A.   Cruise Narrative: P17N_2001a

updated: 2004.MAY.19

A.1. Highlights

WHP Cruise Summary Information

WOCE section designation	**P17N_2001a**
Expedition designation (EXPOCODE)	**49NZ200107_1**
Chief Scientist/affiliation	**Masao Fukasawa/JAMSTEC**
Dates	2001.JUL.25 - 2001.AUG.28
Ship	*R/V Mirai*
Ports of call	Sekinehama, Japan to Dutch Harbor, U.S.
Number of stations	78
Geographic boundaries of the stations	54° 37.27' N 142° 46.08' E 134° 58.6' W 30° 0.01' N
Floats and drifters deployed	0
Moorings deployed or recovered	0
Contributing Authors	none listed

Masao Fukasawa

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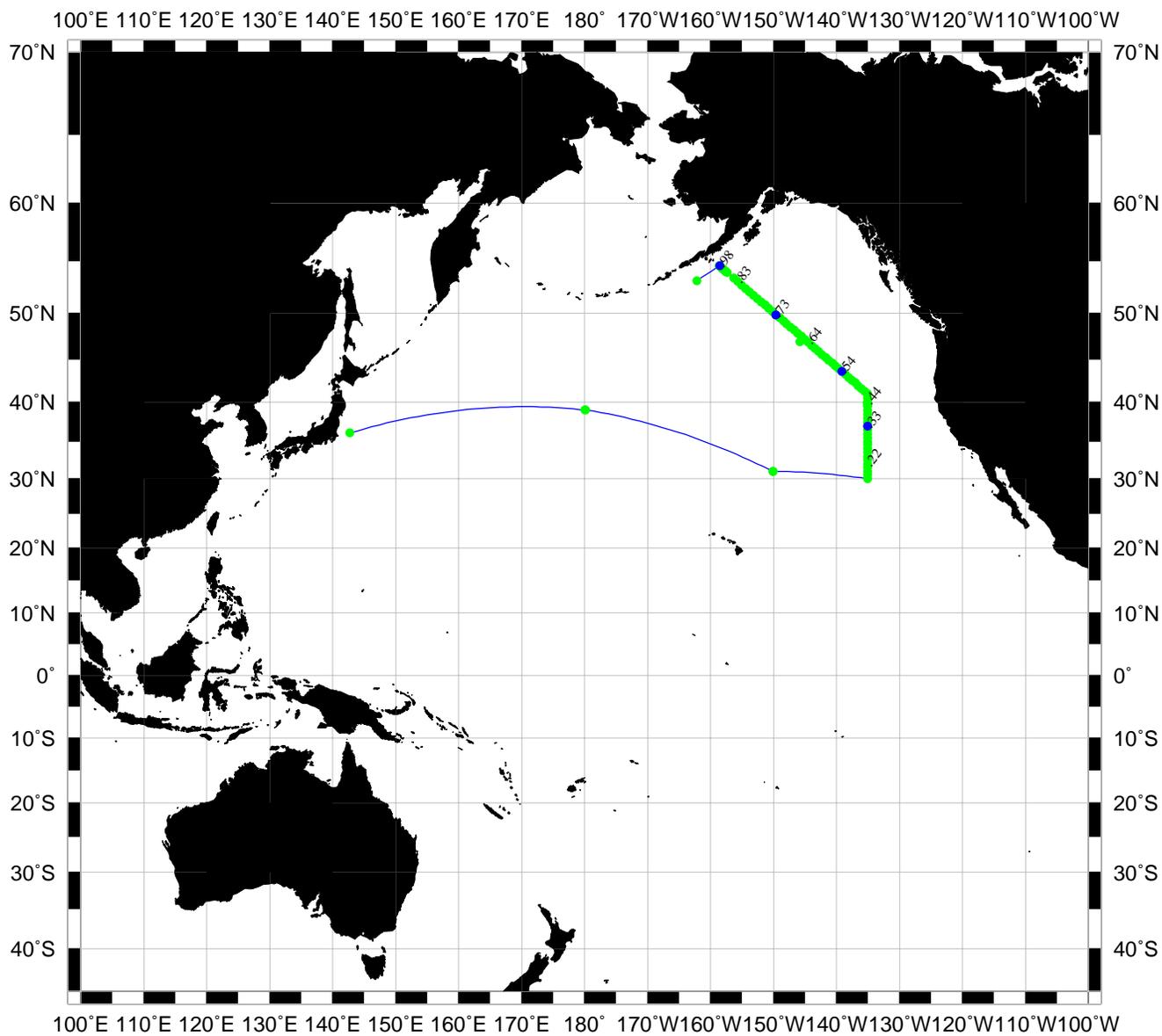Phone: +81-468-67-9470 • FAX: +81-468-67-9455 • Email: fksw@jamstec.go.jp

WHP Cruise and Data Information

Click on headings below to locate primary reference or use navigation tools above.
(Shaded headings were not available when this report was assembled)

Cruise Summary Information	Hydrographic Measurements		
Description of scientific program	**CTD Data**		
	General		
Geographic boundaries		Calibration	
Cruise track PI SIO	Pressure	Pre-Cruise	Post Cruise
Description of stations	Temperature	Pre-Cruise	Post Cruise
Description of parameters sampled	Conductivity/salinity	Pre-Cruise	Post Cruise
Bottle depth distributions (figure)	Oxygen	Pre-Cruise	Post Cruise
Floats and drifters deployed			
Moorings deployed or recovered	**Bottle Data**		
	Salinity		
Principal Investigators	Oxygen		
Cruise Participants	Nutrients		
	CFCs		
Problems and goals not achieved	Helium		
Other incidents of note	Tritium		
	Radiocarbon		
Underway Data Information	CO2 system parameters		
Navigation	Other parameters		
Bathymetry			
Acoustic Doppler Current Profiler	**DQE Reports**		
Thermosalinograph & Related	CTD		
XBT and/or XCTD	S/O2/nutrients		
Meteorological observations	CFCs		
Atmospheric chemistry data	14C		
Data Processing Notes	**References**		
Acknowledgments	Atmos & Surface P(CO_2)		
	Total Alkalinity		
	Total Carbon		
	pH		
	^{13}C and & ^{14}C		

Station locations for P17N • Fukasawa • 2001

1. Cruise Narrative

1.1 Highlights

WOCE P17N+P17C (eight stations) revisit, *R/V Mirai* cruise in the Gulf of Alaska

1.2 Cruise Summary

Number of stations

A total of 78 CTDO/rosette stations including two training stations. CTDO was equipped with LADCP and Transmission meter. A General Oceanics 36 bottle rosette was equipped with 36 12-liter Niskin-X water sample bottles.

Sampling

The following sample measurements ware made: salinity, oxygen, phosphate, silicate, nitrate, nitrite and CFCs 11, 12 and 113, DIC, pH, alkalinity and delta 14C. CTD salinity and oxygen were also measured.

Overview

The first leg of MR01K04 of *R/V Mirai* was assigned for WHP P17N revisit cruise. The cruise was planned under a Japanese ocean science program of Sub-Arctic Gyre Experiment (SAGE). SAGE re-occupied P1 (47N) in 1999 and reported preliminarily an evidence of bottom water warming, an anomalously strong intrusion of the meso-thermal water into the Gulf of Alaska and large scale up-welling and down-welling at the mid and deeper depths which was explainable as a local response of the ocean to changes in the wind curl field. The objectives of the cruise were, therefore, focused to detect changes in the bottom and deeper water property and in the temperature stratification at sub-surface compared to the results from P17N in 1993. Beside these physical interests, it was also very important objective of the cruise to collect carbon related parameters which were not measured in 1993.

The cruise stared on 25 July 2001 at Sekinehama port in Mutsu (Figure 1). On the way to the southernmost our WHP revisit station, 64 XCTDs were casted by Japan Fisheries Agency. Also before the first WHP station, two CTD+ROSSET station were occupied for the training of participants. Reference sample water were also collected for radio-active species at one of these stations.

The observation along P17N (+8 stations of P17C) started at P17C_#26 at 19:25 on 6 August 2001. A new DO censer, SBE43, was used in this cruise. The performance of the sensor was so good (Figure 2) that the calibration of the sensor using results from bottle DO measurements can be carried out much easier than before.

A new station of P17N_X01 was added between P17N_#64 and #65 (Figure 2) to occupy P1_#92 which is the crossover station of P17N and P1.

On 24 August, we encountered a big low after the station P17N_#83. The wave height exceeded 5m. *R/V Mirai* had to make a heaving there for more than 24 hours. This time loss resulted in the replacement of CTD lowering at P17N_#93, #95 and #97 with XCTD casting.
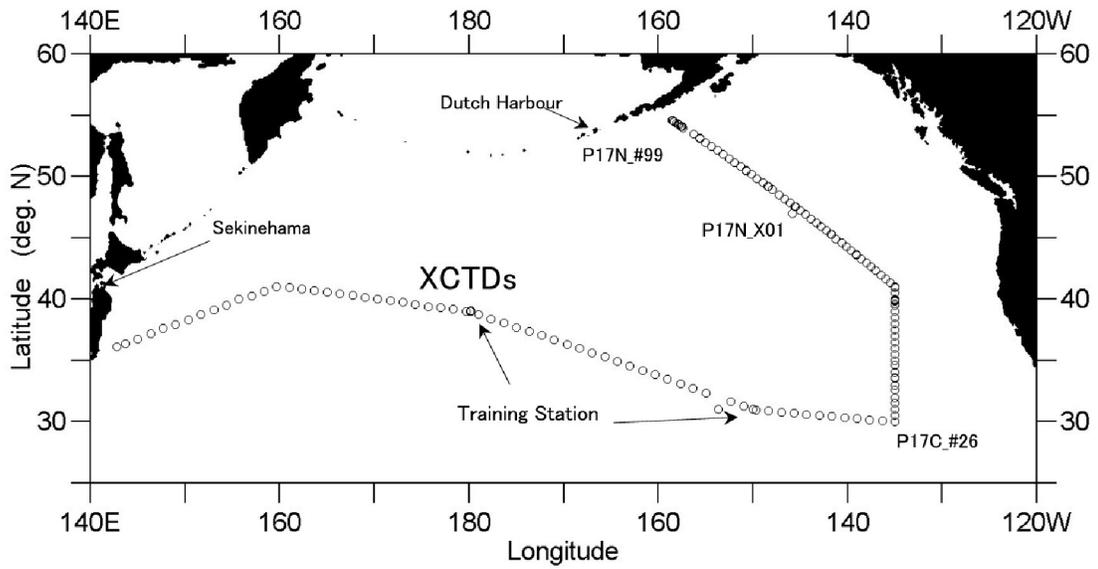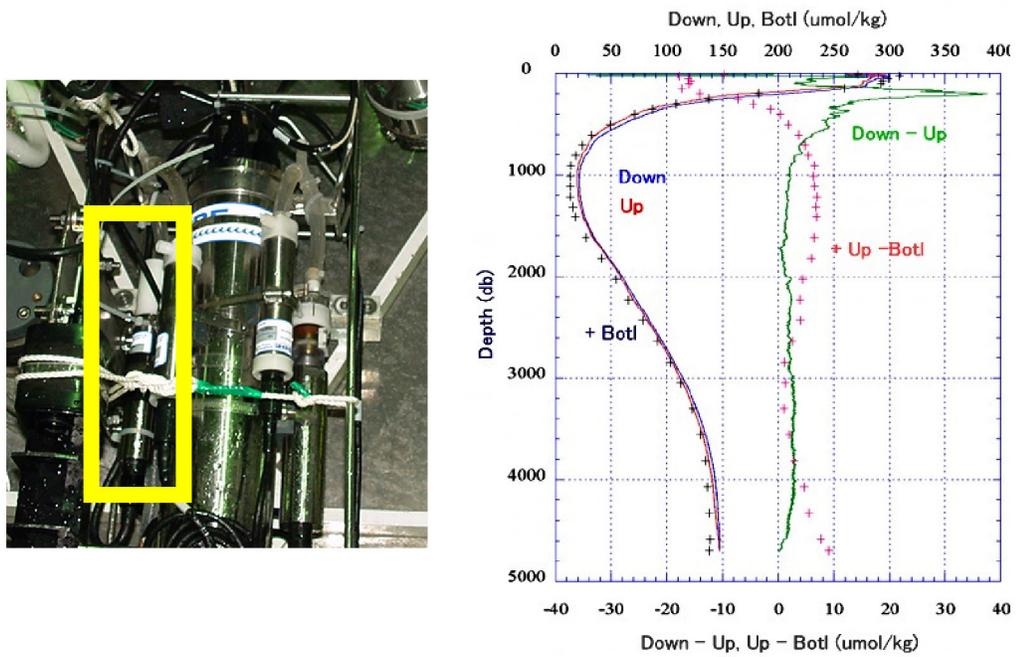
Figure 1: Station locations of MR01K04 Leg1.

Figure 2: left: SBE43, right: Sensor outputs and bottle measured DO values.

1.3 List of Principal Investigators

The principal investigators responsible for the major parameters measured on the cruise are listed below. Also, the persons responsible for the tasks undertaken on the cruise are listed.

Principal investigator(s)	Person in charge	Responsibility
H. Uchida (JAMSTEC)	S. Ozawa (MWJ)	CTD/O2
M. Fukasawa (JAMSTEC)	S. Ozawa (MWJ)	CTD/O2
Y. Yoshikawa (JAMSTEC)	H. Matsunaga(MWJ)	LADCP
T. Kawano (JAMSTEC)	T. Matsumoto (MWJ)	Salinity
M. Fukasawa (JAMSTEC)	N. Komai (MWJ)	Dissolved oxygen
S. Watanabe (JAMSTEC)	K. Satoh (MWJ)	Nutrients
A. Murata (JAMSTEC)	M. Kitada (MWJ)	DIC
A. Murata (JAMSTEC)	F. Shibata (MWJ)	Total alkalinity
S. Andreev (JAMSTEC)	T. Ohama (MWJ)	pH
Y. Kumamoto (JAMSTEC)	A. Murata (JAMSTEC)	delta14C and 13C
S. Watanabe (JAMSTEC)	A. Murata (JAMSTEC)	CFCs
T. Matsumoto (JAMSTEC)	S. Sueyoshi (GODI)	Bathymetry
K. Yoneyama (JAMSTEC)	S. Sueyoshi (GODI)	Meteorology
Y. Yoshikawa (JAMSTEC)	S. Sueyoshi (GODI)	Shipboard ADCP
A. Murata (JAMSTEC)	A. Murata (JAMSTEC)	pCO2
T. Watanabe (TNFRI)	S. Sueyoshi (GODI)	XBT, XCTD
T. Kawano (JAMSTEC)	T. Miyashita (MWJ)	Surface T, S, DO
A. Murata (JAMSTEC)	A. Murata (JAMSTEC)	Surface TCO2

Abbreviations:

JAMSTEC: Japan Marine Science and Technology Center
MWJ: Marine Works Japan, Ltd.
GODI: Global Ocean Development, Inc.
TNFRI: Tohoku National Fisheries Research Institute

1.4 List of Cruise Participants

The members of the scientific party are listed below along with their main tasks undertaken on the cruise.

Name	Affiliation	Main tasks
Masao Fukasawa	JAMSTEC	LADCP
Yasushi Yoshikawa	JAMSTEC	LADCP
Hiroshi Uchida	JAMSTEC	LADCP
Takeshi Kawano	JAMSTEC	Salinity
Akihiko Murata	JAMSTEC	CFCs
Tomowo Watanabe	TNFRI	XBT/XCTD
Munehito Kimura	KANSO	Nutrients
Takashi Kitao	KANSO	TCO2, CFCs
Nobuharu Komai	MWJ	Oxygen
Satoshi Ozawa	MWJ	CTD operations
Fuyuki Shibata	MWJ	Alkalinity, pH
Katsunori Sagisima	MWJ	Oxygen
Takeo Matsumoto	MWJ	Salinity
Ai Yasuda	MWJ	Nutrients
Mikio Kitada	MWJ	TCO2
Kenichiro Sato	MWJ	Nutrients
Keisuke Wataki	MWJ	Alkalinity, pH
Hiroshi Matsunaga	MWJ	CTD operations
Taeko Ohama	MWJ	Alkalinity, pH
Minoru Kamata	MWJ	TCO2, CFCs
Junko Hamanaka	MWJ	Nutrients
Asako Kubo	MWJ	Nutrients
Yuichi Sonoyama	MWJ	Oxygen
Tomoko Miyashita	MWJ	Oxygen
Naoko Takahashi	MWJ	CTD operations
Shinya Iwamida	GODI	Meteorology, XBT/XCTD
Souichiro Sueyoshi	GODI	ADCP, Bathymetry, XBT/XCTD
Yosuke Inoue	Tokyo University of Fisheries	Water sampling
Hisami Suga	Hokkaido University	Water sampling
Tomokazu Hirata	Tokai University	Water sampling
Fuma Matsunaga	Kagoshima University	Water sampling
Satoko Katsuyama	Tokai University	Water sampling
Tae Yamamoto	Tokai University	Water sampling
Takahiro Miura	Tohoku University	Water sampling

Abbreviations:

JAMSTEC: Japan Marine Science and Technology Center
MWJ: Marine Works Japan, Ltd.
GODI: Global Ocean Development, Inc.
TNFRI: Tohoku National Fisheries Research Institute
KANSO: Kansai Environmental Engineering Center Co., Ltd.

2. Underway Measurements

2.1 Surface Meteorological Observation
13 Mar 2002

Personnel

Kunio YONEYAMA (JAMSTEC)
Shinya IWAMIDA* (GODI)
Souichiro SUEYOSHI* (GODI)
* Operators on board

Objective

Accurate and continuous surface meteorological measurements are crucial to understand the air-sea interaction quantitatively. These data are used to study the temporal and spatial distribution of the exchange of heat, momentum, and radiation through the sea surface.

Methods

For accurate measurement of surface meteorology on board, in addition to the MIRAI original surface meteorological station (SMET), two state-of-the-art but unique measurement systems are deployed on the *R/V MIRAI*. One is SOAR (Shipboard Oceanographic and Atmospheric Radiation) measurement system developed by Brookhaven National Laboratory, that focuses on accurate measurement of solar radiation, and the other is turbulent flux measurement system, that measures sensible and latent heat as well as momentum accurately by correcting the influence of ship motion onto the true wind. Sensors of both systems are deployed on the top deck of the foremast, where provides good condition with less influence of ship body dynamically and thermodynamically.

Main components of these systems are listed below (sensor, type, and parameters).

SMET:

Thermometer (Koshin Denki, FT)	air temperature (degC)
Dew point hygrometer (Koshin Denki, DW-1)	dew point (degC)
Anemometer (Koshin Denki, KE-500)	relative wind speed (m/s) and direction (deg)
Barometer (Yokogawa, F451)	pressure (hPa)
Siphonic rain gauge (R.M. Young, 50202)	precipitation (mm)
Optical rain gauge (ScTi, ORG-115DR)	rain rate (mm/hr)
Pyranometer (EKO, MS-801)	downwelling short wave radiation (W/m2)
Pyrgeometer (EKO, MS-200)	downwelling long wave radiation (W/m2)

SOAR (Figure 3)

T/RH sensor (Vaisala, HMP45A)	temperature (degC), relative humidity (%)
Anemometer (R.M. Young, 5106)	relative wind speed (m/s) and direction (deg)
Barometer (R.M. Young, 61201)	pressure (hPa)
Siphonic rain gauge (R.M. Young, 50202)	precipitation (mm)
Optical rain gauge (ScTi, ORG-115DR)	rain rate (mm/hr)
Portable Radiation Package (BNL, PRP) consists of :	
• Pyranometer (Eppley, PSP)	downwelling short wave radiation (W/m2)
• Infrared radiometer (Eppley, PIR)	downwelling long wave radiation (W/m2)
• Fast Rotating Shadowband Radiometer (BNL, FRSR)	direct and diffuse components of solar radiation (W/m2)

Data acquisition system (NOAA, SCS:Scientific Computer System)

* Details of the SOAR can be found at http://www.oasd.bnl.gov/

Turbulent Flux measurement system (Figure 4):

3-D sonic anemometer-thermometer (Kaijo, DA-600) ; wind speed (m/s), temperature (degC)	
Infrared hygrometer (Kaijo, AH-300)	specific humidity (g/kg)
Inclinometer (Applied Geomechanics, MD-900-T)	hip motion (pitch, roll)
Accelerometer (Applied Signal Inc.,QA700-020)	ship motion (acceleration)
Rate gyro (Systron Donner, QRS11-0050-100)	ship motion (angular velocity)

Preliminary results

Original data are taken every 6 seconds for SMET and SOAR, 10Hz for turbulent measurement, respectively, during whole cruise. Time series of basic surface meteorology averaged over one hour are shown in Figure 5.

Data archives

The raw SOAR and SMET data have already been submitted to JAMSTEC Data Management Office(DMO). Corrected data are also available upon request from K. Yoneyama of JAMSTEC (yoneyamak@jamstec.go.jp) and will be available from R.M. Reynolds of BNL. Turbulent flux measurement data, on the other hand, will be processed and archived by O. Tsukamoto of Okayama University. After the processing and quality check, data will be submitted to JAMSTEC DMO and become available at least within 3 years.
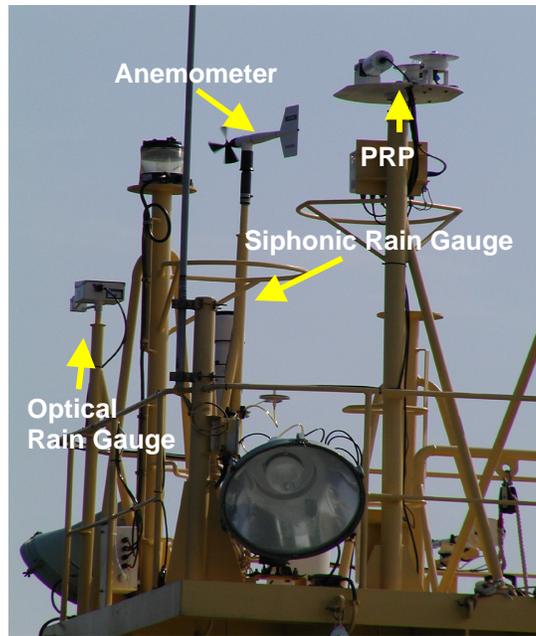
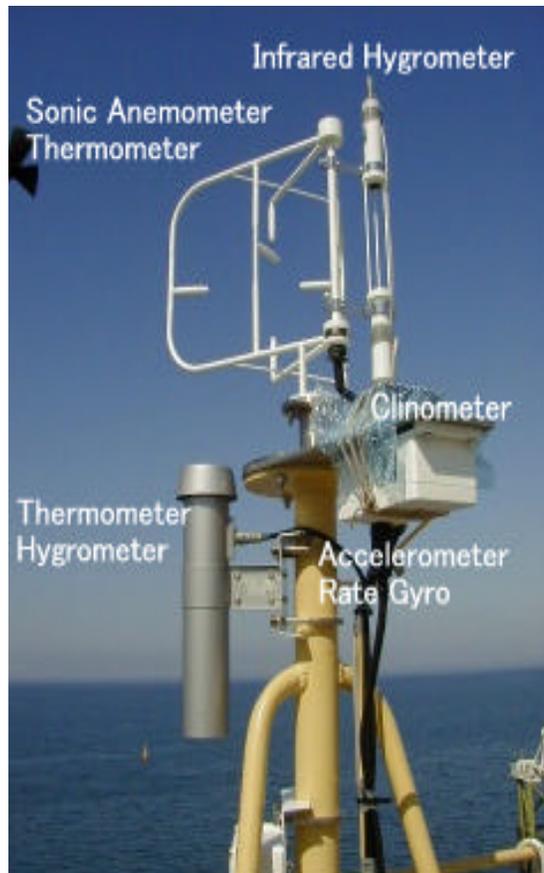**Figure 3**: SOAR sensors on the foremast top deck.

