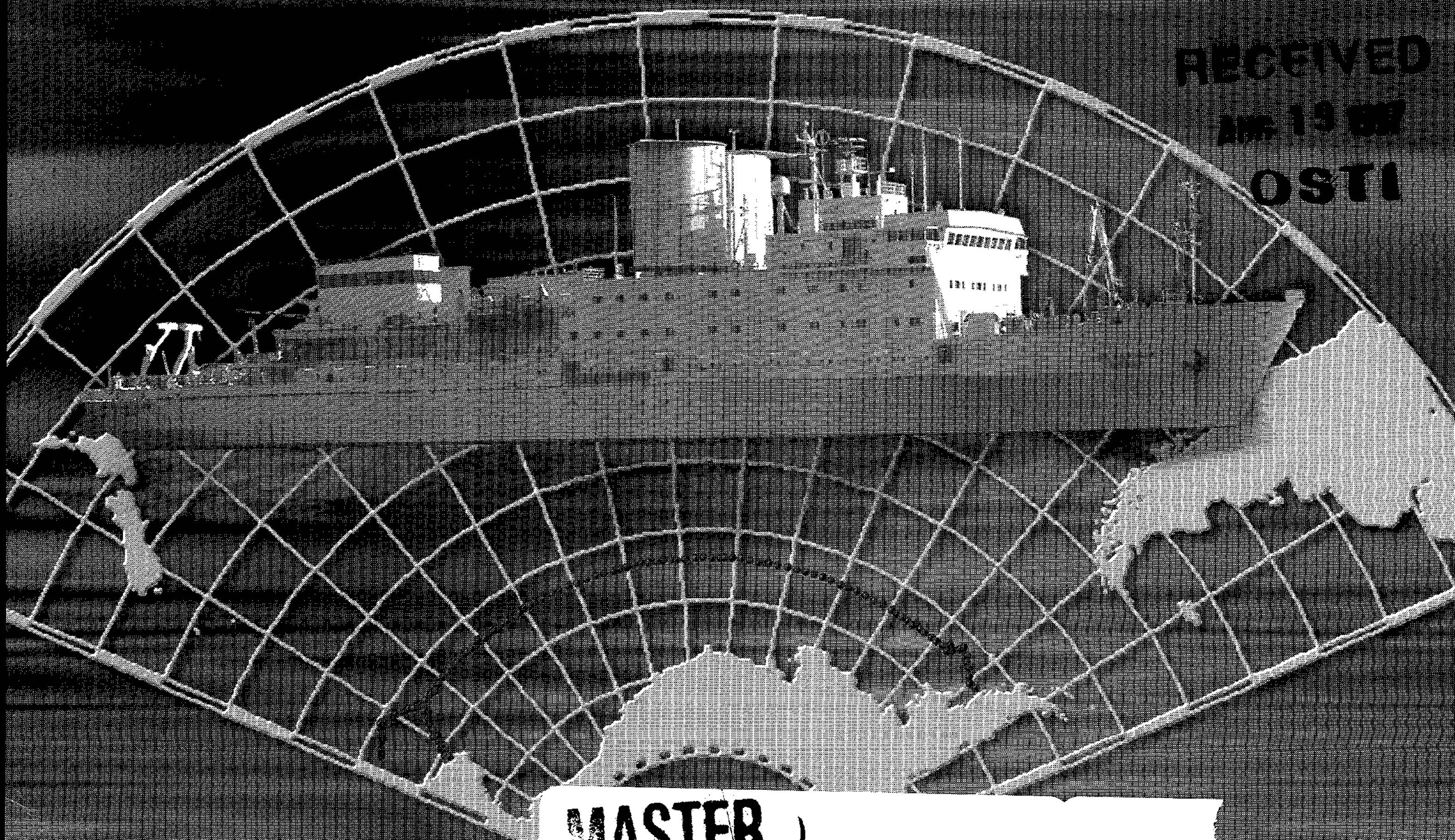
ORNL/CDIAC-100
NDP-063

Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *AKADEMIK IOFFE* Cruise in the South Pacific Ocean (WOCE Section S4P, February - April 1992)



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DISCLAIMER

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CARBON DIOXIDE, HYDROGRAPHIC, AND CHEMICAL DATA OBTAINED DURING THE R/V *AKADEMIK IOFFE* CRUISE IN THE SOUTH PACIFIC OCEAN (WOCE SECTION S4P, FEBRUARY–APRIL 1992)

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ABSTRACT

Chipman D. W., T. Takahashi, S. Rubin, S. C. Sutherland, and M. H. Koshlyakov. 1997. Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Akademik Ioffe* Cruise in the South Pacific Ocean (WOCE Section S4P, February–April 1992). ORNL/CDIAC-100, NDP-063. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 134 pp.

This data documentation discusses the procedures and methods used to measure total carbon dioxide (TCO_2) and partial pressure of CO_2 (pCO_2) in discrete water samples during the Research Vessel (R/V) *Akademik Ioffe* Expedition in the South Pacific Ocean. Conducted as part of the World Ocean Circulation Experiment (WOCE), the cruise began in Montevideo, Uruguay, on February 14, 1992, and ended in Wellington, New Zealand, on April 6, 1992. WOCE Section S4P, located along ~67° S between 73° W and 172° E, was completed during the 51-day expedition. One hundred and thirteen hydrographic stations were occupied. Hydrographic and chemical measurements made along WOCE Section S4P included pressure, temperature, salinity, and oxygen measured by a conductivity, temperature, and depth sensor; bottle salinity; bottle oxygen; phosphate; nitrate; nitrite; silicate; TCO_2; and pCO_2 measured at 4°C.

The TCO_2 concentration in ~1290 seawater samples was determined with a coulometric analysis system; the pCO_2 in ~1270 water samples was determined with an equilibrator-gas chromatograph system. In addition, 172 coulometric measurements for the Certified Reference Material (batch no. 7) were made at sea for 62 bottles and yielded a mean value of 1927.5 ± 1.8 μmol/kg. This mean value agrees within one standard deviation of the 1926.6 ± 0.7 μmol/kg (N = 6) value determined with the manometer of C. D. Keeling at Scripps Institution of Oceanography. The TCO_2 values listed in this report have not been corrected to this difference.

The WOCE Section S4P data set is available free of charge as a numeric data package (NDP) from the Carbon Dioxide Information Analysis Center. The NDP consists of two data files, two FORTRAN 77 routines, a readme file, and this printed documentation.

Keywords: carbon dioxide; World Ocean Circulation Experiment; South Pacific Ocean; hydrographic measurements; carbon cycle; carbonate chemistry; coulometer

PART 1:

OVERVIEW

1. BACKGROUND INFORMATION

The World Ocean Circulation Experiment (WOCE) expeditions in the high-latitude South Pacific Ocean surrounding the Antarctic continent were designed to increase knowledge about an area of the World Ocean that has not been investigated extensively due to its remoteness and difficult ice and weather conditions. Acquiring oceanographic information from the South Pacific Ocean is extremely important because the Southern Ocean is known to be an area of formation for deep and intermediate water masses. These water masses provide a direct link between the atmosphere and global deep oceans through water-mass formation and ventilation processes (Chipman et al. 1996).

According to Tans et al. (1990), the Southern Ocean (south of 50° S) should be a moderate net source of carbon dioxide (CO_2) (0.5 Gt of carbon per year) to the atmosphere to account for the observed meridional gradient of the atmospheric CO_2 concentration. However, the available data suggest that the South Pacific Ocean is a net sink, at least during the summer period. To resolve the controversy, more measurements are needed. The DOE Global Ocean CO_2 Survey is taking advantage of the sampling opportunities provided by the WOCE cruises in the South Pacific Ocean.

This report presents hydrographic and CO_2-related measurements obtained during the 51-day expedition of the Russian Research Vessel (R/V) *Akademik Ioffe* along the WOCE Section S4P, which is located in the Pacific sector of the Southern Ocean along ~67° S, between ~73° W and 172° E (Fig. 1).

The parameters measured during the cruise and listed in this report include the following: total CO_2 (TCO_2) concentration; discrete partial pressure of CO_2 (pCO_2) measured at 4°C; pressure, temperature, salinity, and oxygen measured by the conductivity, temperature, and depth (CTD) sensor; bottle salinity, bottle oxygen, and nutrients.

The CO_2 investigation along WOCE Section S4P was supported by a grant (No. DE-FGO2-92-ER61397) from the U.S. Department of Energy.

