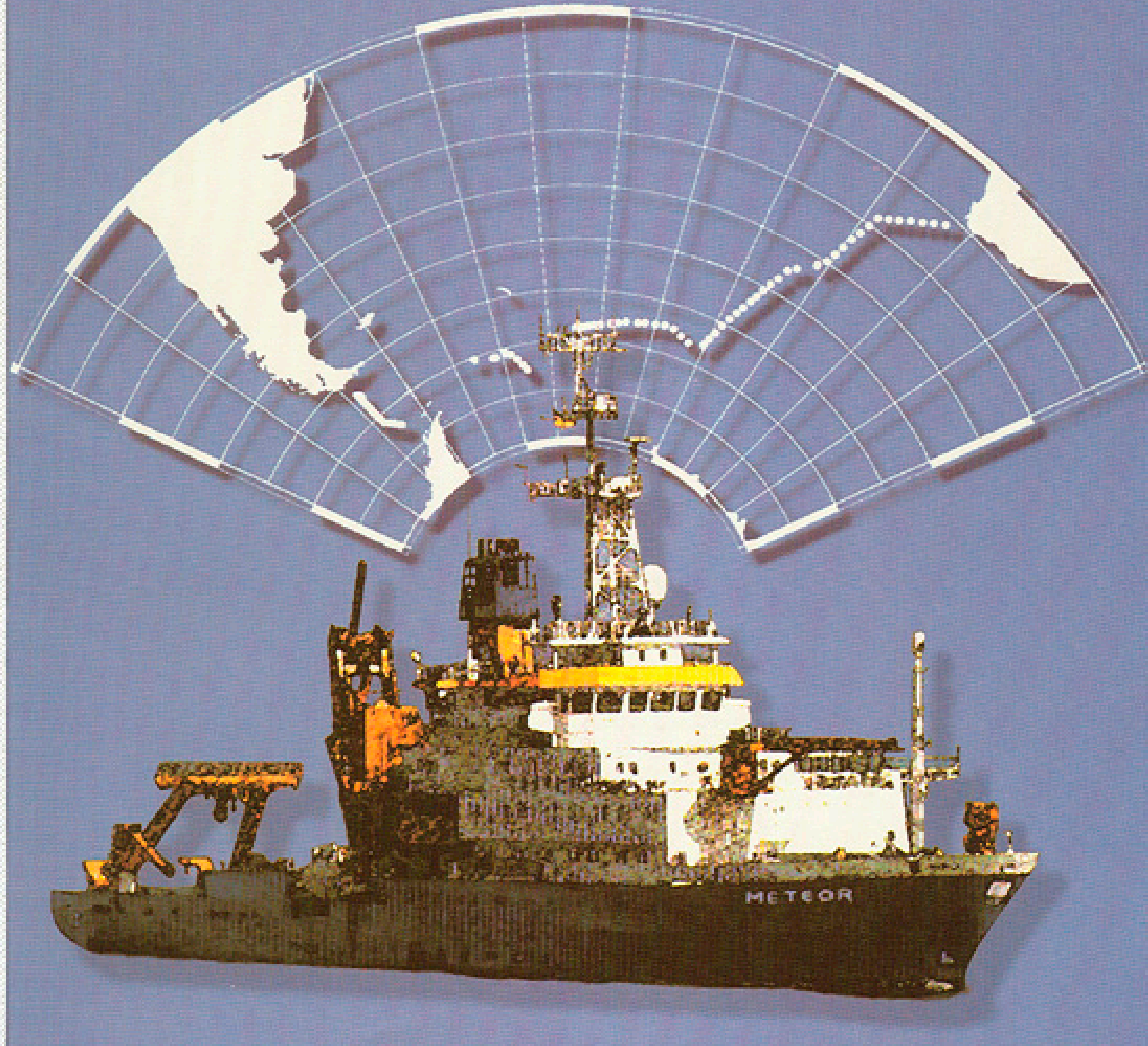
Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V Meteor Cruise 11/5 in the South Atlantic and Northern Weddell Sea Areas (WOCE Sections A-12 and A-21)



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Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Oak Ridge, Tennessee

ORNL/CDIAC-55
(NDP-045)

CARBON DIOXIDE, HYDROGRAPHIC, AND CHEMICAL DATA OBTAINED DURING THE R/V *METEOR* CRUISE 11/5 IN THE SOUTH ATLANTIC AND NORTHERN WEDDELL SEA AREAS (WOCE SECTIONS A-12 AND A-21)

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ABSTRACT

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This document presents the procedures and methods used to obtain carbon dioxide (CO_2), hydrographic, and chemical data during the R/V *Meteor* Expedition 11/5 in the South Atlantic Ocean, including the Drake Passage (Section A-12); the Northern Weddell Sea; and the Eastern South Atlantic Ocean (Section A-21). This cruise was conducted as part of the World Ocean Circulation Experiment (WOCE).

The cruise started from Ushuaia, Argentina, on January 23, 1990, and ended at Capetown, South Africa on March 8, 1990. Samples were collected at 78 stations that covered the Drake Passage (56–63° S); the Northern Weddell Sea (45–35° W); a section along the 58° W parallel (25° W–prime meridian); and two segmented S-N sections between the Northern Weddell Sea and Capetown, South Africa. Measurements taken at WOCE sections A-12 and A-21 included pressure, temperature, salinity measured by the Conductivity, Temperature and Depth sensor (CTD); bottle salinity; oxygen; phosphate; nitrate; nitrite; silicate; total carbon concentration (TCO_2); and partial pressure of CO_2 (pCO_2) measured at 20°C. In addition, potential density at 0 decibar (dbar) and potential temperature were calculated from the measured variables.

The TCO_2 concentration in seawater samples was measured using a coulometer with an estimated precision of approximately ±1 μmol/kg. The coulometer was calibrated frequently at sea by using a high-precision gas pipette and CO_2 gas (99.998%). The pCO_2 value in seawater samples was measured at 20°C by means of a constant volume (500 ml seawater) equilibrator and a gas chromatograph. CO_2 in equilibrated gas was first converted to methane, by using a ruthenium catalyst, and then measured by a flame-ionization detector. The precision of pCO_2 measurements has been estimated to be approximately ±0.1%.

The CO_2 investigation during the R/V *Meteor* Cruise 11/5 was supported by a grant from the U.S. Department of Energy (No. DE-FGO2-90ER60943).

The data set is available, free of charge, as a Numeric Data Package (NDP) from CDIAC. The NDP consists of seven data files and this printed documentation, which describes the contents and format of all data files as well as the procedures and methods used to obtain these data during the R/V *Meteor* Cruise 11/5.

Keywords: Carbon dioxide; World Ocean Circulation Experiment (WOCE); South Atlantic Ocean; Weddell Sea; hydrographic measurements; carbon cycle.

PART 1:

OVERVIEW

1. BACKGROUND INFORMATION

The World Ocean plays a dynamic role in the Earth's climate: it captures heat from the sun, transports it, and releases it thousands of miles away. These oceanic-solar-atmospheric interactions affect winds, rainfall patterns, and temperatures on a global scale. The oceans also play a major role in global carbon cycle processes. Carbon in the oceans is unevenly distributed because of complex circulation patterns and biogeochemical cycles, neither of which is completely understood. In addition to circulation patterns, biological processes (i.e., photosynthesis and respiration) play a crucial role in the carbon cycle. The oceans are estimated to hold 38,000 gigatons of carbon, which is 50 times more carbon than that in the atmosphere and 20 times more carbon than that held by plants, animals, and the soil (Williams 1990). Thus, if only 2% of the carbon stored in the oceans is released, the level of atmospheric carbon dioxide (CO_2) would double (Williams 1990). Furthermore, every year more than 15 times as much CO_2 is exchanged across the sea surface than the amount produced by the burning of fossil fuels, deforestation, and other human activities (Williams 1990).

Several large experiments were conducted in the past, and others are currently under way, attempting to better understand the oceans and their role in climate and the global carbon cycle. One of the earliest large-scale oceanographic projects was the Geochemical Ocean Section Study (GEOSECS). The goal of GEOSECS was to study geochemical properties of the oceans with respect to large-scale circulation problems. The project, which covered the Atlantic (1972–73), Pacific (1973–74), and Indian (1977–78) oceans, officially started in 1971 and was noted for its use of equipment and techniques that were at the forefront of modern technology and knowledge. The Transient Tracers in the Ocean (TTO) project (1982) was designed to measure the distribution of CO_2 and hydrographic properties in the North Atlantic Ocean. The World Ocean Circulation Experiment (WOCE) started in 1990 and is currently under way. WOCE is the first research program of sufficient scope to mount a true global study of the ocean. WOCE brings together the expertise of scientists and technicians from many nations in an oceanographic experiment that is larger than any ever attempted. Another multinational program currently under way is the Joint Global Ocean Flux Study (JGOFS). The purpose of JGOFS is to investigate the processes controlling marine biogeochemical cycles, specifically carbon and nutrient cycles.

During the lifetime of the WOCE project, from 1990 to 1997, approximately 23,000 stations will be sampled in oceans around the world. This document provides and describes data collected during a 45-day expedition in the South Atlantic Ocean, Northern Weddell Sea, and Drake Passage aboard the German research vessel *Meteor*. The cruise, referred to as cruise number 11, leg 5 (11/5), was conducted during the austral summer. It started at Ushuaia, Argentina, on January 23, 1990, and ended at Capetown, South Africa, on March 8, 1990. Seventy-eight stations were occupied along the WOCE sections A-21 and A-12 (Fig. 1).

The CO_2 investigation during the R/V *Meteor* Cruise 11/5 was supported by a grant from the U.S. Department of Energy (DOE) No. DE-FGO2-90ER60943.

2. DESCRIPTION OF THE EXPEDITION

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

The research vessel *Meteor* is owned by the Federal Republic of Germany and is operated by the Federal Ministry for Research and Technology. The basic features of the vessel are described below.

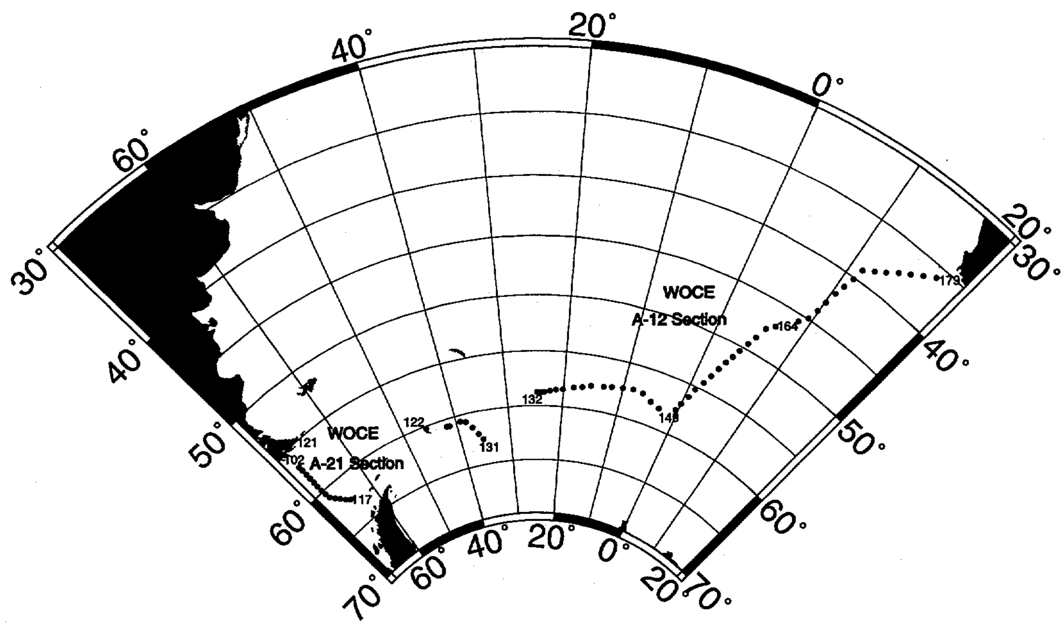

Figure 1. Station locations during the R/V *Meteor* Cruise 11/5.