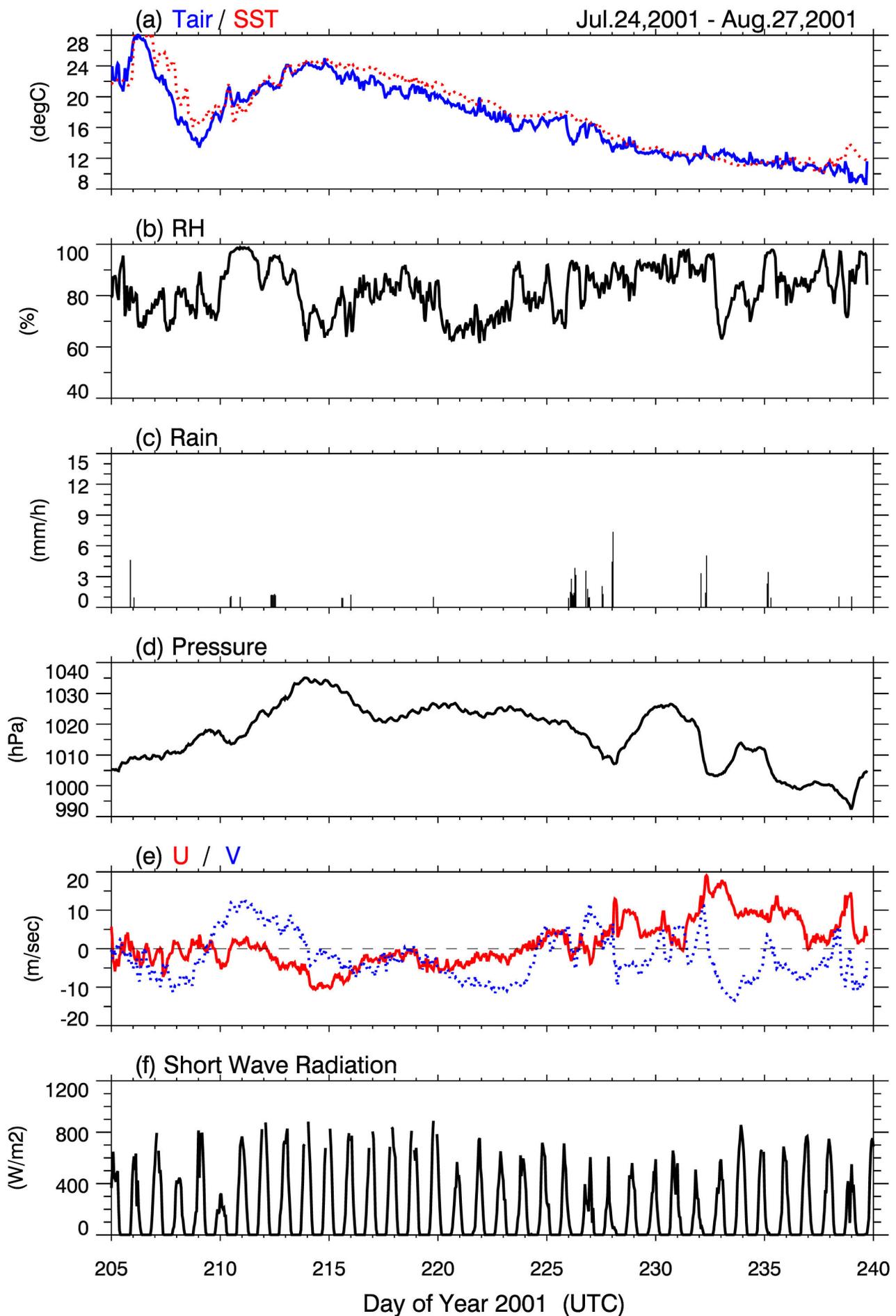**Figure 4**: Turbulent flux measurement system

Figure 5: Time series of (a) air temperature and sea surface temperature, (b) relative humidity, (c) rain rate, (d) pressure at sea level, (e) zonal and meridional wind components, and (f) downwelling short wave radiation, respectively.

2.2 Shipboard ADCP Observation
13 Mar 2002

Summary

Direct velocity measurement was made along the cruise track with a hull-mounted ADCP. The ADCP was a 75 kHz broadband system, RDI, which profiled at 8-meter vertical resolution and vector-averaged the 2-second ping data onto a 5-minute time series with vertical range of sampling from 20 to 660 m depth, approximately. It did reach down to 300 m to 500 m depth. The measurement system included ship's GPS receiver and gyrocompass. The ship position was corrected by using the differential signal from the land when it was received. The alignment misfit between gyrocompass and ADCP, and the scale factor of ADCP were estimated and corrected by using the bottom tracking data obtained in this cruise.

Personnel

Yasushi YOSHIKAWA (JAMSTEC) Principal Investigator
Shoichiro SUEYOSHI   (GODI)   Operation Leader

Objective

Objective is to study the flow fields both hydrographic sections of WHP-P17C and -P17N, and the North Pacific along the ship track.

Instruments and data acquirement system

The ADCP mounted on the *R/V Mirai* was 75 kHz broadband system, RDI-VM75. We set the parameters of each ADCP profile as 8 m vertical resolution with vertical range of sampling from 20 to 660 m depth, approximately. The ship's ADCP did reach down to 300 m to 500 m depth. The 2 seconds ping data were averaged onto a 5 minutes time series. The ADCP observation was carried underway in this cruise from Sekinehama to Dutch Harbor.

A single GPS receiver was used for ship's positioning. It was calibrated by using differential signal sounded from Sapporo, Honolulu, and Vancouver when the signal was received. From the signal from Vancouver was almost covered in this hydrographic section P17C and P17N.

Ship's gyrocompass was used for the measurement of the ADCP direction. The gyrocompass correlated its error factors, so-called 'the velocity error' and 'the latitude error', automatically. There were no system that measured ship's pitch and roll. There existed unknown alignment misfit. The scale factor for the ADCP velocity was also to be estimated. Therefore we took special ship course in this cruise for the estimations.

Estimations of the alignment misfit and the scale factor

In order to estimate the alignment misfit and the scale factor four special ship tracks were arranged; three round-trip courses and two bottom-tracking courses were set up. Among them we used the first bottom tracking data for the estimation because the stable data were collected. Bottom speed data those were sampled every 4 seconds, were averaged

onto a 2 minutes time series. The alignment misfit _ and the scale factor A are estimated by using following formula shown in Joyce (1989) and Pollard and Read (1989),

$$\tan\_ = (v'_d u_s - u'_d v_s)/(u'_d u_s + v'_d v_s),$$
$$A = \text{square root} ((u_s^2 + v_s^2)/(u'^2_d + v'^2_d)),$$

where, u_s and v_s are east-west and north-south components of the ship speed, and u'_d and v'_d are those bottom speed relative to the ship, respectively. The A and _ were calculated in each sample.

The scale factor A was estimated by averaging the data of the track. The mean is 0.9705 with the standard deviation of 0.0011, which corresponds to the error of 0.9 cm/s when the ship speed is 16kt. It is satisfied with the range of the result of another bottom track; the mean is 0.9699 with the standard deviation of 0.0125. The gyrocompass shows the unstable error after the ship heading changing. The time needed for becoming the stable status after the turning back was estimated as 80 minutes. By using the suitable samples the alignment misfit was estimated as −1.34 degree with the standard deviation of 0.07 degree.

Preliminary results

The ADCP velocity vectors along the cruise track were shown in Figure 6. For the sections of P17C and P17N the data when the ship stopped for the CTD operation were used for the velocity calculation. In the crossing the western north Pacific, strong flow pattern (associated with the Kuroshio and/or eddies?) was observed. In the hydrographic section, the ADCP observed the southwestward strong flow of the Alaskan Current in the sea north of 54 N (Figure 7). The flow over 20 cm/s was spreading down to 300m to 500m in this area. The core of the current existed near STN.96, where the current speed was over 50 cm/s at the 50 m depth.

Data archives

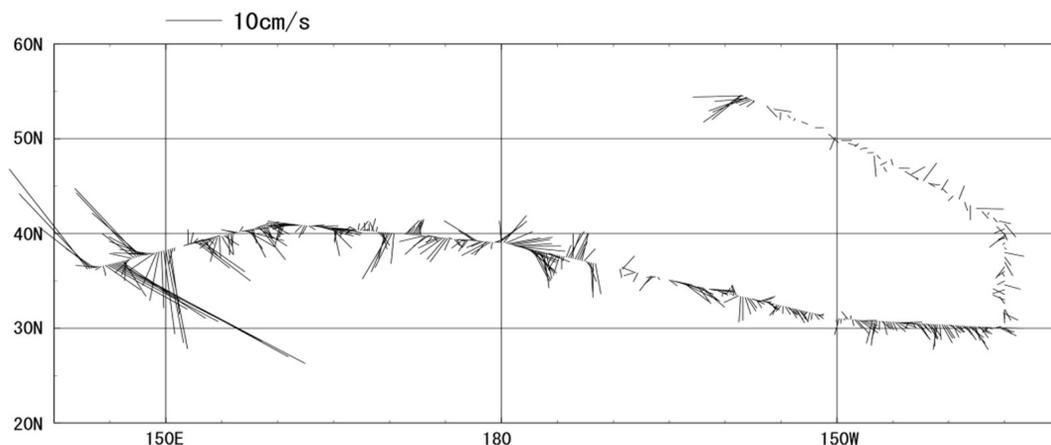The raw data will be submitted to the Data Management Office (DMO) in JAMSTEC.

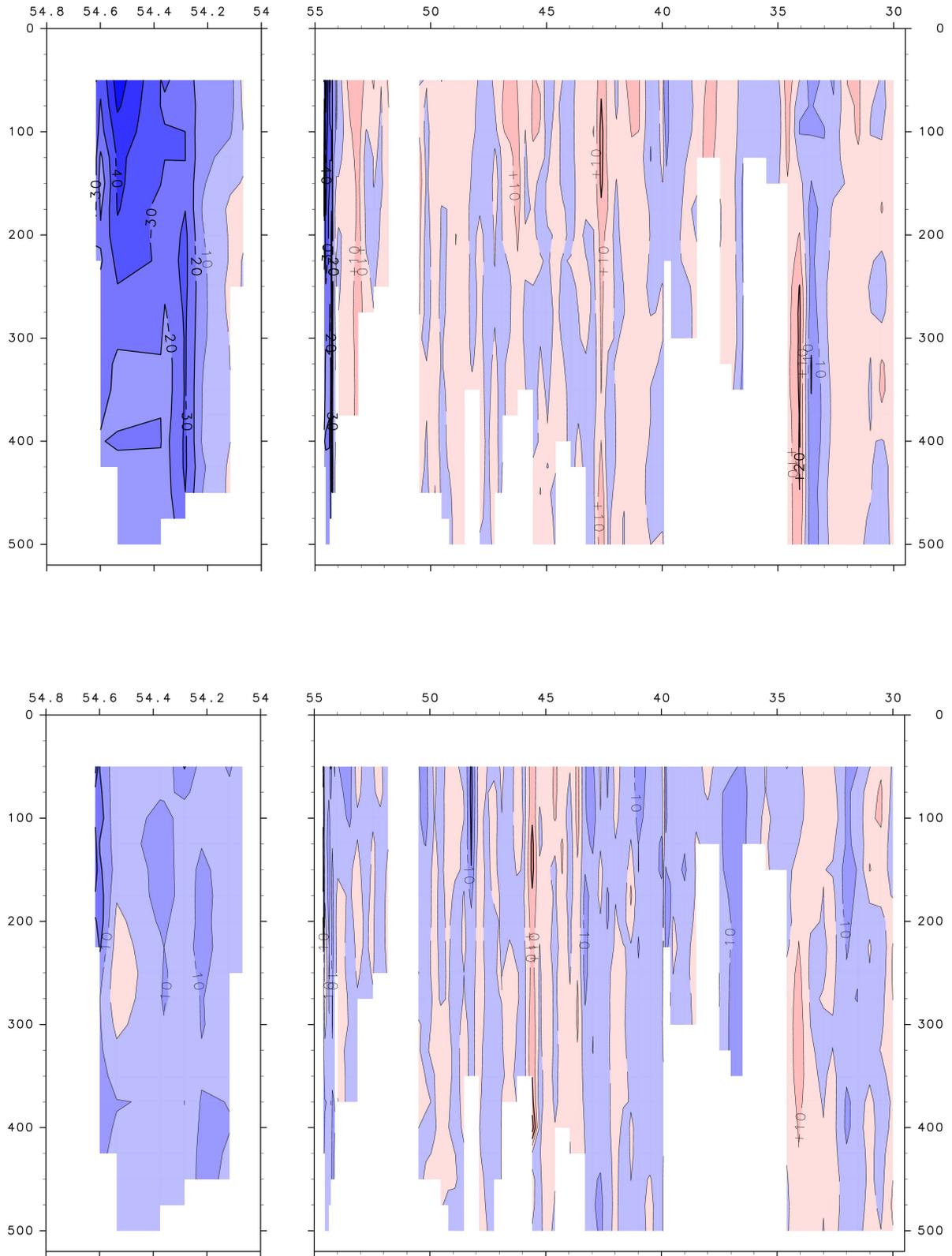**Figure 6:** ADCP velocity vectors along the cruise track for 100 m depth.

Figure 7: ADCP velocity pattern (cm/s) at sections of P17C and P17N, (upper-panel) u-component, lower-panel) v-component. Northern part of the right panel is zoomed in on the left panel.

2.3 Surface Nutrients
13 Mar 2002

Personnel

Junko Hamanaka (MWJ): Operation Leader
Kenichiro Sato   (MWJ)
Asako Kubo   (MWJ)

Scientific background

Phytoplankton require nutrient elements for growth, chiefly nitrogen, phosphorus, and silicon. The data of nutrients in surface seawater is important for investigation of phytoplankton productivity.

Parameters

  • Nitrate + Nitrite
  • Nitrite
  • Phosphate
  • Silicate

Methods

The nutrients monitoring system was performed on BRAN+LUEBBE continuous monitoring system Model TRAACS 800 (4 channels) from July 24 to August 10, 2001. This system was located at the surface seawater laboratory for monitoring in *R/V Mirai*. Seawater at depth of 4.5 m was continuously pumped up to the laboratory and introduced direct to monitoring system with narrow tube. The methods are as follows.

Nitrate + Nitrite: Nitrate in the seawater was reduced to nitrite by reduction tube (Cd-Cu tube), and the nitrite reduced was determined by the nitrite method as shown below. The flow cell was 3 cm length type.

Nitrite: Nitrite was determined by diazotizing with sulfanilamide by coupling with N-1-naphthyl-ethylendiamine (NED) to form a colored azo compound, and by being measured the absorbance of 550 nm using 3 cm length flow cell in the system**.**

Phosphate: Phosphate was determined by complexing with molybdate, by reducing with ascorbic acid to form a colored complex, and by being measured the absorbance of 800 nm using 5 cm length flow cell in the system.

Silicate: Silicate was determined by complexing with molybdate, by reducing with ascorbic acid to form a colored complex, and by being measured the absorbance of 800 nm using 3 cm length flow cell in the system.

Data sharing

All data will be submitted to JAMSTEC Data Management Office (DMO) and under its control.

2.4 Atmospheric and surface seawater $P(CO_2)$

13 Mar 2002

Personnel

A. Murata   (JAMSTEC)
M. Kitada   (MWJ)
M. Kamata (MWJ)
T. Kitao   (KANSO)

Instrument and technique

Continuous underway measurements of atmospheric and surface seawater $P(CO_2)$ were made with the CO_2 measuring system (Nippon ANS, Ltd) installed in the *R/V Mirai* of JAMSTEC. The system comprises of a non-dispersive infrared gas analyzer (NDIR; BINOS® model 4.1, Fisher-Rosemount), an air-circulation module and a showerhead-type equilibrator. To measure concentrations (mole fraction) of CO_2 in dry air (xCO_2a), air sampled from the bow of the ship (approx. 30 m above the sea level) introduced into the NDIR through a dehydrating route with an electric dehumidifier (kept at $3^{\circ}C$), a Pure dryer, and a chemical desiccant ($Mg(ClO_4)_2$). The flow rate of the air was 500 ml min^{-1}. To measure surface seawater concentrations of CO_2 in dry air (xCO_2s), the air equilibrated with seawater within the equilibrator was introduced into the NDIR through the same flow route as the dehydrated used in measuring CO_2. The seawater was taken by a pump from the intake placed at the approx. 4.5 m below the sea surface. The flow rate of seawater in the equilibrator was 500 – 800 ml min^{-1}.

The CO_2 measuring system was set to repeat the measuring cycle such as 4 kinds of CO_2 standard gases (see below), xCO_2a (twice), xCO_2s (7 times), and this system was run throughout the cruise.

Calibration and standards

Four working standard gases, with nominal values of 298, 321, 370, 440 ppmv in synthetic air, were used during the measurements on board the vessel. Prior to the cruise (Jul., 2001), the CO_2 standard gases used on the cruise were calibrated against primary standard gases, which were calibrated by Dr. C.D. Keeling of the Scripps Institution of Oceanography (SIO). The calibrated concentrations were 298.57, 321.19, 370.72 and 439.97 ppmv. After the cruise (Nov., 2001), we re-calibrated the working standard gases. The re-calibrated concentrations were 298.56, 321.15, 370.78 and 439.93 ppmv. Since the differences between before and after the cruise were all less than 0.1 ppmv, we calculated the sampled xCO_2a and xCO_2s using the averaged concentrations of 298.56, 321.17, 370.75 and 439.95 ppmv.

Data selection

The CO_2 measuring system used an analogue recorder for output voltages from the NDIRs. The analogue recorder was used to select background and significant signals of each measured item by rejecting variant signals that resulted from contamination by the

ship's ventilation air, the rolling and pitching of the ship due to rough weather, etc. In addition, plots of the values as a function of sequential time also facilitated the visual detection of abnormal values.

For xCO_2a, we used the data only when difference of two consecutive measurements (6 min. interval) was within 0.15 ppmv to obtain background values. The averages of the two measurements (336 pairs) are reported in the data file.

For xCO_2s, a measurement of 3,418 passed the data selection rule.

Calculation of $P(CO_2)$

$P(CO_2)$ was calculated based on the following equation:

$$P(CO_2) = (1 - e/P)?xCO_2,$$

where e and P are saturated water vapor and air pressure, respectively. The e was calculated as a function of water temperature and salinity (Weiss and Price, 1980).

For surface seawater $P(CO_2)$, the rise in seawater temperature between the intake and the equilibrator is critical.--- in the cruise, the rise was usually less than $0.3°C$. The effects of the temperature rise were corrected using the equation of Gordon and Jones (1973).

Distributions of atmospheric and surface seawater $P(CO_2)$

Latitudinal distributions of atmospheric and surface seawater $P(CO_2)$ along the WOCE line are displayed in Figure 8. From this figure, it was found that south of $43°N$, the sea acted as a source for atmospheric CO_2, while north of $43°N$, it acted as a weak sink for atmospheric CO_2, or was almost saturated with atmospheric CO_2.

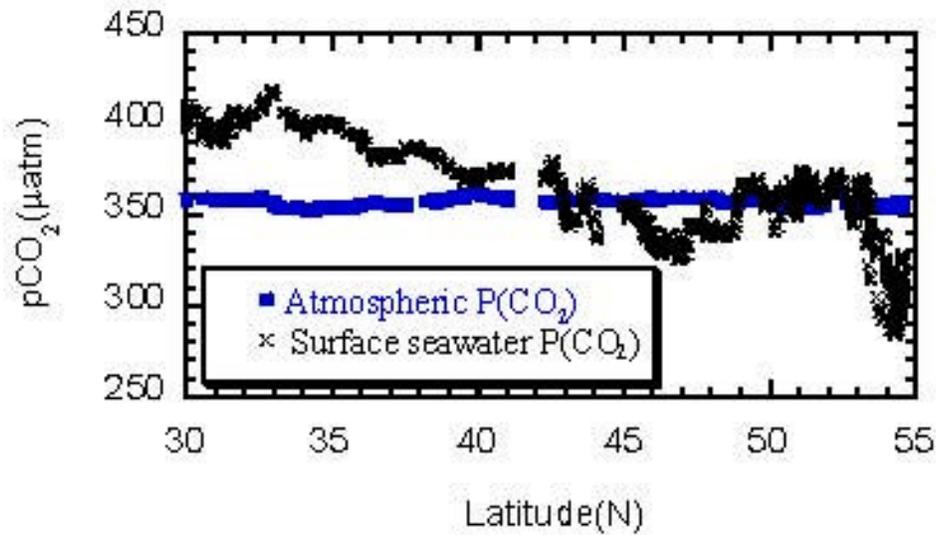**Figure 8**: Distributions of atmospheric and surface seawater P(CO$_2$) as a function of latitude along the WOCE line.

References:

Gordon. L.I. and L.B. Jones. 1973. The effect of temperature on carbon dioxide partial pressure in seawater. *Mar. Chem.* **1**: 317–322.

Weiss, R.F. and B.A. Price. 1980. Nitrous oxide solubility in water and seawater. *Mar. Chem.* **8**: 347-359.

2.5   Surface seawater total carbon (C_T)

13 Mar 2002

Personnel

A. Murata   (JAMSTEC)
M. Kitada   (MWJ)
M. Kamata (MWJ)
T. Kitao   (KANSO)

Instrument and technique

Continuous underway measurements of surface seawater C_T was made with the C_T measuring system (Nippon ANS, Ltd) installed in the *R/V Mirai* of JAMSTEC. The system comprises of a sea water dispensing system, a CO_2 extraction system and a coulometer (Model 5012, UIC Inc.).

The sea water dispensing system has an auto-sampler which collects sea water in a 300 ml borosilicate glass bottle, and dispenses the sea water to a pipette of nominal 30 ml volume by PC control. The sea water taken at approx. 4.5 m depth was introduced to the glass bottle by a pump of the *Mirai*. Time and position of sea water sampling were recorded automatically through a ship's navigation system, together with water temperature and salinity, which were measured by a Continuous Sea Surface Water Monitoring System (Nippon Kaiyo, Ltd) of the *Mirai*.

CO_2 dissolved in a sea water sample was extracted in a stripping chamber of the CO_2 extraction system by adding phosphoric acid (10% v/v). The stripping chamber is made approx. 25 cm long and has a fine frit at the bottom. To degass CO_2 as quickly as possible, heating wire kept at 40°C is rolled from the bottom to a 1/3 height of the stripping chamber. The acid was added to the stripping chamber from the bottom of the chamber by pressurizing an acid bottle for a given time to push out the right amount of acid. The pressurizing was made with nitrogen gas (99.9999%). After the acid was transferred to the stripping chamber, sea water samples collected in a pipette were introduced to the stripping chamber by the same method as in adding an acid. The sea water reacted with phosphoric acid was stripped of CO_2 by bubbling the nigrogen gas through a fine frit at the bottom of the stripping chamber. The CO_2 stripped in the chamber was carried by the nitrogen gas (flow rate of 130 ml min^{-1}) to the coulometer through a dehydrating module. The module consists of two electric dehumidifiers (kept at 1°C) and a chemical desiccant $(Mg(ClO_4)_2)$.

The measurement sequence such as system blank (phosphoric acid blank), 2% CO_2 gas in a nitrogen base, sea water samples (4) was programmed to repeat throughout the operation. The measurement of 2% CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc.).

Calibration

Calibration was made using 6 Na_2CO_3 solutions of nominal 0.0, 500, 1000, 1500, 2000 and 2500 µmol dm^{-3}. The slope of the linear regression equation ($R^2 = 0.99998$) was used

as the calibration factor. Certified reference materials (CRM; Bach #53) provided by Prof. A.G. Dickson of SIO were measured when a coulometer solution was renewed. All the values reported were recalibrated against the certified value of the CRM.

Stability of the measuring system

Changes of C_T due to changes of response of a coulometer were monitored by measuring 2% CO_2 gas periodically; coulometer counts of the 2% CO_2 gas at respective sample measurements were interpolated from the measured coulometer counts of the gas, which were obtained at every 5 measurements. Then, based on the count assigned to each sample measurement, C_Ts were corrected so as to be measured at the coulometer response of CRM measurement.

The values of CRM measured during the operation of the system are plotted as a function of elapsed day (Figure 9).

Figure 9: Plots of measured values of CRM (Bach #53) as a function of elapsed day during the cruise. The horizontal line indicates the certified value of 2012.00 μmol kg^{-1}.