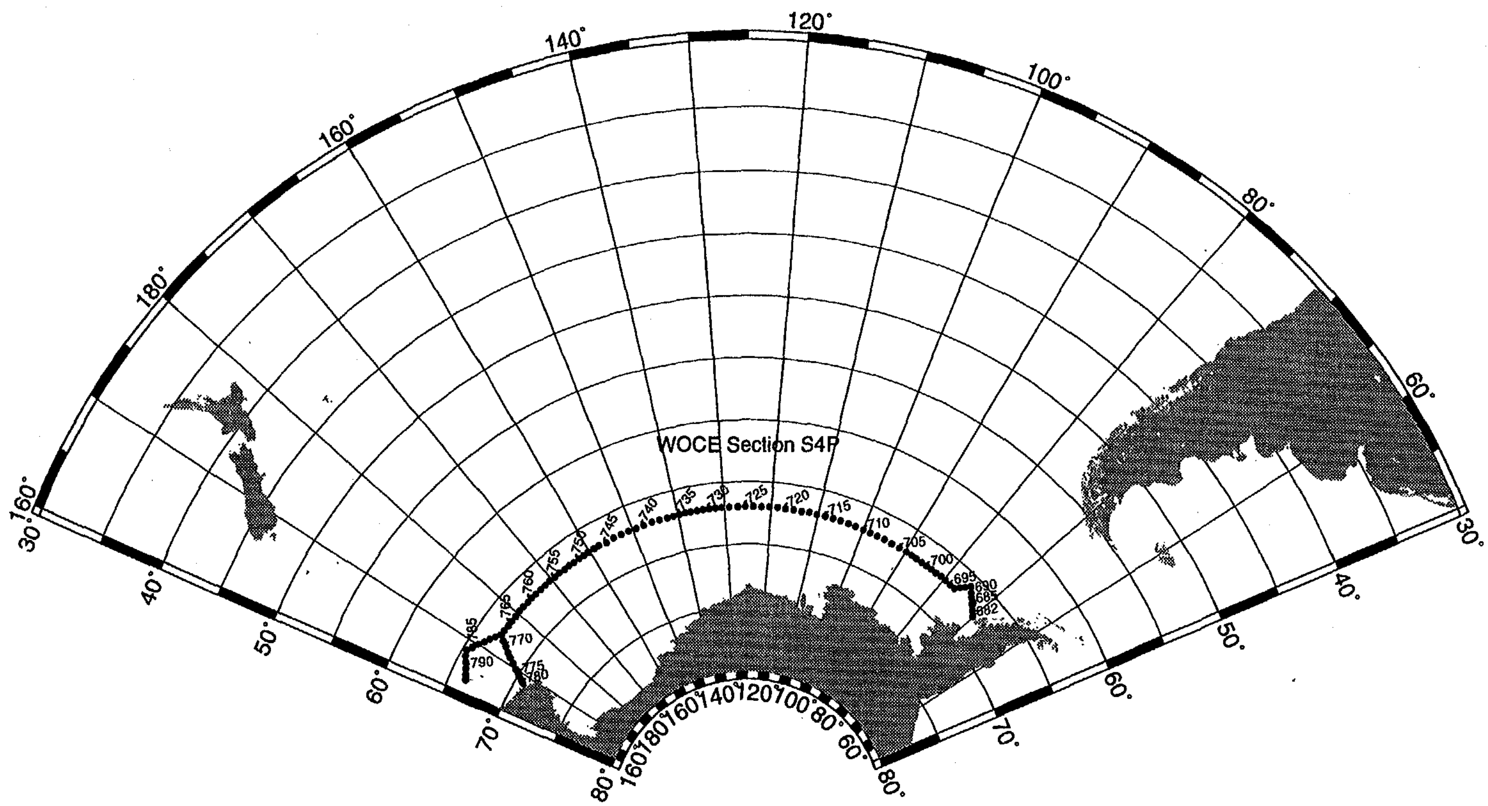

Figure 1. The location of hydrographic stations occupied during R/V *Akademik Ioffe* Expedition along the WOCE Section S4P.

2. DESCRIPTION OF THE EXPEDITION

2.1 R/V *Akademik Ioffe* Expedition Information

R/V *Akademik Ioffe* Expedition information is as follows:

Ship name/country	*Akademik Ioffe*/Russia
Cruise/leg	6/1
Expocode	RUKDIOFFE6/1
WOCE Sections	S4P
Ports of call	Montevideo, Uruguay; Wellington, New Zealand
Dates	February 14–April 6, 1992
Chief Scientist	Mikhail H. Koshlyakov (Shirshov Institute of Oceanography, Russia)

Parameters measured	**Institution**	**Principal investigators**
CTD, oxygen, and nutrients	SIO	J. Swift
Tritium and helium	LDEO	P. Schlosser
TCO_2 and pCO_2	LDEO	D. Chipman and T. Takahashi
Carbon isotopes	NASA (ARC)	G. Rau
Chlorofluorocarbons (CFCs)	PMEL	J. Bullister
Acoustic Doppler current profiler	ShIO, OSU	A. Berezutski and J. Richman
Multibeam bathymetry	ShIO	A. Berezutski
Radiocarbon	LDEO	P. Schlosser
Biological sampling	ShIO	N. Voronina

Participating Institutions

SIO	Scripps Institution of Oceanography (University of California, San Diego)
LDEO	Lamont-Doherty Earth Observatory (Columbia University)
NASA (ARC)	National Aeronautics and Space Administration (Ames Research Center)
PMEL	Pacific Marine Environmental Laboratory
ShIO	Shirshov Institute of Oceanography (Russian Academy of Sciences, Moscow)
OSU	Oregon State University

2.2 Brief Cruise Summary

The WOCE S4P Expedition aboard the Russian R/V *Akademik Ioffe* started in Montevideo, Uruguay, on February 14, 1992, and ended in Wellington, New Zealand, on April 6, 1992, after 51 days at sea. The cruise track included hydrographic stations that began on the continental shelf of the Antarctic Peninsula at 67° 28′ S and 71° 05′ W on February 22, 1992. Stations continued west along ~67° S at intervals of 30 nautical miles. The first ten stations were established along a northwesterly line approximately perpendicular to the continental slope, with stations over the shelf break and slope located on depths separated by an 800-m isobath. Over the Bellingshausen Abyssal Plain, between 91° 34′ W and 130° 41′ W, and over the Amundsen Abyssal Plain, between 142° 11′ W and 157° 41′ W, the station spacing was increased to 40 nautical miles. At 174° 15′ E, the track turned southwest to run perpendicular to the Antarctic continental shelf. The section was completed with a 400-m-deep station off Yang Island of the Balleny Islands at 66° 25′ S and 162° 41′ E. The last station (no. 795) was the eastern terminus for the continuation of the WOCE Section S4 into the Indian Ocean.

3. DESCRIPTION OF VARIABLES AND METHODS

The data file **s4p.dat** (see description in Part 2) in this numeric data package (NDP) contains the following variables: station numbers; cast numbers; sample numbers; bottle numbers; CTD pressure, temperature, salinity, and oxygen; potential temperature; bottle salinity; concentration of dissolved oxygen, silicate, nitrate, nitrite, phosphate, and TCO_2; pCO_2 measured at 4°C; and data-quality flags. The station inventory file **s4psta.inv** (see Part 2) contains the expocode, section number, station number, cast number, sampling date (i.e., month, day, year), sampling time, latitude, longitude, and bottom depth for each station.

3.1 Hydrographic Measurements

The hydrographic measurements and water sampling were conducted by the staff of the SIO Oceanographic Data Facility (ODF). Water samples were collected through the use of Niskin 10-L sampling bottles mounted on an ODF-constructed 24-bottle rosette sampler. The rosette was equipped with an ODF-modified NBIS Mark IIIb CTD for in situ measurements of conductivity, temperature, pressure, and dissolved oxygen.

Salinity samples were drawn into 200-mL Kimax high-alumina borosilicate glass bottles with custom-made plastic insert thimbles and Nalgene screw caps, which provided low container dissolution and sample evaporation. These bottles were rinsed three times before filling, and measurements were usually made within 8–36 h after collection. Salinity was determined on the basis of electrical conductivity measured by an ODF-modified Guildline Autosal Model 8400A salinometer, and the values were obtained according to the equations of the Practical Salinity Scale of 1978 (UNESCO 1981).

Water samples for oxygen analyses were collected shortly after the rosette sampler was brought on board and after the samples for CFCs and helium were drawn. Sampling flasks (100–125 mL), calibrated before the expedition, were carefully rinsed and then filled using a drawing tube (after being allowed to overflow for at least two flask volumes). Reagents were added to fix the oxygen before the flasks were sealed with stoppers. The flasks were shaken immediately after being sealed and again after 20 min to ensure thorough dispersion of the manganous hydroxide [$Mn(OH)_2$] precipitate. The oxygen concentration in these solutions was determined within 4–36 h using the Winkler titration methods of Carpenter (1965) with modifications by Culberson and Williams (1991). The titrator was calibrated with 0.01 *N* potassium iodate standard solutions prepared using preweighed potassium iodate crystals. Oxygen concentrations were converted from milliliters per liter to micromoles per kilogram of seawater using the in situ temperature. A molar volume (at standard temperature and pressure) of 22.3914 L/mol (Kester 1975) was used for this purpose.

Nutrient analyses were performed by analysts from SIO using a Technicon AutoAnalyzer II provided by ODF. The procedures used are described in Gordon et al. (1992). Standardization was performed with solutions prepared aboard the ship from preweighed standards. These solutions were used as working standards before and after each cast (~24 samples) to correct for instrumental drift during analyses. Sets of 4–6 different concentrations of shipboard standards were analyzed periodically to determine the linearity of colorimetric response and the resulting correction factors. Hydrazine reduction of phosphomolybdic acid, as described by Bernhardt and Wilhelms (1967), was used for phosphate analysis, while stannous chloride reduction of silicomolybdic acid was used for silicate analysis. Nitrite was analyzed by use of diazotization and coupling to form dye. Nitrate was reduced by copperized cadmium and then analyzed as nitrite. The last three analyses used the methods of Armstrong et al. (1967).

A full cruise report, which includes details about processing the hydrographic data, and the final CTD data are available from the WOCE Hydrographic Programme (WHP) Office (WHPO) at SIO or the WHP Special Analysis Center in Germany.

3.2 Carbon Measurements

To measure the TCO_2 concentration in seawater, a coulometric analysis system was used during the cruise. This system has been described by Chipman et al. (1993) and consists of a coulometer (Model 5011), manufactured by the UIC, Inc. (Jolliet, IL), and a sample introduction/CO_2 extraction system of the LDEO design. A total of 1290 water samples was analyzed for TCO_2 concentration. In addition, 172 determinations were made at sea for 62 bottles of the Certified Reference Material (batch no. 7) yielding an average value of 1927.5±1.8 μmol/kg. This compares with the SIO manometric value of 1926.6±0.7 μmol/kg (6 determinations) (Fig.2). The mean values for each set of measurements agree with each other within respective standard deviations.

To measure the pCO_2 in seawater a fully-automated equilibrator-gas chromatograph system was used during the cruise. This system has been described by Chipman et al. (1993). A total of 1273 water samples was analyzed for pCO_2. Since pCO_2 is strongly affected by temperature changes, the equilibration flasks were kept in a constant-temperature water bath of 4.0°C throughout the expedition. The precision of the pCO_2 measurements has been estimated to be ~±0.12% for a single station based on the reproducibility of replicate equilibrations. However, the station-to-station reproducibility was about ±0.5%.

A full description of the methods and instrumentation used to perform the TCO_2 and pCO_2 measurements during the R/V *Akademik Ioffe* cruise in the South Pacific Ocean (WOCE Section S4P) is provided in Appendix B.

Figure 3 shows the sampling density and depth along the WOCE Section S4P.

