ORNL/CDIAC-91
NDP-056

CARBON DIOXIDE, HYDROGRAPHIC, AND CHEMICAL DATA OBTAINED DURING THE R/V *METEOR* CRUISE 18/1 IN THE NORTH ATLANTIC OCEAN (WOCE SECTION A1E, SEPTEMBER 1991)

Contributed by
Kenneth M. Johnson*, Bernd Schneider**,
Lutger Mintrop***, and Douglas W. R. Wallace*,

*Brookhaven National Laboratory
Upton, New York, U.S.A.

**Institut für Ostseeforschung
Rostock-Warnemünde, Germany

***Institut für Meereskunde
Kiel, Germany

Prepared by Alexander Kozyr****
Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Oak Ridge, Tennessee, U.S.A.

****Energy, Environment, and Resources Center
The University of Tennessee, Knoxville, Tennessee, U.S.A.

Environmental Sciences Division
Publication No. 4543

Date Published: July 1996

Prepared for the
Global Change Research Program
Environmental Sciences Division
Office of Health and Environmental Research
U.S. Department of Energy
Budget Activity Numbers KP 05 02 00 0 and KP 05 05 00 0

Prepared by the
Carbon Dioxide Information Analysis Center
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6335
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

CONTENTS

Page

LIST OF FIGURES v

LIST OF TABLES vii

ABSTRACT ix

PART 1: OVERVIEW 1

1. BACKGROUND INFORMATION 3

2. DESCRIPTION OF THE RESEARCH VESSEL AND EXPEDITION 4

2.1 R/V *Meteor*: Technical Details and History 4

2.2 Cruise Information 5

2.3 Cruise Summary 6

3. DESCRIPTION OF VARIABLES AND METHODS 8

4. DATA CHECKS AND PROCESSING PERFORMED BY CDIAC 19

5. HOW TO OBTAIN THE DATA AND DOCUMENTATION 23

6. REFERENCES 24

PART 2: CONTENT AND FORMAT OF DATA FILES 27

7. FILE DESCRIPTIONS 29

readme (File 1) 30

stainv.for (File 2) 30

met18dat.for (File 3) 31

uwpco2.for (File 4) 32

met18sta.inv (File 5) 33

Page

met18.dat (File 6) 34

uwpco2.dat (File 7) 36

8. VERIFICATION OF DATA TRANSPORT 38

APPENDIX A: STATION INVENTORY A-1

LIST OF FIGURES

Figure		Page
1	Station locations during R/V *Meteor* Cruise 18/1 (WOCE Section A1E)	4
2	Sampling depths at all hydrographic stations occupied during R/V *Meteor* Cruise 18/1	9
3	Plot of the differences between the measured and certified TCO_2 values for SOMMA-Coulometer Systems I and II during Cruise 18/1 aboard the R/V *Meteor*	13
4	Track of underway pCO_2 measurements made during R/V *Meteor* Cruise 18/1	17
5	Data plots of underway sea surface salinity, temperature, and pCO_2 measured during R/V *Meteor* Cruise 18/1	18
6	Nested profiles: Total carbon (μmol/kg) vs pressure (dbar)	20
7	Nested profiles: Total alkalinity (μmol/kg) vs pressure (dbar)	21
8	Property-property plots for all stations occupied during R/V *Meteor* Cruise 18/1	22

LIST OF TABLES

Table		Page
1	Summary of CRM TCO_2 analyses made aboard the R/V *Meteor* during Cruise 18/1 (September 1991) with two SOMMA-Coulometer Systems (BNL I and BNL II)	12
2	Summary of sample precision for TCO_2 analyses made aboard the R/V *Meteor* during Cruise 18/1 September 4–15, 1991 with two SOMMA-Coulometer Systems (BNL I and BNL II)	14
3	Summary of TCO_2 analyses for "between sample" duplicates, for which one of the duplicates was analyzed on SOMMA-Coulometer System BNL I and the other was analyzed on BNL II aboard the R/V *Meteor* during Cruise 18/1	15
4	Comparison of shipboard analyses of TCO_2 by coulometry (BNL) during the R/V *Meteor* Cruise 18/1 and the shore-based reference analyses of TCO_2 by manometry on duplicate samples in the laboratory of C. D. Keeling at SIO	16
5	Content, size, and format of data files	29
6	Partial listing of "**met18sta.inv**" (File 5)	38
7	Partial listing of "**met18.dat**" (File 6)	39
8	Partial listing of "**uwpco2.dat**" (File 7)	40
A.1	Station inventory information for the 61 sites occupied during R/V *Meteor* Cruise 18/1	A-4

ABSTRACT

Johnson, K. M., B. Schneider, L. Mintrop, and D. W. R. Wallace. 1996. Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Meteor* Cruise 18/1 in the North Atlantic Ocean (WOCE Section A1E, September 1991). ORNL/CDIAC-91, NDP-056. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 53 pp.

The North Atlantic Ocean is characterized by an intense meridional circulation cell carrying near-surface waters of tropical and subtropical origin northward and deep waters of arctic and subarctic origin southward. The related "overturning" is driven by the sinking of water masses at high latitudes. The overturning rate and thus the intensity of the meridional transports of mass, heat, and salt, is an important control parameter for the modeling of the ocean's role in climate. Certainly such estimates require more than one survey of the study area; therefore, the Research Vessel (R/V) *Meteor* Cruise 18/1 was one in a series of cruises in the North Atlantic that started in March 1991 and continued until 1995 (Meincke 1993).

This data documentation discusses the procedures and methods used to measure total carbon dioxide (TCO_2) and total alkalinity (TALK) at hydrographic stations, as well as underway partial pressure of CO_2 (pCO_2) measured during the R/V *Meteor* Cruise 18/1 in the North Atlantic Ocean (Section A1E). Conducted as part of the World Ocean Circulation Experiment (WOCE) and the German North Atlantic Overturning Rate Determination expedition, the cruise began in Reykjavik, Iceland, on September 2, 1991, and ended after 24 days at sea in Hamburg, Germany, on September 25, 1991. WOCE Zonal Section A1E began at 60° N and 42°30' W (southeast of Greenland) and continued southeast with a closely spaced series of hydrocasts to 52°20' N and 14°15' W (Porcupine Shelves). Measurements made along WOCE Section A1E included pressure, temperature, salinity, and oxygen measured by a conductivity, temperature and depth (CTD) sensor; bottle salinity; oxygen; phosphate; nitrate; nitrite; silicate; TCO_2; TALK; and underway pCO_2. A total of 61 CTD casts were made, including 59 bottle casts and 2 calibration stations. Replicate samples from seven Niskin bottles at five stations were also collected for later shore-based reference analyses of TCO_2 by vacuum extraction and manometry and TALK in the laboratory of Dr. Charles D. Keeling, Scripps Institution of Oceanography; these results are also included in this report.

TCO_2 was measured by using an automated sample processor, to extract CO_2 from seawater samples, coupled to a coulometer, to detect the extracted gas. The precision and accuracy of the system was ±1.60 µmol/kg. Samples collected for TALK were measured using standard potentiometric techniques; precision was ±2.0 µmol/kg. Underway pCO_2 was measured by infrared photometry; precision was ± 2 µatm.

The R/V *Meteor* Cruise 18/1 data set is available free of charge as a numeric data package (NDP) from the Carbon Dioxide Information Analysis Center. The NDP consists of three oceanographic data files, three FORTRAN 77 data retrieval routine files, a readme file, and this printed documentation, which describes the contents and format of all files as well as the procedures and methods used to obtain the data.

Keywords: carbon dioxide; alkalinity, pCO_2, World Ocean Circulation Experiment; North Atlantic Ocean; hydrographic measurements; carbon cycle

PART 1:

OVERVIEW

1. BACKGROUND INFORMATION

To better understand the ocean's role in climate and climatic changes, several large experiments have been conducted in the past, and others are currently under way. The World Ocean Circulation Experiment (WOCE) is a major component of the World Climate Research Program. Although total carbon dioxide (TCO_2) is not an official WOCE measurement, a coordinated effort, supported in the United States by the U.S. Department of Energy (DOE) and the National Oceanic and Atmospheric Administration, is being made on WOCE cruises to measure the global, spatial, and temporal distributions of TCO_2 and other carbon-related parameters. The CO_2 survey goals include estimation of the meridional transport of inorganic carbon in a manner analogous to the oceanic heat transport (Bryden and Hall 1980; Brewer et al. 1989; Roemmich and Wunsch 1985), evaluation of the exchange of CO_2 between the atmosphere and the ocean, and preparation of a database suitable for both carbon-cycle modeling and the subsequent assessment of the anthropogenic CO_2 increase in the oceans. The final data set is expected to cover ~23,000 stations in the Atlantic, Pacific, and Indian oceans.

The Research Vessel (R/V) *Meteor* Cruise 18/1, from Reykjavik, Iceland, to Hamburg, Germany, from September 2 to 25, 1991, completed WOCE Zonal Section A1E (Fig. 1). It was one of a series of cruises starting in 1991 that are contributing to the WOCE North Atlantic Overturning Rate Determination (WOCE-NORD) program. The WOCE-NORD program is coordinated jointly by the Bundesamt für Seeschiffahrt und Hydrographie (Hamburg) and the Institut für Meereskunde (Hamburg). The sampling strategy of WOCE-NORD is to combine seasonally repeated hydrographic sections between southern Greenland and Iceland with current measurements from moored arrays. Program objectives include the direct determination of the overturning rates and the intensity of the meridional transports of mass, heat, and salt. Section A1E was chosen to be south of the major wintertime convection regions so as to avoid both water mass formation processes and shallow topography, either of which could cause difficulties in calculating volume transports.

This document describes the cooperative efforts of chemical oceanographers from Brookhaven National Laboratory (BNL) and the Institut für Meereskunde Kiel (IFMK) to make high-quality CO_2 measurements along the WOCE Section A1E.

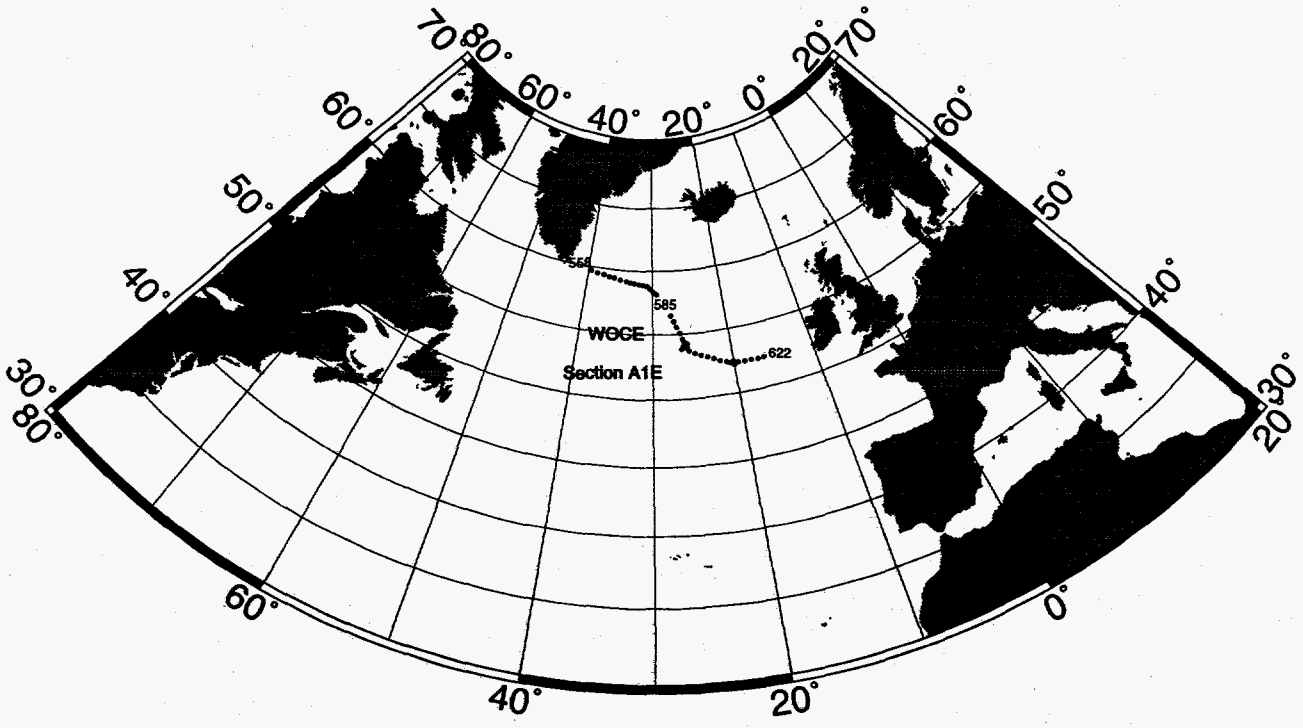

Figure 1. Station locations during R/V *Meteor* Cruise 18/1 (WOCE Section A1E).

2. DESCRIPTION OF THE RESEARCH VESSEL AND EXPEDITION

2.1 R/V *Meteor*: Technical Details and History

The R/V *Meteor* is owned by the Federal Republic of Germany's Ministry of Research and Technology (BMFT), which financed its construction. It is operated by the German Research Foundation (DFG), which provides about 70% of its operating funds while BMFT supplies the remainder. DFG also plans the scientific cruises and appoints the chief scientists. The Operations Control Office of the University of Hamburg is responsible for management, logistics, execution, and supervision of ship operations. These functions are performed through cooperation with expedition coordinators and the managing owners, the Reedereigemeinschaft Forschungsschiffahrt GmbH, located in Bremen, Germany. The latter is responsible for hiring, provisioning, and coordinating ship maintenance. Used for ocean research primarily in the Atlantic and Indian Oceans, the R/V *Meteor* routinely carries scientists from many different countries. Construction

of the *Meteor* was completed in 1986 in Travemunde, Germany. The basic features of the vessel are as follows:

Port of registration	Hamburg
Call sign	DBBH
Classification	GL+100A4E2+MC Auto
Operator	Institut für Meereskunde, Universität Hamburg
Built	1985–1986 at Schlichting Werft, Travemunde, West Germany
Basic dimensions:	
Gross registered tonnage	3990
Net registered tonnage	1284
Displacement	4780 t
Overall length	97.50 m
Beam	16.50 m
Draught max.	5.60 m
Service speed	12 kn
Depth main deck	7.70 m
Personnel	Crew: 32; scientists: 30
Main engine	4 × Mak6M 322 = 4 × 1000 kW at 750 rpm
Propulsion	Diesel-electrical, tandem-motor = 2 × 1150 kW
Fuel consumption	~12.0 t IFO-80 per day at service speed
Maximum cruise duration	60 days
Nautical equipment	Integrated navigation system with data transfer to position computer, echosounder synchronization and supervision, and data-processing facility
Science quarters	20 laboratories on the main deck with ~400 m^2 of working space for multidisciplinary research

R/V *Meteor* (I) was constructed in 1925, the first research and survey vessel of that name. Owned by the German navy, it was based in Wilhelmshaven. One of its first expeditions was the German Atlantic Ocean Expedition of 1925–27, which was organized by the Institute of Marine Research in Berlin. Thereafter, the vessel was used for German physical, chemical, and microbiological marine investigations and for German navy surveying and fisheries protection duties.

R/V *Meteor* (II) was planned after the 1950s; it was operated by the Deutsche Forschungsgemeinschaft (German Science Community) in Bad Godesberg and by the Deutsches Hydrographisches Institut (German Hydrographic Institute) in Hamburg. Commissioned in 1964, R/V *Meteor* (II) participated in the International Indian Ocean Expedition.

Multipurpose R/V *Meteor* (III), used on the cruise described in this documentation, was completed in 1986 and replaced R/V *Meteor* (II). Based in Hamburg, it is used for German ocean research worldwide and for cooperative efforts with other nations researching in this field. The vessel serves scientists of all marine disciplines in all of the world's oceans.