Uncertainty

The CRMs were measured twice from one bottle. The number of measurement was 10 (5 pairs) in total. The average value of the two analyses was used for CRM correction. The average difference between the average of the two CRM analyses and the certified value (2012.00 μmol kg^{-1}) was 2.1 ± 2.1 μmol kg^{-1}.

Distributions of surface seawater C_T

Distributions of surface seawater C_T were illustrated as a function of year day in Figure 10.

Figure 10:Distributions of surface seawater C_T as a function of year day. The year day 205 corresponds to 25 July, 2001.

2.6 Surface T, S, DO

Personnel

Tomoko MIYASHITA   (MWJ)
Katsunori SAGISHIMA (MWJ)
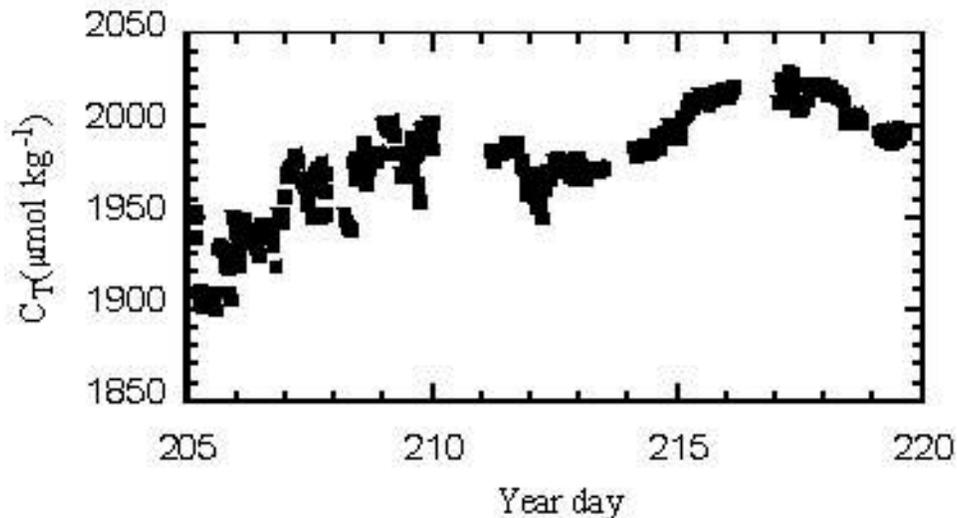Yuichi SONOYAMA   (MWJ)

Objective

To measure salinity, temperature, dissolved oxygen, and fluorescence of near-sea surface water.

Methods

The *Continuous Sea Surface Water Monitoring System* (Nippon Kaiyo co.,Ltd.) has six kind of sensors and can automatically measure salinity, temperature, dissolved oxygen, fluorescence and particle size of plankton in near-sea surface water continuously, every 1-minute. This system is located in the "*sea surface monitoring laboratory*" on *R/V Mirai*. This system is connected to shipboard LAN-system. Measured data is stored in a hard disk of PC every 1-minute together with time and position of ship, and displayed in the data management PC machine.

Near-surface water was continuously pumped up to the laboratory and flowed into the *Continuous Sea Surface Water Monitoring System* through a vinyl-chloride pipe. The flow rate for the system is controlled by several valves and was 12L/min except with fluorometer (about 0.3L/min). The flow rate is measured with two flow meters and each values were checked everyday.

Specification of each sensor in this system listed below.

a) Temperature and Salinity sensor

SEACAT THERMOSALINOGRAPH

Model:	SBE-21, SEA-BIRD ELECTRONICS, INC.	
Serial number:	2118859-2754	
Measurement range:	Temperature -5 to +35_,	Salinity0 to 6.5 S m-1
Accuracy:	Temperature 0.01 _ 6month-1,	Salinity0.001 S m-1 month-1
Resolution:	Temperatures 0.001_,	Salinity0.0001 S m-1

b) Bottom of ship thermometer

Model:	SBE 3S, SEA-BIRD ELECTRONICS, INC.
Serial number:	032607
Measurement range:	-5 to +35_
Resolution:	±0.001_
Stability:	0.002 _ year-1

c) Dissolved oxygen sensor

Model:	2127, Oubisufair Laboratories Japan INC.
Serial number:	44733
Measurement range:	0-14 ppm
Accuracy:	±1% at 5 _ of correction range
Stability:	1% month-1

d) Fluorometer

Model:	10-AU-005, TURNER DESIGNS
Serial number:	5562 FRXX
Detection limit:	5 ppt or less for chlorophyl a
Stability:	0.5% month-1 of full scale

e) Particle Size sensor

Model:	P-05, Nippon Kaiyo LTD.
Serial number:	P5024
Measurement range:	0.02681 mmt to 6.666 mm
Accuracy:	±10% of range
Reproducibility:	±5%
Stability:	5% week-1

f) Flow meter

Model:	EMARG2W, Aichi Watch Electronics LTD.
Serial number:	8672
Measurement range:	0 to 30 l min-1
Accuracy:	±1%
Stability:	±1% day-1

The monitoring Periods (UTC) during this cruise are: 2001.JUL.27 07:06 to
2001.AUG.26 17:48

Data sharing

All data will be submitted to JAMSTEC Data Management Office (DMO) and under its control.

2.8 Sea Bottom Topography Measurement

13 Mar 2002

Personnel

Souichiro Sueyoshi (GODI): Operation Leader
Shinya Iwamida   (GODI)

Objectives

To obtain bathymetry data contributes to geophysical investigation, and supports for CTD and sea water sampling observation.

Methods

The observation was carried out from 24 July 2001 to 26 August 2001. Bathymetry data were obtained continuously by SeaBeam2112.004 (SeaBeam, Inc., USA) 12kHz multi-narrow beam echo sounding system. In order to measure accurate depth, precise sound velocity profiles were calculated from the temperature profile of water column. During this cruise, XCTD/CTD data and SSV data were used to calculate the sound velocity profiles for most of stations.

Data archive

The dataset obtained in this cruise will be submitted to the DMO (Data Management Office), JAMSTEC and will be archived there.

3. Hydrographic Measurement Techniques and Calibrations

3.1 Sample Salinity Measurements
13 Mar 2002

Personnel

Takeshi Kawano   (JAMSTEC)
Takeo Matsumoto (MWJ)

Method and results

Samples were drawn into 250ml Phoenix brown glass bottles with GL45 screw caps. Bottles were reined three times with sample water before filling. Salinity was determined after sample equilibration to Lab. Temperature, at least 12 hours.

The analysis was carried out using "Guildline Autosal 8400B Salinometer", which was modified by addition of an Ocean Scientific International peristaltic-type sample intake pump. The instrument was operated air-conditioned dedicated Lab. for "Autosal" of *R/V Mirai*. The room temperature was around 23°C.

The bath temperature of "Autosal" was set to 24°C and IAPSO Standard Seawater (SSW) Batch P139, at least one fresh vial per cast, was used to standardize the salinometer. A double conductivity ratio was defined as a median of 31 readings of the salinometer. Data collection was started after 5 seconds and it took about 10 seconds to collect 31 readings by a personal computer.

406 pairs of replicate were measured. Figure 11 shows the histgram of all the difference between replicate samples. When we consider goods measurements below 1,000m (263 pairs), the average and the standard deviation were 0.00020 and 0.00014, respectively in Practical Salinity Scale.
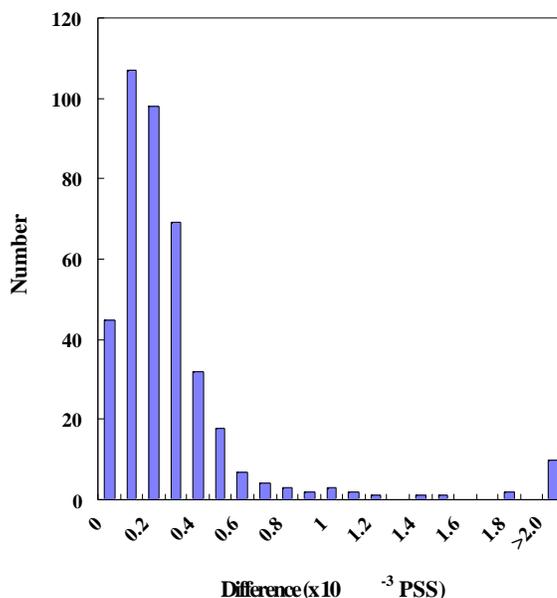

Figure 11: Histgram of the difference between reeplicates

3.2 Sample Dissolved Oxygen Measurements
13 Mar 2002

Personnel

Masao Fukasawa   (JAMSTEC)
Nobuharu Komai   (MWJ)
Katsunori Sagishima (MWJ)

Equipment and techniques

Bottle oxygen samples were taken in calibrated clear glass bottle of 200 ml cpacity before other samples were drawn. The temperature of the water was measured at the time of the drawing for 12/36 rosette bottles to check and to allow corrections for change in density of the sample between the closure of the rosette bottle and fixing of the dissolved oxygen. As for samples of which the water temperature was not measured, potential temperature calculated from CTD results was used after a correction based on the measured temperature data. Analysis followed the whole bottle method. The thiosulfate titration was carried out in a controlled environmental laboratory maintained at temperature between 24 ded.C and 27°C The normality of thiosulfate was set to be 0.07 when the regents were made up, and checked their changes daily. Replicate samples were taken from six bottles (deepest bottle and DO minimum bottle are always included) on every cast.

The end point of titration was determined by an electrode method following Culberson and Huang(1987) using a Metrohm Titrator and DOSIMAT (Switzerland) auto burette with 10 ml cylinder. Titration volume were always smaller than 6 ml and the smallest increment from the burette was 1 microliters.

The volume of oxygen dissolved in the water was converted to mass fraction by use of the factor 44.66 and an appropriate value of the density; corrections for the volume of oxygen added with reagents and for impurities in the manganese chloride were also made as described in the WOCE Manual of Operation and Methods (Cilberson, 1991, WHPO 91-1).

Reproducibility of measurement

During the cruise 2420 samples were taken including 513 of replicates. Statistics on the replicates are given in Table 1. These include both replicates and those taken from different bottles fired at the same depth.

Table 1: Statistics of replicates and duplicate obtained during the cruise

	Oxygen concentration umol/kg		
Number of replicates	mean difference	Std. dev	%mean
473	0.28 µmol/kg	0.22_µmol/kg	0.19

Cross section

Figure 12 shows the cross section of bottle DO produced using data with quality flags of 2 and 3.

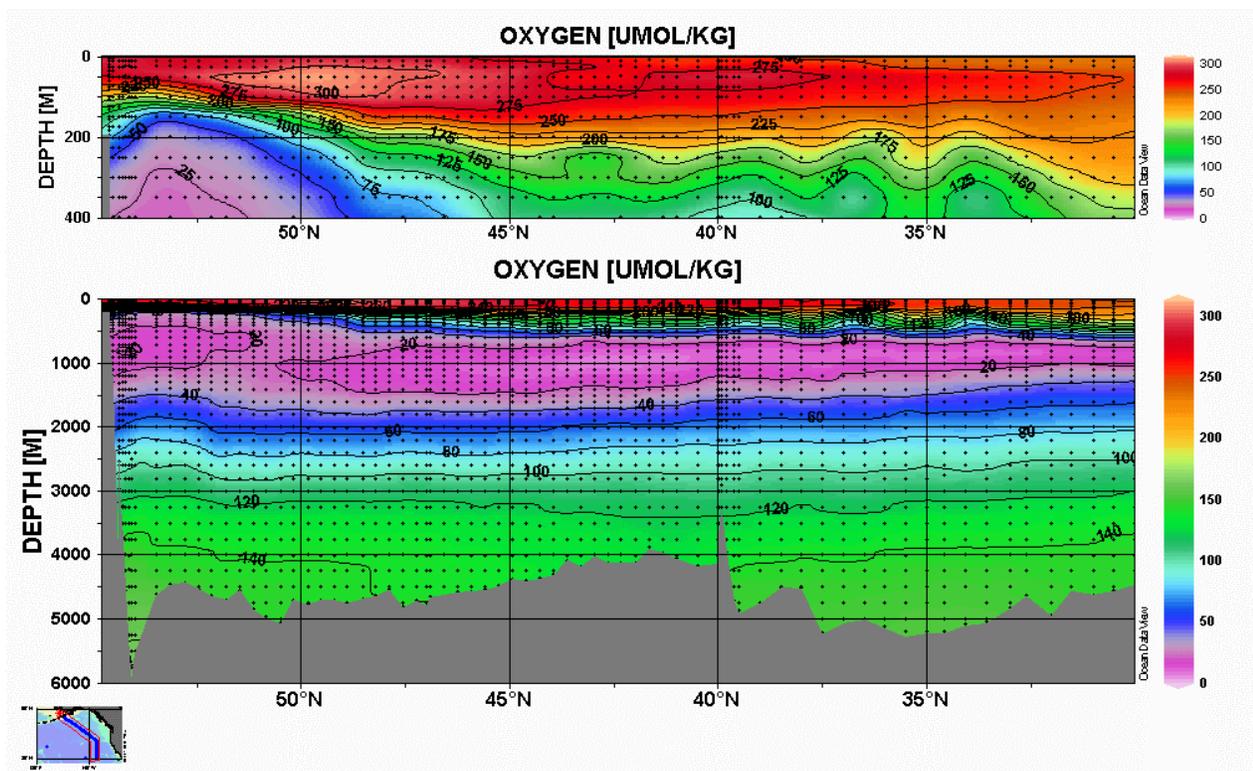Ocean Data View (version 5.4) by Reiner Schlitzer was hired as a graphic software.

Figure 12: Cross section of bottle DO. Bad measurement data were omitted.

3.3 Total alkalinity (A_T)

13 Mar 2002

Personnel

Akihiko Murata (JAMSTEC)
Fuyuki Shibata (MWJ)
Keisuke Watak (MWJ)
Taeko Ohama (MWJ)

Sample collection

All sea water samples collected from depth using 12 liter Niskin bottles at every two stations. The sea water samples for A_T were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into high-density polyethylene (PE) bottles with an inner cup. The PE bottle was filled with sea water smoothly from the bottom after rinsing it twice with a small volume of sea water. The sea water samples were kept at $4^{\circ}C$ in a refrigerator until analysis. A few hours before analysis, the sea water samples were kept at $25^{\circ}C$ in a water bath.

Instrument and technique

A sea water of approx. 100 ml was transferred into a tall beaker of 200 ml (open cell) from a PE bottle using a calibrated pipette (101.63 or 102.14 ml). The water temperature at pipetting was recorded to know transferred water volume.

Measurement of A_T was made using a titration system which comprises of a titration manager (TIM900, Radiometer) and auto-burette (ABU901, Radiometer). A combination of a pH glass electrode (pHG201, Radiometer) and a reference electrode (REF201, Radiometer) was used to monitor changes of emf by titrating a sea water sample by an acid (0.1N HCl + 0.6N NaCl). The best combination of the electrodes was selected by checking titration curves of NaCl solutions titrated by 0.01N HCl. The titration was made in a thermostat bath kept at $25^{\circ}C$, and was controlled by PC with a burrette operation software (Tim Talk 9, Lab Soft).

Calculation of A_T was made based on a modified Gran approach using emfs ranging from 150 to 210 mV.

Calibration of acid titrant

Calibration of acid titrant was made by measuring A_T of 5 solutions of Na_2CO_3 in 0.7N NaCl solutions. The computed A_Ts were approx. 0, 100, 1000, 2000 and 2500 µmol kg^{-1}.

The measured values of A_T (calculated by assuming 0.1N) should be a linear function of the A_T contributed by the Na_2CO_3. The line is fitted by the method of a least square. Theoretically, the slope should be unity. If the measured slope is not equal to one, the acid normality should be adjusted by dividing initial normality by the slope, and the whole set of calculations is repeated until the slope = 1 is obtained.

The normality of the acid titrant used was 0.098211N.

Calibration of titrant dispensing tips

'To deliver' volumes of the auto-burette were calirbrated with pure water. Volumes of 2, 3, 4 ml delivered by the auto-burette were calibrated.

Precision and accuracy

We collected replicate samples at an interval of 5 to 8 sampling depth, approx. 5 replicate samples for each water column. The average difference of field replicate analyses was calculated to be 2.6 ± 2.6 µmol kg^{-1} (n = 181).

The CRMs (mostly Bach #54 and two Bach #53) were measured to remove biases between analyzed values of samples. The average difference between the analysed values of CRM and the certified value (2342.09 µmol kg^{-1}; Bach #45) was calculated to be 3.6 ± 3.3 µmol kg^{-1} (n = 18).

All the values reported were recalibrated against certified values of CRMs.

Comparison with the past P17 data

The A_Ts obtained by the past P17 observation are shown in Figure 13, together with the A_Ts obtained in this cruise. According to Lamb et al. (2002), 12 µmol kg^{-1} was subtracted from the values of the past P17 observation.
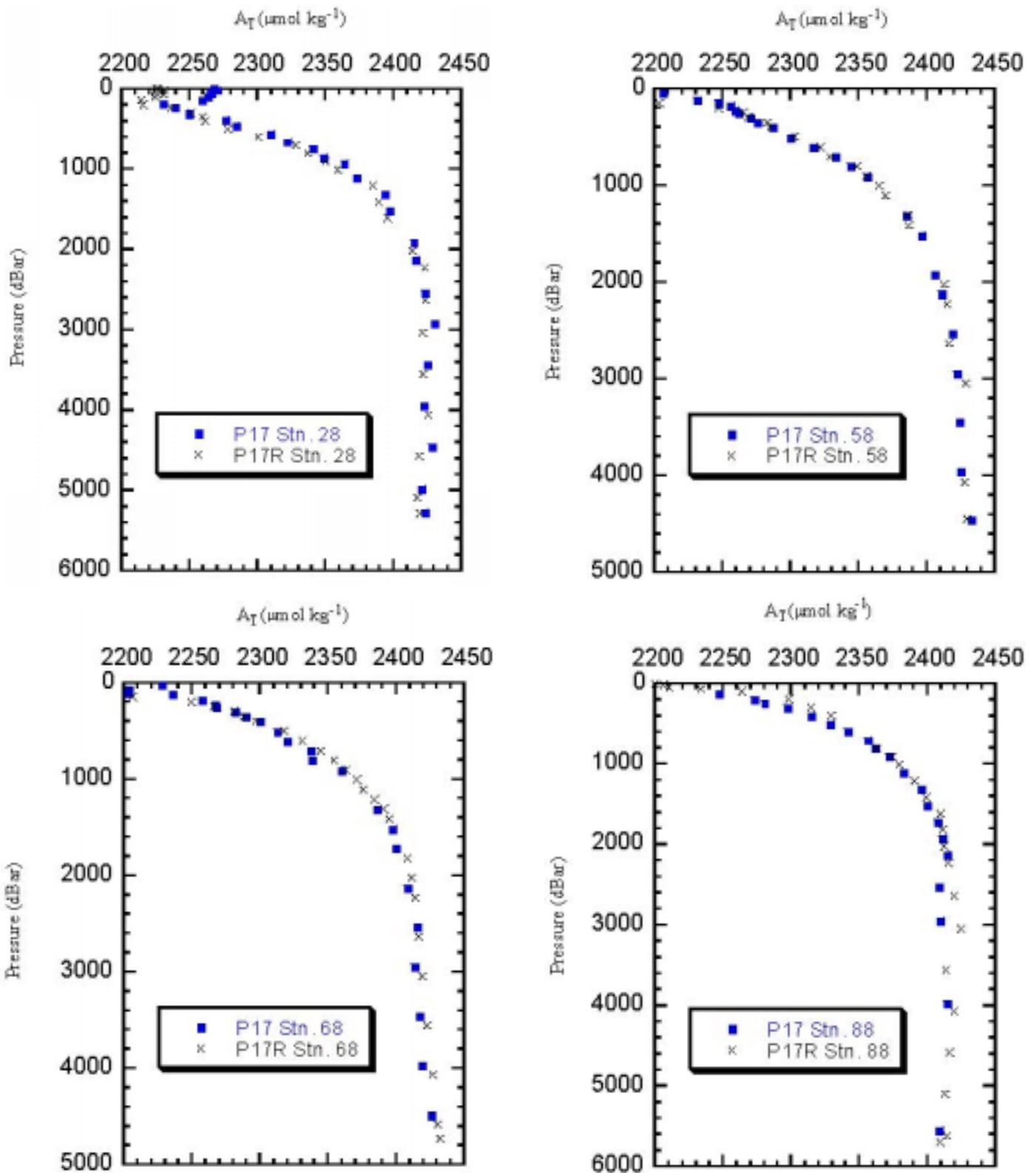
Figure 13: Vertical distributions of A_T obtained (solid squares) in the past P17 and (crosses) in this cruise.

From Figure 13, it is found that in the deep layers, A_Ts obtained in this cruise accord well with the A_Ts obtained in the past P17 cruise. However, further detailed investigations are necessary for evaluating accurate differences between the cruises.

References

Lamb, M.F., C.L. Sabine, R.A. Feely, R. Wanninkhof, R.M., Key, G.C., Johnson, F.J. Millero, K. Lee, T.-H. Peng, A. Kozy, J.L. Bullister, D. Greeley, R.H. Byrne, D.W. Chipman, A.G. Dickson, C. Goyet, P.R. Guenther, M. Ishii, K.M. Johnson, C.D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D.W.R. Wallace, Y.W. Watanabe, C. Winn, and C.S. Wong. 2002. Consistency and Synthesis of Pacific Ocean CO_2 Survey Data. *Deep-Sea Res. II* 49: 21-58.

3.4 Total carbon (C_T)

13 Mar 2002

Personnel

Akihiko Murata   (JAMSTEC)
Mikio Kitada   (MWJ)
Minoru Kamata   (MWJ)
Takashi Kitao   (MWJ)

Sample collection

All sea water samples collected from depth using 12 liter Niskin bottles at every two stations. The sea water samples for C_T were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into 300 ml borosilicate glass bottles. The glass bottle was filled with sea water smoothly from the bottom following a rinse with a sea water of 2 full, bottle volumes. A head-space of approx. 1% of the bottle volume was left by removing sea water using a plastic pipette. A saturated mercuric chloride of 50 µl (later changed to 100 µl) was added to poison the sea water samples. The glass bottles were sealed with a greased (Apiezon M, M&I Materials Ltd) ground glass stopper and the clips were secured. The sea water samples were kept at $4^{\circ}C$ in a refrigerator until analysis. A few hours before analysis, the sea water samples were kept at $20^{\circ}C$ in a water bath.

Instrument and technique

Measurements of C_T was made with the total CO_2 measuring system (Nippon ANS, Ltd) installed in the *R/V Mirai* of JAMSTEC. The system comprises of a sea water dispensing system, a CO_2 extraction system and a coulometer (Model 5012, UIC Inc.).

The sea water dispensing system has an auto-sampler (6 ports), which takes sea water in a 300 ml borosilicate glass bottle and dispenses the sea water to a pipette of nominal 30 ml volume by PC control. The pipette was kept at $20^{\circ}C$ by a water jacket, in which water from a water bath set at $20^{\circ}C$ was circulated.

CO_2 dissolved in a sea water sample was extracted in a stripping chamber of the CO_2 extraction system by adding phosphoric acid (10% v/v). The stripping chamber is made approx. 25 cm long and has a fine frit at the bottom. To degass CO_2 as quickly as possible, heating wire kept at $40^{\circ}C$ is rolled from the bottom to a 1/3 height of the stripping chamber. The acid was added to the stripping chamber from the bottom of the chamber by pressurizing an acid bottle for a given time to push out the right amount of acid. The pressrizing was made with nitrogen gas (99.9999%). After the acid was transferred to the stripping chamber, a sea water sample kept in a pipette was introduced to the stripping chamber by the same method as in adding an acid. The sea water reacted with phosphoric acid was stripped of CO_2 by bubbling the nigrogen gas through a fine frit at the bottom of the stripping chamber. The CO_2 stripped in the chamber was carried by the nitrogen gas (flow rate of 130 ml min^{-1}) to the coulometer through a dehydrating module. The module consists of two electric dehumidifiers (kept at $1^{\circ}C$) and a chemical desiccant ($Mg(ClO_4)_2$).

The measurement sequence such as system blank (phosphoric acid blank), 2% CO_2 gas in a nitrogen base, sea water samples (4) was programmed to repeat. The measurement of 2% CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc.).

