28	76.514	-6.898	1369