2.2 Cruise Information

Information about the R/V *Meteor* 18/1 cruise is summarized as follows:

Ship name	*Meteor*
Cruise/leg	18/1
Ports of call	Reykjavik, Iceland to Hamburg, Germany
Dates	September 2–25, 1991
Funding support	German Science Community; Federal Ministry of Research and Technology, Bonn, Germany; and U.S. Department of Energy (DOE)
Chief Scientist	Professor Dr. Jens Meincke, Institut für Meereskunde, Universität Hamburg, Germany
Master	Heinrich Bruns

Parameters measured	**Institution**	**Principal investigators**
CTD, Salinity, XBT	BSH	A. Sy
Nutrients	SIO	J. Swift, D. Bos, D. Muus
Oxygen	SIO	J. Swift, D. Bos, D. Muus
CFCs	UBP	W. Roether, A. Putzka
Tritium, He, ^{14}C	IUPH	R. Bayer
TCO_2	BNL, IFMK	K. Johnson, B. Schneider, A. Morak, R. Ramirez
Underway pCO_2	IFMK	B. Schneider
Total alkalinity (TALK)	IFMK	L. Mintrop, A. Korves
ADCP	IFMH	M. Bersch, J. Meincke
Rain gauges	IFMK	H.-J. Isemer

Participating Institutions

BNL	Brookhaven National Laboratory, U.S.A.
BSH	Bundesamt für Seeschiffahrt und Hydrographie, Germany
IFMH	Institut für Meereskunde, Universität Hamburg, Germany
IFMK	Institut für Meereskunde, Universität Kiel, Germany
IUPH	Institut für Umweltphysik, Universität Heidelberg, Germany
SIO	Scripps Institution of Oceanography, U.S.A.
UBP	Universität Bremen, Fachbereich Physik, Germany

2.3 Cruise Summary

The BNL CO_2 group, consisting of K. M. Johnson and R. Ramirez, arrived in Reykjavik, Iceland, on August 29 and went aboard the next day to join the IFMK CO_2 group members, Drs. Bernd Schneider and Lutger Mintrop. Dr. Jens Meincke was already aboard as Chief Scientist. Setting up of the equipment began on August 30 and was completed on the morning of September 2. The R/V *Meteor* departed Reykjavik at 11 a.m. on September 2, 1991. The ship immediately encountered rough weather conditions with gale force winds. Two test stations were completed during the transit across the Denmark Strait to the first station (no. 558) on the South-East Greenland shelf, which was reached on September 5. The earlier gale force winds were replaced by a quiet period characterized by humid air masses over cold water, which resulted in fog. The hydrocast routine was interrupted by winch and rosette bottle-release problems on September 6

and 7 and by currentmeter deployments on September 9, 10 ,11, 14, and 19. Bad weather forced several delays on September 13, when the pressure dropped to 980 hPa, wind gusted to 11 Beaufort, and waves rose to 8 m. This scenario was repeated on September 17, and the slowly receding sea conditions thereafter continued to plague the oceanographic work until the end of the hydrographic program of WOCE section A1E at station 622 on September 21. Each rough period was followed by reduced sampling on stations (12 bottles instead of 24 on each rosette), but these stations were restricted to short lines perpendicular to the WOCE line. The station locations are shown in Fig. 1. Of the six stations (592, 593, 595, 606, 607, and 608) taken normal to the WOCE line, only station 607 was sampled for carbonate system parameters. XBT measurements were made at selected CTD stations in parallel with the CTD casts, and acoustic Doppler current profiles (ADCP) were made continuously from September 2 to September 22 to measure the instantaneous near-surface currents.

Two single-operator multiparameter metabolic analyzers (SOMMAs) from BNL (hereafter the systems are designated BNL I and BNL II), one potentiometric alkalinity titrator from IFMK and one ifrared-based system for underway pCO_2 measurements from IFMK, were on board for this cruise. A total of 583 TCO_2 samples, normally collected in conjunction with tracer samples, were taken from 31 section stations, 1 test station (no. 557) and two calibration stations (nos. 581, 608) from a total of 59 bottle casts. Not all 59 stations could be sampled for tracers and TCO_2 because of the limited time available for analysis. The standard WOCE parameters (oxygen, nutrients, and salinity) were sampled on all stations, and on approximately every other station these were augmented by the tracer samples for CFCs, carbonate, helium, tritium, and radiocarbon as the ship steamed eastward from the southeastern tip of Greenland to the coast of Ireland. The density of the CO_2 sampling was fairly constant, ~2 stations per day; the underway pCO_2 system operated continuously.

Both electrical and mechanical problems were noted for each of the SOMMA coulometer systems. BNL II was most severely affected and was declared nonoperational on September 16, when the magnetic valves on the SOMMA chassis could no longer be operated reliably, the electronic calibration factor suddenly changed by +0.11% (a factor of 10 higher than the usual precision of ±0.01%), and the communication between the keyboard and PC became erratic. The final Certified Reference Material (CRM) run on this date was 6 µmol/kg lower than the certified value, and test sample duplication was equally poor. When this system was operated several months later in the laboratory, all components functioned satisfactorily, and it was impossible to determine the cause of the shipboard difficulties. BNL I experienced two serious problems. First, the BNL I coulometer became inoperable when the photodetector amplifier failed on September 7. Fortunately, a backup coulometer from Kiel was available, and it was immediately placed in service. Second, the gas calibration system apparently failed on September 10 as a result of cross-talk between the gas sample loops (CO_2 leaking from one loop into the other through a surface scratch or scoring of the valve, which contaminates the carrier gas). This manifested itself as a very noisy system with a very high and unusable blank. The problem was corrected by disconnecting the gas sample valve from the system so that the carrier gas (N_2) passed directly from the gas cylinder into the SOMMA stripper.

Because of the rough weather, plans for a return voyage around the north of Scotland to Hamburg were changed, and the ship arrived in Hamburg on September 25, via the English Channel, where winds astern arising from a low pressure system near the Faeroe Islands hastened the return voyage.

3. DESCRIPTION OF VARIABLES AND METHODS

The data file **met18.dat** (see descriptions of data files in Part 2) in this numeric data package (NDP) contains the following variables: station numbers; cast numbers; sample numbers; bottle numbers; CTD pressures, temperatures, and salinities; reversing thermometer readings; potential temperatures; bottle salinities; concentrations of dissolved oxygen, silicate, nitrate, nitrite, and phosphate; TCO_2 and TALK concentrations; and quality flags. The station inventory file **m18sta.inv** contains expedition codes, section numbers, station numbers, cast numbers, sampling dates (i.e., month, day, year), sampling times, latitude, longitude, and bottom depth for each station. The data file **uwpco2.dat** contains sampling dates (i.e., day, month, year), sampling times, latitude, longitude, sea surface salinity, sea surface temperature, and underway pCO_2 measurements.

Water samples were collected in 24 General Oceanics 10-L Niskin bottles mounted on a Neil Brown Mark III CTD instrument (S/N NB3) provided by IFMK. Data were acquired at a rate of 32 ms/cycle by using Oceansoft Rev. 3.1. Further details are given by Meincke (1993), and additional data concerning postcruise and precruise laboratory calibrations of the CTD temperature, pressure, conductivity, and oxygen sensors may be found in Siedler and Zenk (1992) and Ruhsam (1994). ADCP measurements to a depth of 300 m were made nearly continuously (with some breaks for rough weather and minor computer malfunctions) from September 2 to 22 with a hull-mounted system from RD Instruments (San Diego) that used a pulse frequency of 150 kHz.

The rosette systems used with the CTD on this cruise experienced various mechanical and electrical problems such that tripping failures were not uncommon—especially at stations 596–613. Repeated checks on board and several careful verifications with the complete bottle data sets were carried out, and the current pressures for each sample are considered correct by the responsible personnel. Reversing thermometers, both electronic (SIS, Kiel) and mechanical (Gohla Precision, Kiel), were also read at the completion of each cast. The processing and quality control of CTD and bottle data performed at BSH followed the guidelines published in the WOCE Operations Manual (WHPO 91-1, 1991). **Salinity** corrections were made by using bottle salinities measured 1–2 days after collection and determined on a Guildline Autosal model 8400A, which was standardized at each station with reference water (batch P112). Because of temporal conductivity sensor shifts, separate corrections were applied for stations 558–566, 567–602, and 603–622. The final salinity data are expected to be accurate to ±0.002 on the Practical Salinity Scale (PSS). Bottle **oxygen** was determined by Winkler titration following the techniques of Carpenter (1965) and Culberson and Will (1991), by using standards and blanks run in seawater. Subsequently, all Winkler results were recalculated and verified by staff of Oceanographic Data Facility at SIO. The concentrations of **nitrate**, **nitrite**, **phosphate**, and **silicate** dissolved in seawater were determined for samples collected in high-density polyethylene screw-capped bottles by using a Technicon Autoanalyzer according to procedures given in Hager et al. (1972) and Atlas et al. (1971) and by using the spectrophotometric methods of Armstrong et al. (1967) and Bernhardt and Wilhelms (1967). The analyses were completed within 24 h of sampling, including storage at 6°C for no more than 15 h. Preweighed standards were used to prepare the working standards on board ship.

The **TCO_2** concentration was determined by using two SOMMAs described and designed by K. M. Johnson and coworkers (Johnson et al. 1985, 1987; Johnson and Wallace 1992). Along with 158 duplicates, 583 individual samples (total analyzed = 741) from 33 stations (Fig. 2) were collected in 300-mL, precombusted (450°C for 24 h) BOD bottles and immediately poisoned with $HgCl_2$, according to DOE's *Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water* (DOE 1994). Before analysis the BOD bottles were kept

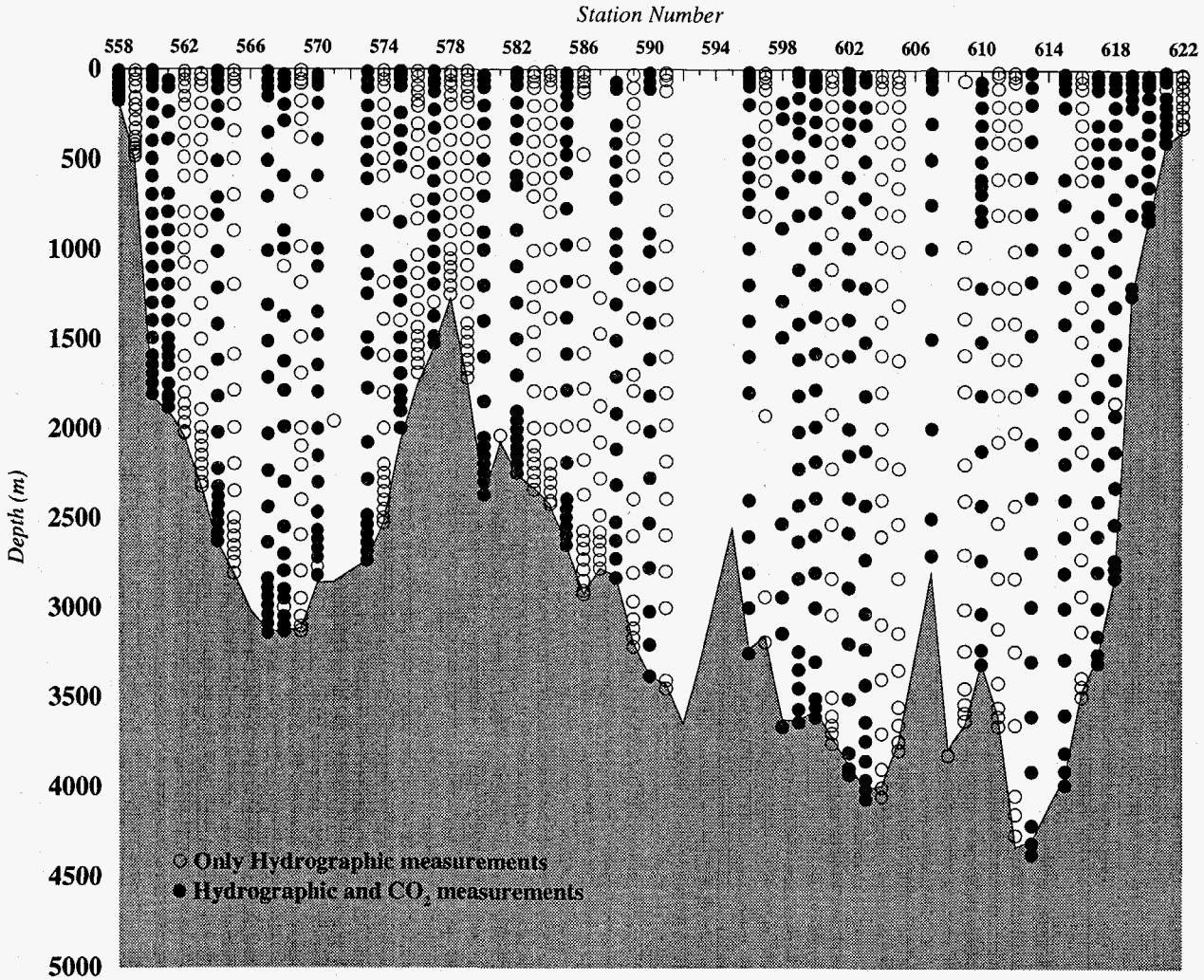

Figure 2. Sampling depths at all hydrographic stations occupied during R/V *Meteor* Cruise 18/1.

in darkness in a cold room until thermally equilibrated to the analytical temperature. Dr. Andrew Dickson of SIO supplied 61 CRMs (DOE 1994), which were also analyzed (37 on BNL I and 24 on BNL II). The CRMs were from Batch 7 (B7), which was a filtered sterile salt solution (S = 37.12) spiked with Na_2CO_3, and analyzed for TCO_2 by vacuum extraction and manometry in the laboratory of C. D. Keeling at SIO. The certified TCO_2 value was 1926.41 ± 0.82 µmol/kg (n = 13).

Seawater introduced from an automated "to deliver" pipette into a stripping chamber was acidified, and the resultant CO_2, after drying, was coulometrically titrated on a model 5011 UIC coulometer. In the coulometer cell, the hydroxyethylcarbamic acid that formed from the reaction of CO_2 and ethanolamine was titrated coulometrically (electrolytic generation of OH^-) with photometric end point detection. The product of the time and the current passed through the cell during the titration was related by Faraday's Constant to the number of moles of OH^- generated and thus to the moles of CO_2 that reacted with ethanolamine to form the acid. When possible (see text below) the SOMMA-coulometer systems were calibrated with pure CO_2 through the use of hardware consisting of an eight-port gas sampling Valve (GSV) with two sample loops connected to a source of pure CO_2 through an isolation valve with the vent side of the GSV plumbed to a barometer. When a gas loop was filled with CO_2, the mass (moles) of CO_2 contained therein was calculated by dividing the loop volume (V) by the Molar Volume of CO_2 at ambient (T) and (P). The molar volume of CO_2 [$V(CO_2)$] was calculated iteratively from an expression using the instantaneous barometric pressure (P), loop temperature (T), gas constant (R), and the first virial coefficient B(T) for pure CO_2:

$$V(CO_2) = RT / P[1 + B(T) / V(CO_2)] . \quad (1)$$

The ratio of the calculated mass to the mass determined coulometrically was the gas calibration factor (CALFAC) used to correct the subsequent titrations for small departures from 100% theoretical response (DOE 1994). The volume of the loops was determined gravimetrically with deionized water by the method of Wilke et al. (1993). When possible (see text below) the standard operating procedure was to make gas calibrations daily or for each new titration cell used (normally one cell per day).