Calibration

Calibration was made using 6 Na_2CO_3 solutions of nominal 0.0, 500, 1000, 1500, 2000 and 2500 µmol dm^{-3}. The slope of the linear regression equation (R^2 = 1.00000) was used as the calibration factor. Certified reference materials (CRM; Bach #54) provided by Prof. A.G. Dickson of SIO were measured when a coulometer solution was renewed. For a renewed coulometer solution, samples of two stations (approx. 80 samples) were measured. Reference materials (RM) produced by KANSO and JAMSTEC were measured subsequently to CRM and at about half a time of one coulometer span. All the values reported were recalibrated against the certified value of CRM.

Stability of the measuring system

Changes of C_T due to changes of response of a coulometer were monitored by measuring 2% CO_2 gas periodically; coulometer counts of the 2% CO_2 gas at respective sample measurements were interpolated from the measured coulometer counts of the gas, which were obtained at every 6 measurements. Then, based on the count assigned to each sample measurement, C_Ts were corrected so as to be measured at the coulometer response of CRM measurement.

The values of CRM measured during the operation of the system are plotted as a function of day (Figure 14). From this figure, it is found that there was a decreasing trend of measured values. We believe that this was caused by a contamination of a pipette.
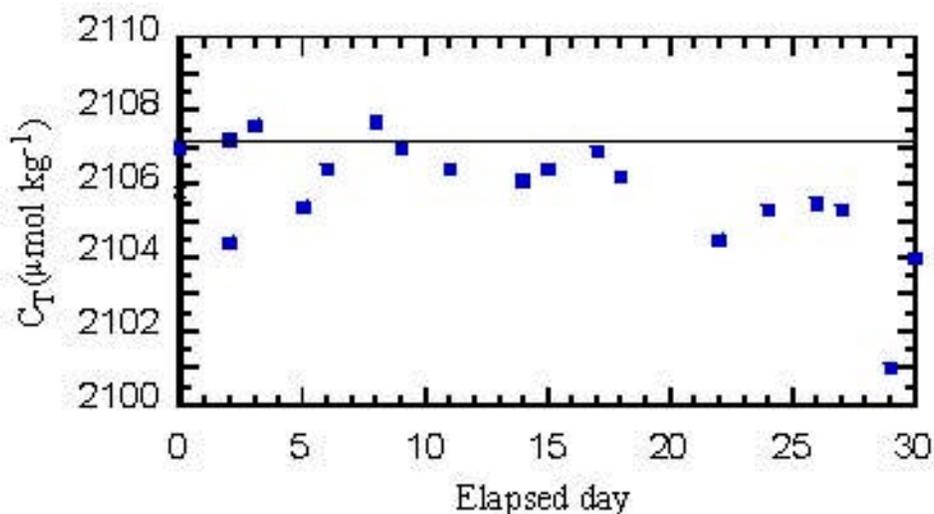

Figure 14: Plots of measured values of CRM (Bach #54) as a function of day during the cruise. The horizontal line indicates the certified value of 2107.35 µmol kg^{-1}.

Uncertainty

We collected replicate samples at an interval of 5 to 8 sampling depth, approx. 5 replicate samples for each water column. The average difference of field replicate analyses was calculated to be 1.5 ± 1.4 µmol kg^{-1} (n = 183).

The CRMs were measured twice from one bottle. The number of measurement was 38 (19 pairs) in total. The average value of the two analyses was used for CRM correction. The average difference between the average of the two CRM analyses and the certified value (2107.35 µmol kg^{-1}) was 1.5 ± 1.5 µmol kg^{-1}.

Comparison with the past P17 data

The C_Ts obtained by the past P17 observation are shown in Figure 15, together with the C_Ts obtained in this cruise. 7 µmol kg^{-1} was subtracted from the values of the past P17 observation, according to Lamb et al. (2002). From the figures, it is found that in the deep layers, C_Ts obtained in this cruise accord well with the C_Ts obtained in the past P17 cruise. However, further detailed investigations are necessary for evaluating accurate differences between the cruises.

Figure 15: Vertical distributions of C_T obtained (solid squares) in the past P17 and (crosses) in this cruise.

References

Lamb, M.F., C.L. Sabine, R.A. Feely, R. Wanninkhof, R.M., Key, G.C., Johnson, F.J. Millero, K. Lee, T.-H. Peng, A. Kozy, J.L. Bullister, D. Greeley, R.H. Byrne, D.W. Chipman, A.G. Dickson, C. Goyet, P.R. Guenther, M. Ishii, K.M. Johnson, C.D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D.W.R. Wallace, Y.W. Watanabe, C. Winn, and C.S. Wong. 2002. Consistency and Synthesis of Pacific Ocean CO_2 Survey Data. *Deep-Sea Res. II* **49**: 21-58.

3.5   pH
13 Mar 2002

Personnel

Andray Andreev (JAMSTEC)
Akihiko Murata   (JAMSTEC)
Taeko Ohama   (JAMSTEC)

Sample collection

All seawater samples collected from depth using 12 liter Niskin bottles at every two stations. The seawater samples for pH were taken with a plastic drawing tube (PEA tubing connected to silicone rubber tubing) into high-density polyethylene (PE) bottles with an inner cup. The PE bottle was filled with seawater smoothly from the bottom after rinsing it twice with a small volume of seawater. Special care was given to allow no air space in the samples. The sea water samples were kept at 4_ in a refrigerator until measurement. A few hours before measurement, the seawater samples were kept at 25_ in a water bath.

Instrument and technique

Separate glass (Radiometer PHG201) and reference (Radiometer REF201) electrodes were used. The e.m.f. of the glass/reference electrode cell was measured with a pH/Ion meter (Radiometer PHM95). In order not to have seawater sample exchange CO_2 with the atmosphere during pH measurement, closed glass container with water jacket was used. The temperature during pH measurement was monitored with temperature sensor (Radiometer T901) and controlled at 25_ within ±0.1_.

Calibration

To calibrate the electrodes the TRIS (pH=8.0936 pH unit at 25_; Delvalls and Dickson, 1998) and AMP (pH=6.786 pH unit at 25_; DOE, 1994) in the synthetic seawater (S=35 PSU) (total hydrogen scale) were applied.

pH_T of seawater sample (pH_{samp}) is calculated from the expression:

$$pH_{samp} = pH_{TRIS} + (E_{TRIS} - E_{samp})/ER$$

where electrode response, ER, is calculated as fllows:

$$ER = (E_{AMP} - E_{TRIS})/(pH_{TRIS} - pH_{AMP})$$

ER value should be equal to the ideal Nernst value as follows:

$$ER = RT\ LN(10)/F = 59.16\ mV/pH\ unit\ at\ 25\_.$$

Precision and accuracy

At each station, 4 to 6 duplicate samples were measured, 180 pairs in total. The average difference was calculated to be 0.003 ± 0.003 pH unit.

References

DelValls, T.A. and A.G. Dickson. 1998. The pH of buffers based on 2-amino-2-hydroxymethyl-1,3-propanediol ("tris") in Synthetic Seawater. *Deep-Sea Res.* **45**: 1541-1554.

DOE. 1994. In: Dickson, A.G. and C. Goyet (Eds.), Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water, version 2, ORNL/CDIAC-74.

3.6 CFCs
13 Mar 2002

Personnel

Shuichi Watanabe   (JAMSTEC)
Akihiko Murata   (JAMSTEC)

Sample collection

All sea water samples were collected from depth using 12 liter Niskin bottles at every two stations. Duplicate sea water samples were taken from each Niskin bottle following sampling for oxygen. The sea water samples were transferred with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) to glass ampoules of a volume of approx. 100 ml. The ampoule was filled with sea water smoothly from the bottom following a rinse with a sea water of 2 full, ampoule volumes. To prevent the samples from contamination from ambient air, the mouths of the ampoules were covered with a small glass container immediately after sampling. The ampoules were flame-sealed under nitrogen (99.9999%) flow.

3.7 Carbon Isotope Ratios in dissolved inorganic carbon (δ^{13}C and Δ^{14}C)
13 Mar 2002_rev. 25 Nov. 2002

Personnel

Yuichiro Kumamoto (JAMSTEC)

Sample collection

The sampling stations and number of samples are summarized in Figure 16 and Table 1. A total of 715 samples, including 60 replicate samples, were collected at 21 stations. The samples were collected from surface (about 10 m depth) to near bottom using 12 liter Niskin bottles. The seawater was siphoned into a 250 ml glass bottle with enough seawater to fill the glass bottle 2 times. Immediately after sampling, 5 ml of seawater was removed from the bottle and poisoned by 50 µl of saturated $HgCl_2$ solution. Then the bottle was sealed by a glass stopper with Apiezon M grease and stored in a cool and dark space on board. The sampling procedure on board basically follows the method in WOCE Operation Manual (McNichol and Jones, 1991).
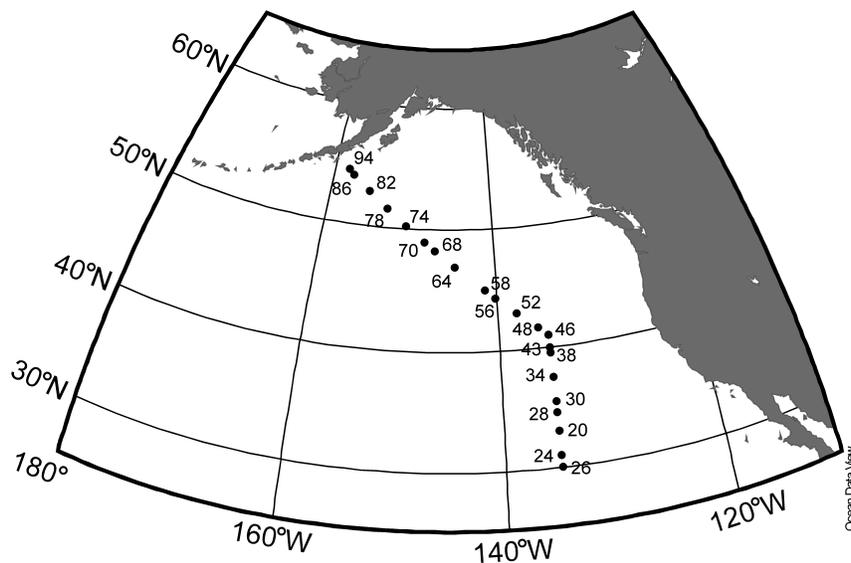

Figure 16: Sampling stations for carbon isotope ratios during P17N revisit cruise in August 2001.

Table 1: The sampling locations, date, number of samples, and maximum sampling pressure

Station	Date	Latitude N degree	Longitude W degree	Number of samples	Number of replicate samples	Max. sampling pressure /db
26	8/06/01	30.000	134.995	32	3	4549
24	8/07/01	31.011	135.002	31	0	4705
20	8/08/01	33.003	135.003	30	3	4906
28	8/08/01	34.588	135.004	30	30	5288
30	8/09/01	35.504	135.010	30	0	5305
34	8/10/01	37.501	135.002	30	3	5309
38	8/11/01	39.504	135.011	30	0	4963
43	8/12/01	39.970	135.010	34	3	3742
46	8/12/01	40.991	134.987	32	0	4113
48	8/13/01	41.642	135.992	32	3	3949
52	8/14/01	42.966	138.053	32	0	4065
56	8/15/01	44.294	140.149	31	3	4445
58	8/15/01	44.949	141.231	31	0	4457
64	8/17/01	46.899	144.444	31	3	4742
68	8/18/01	48.208	146.685	31	0	4730
70	8/18/01	48.914	147.907	31	3	4846
74	8/19/01	50.171	150.137	31	0	4800
78	8/22/01	51.473	152.550	31	3	4635
82	8/23/01	52.788	155.016	31	0	4522
86	8/24/01	53.975	157.371	29	3	5620
94	8/25/01	54.374	158.105	35	0	2567
Total				655	60	

Sample preparation

In our laboratory, dissolved inorganic carbon in the seawater samples were stripped cryogenically and split into three aliquots: Accelerator Mass Spectrometry (AMS) ^{14}C measurement (about 200 μmol), ^{13}C measurement (about 100 μmol), and archive (about 200 μmol). The extracted CO_2 gas for ^{14}C was then converted to graphite catalytically on iron powder with pure hydrogen gas. Details of these preparation procedures using an automated preparation system were described by Kumamoto *et al.* (2000).

Measurements

δ^{13}C analyses

The ^{13}C / ^{12}C ratio of the extracted CO_2 gas (R_{sample}) was measured using Finnigan MAT252 mass spectrometer. The ratio of R_{sample} against the ^{13}C / ^{12}C ratio of the standard ($R_{standard}$) is expressed as ^{13}C and calculated by the following equation:

$$^{13}C\ (‰) = (R_{sample} / R_{standard} − 1) \_ 1000. \qquad (1)$$

Because the value of $R_{standard}$ was validated with NIST RM8544 (NBS19), the measured ^{13}C is the value against the VPDB standard. All of the ^{13}C analyses have been finished. Except the replicate samples (see below), the individual ^{13}C results were given by

average of several time measurements with its error (standard deviation). These errors were less than 0.01 ‰.

The 60 replicate analyses are tabulated in Table 2. The table shows the error weighted mean and uncertainty for each set of replicates. The uncertainty is defined here as the larger of the standard deviation of the mean and the error weighted standard deviation. The simple average of the uncertainty, 0.02 ‰ is larger than the individual errors (standard deviation) because the uncertainty obtained for the replicate analyses includes errors due to sample collection and preparation.

Δ^{14}C analyses

The ^{14}C in the graphite sample was measured by AMS facilities at National Institute for Environmental Studies in Tsukuba, Japan (Tanaka *et al.*2000) and Institute of Accelerator Analysis Ltd in Shirakawa, Japan. The ^{14}C results are reported as Δ^{14}C. The equation for Δ^{14}C is:

$$\Delta^{14}C\ (‰) = \delta^{14}C - 2\ (\delta^{13}C + 25)\ (1 + \delta^{14}C\ /\ 1000), \qquad (2)$$

where

$$\delta^{14}C\ (‰) = (R_{sample}\ /\ R_{standard} - 1)\ \_\ 1000, \qquad (3)$$

where R_{sample} and $R_{standard}$ denote, respectively, ^{14}C / ^{12}C ratios of the seawater sample and the NIST oxalic acid standard (HOxII) with corrections for isotopic fractionation and age correction to A.D. 1950 (Stuiver and Polach, 1977; Stuiver, 1983). All of Δ^{14}C analyses have been finished. Except the replicate samples (see below), the individual Δ^{14}C results were given by average of several time measurements with its error that was the larger of the standard deviation and the counting error.

The results of the Δ^{14}C replicates are also shown in Table 2. The definition of the uncertainty is same as that of the δ^{13}C analyses. The simple average of the uncertainty (3.4 ‰) is almost same as that of the individual errors (3.7 ‰), which suggests that errors due to sample collection and preparation were negligible during the AMS radiocarbon measurements.

Table 2: Summary of replicate analyses

Station	Bottle	δ¹³C / ‰				Δ¹⁴C / ‰			
		δ^{13}C	Error[a]	E.W.Mean[b]	Uncertainty[c]	Δ^{14}C	Error[d]	E.W.Mean[b]	Uncertainty[c]
26	7	-0.05	0.01	-0.05	0.00	-254.3	3.2	-250.4	5.1
		-0.05	0.00			-247.2	2.9		
26	18	-0.36	0.01	-0.38	0.02	-230.6	2.9	-228.1	3.3
		-0.39	0.00			-225.9	2.8		
26	30	0.72	0.00	0.72	0.02	66.7	5.9	72.5	5.8
		0.70	0.01			74.8	3.8		
20	9	-0.07	0.01	-0.06	0.00	-243.9	3.3	-246.5	3.8
		-0.06	0.00			-249.2	3.4		
20	18	-0.44	0.01	-0.44	0.01	-224.4	3.5	-228.6	5.8
		-0.45	0.01			-232.6	3.4		
20	30	0.63	0.00	0.64	0.01	46.3	3.3	43.9	5.3
		0.65	0.00			38.9	4.7		
28	1	0.03	0.00	0.10	0.08	-229.5	2.7	-229.9	1.9
		0.14	0.00			-230.4	2.7		
28	2	0.16	0.00	0.14	0.02	-232.5	2.9	-228.7	5.1
		0.12	0.00			-225.4	2.7		
28	4	0.11	0.01	0.13	0.01	-224.7	2.8	-226.5	2.5
		0.13	0.00			-228.2	2.7		
28	6	0.07	0.00	0.07	0.01	-228.7	2.7	-232.1	5.1
		0.08	0.00			-235.8	2.8		
28	8	0.03	0.00	0.02	0.01	-237.2	2.7	-236.1	1.9
		0.02	0.00			-235.1	2.6		
28	10	-0.12	0.01	-0.11	0.01	-241.2	2.6	-243.4	3.5
		-0.10	0.00			-246.2	2.9		
28	12	-0.19	0.01	-0.19	0.00	-247.2	2.6	-248.6	2.0
		-0.19	0.00			-249.9	2.5		
28	14	-0.24	0.00	-0.27	0.04	-251.3	2.7	-250.9	1.8
		-0.29	0.00			-250.4	2.5		
28	15	-0.30	0.01	-0.31	0.01	-247.7	2.5	-247.7	1.8
		-0.32	0.00			-247.7	2.6		
28	16	-0.33	0.00	-0.33	0.01	-249.3	2.7	-246.1	4.4
		-0.35	0.01			-243.2	2.6		
28	17	-0.40	0.00	-0.38	0.04	-249.0	2.7	-246.7	3.3
		-0.35	0.01			-244.4	2.7		
28	18	-0.43	0.01	-0.42	0.00	-241.6	2.7	-240.5	1.9
		-0.42	0.00			-239.4	2.7		
28	19	-0.48	0.01	-0.48	0.00	-234.4	2.5	-233.4	1.8
		-0.47	0.01			-232.4	2.5		
28	20	-0.54	0.01	-0.54	0.01	-213.2	2.8	-215.0	4.0
		-0.53	0.00			-218.8	4.1		
28	21	-0.54	0.00	-0.54	0.01	-204.5	2.8	-203.3	2.0
		-0.55	0.00			-202.0	2.8		
28	22	-0.60	0.00	-0.59	0.05	-188.9	2.8	-187.4	2.2
		-0.53	0.00			-185.7	2.9		
28	23	-0.57	0.00	-0.56	0.01	-162.7	2.9	-162.5	2.1
		-0.55	0.00			-162.4	2.9		

Table 2: Summary of replicate analyses

Station	Bottle	δ¹³C / ‰				Δ¹⁴C / ‰			
		^{13}C	Error[a]	E.W.Mean[b]	Uncertainty[c]	^{14}C	Error[d]	E.W.Mean[b]	Uncertainty[c]
28	24	-0.48	0.00	-0.48	0.00	-128.0	2.9	-131.8	5.4
		-0.48	0.00			-135.6	2.9		
28	25	-0.36	0.00	-0.35	0.01	-83.8	3.0	-85.0	2.2
		-0.34	0.00			-86.3	3.1		
28	26	-0.13	0.01	-0.13	0.00	-27.1	3.0	-29.2	3.1
		-0.13	0.01			-31.5	3.2		
28	27	-0.02	0.00	-0.01	0.01	-6.2	3.2	-4.6	2.3
		-0.01	0.00			-3.1	3.2		
28	28	0.16	0.01	0.16	0.00	21.9	3.0	22.3	2.1
		0.16	0.00			22.8	3.0		
28	29	0.33	0.00	0.32	0.03	39.8	3.1	42.5	3.9
		0.29	0.00			45.3	3.2		
28	30	0.69	0.00	0.70	0.03	47.8	3.0	46.2	2.5
		0.72	0.01			44.2	3.3		
28	31	1.02	0.01	1.06	0.03	51.4	3.3	52.3	2.2
		1.06	0.00			53.0	3.0		
28	32	1.49	0.01	1.52	0.02	57.6	3.2	52.6	7.0
		1.52	0.00			47.7	3.2		
28	33	1.58	0.01	1.59	0.01	55.5	3.2	57.1	2.3
		1.60	0.00			58.6	3.2		
28	34	1.68	0.00	1.72	0.04	48.9	3.3	49.5	2.3
		1.73	0.00			50.1	3.3		
28	35	1.77	0.01	1.78	0.01	36.7	3.3	41.5	6.7
		1.78	0.00			46.2	3.3		
28	36	1.75	0.00	1.76	0.01	54.3	3.3	51.5	3.9
		1.77	0.01			48.7	3.3		
34	2	0.12	0.00	0.13	0.01	-216.1	4.1	-218.9	7.7
		0.14	0.00			-226.9	7.0		
34	18	-0.54	0.00	-0.54	0.00	-229.2	5.0	-227.9	3.2
		-0.54	0.00			-227.0	4.1		
34	30	0.54	0.00	0.52	0.03	42.4	3.8	43.5	2.6
		0.50	0.00			44.5	3.5		
43	7	-0.20	0.00	-0.20	0.00	-250.5	5.3	-246.7	6.9
		-0.20	0.00			-240.8	6.7		
43	18	-0.57	0.00	-0.57	0.00	-230.4	4.9	-231.0	3.2
		-0.57	0.01			-231.5	4.2		
43	30	0.48	0.00	0.48	0.00	33.1	4.4	31.1	3.0
		0.48	0.00			29.4	4.0		
48	7	-0.20	0.00	-0.20	0.00	-245.2	6.6	-245.0	3.6
		-0.20	0.00			-244.9	4.3		
48	18	-0.59	0.00	-0.61	0.01	-227.4	5.5	-225.7	4.3
		-0.61	0.00			-223.0	6.9		
48	30	0.44	0.00	0.44	0.01	29.9	4.6	28.7	3.3
		0.43	0.01			27.4	4.8		
56	7	-0.11	0.01	-0.16	0.04	-240.8	3.0	-241.3	2.2
		-0.17	0.00			-242.0	3.2		

Table 2: Summary of replicate analyses

Station	Bottle	δ¹³C / ‰				Δ¹⁴C / ‰			
		δ^{13}C	Error[a]	E.W.Mean[b]	Uncertainty[c]	Δ^{14}C	Error[d]	E.W.Mean[b]	Uncertainty[c]
56	18	-0.69	0.00	-0.69	0.01	-218.3	2.9	-222.6	6.0
		-0.68	0.00			-226.9	2.9		
56	30	0.43	0.00	0.43	0.01	24.5	3.8	23.7	2.5
		0.41	0.00			22.9	3.4		
64	8	-0.10	0.01	-0.12	0.03	-239.1	2.4	-240.2	1.8
		-0.15	0.01			-241.6	2.6		
64	18	-0.65	0.00	-0.65	0.02	-229.6	2.8	-228.5	1.9
		-0.63	0.01			-227.6	2.6		
64	30	-0.13	0.01	-0.19	0.04	-36.1	2.6	-35.8	1.8
		-0.19	0.00			-35.6	2.6		
70	8	-0.09	0.00	-0.09	0.01	-235.3	2.6	-235.6	1.8
		-0.08	0.00			-235.9	2.5		
70	18	-0.62	0.00	-0.63	0.01	-221.6	2.8	-223.7	2.7
		-0.64	0.01			-225.4	2.5		
70	30	-0.35	0.01	-0.41	0.06	-58.7	3.2	-59.9	2.3
		-0.43	0.00			-61.1	3.2		
78	8	-0.16	0.01	-0.16	0.00	-239.2	3.5	-239.9	2.5
		-0.16	0.00			-240.6	3.6		
78	18	-0.62	0.00	-0.60	0.03	-228.8	3.6	-225.8	4.0
		-0.58	0.00			-223.1	3.4		
78	30	-0.73	0.00	-0.72	0.01	-88.7	4.1	-93.8	6.8
		-0.71	0.00			-98.4	3.9		
86	3	0.11	0.00	0.14	0.07	-207.7	3.3	-208.8	2.4
		0.21	0.01			-210.0	3.4		
86	18	-0.50	0.00	-0.51	0.01	-238.8	3.1	-238.8	2.2
		-0.51	0.00			-238.8	3.2		
86	30	-0.74	0.00	-0.75	0.02	-105.2	3.6	-106.5	2.5
		-0.76	0.00			-107.8	3.6		

a. Normal standard deviation of several time measurements
b. Error weighted mean reported with data set
c. Larger of the standard deviation of the mean and the error weighted standard deviation
d. Larger of the standard deviation and the counting error

Quality control samples

During the sample measurements (Nov. 2001 – Aug. 2002), we synchronously carried out preparation and measurement of 19 quality control samples (QCS). The QCS was prepared by a large volume of surface seawater collected in open ocean and kept in our laboratory from 1999. The QCS results are shown in Table 3. The normal standard deviations of the simple average for $\delta^{13}C$ and $\Delta^{14}C$ are 0.03 ‰ and 4.5 ‰, respectively. These standard deviations of the QCS replicates are estimates of the true error which includes errors due to the sample preparation and the measurement for the time frame over which all the samples were measured.