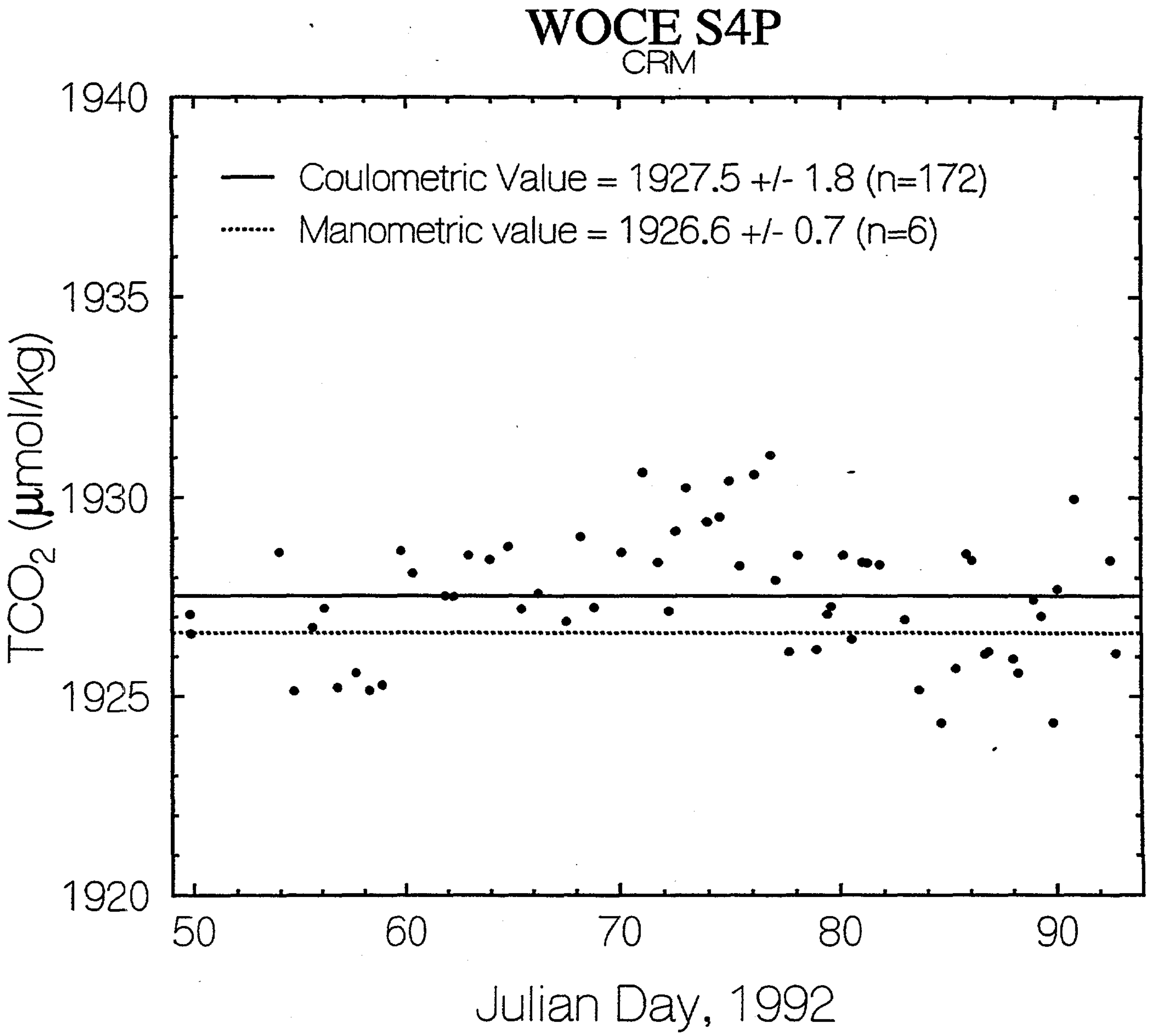

Figure 2. Comparison between the results of the coulometric determinations of total CO_2 concentration in the SIO Certified Reference Material (batch no. 7) obtained during the expedition and the manometric determinations obtained by the staff of C. D. Keeling at SIO.

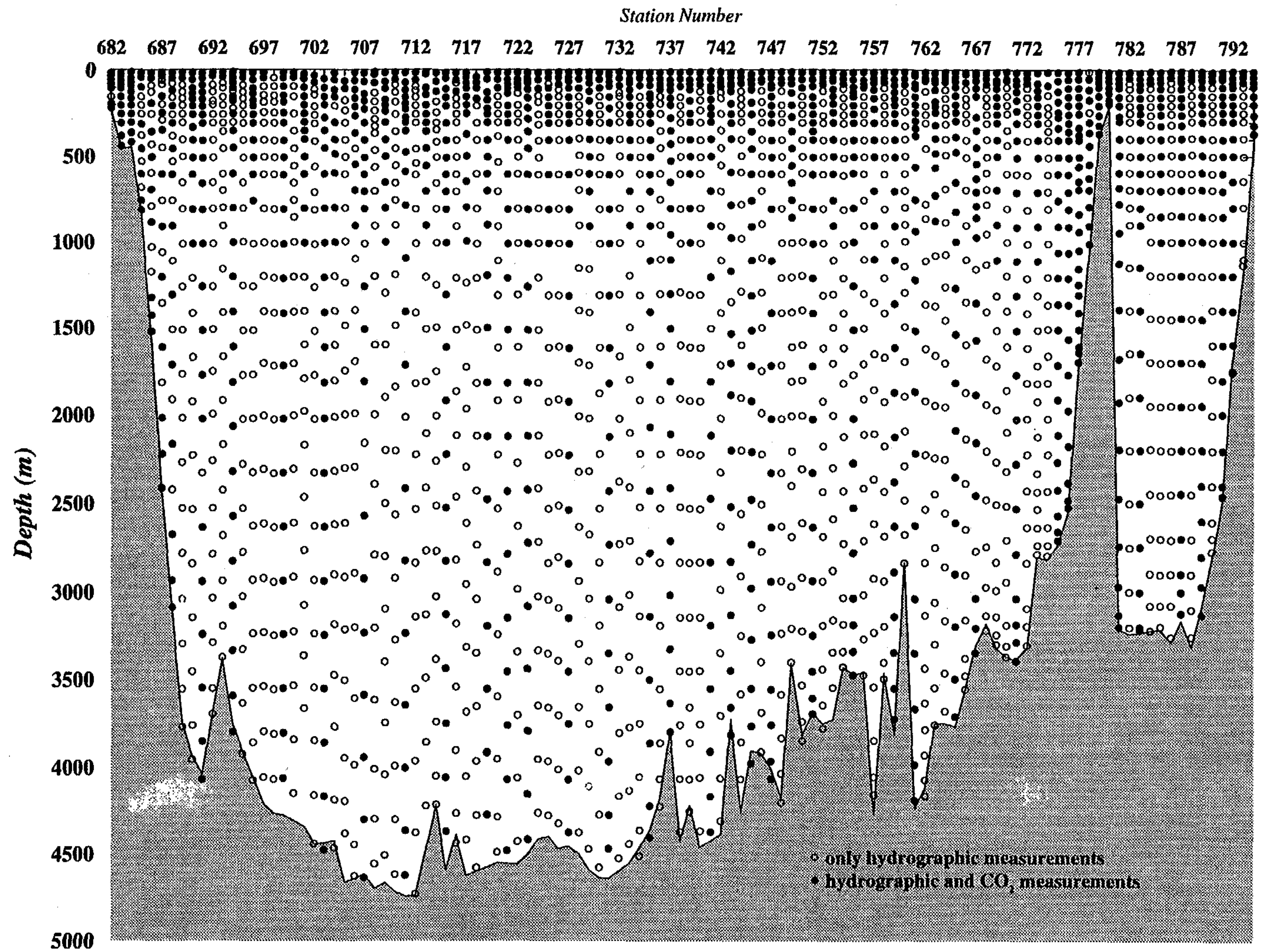

Figure 3. Sampling depths at all hydrographic stations occupied during R/V *Akademik Ioffe* Expedition in the South Pacific Ocean (WOCE Section S4P).

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 and often require 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 information summarizes the data-processing and QA checks performed by CDIAC on the data obtained during the R/V *Akademik Ioffe* Expedition in the South Pacific Ocean (WOCE Section S4P).

1. Carbon-related data and preliminary hydrographic measurements were provided to CDIAC by Taro Takahashi of LDEO. The final hydrographic and chemical measurements and the station information files were provided by the WHPO after quality evaluation. A FORTRAN 77 retrieval code was written and used to merge and reformat all data files.

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

3. To check for obvious outliers, all data were plotted with a PLOTNEST.C program written by Stewart C. Sutherland (LDEO). 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. 4–9). Several outliers were identified and removed after consultation with the principal investigators.

4. To identify "noisy" data and possible systematic, methodological errors, property-property plots for all parameters were generated (Fig. 10), carefully examined, and compared with plots from previous expeditions in the South Pacific Ocean.

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

6. Dates and times were checked for bogus values (e.g., values of MONTH <1 or >12, DAY <1 or >31, YEAR ≠1992, TIME <0000 or >2400).

7. Station locations (latitudes and longitudes) and sampling times were examined for consistency with maps and cruise information supplied by Chipman et al. (1996).