Port of registration:	Hamburg
Call sign:	DBBH
Classification:	GL+100A4E2+MC Auto
Operator:	University of Hamburg, Institute for Ocean Research
Built:	1985–86 at Schlichting Werft, Travemunde
Basic dimensions:	GRT: 3990, NRT 1284; Displacement: 4780t; Length o.a.: 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 × 1,000kW at 750 rpm
Propulsion:	Diesel-electrical, Tandem-Motor = 2 × 1,150 kW
Fuel consumption:	approximately 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, data-processing facility
Science quarters:	20 laboratories on the main deck with approximately 400 m^2 of working space for multidisciplinary research

The original *Meteor* (I) was constructed in 1925; it was the first research and survey vessel of that name. R/V *Meteor* was owned by the German navy and was based in Wilhelmshaven. One of the *Meteor's* 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 navy surveying and fisheries protection duties.

The *Meteor* (II) was planned since the end of the 1950s and was operated by the Deutsche Forschungsgemeinschaft (German Science Community) in Bad Godesberg and the Deutsches Hydrographisches Institut (German Hydrographic Institute) in Hamburg. *Meteor* (II) was commissioned in 1964 and participated in the International Indian Ocean Expedition.

It was replaced by the newly built, multipurpose vessel *Meteor* (III), which was completed in 1986. The Hamburg-based *Meteor* (III) is used for German ocean research worldwide and for cooperative efforts with other nations in this field. The vessel serves scientists of all marine disciplines in all of the world's oceans.

2.2 R/V *Meteor* Cruise 11/5 Information

The following is the cruise information:

Ship Name:	*Meteor*
Cruise/Leg:	11/5
Location:	Ushuaia, Argentina, to Cape Town, South Africa
Dates:	January 23–March 8, 1990
Funding:	German Science Community
	Federal Ministry of Research and Technology, Bonn, Germany
Chief Scientist:	Dr. Wolfgang Roether
	University of Bremen, Germany

Parameters measured, institution, and responsible Principal Investigators (PI):

Parameter	**Institution**	**PI**
CTD, Salinity	Alfred Wegner Institute, Bremerhaven	G. Rohardt, E. Fahrbach
Nutrients, Oxygen	Scripps Institution of Oceanography (SIO)	J. Swift, F. Delahoyde
CFM's	University of Bremen	W. Roether
Tritium, ^{3}He	University of Bremen	W. Roether
^{14}C (L-V and AMS)	University of Heidelberg	P. Schlosser, K. O. Munnich
^{39}Ar	University of Bern	H. H. Loosli
^{85}Kr	Lamont-Doherty Earth Observatory	W. M. Smethie
TCO_2 and pCO_2	Lamont-Doherty Earth Observatory	D. Chipman, T. Takahashi
$^{226/228}Ra$	Princeton University, Univ. of Kiel	R. Key, M. Rhein
XBT	Alfred Wegner Institute, Bremerhaven	U. Schauer, E. Farhrbach
ADCP	Alfred Wegner Institute, Bremerhaven	E. Farhrbach
CTD-intercomparison	AWI, SIO	G. Rohardt, F. Delahoyde
ALACE Drifter	SIO, Texas A&M University	R. Davis, W. D. Nowlin

2.3 Brief cruise summary

The R/V *Meteor* left Ushuaia on the morning of January 23, 1990. The next morning, sampling started southwest of Cape Horn and continued south-ward at 30-nm station spacing. Basic equipment included a Neil Brown Mark IIIB CTD (AWI, calibrated at SIO Oceanographic Data Facility) and a 24 × 12 liter General Oceanic rosette system. Large-volume stations were placed between the fronts in order to characterize the four principle hydrographic zones of the passage (Sievers and Nowlin 1984). Apart from pCO_2, which became operative only toward the end of the section, all measurements were carried out successfully. Measurements of salinity, oxygen, and nutrients (nitrate, nitrite, silicate, and phosphate) were made in the standard fashion. The weather was advantageous for all of the Drake Passage section work.

After 3 days of station work, the winch computer system malfunctioned. The ship crew managed to provide makeshift operation for the CTD/Rosette winch, and the trawl winch operation for large-volume sampling was similarly resumed 2 days later. It was decided to continue the section and then return to Ushuaia for repairs. The section was concluded after sampling near the South Shetland Arc shelf off Smith Island. During the section, 13 standard and 4 large-volume stations were occupied. However, the large-volume samples in the Polar Frontal Zone were collected on the way back to Ushuaia (i.e. not simultaneously with the corresponding main CTD/Rosette work). In total, at least 4 days were lost as a result of the winch malfunction.

After the vessel left Ushuaia (February 3, 1990) the second time, station work resumed on February 6, 1990, with a short section north and east of the South Orkney Islands (Stations 122–131).

On February 12, 1990, after rounding Southern Thule of the South Sandwich Islands, sampling began on WOCE section A-12 (stations 132–179), and continued up to the African shelf until the morning of March 8, 1990, when R/V METEOR entered Cape Town.

A historic comment: From January 21 to March 10, 1926, the original *Meteor* (I) also explored a transect from Ushuaia to Cape Town, which was leg 5 of its famous South Atlantic survey. The scientific topic, i.e. hydrography, was quite similar. A total of 34 stations were sampled (6 across Drake Passage), 3 properties were measured (temperature, salinity, and oxygen), and 26 depths typically were sampled (in 3 casts) (Roether et al. 1990).

3. DESCRIPTION OF VARIABLES

Data file **m115.dat** (see description on pp. 26–28) in this numeric data package contains the following variables: station numbers; cast numbers; sample numbers; bottle numbers; CTD pressures; CTD temperatures; CTD salinities; potential temperatures; bottle salinities; concentrations of dissolved oxygen, silicate, nitrate, nitrite, phosphate; total CO_2 concentrations; partial pressures of CO_2 at 20°C; potential densities at 0 dbar; and quality flags. Station inventory file **m115sta.inv** (pp. 24–25) contains section numbers; station numbers; latitude, longitude, sampling date (i.e., day, month, and year), and bottom depth for each station.

In accordance with WOCE data management policies, which stipulate that WOCE data are not final until designated as such by the chief scientist, we have rounded the CTD salinity, CTD temperature, potential temperature, and density values to two decimal places. If the chief scientist designates these parameters as final, these variables will be restored to their original precision.

The **temperature and pressure** readings of the Neil Brown IIIB CTD unit were corrected through the use of 4–6 pairs of reversing thermometers; the electrical conductivity readings were corrected by using the salinity values determined aboard the ship for all 24 Niskin samplers. A Guildline® Autosal 8400A salinometer and the Wormley Salinity Standards were used for the determination of **salinity** in the discrete water samples. The precision of the measurements obtained by the CTD unit has been estimated to be ±0.002°C for temperature and $\pm 0.002^{0}/_{00}$ for salinity. **Potential temperature** (Θ) and **potential density** (σ_0) values were computed through the use of the potential temperature algorithm of Fofonoff (1980), the International Equation of State for Seawater (Millero et al. 1980), and Bryden's (1973) formulation for the adiabatic temperature gradient.

The **concentration of dissolved oxygen** was determined by means of the Winkler titration method. A molar volume at STP of 22.385 liter/mole (Kester 1975) was used to convert oxygen concentrations from milliliter per liter to micromoles per kilogram of seawater at the in situ temperature.

The **concentrations of nitrate, nitrite, phosphate,** and **silicate** dissolved in the seawater samples were determined through the use of standard calorimetric methods with an Auto-Analyzer. Determinations were generally made within 6 hours of collection. The water samples were stored in a refrigerator at 4°C before analysis.

All of the concentration values are expressed in units of per kilogram of seawater, although analytical samples were isolated by volumetric means. For the conversion from the volume to the mass of seawater sample, the density of each water sample was computed by using the International Equation of State for Seawater (Millero et al. 1980) and the measured salinity and the temperature at which the volumetric measurements were made.

The **total CO_2** concentration in approximately 1300 seawater samples and the **CO_2 partial pressure** in approximately 870 seawater samples collected at 76 stations (Fig. 2) were determined aboard the ship. The TCO_2 concentration in seawater samples was determined by the use of a coulometric system, which was modified from that described by Johnson et al. (1985).