QCS	$\delta^{13}C$ / ‰			$\Delta^{14}C$ / ‰		
No	Measurement date	$\delta^{13}C$	Error	Measurement date	$\Delta^{14}C$	Error
15	11-Jun -02	0.12	0.00	30-Jul -02	88.5	4.3
17	28-May-02	0.09	0.00	02-Jul -02	82.4	3.5
27	23-Apr -02	0.11	0.01	23-May-02	81.6	3.2
29	19-Dec -01	0.10	0.00	04-Feb -02	87.1	3.8
34	19-Feb -02	0.09	0.00	05-Aug -02	86.6	4.2
38	10-Jun -02	0.15	0.00	30-Jul -02	83.7	4.4
51	24-Apr -02	0.09	0.00	23-May-02	79.9	4.2
57	18-Dec -01	0.08	0.00	04-Feb -02	86.8	3.4
58	07-Nov -01	0.14	0.01	04-Dec -01	83.6	3.8
60	08-May-02	0.10	0.00	02-Jul -02	79.7	3.0
66	14-Jun -02	0.12	0.01	20-Aug -02	81.4	4.3
73	28-Jun -02	0.14	0.00	20-Aug -02	90.1	3.1
75	22-Apr -02	0.16	0.00	23-May-02	79.7	3.4
78	10-May-02	0.11	0.01	02-Jul -02	78.6	3.2
85	26-Apr -02	0.11	0.00	23-May-02	82.3	4.0
86	12-Jun -02	0.15	0.00	05-Aug -02	82.0	4.0
95	14-Nov -01	0.13	0.00	01-Feb -02	80.1	3.2
99	20-Dec -01	0.08	0.00	25-Feb -02	91.2	3.7
113	07-Jan -02	0.07	0.01	28-Feb -02	94.9	3.8
	mean	0.11		mean	84.2	
	standard deviation	**0.03**		standard deviation	**4.5**	

Quality control flag assignment

Quality flag values were assigned to all ^{13}C and ^{14}C measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev.2 section 4.5.2 (Joyce *et al.*, 1994). Measurement flags of 2, 3, 4, 5, and 6 have been assigned (Table 4). For the choice between 2 (good), 3 (questionable) or 4 (bad), we basically followed a flagging procedure that described by Key *et al.* (1996) as listed below:

  a. On a station-by-station basis, a datum was plotted against pressure. Any points not lying on a generally smooth trend were noted.

  b. [13]C (^{14}C) was then plotted against dissolved oxygen (silicate) concentration and deviant points noted. If a datum deviated from both the depth and dissolved oxygen (silicate) plots, it was flagged 3.

c. Data below 1000 m depth were checked against the first visits of WHP P17N (1993) and P17C (1991). Deviant points were flagged 3.
d. Vertical sections against depth (see section 6) were prepared using the Ocean Data View (Schlitzer, 2002). If a datum was anomalous on the section plots, datum flag was degraded from 2 to 3, or form 3 to 4.

Table 4: Summary of assigned quality control flags

Flag	Definition	Number	
		^{13}C	^{14}C
2	Good	571	562
3	Questionable	12	18
4	Bad	3	5
5	Not reported (missing)	9	10
6	Replicate	60	60
	Total	**655**	**655**

Data Summary

Figure 17 shows vertical sections of $_{13}C$ (upper) and $_{14}C$ (lower) against depth. $_{13}C$ value is large in surface water and its minimum appears in mid layer (200 – 1000 m). This ^{13}C profile is consistent with vertical profile of dissolved oxygen concentration, suggesting strong biological effect on the ^{13}C vertical profile. ^{14}C vertical profile is similar with the ^{13}C profile: larger value in surface and mid layer minimum (2000 – 2500 m). This profile, however, is controlled by "physical" factors, namely both intrusion of the bomb-produced ^{14}C in surface water and decrease due to the radioactive decay. On the other hands, slight increases of both ^{13}C and ^{14}C near bottom indicate bottom ventilation by "younger" Pacific Bottom Water in the eastern North Pacific.
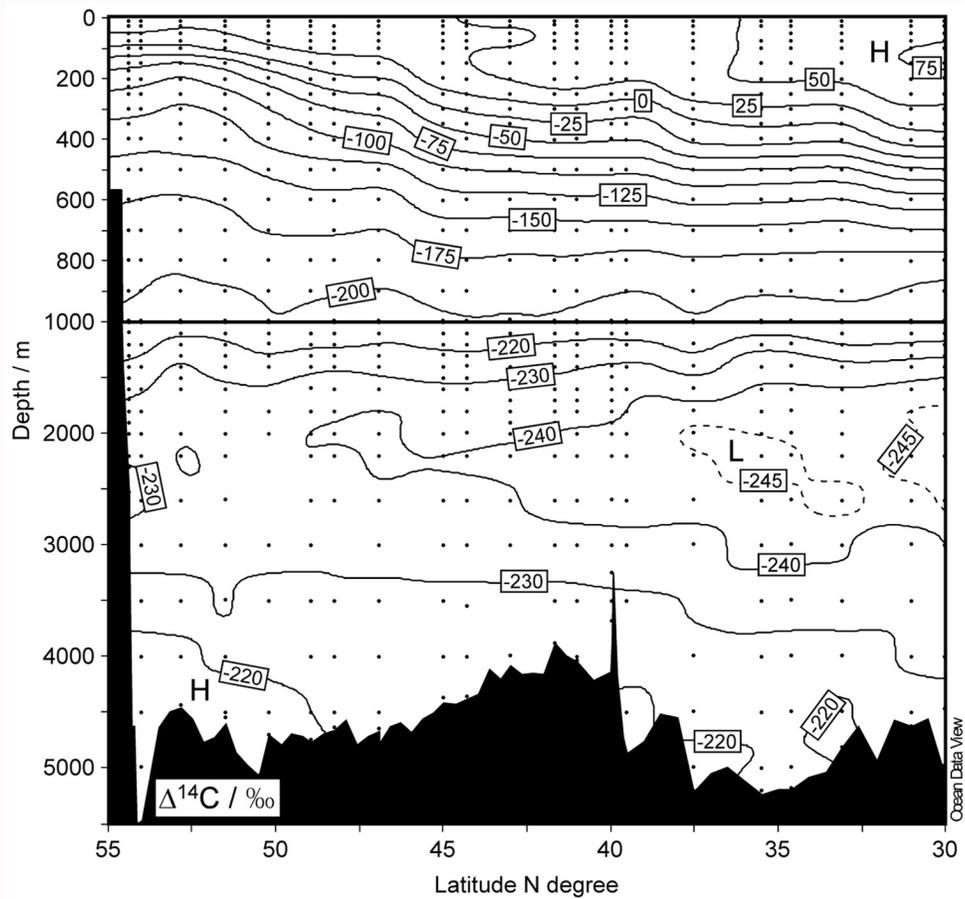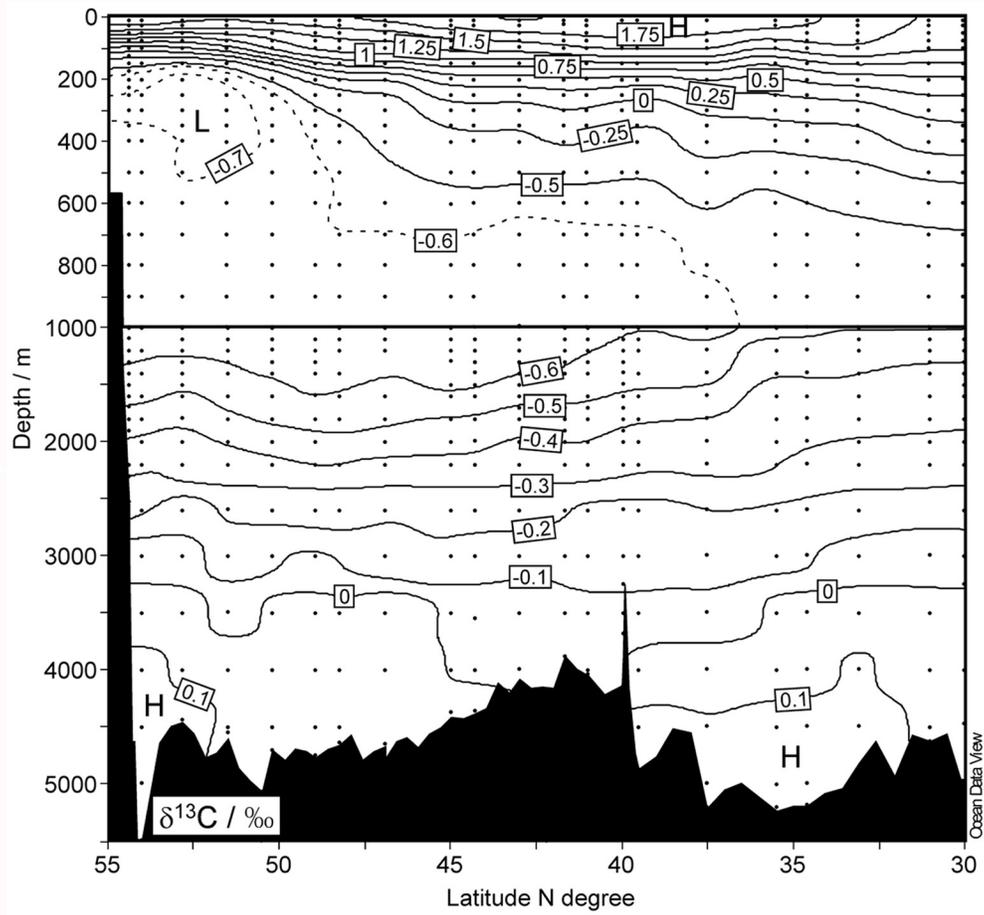
Figure 17: Vertical sections of d13C (upper) and D14C (lower) against depth during P17N revisit cruise in August 2001.

In surface and intermediate waters (< 1000 m), comparison of ^{13}C and ^{14}C between the first visit in 1991 (Tsuchiya, 2002) & 1993 (Musgrave, 2002) and the revisit in 2001 will evaluate water circulation and air-sea gas exchange in the eastern North Pacific during the past decade. However, it is hard to discuss temporal change of ^{13}C, because the previous data in 1991 and 1993 were sparse. ^{14}C in surface water above 200 m depth decreased at all the stations in the past decade. At the northernmost stations in the Alaskan Stream, radiocarbon decrease was also observed in deeper layer. While radiocarbon increased in the mid layer around 35°N, in the other stations the intermediate radiocarbon decreased slightly or did not change. Further discussion about these changes in ^{14}C will be described in other publications.

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3.7 CTD/O2 Measurements
13 Mar 2002

Personnel

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Winch arrangements

The CTD package wad deployed using 4.5 Ton Traction Winch System (Dynacon, Inc., USA) which was installed to the *R/V Mira*i in April 2001. The CTD Traction Winch System with the Heave Compensation Systems (Dynacon, Inc., USA) is designed to reduce cable stress resulted from loads variation caused by wave or vessel motion. The system is operated passively by providing a nodding boom crane that moves up or down in response to line tension variations. Primary system components include a complete CTD Traction Winch System with 10 km of 9.5 mm armored cable rocker and Electro-Hydraulic Power Unit, nodding-boom crane assembly, two hydraulic cylinders and two hydraulic oil/nitrogen accumulators mounted within a single frame assembly. The system also contains related electronic hardware interface and a heave compensation computer control program.

Overview of the equipment

The CTD system, SBE911plus system (Sea-Bird Electronics, Inc., USA), is a real time data system with the CTD data transmitted from a SBE 9plus underwater unit via a conducting cable to the SBE 11plus deck unit. The SBE 11plus deck unit is a rack-mountable interface which supplies DC power to the underwater unit, decodes the serial data stream, formats the data under microprocessor control, and passes the data to a companion computer. The serial data from the underwater unit is sent to the deck unit in RS-232 NRZ format using a 34560 Hz carrier-modulated differential-phase-shift-keying (DPSK) telemetry link. The deck unit decodes the serial data and sends them to a personal computer to display, at the same time, to storage in a disk file using SBE SEASOFT software.

The SBE 911pus system acquires data from primary, secondary and auxiliary sensors in the form of binary numbers corresponding to the frequency or voltage outputs from those sensors at 24 samples per second. The calculations required to convert from raw data to engineering units of the parameters are performed by the SBE SEASOFT in real-time. The same calculations can be carried out after the observation using data stored in a disk file.

The SBE 911plus system controls the 36-position SBE 32 Carousel Water Sampler. The Carousel accepts 12-litter water sample bottles. Bottles ware fired through the RS-232C modem connector on the back of the SBE 11plus deck unit while acquiring real time data. The 12-litter Niskin-X water sample bottle (General Oceanics, Inc., USA) is equipped with two stainless steel springs externally. The external springs are ideal for applications such as the trace metal analysis because the inside of the sampler is free from contaminants from springs.

SBE's standard temperature (SBE 3F) and conductivity (SBE 4) sensor modules were used with the SBE 9plus underwater unit fixed by a single clamp and "L" bracket to the lower end cap. The conductivity cell entrance is co-planar with the tip of the temperature sensor's protective steel sheath. The pressure sensor is mounted in main housing of the underwater unit and is ported to outside through the oil-filled plastic capillary tube. A compact, modular unit consisting of a centrifugal pump head and a brushless DC ball bearing motor contained in an aluminum underwater housing pump (SBE 5T) flushes water through sensor tubing at a constant rate independent of the CTD's motion. Motor speed and pumping rate (3000 rpm) remain nearly constant over the entire input voltage range of 12-18 volts DC.

The system used in this cruise is summarized as follows:

Under water unit	SBE, Inc.	SBE 9plus,	S/N 79492	
Temperature sensor (primary)	SBE, Inc.	SBE 3-04/F,	S/N 031464	
Temperature sensor (secondary)	SBE, Inc.	SBE 3-04/F,	S/N 031524	
Conductivity sensor (primary)	SBE, Inc.	SBE 4-04/0,	S/N 041203	
Conductivity sensor (secondary)	SBE, Inc.	SBE 4-04/0,	S/N 041206	
Oxygen sensor (primary)	SBE, Inc.	SBE 13-04,	S/N 130540	from station 431 to P17N 30
	SBE, Inc.	SBE 43,	S/N 430069	from station P17N 31 to P17N 99
Oxygen sensor (secondary)	SBE, Inc.	SBE 43,	S/N 430069	from station 431 to P17N 30
	SBE, Inc.	SBE 13-04,	S/N 130540	from station P17N 31 to P17N 99
Pump (primary)	SBE, Inc.	SBE 5T,	S/N 053118	
Pump (secondary)	SBE, Inc.	SBE 5T,	S/N 050984	
Altimeter	Benthos, Inc.	2110-2,	S/N 228	from station 431 to P17N 29, and
	Benthos, Inc.	2110-2,	S/N 228	from station P17N 31 to P17N 33
	Benthos, Inc.	2110-2,	S/N 206	station P17N 30
	Datasonics, Inc.	PSA-900D,	S/N 396	from station P17N 34 to P17N 99
Fluorometer	Seapoint sensors, Inc.		S/N 2148	
Transmissometer	WET Labs, Inc.	C-Star Transmissometer	S/N CST-207RD	
Deck unit	SBE, Inc.	SBE 11plus,	S/N 11P8010-0308	from station 431 to P17N 70
	SBE, Inc.	SBE 11plus,	S/N 11P7030-0272	from station P17N 71 to P17N 99
Carousel Water Sampler	SBE, Inc.	SBE 32,	S/N 3221746-0278	
Water sample bottle	General Oceanics, Inc.	12-litter Niskin-X		

Pre-cruise calibration

(1) Pressure

The Paroscientific series 4000 Digiquartz high pressure transducer (Paroscientific, Inc., USA) uses a quartz crystal resonator whose frequency of oscillation varies with pressure induced stress with 0.01 per million of resolution over the absolute pressure range of 0 to 15,000 psia (0 to 10,332 dbar). Also, a quartz crystal temperature signal is used to compensate for a wide range of temperature changes at the time of an observation. The pressure sensor (MODEL 415K-187) has a nominal accuracy of 0.015% FS (1.5 dbar), typical stability of 0.0015% FS/month (0.15 dbar/month) and resolution of 0.001% FS (0.1 dbar).

Pre-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were used in the SEASOFT through software module SEACON:

S/N 79492 October 27, 1999

c_1 =	-65706.8
c_2 =	-0.1758329
c_3 =	2.04245e-02
d_1 =	0.027146
d_2 =	0.0
t_1 =	29.92375
t_2 =	-2.63869e-04
t_3 =	3.92132e-06
t_4 =	1.35947e-09
t_5 =	4.49704e-12

(The coefficients c_1, c_2, t_1 and t_2 were changed on December 6, 1999.)

Pressure coefficients are first formulated into

$$c = c_1 + c_2 * U + c_3 * U^2$$
$$d = d_1 + d_2 * U$$
$$t_0 = t_1 + t_2 * U + t_3 * U^2 + t_4 * U^3 + t_5 * U^4$$

where U is temperature in degrees Celsius. The pressure temperature, U, is determined according to

$$U (degC) = M * (12 \text{ bit pressure temperature compensation word}) - B$$

The following coefficients were used in SEASOFT through software module SEACON:

M =	1.284934e-2
B =	-8.388034

(in the underwater unit system configuration sheet dated on November 30, 1999)

Finally, pressure is computed as

$$P \text{ (psi)} = c * [1 - (t0\wedge 2 / t\wedge 2)] * \{1 - d * [1 - (t0\wedge 2 / t\wedge 2)]\}$$

where t is pressure period (microsec). Since the pressure sensor measures the absolute value, it inherently includes atmospheric pressure (about 14.7 psi). SEASOFT subtracts 14.7 psi from computed pressure above automatically.

Pressure sensor calibration against a dead-weight piston gauge are performed at Marine Works Japan Ltd. in Yokosuka, Kanagawa, Japan, usually once in a year in order to monitor its time drift and the linearity. The pressure sensor drift is known to be primarily by an offset at all pressures rather than by a change of span slope. The pressure sensor hysterisis are typically 0.2 dbar. The following coefficients for the sensor drift correction were also used in SEASOFT through the software module SEACON:

S/N 79492 April 24, 2001

    slope = 0.99995898
    offset = 1.78677

The drift-corrected pressure is computed as

    Drift-corrected pressure (dbar) = slope * (computed pressure in dbar) + offset
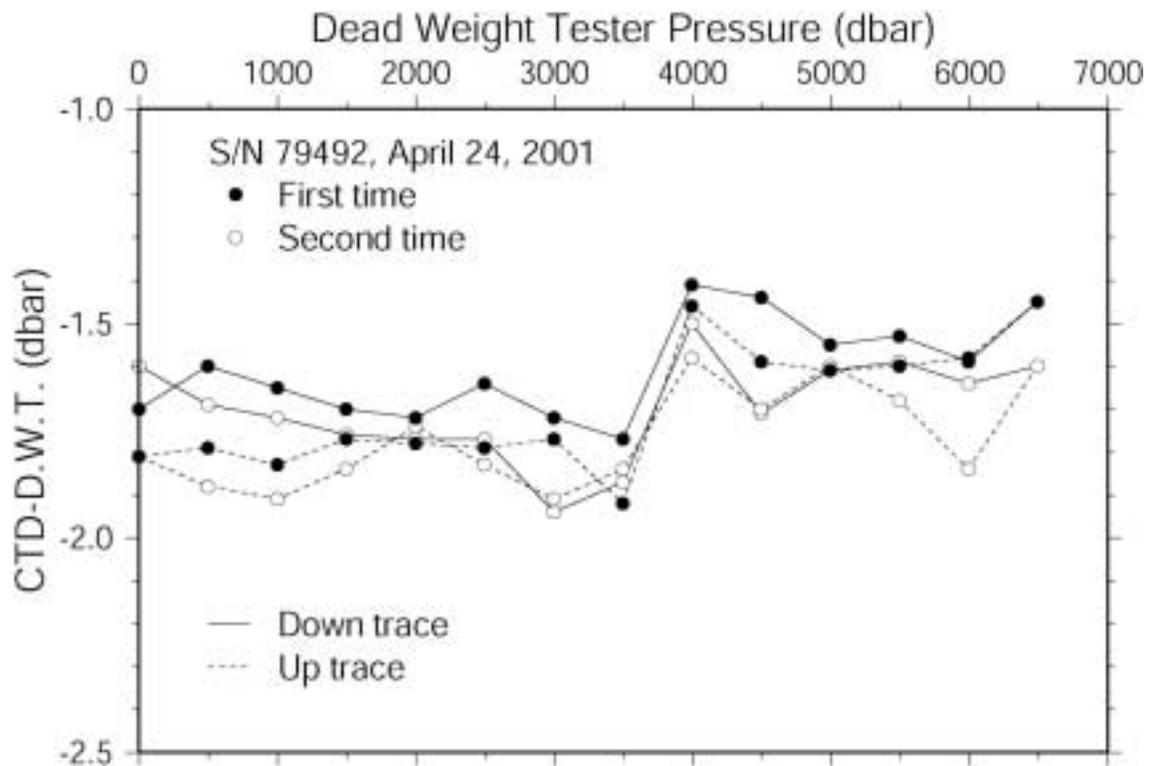

Figure 18: The residual pressures between the Dead Weight Tester and the CTD.

(2) Temperature (SBE 3F)

The temperature sensing element is a glass-coated thermistor bead in a stainless steel tube to provide a pressure-free measurement at depths up to 10,500 meters. The sensor output frequency ranges from approximately 5 to 13 kHz corresponding to temperature from –5 to 35 degC. The output frequency is inversely proportional to the square root of the thermistor resistance, which controls the output of a patented Wien Bridge circuit. The thermistor resistance is exponentially related to temperature. The SBE 3F thermometer has a nominal accuracy of 0.001 degC, typical stability of 0.0002 degC/month and resolution of 0.0002 degC at 24 samples per second.

Pre-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were used in SEASOFT through the software module SEACON:

S/N 031464 (primary) June 16, 2001

g =	4.84394400e-03
h =	6.80848240e-04
i =	2.70328214e-05
j =	2.13867061e-06
f0 =	1000.000

S/N 031524 (secondary) June 16, 2001

g =	4.83484327e-03
h =	6.75462258e-04
i =	2.64451174e-05
j =	2.13440093e-06
f0 =	1000.000

Temperature (ITS-90) is computed according to

Temperature (ITS-90) =

$$1 / \{g + h * [\ln(f0 / f)] + i * [\ln^2(f0 / f)] + j * [\ln^3(f0 / f)]\} - 273.15$$

where f is the instrument frequency (kHz).

(3) Conductivity (SBE 4)

The flow-through conductivity sensing element is a glass tube (cell) with three platinum electrodes to provide in-situ measurements at depths up to 10,500 meters. The impedance between the center and the end electrodes is determined by the cell geometry and the specific conductance of the fluid within the cell. The conductivity cell composes a Wien Bridge circuit with other electric elements of which frequency output is approximately 3 to 12 kHz corresponding to conductivity of the fluid from 0 to 7 S/m. The conductivity cell of SBE 4 has a nominal accuracy of 0.0003 S/m, typical stability of 0.0003 S/m/month and resolution of 0.00004 S/m at 24 samples per second.