Before the cruise, the "to deliver" volume (TDV) of the SOMMA sample pipette was determined (calibrated) gravimetrically at 20°C with milli-Q deionized water, which had been degassed with Helium. The thermostatted sample pipette was filled with water at the same temperature, and then discharged into preweighed 50-mL serum bottles which were reweighed on a model R300S (Sartorius, Göttingen, Germany) balance. The apparent weight (g) of water collected (W_{air}) was corrected to the mass in vacuo (M_{vac}) from the following equation:

$$M_{vac} = W_{air} + W_{air}(0.0012/d - 0.0012/8.0) , \quad (2)$$

where 0.0012 is the sea level density of air at 1 atm, d is the density of the calibration fluid at the pipette temperature and sample salinity, and 8.0 is the density of the stainless steel weights. TDV was calculated by using the following equation:

$$TDV = M_{vac}/d . \quad (3)$$

This procedure was repeated at sea, except the serum bottles were crimp-sealed and reweighed on shore within 3 weeks of collection. The precruise TDV of the pipette for system

BNL I was 28.7108 mL at 20°C. During the cruise the pipette temperature was kept at ~10.2°C ± 0.3°C. The calculated TDV at 10.2°C (TDV_{T2}) was 28.7080 mL:

$$\mathbf{TDV_{T2} = TDV_{T1}\,[1 + a_v\,(T_2 - T_1)]}\,, \qquad (4)$$

where a_v is the coefficient of volumetric expansion for pyrex-type glass (1×10^{-5}°C^{-1}), T_2 is the measurement temperature, and T_1 is the calibration temperature. The corresponding results for the BNL II pipette were 29.6954 and 29.6925 mL, respectively. During the cruise, eight TDV samples were collected at 10.2°C from the BNL I pipette and sealed for reweighing. The TDV from these weighings was 28.6845 ± 0.0058 mL (0.02%), which differed from the calculated TDV of 28.7080 mL by -0.0235 mL, or -0.082%. For the BNL II pipette, 11 samples were taken at 10.2°C which gave a TDV of the 29.6712 ± 0.0065 mL (0.02%), which differed from the calculated TDV of 29.6925 mL by -0.0213 mL, or -0.072%. Because the original laboratory calibration took place at 20°C, and all of the analytical work aboard ship was done at 10.2°C ± 0.3°C we have used the latter (shipboard) results for TDV to calculate the TCO_2 values (i.e., for BNL I, TDV = 28.6845 mL at 10.2°C; for BNL II, TDV = 29.6712 mL at 10.2°C). These data support the current practice of ensuring identical calibration and analytical temperatures because it appeared that theoretical correction for glass expansion was not adequate to describe the TDV at temperatures significantly different from the calibration temperature (see also DOE 1994).

An IBM-compatible personal computer with two RS232 serial ports, one 24-line digital input/output port, and one analog-to-digital port was used to control the coulometer, barometer, solid state control relays, and temperature sensors, respectively. The temperature sensors (model LM34CH, National Semiconductor, Santa Clara, California), with a voltage output of 10 mV/°F built into the SOMMA, were calibrated against thermistors certified to 0.01°C (PN CSP60BT103M, Thermometrics, Edison, New Jersey) by using a certified mercury thermometer as a secondary standard. These sensors monitored the pipette, gas sample loop, and the coulometer cell temperatures. The barometer, model 216B-101 Digiquartz Transducer (Paroscientific, Inc., Redmond, Washington), was factory-calibrated for pressures between 11.5 and 16.0 psia. The SOMMA software was written in GWBASIC Version 3.20 (Microsoft Corp., Redmond, Washington), and the instrument was driven from the computer.

The analytical method for determination of TCO_2 concentration in seawater used during R/V *Meteor* Cruise 18/1 differed from the technique described in an earlier data report (Johnson et al. 1995) for R/V *Meteor* Cruise 15/3 (March 1991). During Cruise 18/1 an electronic calibration procedure was used to check the theoretical response of the coulometers's voltage to frequency converter (VFC) as described in Johnson et al. (1993) and DOE (1994). At least two levels of current (usually 50 and 2 mA) were passed through an independent and very precisely known resistance (R) for a fixed time. The voltage (V) across the resistance was continuously measured, and the instantaneous current (I) across the resistance was calculated from Ohm's law and integrated over the calibration time. Then the number of pulses (counts) accumulated by the VFC during this time was compared with the theoretical number computed from the factory calibration of the VFC [frequency = 10^5 pulses (counts) generated per second at 200 mA] and the measured current. If the VFC was perfectly calibrated, electronic calibration yielded a straight line passing through the origin (intercept = 0) with a slope of 1. Calibrations and titrations were done with the coulometer in the counts mode (the total charge passed during a titration was displayed as the number of counts accumulated by the VFC). From the factory calibration of the VFC and the value of the Faraday (96489 Coulomb/mol), a scaling factor of 4.82445×10^3 counts/µmol was derived, and the theoretical number micromoles of carbon titrated (M) was determined by the following equation:

$$M = [\text{counts}/4824.45 - (Blank \times T_T) - (INT_{ec} \times I_T)]/SLOPE_{ec}\ , \quad (5)$$

where T_T is the length of the titration in minutes, *Blank* is the system blank in µmol/min, INT_{ec} is the intercept from electronic calibration in µmol/min, I_T the time of continuous current flow in minutes, and $SLOPE_{ec}$ is the slope from electronic calibration. Note that the slope obtained from the electronic calibration procedure applied for the entire length of the titration, but the intercept applied only for the period of continuous current flow (usually 3–4 min). The TCO_2 concentration in µmol/kg was calculated with the following equation:

$$C_T = M \times \text{CALFAC} \times [1/(TDV_T \times \rho)] \times 1.00017\ , \quad (6)$$

where C_T is the TCO_2, CALFAC is the gas calibration factor, TDV_T is the "to deliver" volume of the pipette in mL at the analytical temperature (T), ρ is the density of seawater in kg/mL from the equation of state (Millero and Poisson 1981), and 1.00017 corrects for the dilution of the sample by the 100 µL of $HgCl_2$ solution added to the sample bottle.

As a consequence of the coulometer and gas calibration problems described in Sect. 2.3, BNL I was operated between September 13 and September 23 without a gas calibration system. For TCO_2 calculations starting on September 13, the mean CALFAC of 1.002844 (n = 7) obtained for the period September 4–10 was used. No samples were run on BNL I on September 11 and 12. BNL II was continuously operated between September 4 and 15, and calculations were made with the daily gas calibration factors for that instrument. No samples were run on BNL II after September 15. The results of the CRM analyses are shown in Fig. 3 and summaryzed in Table 1.

Table 1. Summary of CRM TCO_2 analyses made aboard the R/V *Meteor* during Cruise 18/1 (September 1991) with two SOMMA-Coulometer Systems (BNL I and BNL II).

System	No. (n)	Mean ------(µmol/kg)-----	SD	R. S. D. (%)	Difference measured – certified[a]	Period (1991)
BNL I [b]	14	1925.87	0.89	0.05	– 0.54	4–10 September
BNL I [c]	23	1925.33	1.46	0.08	– 1.08	13–23 September
BNL II	24	1926.89	1.65	0.09	+ 0.48	4–15 September
Combined	61	1926.07	1.58	0.08	– 0.32	4–23 September

[a]The CRMs were from Batch 7 and had a salinity of 37.12 and a certified TCO_2 of 1926.41 ± 0.82 µmol/kg (n = 13).
[b]Period with gas calibration unit (September 4–10).
[c] Period without gas calibration unit (September 13–22).

This was the first cruise during which two SOMMA systems were used side-by-side to analyze samples from the same profile and measurements of system precision and bias were made in addition to the CRM analyses. The system precision data are given in Table 2. For these data, "within-sample" precision was the average difference between two replicates analyzed from the same sample bottle, "between-sample" precision was the average difference between duplicate sample bottles taken from the same Niskin bottle, "between-Niskin" precision was the average difference between single sample bottles taken from two Niskin bottles closed at the same depth, and S_p^2 was the pooled standard deviation calculated from multiple "between-sample" replicates

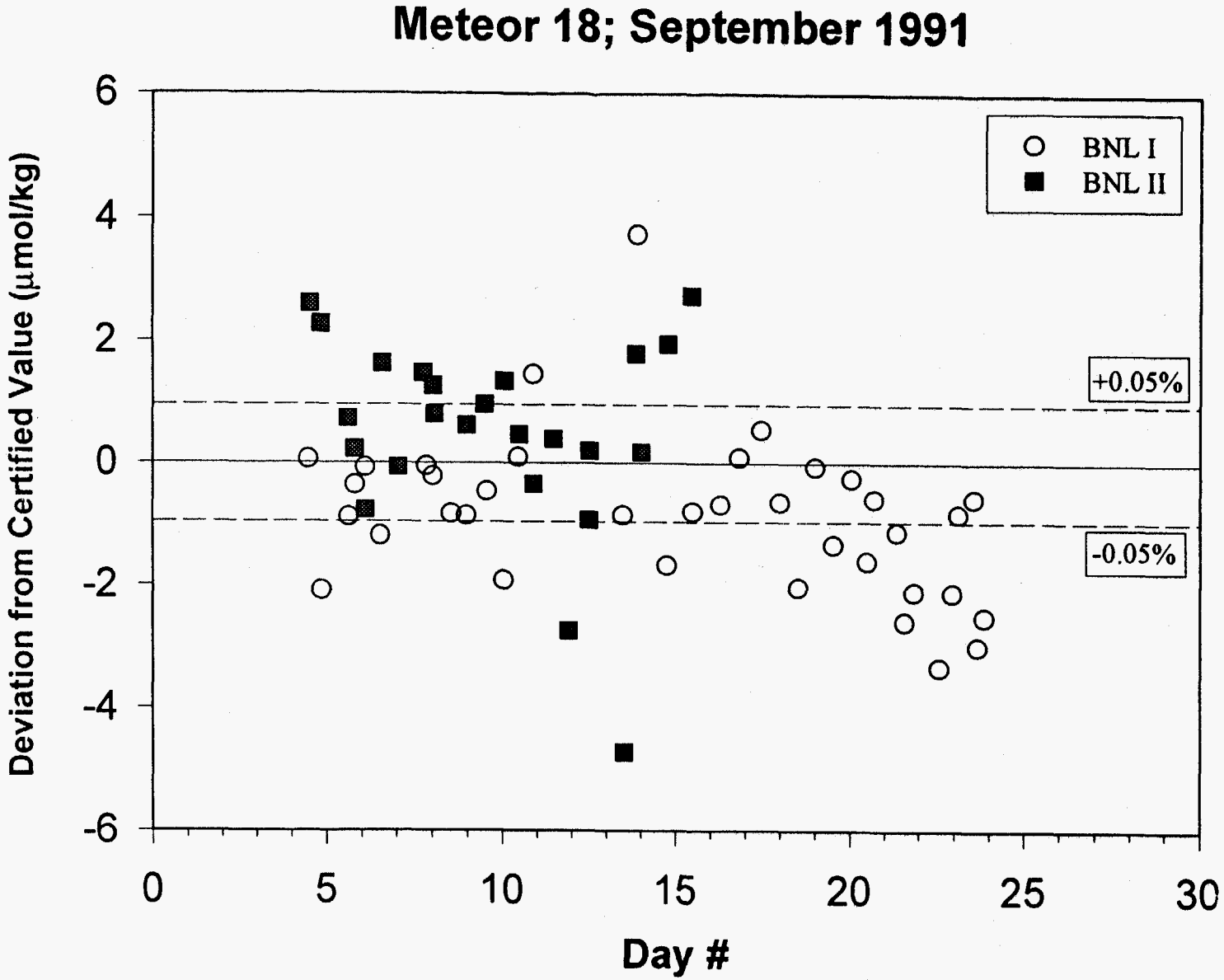

Figure 3. Plot of the differences between the measured and certified TCO_2 values for SOMMA - Coulometer Systems I and II during Cruise 18/1 aboard the R/V *Meteor*. Day # refers to the day of the month during September 1991.

(n > 2; stations 557, 581, and 608) analyzed on the same instruments (instrument specific) or from replicates of the same sample analyzed on both instrument (method specific). The S_p^2 was the square root of the pooled variance, according to Youden (1951):

$$S_p^2 = \sqrt{\frac{\sum_{i=1}^{K}\left(\sum_{j=1}^{n_i}(x_{ij} - \bar{x}_j)^2 - \left[\sum_{j=1}^{n_i}(x_{ij} - \bar{x}_j)\right]^2 / n_i\right)}{\sum_{i=1}^{K} n_i - K}} \quad (7)$$

where K is the number of samples analyzed, and $\sum_{i=1}^{K} n_i - K$ are the degrees of freedom for the calculation.

Table 2. Summary of sample precision for TCO_2 analyses made aboard the R/V *Meteor* during Cruise 18/1 September 4–15, 1991 with two SOMMA-Coulometer Systems (BNL I and BNL II).

System	Mean precision (± µmol/kg)[a]			S_p^2
	Within-sample (n)	Between-sample (n)	Between-Niskin (n)	(K,n)
BNL I	0.77 (18)	0.73 (31)	0.39 (12)	1.49 (3,26)[b]
BNL II	1.10 (19)	0.83 (3)	0.65 (3)	1.68 (2,26)[b]
Cruise totals	0.93 (37)	0.79 (34)	0.52 (15)	1.65 (34,93)[c]

[a]The mean precision is given as the mean of the absolute differences between duplicates analyzed on the same instrument, i.e. $\sum_{x=1}^{n} \text{abs}\,(x_1 - x_2)/n$, where n is the number of comparisons between duplicate analyses x_1 and x_2. See text for explanation of S_p^2.

[b]Instrument specific.

[c]Method Specific.

For the instrument specific S_p^2, K is the number of samples for which more than two replicates were analyzed on the same instrument, and n is the total number of replicates analyzed from K samples. The method specific S_p^2 was calculated from 34 samples (K) for which at least one replicate was analyzed on each instrument [93 replicates (n) analyzed between the two instruments]. If more than one replicate was analyzed on the same instrument, the mean was used to calculate S_p^2 according to the equation from Youden (1951), (Eq. 7). Thus, for the method s pecific calculation $n_j = K \times 2$ (68 instead of 93). This treatment reduces the degrees of freedom ($n_j - K$) to 34 from 59 (93 – K) and yields the most conservative estimate of precision for a single measurement, irrespective of the instrument it was made on. Overall sample precision (method specific S_p^2) was ±1.65 µmol/kg which agreed very well with the precision of the CRM analyses measured on both instruments (±1.58 µmol/kg, n = 61, Table 1). Note that BNL I, as a rule, gave slightly better precision than BNL II and that the other precision estimates were consistently

better than S_p^2. However, the higher value of ±1.65 μmol/kg was considered to be the most conservative estimate of analytical precision because it includes all sources of error—random and systematic—encountered over several days.

System bias was also checked by comparing the calibration station (station 581) samples from a depth of ~2033 m on both instruments over a period of 3–5 days. These data are shown in Table 3. For BNL I, the mean result was 2159.07 ± 0.61 μmol/kg (n = 5, analyzed between September 12 and 16), and the corresponding result for BNL II was 2158.26 ± 1.18 μmol/kg (n = 12, analyzed between September 11 and 13). The absolute value of the difference was 0.81 μmol/kg with BNL I giving a slightly higher result. The mean difference and the absolute value of the mean difference between duplicate analyses for the 34 samples used for the calculation of the method specific S_p^2 in Table 2 are shown in Table 3.

Table 3. Summary of TCO_2 analyses for "between sample" duplicates, for which one of the duplicates was analyzed on SOMMA-Coulometer System BNL I and the other was analyzed on BNL II aboard the R/V *Meteor* during Cruise 18/1

Comparison	K	BNL I (n)	BNL II (n)	Difference (I – II)	Abs (I – II)
Station 581	1	2159.07	2158.26	+ 0.81	0.81
Samples, other	34	2126.73	2128.38	– 1.65	1.65
				---	---
Mean				– 0.42	1.23

Tables 1 and 3 show that BNL I gave slightly lower results in comparison with BNL II for the CRM, and most samples but that was reversed for the test station (581) samples. The sign differences for these data suggests that it would be unwarranted to assign a uniform instrument bias for the duration of the cruise, and accordingly, no correction for instrumental bias has been applied to the data. In effect, it has been decided to accept a conservative estimate of precision that includes an estimate of bias (±1.65 μmol/kg, Table 2) for any single measurement instead of applying a bias correction to the data from either instrument. In aggregate, Tables 1–3 indicate that a single TCO_2 measurement is accurate and precise to ±1.6 μmol/kg.