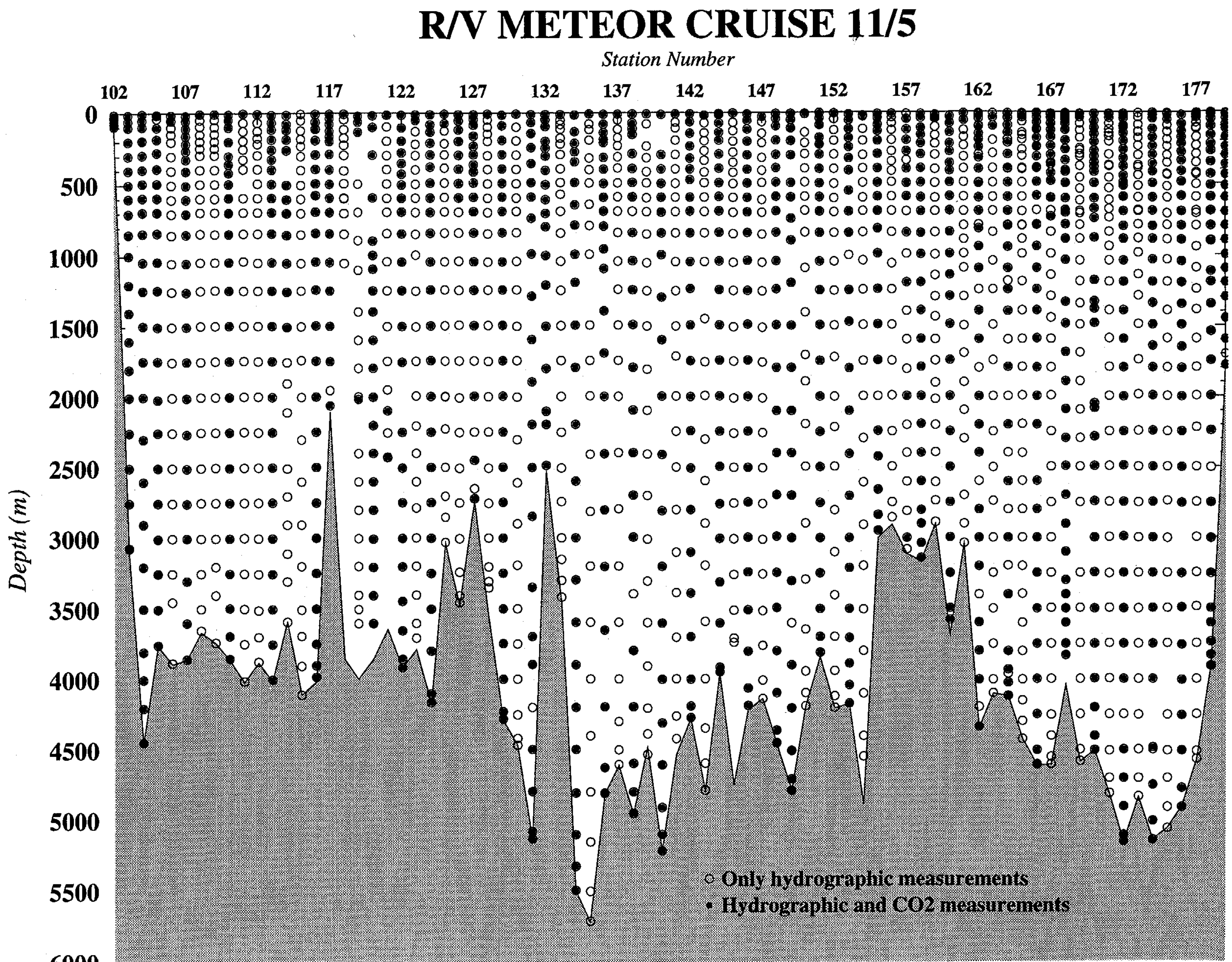

Figure 2. Sampling depths at the 78 hydrographic stations occupied during the R/V METEOR Cruise 11/5.

For analysis, the seawater was introduced into the stripping chamber using fixed-volume syringes. The sample was acidified with 1 ml of 8.5% phosphoric acid while it was in the stripping chamber, where the evolved CO_2 gas was swept from the sample and transferred with a stream of CO_2-free air into the electrochemical cell of the CO_2 coulometer (UTC-Coulometric Model-5011). In the coulometer cell, the CO_2 was quantitatively absorbed by a solution of ethanolamine in dimethylsulfoxide (DMSO). Reaction between the CO_2 and the ethanolamine formed the weak hydroxyethylcarbamic acid. The pH change of the solution associated with the formation of the acid resulted in a color change of the thymophthalein pH indicator in the solution. The color change, from deep blue to colorless, was detected by a photodiode, which continually monitored the transmissivity of the solution. The electronic circuitry of the coulometer, on detecting the change in the color of the pH indicator, caused a current to be passed through the cell generating hydroxyl (OH^-) ions from a small amount of water in the solution. The OH^- that was generated titrated the acid, returning the solution to its original pH (and hence color); the circuitry then interrupted the current flow. The product of current passed through the cell and time was related by the Faraday constant to the number of moles of OH^- generated to titrate the acid and hence to the number of moles of CO_2 absorbed to form the acid.

The volumes delivered by the constant-volume syringes were determined by repeatedly weighing distilled water dispensed in the same manner as a sample; the volume was calculated from the delivered weight by using the density of pure water at the temperature of the measurement and a buoyancy correction for the air displaced by the water (amounts to approximately 0.1% of the weight of the water). The density of the seawater in the pipet was calculated at the temperature of injection by using the International Equation of State (Millero et al. 1980).

The coulometer was calibrated by introducing research-grade CO_2 gas (99.998%) into the carrier gas line upstream of the extraction tube, using a pair of fixed-volume sample loops on a gas-sampling valve and measuring the gas pressure in the loops as the gas was vented to the ambient atmosphere, and determining the barometric pressure by means of the electronic barometer used with the pCO_2 system. The loop temperature was measured to ±0.05°C with a thermometer calibrated against one traceable to the National Institute of Standards and Technology (NIST), and the non-ideality of CO_2 was incorporated in the computation of the loop contents. The volume of the calibration loop had previously been determined by weighing empty loops and then loops filled with mercury. The volumes of these loops have additionally been checked by comparing the amount of CO_2 introduced by them with the amount derived from gravimetric samples of calcium carbonate and sodium carbonate. They were found to be accurate to within 0.1%. During the expedition, the coulometer was calibrated several times daily by using the calibrated loop and pure CO_2 gas.

In order to evaluate the long-term reproducibility and precision of the coulometric determination of CO_2 in seawater, a number of sample bottles were filled with a homogeneous sample of surface water and deep water. Bottles made of Pyrex glass and PET plastic (500 ml and 1000 ml, respectively) were used. Bottled samples were poisoned with mercuric chloride solutions (200 μl for each 500-ml water sample) and analyzed for total CO_2 during the expedition. On the basis of these measurements (Fig. 3), the precision of TCO_2 measurements during this expedition was estimated to be approximately ±1 μmol/kg. Additional details on the TCO_2 measurements are discussed in Chipman et al. (1992).

A fully automated equilibrator-gas chromatograph system was used during the expedition to determined the **pCO_2** exerted by the seawater samples. Prior to analysis, the sample flasks were brought to 20°C in the thermostated water bath, and approximately 45 ml of seawater was

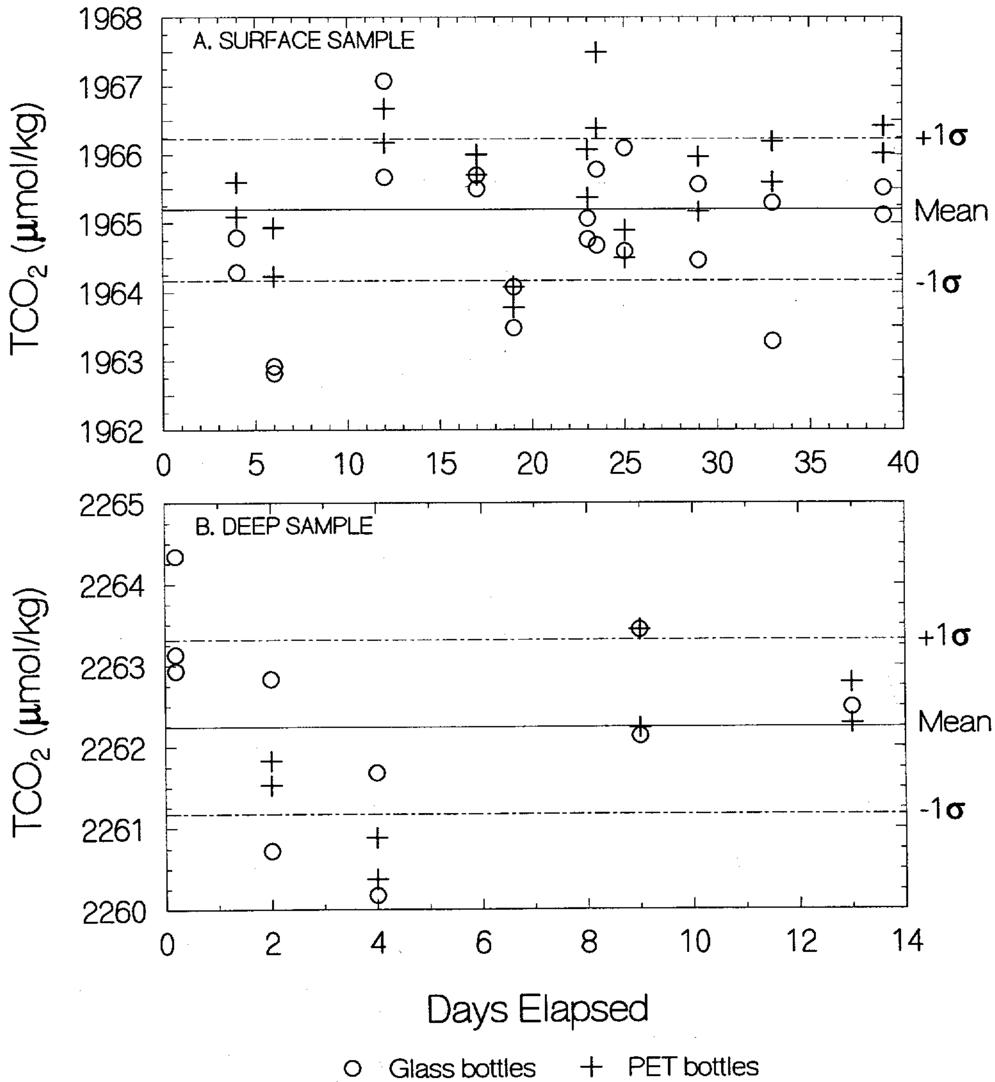

Figure 3. Repeated measurements of the total CO_2 concentration in sea surface (A) and in deep water (B) samples. About 50 sample bottles were analyzed over a 50-day period during the expedition. Only 20 bottles were filled with a homogenized deep water sample and analyzed subsequently over a period of 13 days. The analyses of these samples yield a mean value of 1965.2±1.0 for the surface samples and 2262.2±1.0 for the deep water samples.

displaced with air that had a known CO_2 concentration. The air in the flasks and in the tubing connecting the flasks to the sample loop of the gas chromatograph was recirculated continuously for approximately 20 minutes; the gas disperser about 1 cm below the water surface provided a large contact area between the water and air bubbles. At the end of the equilibration period, the circulation pump was switched off, and the air pressure throughout the system was allowed to equalize. A 1-ml aliquot of the equilibrated air was isolated from the equilibration subsystem and injected into the carrier gas stream of the gas chromatograph by cycling the gas sampling valve to which the sample loop was attached. After chromatographic separation, the CO_2 was converted into methane and water vapor through a reaction with the hydrogen carrier in the catalytic converter. The methane produced by this reaction was then measured with a precision of ±0.05% (one standard deviation) by the flame ionization detector. The concentration of CO_2 in the sample was determined through comparison with the peak areas of known amounts of CO_2 from injections of three reference gas mixtures, which were calibrated against the World Meteorological Organization standards created by C. D. Keeling. The reference gas mixtures were injected into the gas chromatograph by means of the same sample loop used for the equilibrated air samples; the pressure of the gas in the sample loop at the time of injection was determined by venting the loop to atmospheric pressure and measuring that pressure by means of a high-accuracy electronic barometer (Setra Systems, Inc., Model 270, accuracy ±0.3 millibar; calibration traceable to the NIST provided by the manufacturer). The sample loop was located within the well-controlled temperature environment of the column oven of the gas chromatograph; hence, all injections were made at a constant temperature.