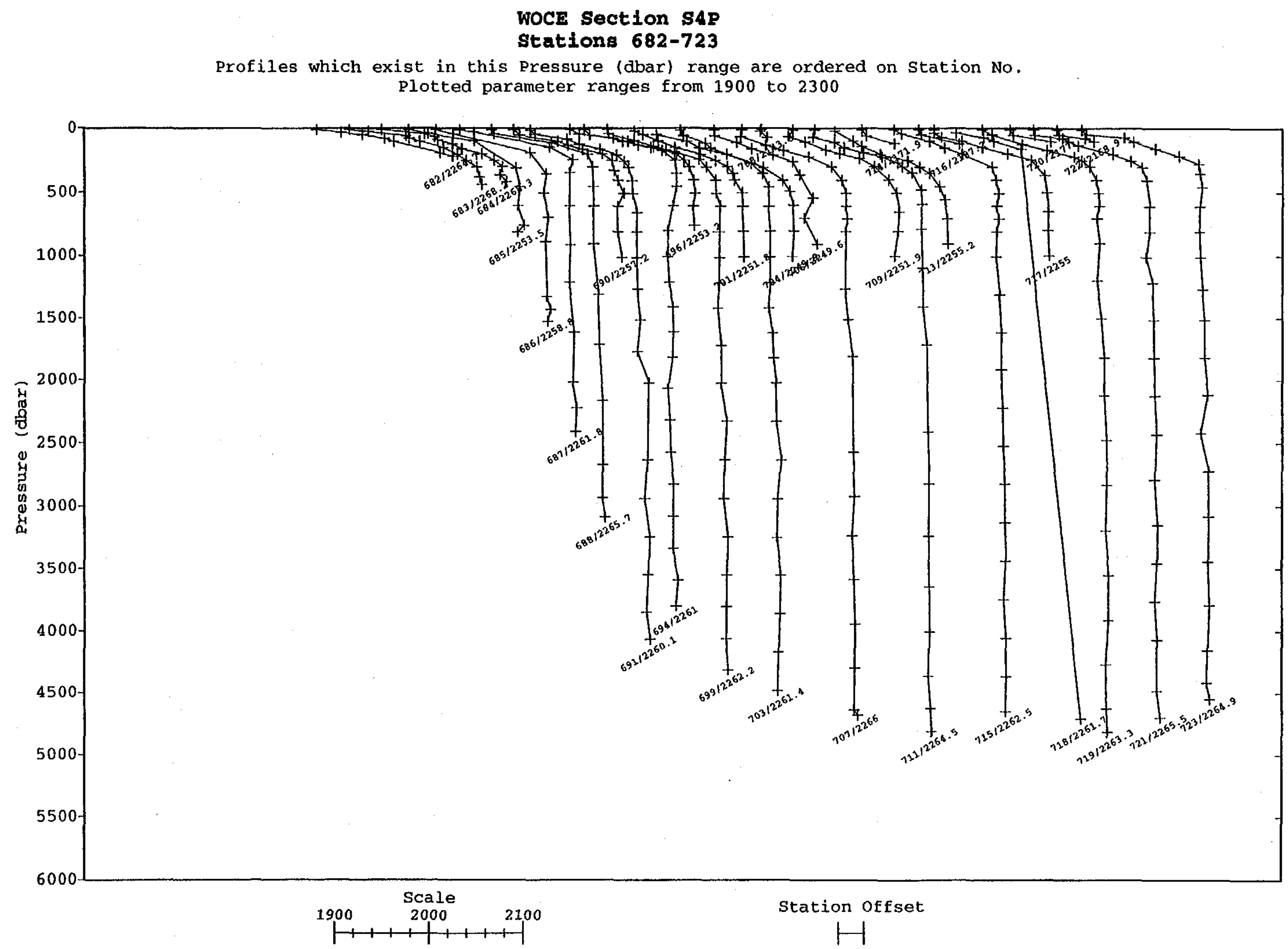

Figure 4. Nested profiles: total carbon (μmol/kg) vs pressure (dbar) for stations 682–723.

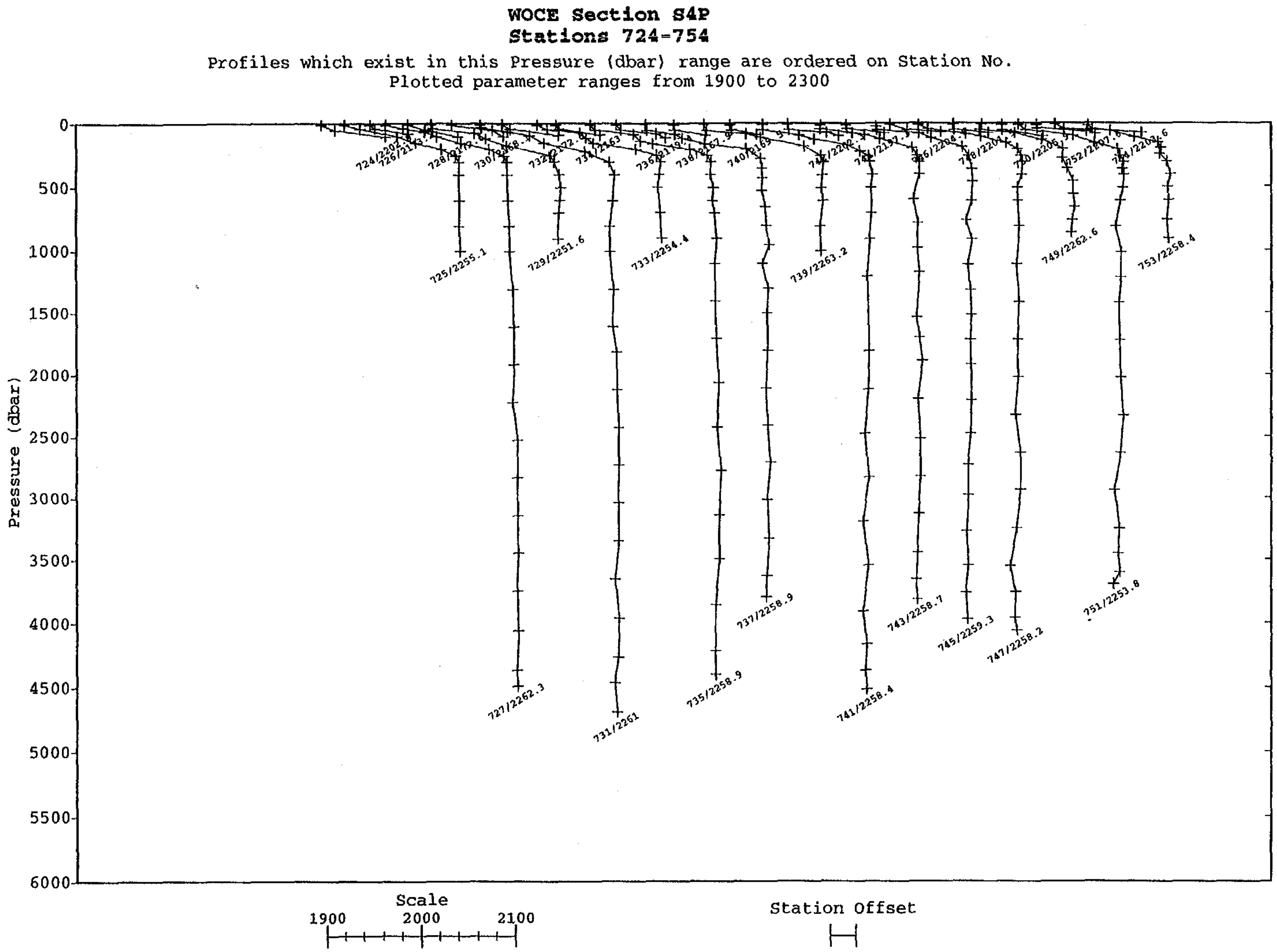

Figure 5. Nested profiles: total carbon (μmol/kg) vs pressure (dbar) for stations 724–754.

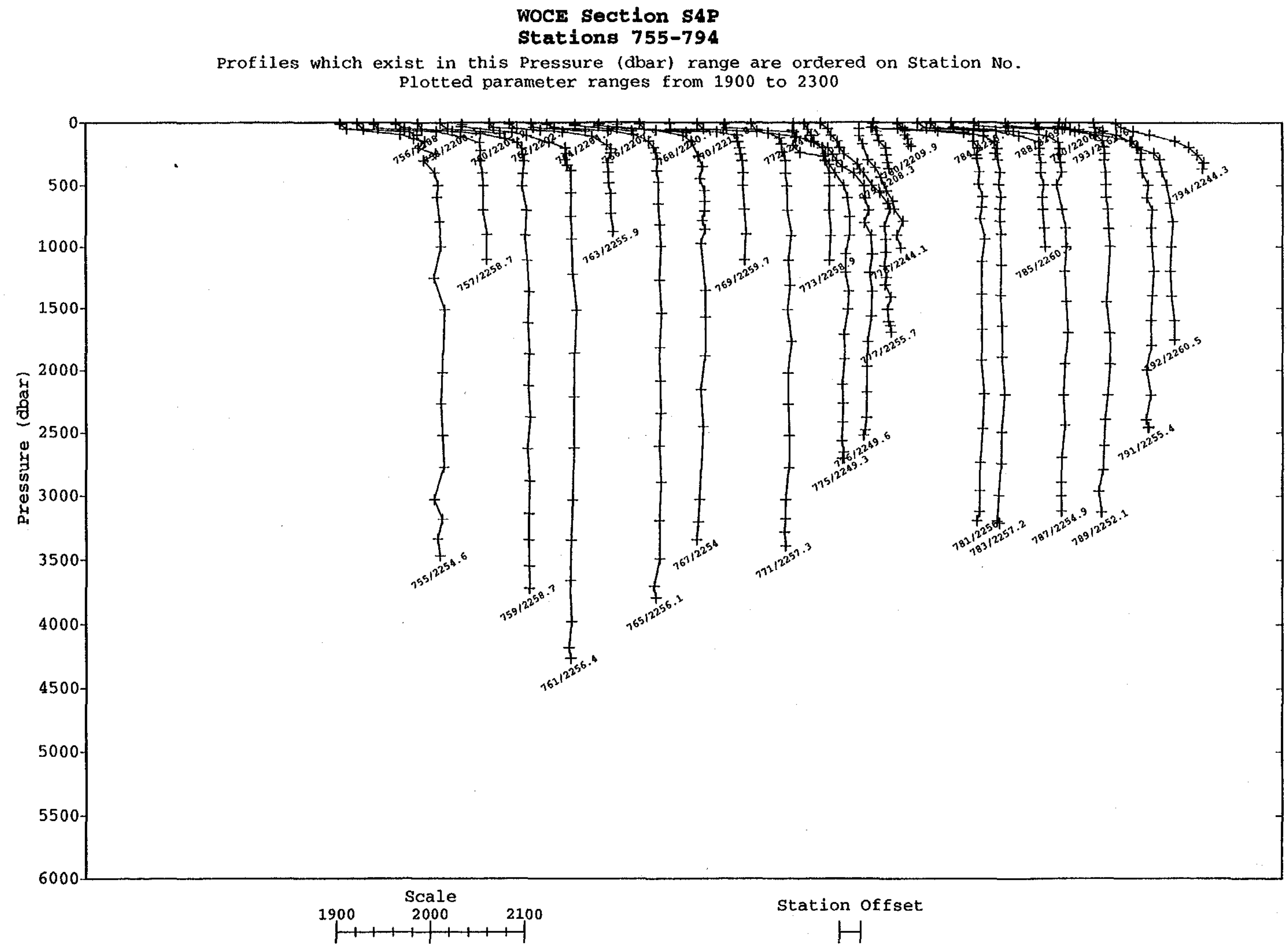

Figure 6. Nested profiles: total carbon (μmol/kg) vs pressure (dbar) for stations 755–794.