As a final estimate of data quality, duplicate samples from seven Niskin bottles at five stations were collected for later shore-based reference analyses of TCO_2 by vacuum extraction/manometry performed in the laboratory of Dr. Charles Keeling at SIO. The results are given in Table 4, in which the BNL data are compared with the SIO results (Guenther et al. 1994). All samples except the shallow sample from station 580 are clearly consistent with our estimate of accuracy and precision, given previously. Temperature sensors were not included in the shipping crates (as is now standard operating procedure), so the temperature history of these samples between cold storage aboard ship and their arrival at SIO was not known. Table 4 supersedes Tables 3e and 5e from Guenther et al. (1994).

Table 4. Comparison of shipboard analyses of TCO_2 by coulometry (BNL) during the R/V *Meteor* Cruise 18/1 and the shore-based reference analyses of TCO_2 by manometry on duplicate samples in the laboratory of C. D. Keeling at SIO. The reference analyses were made February–March 1994.

Station no.	Sample date	Niskin no.	Depth (m)	TCO_2 (BNL) (μmol/kg)	TCO_2 (SIO) (μmol/kg)	Differ. BNL – SIO	Salinity differ.[a]
575	09.09.91	24	10	2088.25	2087.98	+ 0.27	+ 0.002
575	09.09.91	13	1095	2152.24	2154.55	– 2.31	– 0.019
580	10.09.91	23	27	2085.75	2094.58	– 8.83	– 0.003
580	10.09.91	1	2367	2157.52	2160.00	– 2.48	– 0.003
581[b]	10.09.91	2	2033	2158.48	2158.73	– 0.25	– 0.004
596	14.09.91	14	690	2167.83	2167.74	+ 0.09	– 0.005
603	16.09.91	1	4063	2202.42	2203.84	– 1.42	– 0.001
						---	---
Mean differences						– 2.13	– 0.005

[a]The difference between the ship's CTD sample salinity and the salinity measured at SIO.
[b]Calibration station. The BNL result is the mean of 17 analyses on the two systems between September 11 and 16.

Note that six of the seven differences were within the analytical precision of the methods, and salinities agreed to within 0.005, which rules out evaporative losses.

Total Alkalinity samples were collected in 500-mL bottles with the same precautions as for TCO_2. Samples were stored in the dark at 4°C and analyzed within 24 h. Samples were transferred into a closed titration cell with a volume of ~120 mL and titrated at 25°C ± 0.1°C with 0.1 *M* HCl containing 0.6 *M* NaCl. The titration cell was based on the systems described by Bradshaw and Brewer (1988) and Millero et al. (1993). The potential was followed with an electrode pair consisting of a ROSS (Orion Inc.) glass pH electrode and a ROSS AgCl reference electrode connected to a high-precision digital voltmeter. The titration was controlled by a computer, which waited for stable emf-readings before adding the next acid increment. The titration curve was analyzed with a modified GRAN-plot method described by Stoll et al. (1993), using the carbonic acid constants of Goyet and Poisson (1989), and taking into account the silicate and phosphate concentrations of the sample to obtain the titration alkalinity. The precision of the method was ±2.0 μmol/kg, which was determined by replicate analysis of samples. Standardization was accomplished with $NaCO_3$ standards in NaCl solutions corrected for the blank arising from impurities in the salt.

Underway pCO_2 was measured by using the method of Schneider et al. (1992). Surface seawater was continuously pumped along the cruise track (Fig. 3) at a rate of 200–300 mL/min into a glass equilibrator with a volume of ~300 mL. The seawater was equilibrated with continuously circulating air entering the bottom of the equilibrator through a frit from a closed-loop system. This system included a heat exchanger to keep the air at sample temperature, a filter and water trap, and an infrared (IR) analyzer (Siemens, Ultrmat 5F) for the determination of the CO_2 content of the equilibrated air. The infrared analyzer and equilibrator temperature sensor were connected to a computer or to an analog recorder for data display and preservation. The

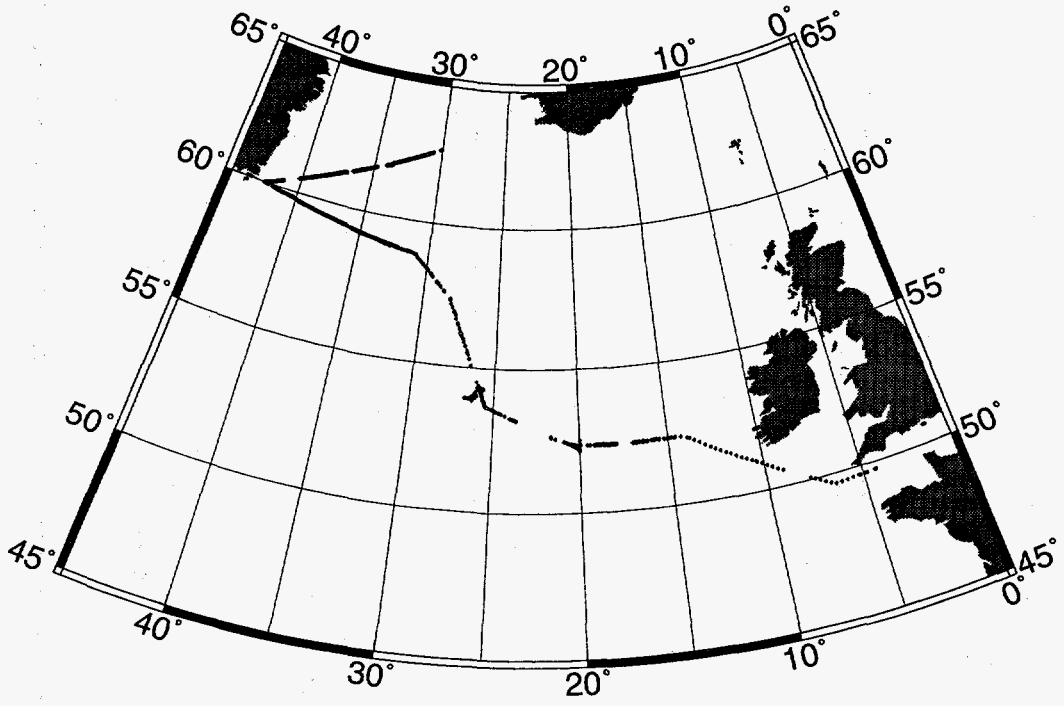

Figure 4. Track of underway pCO_2 measurements made during R/V *Meteor* Cruise 18/1.

time constant for the equilibration was ~3 min, which corresponded to a spatial resolution of 0.5 mile with the ship steaming at 10 knots. Atmospheric air was periodically measured, and the system was calibrated every 12 h through the use of calibration gases with CO_2 mixing ratios of 252.5 and 412.8 ppm (v). Pressure corrections were made for the effect of water vapor on total pressure in the equilibrator and the pressure at the inlet of the IR analyzer; the correction for the difference between in situ temperature and measuring temperature was made according to Gordon and Jones (1973). Figure 4 presents the plots of the underway sea surface salinity, temperature, and pCO_2 measured during R/V *Meteor* Cruise 18/1.

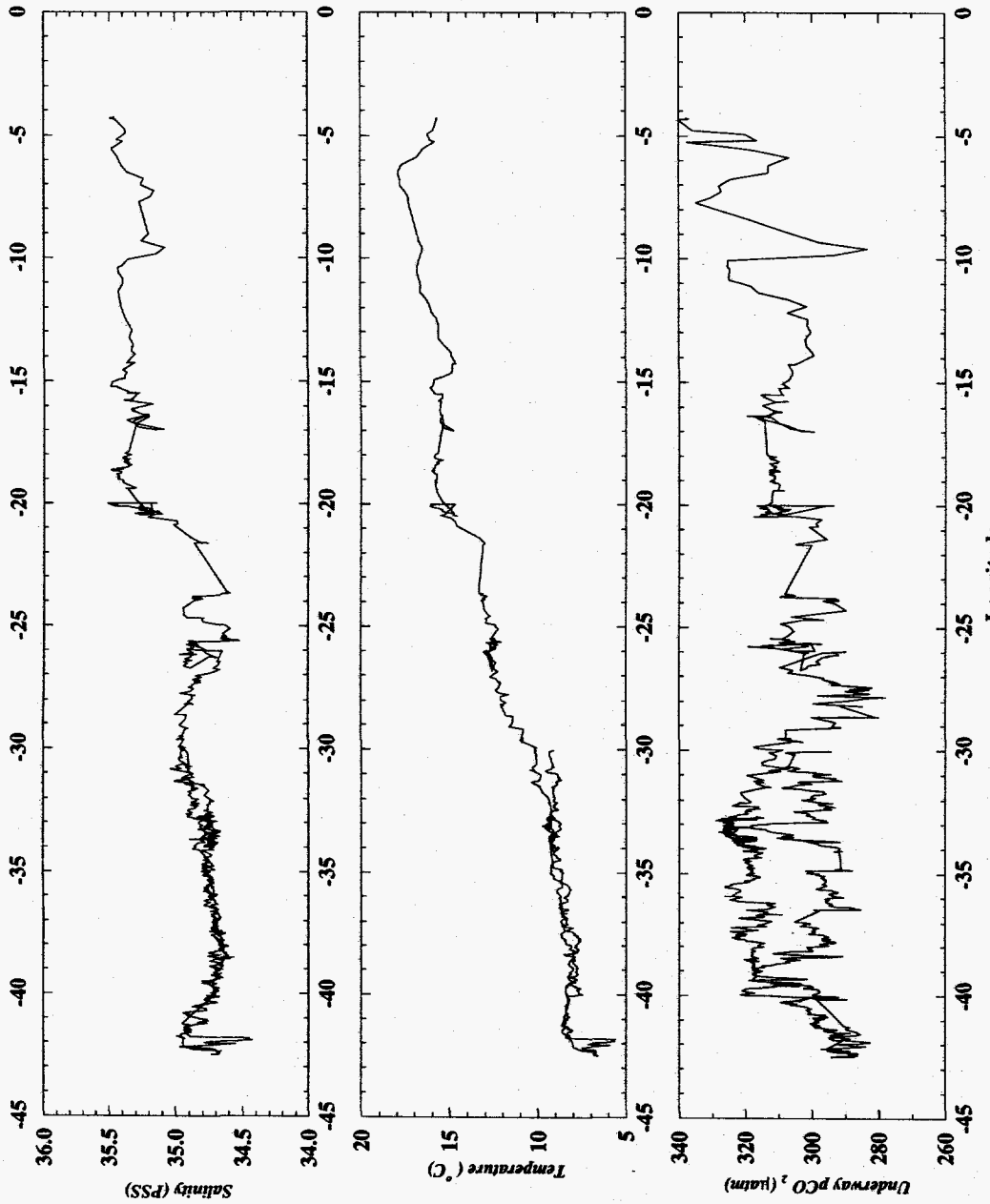

Figure 5. Data plots of underway sea surface salinity, temperature, and pCO_2 measured during R/V *Meteor* Cruise 18/1.

4. DATA CHECKS AND PROCESSING PERFORMED BY CDIAC

An important part of the NDP process at the Carbon Dioxide Information Analysis Center (CDIAC) involves the quality assurance (QA) of data before distribution. Data received at CDIAC are rarely in a condition that would permit immediate distribution, regardless of the source. To guarantee data of the highest possible quality, CDIAC conducts extensive QA reviews that involve examining the data for completeness, reasonableness, and accuracy. Although they have common objectives, these reviews are tailored to each data set, often requiring extensive programming efforts. In short, the QA process is a critical component in the value-added concept of supplying accurate, usable data.

The following summarizes the data processing and QA checks performed by CDIAC on the data obtained during the R/V *Meteor* Cruise 18/1 in the North Atlantic Ocean.

1. Carbon-related data and preliminary hydrographic measurements were provided to CDIAC by K. M. Johnson and D. W. R. Wallace of BNL. The final hydrographic and chemical measurements and the station information files were provided by the WOCE Hydrographic Program Office after quality evaluation. A FORTRAN 77 retrieval code was written and used to merge and reformat all data files.

2. To check for obvious outliers, all data were plotted using a PLOTNEST.C program written by Stewart C. Sutherland of Lamont-Doherty Earth Observatory. The program plots a series of nested profiles, using the station number as an offset; the first station is defined at the beginning, and subsequent stations are offset by a fixed interval (Figs. 5 and 6).

3. To identify "noisy" data and possible systematic, methodological errors, property-property plots for all parameters were generated (Fig. 7) and carefully examined.

4. All variables were checked for values that exceeded physical limits, such as sampling depth values exceeding the given bottom depths.

5. Dates, times, and coordinates were checked for bogus values (i.e., values of MONTH that were <1 or >12; DAY values <1 or >31; YEAR values ≠1991; TIME values <0000 or >2400; LAT values <49.000 or >65.000; LONG values <–43.000 or >–3.000).

6. Station locations (latitudes and longitudes) and sampling times were examined for consistency with maps and with cruise information supplied by K. M. Johnson and D. W. R. Wallace, BNL.

7. The designation for missing values, given as –9.0 in the original files, was changed to –999.9.

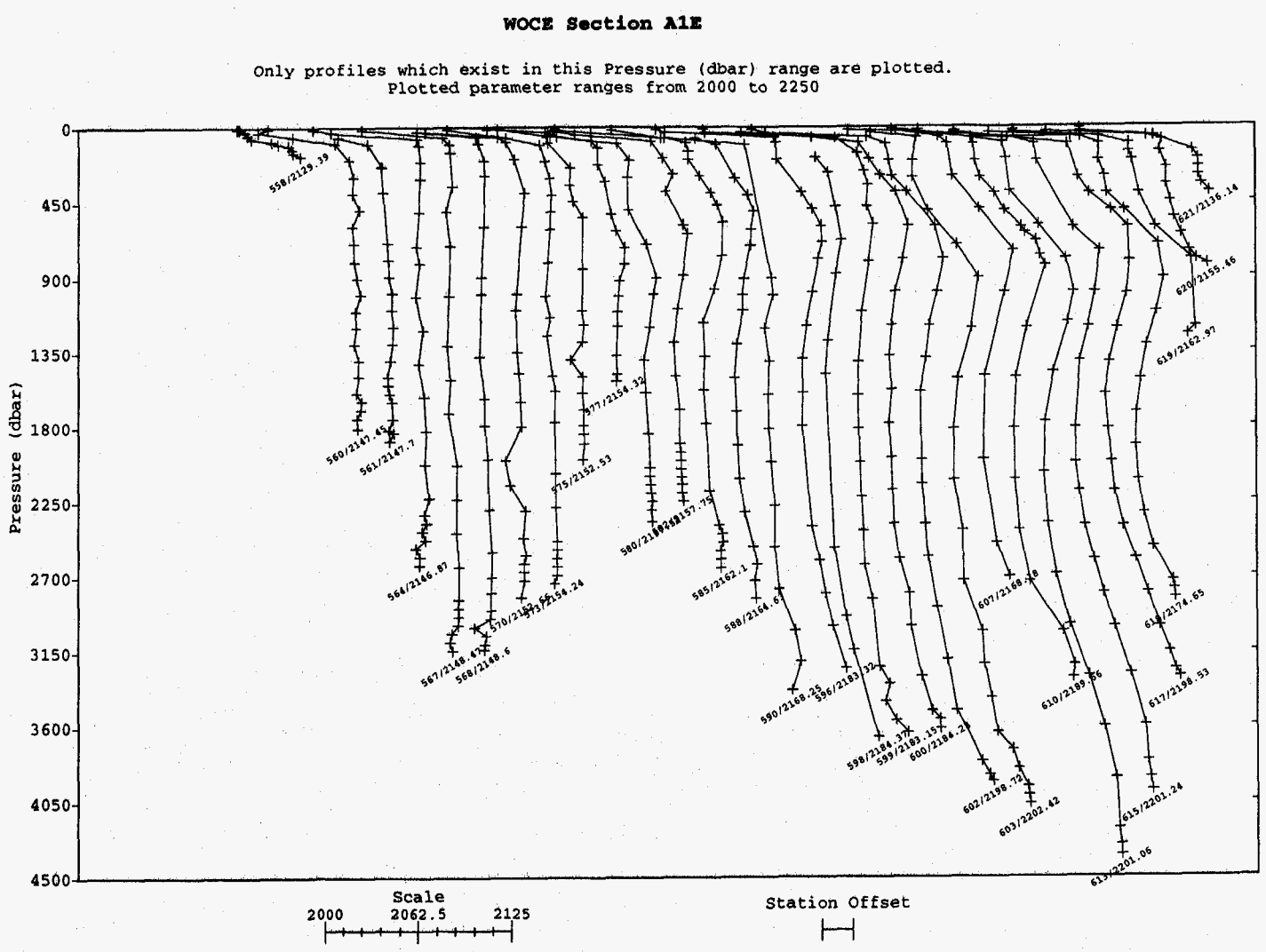

Figure 6. Nested profiles: Total carbon (μmol/kg) vs pressure (dbar).