The equilibrated air samples were saturated with water vapor at the temperature of equilibration and had the same pCO_2 as the water sample. By injecting the air aliquot without removing the water vapor, the partial pressure of CO_2 was determined directly, without the need to know the water vapor pressure (Takahashi et al. 1982). However, was necessary to know the pressure of equilibration, which was controlled by keeping the equilibrator flask at atmospheric pressure. The atmospheric pressure was, in turn, measured with the electronic barometer at the time each equilibrated air sample was injected into the gas chromatograph. Corrections were required to account for the change in pCO_2 of the sample water as a result of the transfer of CO_2 to or from the water during equilibration with the recirculating air. The overall precision of the pCO_2 measurement is estimated to be about ±0.10%, based on the reproducibility of replicate equilibrations. Greater details on the pCO_2 measurements are discussed in Chipman et al. (1992).

4. DATA CHECKS PERFORMED BY CDIAC

An important part of the numeric data package (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. Reviews 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 for researchers.

The following summarizes the checks performed by CDIAC on the data obtained during the R/V *Meteor* 11/5 Expedition in the South Atlantic Ocean and Northern Weddell Sea areas.

1. These data were provided to CDIAC in three files: CO_2 measurements, along with downgraded hydrographic and chemical data, provided by Taro Takahashi and David Chipman from Lamont-Doherty Earth Observatory; hydrographic and chemical measurements, and station information files provided by the WOCE Hydrographic Program Office (WHPO) after quality evaluation; FORTRAN 77 retrieval code written and used to merge and reformat the first two data files.

2. All data were plotted by using a PLOTNEST.C program written by Stewart C. Sutherland (LDEO) to check for obvious outliers. 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. 4 and 5). Some outliers were identified and removed after consultation with the principal investigators.

3. Property-property plots for all parameters were generated (Fig. 6), carefully examined, and compared with plots from previous expeditions in the South Atlantic Ocean to identify "noisy"data and possible systematic, methodological errors.

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

5. Station locations (latitudes and longitudes) and sampling times were examined for consistency with maps and with cruise information supplied by Chipman et al. (1992).

6. CTD salinity, CTD temperature, potential temperature, and density have been downgraded to two decimal places in accordance with WOCE data management policies, which stipulate that data are not final until designated as such by the chief scientist. If the chief scientist designates these parameters as final, these values will be restored to their original precision.

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

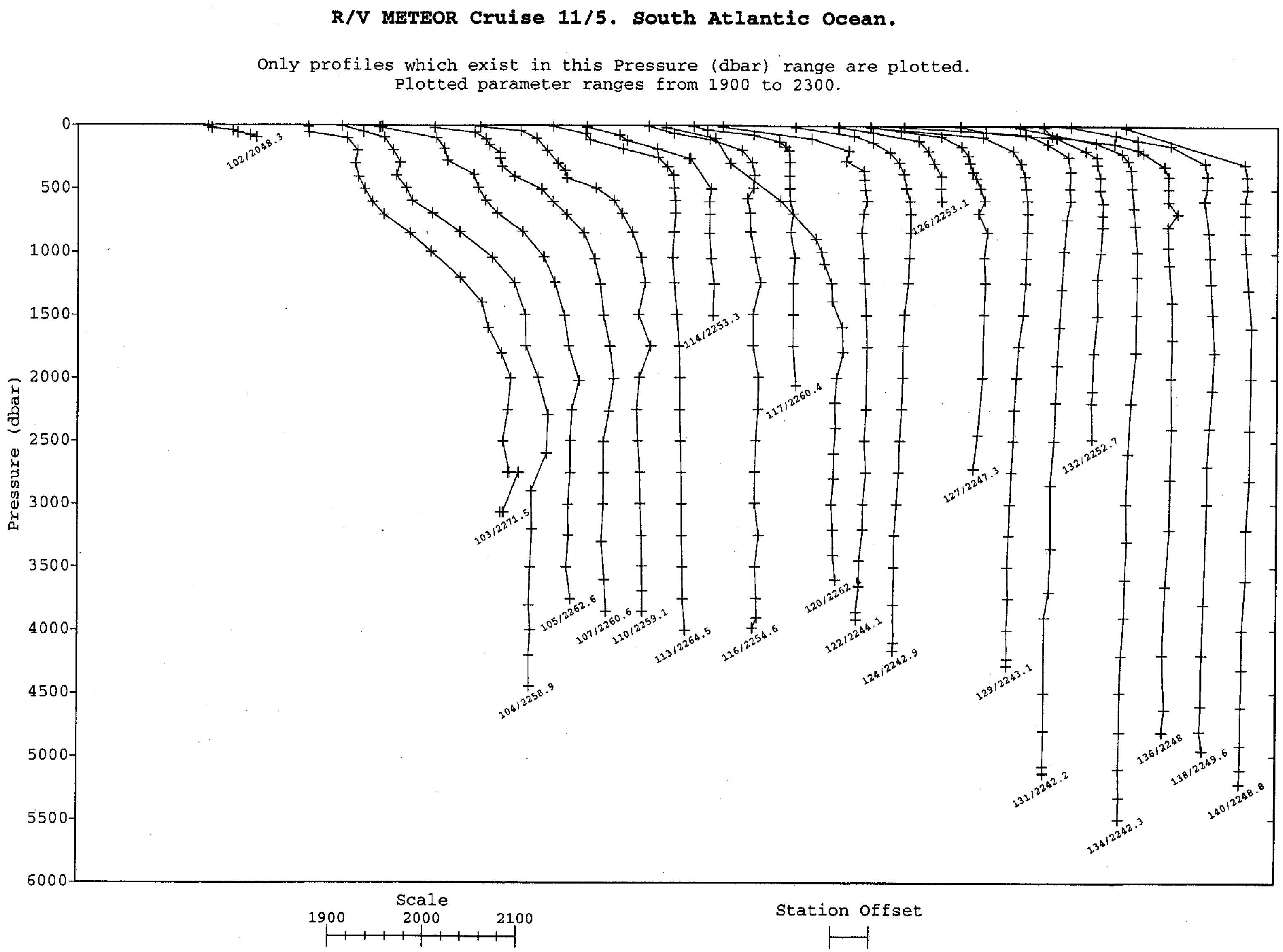

Figure 4. **Nested profiles: Total carbon (μmol/kg) vs pressure (dbar) for stations 102–141.**

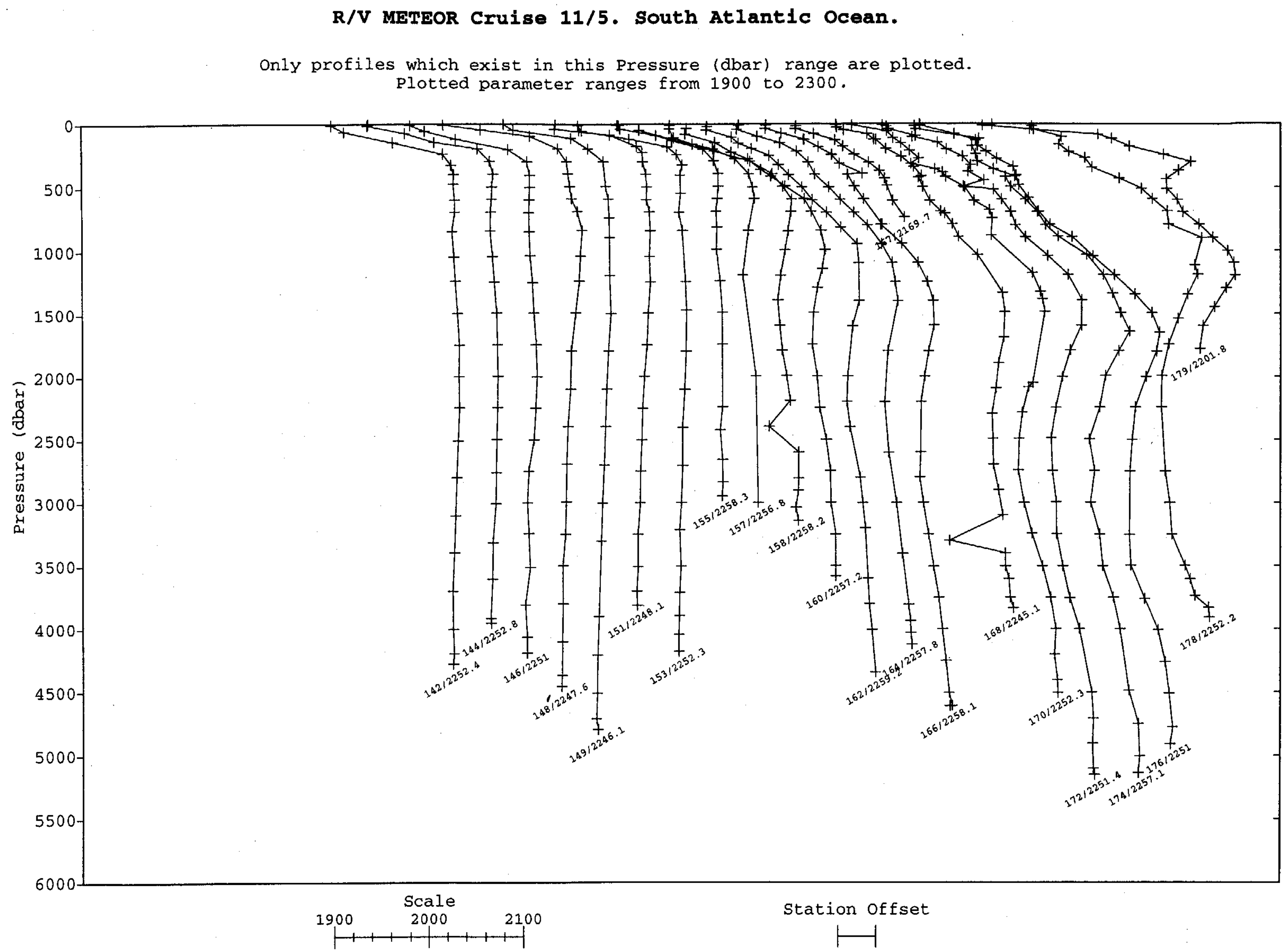

Figure 5. Nested profiles: Total carbon (μmol/kg) vs pressure (dbar) for stations 142–179.