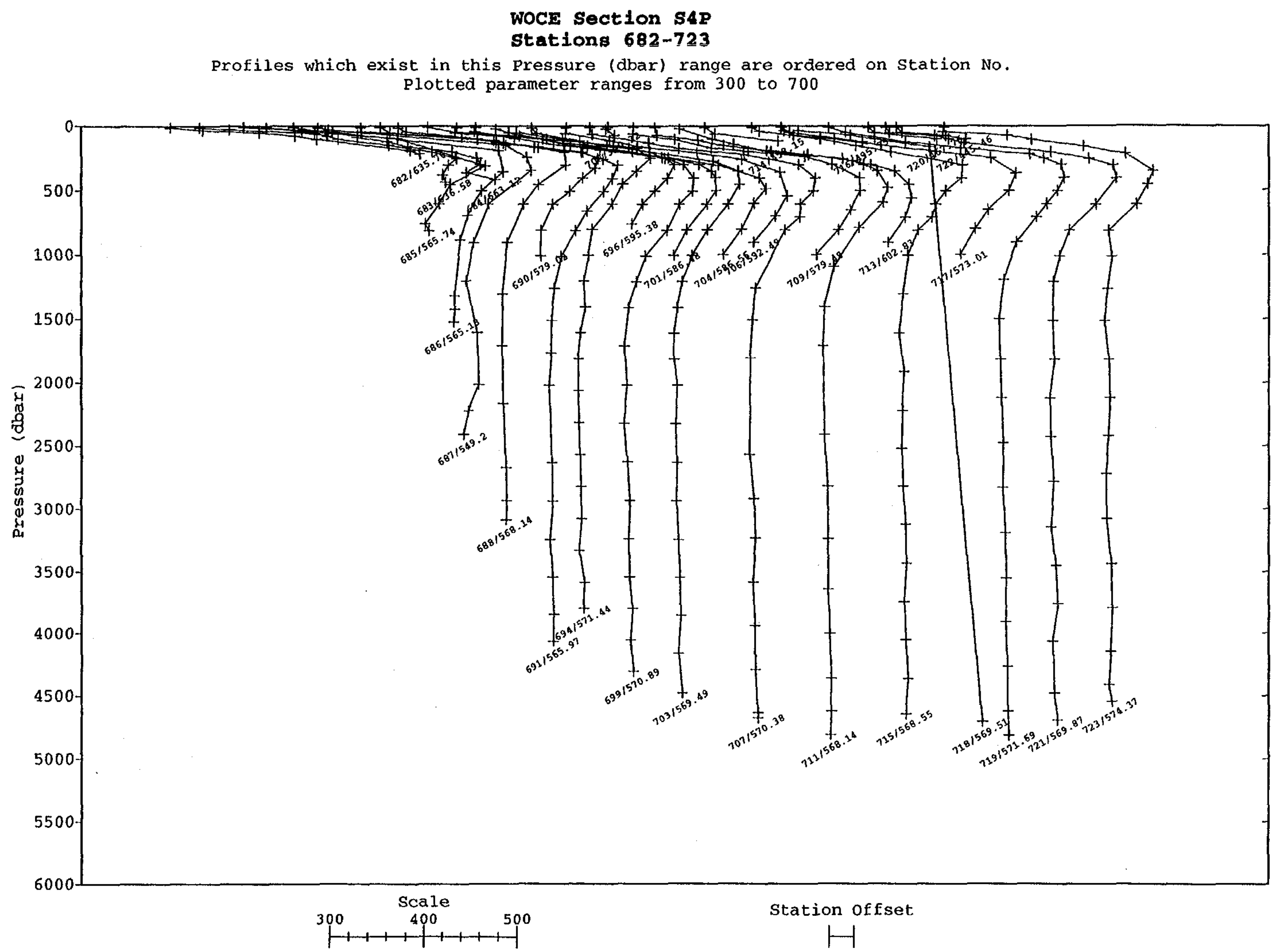

Figure 7. Nested profiles: partial pressure of CO_2 at 4.0°C (μatm) vs pressure (dbar) for stations 682–723.

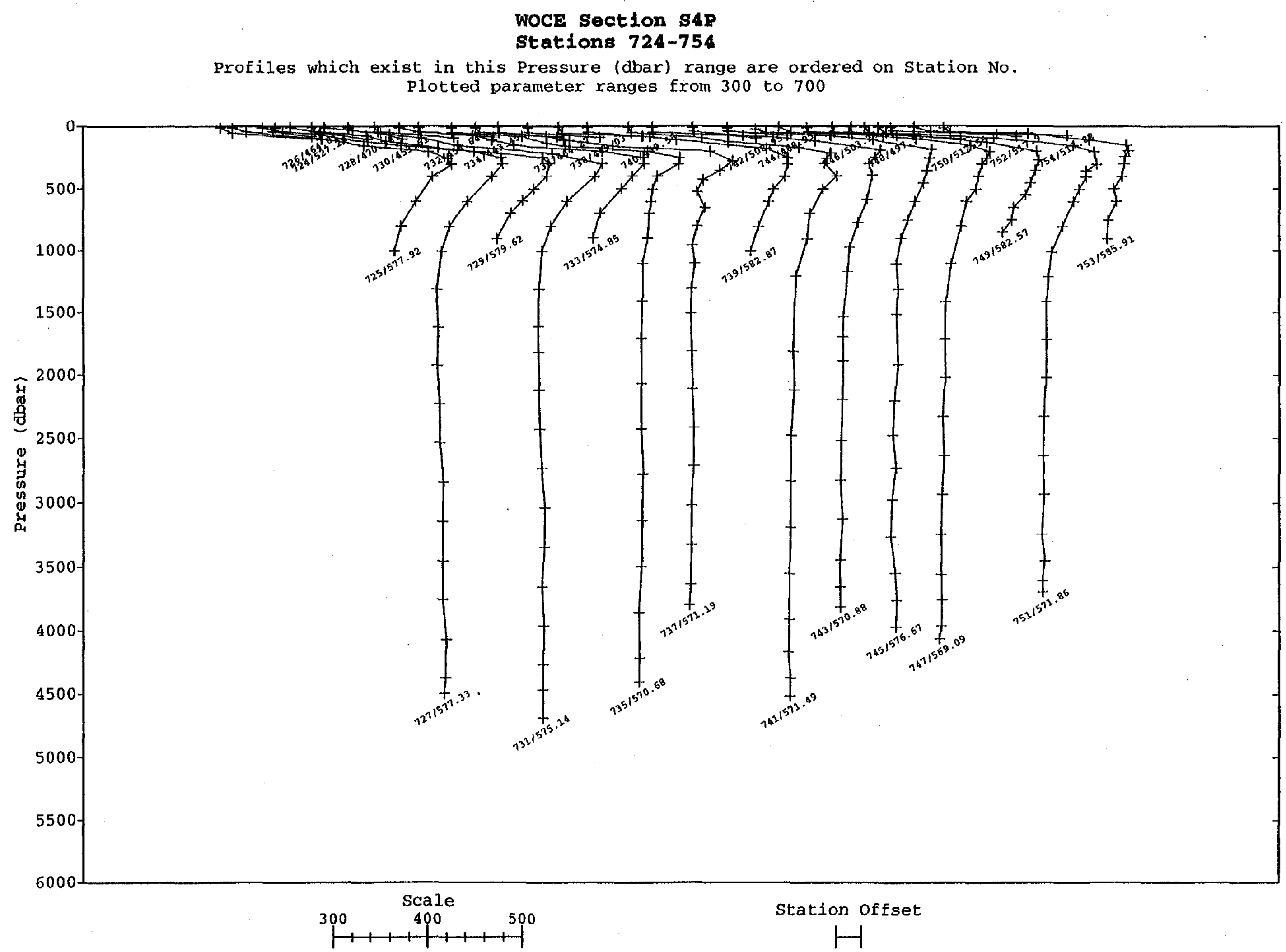

Figure 8. Nested profiles: partial pressure of CO_2 at 4.0°C (μatm) vs pressure (dbar) for stations 724–754.

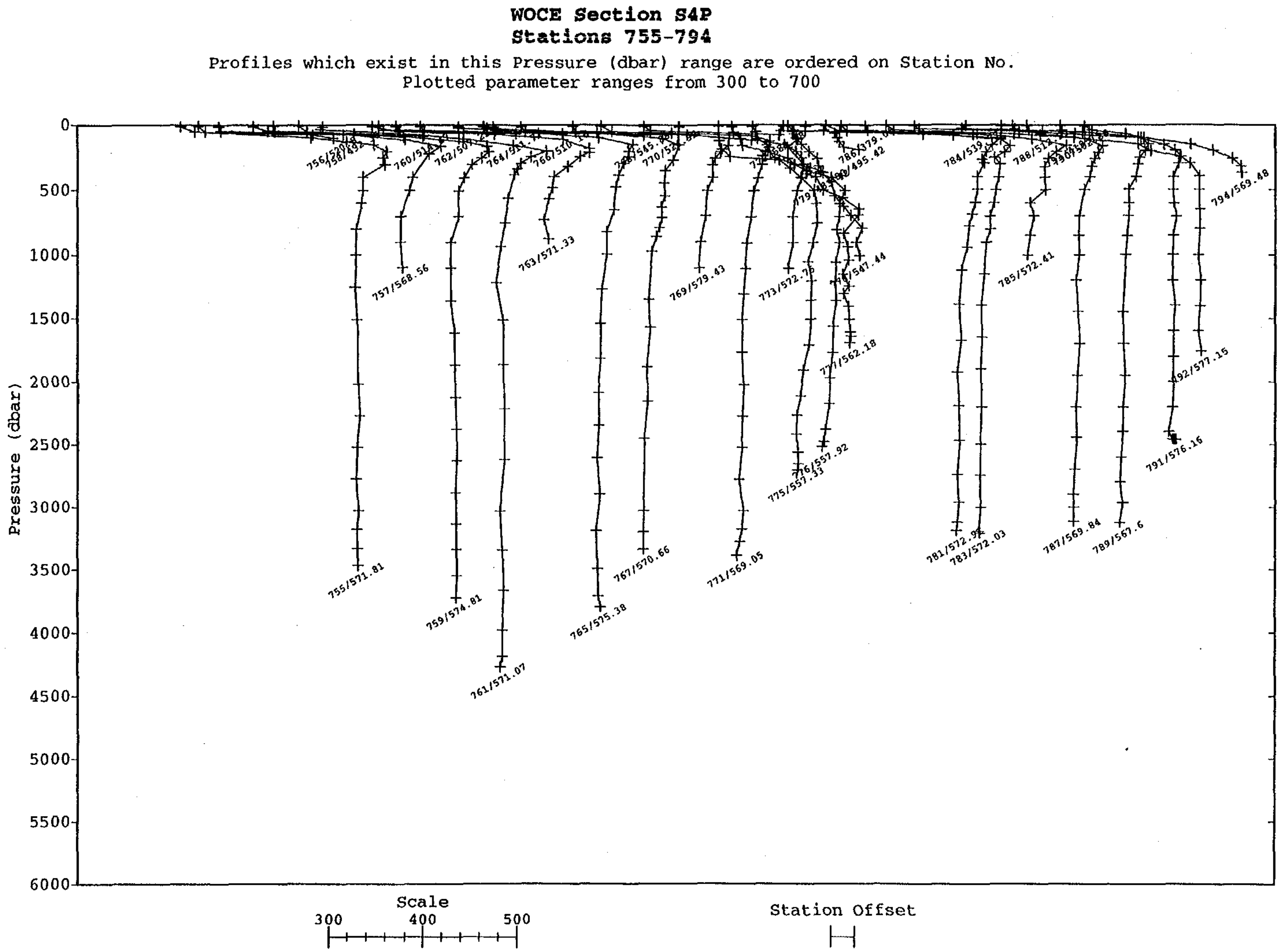

Figure 9. Nested profiles: partial pressure of CO_2 at 4.0°C (μatm) vs pressure (dbar) for stations 755–794.