Pre-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were used in SEASOFT through the software module SEACON:

S/N 041203 (primary) June 15, 2001

g	= -4.05180978
h	= 4.93348008e-01
i	= 9.46008409e-05
j	= 2.18812300e-05
CPcor	= -9.57e-08 (nominal)
CTcor	= 3.25e-06 (nominal)

S/N 041206 (secondary) June 15, 2001

g	= -4.28945276
h	= 5.03354673e-01
i	= 1.03033274e-04
j	= 2.08217238e-05
CPcor	= -9.57e-08 (nominal)
CTcor	= 3.25e-06 (nominal)

Conductivity of a fluid in the cell is expressed as:

$$C \ (S/m) = (g + h * f^2 + i * f^3 + j * f^4) / [10 \ (1 + CTcor * t + CPcor * p)]$$

where f is the instrument frequency (kHz), t is the water temperature (degC) and p is the water pressure (dbar). The value of conductivity at salinity of 35, temperature of 15 degC (IPTS-68) and pressure of 0 dbar is 4.2914 S/m.

(4) Oxygen (SBE 13)

The SBE 13 dissolved oxygen sensor uses a Beckman polarographic element to provide in-situ measurements at depths up to 10,500 meters. The sensor is included in the path of pumped sea water. The oxygen sensor determines the dissolved oxygen concentration by counting the number of oxygen molecules per second (flux) that diffuse through a membrane. By knowing the flux of oxygen and the geometry of the diffusion path, the concentration of oxygen can be computed. The permeability of the membrane to oxygen is a function of temperature and ambient pressure. The interface electronics outputs voltages proportional to oxygen flux (oxygen current) and membrane temperature (oxygen temperature). Oxygen temperature is used for internal temperature compensation. Computation of dissolved oxygen in engineering units is done in SEASOFT software. The range for dissolved oxygen is 0 to 15 ml/l; nominal accuracy is 0.1 ml/l; resolution is 0.01 ml/l.

The following coefficients were used in SEASOFT through the software module SEACON:

S/N 130540 June 18, 2001

m =	2.4424e-07
b =	-4.2986e-10
k =	8.9712
c =	-6.8923
Soc =	2.2237
Boc =	-0.0143
tcor =	-0.033
pcor =	1.50e-04
tau =	2.0
wt =	0.67

The use of these constants in linear equations of the form $I = m * V + b$ and $T = k * V + c$ yield the oxygen current and the oxygen temperature (with a maximum error of about 0.5 degC), respectively. These scaled values of the oxygen current and the oxygen temperature are used in the SEASOFT processing stream.

The oxygen sensor of S/N 130540 was used with primary temperature and conductivity sensors at stations from 431 to P17N 30 and used with secondary temperature and conductivity sensors at station from P17N 31 to P17N 99.

(5) Oxygen (SBE 43)

The SBE 43 oxygen sensor uses a Clark polarographic element to provide in-situ measurements at depths up to 7,000 meters. Calibration stability is improved by an order of magnitude and pressure hysterisis is largely eliminated in the upper ocean (1000 m). Continuous polarization eliminates the wait-time for stabilization after power-up. Signal resolution is increased by on-board temperature compensation. This Sensor is also included in the path of pumped sea water. This oxygen sensor determines the dissolved oxygen concentration also by counting the number of oxygen molecules per second (flux) that diffuse through a membrane, where the permeability of the membrane to oxygen is a function of temperature and ambient pressure. Computation of dissolved oxygen in engineering units is done in SEASOFT software through almost the same way as for the case of SBE 13. The range for dissolved oxygen is 120% of surface saturation in all natural waters; nominal accuracy is 2% of saturation; typical stability is 2% per 1000 hours.

The following coefficients were used in SEASOFT through the software module SEACON:

S/N 430069 July 6, 2001

Soc=	0.3268
Boc=	0.0184
TCor=	0.0004
PCor=	1.500e-04
Offset=	-0.6181
tau=	0

Oxygen (ml/l) is computed as

$$\text{Oxygen (ml/l)} = [\text{Soc} * \{(v + \text{offset}) + (\text{tau} * doc/dt)\} + \text{Boc} * \exp(-0.03 * t)] * \exp(\text{TCor} * t + \text{PCor} * p) * \text{Oxsat}(t, s)$$

$$\text{Oxsat}(t, s) = \exp[A1 + A2 * (100 / t) + A3 * \ln(t / 100) + A4 * (t / 100) + s * (B1 + B2 * (t / 100) + B3 * (t / 100) * (t / 100))]$$

where p is pressure in dbar, t is absolute temperature and s is salinity in psu. Oxsat is oxygen saturation value minus the volume of oxygen gas (STP) absorbed from humidity-saturated air. Its coefficients are as follows;

A1	=	-173.4292
A2	=	249.6339
A3	=	143.3483
A4	=	-21.8482
B1	=	-0.033096
B2	=	-0.00170

The oxygen sensor of S/N 130540 was used with secondary temperature and conductivity sensors at stations from 431 to P17N 30 and used with primary temperature and conductivity sensors at station from P17N 31 to P17N 99.

(6) Altimeter

The Benthos 2110 Series Altimeter (Benthos, Inc., USA) follows the basic principal of most echo ranging devices. That is, a burst of acoustic energy is transmitted and the time until the first reflection is received is determined. In this unit, a 400 microsecond pulse at 100 kHz is transmitted twice a second; concurrent with the transmission, a clock is turned off, thus the number of pulses out relates directly to the distance of the target from the unit. The internal ranging oscillator has an accuracy of approximately 5% and is set assuring a speed of sound of 1500 m/s. Thus the unit itself, neglecting variations in the speed of sound, can be considered accurate to 5% or 0.1 meter, whichever is greater. The unit is rated to a depth of 12,000 meters.

The Datasonics PSA-900 Programmable Sonar Altimeter (Datasonics, Inc., USA) determines the distance of the target from the unit in almost the same way as the Benthos 2110. PSA-900 also uses also uses the nominal speed of sound as 1500 m/s. But, PSA-900 compensates for sound velocity errors due to temperature. In a PSA-900 operating at a 350 microsecond pulse at 200 kHz, the jitter of the detectors can be as small as 5 microseconds or approximately 0.4 centimeters total distance. Since the total travel time is divided by two, the jitter error is 0.25 centimeters. The unit is rated to a depth of 6,000 meters.

The following scale factors were used in SEASOFT through the software module SEACON:

FSVolt * 300 / FSRange = 0.5
Offset = 0.0

(7) Fluorometer

The Seapoint Chlorophyll Fluorometer (Seapoint sensors, Inc., USA) is a high-performance, low power instrument to provide in-situ measurements of chlorophyll-a at depths up to 6,000 meters. The instrument uses modulated blue LED lamps and a blue excitation filter to excite chlorophyll-a. The fluorescent light emitted by the chlorophyll-a passes through a red emission filter and is detected by a silicon photodiode. The low level signal is then processed using synchronous demodulation circuitry which generates an output voltage proportional to chlorophyll-a concentration.

The following coefficients were used in SEASOFT through the software module SEACON as user defined polynomial:

S/N 2148 (unknown calibration date)

A0 = 0.0
A1 = 5.0

Chlorophyll-a concentration is computed as

Chlorophyll-a (ug/l) = A0 + A1 * Voltage

(8) Transmissometer

The C-Star Transmissometer (WET Labs, Inc., USA) measures light transmittance at a single wavelength over a known path. In general, losses of light propagating through water can be attributed to two primary causes: scattering and absorption. By projecting a collimated beam of light through the water and placing a focused receiver at a known distance away, one can quantify these losses. The ratio of light gathered by the receiver to the amount originating at the source is known as the beam transmittance. Suspended particles, phytoplankton, bacteria and dissolved organic matter contribute to the losses sensed by the instrument. Thus, the instrument provides information both for an indication of the total concentrations of matter in the water as well as for a value of the water clarity.

The following coefficients were used in SEASOFT through the software module SEACON:

S/N CST-207RD March 19, 1998

M	= 19.6415
B	= -1.3945
Path length (m)	= 0.25

The beam transmittance (Tr) iscomputed as

Tr (%) = M * voltage + B

Data Collection and Processing

(1) Data collection

CTD/O2 measurements were made using a SBE 9plus CTD equipped with two pumped temperature-conductivity (TC) sensors and dissolved oxygen sensor pair. The TC pairs ware monitored to check drift and shifts by examining the differences between the two pairs. Also a newly developed oxygen sensor (SBE 43) was compared with a Beckman type oxygen sensor (SBE 13).

The SBE 9plus CTD/O2 (sampling rate of 24 Hz) was mounted in a 36-position frame. Auxiliary sensors included altimeter, fluorometer and transmissometer. Water samples were collected using a 36-bottle SBE 32 Carousel Water Sampler with 12-litter Nisken-X bottles.

The package was lowered into the water from the board side and was held 10 m beneath the surface for about one minute in order to activate the pump. After the pump was activated the package was lowered at a rate of 0.5 m/s to 100 m then the package was stopped in order to operate the heave compensator of the crane. The package was lowered again at a rate of 0.8 m/s to 300 m, 1.0 m/s to 500 m, and 1.2 m/s to the bottom. The position of the package relative to the bottom was monitored by the altimeter reading. Also the bottom depth was monitored by the SEABEAM multibeam sounder on the board. For the up cast, the package was heightened at a rate of 1.2 m/s except for a time when sampling water at a rate of 0.5 m/s. At 100 m deep from the surface, the package was stopped in order to stop the heave compensator of the crane.

Niskin-X bottle sampled water for analysis of salinity, dissolved oxygen, inorganic nutrients, CFCs, DIC, C-14, pH and total alkalinity. The 36-position frame and Niskin-X bottles were periodically wiped with acetone in order to prevent water samples from contamination. Niskin-X bottle's caps and O-rings were re-arranged and wiped with acetone when a bottle leaking was found.

The SBE 11plus deck unit received the data signal from the CTD. Digitized data were forwarded to a personal computer prepared for SEASAVE module of the SEASOFT acquisition and processing software of which version was 4.249. Temperature, salinity, oxygen and descent rate profiles were displayed in real-time with the package depth and altimeter reading.

(2) Data collection problems

At station P17N 29, altimeter reading was not stable and altimeter was replaced after the cast. At station P17N 30, the replaced altimeter did not work correctly and the altimeter which was removed at P17N 29 was used again. At station P17N 33, altimeter did not work and replaced with other one after the cast.

At station P17N 36, SEASAVE data acquisition software was restarted during the package was holding at 10 m depth because of incorrect setting of the software. Therefore, data shallower than 10 m were lost.

At station P17N 47, up cast CTD data was very noisy and sensor connectors were checked and cleaned after the cast. At station P17N 71, bottle #1 fired unwillfully at 900 m depth during the down cast and the first cast was aborted. On the second cast, communication error was detected at 90 m depth during the down cast and the cast was aborted. CTD cable was checked electrically and some of connectors were replaced. Also the deck unit was replaced to complete the third cast.

At station P17N 76, 78, 82, 83 and 86, the down cast was started without holding at 10 m depth because of bad weather. At station P17N 77, the package was lowered and stopped at 20 m depth because the pump did not work at 10 m depth. So the down cast was started from 20 m depth.

At station P17N 94, descent rate exceeded 3 m/s for unknown reason and the package was stopped at 326 m deep. Then the down cast was restarted checking the heave motion mechanism of the crane. A communication error was detected when the package was lowered faster than 0.8 m/s. Therefore, the package had to be lowered at slower rate than 0.8 m/s to the bottom. During the up cast, bottle #1 did not fire. Hence, the deck unit and SEASAVE data acquisition software were restarted at 100 m above bottom and the up cast restarted at the 10 m above bottom. After the cast, the end of the CTD cable was cut about 50 m. At station P17N 96, sensor error was detected at 80 m depth during the down cast and the cast was aborted. After the cast, sensor connectors were checked.

(3) Other incidents of note

Before the first CTD station of this cruise, load test of CTD cable was performed on the deck up to 4.5 ton load. At station 431, CTD package was lowered to 100 m deep before the down cast in order to regulate CTD winch system. Also on the second cast at station 431, CTD package was lowered further 70 m after firing all bottles at 3000 m deep in

order to regulate CTD winch system. After the station P17N 76, the CTD cable was cut 50 m from the end and load test of CTD cable was performed on the deck up to the load of 3.3 ton. After the station P17N 94, the CTD cable was cut 23 m from the end and load test of CTD cable was performed on the deck up to the load of 4 ton.

On the fourth cast at station 431, stainless steel weight of 60 kg (10 kg * 6) were attached to the water sampler frame in order to increase the tension of the CTD cable near the surface. After the CTD cast at station P17N 40, more stainless steel weight of 60 kg (10 kg * 6) were added to the water sampler frame so that the CTD package stops rotating horizontally during down casts. But the rotation rate of the package checked from the LADCP data still to be about 0.5 revolution per minute. Therefore, at station P17N 64 and 67, the package was stopped one hour at 100 m above bottom in order to untwist the cable before the up cast.

At station P17N 69, the package was stopped 20 minutes at 100 m deep in the down cast in order to supply nitrogen gas to the Heave Compensation System. The CTD package was stopped a few minutes in order to stabilize the heave motion during down casts at station P17N 66 (1545 m), P17N 67 (350 and 1450 m), P17N 70 (1000 m), P17N 73 (1363 and 1611 m), P17N 80 (940 m), P17N 90 (723 m) and P17N 92 (1365 m).

Since the new oxygen sensor SBE 43 was recognized as a surprisingly good sensor compared to the old oxygen sensor SBE 13, the new sensor was used as primary sensor and the old sensor was used as secondary sensor after P17N 31.

CTD casts at station P17N 41 and 91 has been scheduled to be skipped. The station P17N X01 was located at the same geographical position as station 92 of WHP-P01, where CTD casts were carried out in 1985 by R/V Thomas Thompson and in 1999 by *R/V Mirai* and *R/V J.P. Tully*.

The CTD cast at station P17N 76 was delayed about 2 days than the plan because sea and weather were too severe for a CTD operation. For this reason, the station P17N 85 and 89 were canceled and the station P17N 95 and 97 were replaced with XCTD casts.

Data processing

SEASOFT:
consists of modular menu driven routines for acquisition, display, processing, and archiving of oceanographic data acquired with SBE equipment and is designed to work with an IBM or compatible personal computer. Raw data are acquired from instruments and are stored as unmodified data. The conversion module DATCNV uses the instrument configuration and calibration coefficients to create a converted engineering unit data file that is operated on by all SEASOFT post processing modules. Each SEASOFT module that modifies the converted data file adds proper information to the header of the converted file permitting tracking of how the various oceanographic parameters were obtained. The converted data is stored in either rows and columns of ascii numbers. The last data column is a flag field used to mark scans as good or bad.

The following are the SEASOFT-Win32 (Ver. 5.21 or 5.23) processing module sequence and specifications used in the reduction of CTD/O2 data in this cruise. Some modules are originally developed for additional processing and post-cruise calibration.

DATCNV:
converted the raw data to scan number, pressure, temperatures, conductivities, oxygen current (SBE 13), oxygen temperature (SBE 13), oxygen voltage (SBE 43), chlorophyll-a concentration, transmissometer voltage and altitude. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition. The first scan was set to 2 seconds prior to the confirm bit and the duration was set to 4 seconds.

ROSSUM:
created a summary of the bottle data. The bottle position, date, time were output as the first two columns. Pressure, temperatures, conductivities, oxygen current (SBE 13), oxygen temperature (SBE 13), oxygen voltage (SBE 43), chlorophyll-a concentration, transmissometer voltage and altitude were averaged over 4 seconds.

ALIGNCTD:
converted the time-sequence of conductivity and oxygen sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9 CTD with the ducted temperature and conductivity sensors and a 3000 rpm pump, the typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit was set to advance the primary conductivity for 1.73 scans (1.75/24 = 0.073 seconds). As the result, the secondary conductivity was advanced 0.073 seconds relative to the temperature. Oxygen data are also systematically delayed with respect to depth mainly because of the long time constant of the oxygen sensor and of an additional delay from the transit time of water in the pumped plumbing line. As for the temperature and the conductivity, this delay was compensated by 5 seconds advancing oxygen sensor outputs relative to the pressure.

WILDEDIT:
marked extreme outliers in the data files. The first pass of WILDEDIT obtained an accurate estimate of the true standard deviation of the data. The data were read in blocks of 48 scans. Data greater than two standard deviations were flagged. The second pass computed a standard deviation over the same 48 scans excluding the flagged values. Values greater than 10 standard deviations were marked bad. This process was applied to pressure, temperatures, conductivities, oxygen and altimeter outputs. For oxygen voltage (SBE 43), values within displacement of 0.006 V from the mean were not marked bad. For oxygen current (SBE 13), values within displacement of 0.0015 microA from the mean were not marked bad. For oxygen temperature (SBE 13), values within displacement of 0.055 degC from the mean were not marked bad. For the data at stations of P17N 47 and P17N 71 cast 1, this process was applied twice in order to remove remaining spikes.

CELLTM:
used a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. Typical values were used for thermal anomaly amplitude (alpha = 0.03) and the time constant (1/beta = 9.0).

FILTER:
performed as a low pass filter on pressure with a time constant of 0.15 seconds. In order to produce zero phase lag (no time shift) the filter runs forward first then backwards.

WFILTER:
performed as a median filter to remove spikes in Fluorometer and Transmissometer data. A median value was determined by 49 scans of the window.

WHPHEADER:
(original module) added information in header record correspondingly to the WHP CTD data (EXPOCODE, WHP-ID, STNNBR, CASTNO, DATE, INSTRUMENT NO. and SAMPLING RATE).

SECTION:
selected a time span of data based on scan number in order to reduce a file size. The minimum number was set to be a starting time when the CTD package was beneath the sea-surface after the activation of the pump. The maximum number was set to be an ending time when the package came up from the surface. (Data to check the CTD pressure drift were prepared before SECTION.)

LOOPEDIT:
marked scans where the CTD was moving less than the minimum velocity of 0.0 m/s (traveling backwards due to ship roll).

DERIVE:
was used only to compute the time derivative of oxygen (for the term doc/dt of SBE 13) with a time window size of 2.0 seconds.

BINAVG:
averaged the data into 1 dbar pressure bins. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center value plus and minus half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data record exists every dbar.

DERIVE:
was re-used to compute salinity, depth, potential temperature, sigma-t and sigma-theta.

SPLIT:
was used to split data into the down cast and the up cast.

CTD/O2 Post-Cruise Calibration

(1) Pressure calibration

The CTD pressure sensor drift in the period of this cruise is estimated from the pressure readings on the ship deck. For best results the Paroscientific sensor has to be powered for at least 10 minutes before the operation and carefully temperature equilibrated. However, CTD system was powered only several minutes before the operation at most of stations. Only "pre-cast on deck CTD pressure" data with longer aging time than two minutes were selected and were averaged over one minute to prepare cariblation data for the pre-cast pressure sensor drift. As for the calibration data for the post-cast pressure sensor drift, the CTD deck pressure is averaged over last one minute to get a calibration data. Then the atmospheric pressure deviation from a standard atmospheric pressure (14.7 psi) is subtracted from the CTD pressure. The atmospheric pressure was measured at the captain deck (20 m high from the base line) and averaged over one minute for a meteorological data.

The CTD pressure sensor drift is estimated from the deck pressure obtained above. An average of the pre- and the post-casts data over the whole period of this cruise gave an estimation of –0.61 dbar and the root-mean-square difference of 0.14 dbar. Since the cruise period (August 2001) was 4 months later from the pre-cruise calibration (April 2001), the typical drift was expected about 0.6 dbar. The estimated drift (0.61 dbar) is comparable to the typical drift in the specification of the present pressure sensor. Finally the CTD pressure is calibrated as

Calibrated pressure (dbar) = p + 0.61
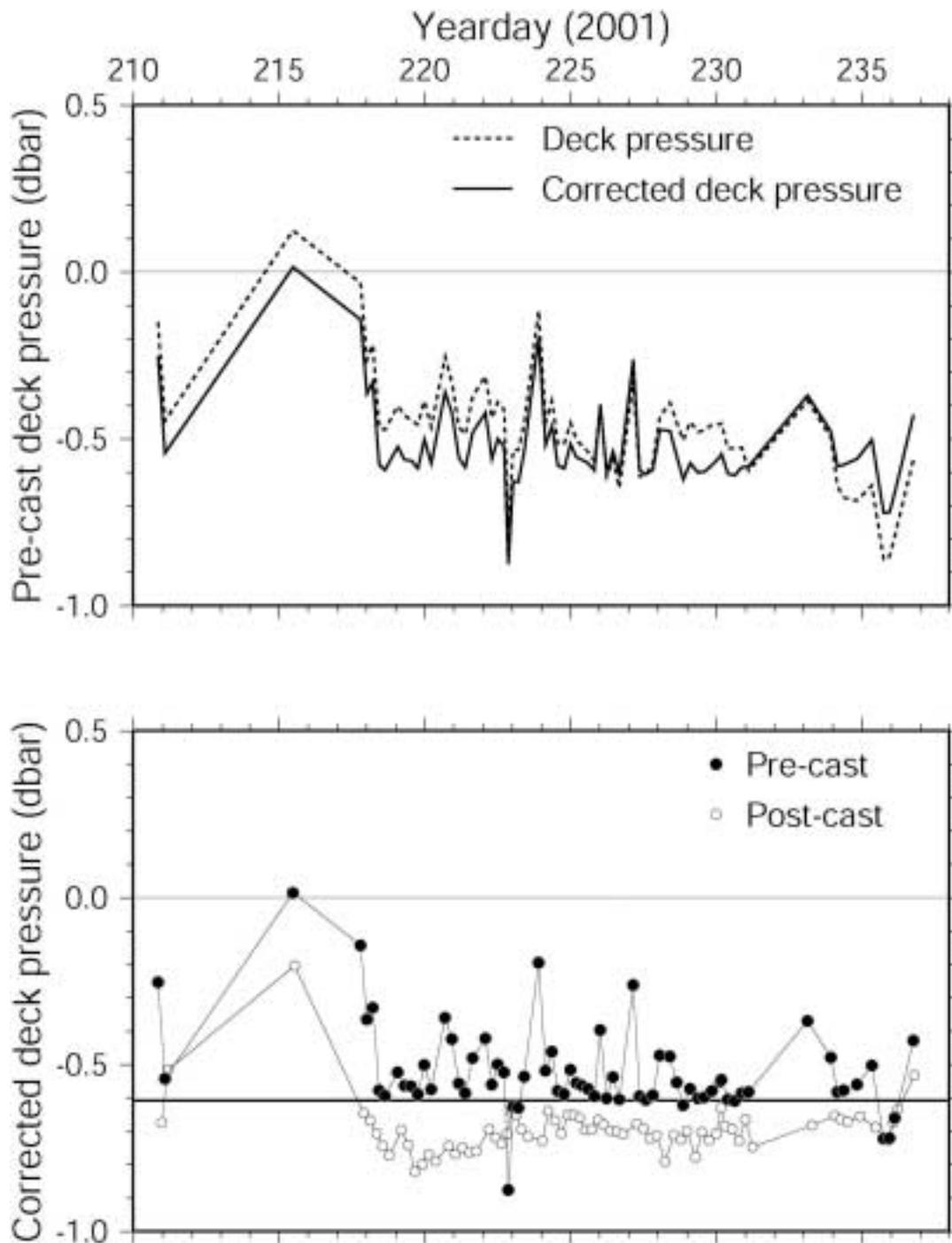
where p is the CTD pressure in dbar.

Figure 19: Time series of the CTD deck pressure. Upper panel shows the pre-cast deck pressure (dotted line) and the corrected deck pressure subtracting the atmospheric pressure deviation from the pre-cast deck pressure (solid line). Lower panel shows the corrected deck pressure for the pre- and post-cast.

(2) Temperature calibration

Post-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were the results.