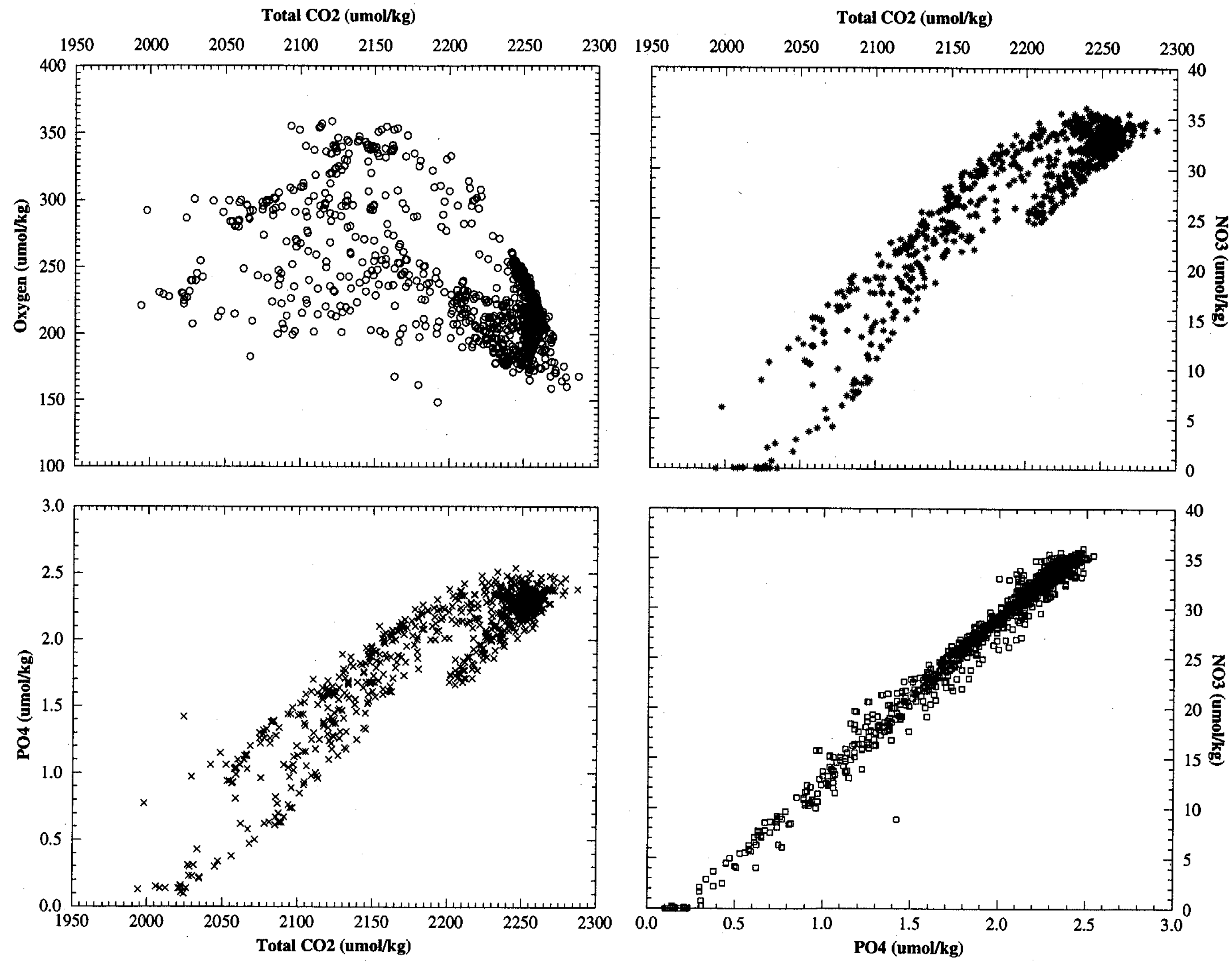

Figure 6. Property-property plots for all stations occupied during the R/V *Meteor* Cruise 11/5.

5. HOW TO OBTAIN THE DATA AND DOCUMENTATION

This data base is available in machine-readable form, on request, from CDIAC free of charge. CDIAC will also distribute subsets of the data base as needed. It can be acquired on 9-track magnetic tape; 8-mm tape; 150-mB, quarter-inch tape cartridge; IBM-formatted floppy diskettes; or from CDIAC's anonymous File Transfer Protocol (FTP) area via Internet (see FTP address below). Requests should include any specific media instructions (i.e., 1600 or 6250 BPI, labeled or nonlabeled, ASCII or EBCDIC characters, and variable- or fixed-length records; 3.5- or 5.25-inch floppy diskettes, high or low density; 8200 or 8500 format, 8-mm tape) required by the user to access the data. 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 addressed to:

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

Telephone: (615) 574-0390 or (615) 574-3645
Fax: (615) 574-2232

Electronic Mail: BITNET: CDP@ORNLSTC
INTERNET: CDP@STC10.CTD.ORNL.GOV
OMNET: CDIAC

The data files can be also acquired from CDIAC's anonymous FTP account via Internet:

- FTP to cdiac.esd.ornl.gov (128.219.24.36)
- Enter "ftp" or "anonymous" as the userid
- Enter your electronic mail address as the password (e.g.,"alex@alex.esd.ornl.gov")[1]
- Change to the directory "/pub/ndp045"
- Acquire the files using the FTP "get" or "mget" command

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

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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 comprise this NDP (Table 1). Because CDIAC distributes the data set in several ways (e.g., via anonymous FTP and on 9-track magnetic tape), each of the seven files is referenced by both an ASCII file name, which is given in lower-case, bold-faced type (e.g., **readme**) and a file number. The files and their contents include the following:

- □ **readme** (File 1), a detailed description of the cruise network, the three FORTRAN 77 data retrieval routines, and the three oceanographic data files;
- □ **stainv.for** (File 2), a FORTRAN 77 data retrieval routine to read and print **m115sta.inv** (File 4);
- □ **m115dat.for** (File 3), a FORTRAN 77 data retrieval routine to read and print **m115.dat** (File 5);
- □ **m115sta.inv** (File 4), a listing of the station locations, sampling dates, and sounding bottom depths for each of the 78 stations;
- □ **m115.dat** (File 5), a listing of hydrographic, carbon dioxide, and chemical data for all stations occupied during the R/V *Meteor* Cruise 11/5;
- □ **girarbot.for** (File 6), a FORTRAN 77 data retrieval routine to read and print **m115gir.dat** (File 7);
- □ **m115gir.dat** (File 7), a listing of total CO_2 and hydrographic data sampled from Girard barrels during the R/V *Meteor* Cruise 11/5.

The remainder of this section describes (or lists, where appropriate) the contents of each of the seven files. The files are discussed in the order in which they appear on the magnetic tape.

Table 1. 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	856	48,004	8,000	80
2. **stainv.for**: a FORTRAN 77 data retrieval routine to read and print **m115sta.inv** (File 4)	29	1,106	8,000	80
3. **m115dat.for:** a FORTRAN 77 data retrieval routine to read and print **m115.dat** (File 5)	44	1,853	8,000	80
4. **m115sta.inv**: a listing of the station locations, sampling dates, and sounding bottom depths for each of the 78 stations	78	3,276	4,100	41
5. **m115.dat:** a listing of hydrographic, carbon dioxide, and chemical data for all stations.	2,033	327,313	16,000	160
6. **girarbot.for:** a FORTRAN 77 data retrieval routine to read and print **m115gir.dat** (File 7)	31	992	8,000	80
7. **m115gir.dat:** a listing of total CO_2 and hydrographic data sampled from the Girard barrels	232	13,920	6,500	65
Total	3,303	396,464		

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 the data files from CDIAC's anonymous FTP area.

stainv.for (File 2)

This file contains a FORTRAN 77 data retrieval routine to read and print **m115sta.inv** (File 4). 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 **m115sta.inv** file on pages 24–25.

```
c*********************************************************************
c* FORTRAN 77 data retrieval routine to read and print the file named
c* "m115sta.inv" (File 4)
c*********************************************************************

      INTEGER  STAT, MONTH, DAY, YEAR, SDE
      REAL LAT, LON
      CHARACTER SECTION*4
      OPEN (unit=5, file='m115sta.inv')
      OPEN (unit=2, file='m115stat.inv')
      WRITE (2, 5)

5     FORMAT (7X, 'STATION INVENTORY: R/V METEOR CRUISE 11/5', 6X,/,
     1 1X,'SECTION', 1X,'STAT', 2X,'LATITUDE', 2X,'LONGITUDE',2X,
     2 'MON', 2X,'DAY', 2X,'YEAR',2X,'DEPTH',/)

7     CONTINUE
      READ (5, 10, end=999)  SECTION, STAT, LAT, LON, MONTH,
     1 DAY, YEAR, SDE
10    FORMAT (A4, 2X, I3, 1X, F7.3, 2X, F7.3, 2X, I1, 1X, I2,
     1 1X, I2, 2X, I4)

      WRITE (2, 20) SECTION, STAT, LAT, LON, MONTH, DAY, YEAR, SDE
20    FORMAT (3X, A4, 3X, I3, 3X, F7.3, 3X, F7.3, 5X, I1, 3X, I2,
     1 3X, I2, 4X, I4)
      GOTO 7

999   CLOSE(unit=5)
      CLOSE(unit=2)
      STOP
      END
```

m115dat.for (File 3)

This file contains a FORTRAN 77 data retrieval routine to read and print **m115.dat** (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 **m115.dat** file on pages 26–28.

```
c***************************************************
c*  FORTRAN 77 data retrieval ROUTINE to read and
c*  print the file named m115.dat (File 5)
c***************************************************

       INTEGER  STAT, CAST, SAMP, BOTTLE
       CHARACTER FLAG*8
       REAL CTDPRS, CTDTMP, CTDSAL, THETA, BTLSAL, OXYGEN, SILICA
       REAL NITRAT, NITRIT, PHSPHT, TCO2, PCO2
       REAL PCO2TEMP, SIGMA0
       OPEN (unit=5, file='m115.dat')
       OPEN (unit=2, file='met115.dat')
       WRITE (2, 5)

 5     FORMAT ('STNNBR',1X,'CAST',1X,'SAMP',1X,'BTLNBR',2X,
     2 'CTDPRS',3X,'CTDTMP',4X,'CTDSAL',5X,'THETA',5X,'BOTSAL',2X,
     3 'OXYGEN',3X,'SILICA',3X,'NITRAT',3X,'NITRIT',3X,'PHSPHT',5X,
     4 'TCO2',5X,'PCO2',1X,'PCO2TMP',1X,'SIGMA0',4X,'QUALTFLG',/,
     5 27X,'DBAR',3X,'ITS-90',4X,'PSS-78',4X,'ITS-90',5X,'PSS-78',
     6 1X,6('UMOL/KG',2X,),3X,'UATM',2X,'DEG(C)',2X,'THETA',/,16X,
     7 '*******',20X,'*******',14X,'*******',1X,'*******',
     8 2X,4('*******',2X,),/)

 7     CONTINUE
       READ (5, 10,end=999) STAT, CAST, SAMP, BOTTLE, CTDPRS, CTDTMP,
     1 CTDSAL, THETA, BTLSAL, OXYGEN, SILICA, NITRAT, NITRIT, PHSPHT,
     2 TCO2, PCO2, PCO2TEMP, SIGMA0, FLAG
 10    FORMAT (2X,I3,3X,I1,3X,I2,4X,I4,3X,F6.1,4X,F5.2,5X,F5.2,5X,
     1 F5.2,4X,F7.2,2X,F6.1,3X,F6.1,2X,F7.2,2X,F7.2,2X,F7.2,3X,
     2 F6.1,3X,F6.1,3X,F5.2,2X,F5.2,4X,A8)

       WRITE (2, 20) STAT, CAST, SAMP, BOTTLE, CTDPRS, CTDTMP, CTDSAL,
     1 THETA, BTLSAL, OXYGEN, SILICA, NITRAT, NITRIT, PHSPHT, TCO2,
     2 PCO2, PCO2TEMP, SIGMA0, FLAG
 20    FORMAT (2X,I3,3X,I1,3X,I2,4X,I4,3X,F6.1,4X,F5.2,5X,F5.2,5X,
     1 F5.2,4X,F7.2,2X,F6.1,3X,F6.1,2X,F7.2,2X,F7.2,2X,F7.2,3X,
     2 F6.1,3X,F6.1,3X,F5.2,2X,F5.2,4X,A8)
       GOTO 7

 999   CLOSE(unit=5)
       CLOSE(unit=2)
       STOP
       END
```

m115sta.inv (File 4)