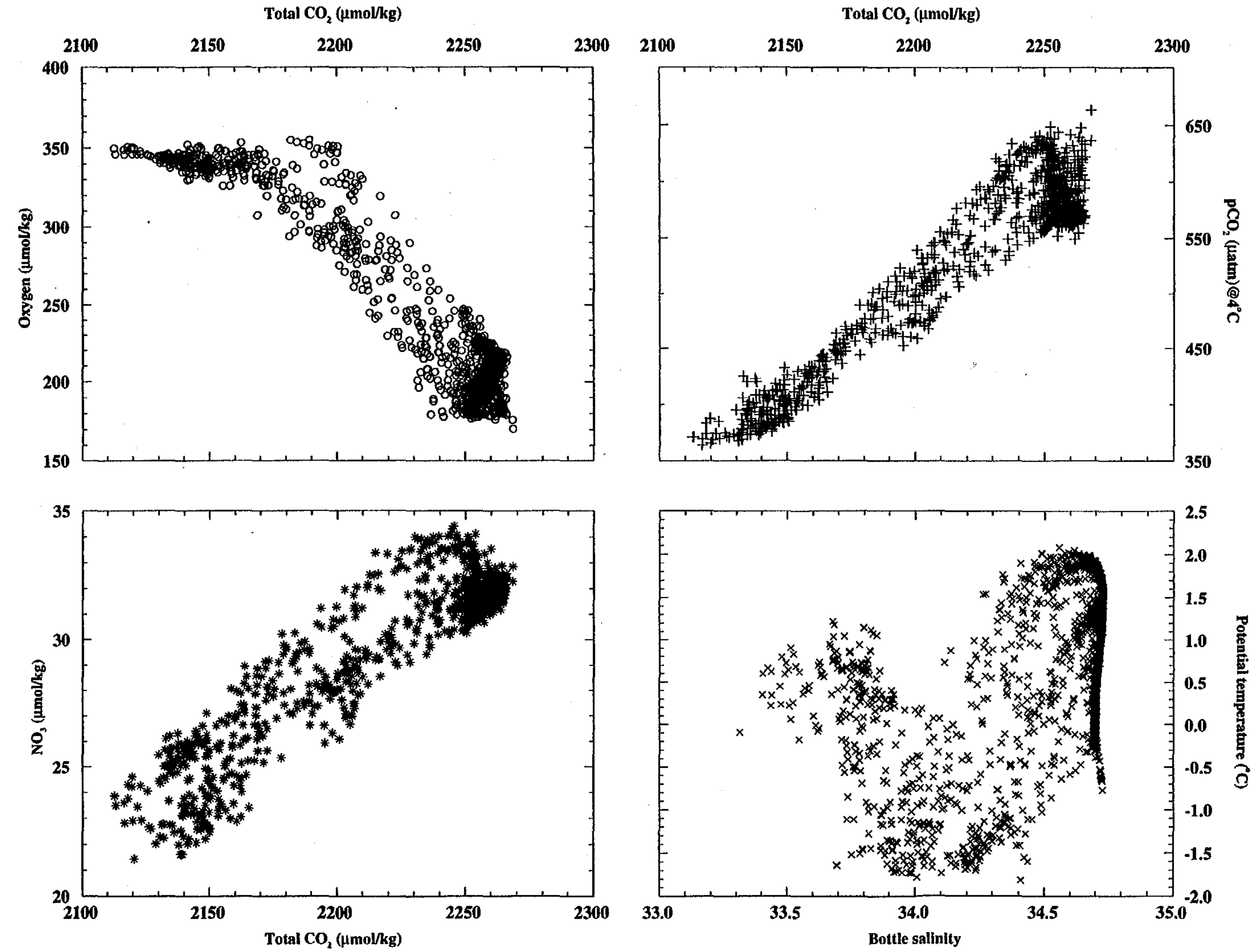

Figure 10. Select property-property plots for all stations occupied during R/V *Akademik Ioffe* Cruise along WOCE Section S4P.

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, 0.25-in. tape cartridge; MAC- or IBM-formatted floppy diskettes; or from CDIAC's anonymous file transfer protocol (FTP) area via the Internet (see FTP address below). Requests should include any specific media instructions required by the user to access the data (e.g., 1600 or 6250 BPI, labeled or nonlabeled, ASCII or EBCDIC characters, and variable- or fixed-length records; 3.5- or 5.25-in. floppy diskettes, high or low density; and 8200 or 8500 format, 8-mm tape). Magnetic tape requests not accompanied by specific instructions will be filled on 9-track, 6250-BPI, nonlabeled tapes with ASCII characters. Requests should be addressed to

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
P.O. 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 may also be acquired from CDIAC's anonymous FTP area via the Internet:

- 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/ndp063," and
- acquire the files using the FTP "get" or "mget" command.

As an alternative, one can access the following World Wide Web URL
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 revisions and updates.

6. REFERENCES

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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 five files that make up this NDP (see Table 1). Because CDIAC distributes the data set in several ways (e.g., via anonymous FTP, on floppy diskette, and on 9-track magnetic tape), each of the five files is referenced by both an ASCII file name, which is given in lowercase, boldfaced type (e.g., **ndp063.doc**), and a file number. The remainder of this section describes (or lists, where appropriate) the contents of each file. 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. **ndp063.doc**: a detailed description of the cruise network, the two FORTRAN 77 data-retrieval routines, and the two oceanographic data files	836	42,114	8,000	80
2. **stainv.for**: a FORTRAN 77 data-retrieval routine to read and print **s4psta.inv** (File 4)	43	1,335	8,000	80
3. **s4pdat.for:** a FORTRAN 77 data-retrieval routine to read and print **s4p.dat** (File 5)	51	2,067	8,000	80
4. **s4psta.inv**: a listing of the station locations, sampling dates, and sounding bottom depths for each of the 113 stations	123	9,132	4,100	41
5. **s4p.dat:** hydrographic, carbon dioxide, and chemical data from 113 stations	2,599	428,122	8,000	80
Total	3,652	482,770		

ndp063.doc (File 1)

This file contains a detailed description of the data set, the two FORTRAN 77 data retrieval routines, and the two 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 **s4psta.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 **s4psta.inv**.

```
c*****************************************************************
c* This is a Fortran retrieval code to read and print the
c* station inventory R/V Akademik Ioffe Cruise, WOCE S4P Line
c*****************************************************************

c*Defines variables*

       INTEGER  stat, cast, depth
       REAL latdcm, londcm
       CHARACTER expo*12, sect*3, date*6, time*4
       OPEN (unit=1, file='s4psta.inv')
       OPEN (unit=2, file='s4pstat.inv')
       write (2, 5)

c*Writes out column labels and sets up a loop to read and format all
c*data in the file*

 5     format (3X, 'STATION INVENTORY: R/V AKADEMIK IOFFE',/,
     1 4X,'EXPOCODE',1X,'SECT',1X,'STNBR',2X,'CAST',
     2 5X,'DATE',2X,'TIME',3X,'LATITUDE',3X,'LONGITUDE',2X,
     3 '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 (A12, 2X, A3, 3X, I3, 5X, I1, 3X, A6, 2X, A4, 4X,
     1 F7.3, 4X, F8.3, 3X, I4)

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

 20    format (A12, 2X, A3, 3X, I3, 5X, I1, 3X, A6, 2X, A4, 4X,
     1 F7.3, 4X, F8.3, 3X, I4)

       GOTO 7
 999   close(unit=5)
       close(unit=2)
       stop
       end
```

s4pdat.for (File 3)