S/N 031464 September 25, 2001

g	=	4.84437595e-03
h	=	6.81426982e-04
i	=	2.72899771e-05
j	=	2.17701451e-06
f0	=	1000.000

S/N 031524 September 25, 2001

g	=	4.83461183e-03
h	=	6.75115071e-04
i	=	2.62742100e-05
j	=	2.10734809e-06
f0	=	1000.000

These temperature sensor drifts are traced since 1994 based on laboratory calibrations performed at SBE, Inc. The mean absolute residuals between the bath temperature and the CTD temperature at 11 calibration points show almost linear tendency in time for the primary temperature sensor (about 1 mdegC per year). The CTD temperature drift during each period of observation is estimated lineally using the pre- and post-cruise laboratory calibration equations. The CTD temperature calibration was carried out by subtracting the corresponding estimated drift from in-situ temperature readings.
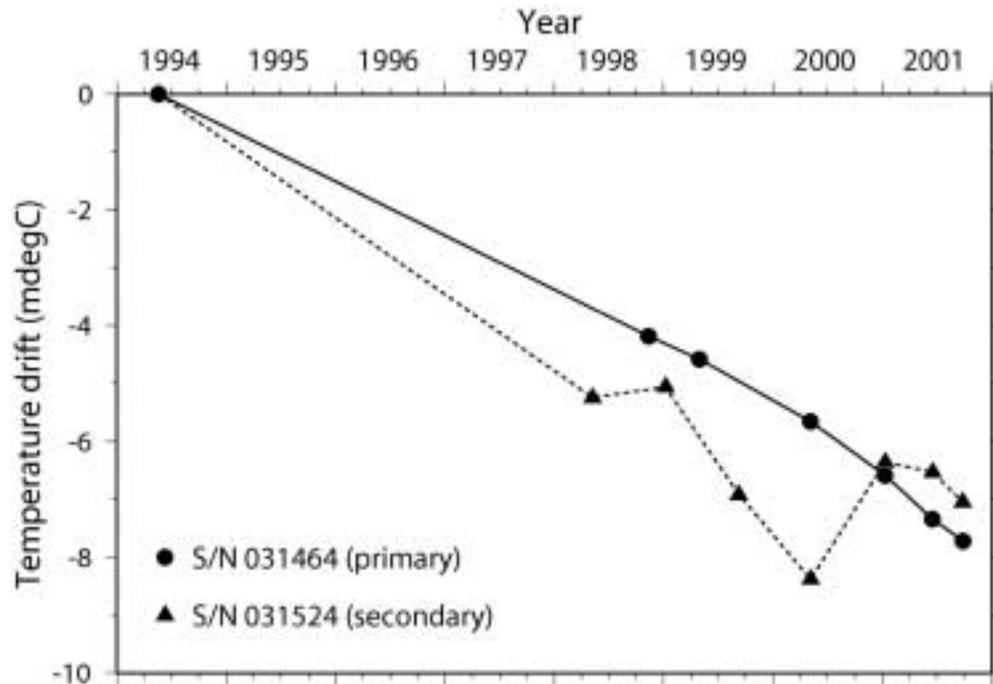

Figure 20: Temperature sensor drift based on laboratory calibrations performed at SBE, Inc.
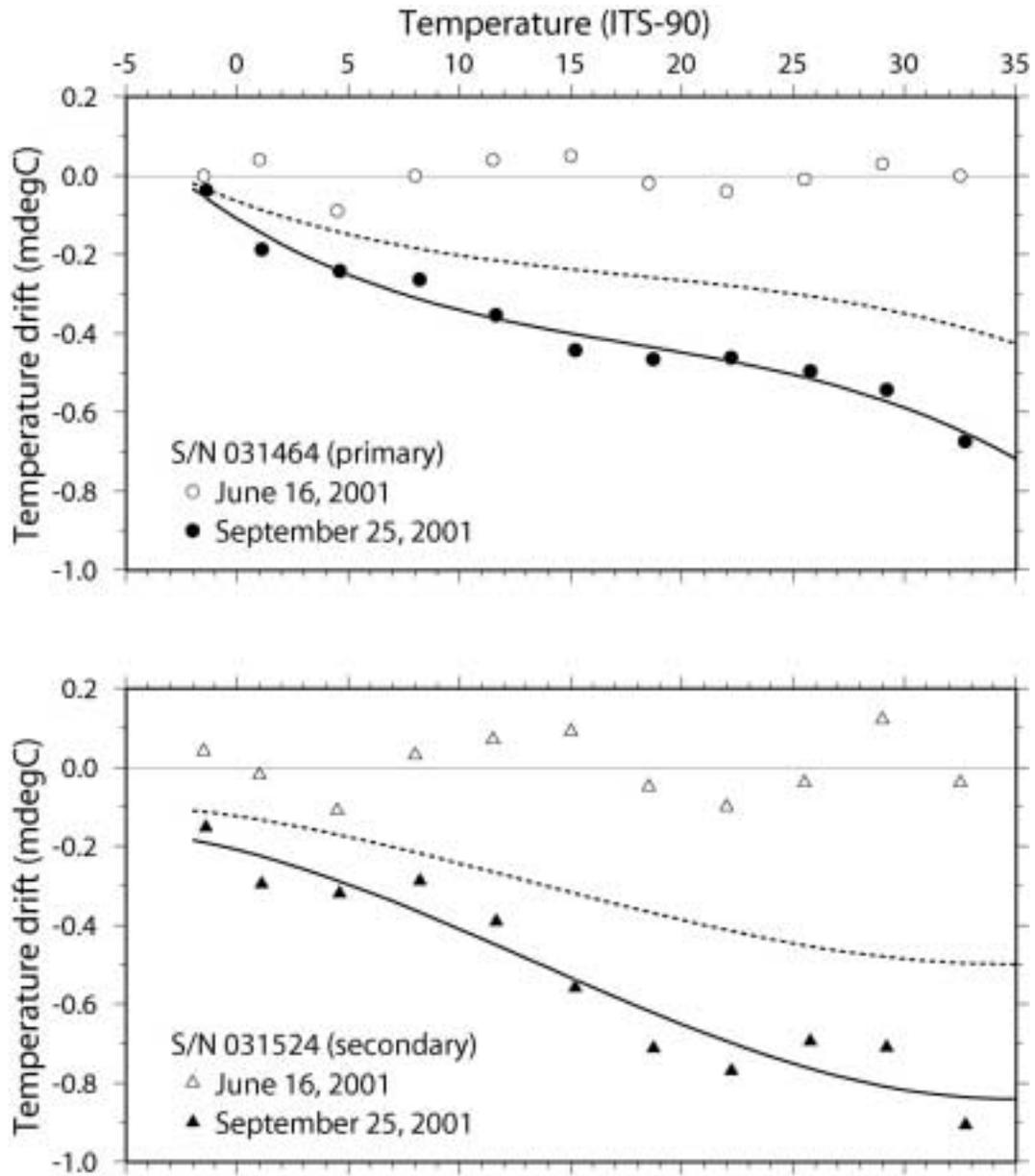
Figure 21: Temperature sensor drift between the pre-cruis calibration and the post-cruise calibration. Dotted line shows estimated drift at August 15, 2001. Upper panel is for the primary sensor and lower panel is for the secondary sensor.

(3) Salinity calibration

The discrepancies of the CTD salinity from the bottle salinity showed each linear behavior against the pressure at the depths upper and lower than about 2000 dbar, separately. Therefore the CTD salinity can be calibrated as

Calibrated salinity = s − (a0 + b0 * p) [when p < pr]
                    = s − (a1 + b1 * p) [when p >= pr]
        a0 + b0 * pr = a1 + b1 * pr

where s is CTD salinity, p is CTD pressure in dbar, pr is the bordering pressure in dbar (i.e. about 2000 dbar) and a0, b0, a1 and b1 are calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation from the bottle salinity data. Fortran routine MEDFIT in the Numerical Recipies (Press et al., 1986) is used with a slight modification to determine the sets. The coefficients of a1 and b1 are determined first then the coefficients of a0 and b0 are determined with a restriction that the two equations take same value at a pressure of pr.

The pr is set to 2000 dbar. The coefficients are determined for each station. For the station P17N 96, 98 and 99, only coefficients of a0 and b0 are determined with no restriction because the maximum pressure is shallower than 2000 dbar. The CTD data created by the software module ROSSUM are used after the post-cruise calibration for the CTD pressure and temperature. The calibration is performed for the CTD salinity calculated from the primary temperature and the primary conductivity sensor data. For depths where the vertical salinity gradient calculated from the up cast CTD data as greater than 0.003 (per dbar), bottle salinity data are not used for calibration because of the ambiguity resulted from the vertical separation of the bottles and CTD sensors. Nevertheless, for the station P17N 98 and 99, the threshold is enlarged to 0.01 and 0.03, respectively, because vertical salinity gradients greater than 0.003 (per dbar) at most of depths of observation.

The calibration coefficients, the mean absolute deviation (dev) from the bottle salinity
and the number of the data (n) used for the calibration are as follows:

Station		[P < pr]				[p >= pr]			
		a0	b0	dev	n	a1	b1	dev	n
P17C 26	1	-0.00323796359	8.36601939e-07	0.0037	19	-0.00271393877	5.74589528e-07	0.0002	11
P17C 25	1	-0.00257052449	8.82155636e-07	0.0014	16	-0.00132877162	2.61279201e-07	0.0002	13
P17C 24	1	-0.00331067064	1.16289883e-06	0.0016	16	-0.00184117328	4.28150144e-07	0.0003	12
P17C 23	1	-0.00382368966	1.40692913e-06	0.0015	16	-0.00179434874	3.92258671e-07	0.0001	12
P17C 22	1	-0.00326188564	1.41985481e-06	0.0007	15	-0.00096517101	2.71497497e-07	0.0002	12
P17C 21	1	-0.00319830505	1.43389220e-06	0.0017	17	-0.00147579046	5.72634908e-07	0.0003	11
P17C 20	1	-0.00261318529	1.00304935e-06	0.0011	15	-0.00138810474	3.90509077e-07	0.0002	12
P17C 19	1	-0.00202409855	1.25230270e-06	0.0029	14	-0.00004195469	2.61230772e-07	0.0003	15
P17C 18	1	-0.00283864140	1.71584117e-06	0.0026	13	+0.00002441331	2.84313809e-07	0.0001	15
P17N 28	1	-0.00112514634	7.56885977e-07	0.0021	15	-0.00055319685	4.70911231e-07	0.0002	15
P17N 29	1	-0.00370425677	2.22804475e-06	0.0029	12	+0.00017592133	2.87955697e-07	0.0002	15
P17N 30	1	-0.00280488879	1.69012529e-06	0.0036	16	-0.00044555799	5.10459893e-07	0.0002	15
P17N 31	1	-0.00098135226	9.06224203e-07	0.0010	16	+0.00022851796	3.01289096e-07	0.0002	15
P17N 32	1	-0.00126321674	8.70164912e-07	0.0013	18	-0.00005488577	2.65999429e-07	0.0002	14
P17N 33	1	-0.00100392508	7.57475347e-07	0.0017	17	-0.00017721020	3.44117904e-07	0.0002	15
P17N 34	1	-0.00210535284	1.44937246e-06	0.0022	14	+0.00024544860	2.73971739e-07	0.0001	15
P17N 35	1	-0.00100620500	8.98826507e-07	0.0021	19	+0.00009644912	3.47499447e-07	0.0002	13
P17N 36	1	-0.00084307915	8.22056902e-07	0.0011	17	+0.00003336582	3.83834416e-07	0.0002	12
P17N 37	1	-0.00206571751	1.65780681e-06	0.0008	14	+0.00086308272	1.93406694e-07	0.0002	12
P17N 38	1	-0.00274848175	1.90594484e-06	0.0027	18	+0.00043136806	3.16019935e-07	0.0001	13
P17N 39	1	-0.00219115023	1.59192468e-06	0.0015	16	+0.00043326578	2.79716674e-07	0.0002	13
P17N 40	1	-0.00480874195	2.84841427e-06	0.0018	20	-0.00002631819	4.57202389e-07	0.0001	10
P17N 42	1	-0.00364456318	2.16124869e-06	0.0028	21	-0.00103968629	8.58810246e-07	0.0001	10
P17N 43	1	-0.00187164002	1.22702118e-06	0.0030	16	-0.00104440142	8.13401881e-07	0.0001	10
P17N 44	1	-0.00301327646	1.75063559e-06	0.0020	18	-0.00049127870	4.89636713e-07	0.0001	11
P17N 45	1	-0.00221023727	1.31971058e-06	0.0009	18	-0.00081721950	6.23201692e-07	0.0002	11
P17N 46	1	-0.00351928388	2.21918435e-06	0.0029	20	+0.00018003287	3.69525974e-07	0.0001	11
P17N 47	1	-0.00149713124	1.16861624e-06	0.0013	20	+0.00022286518	3.08618031e-07	0.0001	8
P17N 48	1	-0.00739143072	4.18611668e-06	0.0035	22	-0.00003244765	5.06625144e-07	0.0006	9
P17N 49	1	-0.00274069485	1.72223501e-06	0.0015	21	-0.00020164018	4.52707674e-07	0.0001	10
P17N 50	1	-0.00179353576	1.30327572e-06	0.0010	20	+0.00005565780	3.78678942e-07	0.0001	10

Station		[P < pr]				[p >= pr]			
		a0	b0	dev	n	a1	b1	dev	n
P17N 51	1	-0.00236921437	1.71007795e-06	0.0019	18	+0.00036073481	3.45103364e-07	0.0002	10
P17N 52	1	-0.00431883257	2.60325069e-06	0.0010	15	-0.00009230456	4.89986690e-07	0.0001	10
P17N 53	1	-0.00389149710	2.36791128e-06	0.0021	22	-0.00051017140	6.77248430e-07	0.0003	11
P17N 54	1	-0.00656862167	3.92821012e-06	0.0033	18	+0.00040671843	4.40540072e-07	0.0001	10
P17N 55	1	-0.00395174000	2.47307957e-06	0.0016	17	+0.00006997511	4.62222014e-07	0.0003	12
P17N 56	1	-0.00424859112	2.54919462e-06	0.0037	16	-0.00045596387	6.52880998e-07	0.0001	9
P17N 57	1	-0.00632590758	3.78120284e-06	0.0024	18	+0.00072592490	2.55286594e-07	0.0003	9
P17N 58	1	-0.00391224558	2.51015183e-06	0.0010	18	-0.00023526510	6.71661595e-07	0.0002	12
P17N 59	1	-0.00648368908	4.00245706e-06	0.0030	18	+0.00115609924	1.82562902e-07	0.0006	10
P17N 60	1	-0.00619373052	3.53760486e-06	0.0018	17	-0.00012297052	5.02224860e-07	0.0002	12
P17N 61	1	-0.00287315314	2.23506005e-06	0.0011	19	+0.00064993799	4.73514483e-07	0.0002	13
P17N 62	1	-0.00579580478	3.62060307e-06	0.0011	17	+0.00042784185	5.08779752e-07	0.0002	12
P17N 63	1	-0.00380900743	2.34187157e-06	0.0019	20	-0.00102612201	9.50428857e-07	0.0002	13
P17N 64	1	-0.00557255381	3.40483902e-06	0.0015	18	+0.00002883384	6.04145195e-07	0.0002	12
P17N X01	1	-0.00492856194	3.33574011e-06	0.0011	14	+0.00087074293	4.36087680e-07	0.0002	14
P17N 65	1	-0.00672411653	4.32041464e-06	0.0015	16	+0.00107943845	4.18637148e-07	0.0002	13
P17N 66	1	-0.00433764720	3.06272946e-06	0.0013	15	+0.00089342267	4.47194522e-07	0.0002	13
P17N 67	1	-0.00363321500	2.68804962e-06	0.0012	16	+0.00062632815	5.58278049e-07	0.0002	12
P17N 68	1	-0.00289688175	2.50376971e-06	0.0009	16	+0.00124164132	4.34508177e-07	0.0002	11
P17N 69	1	-0.00206561032	1.82391954e-06	0.0010	17	+0.00011845680	7.31885980e-07	0.0002	13
P17N 70	1	-0.00652305713	4.20119396e-06	0.0027	16	+0.00083172904	5.23800872e-07	0.0001	11
P17N 71	3	-0.00516241726	3.52364120e-06	0.0021	16	+0.00078813535	5.48364888e-07	0.0002	13
P17N 72	1	-0.00260120648	2.47380727e-06	0.0010	19	+0.00164166493	3.52371566e-07	0.0003	13
P17N 73	1	-0.00091898367	1.55554863e-06	0.0007	17	+0.00125905785	4.66527870e-07	0.0002	14
P17N 74	1	-0.00371667927	3.38154846e-06	0.0014	14	+0.00243689634	3.04760658e-07	0.0002	10
P17N 75	1	-0.00486364697	3.37219811e-06	0.0017	16	+0.00041573837	7.32505441e-07	0.0003	14
P17N 76	1	-0.00424812495	3.16531365e-06	0.0010	17	+0.00140274108	3.39880636e-07	0.0001	14
P17N 77	1	-0.00277322927	2.49874131e-06	0.0018	18	+0.00157255241	3.25850470e-07	0.0002	14
P17N 78	1	-0.00317585841	2.74326963e-06	0.0014	18	+0.00144148287	4.34598993e-07	0.0001	11
P17N 79	1	-0.00069385904	1.56374525e-06	0.0007	17	+0.00186176145	2.85935009e-07	0.0001	12
P17N 80	1	-0.00456970497	3.72415366e-06	0.0015	18	+0.00232147753	2.78562409e-07	0.0002	12
P17N 81	1	-0.00211883577	2.35442232e-06	0.0012	17	+0.00188724978	3.51379543e-07	0.0001	12
P17N 82	1	-0.00027518314	1.34440570e-06	0.0009	17	+0.00155926357	4.27182341e-07	0.0001	9
P17N 83	1	-0.00075817689	1.78319230e-06	0.0008	17	+0.00238703497	2.10586372e-07	0.0001	11

		[P < pr]				[p >= pr]			
Station		a0	b0	dev	n	a1	b1	dev	n
P17N 84	1	-0.00172366742	2.10642746e-06	0.0014	19	+0.00166914832	4.10019591e-07	0.0002	10
P17N 86	1	-0.00082332938	1.83224240e-06	0.0017	13	+0.00233071217	2.55221624e-07	0.0001	14
P17N 87	1	-0.00292921563	2.98581447e-06	0.0013	14	+0.00254923496	2.46589172e-07	0.0002	14
P17N 88	1	-0.00107680266	2.10124760e-06	0.0008	12	+0.00279254161	1.66575462e-07	0.0002	17
P17N 90	1	-0.00083228193	1.91158460e-06	0.0019	18	+0.00230746930	3.41708982e-07	0.0001	12
P17N 92	1	-0.00074134491	1.76061628e-06	0.0015	20	+0.00198020219	3.99842728e-07	0.0001	10
P17N 93	1	0.001337410210	9.21610307e-07	0.0012	21	+0.00174232110	7.19154863e-07	0.0001	9
P17N 94	1	-0.00031490228	2.00050960e-06	0.0010	22	+0.00270481639	4.90650267e-07	0.0001	6
P17N 96	2	-0.00195391654	4.17750848e-06	0.0011	16				
P17N 98	1	-0.00137970523	2.52920668e-06	0.0023	11				
P17N 99	1	-0.00993932076	4.01977009e-06	0.0056	6				

The mean   absolute deviation averaged over all stations is as follows:

0.0 018 [p < 2000 dbar]
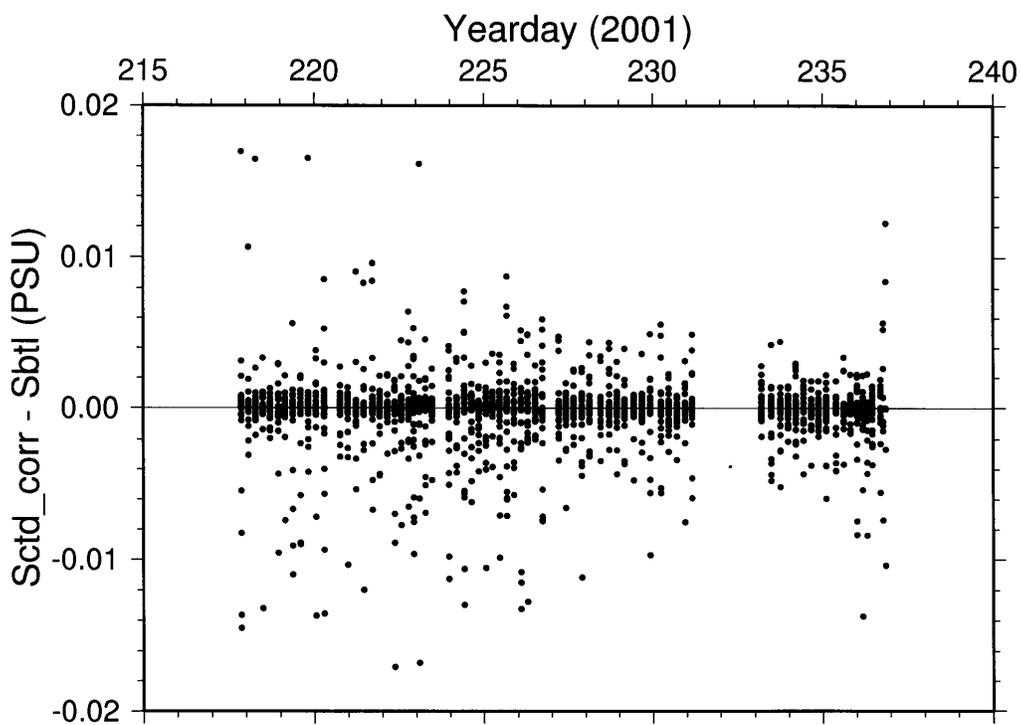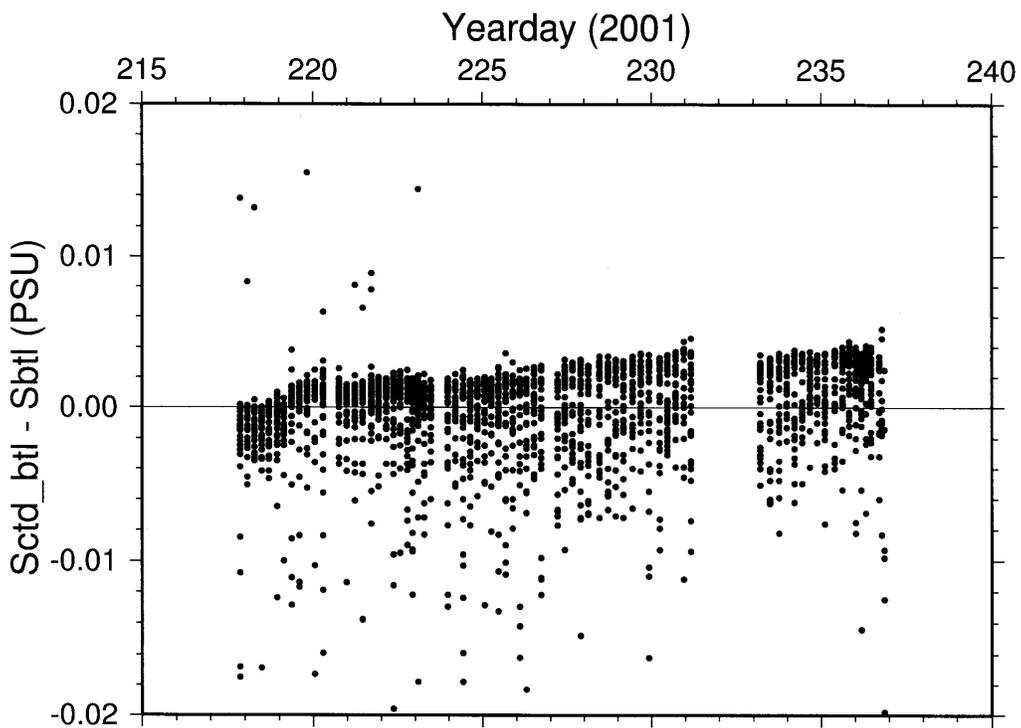
0.0 002 [p >= 2000 dbar]

P17

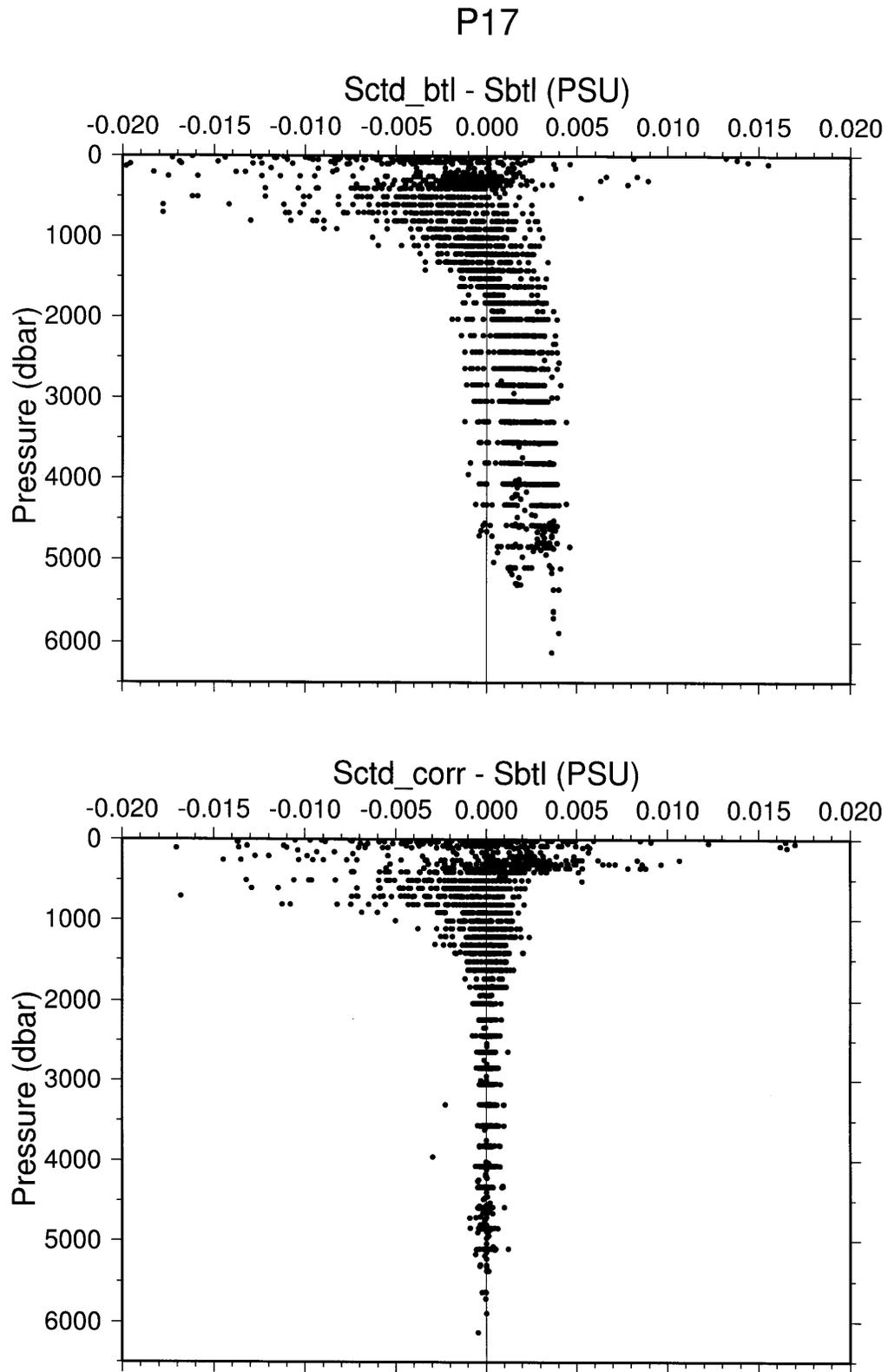**Figure 22**: Time series of salinity residuals before (upper panel) and after (lower panel) the calibration.