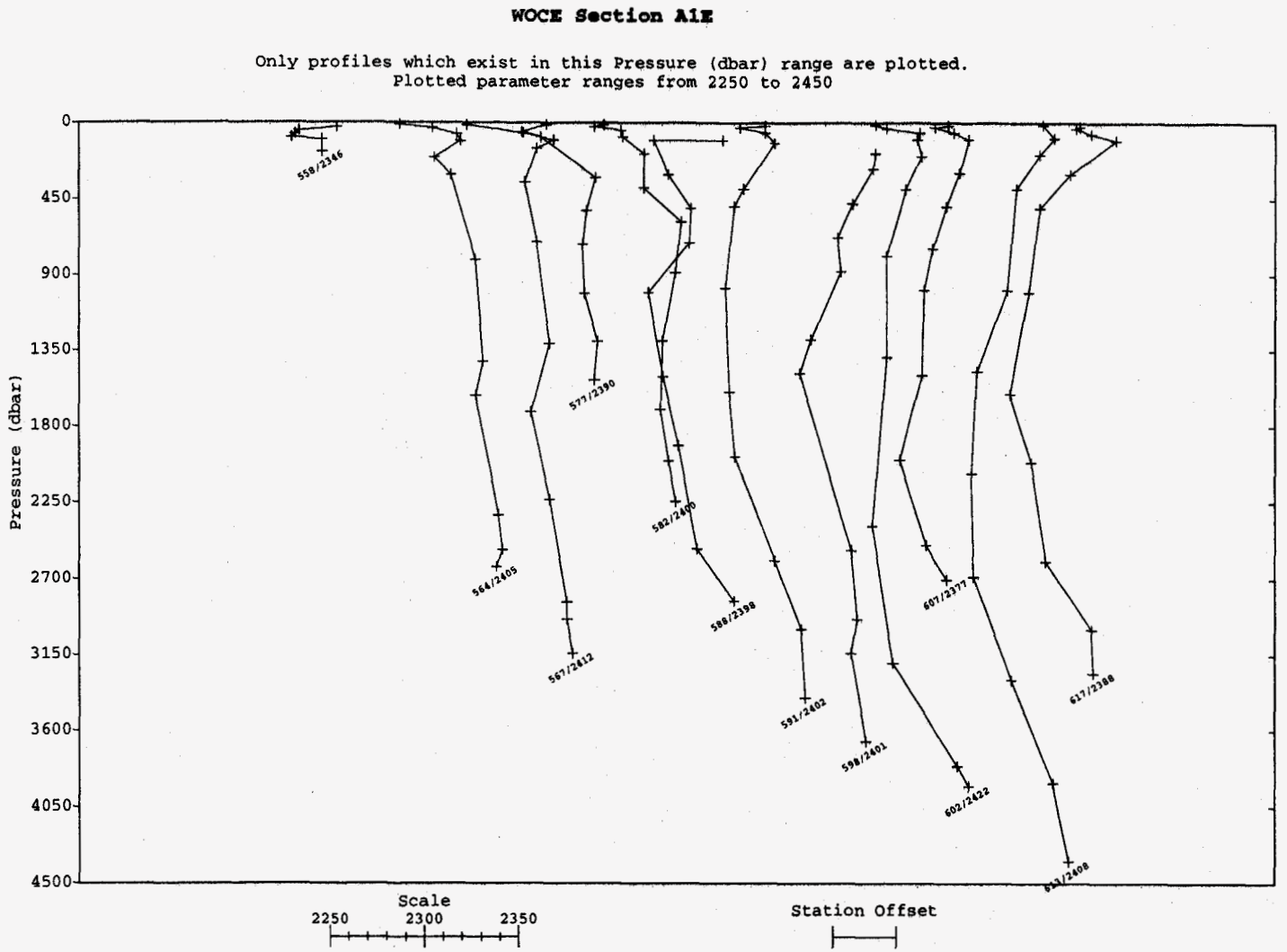

Figure 7. Nested profiles; Total alkalinity (μmol/kg) vs pressure (dbar).

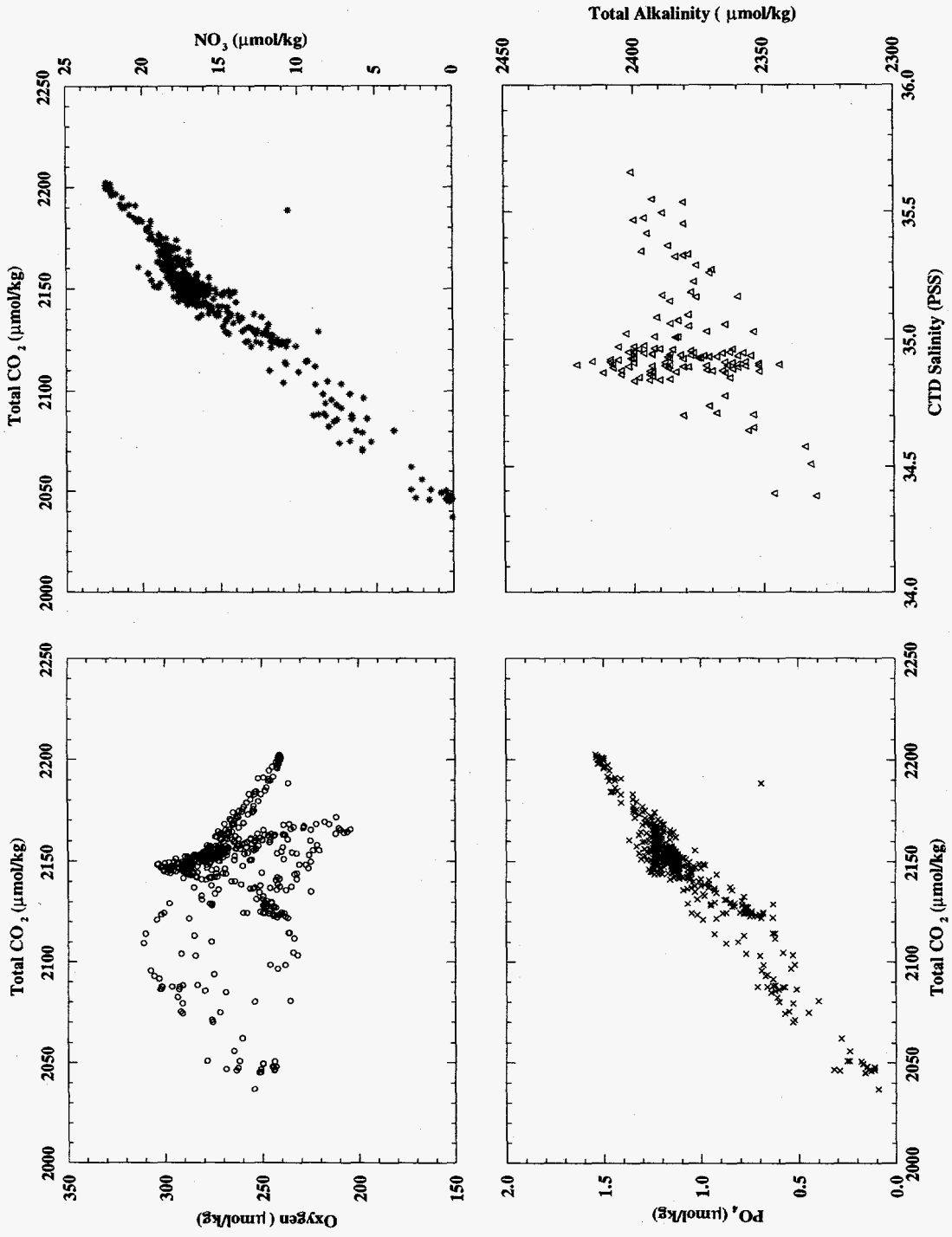

Figure 8. Property-property plots for all stations occupied during R/V *Meteor* Cruise 18/1.

5. HOW TO OBTAIN THE DATA AND DOCUMENTATION

This database is available on request in machine-readable form, without charge, from CDIAC. CDIAC will also distribute subsets of the database as needed. It can be acquired on 9-track magnetic tape; 8-mm tape; 150-mB, 1/4-in. tape cartridge; IBM-formatted floppy diskettes; or from CDIAC's anonymous File Transfer Protocol (FTP) area through the Internet (see FTP address below). Requests should include any specific media instructions required by the user to access the data (i.e., 1600- or 6250-BPI, labeled or nonlabeled tapes, ASCII or EBCDIC characters, variable- or fixed-length records; 3.5- or 5.25-in. floppy diskettes, high or low density; 8200 or 8500 format, 8-mm tape). Magnetic tape requests not accompanied by specific instructions will be filled on 9-track, 6250-BPI, standard-labeled tapes with EBCDIC characters. Requests should be send to the following address:

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Post Office Box 2008
Oak Ridge, Tennessee 37831-6335
U.S.A.

Telephone: (423) 574-0390 or (423) 574-3645
Fax: (423) 574-2232

Electronic Mail: cdiac@ornl.gov

The data files can also be acquired from CDIAC's anonymous FTP area through the Internet by following these steps:

- FTP to cdiac.esd.ornl.gov (128.219.24.36),
- Enter "ftp" or "anonymous" as the user ID,
- Enter your electronic mail address as the password (e.g.,"alex@alex.esd.ornl.gov")[1],
- Change to the directory "/pub/ndp056", and
- Acquire the files by using the FTP "get" or "mget" command.

The data files can also be acquired through CDIAC's World Wide Web site at the following address:

- http://cdiac.esd.ornl.gov/oceans/home.html

[1]Please enter your correct address. This address is used by CDIAC to inform data recipients of data revisions and updates.

6. REFERENCES

Armstrong, F. A. J., C. R. Stearns, and J. D. H. Strickland. 1967. The measurement of upwelling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment. *Deep-Sea Res.* 14:381–89.

Atlas, E. L., S. W. Hager, L. L. Gordon, and P. K. Park. 1971. A Practical Manual for Use of the Technicon Autoanalyzer in Seawater Nutrient Analyses, Revised. Technical Report 215, Reference 71-22. Oregon State University, Department of Oceanography.

Bernhardt, H., and A. Wilhelms. 1967. The continuous determination of low level iron, soluble phosphate and total phosphate with the AutoAnalyzer (R). *Technicon Symposia*, Vol. I, 385–89.

Bradshaw, A. L., and P. G. Brewer. 1988. High precision measurements of alkalinity and total carbon dioxide in seawater by potentiometric titration-1. Presence of unknown protolyte(s). *Mar. Chem.*, 23:69–86.

Brewer, P. G., C. Goyet, and D. Dyrssen. 1989. Carbon dioxide transport by ocean currents at 25° N latitude in the Atlantic Ocean. *Science* 246:477–79.

Bryden, H. L., and M. M. Hall. 1980. Heat transport by ocean currents across 25° N latitude in the North Atlantic Ocean. *Science* 207:884.

Carpenter, J. H. 1965. The Chesaspeake Bay Institute technique for the Winkler dissolved oxygen method. *Limnol. Oceanogr.* 10:141–43.

Culberson, C. H., and R. T. Will. 1991. A comparison of methods for the determination of dissolved oxygen in seawater. WHP Office Report, WHPO 91-2.

DOE (U.S. Department of Energy). 1994. Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water. Ver. 2. ORNL/CDIAC-74. A. G. Dickson and C. Goyet (eds.). Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Gordon, L. I., and L. B. Jones. 1973. The effect of temperature on carbon dioxide partial pressure in seawater. *Mar. Chem.* 1:317–22.

Goyet, C., and A. Poisson. 1989. New determination of carbonic acid dissociation constants in seawater as a function of temperature and salinity. *Deep-Sea Res.* 36:1635–54.

Guenther, P. R., C. D. Keeling, and G. Emanuele III. 1994. Oceanic CO_2 Measurements for the WOCE Hydrographic Survey in the Pacific Ocean, 1990–1991: Shore Based Analyses. SIO Reference Series, Ref. No. 94-28. University of California, San Diego, Calif.

Hager, S. W., E. L. Atlas, L. G. Gordon, A. W. Mantyla, and P. K. Park. 1972. A comparison at sea of manual and autoanalyzer analyses of phosphate, nitrate, and silicate. *Limnol. Oceanogr.* 17:931–37.

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, Oak Ridge, Tenn.

Johnson, K. M., A. E. King, and J. M. Sieburth. 1985. Coulometric TCO_2 analyses for marine studies: An introduction. *Mar. Chem.* 16:61–82.

Johnson, K. M., J. M. Sieburth, P. J. B. Williams, and L. Brändström. 1987. Coulometric TCO_2 analysis for marine studies: Automation and calibration. *Mar. Chem.* 21:117–33.

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.* 44:167–87.

Johnson, K. M., D. W. R. Wallace, R. Wilke, and C. Goyet. 1995. Carbon dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Meteor* Cruise 15/3 in the South Atlantic Ocean (WOCE Section A9, February–March 1991). Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Meincke, J. (ed.). 1993. WOCE-NORD 1991, Cruise No. 18, 2 September–26 September 1991. METEOR-Berichte No. 93-1. Institut für Meereskunde, Universität Hamburg, Germany.

Millero, F. J., and A. Poisson. 1981. International one-atmosphere equation of state for sea water. *Deep-Sea Res.* 28:625–29.

Millero, F. J., J.-Z. Zhang, K. Lee, and D. M. Campbell. 1993. Titration alkalinity of seawater. *Mar. Chem.* 44:153–65.

Roemmich, D., and C. Wunsch. 1985. Two transatlantic sections: Meridional circulation and heat flux in the subtropical North Atlantic Ocean. *Deep-Sea Res.* 32:619–64.

Ruhsam, C. M. 1994. WHP One-Time Section A9 Data Report. WOCE Special Analysis Center, Bundesamt für Seeschiffahrt and Hydrographie, Hamburg, Germany (unpublished manuscript).

Schneider, B., K. Kremling, and J. C. Duinker. 1992. CO_2 partial pressure in northeast Atlantic and adjacent shelf waters: Processes and seasonal variability. *J. Mar. Systems* 3:453–63.

Siedler, G., and W. Zenk. 1992. WOCE Sudatlantik 1991, Reise Nr. 15, 30 Dezember 1990–23 Marz 1991. METEOR-Berichte 92-1. Universität Hamburg, Germany.

Stoll, M. H. C., J. W. Rommets, and H. J. W. De Baar. 1993. Effect of selected calculation routines and dissociation constants on the determination of total carbon dioxide in seawater. *Deep-Sea Res.* 40:1307–22.

Wilke, R. J., D. W. R. Wallace, and K. M. Johnson. 1993. A water-based, gravimetric method for the determination of gas sample loop volume. *Anal. Chem.* 65:2403–06.

WOCE Operations Manual. 1991. WHP Office Report 90-1. Rev.1. Unpublished Manuscript. WOCE Hydrographic Programme Office. Woods Hole Oceanographic Institution, Woods Hole, Mass. (unpublished manuscript).

Youden, W. J. 1951. *Statistical Methods for Chemists.* Wiley, New York.

PART 2:

CONTENT AND FORMAT OF DATA FILES

7. FILE DESCRIPTIONS

This section describes the content and format of each of the seven files that compose this NDP (Table 5). Because CDIAC distributes the data set in several ways (e.g., by anonymous FTP, on floppy diskette, on 9-track magnetic tape), each of the five files is referenced by both a file number and an ASCII file name, which is given in lower-case, bold-faced type (e.g., **readme**). The remainder of this section describes or lists the contents of each file. The files are discussed in the order presented in Table 5.