This file contains a FORTRAN 77 data-retrieval routine to read and print **s4p.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 **s4p.dat**.

```
c*****************************************************************
c* FORTRAN 77 data retrieval routine to read and print the
c* file named "s4p.dat" (File 5).
c*****************************************************************
      CHARACTER qualt*11
      INTEGER sta, cast, samp, bot
      REAL pre, ctdtmp, ctdsal, ctdoxy, theta, sal, oxy, silca
      REAL nitrat, nitrit, phspht, tcarb, pco2, pco2tmp
      OPEN (unit=1, file='s4p.dat')
      OPEN (unit=2, file='s4p.data')
      write (2, 5)

c*Writes out column labels*

 5    format (2X,'STNNBR',2X,'CASTNO',2X,'SAMPNO',2X,'BTLNBR',2X,
     1 'CTDPRS',4X,'CTDTMP',4X,'CTDSAL',2X,'CTDOXY',5X,'THETA',4X,
     2 'SALNTY',2X,'OXYGEN',2X,'SILCAT',2X,'NITRAT',2X,'NITRIT',2X,
     3 'PHSPHT',2X,'TCARBN',4X,'PCO2',1X,'PCO2TMP', 6X,'QUALT1',/,
     5 36X,'DBAR',4X,'ITS-90',4X,'PSS-78',1X,'UMOL/KG',4X,'ITS-90',
     6 4X,'PSS-78',1X,6('UMOL/KG',1X,),3X,'UATM',3X,'DEG C',
     7 11X,'*',/,25X,'*******',21X,2('*******',1X,),
     8 12X,8('*******',1X,),18X,'*',)

c*Sets up a loop to read and format all the data in the file*

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

 7    CONTINUE
      read (1, 10, end=999) sta, cast, samp, bot, pre, ctdtmp,
     1 ctdsal, ctdoxy, theta, sal, oxy, silca, nitrat, nitrit,
     2 phspht, tcarb, pco2, pco2tmp, qualt

 10   format (5X, I3, 7X, I1, 6X, I2, 6X, I2, 1X, F7.1, 1X, F9.4,
     1 1X, F9.4, 1X, F7.2, 1X, F9.4, 1X, F9.4, 1X, F7.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.1, 1X, F7.2, 1X, F7.2,
     3 1X, A11)

      write (2, 20) sta, cast, samp, bot, pre, ctdtmp,
     1 ctdsal, ctdoxy, theta, sal, oxy, silca, nitrat, nitrit,
     2 phspht, tcarb, pco2, pco2tmp, qualt

 20   format (5X, I3, 7X, I1, 6X, I2, 6X, I2, 1X, F7.1, 1X, F9.4,
     1 1X, F9.4, 1X, F7.2, 1X, F9.4, 1X, F9.4, 1X, F7.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.1, 1X, F7.2, 1X, F7.2,
     3 1X, A11)

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

s4psta.inv (File 4)

This file provides station inventory information for each of the 113 stations occupied during the R/V *Akademik Ioffe* Expedition along the WOCE Section S4P. Each record of the file contains an expocode, section number, station number, cast, sampling date, sampling time, coordinates, 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
      REAL latdcm, londcm
      CHARACTER expo*12, sect*3, date*6, time*4

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

 10   format (A12, 2X, A3, 3X, I3, 5X, I1, 3X, A6, 2X, A4, 4X,
     1 F7.3, 4X, F8.3, 3X, I4)
```

Stated in tabular form, the contents include the following:

Variable	Variable type	Variable width	Starting column	Ending column
expo	Character	12	1	12
sect	Character	3	15	17
stat	Numeric	3	21	23
cast	Numeric	1	29	29
date	Character	6	33	38
time	Character	4	41	44
latdcm	Numeric	7	49	55
londcm	Numeric	8	60	67
depth	Numeric	4	71	74

where

expo is the expocode of the cruise (always RUKDIOFFE6/1);

sect is the WOCE section number (always S4P);

stat is the station number (values range from 682 to 795);

cast is the cast number;

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

time is the sampling time (Greenwich mean time);

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).

s4p.dat (File 5)

This file provides hydrographic, CO_2, and chemical data for the 113 stations occupied during the R/V *Akademik Ioffe* Expedition along the WOCE Section S4P. Each record contains a station number; cast number; sample number; bottle number; CTD pressure, temperature, salinity, and oxygen; potential temperature; bottle salinity; concentrations of oxygen, silicate, nitrate, nitrite, phosphate, and TCO_2; pCO_2; pCO_2 temperature; 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 **s4pdat.for,** File 3):

```
      CHARACTER qualt*11
      INTEGER sta, cast, samp, bot
      REAL pre, ctdtmp, ctdsal, ctdoxy, theta, sal, oxy, silca
      REAL nitrat, nitrit, phspht, tcarb, pco2, pco2tmp

      read (1, 10, end=999) sta, cast, samp, bot, pre, ctdtmp,
     1 ctdsal, ctdoxy, theta, sal, oxy, silca, nitrat, nitrit,
     2 phspht, tcarb, pco2, pco2tmp, qualt

10    format (5X, I3, 7X, I1, 6X, I2, 6X, I2, 1X, F7.1, 1X, F9.4,
     1 1X, F9.4, 1X, F7.2, 1X, F9.4, 1X, F9.4, 1X, F7.1, 1X, F7.2,
     2 1X, F7.2, 1X, F7.2, 1X, F7.2, 1X, F7.1, 1X, F7.2, 1X, F7.2,
     3 1X, A11)
```

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	Numeric	2	31	32
pre	Numeric	7	35	40
ctdtmp	Numeric	9	42	50
ctdsal	Numeric	9	52	60

ctdoxy	Numeric	7	62	68
theta	Numeric	9	70	78
sal	Numeric	9	80	88
oxy	Numeric	7	90	96
silca	Numeric	7	98	104
nitrat	Numeric	7	106	112
nitrit	Numeric	7	114	120
phspht	Numeric	7	122	128
tcarb	Numeric	7	130	136
pco2	Numeric	7	138	144
pco2tmp	Numeric	7	146	152
qualt	Character	11	154	164

where

sta is the station number;

cast is the cast number;

samp is the sample number;

bot[a] is the bottle number;

pre is the CTD pressure (in dbar);

ctdtmp is the CTD temperature (in °C);

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

ctdoxy[a] is the CTD oxygen concentration (in μmol/kg);

theta is the potential temperature (in °C);

sal[a] is the bottle salinity (PSS);

oxy[a] is the bottle oxygen concentration (in μmol/kg);

silca[a] is the silicate concentration (in μmol/kg);

nitrat[a] is the nitrate concentration (in μmol/kg);

nitrit[a] is the nitrite concentration (in μmol/kg);

phspht[a] is the phosphate concentration (in μmol/kg);

tcarb[a] is the total carbon dioxide concentration (in μmol/kg);

pco2[a] is the partial pressure of CO_2 (in μatm and measured at **pco2tmp**);

pco2tmp is the temperature of equilibration of the pCO_2 samples in the equilibrator (in °C);

qualt is an 11-digit character that contains the data-quality flag codes for each of the eleven parameters underlined with asterisks (*) in the output file.

---

[a]Variables that are underlined with asterisks in the data file to indicate they have a data-quality flag. Data-quality flags are defined as follows:

1 = sample for this measurement was drawn from water bottle but results of analyses were 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 was not drawn for this measurement from this bottle.

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 and 3. Each of these tables contains the first and last five lines of a data file.

Table 2. Partial listing of "s4psta.inv" (File 4)

First five lines of the file:

RUKDIOFFE6/1	S4P	682	1	022292	2033	-67.468	-70.089	236
RUKDIOFFE6/1	S4P	683	1	022292	2344	-67.166	-71.121	453
RUKDIOFFE6/1	S4P	684	1	022392	1054	-66.895	-71.998	445
RUKDIOFFE6/1	S4P	685	1	022392	1912	-66.814	-72.261	831
RUKDIOFFE6/1	S4P	686	1	022392	2206	-66.782	-72.264	1571

Last five lines of the file:

RUKDIOFFE6/1	S4P	790	1	032992	0022	-66.022	164.803	2814
RUKDIOFFE6/1	S4P	791	1	032992	0715	-66.250	163.724	2489
RUKDIOFFE6/1	S4P	792	1	032992	1407	-66.395	162.897	1680
RUKDIOFFE6/1	S4P	793	1	032992	2022	-66.400	162.742	-999
RUKDIOFFE6/1	S4P	794	1	032992	2327	-66.419	162.686	421

Table 3. Partial listing of "s4p.dat" (File 5)

First five lines of the file:

```
   682        1       8        8    13.2    -0.0900   33.3128  331.30    -0.0904   33.3142    349.8    63.40    21.43
 0.15    1.55   2120.5  369.04     3.99 22222222222
   682        1       7        7    33.4    -0.0080   33.6090  307.80    -0.0092   33.6110    336.9    62.31    23.28
 0.13    1.69   2147.1  403.93     3.99 22222222222
   682        1       6        6    53.2    -1.1119   33.7673  308.60    -1.1132   33.7587    307.3    71.89    25.63
 0.19    1.86   2169.1  464.16     3.99 22222222222
   682        1       5        5    78.7    -1.4715   33.9073  289.00    -1.4732   33.9139    298.6    74.23    27.38
 0.23    1.94   2192.7  502.15     3.99 22222222222
   682        1       4        4   103.2    -1.5324   34.0166  288.20    -1.5347   34.0250    289.8    77.06    28.65
 0.09    1.99   2202.6  526.22     3.99 22222222222
```

Last five lines of the file:

```
   794        1       29      29   196.2    -0.6962   34.4879  254.00    -0.7023   34.4859    261.4    87.12    30.28
 0.13    2.18   2231.0  539.07     4.00 22222222222
   794        1       28      28   260.7    -0.0390   34.5701  233.90    -0.0487   34.5663    237.8    92.21    30.85
 0.07    2.21   2238.9  559.08     4.00 22222222222
   794        1       3        3   318.3     0.3007   34.6158  224.70     0.2879   34.6136    224.3    96.24    30.96
 0.02    2.23   2246.2  568.23     4.00 22222222222
   794        1       2        2   364.6     0.3113   34.6166  223.90     0.2964 -999.9000   -999.9  -999.90  -999.90
-999.90 -999.90   -999.9 -999.90 -999.90 22299999999
   794        1       1        1   368.7     0.3141   34.6166  224.60     0.2990   34.6155    223.7    96.23    31.12
 0.02    2.24   2244.3  569.48     4.00 22222222222
```

APPENDIX A:

STATION INVENTORY

APPENDIX A:
STATION INVENTORY

This appendix lists station inventory information for the 113 stations occupied during the R/V *Akademik Ioffe* Expedition in the South Pacific Ocean (WOCE Section S4P). 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;

STNBR is the station number;

CAST is the cast number;

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

TIME is the sampling time (Greenwich mean time);

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); and

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

Table A.1 Station inventory information for the 113 sites occupied during R/V *Akademik Ioffe* Expedition in the South Pacific Ocean (WOCE Section S4P)