This file provides station inventory information for each of the 78 stations occupied during the R/V *Meteor* Cruise 11/5. There is one entry for each station; consequently, the file has 78 lines. Each line contains a section number, station number, latitude, longitude, sampling date, 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**, which is File 2):

```
      INTEGER  STAT, MONTH, DAY, YEAR, SDE
      REAL LAT, LON   •
      CHARACTER SECTION*4

      READ (5, 10, end=999)  SECTION, STAT, LAT, LON, MONTH,
     1 DAY, YEAR, SDE
 10   FORMAT (A4, 2X, I3, 1X, F7.3, 2X, F7.3, 2X, I1, 1X, I2,
     1 1X, I2, 2X, I4)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
SECTION	Character	4	1	4
STAT	Numeric	3	7	9
LAT	Numeric	7	11	17
LON	Numeric	7	20	26
MONTH	Numeric	1	29	29
DAY	Numeric	2	31	32
YEAR	Numeric	2	34	35
SDE	Numeric	4	38	41

where

SECTION is the WOCE section number;

STAT is the station number (values range from 102 to 179);

LAT is the latitude of the station (in decimal degrees);

LON is the longitude of the station (in decimal degrees);

MONTH is the month the station was sampled;

DAY is the day the station was sampled;

YEAR is the year the station was sampled;

SDE is the sounding depth of the station (in meters).

m115.dat (File 5)

This file provides hydrographic, carbon dioxide, and chemical data for the 78 stations occupied during the R/V *Meteor* Cruise 11/5. Each line consists of a station number, cast number, sample number, bottle number, CTD pressure, CTD temperature, CTD salinity, potential temperature, bottle salinity; concentrations of oxygen, silicate, nitrate, nitrite, phosphate, and total carbon; pCO_2; pCO_2 temperature; potential density; and data quality flags. The file is sorted by station number and pressure and can be read by using the following FORTRAN 77 code (contained in **m115dat.for,** which is File 3):

```
      INTEGER  STAT, CAST, SAMP, BOTTLE
      CHARACTER FLAG*8
      REAL CTDPRS, CTDTMP, CTDSAL, THETA, BTLSAL, OXYGEN, SILICA
      REAL NITRAT,NITRIT, PHSPHT, TCO2, PCO2, PCO2TEMP, SIGMA0

      READ (5, 10,end=999) STAT, CAST, SAMP, BOTTLE, CTDPRS, CTDTMP,
    1 CTDSAL, THETA, BTLSAL, OXYGEN, SILICA, NITRAT, NITRIT, PHSPHT,
    2 TCO2, PCO2, PCO2TEMP, SIGMA0, FLAG
 10   FORMAT (2X,I3,3X,I1,3X,I2,4X,I4,3X,F6.1,4X,F5.2,5X,F5.2,5X,
    1 F5.2,4X,F7.2,2X,F6.1,3X,F6.1,2X,F7.2,2X,F7.2,2X,F7.2,3X,
    2 F6.1,3X,F6.1,3X,F5.2,2X,F5.2,4X,A8)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
STAT	Numeric	3	3	5
CAST	Numeric	1	9	9
SAMP	Numeric	2	13	14
BOTTLE	Numeric	4	19	22
CTDPRS	Numeric	6	26	31
CTDTMP	Numeric	5	36	40
CTDSAL	Numeric	5	46	50
THETA	Numeric	5	56	60
BTLSAL	Numeric	7	65	71
OXYGEN	Numeric	6	74	79
SILICA	Numeric	6	83	88
NITRAT	Numeric	7	91	97
NITRIT	Numeric	7	100	106
PHSPHT	Numeric	7	109	115
TCO2	Numeric	6	119	124
PCO2	Numeric	6	128	133
PCO2TEMP	Numeric	5	137	141
SIGMA0	Numeric	5	144	148
FLAG	Character	8	153	160

where

STAT	is the station number (values from 102 to 179);
CAST	is the cast number;
SAMP	is the sample number;
BOTTLE*	is the bottle number;
CTDPRS	is the CTD pressure (in dbar);
CTDTMP	is the CTD temperature (in °C);
CTDSAL*	is the CTD salinity [in Practical Salinity Units (PSU)];
THETA	is the potential temperature (in °C);
BTLSAL*	is the salinity (in PSU);
OXYGEN*	is the oxygen concentration (in µmol/kg);
SILICA*	is the silicate concentration (in µmol/kg);
NITRAT*	is the nitrate concentration (in µmol/kg);
NITRIT*	is the nitrite concentration (in µmol/kg);
PHSPHT*	is the phosphate concentration (in µmol/kg);
TCO2	is the total carbon concentration (in µmol/kg);
PCO2	is the partial pressure of CO_2 (in µatm and measured at 20°C);
PCO2TEMP	is the temperature of the pCO_2 samples (in °C);
SIGMA0	is the potential density (in sigma units at 0 dbar);
FLAG	is an 8-digit character variable that contains data quality flag codes for parameters flagged by an asterisk (*): Quality flags 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.

girarbot.for (File 6)

This file contains a FORTRAN 77 data retrieval routine to read and print **m115gir.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 **m115gir.dat** file on pages 28–29.

```
c*************************************************************************
c* FORTRAN 77 data retrieval routine to read and print the file named
c* "m115gir.dat" (File 7)
c*************************************************************************
       INTEGER  STAT, BOTTLE
       REAL PRES, TEMP, SALTY, TCO2, THETA, SIGMA0
       OPEN (unit=5, file='m115gir.dat')
       OPEN (unit=2, file='m115gira.dat')
       WRITE (2, 5)

 5     FORMAT (1X,'STA',3X,'BOT',4X,'PRES',6X,'TEMP',6X,
     2 'SAL',4X,'TCO2',5X,'THETA',4X,'SIGMA0',/)


 7     CONTINUE
       READ (5, 10,end=999) STAT, BOTTLE, PRES, TEMP, SALTY, TCO2,
     1 THETA, SIGMA0
 10    FORMAT (1X,I3,1X,I4,1X,F6.1,1X,F8.3,3X,F6.3,1X,F6.1,1X,F8.3,
     1 1X,F8.3)

       WRITE (2, 20) STAT, BOTTLE, PRES, TEMP, SALTY, TCO2,
     1 THETA, SIGMA0
 20    FORMAT (1X,I3,2X,I4,2X,F6.1,2X,F8.3,3X,F6.3,2X,F6.1,2X,F8.3,
     1 2X,F8.3)
       GOTO 7

999    CLOSE(unit=5)
       CLOSE(unit=2)
       STOP
       END
```

m115gir.dat (File 7)

This file provides the hydrographic and total CO_2 data sampled from Girard barrels during R/V *Meteor* Cruise 11/5. Each line consists of a station number, girard bottle number, pressure (depth), temperature, salinity, total CO_2, potential temperature, and potential density. The file is sorted by station number and pressure and can be read by using the following FORTRAN 77 code (contained in **girarbot.for**, which is File 6):

```
      INTEGER  STAT, BOTTLE
      REAL PRES, TEMP, SALTY, TCO2, THETA, SIGMA0
      OPEN (unit=5, file='m115gir.dat')
      OPEN (unit=2, file='m115gira.dat')

      READ (5, 10,end=999) STAT, BOTTLE, PRES, TEMP, SALTY, TCO2,
     1 THETA, SIGMA0
 10   FORMAT (1X,I3,1X,I4,1X,F6.1,1X,F8.3,3X,F6.3,1X,F6.1,1X,F8.3,
     1 1X,F8.3)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
STAT	Numeric	3	2	4
BOTTLE	Numeric	4	7	10
PRES	Numeric	6	13	18
TEMP	Numeric	8	21	28
SALTY	Numeric	6	32	37
TCO2	Numeric	6	40	45
THETA	Numeric	8	48	55
SIGMA0	Numeric	8	58	65

where

STAT is the station number (values range from 102 to 179);

BOTTLE is the girard bottle number;

PRES is the CTD pressure (in dbar);

TEMP is the CTD temperature (in °C);

SALTY is the bottle salinity (in PSU);

TCO2 is the total carbon concentration (in µmol/kg);

THETA is the potential temperature (in °C);

SIGMA0 is the potential density (in sigma units at 0 dbar).

8. VERIFICATION OF DATA TRANSPORT

The data files contained in this Numeric Data Package 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 2–4. Each of these tables contains the first and last five lines of a data file.

Table 2. Partial listing of "m115sta.inv"
(File 4)

First five lines of the file:

```
A-21  102 -56.330  -67.995  1 24 90   103
A-21  103 -56.917  -68.250  1 24 90  3090
A-21  104 -57.330  -68.250  1 24 90  4390
A-21  105 -57.835  -68.242  1 25 90  3757
A-21  106 -58.335  -68.238  1 26 90  3855
```

Last five lines of the file:

```
A-12  175 -37.537   14.352  3  4 90  4963
A-12  176 -36.997   15.385  3  5 90  4804
A-12  177 -36.447   16.413  3  5 90  4506
A-12  178 -35.870   17.453  3  6 90  3891
A-12  179 -35.332   18.450  3  6 90  1794
```

Table 3. Partial listing of "m115.dat"
(File 5)

First five lines of the file:

```
 102   1   17     117      10.0      9.75      33.35      9.75      33.36   292.3      2.0      6.17      0.22
  0.77   1997.8   -999.9    20.00   25.71      23222222
 102   1    7     106      25.5      9.74      33.37      9.73    -999.90  -999.9   -999.9   -999.90   -999.90
-999.90   -999.9   -999.9    20.00   25.73      23555555
 102   1    8     107      25.5      9.74      33.37      9.73    -999.90  -999.9   -999.9   -999.90   -999.90
-999.90   -999.9   -999.9    20.00   25.73      23555555
 102   1    9     108      25.5      9.74      33.37      9.73    -999.90  -999.9   -999.9   -999.90   -999.90
-999.90   -999.9   -999.9    20.00   25.73      23555555
 102   1   16     109      25.5      9.74      33.37      9.73    -999.90   292.7      1.7      6.39      0.22
  0.75   -999.9   -999.9    20.00   25.73      23522222
```

Last five lines of the file:

```
 179   1    5     105   1297.4      2.89      34.67      2.80      34.67   186.0     65.3     31.70      0.00
  2.18   2229.7   1083.0    20.00   27.64      23222222
 179   1    4     104   1447.9      2.91      34.74      2.81      34.74   197.2     58.1     29.36      0.00
  2.01   2217.1   1002.1    20.00   27.69      23222222
 179   1    3     103   1596.7      2.95      34.80      2.83      34.79   207.4     52.4     27.37      0.01
  1.85   2205.1    941.5    20.00   27.74      23222222
 179   1    2     102   1699.6      2.92      34.82      2.80      34.82   213.4     50.5     26.62      0.00
  1.83   -999.9    913.5    20.00   27.76      23222222
 179   1    1     101   1780.0      2.91      34.84      2.78      34.83   217.7     48.5     25.86      0.00
  1.73   2201.8    896.2    20.00   27.77      23222222
```

Table 4. Partial listing of "m115gir.dat"
(File 7)

First five lines of the file:

104	9310	14.1	-999.900	34.005	2060.9	-999.900	-999.900
104	9317	54.5	8.133	34.025	2068.6	8.128	26.489
104	9306	105.0	-999.900	34.056	2100.9	-999.900	-999.900
104	9302	255.6	-999.900	34.186	2113.4	-999.900	-999.900
104	9303	507.5	-999.900	34.211	2120.7	-999.900	-999.900

Last five lines of the file:

172	9417	4072.3	1.477	34.770	2236.6	1.150	27.850
172	9404	4792.1	1.124	34.734	2248.3	0.727	27.849
172	9401	5018.9	1.075	34.728	2250.1	0.653	27.849
173	9306	3278.9	2.172	34.836	2213.1	1.911	27.847
173	9303	3299.3	2.151	34.835	2215.0	1.889	27.848

APPENDIX A

STATION INVENTORY

APPENDIX A
STATION INVENTORY

This appendix lists station inventory information for the 78 sites occupied during the R/V *Meteor* Cruise 11/5 in the South Atlantic Ocean and Northern Weddell Sea. The meanings of the column headings in Table A-1 are as follows.

SECTION is the WOCE section number;

STAT is the station number;

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

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

MON is the month the station was sampled;

DAY is the day the station was sampled;

YEAR is the year the station was sampled;

DEPTH is the sounding bottom depth of each station (in meters).

Table A.1 Station inventory information for the 78 sites occupied during the R/V *Meteor* Cruise 11/5.

SECTION	STAT	LATITUDE	LONGITUDE	MON	DAY	YEAR	DEPTH
A-21	102	-56.330	-67.995	1	24	90	103
A-21	103	-56.917	-68.250	1	24	90	3090
A-21	104	-57.330	-68.250	1	24	90	4390
A-21	105	-57.835	-68.242	1	25	90	3757
A-21	106	-58.335	-68.238	1	26	90	3855
A-21	107	-58.833	-68.248	1	26	90	3842
A-21	108	-59.332	-68.247	1	26	90	3665
A-21	109	-59.832	-68.250	1	27	90	3738
A-21	110	-60.330	-68.133	1	27	90	3818
A-21	111	-60.832	-68.000	1	28	90	3954
A-21	112	-61.215	-67.330	1	28	90	3849
A-21	113	-61.598	-66.672	1	28	90	4013
A-21	114	-62.000	-65.985	1	29	90	3587
A-21	115	-62.282	-65.212	1	29	90	4080
A-21	116	-62.600	-64.272	1	29	90	4015
A-21	117	-62.857	-63.525	1	30	90	2099
A-21	118	-62.283	-65.217	1	30	90	3860
A-21	119	-61.600	-66.672	2	1	90	3995
A-21	120	-58.335	-68.255	2	1	90	3855
A-21	121	-55.490	-64.485	2	3	90	3642
A-12	122	-59.252	-47.250	2	6	90	3895
A-12	123	-60.205	-45.665	2	6	90	3785
A-12	124	-60.652	-41.935	2	7	90	3978
A-12	125	-60.687	-41.287	2	8	90	2905
A-12	126	-60.538	-39.197	2	8	90	3471
A-12	127	-60.707	-38.233	2	8	90	2738
A-12	128	-61.363	-37.127	2	8	90	3556
A-12	129	-62.043	-36.238	2	9	90	4264
A-12	130	-62.600	-35.507	2	9	90	4469
A-12	131	-63.165	-34.747	2	10	90	5098
A-12	132	-59.110	-25.620	2	12	90	2524
A-12	133	-58.717	-24.682	2	12	90	3448
A-12	134	-58.733	-24.067	2	12	90	5413
A-12	135	-58.710	-23.378	2	13	90	5551
A-12	136	-58.592	-22.412	2	13	90	4769
A-12	137	-58.450	-21.342	2	13	90	4580
A-12	138	-58.368	-20.153	2	14	90	3420
A-12	139	-58.137	-18.332	2	14	90	4485
A-12	140	-57.990	-16.855	2	14	90	5143
A-12	141	-57.802	-15.415	2	15	90	4541
A-12	142	-57.652	-13.293	2	15	90	4235
A-12	143	-57.532	-11.925	2	16	90	4766
A-12	144	-57.390	-10.040	2	16	90	3949
A-12	145	-57.248	-8.345	2	17	90	3688
A-12	146	-57.328	-6.590	2	17	90	4225
A-12	147	-57.818	-4.858	2	17	90	4142
A-12	148	-58.150	-3.103	2	18	90	4321

Table A.1 (continued)

SECTION	STAT	LATITUDE	LONGITUDE	MON	DAY	YEAR	DEPTH
A-12	149	-58.498	-1.000	2	18	90	4759
A-12	150	-57.700	-0.417	2	19	90	4101
A-12	151	-56.998	0.000	2	19	90	3849
A-12	152	-56.132	0.627	2	19	90	4157
A-12	153	-55.253	1.093	2	20	90	4130
A-12	154	-54.362	1.752	2	21	90	4890
A-12	155	-53.517	2.335	2	22	90	3002
A-12	156	-52.702	2.832	2	22	90	2910
A-12	157	-51.877	3.348	2	23	90	3116
A-12	158	-51.157	3.785	2	23	90	3170
A-12	159	-50.418	4.247	2	24	90	2902
A-12	160	-49.498	4.750	2	24	90	3574
A-12	161	-48.693	5.262	2	24	90	3067
A-12	162	-47.583	5.822	2	25	90	4289
A-12	163	-47.000	6.667	2	26	90	4093
A-12	164	-46.160	7.855	2	26	90	4055
A-12	165	-45.582	8.682	2	27	90	4396
A-12	166	-44.887	9.497	2	27	90	4562
A-12	167	-43.950	9.835	2	28	90	4529
A-12	168	-43.028	10.127	3	1	90	4091
A-12	169	-41.965	10.418	3	1	90	4534
A-12	170	-41.050	10.733	3	1	90	4420
A-12	171	-40.115	11.063	3	2	90	4727
A-12	172	-39.117	11.330	3	2	90	5051
A-12	173	-38.620	12.370	3	3	90	4838
A-12	174	-38.118	13.337	3	3	90	5035
A-12	175	-37.537	14.352	3	4	90	4963
A-12	176	-36.997	15.385	3	5	90	4804
A-12	177	-36.447	16.413	3	5	90	4506
A-12	178	-35.870	17.453	3	6	90	3891
A-12	179	-35.332	18.450	3	6	90	1794

APPENDIX B

SURFACE WATER DATA

APPENDIX B
SURFACE WATER DATA

This appendix lists surface water data collected during the R/V *Meteor* Cruise 11/5. The meanings of the column headings in table B-1 are as follows.

Sta	is the station number;
Date	is the date (month, day, and year) the station was sampled;
Lat	is the latitude of the station (in degrees and minutes);
Long	is the longitude of the station (in degrees and minutes);
Temp	is the surface water temperature (in °C);
Sal	is the surface water salinity (in PSU);
Seawater pCO_2 in situ	is the partial pressure of CO_2 measured at in situ temperature (in μatm);
Seawater pCO_2 20°C	is the partial pressure of CO_2 measured at 20°C (in μatm);
Atmosphere VCO_2	is the atmospheric CO_2 concentration (in ppm);
Atmosphere pCO_2	is the atmosphere partial pressure of CO_2 (in μatm), calculated from VCO_2 of dry air at 100% relative humidity by using 350.0 ppm as the mean value of VCO_2 (air);
Delta pCO_2	is the sea-air pCO_2 difference (in μatm);
TCO_2	is the total carbon concentration (in μmol/kg);
O_2	is the oxygen concentration (in μmol/kg);
PO_4	is the phosphate concentration (in μmol/kg);
NO_3	is the nitrate concentration (in μmol/kg);
SiO_3	is the silicate concentration (in μmol/kg);
TALK	is the total alkalinity (in μEQ/kg), computed by using the total CO_2, pCO_2, salinity, and nutrient data;
PALK	is the potential alkalinity (in μEQ/kg), defined by Total Alkalinity + Nitrate.

Table B.1 Surface water data obtained during the R/V *Meteor* Cruise 11/5
[reprinted from Chipman et al. (1992)]

Sta No.	Date MM/DD/YY	Lat DD-MM	Long DDD-MM	Temp C	Sal PSU	Seawater pCO_2 (μatm) insitu	Seawater pCO_2 (μatm) 20°C	Atmosphere VCO_2 ppm	Atmosphere pCO_2 μatm	Delta pCO_2 sw-air μatm	TCO_2 (μM/kg)	O_2 (μM/kg)	PO_4 (μM/kg)	NO_3 (μM/kg)	SiO_3 (μM/kg)	Alkalinity μEQ/kg TALK	Alkalinity μEQ/kg PALK
102	1/24/90	56-20S	67-60W	9.74	33.373	-999	-999	-999.9	-999	-999	2000	295	0.76	6.3	1.9	-999	-999
103	1/24/90	56-55S	68-15W	8.65	34.052	-999	-999	-999.9	-999	-999	2064	299	1.10	14.8	1.2	-999	-999
104	1/24/90	57-20S	68-15W	8.73	34.004	-999	-999	-999.9	-999	-999	2060	301	1.04	14.1	1.3	-999	-999
105	1/25/90	57-50S	68-15W	8.78	34.114	311	497	-999.9	346	-35	2060	303	1.07	15.2	1.4	2272	2287