Table 5. Content, size, and format of data files

File number, name, and description	Logical records	File size in bytes	Block size	Record length
1. **readme**: A detailed description of the cruise network, the three FORTRAN 77 data retrieval routines, and the three oceanographic data files	1,411	83,319	8,000	80
2. **stainv.for**: A FORTRAN 77 data retrieval routine to read and print **met18sta.inv** (File 5)	36	1,249	8,000	80
3. **met18dat.for:** A FORTRAN 77 data retrieval routine to read and print **met18.dat** (File 6)	44	1,892	8,000	80
4. **uwpco2.for:** A FORTRAN 77 data retrieval routine to read and print **uwpco2.dat** (File 7)	36	1,218	8,000	80
5. **met18sta.inv**: A listing of the station locations, sampling dates, and sounding bottom depths for all stations	76	5,598	4,100	41

Table 5. (continued)

File number, name, and description	Logical records	File size in bytes	Block size	Record length
6. **met18.dat:** Hydrographic, carbon dioxide, and nutrient data from all stations	1,224	192,149	16,000	160
7. **uwpco2.dat:** Underway pCO_2 data collected along the cruise track	2,122	132,833	16,000	120
Total	4,949	418,258		

readme (File 1)

This file contains a detailed description of the data set, the three FORTRAN 77 data retrieval routines, and the three oceanographic data files. It exists primarily for the benefit of individuals who acquire this database as machine-readable data files from CDIAC.

stainv.for (File 2)

This file contains a FORTRAN 77 data retrieval routine to read and print **met18sta.inv** (File 5). The following is a listing of this program. For additional information regarding variable definitions, variable lengths, variable types, units, and codes, please see the description for **met18sta.inv** on page 33.

```
c*****************************************************************
c* FORTRAN 77 data retrieval routine to read and print the       *
c* file named "met18sta.inv" (File 5)                            *
c*****************************************************************

      INTEGER stat, cast, depth
      CHARACTER date*6, expo*8, sect*3, time*4
      REAL latdcm, londcm
      OPEN (unit=1, file='met18sta.inv')
      OPEN (unit=2, file='m18stat.inv')
      write (2, 5)
```

```
 5      format (2X,'R/V METEOR CRUISE 18 LEG 1',5X,'WOCE LINE A1E',/,
     1 2X,'EXPOCODE',2X,'SECT',2X,'STNNBR',2X,'CASTNO',5X,'DATE',
     2 3X,'TIME',5X,'LATDCM',5X,'LONDCM',3X,'DEPTH',/)

        read (1, 6)
 6      format (/////////////)

 7      CONTINUE
        read (1, 10, end=999) expo, sect, stat, cast, date, time,
     1 latdcm, londcm, depth

 10     format (2X, A8, 3X, A3, 5X, I3, 7X, I1, 3X, A6, 3X, A4, 5X,
     1 F6.3, 4X, F7.3, 4X, I4)

        write (2, 20) expo, sect, stat, cast, date, time, latdcm,
     1 londcm, depth

 20     format (2X, A8, 3X, A3, 5X, I3, 7X, I1, 3X, A6, 3X, A4, 5X,
     1 F6.3, 4X, F7.3, 4X, I4)

        GOTO 7
 999    close(unit=1)
        close(unit=2)
        stop
        end
```

met18dat.for (File 3)

This file contains a FORTRAN 77 data retrieval routine to read and print **met18.dat** (File 6). The following is a listing of this program. For additional information regarding variable definitions, variable lengths, variable types, units, and codes, please see the description for **met18.dat** on page 34.

```
c*****************************************************************
c* FORTRAN 77 data retrieval routine to read and print the       *
c* file named "met18.dat" (File 6).                              *
c*****************************************************************

        CHARACTER bot*3, qualt*10
        INTEGER sta, cast, samp
        REAL pre, ctdtmp, theta, revtmp, ctdsal, salt, oxygen, silcat
        REAL nitrat, nitrit, phspht, tcarb, talk
        OPEN (unit=1, file='met18.dat')
        OPEN (unit=2, file='met18.data')
        write (2, 5)

 5      format (2X,'STNNBR',2X,'CASTNO',2X,'SAMPNO',2X,'BTLNBR',2X,
     1 'CTDPRS',4X,'CTDTMP',3X,'REVTMP',4X,'CTDSAL',5X,'THETA',4X
     2 'SALNTY',2X,'OXYGEN',2X,'SILCAT',2X,'NITRAT',2X,'NITRIT',2X,
     3 'PHSPHT',2X,'ALKALI',2X,'TCARBN',6X,'QUALT1',/,36X,'DBAR',
     4 4X,'ITS-90',3X,'ITS-90',4X,'PSS-78',7X,'DEG',4X,'PSS-78',1X,
     5 7('UMOL/KG',1X),10X,'*',/,25X,'*******',30X,'*******',13X,
     6 8('*******',1X),10X,'*')

        read (1, 6)
 6      format (/////////////)
```

```
7     CONTINUE
      read (1, 10, end=999) sta, cast, samp, bot, pre, ctdtmp,
     1 revtmp, ctdsal, theta, salt, oxygen, silcat, nitrat, nitrit,
     2 phspht, talk, tcarb, qualt

10    format (5X, I3, 7X, I1, 6X, I2, 5X, A3, 2X, F6.1, 1X, F9.4,
     1 1X, F8.3, 1X, F9.4, 1X, F9.4, 1X, F9.4, 2X, F6.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.1, 2X, A10)


      write (2, 20)  sta, cast, samp, bot, pre, ctdtmp,
     1 revtmp, ctdsal, theta, salt, oxygen, silcat, nitrat, nitrit,
     2 phspht, talk, tcarb, qualt

20    format (5X, I3, 7X, I1, 6X, I2, 5X, A3, 2X, F6.1, 1X, F9.4,
     1 1X, F8.3, 2X, F9.4, 1X, F9.4, 1X, F9.4, 2X, F6.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.1, 2X, A10)

     GOTO 7

999   close(unit=1)
      close(unit=2)
      stop
      end
```

uwpco2.for (File 4)

This file contains a FORTRAN 77 data retrieval routine to read and print **uwpco2.dat** (File 7). The following is a listing of this program. For additional information regarding variable definitions, variable lengths, variable types, units, and codes, please see the description for **uwpco2.dat** on page 36.

```
c*****************************************************************
c* FORTRAN 77 data retrieval routine to read and print the      *
c* file named "uwpco2.dat" (File 7)                             *
c*****************************************************************

      INTEGER day, month, year
      CHARACTER time*5
      REAL latdcm, londcm, salt, temp, pco2
      OPEN (unit=1, file='uwpco2.dat')
      OPEN (unit=2, file='uwpco2.data')
      write (2, 5)

5     format (2X,'R/V METEOR CRUISE 18 LEG 1',5X,'WOCE LINE A1E',/,
     1 4X,'DATE',6X,'TIME',3X,'LATDCM',4X,'LONDCM',3X,'SURFSAL',
     2 1X,'SURFTMP',2X,'PCO2',/)

      read (1, 6)
6     format (/////////////)

7     CONTINUE
      read (1, 10, end=999) day, month, year, time, latdcm,
     1 londcm, salt, temp, pco2

10    format (I2, 2X, I1, 2X, I4, 2X, A5, 3X, F6.3, 3X, F7.3, 3X,
     1 F7.4, 2X, F5.2, 2X, F5.1)

      write (2, 20) day, month, year, time, latdcm,
```

```
     1 londcm, salt, temp, pco2

 20    format (I2, 2X, I1, 2X, I4, 2X, A5, 3X, F6.3, 3X, F7.3, 3X,
     1 F7.4, 2X, F5.2, 2X, F5.1)
       GOTO 7
 999   close(unit=1)
       close(unit=2)
       stop
       end
```

met18sta.inv (File 5)

This file provides station inventory information for each of the 61 stations occupied during the R/V *Meteor* Cruise 18/1. Each line of the file contains an expocode, section number, station number, cast number, sampling date, sampling time, latitude, longitude, and sounding depth. The file is sorted by station number and can be read by using the following FORTRAN 77 code (contained in **stainv.for**, File 2):

```
       INTEGER stat, cast, depth
       CHARACTER date*6, expo*8, sect*3, time*4
       REAL latdcm, londcm

       read (1, 10, end=999) expo, sect, stat, cast, date, time,
     1 latdcm, londcm, depth

 10    format (2X, A8, 3X, A3, 5X, I3, 7X, I1, 3X, A6, 3X, A4, 5X,
     1 F6.3, 4X, F7.3, 4X, I4)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
expo	Character	8	3	10
sect	Character	3	14	16
stat	Numeric	3	22	24
cast	Numeric	1	32	32
date	Character	6	36	41
time	Character	4	45	48
latdcm	Numeric	6	54	59
londcm	Numeric	7	64	70
depth	Numeric	4	75	78

where

expo is the expocode of the cruise (i.e., 06MT18/1);

sect	is the WOCE section number (i.e., A1E);
stat	is the station number (values range from 558 to 622);
cast	is the cast number;
date	is the sampling date (month/day/year);
time	is the sampling time (GMT);
latdcm	is the latitude of the station (in decimal degrees; negative values indicate the Southern Hemisphere);
londcm	is the longitude of the station (in decimal degrees; negative values indicate the Western Hemisphere);
depth	is the sounding depth of the station (in meters).

met18.dat (File 6)

This file provides hydrographic, carbon dioxide, and chemical data for the 61 stations occupied during R/V *Meteor* Cruise 18/1. Each line consists of a station number; cast number; sample number; bottle number; CTD pressure and temperature; potential temperature; reversing thermometer reading; CTD salinity; bottle salinity; concentrations of oxygen, silicate, nitrate, nitrite, phosphate, total carbon dioxide, and total alkalinity; and data quality flags. The file is sorted by station number and pressure and may be read by using the following FORTRAN 77 code (contained in **met18dat.for,** File 3):

```
      CHARACTER bot*3, qualt*10
      INTEGER sta, cast, samp
      REAL pre, ctdtmp, theta, revtmp, ctdsal, salt, oxygen, silcat
      REAL nitrat, nitrit, phspht, tcarb, talk
      OPEN (unit=1, file='met18.dat')
      OPEN (unit=2, file='met18.data')
      write (2, 5)

      read (1, 10, end=999) sta, cast, samp, bot, pre, ctdtmp,
     1 revtmp, ctdsal, theta, salt, oxygen, silcat, nitrat, nitrit,
     2 phspht, talk, tcarb, qualt

 10   format (5X, I3, 7X, I1, 6X, I2, 5X, A3, 2X, F6.1, 1X, F9.4,
     1 1X, F8.3, 2X, F9.4, 1X, F9.4, 1X, F9.4, 2X, F6.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.1, 2X, A10)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
sta	Numeric	3	6	8
cast	Numeric	1	16	16
samp	Numeric	2	23	24
bot	Character	3	30	32
pre	Numeric	6	35	40
ctdtmp	Numeric	9	42	50
revtmp	Numeric	8	52	59
ctdsal	Numeric	9	61	69
theta	Numeric	9	71	79
salt	Numeric	9	81	89
oxygen	Numeric	6	92	97
silcat	Numeric	7	99	105
nitrat	Numeric	7	107	113
nitrit	Numeric	7	115	121
phspht	Numeric	7	123	129
talk	Numeric	7	131	137
tcarb	Numeric	7	139	145
qualt	Character	10	148	157

where

sta is the station number;

cast is the cast number;

samp is the sample number;

bot* is the bottle number;

pre is the CTD pressure (dbar);

ctdtmp is the CTD temperature (°C);

revtmp is the reversing thermometer reading (°C);

ctdsal* is the CTD salinity [on the Practical Salinity Scale (PSS)];

theta is the potential temperature (°C);

salt* is the bottle salinity;

oxygen* is the oxygen concentration (µmol/kg);

silcat* is the silicate concentration (µmol/kg);

nitrat* is the nitrate concentration (µmol/kg);

nitrit* is the nitrite concentration (µmol/kg);

phspht* is the phosphate concentration (µmol/kg);

talk* is the total alkalinity concentration (µmol/kg);

tcarb* is the total carbon dioxide concentration (µmol/kg);

qualt is a 10-digit character variable that contains data quality flag codes for parameters flagged by an asterisk (*) in the output file.
Quality flag definitions:

1 = Sample for this measurement was drawn from water bottle but analysis was not received;
2 = Acceptable measurement;
3 = Questionable measurement;
4 = Bad measurement;
5 = Not reported;
6 = Mean of replicate measurements;
7 = Manual chromatographic peak measurement;
8 = Irregular digital chromatographic peak integration;
9 = Sample not drawn for this measurement from this bottle.

uwpco2.dat (File 7)

This file contains underway pCO_2 measurements taken along the cruise track during the R/V *Meteor* Cruise 18/1. Each line of the file contains a sampling date; sampling time; latitude; longitude; and measurements of sea surface salinity, temperature, and pCO_2. The file is sorted by date and time and can be read by using the following FORTRAN 77 code (contained in **uwpco2.for**, File 4):

```
      INTEGER day, month, year
      CHARACTER time*5
      REAL latdcm, londcm, salt, temp, pco2
      OPEN (unit=1, file='uwpco2.dat')
      OPEN (unit=2, file='uwpco2.data')
      write (2, 5)

      read (1, 10, end=999) day, month, year, time, latdcm,
     1 londcm, salt, temp, pco2

 10   format (I2, 2X, I1, 2X, I4, 2X, A5, 3X, F6.3, 3X, F7.3, 3X,
```

```
1 F7.4, 2X, F5.2, 2X, F5.1)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
day	Numeric	2	1	2
month	Numeric	1	5	5
year	Numeric	4	8	11
time	Character	5	14	18
latdcm	Numeric	6	22	27
londcm	Numeric	7	31	37
salt	Numeric	7	41	47
temp	Numeric	5	50	54
pco2	Numeric	5	57	61

where

day is the sampling day;

month is the sampling month;

year is the sampling year;

time is the sampling time (GMT);

latdcm is the latitude of the station (in decimal degrees; negative values indicate the Southern Hemisphere);

londcm is the longitude of the station (in decimal degrees; negative values indicate the Western Hemisphere);

salt is the sea surface salinity;

temp is the sea surface temperature (°C);

pco2 is the sea surface pCO_2 (µatm).

8. VERIFICATION OF DATA TRANSPORT

The data files contained in this NDP can be read by using the FORTRAN 77 data retrieval programs provided. Users should visually examine each data file to verify that the data were correctly transported to their systems. To facilitate the visual inspection process, partial listings of each data file are provided in Tables 6–8. Each of these tables contains the first and last five lines of a data file.

Table 6. Partial listing of "met18sta.inv" (File 5)

First five lines of the file:

06MT18/1	A1E	558	1	090591	1346	60.000	-42.507	185
06MT18/1	A1E	559	1	090591	1607	59.967	-42.175	504
06MT18/1	A1E	560	1	090591	1855	59.930	-41.853	1823
06MT18/1	A1E	561	1	090591	2242	59.895	-41.510	1898
06MT18/1	A1E	562	1	090691	0251	59.863	-41.200	2042

Last five lines of the file:

06MT18/1	A1E	618	2	092091	1657	52.335	-15.500	2834
06MT18/1	A1E	619	1	092091	2251	52.332	-15.218	1262
06MT18/1	A1E	620	1	092191	0220	52.333	-14.932	839
06MT18/1	A1E	621	1	092191	0508	52.337	-14.643	417
06MT18/1	A1E	622	1	092191	0737	52.333	-14.253	335

Table 7. Partial listing of "met18.dat" (File 6)

First five lines of the file:

```
   558       1      12     B44     7.9    6.7531 -999.900   34.7076    6.7524   34.7090   301.9    2.34    6.54
0.16    0.60 -999.90  2086.3  2222244492
   558       1      13     B42     8.0    6.7531 -999.900   34.7065    6.7524   34.7090   301.4    2.54    6.54
0.17    0.57 -999.90  2087.5  2222244492
   558       1      11     B46     8.5    6.7571    6.754   34.7066    6.7563   34.7090   302.4    2.34    6.54
0.16    0.60 -999.90  2086.5  2222244492
   558       1      14      K7     8.7    6.7511 -999.900   34.7059    6.7503   34.7090   301.6    2.54    6.54
0.16    0.58 -999.90  2087.8  2222244492
   558       1      10     B45    26.9    6.2526 -999.900   34.6606    6.2503   34.6650   302.9    2.73    7.23
0.18    0.63 2354.00  2091.5  2222244422
```

Last five lines of the file:

```
   622       1       5     B49   149.2   10.0789 -999.900   35.4284   10.0614   35.4340   248.5    5.47   12.21
0.00    0.79 -999.90  -999.9  2222222299
   622       1       4     B43   197.5    9.9849    9.988   35.4317    9.9619   35.4560   250.5    4.98   12.11
0.01    0.79 -999.90  -999.9  2222222299
   622       1       3     K30   248.0    9.9720 -999.900   35.4517    9.9430   35.4560   251.1    4.98   11.82
0.00    0.77 -999.90  -999.9  2222222299
   622       1       2     B46   296.4    9.8781    9.882   35.4570    9.8436   35.4610   241.3    7.32   12.50
0.01    0.86 -999.90  -999.9  2222222299
   622       1       1     K31   316.0    9.8701 -999.900   35.4589    9.8333   35.4620   239.1    8.01   12.60
0.01    0.87 -999.90  -999.9  2222222299
```

Table 8. Partial listing of "uwpco2.dat" (File 7)

First five lines of the file:

```
 3   9   1991   20:20    62.666    -30.026    34.9400    9.13   294.3
 3   9   1991   20:25    62.660    -30.057    34.9300    9.30   303.4
 3   9   1991   20:30    62.655    -30.088    34.9267    9.37   307.9
 3   9   1991   20:35    62.648    -30.120    34.9150    9.40   306.6
 3   9   1991   20:40    62.640    -30.151    34.9133    9.40   305.3
```

Last five lines of the file:

```
22   9   1991   19:30    49.722     -4.782    35.3800   15.90   336.1
22   9   1991   21:00    49.747     -4.353    35.4600   15.70   340.2
22   9   1991   21:05    49.748     -4.329    35.4800   15.70   340.2
22   9   1991   21:10    49.750     -4.306    35.4950   15.65   337.2
22   9   1991   21:15    49.751     -4.282    35.4633   15.70   337.9
```

APPENDIX A:

STATION INVENTORY

APPENDIX A:
STATION INVENTORY

This appendix lists station inventory information for the 61 sites occupied during the R/V *Meteor* Cruise 18/1 in the North Atlantic Ocean . The meanings of the column headings in Table A-1 are as follows.

EXPOCODE is the expocode of the cruise;

SECT is the WOCE section number;

STNNBR is the station number;

CASTNO is the cast number;

DATE is the sampling date (month/day/year);

TIME is the sampling time (GMT);

LATDCM is the latitude of the station (in decimal degrees). Stations in the Southern Hemisphere have negative latitudes;

LONDCM is the longitude of the station (decimal degrees). Stations in the Western Hemisphere have negative longitudes;

DEPTH is the sounding bottom depth (in meters).

Table A.1 Station inventory information for the 61 sites occupied during R/V *Meteor* Cruise 18/1.

EXPOCODE	SECT	STNNBR	CASTNO	DATE	TIME	LATDCM	LONDCM	DEPTH
06MT18/1	A1E	558	1	090591	1346	60.000	-42.507	185
06MT18/1	A1E	559	1	090591	1607	59.967	-42.175	504
06MT18/1	A1E	560	1	090591	1855	59.930	-41.853	1823
06MT18/1	A1E	561	1	090591	2242	59.895	-41.510	1898
06MT18/1	A1E	562	1	090691	0251	59.863	-41.200	2042
06MT18/1	A1E	563	1	090691	0657	59.833	-40.867	2330
06MT18/1	A1E	564	1	090691	1138	59.787	-40.205	2631
06MT18/1	A1E	565	1	090691	1624	59.705	-39.590	2807
06MT18/1	A1E	566	1	090691	2205	59.590	-38.598	3013
06MT18/1	A1E	567	1	090791	1139	59.505	-37.548	3129
06MT18/1	A1E	568	1	090791	1701	59.402	-36.648	3130
06MT18/1	A1E	569	1	090791	2210	59.335	-35.943	3116
06MT18/1	A1E	570	1	090891	0348	59.233	-35.002	2861
06MT18/1	A1E	571	1	090891	1222	59.145	-34.037	2855
06MT18/1	A1E	573	1	090991	0035	59.137	-33.993	2734
06MT18/1	A1E	574	1	090991	0453	59.077	-33.403	2521
06MT18/1	A1E	575	1	090991	0920	59.013	-32.772	2063
06MT18/1	A1E	576	1	090991	1401	58.942	-32.128	1752
06MT18/1	A1E	577	2	090991	2040	58.882	-31.490	1550
06MT18/1	A1E	578	1	091091	0041	58.798	-30.832	1272
06MT18/1	A1E	579	1	091091	0437	58.562	-30.387	1736
06MT18/1	A1E	580	1	091091	0858	58.330	-29.942	2369
06MT18/1	A1E	581	1	091091	1547	58.185	-29.618	2070
06MT18/1	A1E	582	1	091091	1944	58.085	-29.500	2252
06MT18/1	A1E	583	1	091191	0020	57.858	-29.057	2333
06MT18/1	A1E	584	1	091191	0519	57.617	-28.635	2420
06MT18/1	A1E	585	1	091191	1321	57.370	-28.158	2645
06MT18/1	A1E	586	1	091191	2005	56.912	-27.840	2922
06MT18/1	A1E	587	1	091291	0242	56.460	-27.493	2779
06MT18/1	A1E	588	1	091291	0950	55.992	-27.125	2819
06MT18/1	A1E	589	1	091291	1545	55.533	-26.800	3194
06MT18/1	A1E	590	1	091291	2159	55.068	-26.460	3378
06MT18/1	A1E	591	1	091391	0505	54.610	-26.118	3420
06MT18/1	A1E	592	1	091491	0256	53.865	-26.285	3643
06MT18/1	A1E	593	1	091491	0656	54.033	-26.018	3319
06MT18/1	A1E	595	1	091491	1407	54.265	-25.600	2554
06MT18/1	A1E	596	1	091491	1741	54.377	-25.950	3229
06MT18/1	A1E	597	1	091491	2254	54.155	-25.762	3156
06MT18/1	A1E	598	1	091591	0334	53.920	-25.637	3622
06MT18/1	A1E	599	1	091591	1120	53.672	-25.425	3626
06MT18/1	A1E	600	1	091591	1715	53.463	-24.685	3570
06MT18/1	A1E	601	1	091591	2340	53.267	-23.898	3718
06MT18/1	A1E	602	1	091691	0559	53.068	-23.130	3875
06MT18/1	A1E	603	1	091691	1236	52.858	-22.377	4005
06MT18/1	A1E	604	1	091691	1846	52.655	-21.613	3990
06MT18/1	A1E	605	1	091791	0114	52.467	-20.863	3739
06MT18/1	A1E	607	1	091791	1601	52.497	-20.000	2803
06MT18/1	A1E	608	1	091791	2123	52.175	-19.993	3783
06MT18/1	A1E	609	1	091891	0345	52.358	-20.468	3646
06MT18/1	A1E	610	1	091891	0920	52.337	-20.000	3308
06MT18/1	A1E	611	1	091891	1459	52.337	-19.412	3600
06MT18/1	A1E	612	1	091891	2103	52.323	-18.620	4329
06MT18/1	A1E	613	1	091991	0402	52.332	-17.815	4292
06MT18/1	A1E	615	1	091991	1859	52.327	-16.988	3931
06MT18/1	A1E	616	1	092091	0119	52.325	-16.202	3465
06MT18/1	A1E	617	1	092091	0706	52.338	-15.772	3273
06MT18/1	A1E	618	1	092091	1207	52.335	-15.502	2839
06MT18/1	A1E	618	2	092091	1657	52.335	-15.500	2834
06MT18/1	A1E	619	1	092091	2251	52.332	-15.218	1262
06MT18/1	A1E	620	1	092191	0220	52.333	-14.932	839
06MT18/1	A1E	621	1	092191	0508	52.337	-14.643	417
06MT18/1	A1E	622	1	092191	0737	52.333	-14.253	335

INTERNAL DISTRIBUTION

1. L. D. Bates
2. B. A. Berven
3. T. A. Boden
4. R. B. Cook
5. J. H. Cushman
6. R. M. Cushman
7. V. H. Dale
8. M. P. Farrell
9. D. E. Fowler
10. R. L. Graham
11. S. G. Hildebrand
12. G. K. Jacobs
13. P. Kanciruk
14. D. P. Kaiser
15. A. Kozyr
16. J. M. Loar
17. D. E. Reichle
18. F. E. Sharples
19. D. E. Shepherd

20-219. CDIAC

221. Central Research Library

222-223. ESD Library

224-225. Laboratory Records Department

226. Laboratory Records, RC

227. ORNL Patent Office

228. ORNL Y-12 Technical Library

EXTERNAL DISTRIBUTION

229. William Asher, Marine Sciences Laboratory, Pacific Northwest Laboratory, 1529 West Sequim Bay Road, Sequim, WA 98382

230. James R. Akse, Umpqua Research Company, P.O. Box 791-125 Volunteer Way, Myrtle Creek, OR 97457

231. S. S. Alexander, Pennsylvania State University, Department of Geosciences, 503 Deike Building, University Park, PA 16802

232. J. H. Allen, National Oceanic and Atmospheric Administration, National Geophysical Data Center Code E/GC2, 325 Broadway, Boulder, CO 80303

233. D. Alvic, EERC/UT, Pellissippi Office, Ste. 100, 10521 Research Drive, Knoxville, TN 37932

234. Robert F. Anderson, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964

235. Colin Attwood, Sea Fisheries Research Institute, Private Bag X2 Roggebaai, 8012, South Africa

236. Donald K. Atwood, NOAA/AOML/OCD, 4301 Rickenbacker Causeway, Miami, FL 33149

237. Rich Barber, Duke University of North Carolina Oceanographic Consortium, Duke University Marine Laboratory, Beaufort, NC 28516

238. R. C. Barry, University of Colorado, World Data Center A, Glaciology, CIRES, Campus Box449, Boulder, CO 80309-0449

239. Jim Bauer, Department of Oceanography, B-169, Florida State University, Tallahassee, FL 32306-3048

240. Robert Bidigare, University of Hawaii, 1000 Pope Road, Honolulu, HI 96822

241. Peter G. Brewer, Monterey Bay Aquarium Research Institute, 160 Central Avenue, Pacific Grove, CA 93950

242. John A. Brimble, UIC, Inc., P.O. Box 83, 1225 Channahon Road, Joliet, IL 60434-0863

243. Jose Joaquin Hernandex Brito, Facultad de Ciencias del Mar, Dep. Quimica, Universidad de las Palmas, AP. 550, Las Palmas 35017, Spain

244. Michelle Broido, Acting Director, Environmental Sciences Division, Office of Health and Environmental Research, Department of Energy, ER-74, 19901 Germantown Road, Germantown, MD 20874-1290

245. Otis B. Brown, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149

246. Lutz Brugmann, Department of Geology and Geochemistry, Stockholm University, S-106 91 Stockholm, Sweden

247. Alexander S. Bychkov, Climate Chemistry Laboratory, 43, Baltiyskaya Street, Vladivostok, 690041 Russia

248. Robert H. Byrne, University of South Florida, Department of Marine Science ,140 Seventh Avenue South, St. Petersburg, FL 33701-5016

249. M. A. Chinnery, National Oceanic and Atmospheric Administration, National Geophysical Data Center Code E/GC2, 325 Broadway, Boulder, CO 80303

250. David W. Chipman, Lamont-Doherty Earth Observatory of Columbia University, Climate/Environment/Ocean Division, RT 9W, Palisades, NY 10964-8000

251. Y. Collos, Laboratoire d'Hydrobiologie, Univ. Montpellier, CC093 34095 Montpellier Cedex 5, France

252. Claire Copin-Montegut, Laboratoire de Physique et Chimie Marines, Universite Pierre et Marie Curie, Quai de la Darse BP 8, 06230 Villefranche sur Mer, France

253. Greg Cutter, Department of Oceanography, Old Dominion University, Norfolk, VA 23529-0276

254. Giovanni Daneri, Dept De Oceanografia y Biologia Pesquera, CEA Universidad Del Mar, Amunategui 1838, Vina Del Mar, Chile

255. Hein J. W. de Baar, Netherlands Institute for Sea Research, P.O. Box 59 1790, Ab den Burg, Texel, The Netherlands

256. Thomas Dickey, University of Southern California, Ocean Physics Group, Los Angeles, CA 90007

257. Andrew G. Dickson, University of California, Marine Physical Laboratory-0902 9500 Gilman Drive, La Jolla, CA 92093-0902

258. Scott Doney, Oceanography Section, NCAR, PO Box 3000, Boulder, CO 80307

259. W. Draeger, EROS Data Center, U.S. Geological Survey, Sioux Falls, SD 57198

260. M. Dryer, National Oceanic and Atmospheric Administration, Space Environmental Lab., ERL/OAR, R/E/SE, 320 Broadway, Boulder, CO 80303

261. Hugh W. Ducklow, Woods Hole Oceanographic Institution, Clark 4th Floor, Woods Hole, MA 02543

262. Brian J. Eadie, Great Lakes Environmental Research Laboratory, NOAA U.S. Department of Commerce, 2205 Commonwealth Blvd., Ann Arbor, MI 48105

263. J. F. Farvolden, Professor, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1 Canada

264. Richard Feely, National Oceanic & Atmospheric Administration, Pacific Marine Envir. Lab, 7600 Sand Point Way, NE, Seattle, WA 98115

265. Gene C. Feldman, NASA/GSFC, Code 936, Building 28, Room W161B, Goddard Space Flight Center, Greenbelt, MD 20771

266. J. Filson, National Earthquake Information Center, U.S. Geological Survey, Denver Federal Center, P.O. Box 20546, Denver, CO 80225

267. Martin Q. Fleisher, Dept. of Geochemistry, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964

268. Jerry F. Franklin, Bloedel Professor of Ecosystem Analysis, College of Forest Resources, University of Washington, Anderson Hall (AR-10), Seattle, WA 98195

269. Diana W. Freckman, Director, College of Natural Resources, 101 Natural Resources Building, Colorado State University, Fort Collins, CO 80523

270. Richard H. Gammon, University of Washington, Chemistry Department, BG-10, Seattle, WA 98195

271. Wilford D. Gardner, Department of Oceanography, Texas A & M University, College Station, TX 77843

272. Christopher Garside, Bigelow Laboratory for Ocean Science, McKnown Point, West Boothbay Harbor, ME 04575

273. Jean-Pierre Gattuso, Observatoire Oceanologique European, Avenue Saint-Martin, MC-98000, Monaco

274. Bob Gershey, Bedford Institute of Oceanography, Box 1006 1 Challenger Drive/Shannon Park, Dartmouth, Nova Scotia, Canada B2Y 4A2

275. Jorunn S. Gislefoss, Radiological Dating Laboratory, The Norwegian Institute of Technology, N-7034 Trondheim-NTH, Norway

276. John G. Goddard, Lamont-Doherty Earth Observatory of Columbia University, ClimateEnviornment/Ocean Division, RT 9W, Palisades, NY 10964-8000

277. Lars G. Golmen, Norwegian Institute for Water Research, Regional Office, Bergen, Thormohlensgt. 55 5008, Bergen, Norway

278. Catherine Goyet, Chemistry Dept., Woods Hole Oceanographic Institution, Clark 461, Woods Hole, MA 02543

279. S. Graves, National Aeronautics and Space Administration Headquarters Code SED, 600 Independence Avenue, Washington, DC 20546

280. J. L. Green, National Space Science Data Center, NASA Goddard Space Flight Center, Code 630.2, Greenbelt, MD 20771

281. Elizabeth Gross, SCOR, Department of Earth and Planetary Sciences, The John Hopkins University, Baltimore, MD 21218

282. Nicolas Gruber, Climate and Environmental Physics, Physics Insitute, University of Bern, Sidlerstr.5, CH-3012 Bern, Switzerland

283. Peter Guenther, Scripps Institution of Oceanography, University of California, Geological Research Div. 0220, 9500 Gilman Drive, La Jolla, CA 92093-0220

284. K. D. Hadeen, National Oceanic and Atmospheric Administration, NESDIS/NCDC, Federal Building MC E/CC, Asheville, NC 28801

285. Koh Harada, National Institute for Resources and Environment, 16-3 Onogawa, Tsukuba, Ibaraki 305, Japan

286. Akira Harashima, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305, Japan

287. R. C. Harriss, Institute for the Study of Earth, Oceans, and Space, Science and Engineering Research Building, University of New Hampshire, Durham, NH 03824

288. Mette Hein, Freshwater Biological Laboratory, Helsingoersgade 51, DK-3400 Hilleroed, Denmark

289. James C. Hendee, Data Manager, NOAA/AOML/OCD, 4301 Rickenbacker Causeway, Miami, FL 33149

290. W. J. Hinze, Purdue University, Department of Earth and Atmospheric Sciences, West Lafayette, IN 47907

291. Hilary Hodgson, DSC, Special Acquisitions, British Library, Boston Spa, Wetherby, West Yorkshire LS23 7BQ, United Kingdom

292. Huasheng Hong, Research Centre, The Hong Kong University of Science & Technology, Clear Water Bay, Kowloon, Hong Kong

293. Masao Ishii, Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki, 305, Japan

294. John Jamerlan, Customer and Applications Support Technician, Europa Scientific,1776 Mentor Avenue, Cincinnati, OH 45212-3597

295-299. Kenneth M. Johnson, Brookhaven National Laboratory, OASD Bldg. 318, Upton, NY 11973

300. W. Keith Johnson, Centre For Ocean Climate Chemistry, Institute of Ocean Sciences, 9860 W. Saanich Road, Sidney, BC, Canada V8L 4B2

301. Fortunat Joos, Physics Institute, KUP, Sidlerstr. 5, CH-3012 Bern, Switzerland

302. G. Y. Jordy, Director, Office of Program Analysis, Office of Energy Research, ER-30, G-226, U.S. Department of Energy, Washington, DC 20585

303. Terrence M. Joyce, WOCE Hydrographic Program Office, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

304. Susan Kadar, Clark 461, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

305. Dong-Jin Kang, Marine Natural Products Chemistry Laboratory, Ansan P.O. Box 29, Seoul 425-600, Korea

306. David Karl, Department of Oceanography, University of Hawaii, 1000 Pope Road, Honolulu, HI 96822

307. Charles D. Keeling, Scripps Institution of Oceanography, University of California San Diego, Geological Research Division, A020, 2314 Ritter Hall, La Jolla, CA 92093-0220

308. Kimberly C. Kelly, PMEL/NOAA, 7600 Sandpoint Way NE, Building 3, Seattle, WA 98115

309. Stephan Kemp, Geologisch-Palaontologisches Institut, H Darmstadt, Schnittspahnstrabe 9, 64287 Darmstadt, Gemany

310. Robert Key, Princeton University, Geology Department, Princeton, NY 08544

311. Kyung-Ryul Kim, Ph.D., Department of Oceanology, Seoul National University, Seoul 151-742, Korea

312. Takashi Kimoto, Research Institute of Oceano-Chemistry, Osaka Office - 5-19 Funahashi-cho, Tennoji-ku, Osaka 543, Japan

313. Bert Klein, GIROQ Universite, Laval Pav., Vachon, Quebec PQ, Canada G1K 7P4

314. Anthony H. Knap, BBSR, Inc., Ferry Reach 1-15, Bermuda

315. S. Krishnaswami, Physical Research Laboratory, Navrangpura, Ahmedabad-380009, India

316. D. Lauer, EROS Data Center, U.S. Geological Survey, Sioux Falls, SD 57198

317. Dr. Nathalie Lefevre, Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, United Kingdom

318. Margaret Leinen, Graduate School of Oceanography, University of Rhode Island, Kingston, RI 02882-1197

319. S. Levitus, NOAA/National Oceanographic Data Center, 1825 Connecticut Avenue, NW, Washington, DC 20235

320. Ernie Lewis, Oceanographic Sciences Division, Brookhaven National Laboratory, Upton, NY 11973

321. Marlon Lewis, Department of Oceanography, Dalhousie University, Halifax, Nova Scotia B3H 4J1, Canada

322. A. M. Linn, Program Officer, BESR, National Academy of Sciences, Harris Building 372, 2101 Constitution Avenue NW, Washington, DC 20418

323. Hugh D. Livingston, Woods Hole Oceanographic Institution, Clark 4, Woods Hole, MA 02543

324. M. S. Loughridge, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Code E/GC3, 325 Broadway, Boulder, CO 80303

325. Clarence Low, NASA-Ames Research Center, Mail Stop 239-4, Moffett Field, CA 94035-1000

326. Bram Majoor, Netherlands Institute for Sea Research, P.O. Box 59, 1790 Ab den Burg, Texel, The Netherlands

327. James J. McCarthy, Museum of Comparative Zoology, Harvard University, 26 Oxford Street, Cambridge, MA 02139

328. Dennis McGillicuddy, Physical Oceanography Department, Woods Hole Oceanographic Institution, Clark 205A, Woods Hole, MA 02543

329. Nicolas Metzl, Universite Pierre et Marie Curie - Paris 6, Laboratoire de Physique et Chimie Marines, T24-25 - Case 134-4, place Jussieu-75252, Cedex 05, France

330. Frank J. Millero, University of Miami, RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149-1098

331. DongHa Min, Trace Gas Lab, Department of Oceanography, Seoul National University, Seoul, Korea (151-742)

332-336. Dr. Ludger Mintrop, Marine Chemist, Institute for Marine Research, Marine Chemistry Department, Duesternbrooker Weg 20, D-214105 Kiel, Germany

337. M. Nicole Momzikoff, Bibliothecaire, Institut Oceanographique Bibliotheque, 195, rue Saint-Jacques, F 75005 Paris, France

338. Pedro M. S. Monteiro, Department of Oceanography, University of Cape Town, Rondebosch 7700, South Africa

339. Lloyd Moore, NOAA/AOML/OCD, 4301 Rickenbacker Causeway, Miami, FL 33149

340. Mary Morris, The Martin Ryan Marine Science Institute, University College, Galway, Ireland

341. John W. Morse, Department of Oceanography, Texas A & M University, College Station, TX 77843-3148

342. Peter J. Muller, Universitat Bremen, Fachbereich Geowissenschaften, Postfach 330 440, D-28334 Bremen, Germany

343. Shohei Murayama, Atmospheric Environment Division, National Institute for Resources and Environment, 16-3 Onogawa, Tsukuba, Ibaraki 305 Japan

344. Paulette P. Murphy, PMEL/NOAA, 7600 Sandpoint Way NE, Building 3, Seattle, WA 98115

345. James W. Murray, School of Oceanography, WB-10, University of Washington, Seattle, WA 98195

346. Jae Ryoung Oh, Chemical Oceanography lab, KORDI, An San P.O. Box 29, Seoul 425-600, Korea

347. Eiji Ohtaki, Environmental Science and Technology, Okayama University, Okayama 700, Japan

348. Jon 'Olafsson, Marine Research Institute, P.O. Box 1390, Skulagata 4, *121 Reykjavik*, Iceland

349. Curtis R. Olsen, US Department of Energy, Environmental Sciences Division, ER-74, Office of Energy Research, 19901 Germantown Road, Germantown, MD 20874-1290

350. R. H. Olsen, Vice President for Research, University of Michigan, Medical Science Building II, #5605, 1301 East Catherine Street, Ann Arbor, MI 48109-0620

351. Michael J. Orren, Professor, Head. Dept. Of Oceanography, Universtiy College Galway, 80 Harcourt Street, Dublin 2, Ireland

352. Claude Oudot, Centre ORSTOM de Cayenne, B. P. 165-97323, CAYENNE Cedex, French Guyana

353. J. T. Overpeck, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Paleoclimatology Program, 325 Broadway E/EC, Boulder, CO 80303

354. Bobbi Parra, US Department of Energy, Environmental Sciences Division, Office of Health and Environmental Research, 19901 Germantown Road, Germantown, MD 20874-1290

355. Ari Patrinos, Associate Director, Office of Health and Environmental Research, U.S. Department of Energy, 19901 Germantown Road, Germantown, MD 20874-1290

356. Kay Pegler, Universitat Hamburg, Institut fur Biogeochemie und Meereschemie, Jungiusstrasse, 6, 1000 Hamburg 36, Germany

357. T-H Peng, Ocean Chemistry Division, NOAA/AOML/OCD, 4301 Rickenbacker Causeway, Miami, FL 33149

358. Dr. Fiz F. Perez, Consejo Superior de Investigaciones Cientificas, Instituto de Investigacions Marinas, Eduardo Cabello, 6-36208 VIGO (Espana)

359. Trevor Platt, Department of Fisheries & Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2, Canada

360. Alain R. H. Poisson, Univ. Pierre et Marie Cuie, Lab de Phys. et Chimie Marines, Case 134, 4 Place Jussieu, 75252 Paris Cedex 05, France

361. Barbara Preselin, Dept. of Biological Sciences, University of California, Santa Barbara, CA 93106

362. Paul Quay, School of Oceanography, WB-10, University of Washington, Seattle, WA 98195

363. S. Ichtiaque Rasool, IGBP Data and Information System Office, Universite Paris, Tour 26, 4 Etage, Aile 26-16, 4 Place Jussieu, 75230 Paris, Cedex 06, France

364. Clare Reimers, Institute of Marine and Coastal Sciences, Rutgers University, P.O. Box 231, New Brunswick, NJ 08903-0231

365. Joachim Ribbe, Flinders University of S. A., School of Earth Sciences, GPO Box 2100, Adelaide, 5001 S. A., Australia

366. Michael R. Riches, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, 19901 Germantown Road, Germantown, MD 20874-1290

367. Aida F. Rios, Consejo Superior de Investigaciones Cientifican, Instituto de Investigacions Marinas, Eduardo Caballo 6-36208, Vigo, Spain

368. Marilyn Roberts, NOAA/PMEL, 7600 Sandpoint Way NE, Building 3, Seattle, WA 98115

369. Jane Robertson, University of Wales, Department of Geology, P.O. Box 914, Cardiff CF1 3YE, United Kingdom

370. Carol Robinson, University of Wales: Bangor, School of Ocean Sciences, Menai Bridge, Gwynedd LL59 5EY, United Kingdom

371. Stephany Rubin, Lamont-Doherty Earth Observatory of Columbia University, Ulimate/Environment/Ocean Division, RT 9W, Palisades, NY 10964-8000

372. Christopher Sabine, Princeton University, Geology Dept./Guyot Hall, Princeton, NJ 08544

373. Dan Sadler, Univerrsity of Hawaii, 1000 Pope Road, Honolulu, HI 96822

374. Ray Sambrotto, Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, Palisades, NY 10964

375. Jorge L. Sarmiento, Universitat Bern, Physikalisches Institut, Abteilung KUP, Sidlerstrasse 5, 3012 Bern, Switzerland

376. Tatyana G. Sazhina, P. Shirshov Institute of Oceanology, Russian Academy of Sciences, 23, Krasikova Str., Moscow 117218 Russia

377. Claire L. Schelske, Department of Fisheries and Aquaculture, University of Florida, 7922 W 71st Street, Gainesville, FL 32606

378-382. Bernd Schneider, Institut fur Ostseeforschung, SeestraBe 15, Rostock-Warnemunde, Germany

383. Alan Shiller, Center for Marine Science, University of Southern Mississippi, Stennis Space Center, MS 39529

384. Kiminori Shitashima, Environmental Science Department, Abiko Research Laboratory, Central Research Institute of Electric Power Industry, 1646, Abiko, Abiko City, Chiba, 270-11, Japan

385. A. L. Shumbera, National Oceanic and Atmospheric Administration, WDC-A for Meteorology, National Climatic Data Center, Federal Building MC E/CC, Asheville, NC 28801

386. Nelson Silva, Escuela de Ciencias del Mar, Universidad Catolica de Valparaiso, Casilla 1020, Valparaiso, Chile

387. Sharon Smith, RSMAS, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149

388. Michel H. C. Stoll, Centre for Environmental and Resources Studies, Hoeyteknologisenteret University of Bergen, N-5020 Bergen, Norway

389. Eric T. Sundquist, U.S. Geological Survey, Branch of Atlantic Marine Geology, Quissett Campus, Woods Hole, MA 02543

390. Stewart C. Sutherland, Lamont-Doherty Earth Observatory of Columbia University, Climate/Environment/Ocean Division, RT 9W, Palisades, NY 10964-8000

391. James H. Swift, Scripps Institution of Oceanography, University of California, San Diego Oceanographic Data Facility, 9500 Gilman Drive, La Jolla, CA 92093-0124

392. Taro Takahashi, Lamont-Doherty Earth Observatory of Columbia University, Climate/Environment/Ocean Division, RT 9W, Palisades, NY 10964-8000

393. Lynne D. Talley, Scripps Institution of Oceanography, UCSD 0230, 9500 Gilman Drive, La Jolla, CA 92075-0230

394. James F. Todd, NOAA/OAR Office of Global Programs, Room 4142, SSMC-1, 1335 East-West Highway, Silver Spring, MD 20910

395. Jane Tucker, Marine Biological Laboratory, Woods Hole, MA 02543

396. David Turner, Department of Analytical and Marine Chemistry, University of Goteborg, S-41296 Goteborg, Sweden

397. J. Val Klump, Center for Great Lakes Studies, University of Wisconsin, 600 East Greenfield Avenue, Milwaukee, WI 53204

398. Michiel Rutgers van der Loeff, Alfred Wwegener Institute for Polar and Marine Research, Columbusstrasse 2855, Bremerhaven, Germany

399-403. Douglas W. R. Wallace, Brookhaven National Laboratory, Oceanographic Sciences Division, Bldg. 318, Upton, NY 11973

404. Richard H. Wanninkhof, NOAA/AOML/OCD, 4301 Rickenbacker Causeway, Miami, FL 33149

405. Bess B. Ward, Marine Sciences Program, University of California, Santa Cruz, CA 95064

406. Richard Weisburd, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki, 305, Japan

407. Ray F. Weiss, University of California, Scripps Institute of Oceanography, Mail code A-020, Room 2271, Ritter Hall, La Jolla, CA 92093

408. Richard J. Wilke, Brookhaven National Laboratory, Oceanographic Sciences Division, Bldg. 318, Upton, NY 11973

409. Christopher Winn, Scripps Institution of Oceanography, Marine Physical Lab, 9500 Gilman Drive, La Jolla, CA 92093-0230

410. Amos Winter, Ph.D., Associate Professor, Marine Geology, University of Puetro Rico, Department of Marine Sciences, Mayaguez, Puerto Rico 00681-5000

411. F. J. Wobber, Environmental Sciences Division, Office of Health and Environmental Research, Office of Energy Research, ER-74, U.S. Department of Energy, 19901 Germantown Road, Germantown, MD 20874-1290

412. C. S. Wong, Centre for Ocean Climate Chemistry, Institute of Ocean Sciences, P.O. Box 6000, Sidney, British Columbia V8L 4B2, Canada

413. L. Xu, Department of Oceanography, Xiamen University, Xiamen, Fujian, Peoples Republic of China

414. Evgeniy V. Yakushev, Ph.D., Senior Associate Scientist, P. P. Shirshov Institute of Oceanology, Russian Academy of Sciences, 26 Krasikova Street, 109017 Moscow, Russia

415. Masumi Yamamuro, Marine Geology Department, Geological Survey of Japan, 1-1-3 Higashi, Tsukuba, Ibaraki 305, Japan

416. D. B. Yang, Korea Ocean Research and Development Institute, Ansan, P.O. Box 29, Seoul, 425-600, Korea

417. Office of Assistant Manager for Energy Research and Development, U.S. Department of Energy Oak Ridge Operations, P. O. Box 2001, Oak Ridge, TN 37831-8600

418-419. Office of Scientific and Technical Information, P. O. Box 62, Oak Ridge, TN 37831