EXPOCODE	SECT	STNBR	CAST	DATE	TIME	LATITUDE	LONGITUDE	DEPTH
RUKDIOFFE6/1	S4P	682	1	022292	2033	-67.468	-70.089	236
RUKDIOFFE6/1	S4P	683	1	022292	2344	-67.166	-71.121	453
RUKDIOFFE6/1	S4P	684	1	022392	1054	-66.895	-71.998	445
RUKDIOFFE6/1	S4P	685	1	022392	1912	-66.814	-72.261	831
RUKDIOFFE6/1	S4P	686	1	022392	2206	-66.782	-72.264	1571
RUKDIOFFE6/1	S4P	687	2	022492	0247	-66.732	-72.238	2430
RUKDIOFFE6/1	S4P	688	1	022492	0711	-66.685	-72.265	3098
RUKDIOFFE6/1	S4P	689	1	022492	1225	-66.503	-73.243	3748
RUKDIOFFE6/1	S4P	690	1	022492	1713	-66.270	-73.996	3932
RUKDIOFFE6/1	S4P	691	1	022492	2241	-65.906	-75.013	4037
RUKDIOFFE6/1	S4P	692	1	022592	0336	-66.284	-75.661	3685
RUKDIOFFE6/1	S4P	693	1	022592	0821	-66.633	-76.405	3381
RUKDIOFFE6/1	S4P	694	1	022592	1319	-67.006	-77.029	3755
RUKDIOFFE6/1	S4P	695	1	022692	0244	-66.999	-78.313	3906
RUKDIOFFE6/1	S4P	696	1	022692	0810	-67.009	-79.607	4048
RUKDIOFFE6/1	S4P	697	1	022692	1329	-66.981	-80.864	4208
RUKDIOFFE6/1	S4P	698	1	022692	1908	-66.998	-82.233	4262
RUKDIOFFE6/1	S4P	699	1	022792	0014	-66.997	-83.437	4273
RUKDIOFFE6/1	S4P	700	1	022792	0544	-67.010	-84.704	4367
RUKDIOFFE6/1	S4P	701	1	022792	1224	-67.013	-85.882	4339
RUKDIOFFE6/1	S4P	702	2	022892	0405	-66.991	-87.291	4444
RUKDIOFFE6/1	S4P	703	1	022892	1416	-67.001	-88.534	4437
RUKDIOFFE6/1	S4P	704	1	022992	0107	-67.005	-89.787	4423
RUKDIOFFE6/1	S4P	705	1	022992	0806	-67.026	-91.486	4663
RUKDIOFFE6/1	S4P	706	1	022992	1559	-67.036	-93.211	4640
RUKDIOFFE6/1	S4P	707	1	030192	0518	-66.993	-94.919	4617
RUKDIOFFE6/1	S4P	708	1	030192	1410	-67.034	-96.702	4697
RUKDIOFFE6/1	S4P	709	1	030292	0131	-67.010	-98.365	4666
RUKDIOFFE6/1	S4P	710	1	030292	1011	-66.987	-99.980	4718
RUKDIOFFE6/1	S4P	711	1	030292	1744	-66.989	-101.839	4744
RUKDIOFFE6/1	S4P	712	1	030392	0048	-66.996	-103.453	4740
RUKDIOFFE6/1	S4P	713	1	030392	0804	-66.986	-105.168	4725
RUKDIOFFE6/1	S4P	714	1	030392	1529	-67.018	-106.856	4212
RUKDIOFFE6/1	S4P	715	1	030492	0148	-67.007	-108.546	4589
RUKDIOFFE6/1	S4P	716	1	030492	0819	-67.003	-110.248	4388
RUKDIOFFE6/1	S4P	717	1	030492	1524	-66.989	-111.907	4623
RUKDIOFFE6/1	S4P	718	1	030492	2203	-67.007	-113.638	4644
RUKDIOFFE6/1	S4P	719	1	030592	0455	-67.000	-115.366	4751
RUKDIOFFE6/1	S4P	720	1	030592	1233	-67.006	-117.085	4548
RUKDIOFFE6/1	S4P	721	1	030692	0035	-66.996	-118.767	4634
RUKDIOFFE6/1	S4P	722	1	030692	0752	-67.002	-120.460	4555
RUKDIOFFE6/1	S4P	723	1	030692	1516	-67.008	-122.177	4501
RUKDIOFFE6/1	S4P	724	1	030692	2217	-66.985	-123.836	4407
RUKDIOFFE6/1	S4P	725	1	030792	0441	-67.007	-125.579	4395
RUKDIOFFE6/1	S4P	726	1	030792	1342	-66.982	-127.236	4465
RUKDIOFFE6/1	S4P	727	1	030892	0008	-66.998	-128.972	4452
RUKDIOFFE6/1	S4P	728	1	030892	0629	-66.996	-130.678	4493
RUKDIOFFE6/1	S4P	729	1	030892	1348	-66.997	-131.961	4589
RUKDIOFFE6/1	S4P	730	1	030892	2018	-67.001	-133.224	4636
RUKDIOFFE6/1	S4P	731	1	030992	0215	-67.000	-134.508	4640
RUKDIOFFE6/1	S4P	732	1	030992	0920	-67.000	-135.834	4661
RUKDIOFFE6/1	S4P	733	1	030992	1705	-66.991	-137.137	4551
RUKDIOFFE6/1	S4P	734	1	031092	0252	-67.007	-138.398	4460
RUKDIOFFE6/1	S4P	735	1	031092	0925	-67.007	-139.654	4360
RUKDIOFFE6/1	S4P	736	1	031092	1556	-66.991	-140.951	4175
RUKDIOFFE6/1	S4P	737	1	031092	2201	-67.005	-142.195	3788
RUKDIOFFE6/1	S4P	738	1	031192	0510	-67.002	-143.889	4421
RUKDIOFFE6/1	S4P	739	1	031192	1410	-66.988	-145.615	4218
RUKDIOFFE6/1	S4P	740	1	031292	0105	-67.007	-147.483	4457
RUKDIOFFE6/1	S4P	741	1	031292	0850	-67.012	-149.212	4470
RUKDIOFFE6/1	S4P	742	1	031292	1718	-66.978	-150.964	4386
RUKDIOFFE6/1	S4P	743	1	031392	0013	-66.994	-152.548	3734

Table A.1 (continued)

RUKDIOFFE6/1	S4P	744	1	031392	0738	-66.967	-154.328	4251
RUKDIOFFE6/1	S4P	745	1	031392	1628	-67.026	-156.084	3902
RUKDIOFFE6/1	S4P	746	1	031492	1835	-66.954	-157.694	3914
RUKDIOFFE6/1	S4P	747	1	031592	0455	-66.984	-158.979	4005
RUKDIOFFE6/1	S4P	748	1	031592	1059	-66.983	-160.290	4172
RUKDIOFFE6/1	S4P	749	1	031592	1800	-66.972	-161.541	3410
RUKDIOFFE6/1	S4P	750	1	031692	0006	-66.996	-162.775	3812
RUKDIOFFE6/1	S4P	751	1	031692	0615	-67.010	-164.082	3689
RUKDIOFFE6/1	S4P	752	1	031692	1246	-67.010	-165.340	3748
RUKDIOFFE6/1	S4P	753	1	031692	1900	-67.012	-166.595	3722
RUKDIOFFE6/1	S4P	754	1	031792	0440	-66.993	-167.907	3427
RUKDIOFFE6/1	S4P	755	1	031792	1029	-67.024	-169.250	3463
RUKDIOFFE6/1	S4P	756	1	031792	1809	-66.998	-170.577	3458
RUKDIOFFE6/1	S4P	757	1	031892	0003	-67.003	-171.861	4264
RUKDIOFFE6/1	S4P	758	1	031892	0549	-67.005	-173.124	3468
RUKDIOFFE6/1	S4P	759	1	031892	1134	-66.992	-174.397	3804
RUKDIOFFE6/1	S4P	760	1	031892	1809	-66.973	-175.628	2831
RUKDIOFFE6/1	S4P	761	1	031992	0443	-66.984	-176.913	4227
RUKDIOFFE6/1	S4P	762	1	031992	1102	-66.975	-178.163	4113
RUKDIOFFE6/1	S4P	763	1	031992	1836	-66.983	-179.427	3748
RUKDIOFFE6/1	S4P	764	1	032092	0052	-67.037	179.231	3747
RUKDIOFFE6/1	S4P	765	1	032092	0652	-67.027	177.870	3763
RUKDIOFFE6/1	S4P	766	1	032092	1335	-67.025	176.673	3550
RUKDIOFFE6/1	S4P	767	1	032092	2022	-67.035	175.385	3302
RUKDIOFFE6/1	S4P	768	1	032192	0206	-67.049	174.319	3179
RUKDIOFFE6/1	S4P	769	1	032192	0824	-67.469	173.573	3319
RUKDIOFFE6/1	S4P	770	1	032192	1406	-67.895	172.914	3364
RUKDIOFFE6/1	S4P	771	1	032192	1939	-68.295	172.093	3382
RUKDIOFFE6/1	S4P	772	1	032292	0413	-68.703	171.441	3312
RUKDIOFFE6/1	S4P	773	1	032292	0917	-69.138	170.768	2800
RUKDIOFFE6/1	S4P	774	1	032292	1450	-69.582	169.977	2816
RUKDIOFFE6/1	S4P	775	1	032292	1944	-69.933	169.344	2731
RUKDIOFFE6/1	S4P	776	1	032392	0246	-70.172	168.915	2544
RUKDIOFFE6/1	S4P	777	1	032392	1031	-70.411	168.496	1722
RUKDIOFFE6/1	S4P	778	1	032392	1615	-70.451	168.414	1058
RUKDIOFFE6/1	S4P	779	1	032392	1935	-70.493	168.308	386
RUKDIOFFE6/1	S4P	780	1	032392	2241	-70.648	168.066	209
RUKDIOFFE6/1	S4P	781	1	032592	1851	-67.004	174.225	3205
RUKDIOFFE6/1	S4P	782	1	032692	0401	-66.714	173.177	3234
RUKDIOFFE6/1	S4P	783	1	032692	0947	-66.450	172.113	3229
RUKDIOFFE6/1	S4P	784	1	032692	1535	-66.162	171.048	3215
RUKDIOFFE6/1	S4P	785	1	032692	2111	-65.880	169.988	3210
RUKDIOFFE6/1	S4P	786	1	032792	0310	-65.590	168.979	3285
RUKDIOFFE6/1	S4P	787	1	032792	0851	-65.327	167.987	3164
RUKDIOFFE6/1	S4P	788	1	032792	2300	-65.483	166.903	3310
RUKDIOFFE6/1	S4P	789	1	032892	1838	-65.771	165.883	3084
RUKDIOFFE6/1	S4P	790	1	032992	0022	-66.022	164.803	2814
RUKDIOFFE6/1	S4P	791	1	032992	0715	-66.250	163.724	2489
RUKDIOFFE6/1	S4P	792	1	032992	1407	-66.395	162.897	1680
RUKDIOFFE6/1	S4P	793	1	032992	2022	-66.400	162.742	-999
RUKDIOFFE6/1	S4P	794	1	032992	2327	-66.419	162.686	421

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