106	1/26/90	58-20S	68-14W	8.59	34.034	334	542	-999.9	346	-12	2083	297	1.38	19.0	2.1	2284	2303
107	1/26/90	58-50S	68-15W	8.64	34.111	326	527	-999.9	346	-20	2072	302	1.32	17.8	2.0	2283	2300
108	1/26/90	59-20S	68-15W	9.28	34.079	313	493	-999.9	346	-33	2068	295	1.20	16.5	1.4	2286	2302
109	1/27/90	59-50S	68-15W	8.61	34.016	316	511	-999.9	346	-31	2074	296	1.26	17.6	1.4	2285	2303
110	1/27/90	60-20S	68-08W	7.40	34.020	313	534	-999.9	346	-33	2085	308	1.28	19.3	2.6	2289	2308
111	1/28/90	60-50S	68-00W	7.90	34.057	314	523	-999.9	346	-33	2087	298	1.33	18.0	1.7	2296	2314
112	1/28/90	61-13S	67-20W	5.56	33.994	322	593	-999.9	347	-25	2102	316	1.33	21.5	2.7	2287	2308
113	1/28/90	61-36S	66-40W	4.62	33.864	342	656	-999.9	347	-5	2124	322	1.58	22.3	14.0	2293	2316
114	1/29/90	62-00S	65-59W	4.42	33.880	-999	-999	-999.9	-999	-999	2119	322	1.61	22.4	13.7	-999	-999
115	1/29/90	62-17S	65-13W	3.53	33.875	-999	-999	-999.9	-999	-999	-999	-999	-999.90	-999.9	-999.9	-999	-999
116	1/29/90	62-36S	64-16W	3.10	33.925	353	722	-999.9	347	6	2145	332	1.69	24.1	38.2	2301	2326
117	1/30/90	62-51S	63-31W	1.64	33.984	355	743	-999.9	348	8	2157	319	1.84	24.3	45.4	2305	2329
118	1/30/90	62-17S	65-13W	3.61	33.875	337	674	-999.9	347	-10	2125	325	1.60	23.1	18.9	2290	2313
119	2/01/90	61-36S	66-40W	4.51	33.875	-999	-999	-999.9	-999	-999	2117	-999	-999.90	-999.9	-999.9	-999	-999
120	2/01/90	58-20S	68-15W	8.06	34.038	329	545	-999.9	346	-17	2084	-999	1.39	18.6	2.2	2283	2302
121	2/03/90	55-29S	64-29W	8.23	34.042	287	472	-999.9	346	-60	2052	299	1.06	12.5	1.9	2276	2288
122	2/06/90	59-15S	47-15W	3.68	33.909	282	562	-999.9	347	-65	2103	340	1.16	18.5	0.0	2298	2317
123	2/06/90	60-12S	45-40W	1.75	33.948	272	590	-999.9	348	-75	2121	359	1.24	18.1	50.3	2312	2330
124	2/07/90	60-39S	41-56W	1.60	33.775	324	706	348.4	348	-24	2141	345	1.46	22.7	63.8	2299	2321
125	2/08/90	60-41S	41-17W	1.51	33.878	326	712	-999.9	348	-22	2146	345	1.50	22.9	65.0	-999	-999
126	2/08/90	60-32S	39-12W	1.92	34.043	309	663	-999.9	348	-39	2145	342	1.33	21.3	45.0	2317	2338
127	2/08/90	60-42S	38-14W	2.08	33.996	301	642	-999.9	348	-47	2138	344	1.25	20.6	42.0	2315	2336
128	2/08/90	61-22S	37-08W	1.82	33.943	286	618	-999.9	348	-61	2131	345	1.19	19.6	17.5	2313	2332
129	2/09/90	62-03S	36-14W	1.22	33.666	246	546	351.0	348	-102	2104	352	1.20	17.6	71.1	2302	2320
130	2/09/90	62-36S	35-30W	1.10	33.864	258	573	-999.9	348	-90	2114	357	1.25	19.1	68.0	2310	2329
131	2/10/90	63-10S	34-45W	1.56	33.819	236	514	-999.9	348	-112	2097	355	1.04	15.3	57.2	2308	2323
132	2/12/90	59-07S	25-37W	1.01	33.894	246	550	-999.9	348	-101	2113	355	0.97	15.7	40.0	2315	2331
133	2/12/90	58-43S	24-41W	1.63	33.981	282	614	-999.9	348	-65	2132	343	1.18	18.3	34.2	2316	2335
134	2/12/90	58-44S	24-04W	2.33	33.915	-999	-999	-999.9	-999	-999	2135	-999	-999.90	-999.9	-999.9	-999	-999
135	2/13/90	58-43S	23-23W	2.30	33.925	298	630	-999.9	348	-49	2132	335	1.31	19.2	16.5	2311	2330
136	2/13/90	58-36S	22-25W	2.29	33.787	298	631	-999.9	348	-49	2120	335	1.39	19.5	10.0	2296	2316
137	2/13/90	58-27S	21-21W	2.29	33.812	294	623	-999.9	348	-53	2120	334	1.34	18.2	10.7	2298	2316
138	2/14/90	58-22S	20-09W	1.94	33.647	278	597	-999.9	348	-70	2109	337	1.25	16.5	10.0	2293	2309
139	2/14/90	58-08S	18-20W	2.12	33.730	291	620	-999.9	348	-57	2117	336	1.37	18.5	11.7	2295	2314

Table B.1 (continued)

Sta No.	Date MM/DD/YY	Lat DD-MM	Long DDD-MM	Temp C°	Sal PSU	Seawater pCO_2 (µatm) insitu	Seawater pCO_2 (µatm) 20°C	Atmosphere VCO_2 ppm	Atmosphere pCO_2 µatm	Delta pCO_2 sw-air µatm	TCO_2 (µM/kg)	O_2 (µM/kg)	PO_4 (µM/kg)	NO_3 (µM/kg)	SiO_3 (µM/kg)	Alkalinity µEQ/kg TALK	Alkalinity µEQ/kg PALK
140	2/14/90	57-59S	16-51W	2.38	33.863	-999	-999	352.1	-999	-999	2127	-999	-999.90	-999.9	-999.9	-999	-999
141	2/15/90	57-48S	15-25W	1.93	33.794	306	656	-999.9	348	-42	2122	341	1.43	21.5	18.1	2291	2312
142	2/15/90	57-39S	13-18W	1.72	33.811	300	651	-999.9	348	-47	2125	346	1.37	21.4	18.4	2296	2317
143	2/16/90	57-32S	11-56W	1.55	33.718	296	646	-999.9	348	-52	2123	340	1.37	20.3	18.4	2295	2315
144	2/16/90	57-23S	10-02W	1.94	33.762	302	648	350.9	348	-46	2123	340	1.40	20.1	15.8	2294	2315
145	2/17/90	57-15S	8-21W	1.70	33.706	298	647	-999.9	348	-49	2124	337	1.45	19.1	20.6	2296	2315
146	2/17/90	57-20S	6-35W	1.73	33.747	311	674	-999.9	348	-36	2128	339	1.48	20.6	20.5	2292	2313
147	2/17/90	57-49S	4-51W	1.24	33.897	317	701	-999.9	348	-31	2145	339	1.45	21.5	41.5	2306	2328
148	2/18/90	58-09S	3-06W	1.34	33.723	289	635	-999.9	348	-59	2123	341	1.28	18.9	19.4	2298	2316
149	2/18/90	58-30S	1-00W	1.29	33.880	324	715	-999.9	348	-24	2147	338	1.52	21.9	42.8	2305	2327
150	2/19/90	57-42S	0-25W	1.11	33.979	339	754	-999.9	348	-9	2162	339	1.64	23.4	54.7	2313	2336
151	2/19/90	56-60S	0-00E	1.25	33.976	337	745	-999.9	348	-10	2161	338	1.61	22.9	48.1	2315	2337
152	2/19/90	56-08S	0-38E	1.57	33.886	334	728	-999.9	348	-14	2152	335	1.43	22.9	40.9	2307	2330
153	2/20/90	55-15S	1-06E	1.55	33.834	-999	-999	-999.9	-999	-999	2145	-999	-999.90	-999.9	-999.9	-999	-999
154	2/21/90	54-22S	1-45E	1.33	33.837	340	749	-999.9	348	-8	2148	342	1.67	24.4	37.0	2298	2322
155	2/22/90	53-31S	2-20E	1.53	33.847	346	755	-999.9	348	-2	2149	340	1.68	24.6	42.3	2297	2322
156	2/22/90	52-42S	2-50E	1.75	33.923	356	770	-999.9	348	8	2155	340	1.83	26.4	45.7	2301	2328
157	2/23/90	51-53S	3-21E	3.02	33.838	-999	-999	-999.9	-999	-999	-999	331	1.60	24.4	18.5	-999	-999
158	2/23/90	51-09S	3-47E	3.88	33.865	339	670	-999.9	347	-8	2123	-999	1.61	22.9	16.7	2289	2312
159	2/24/90	50-25S	4-15E	4.38	33.871	343	664	-999.9	347	-4	2121	320	1.60	22.2	16.2	2288	2310
160	2/24/90	49-30S	4-45E	5.79	33.879	333	607	-999.9	347	-14	2101	310	1.44	19.2	4.9	2282	2301
161	2/24/90	48-42S	5-16E	6.24	33.887	335	600	-999.9	347	-11	2095	307	1.44	18.9	3.8	2277	2296
162	2/25/90	47-35S	5-49E	7.35	33.886	334	571	-999.9	346	-13	2083	303	1.38	17.8	3.3	2274	2292
163	2/26/90	47-00S	6-40E	7.72	33.866	-999	-999	-999.9	-999	-999	-999	-999	-999.90	-999.9	-999.9	-999	-999
164	2/26/90	46-10S	7-51E	8.17	33.901	327	539	-999.9	346	-20	2077	300	1.29	16.2	2.7	2277	2293
165	2/27/90	45-35S	8-41E	8.79	33.920	336	539	-999.9	346	-10	2075	296	1.22	15.9	2.3	2275	2291
166	2/27/90	44-53S	9-30E	9.98	33.993	335	511	-999.9	346	-11	2068	286	1.13	13.7	3.0	2275	2289
167	2/28/90	43-57S	9-50E	10.97	34.190	325	476	-999.9	345	-21	2056	282	0.93	10.4	3.0	2280	2290
168	3/01/90	43-02S	10-08E	10.59	34.061	326	486	349.0	346	-19	2058	285	1.02	12.3	2.7	2277	2289
169	3/01/90	41-58S	10-25E	11.48	34.157	322	463	-999.9	345	-24	2054	284	0.93	10.7	3.0	2282	2293
170	3/01/90	41-03S	10-44E	17.01	35.184	311	353	-999.9	343	-32	2035	243	0.21	0.0	2.7	2328	2328
171	3/02/90	40-07S	11-04E	17.57	35.206	310	344	-999.9	343	-33	2028	241	0.22	0.1	2.4	2326	2326
172	3/02/90	39-07S	11-20E	17.09	35.167	306	345	-999.9	343	-37	2030	244	0.31	0.6	2.2	2326	2327
173	3/03/90	38-37S	12-22E	19.23	35.390	327	336	348.5	342	-16	-999	233	0.15	0.0	1.9	-999	-999
174	3/03/90	38-07S	13-20E	19.85	35.571	316	318	-999.9	342	-26	2023	232	0.14	0.0	3.2	2343	2343
175	3/04/90	37-32S	14-21E	21.82	35.489	318	295	-999.9	341	-23	1994	222	0.14	0.1	3.5	2326	2326
176	3/05/90	36-60S	15-23E	22.69	35.490	317	283	-999.9	341	-23	1987	218	0.10	0.0	2.5	2328	2328
177	3/05/90	36-27S	16-25E	20.40	35.396	316	310	-999.9	342	-26	2007	230	0.14	0.1	2.8	2329	2329
178	3/06/90	35-52S	17-27E	20.85	35.483	309	298	-999.9	342	-32	2017	228	0.12	0.0	2.8	2352	2352
179	3/06/90	35-20S	18-27E	20.98	35.428	326	313	-999.9	341	-16	2024	227	0.12	0.0	3.9	2348	2348

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