Figure 23: Vertical distribution of salinity residuals before (upper panel) and after (l ower panel) the calibration.

(4) Oxygen calibration

The discrepancies of the CTD oxygen (SBE 43) from the bottle oxygen show linear behavior against the bottle oxygen values at depths shallower than about 3000 dbar and against the pressure deeper than about 3000 dbar. Therefore the CTD oxygen is calibrated as

$$\text{Calibrated oxygen} = (a0 + b0 * o) - (a1 + b1 * p)$$
$$a1 = 0, \quad b1 = 0 \quad [\text{when } p < pr]$$
$$a1 + b1 * pr = 0$$

where o is CTD oxygen in micro-mol/kg, p is CTD pressure in dbar, pr is the bordering pressure (about 3000 dbar) in dbar and a0, b0, a1, b1 are the calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviations from the bottle oxygen data. Fortran routine MEDFIT in the Numerical Recipies (Press et al., 1986) is used with a slight modification to determine the coefficients. The coefficients a0 and b0 are determined first then the coefficients a1 and b1 are determined with a restriction that the two equations take same value at a pressure of pr.

(A calibration with the coefficients a0 and b0 in above equation may correspond to that with the coefficients of Soc and Offset (see 3-4 and 3-5) in the oxygen model. Although a calibration with Soc and Offset should be essential, the pressure dependency mentioned above could not be retrieved with sufficient accuracy through such a calibration. Therefore the simple linear calibration equations are used to calibrate the CTD oxygen.)
The pr was set to 2500 dbar or 3000 dbar. The coefficients are determined at each station. The deviation of CTD oxygen from the bottle oxygen at depth shallower than 800 dbar is too large to determine a proper sets of the coefficients since the vertical oxygen gradient is strong in the regions. So the coefficients a0 and b0 are determined using the data in the pressure range from 800 dbar to pr. Nevertheless, for the station P17N 96, 98 and 99, the coefficients of a0 and b0 are determined using the data in the whole pressure range because the numbers of bottle oxygen data were small. The down cast CTD data were used after the post-cruise calibration for CTD pressure, temperature and salinity. For depths where the vertical oxygen gradient calculated from the down cast CTD data as greater than 5 micro-mol/kg, bottle oxygen data are not used for calibration because of the ambiguity resulted from the vertical separation of the bottles and CTD sensors.

The pr, the calibration coefficients, the mean absolute deviation from the bottle oxygen and the number of available data for the calibration are as follows:

dev and n: the mean absolute deviation and the number of the data [p < 800 dbar]
dev0 and n0: the mean absolute deviation and the number of the data [pr > p >= 800 dbar]
dev1 and n1: the mean absolute deviation and the number of the data [p >= pr]

Station	pr			a0	b0	dev	n	dev0	n0	a1	b1	dev1	n1
P17C	26	1	3000	-6.099360405	1.040369946	6.86	13	0.94	14	-10.9299107	0.00364330357	0.35	7
P17C	25	1	3000	-8.971520275	1.075145280	7.44	12	0.42	13	-14.4504841	0.00481682805	0.50	8
P17C	24	1	3000	-5.529627844	1.028365598	4.53	14	0.68	14	-6.77747736	0.00225915912	0.40	7
P17C	23	1	3000	-7.386595950	1.047246541	4.23	12	0.28	11	-7.53960919	0.00251320306	0.22	6
P17C	22	1	3900	-7.305887486	1.049203595	4.80	14	0.50	11	-8.46202316	0.00282067439	0.35	8
P17C	21	1	3000	-9.059589750	1.070725686	5.07	14	0.84	14	-12.5271348	0.00417571159	0.70	6
P17C	20	1	2500	-7.576914038	1.062166023	3.99	12	0.65	10	-7.26808020	0.00290723208	0.27	9
P17C	19	1	3000	-6.888153605	1.050814179	3.54	14	0.87	11	-10.0069168	0.00333563892	0.34	10
P17C	18	1	2500	-8.676846720	1.091437969	7.52	12	0.44	08	-10.2718365	0.00410873459	0.55	10
P17N	28	1	2500	-8.949509795	1.095178051	6.29	13	0.24	10	-11.7304995	0.00469219980	0.83	12
P17N	29	1	2500	-10.71553764	1.108806876	6.21	11	1.10	08	-13.9391875	0.00557567501	0.80	12
P17N	30	1	3000	-9.991639224	1.076033076	2.98	12	0.31	10	-13.9476730	0.00464922434	0.41	10
P17N	31	1	3000	-8.781873275	1.059551905	8.41	13	0.31	11	-12.3603037	0.00412010122	0.67	10
P17N	32	1	3000	-7.409800688	1.031783329	4.84	11	0.50	13	-6.89646032	0.00229882011	0.68	9
P17N	33	1	3000	-8.873530679	1.060111768	6.25	14	0.62	11	-13.8277935	0.00460926451	0.43	10
P17N	34	1	3000	-10.31154992	1.091510132	8.47	12	0.75	11	-19.6614446	0.00655381487	0.70	10
P17N	35	1	3000	-9.084332713	1.046265000	5.97	14	0.57	13	-8.88625332	0.00296208444	0.43	8
P17N	36	1	3000	-9.399049595	1.056992029	6.70	11	0.64	13	-11.9565125	0.00398550416	0.46	7
P17N	37	1	3000	-8.364248414	1.042942612	2.91	10	0.35	12	-8.37163711	0.00279054570	0.62	6
P17N	38	1	3000	-10.13053131	1.073233270	4.53	12	0.79	12	-16.4941999	0.00549806665	0.52	9
P17N	39	1	3000	-9.434457480	1.055735385	7.58	11	0.73	14	-12.2868186	0.00409560619	0.47	8
P17N	40	1	3000	-8.422725258	1.043201281	5.09	11	0.82	17	-10.8458844	0.00361529479	0.48	5
P17N	42	1	3000	-10.24374321	1.058984335	4.74	11	0.93	18	-16.0869251	0.00536230838	0.31	3
P17N	43	1	3000	-9.382698183	1.062958957	5.26	11	0.49	14	-18.7986256	0.00626620852	0.53	5
P17N	44	1	3000	-9.981734298	1.061992123	5.80	14	0.29	16	-12.6278156	0.00420927187	0.20	6
P17N	45	1	3000	-10.58694741	1.067900558	3.96	11	0.49	15	-14.4999088	0.00483330294	0.29	6
P17N	46	1	3000	-8.581704444	1.035389951	7.26	14	0.53	14	-6.65999935	0.00221999978	0.40	6
P17N	47	1	3000	-9.576965449	1.050655685	5.16	14	0.69	14	-8.81065801	0.00293688600	0.28	5
P17N	48	1	3000	-9.473259386	1.047975147	8.31	11	0.52	16	-7.72022568	0.00257340856	0.34	5
P17N	49	1	2500	-9.834545198	1.081214717	6.36	14	0.41	14	-11.3991842	0.00455967368	0.26	6
P17N	50	1	2500	-10.10495099	1.095254233	8.22	09	0.37	11	-13.5234429	0.00540937715	0.90	6

Station	pr			a0	b0	dev	n	dev0	n0	a1	b1	dev1	n1
P17N	51	1	2500	-9.638736644	1.081947704	2.00	11	0.43	12	-11.3137098	0.00452548393	0.49	7
P17N	52	1	3000	-8.121769450	1.044767285	6.81	09	0.61	13	-11.1193260	0.00370644201	0.38	3
P17N	53	1	3000	-9.604492361	1.067672633	5.95	13	0.68	16	-15.5654310	0.00518847700	0.73	5
P17N	54	1	3000	-10.28221502	1.064388502	4.91	10	0.83	13	-11.5592357	0.00385307857	0.45	4
P17N	55	1	3000	-8.215101362	1.056469182	2.18	11	0.95	14	-15.7699668	0.00525665560	0.42	7
P17N	56	1	3000	-9.791078427	1.057042803	2.86	12	0.73	15	-10.5405558	0.00351351859	0.24	6
P17N	57	1	3000	-10.66876483	1.080050297	5.21	12	0.35	13	-16.4940112	0.00549800374	0.54	6
P17N	58	1	2500	-10.76470289	1.100402187	5.59	14	0.71	11	-13.8494455	0.00553977820	0.66	9
P17N	59	1	2500	-10.53793839	1.092647127	5.34	14	0.65	13	-12.2999378	0.00491997513	0.72	9
P17N	60	1	3000	-9.836038299	1.064379433	2.11	13	0.34	13	-12.3644234	0.00412147447	0.69	7
P17N	61	1	3000	-9.408143455	1.056110095	5.71	12	0.35	14	-10.7805048	0.00359350161	0.26	8
P17N	62	1	3000	-9.923429623	1.073515852	3.87	11	0.64	13	-15.2642608	0.00508808694	0.35	8
P17N	63	1	3000	-9.557855591	1.048627293	6.34	14	0.28	13	-11.5186339	0.00383954465	0.33	7
P17N	64	1	3000	-9.740348640	1.088424387	4.00	13	0.31	13	-21.7283223	0.00724277409	0.41	7
P17N	X01	1	3000	-8.371952559	1.038180592	8.83	13	0.60	09	-9.78801865	0.00326267288	0.69	9
P17N	65	1	3000	-9.551040280	1.079632823	11.09	11	0.60	11	-19.3524499	0.00645081664	0.76	8
P17N	66	1	3000	-10.27693516	1.091416152	6.31	11	0.53	13	-21.3706714	0.00712355714	0.44	8
P17N	67	1	3000	-9.412121367	1.075727953	3.39	13	0.55	12	-16.9440724	0.00564802414	0.43	7
P17N	68	1	3000	-8.714350922	1.060143438	7.42	10	0.57	14	-13.7545611	0.00458485371	0.31	6
P17N	69	1	3000	-9.408301211	1.071835344	8.02	13	0.78	14	-15.8136664	0.00527122215	0.53	8
P17N	70	1	3000	-10.32013012	1.076201596	6.76	11	0.56	12	-15.4215410	0.00514051366	0.41	7
P17N	71	3	3000	-8.919832027	1.050925439	4.18	10	0.45	13	-11.2263973	0.00374213242	0.20	8
P17N	72	1	3000	-9.052916259	1.047460170	8.98	14	0.49	14	-11.6939781	0.00389799269	0.18	8
P17N	73	1	3000	-9.219642560	1.073557224	6.08	12	0.61	13	-17.2527649	0.00575092164	0.58	9
P17N	74	1	3000	-8.775778186	1.060304930	6.37	11	0.25	11	-13.9816700	0.00466055667	0.20	7
P17N	75	1	3000	-9.997667857	1.075134400	5.43	12	0.51	12	-16.9202792	0.00564009308	0.61	9
P17N	76	1	3000	-8.990971722	1.042222397	7.76	14	0.40	13	-15.4331625	0.00514438751	1.16	9
P17N	77	1	3000	-9.710916843	1.060383262	3.41	11	0.47	13	-13.6283141	0.00454277136	0.29	9
P17N	78	1	3000	-8.568935573	1.044311498	4.35	11	0.47	12	-12.0664230	0.00402214101	0.23	8
P17N	79	1	3000	-8.738046345	1.043973027	4.87	13	0.50	14	-13.4045628	0.00446818759	0.38	7
P17N	80	1	3000	-8.097798952	1.043270916	4.01	10	0.54	14	-12.2593489	0.00408644964	0.34	8
P17N	81	1	3000	-9.233743802	1.053771754	3.80	14	0.68	12	-16.4023224	0.00546744080	0.29	8
P17N	82	1	3000	-8.881406499	1.051434887	7.17	11	0.28	13	-15.1862347	0.00506207823	0.24	7
P17N	83	1	3000	-7.975074171	1.028412310	4.26	10	0.47	13	-6.97467826	0.00232489275	0.26	7
P17N	84	1	3000	-9.985211184	1.057807940	5.17	12	0.43	13	-12.9007483	0.00430024945	0.39	8

Station	pr			a0	b0	dev	n	dev0	n0	a1	b1	dev1	n1
P17N	86	1	3000	-10.19567244	1.043387069	5.30	09	0.56	10	-15.2588930	0.00508629768	0.83	10
P17N	87	1	2500	-9.730194504	1.057040862	9.18	09	0.38	09	-9.91423923	0.00396569569	0.56	14
P17N	88	1	2500	-10.41733909	1.063737279	16.76	11	0.23	09	-12.4798272	0.00499193089	1.00	14
P17N	90	1	2500	-12.56598991	1.124036761	3.03	12	0.67	10	-19.9885598	0.00799542391	1.32	10
P17N	92	1	3000	-8.952500275	1.027299076	11.14	13	0.78	16	-1.61467574	0.000538225245	0.56	5
P17N	93	1	3000	-9.686243469	1.043885543	7.03	14	0.78	17				
P17N	94	1	3000	-10.52427791	1.049230691	8.71	17	0.48	16				
P17N	96	2	3000	-10.54840239	1.091405576	*	*	1.59	20				
P17N	98	1	3000	-11.10571481	1.094795619	*	*	3.15	17				
P17N	99	1	3000	-14.02518652	1.104887956	*	*	6.22	10				

The mean absolute deviation averaged over all stations is as follows:

      5.90 micro-mol/kg [p < 800 dbar]

      0.68 micro-mol/kg [pr > p >= 800 dbar]

      0.49 micro-mol/kg [p >= pr]

Figure 24: Time series of oxygen residuals before (upper panel) and after (lower panel) the calibration.

P17

Octd_down - Obtl (umol/kg)

Octd_corr - Obtl (umol/kg)

Figure 25: Vertical distribution of oxygen residuals before (upper panel) and after (lower panel) the calibration.

SIO Data Processing Notes

Date	Contact	Data Type	Data Status Summary
01/20/03	Fukasawa	CTD/BTL/SUM/DOC	Submitted
	The data disposition is: Public The bottle file has the following parameters: CTDPRS CTDTMP CTDSAL CTDOXY SALNTY OXYGEN NITRAT NITRIT SILCAT PHSPHT CFC-11 CFC-12 CFC113 PH ALKALI TCARBN DELC13 C13ERR DELC14 C14ERR The file format is: WOCE Format (ASCII) The archive type is: Other: lha The data type(s) is: • Summary (navigation) • Bottle Data (hyd) • CTD File(s) • Documentation The file contains these water sample identifiers: • Cast Number (CASTNO) • Station Number (STATNO) • Bottle Number (BTLNBR) • Sample Number(SAMPNO) FUKASAWA, MASAO would like the following action(s) taken on the data: Place Data Online		
04/23/04	Anderson	CTD/BTL/SUM	Data Reformatted to WOCE format
	I have put the p17n from the cd Lynne gave me in the p17n directory on the new co2clivar website area. The files are sort of in WOCE format.		
05/19/04	Kappa	Documentation	Preliminary Cruise Report reformatted
	Converted to PDF & TXTformats • PDF: Added 2 CCHDO Summary pages to beginning of report • PDF: Added CCHDO station track generated from .sum file to • PDF: Added links from figures to references to them within the body of the report • PDF and Text versions: Added these Data Processing Notes		

Data Processing Notes

Date	Contact	Data Type	Data Status Summary
01/20/03	Fukasawa	CTD/BTL/SUM/DOC	Submitted

	The data disposition is:
	    Public
	The bottle file has the following parameters:
	    CTDPRS CTDTMP CTDSAL CTDOXY SALNTY OXYGEN NITRAT
	    NITRIT SILCAT PHSPHT CFC-11 CFC-12 CFC113 pH
	    ALKALI TCARBN DELC13 C13ERR DELC14 C14ERR
	The file format is:
	    WOCE Format (ASCII)
	The archive type is:
	    Other: lha
	The data type(s) is:
	    Summary (navigation)
	    Bottle Data (hyd)
	    CTD File(s)
	    Documentation
	The file contains these water sample identifiers:
	    Cast Number (CASTNO)
	    Station Number (STATNO)
	    Bottle Number (BTLNBR)
	FUKASAWA, MASAO would like the following action(s) taken on the data:
	    Place Data Online		

04/13/04	Anderson	Data Update	New data submitted
	Lynne gave me a cd yesterday so I could extract the p01 information from it. It also has some p17n data, but I haven't looked at it to see in what format it is. I'll check and let you know, hopefully this week. The cd is from Fukasawa and has p01c, p01e, p01h, p01w, and p17n.		
04/16/04	Bartolacci	CTD/BTL/SUM	Update Needed: Unfamiliar with format
	WHPO (and Lynne), I was going to start putting up the submitted P17N reoccupations that are sitting in our incoming directory. However, the associated README states the data are in file format "lha", which is a DOS based compression similar to zip or winzip. I'm pretty unfamiliar with it or how to use it/where to get it but have read that it's incompatible with zip or winzip, so one has to be in DOS to use the utility. I can move the files over, however they are illegible at this point. Can anyone help out? Anyone familiar with lha archival format? Otherwise I'll be writing Fukasawa back for assistance on reformatting.		
04/23/04	Anderson	CTD/BTL/SUM	Data Reformatted to WOCE format
	I have put the p17n from the cd Lynne gave me in the p17n directory on the new co2clivar website area. The files are sort of in WOCE format.		

Data Processing Notes

Date	Contact	Data Type	Data Status Summary
04/26/04	Bartolacci	CTD/BTL/SUM	Update Needed: CTD and SUM file probs.

Lynne- I took a look at the P17N data files that Sarilee moved over. She did some reformatting on the sumfile and I took a look at the ctd and bottle files. The bottle file, although in excel, looks okay and I'll convert it to WOCE and then to exchange, etc. but the CTD files have some issues some of which relate to the sumfile:

• in the sumfile there are two station 67 cst 1 entries, one 08/15/01 and one 08/18/01. There is only one CTD station file matching 08/18/01.

• station file 92, cst 1 had only 2507 lines but the no. of records was 3804... was the file truncated.

• finally, stations 93, 94, 96, 98, 99 and X01 are all empty files.

I was wondering if you are in correspondence with the data originators and could ask about these issues, otherwise I'll try to track them down and tackle them.

Date	Contact	Data Type	Data Status Summary
04/27/04	Anderson	CTD/BTL/SUM	Update Needed

That is very strange. I unzipped the ctd file on my machine And sta 92 is complete and 93-99 and X01 are not empty. I unzipped the original file that I read from the cd and then I ftp'd the file in the p17n north directory and unzipped it. They both had all the stations, no empty files.

Let me know if you want me to copy them to WHPO.

Date	Contact	Data Type	Data Status Summary
05/21/04	Bartolacci	CTD/BTL/SUM	Data Reformatted/OnLine

EXPOCODE: 49NZ200107_1
Dates: July 25 - Aug 27, 2001
Ship/Country: MIRAI/JAPAN
Chief Scientist: Fukasawa
Sum: 82 Rosette stations
CTD: zip file contains 76 station files.

Bot: contains following parameters:

CTDPRS	CTDTMP	CTDSAL	CTDOXY	THETA	SIG0	SALNTY
OXYGEN	NITRAT	NITRIT	SILCAT	PHSPHT	CFC-11	CFC-12
CFC113	PH	ALKALI	TCARBN	DELC13	C13ERR	DELC14
C14ERR						

REFORMATTING NOTES:

  SUM:

   in order to convert bottle file to exchange and NetCDF, the sumfile needed WHP-ID field entirely filled. Therefore, empty spaces in this column were filled with UNK. This was saved as the final sumfile and replaced the previously reformatted (by SA) version. Sumfile has two station 67, cast 1 entries however one entry is associated with P17N and the other is not on any WOCE line and was labeled as UNK. This caused no problem in format checks or conversions.

  Expocode was changed to 49NZ200107_1

Data Processing Notes

Date	Contact	Data Type	Data Status Summary
			BOT: • Original bottle file was .csv format, however not in exchange format. it was an excel file with Q1 word comma separated at the end of each line. File was converted to WOCE format and Q1 words constructed from individual bytes. First WOCE header line was added including name/date stamp. • File passed wocecvt with no errors. • File converted to Exchange and NetCDF with no apparent errors. **CTD:** • Edited expocode to conform with SUM file. • Files passed wctcvt with no errors. • Files were converted to exchange and • NetCDF with no apparent errors. **DOC:** documentation files were copied from the NEWDOCS directory and placed online. Old word documentation file was moved to original directory. All web pages and station track files were generated and placed online, however this cruise will not link until hand linked into appropriate tables.
05/28/04	Talley	CTD	Data Update: New CTD files
			I sent a question to Masao Fukasawa about the flags in the 2001 SAGE P01 CTD files, he answered back that there is a newer version of the data. He has had Hiroshi Uchida ftp over the new p17n data set. I'm putting the data set in my ftp site
06/03/04	Bartolacci	CTD	Website Updated: New CTD files online
			New files for p17n_2001a were ftp'd from Lynne Talley. Files were updates of previously submitted files also obtained from Lynne Talley. Complete replacement of all files was sent. Only edits made to files were of expocode numbers. All files had expocodes changed from : 49MR01K04/1 to 49NZ200107_1 All file names were edited to comply with new CCHDO file naming convention. Problems were encountered when attempting to convert the submitted .csv files into exchange. Therefore, exchange files were recreated using WOCE files and in-house software. Exchange files sent by data originator were retained, however were not placed online.

Data Processing Notes

Date	Contact	Data Type	Data Status Summary
07/01/04	Kappa	DOC	Cruise report changes:

Added "13C" to (PI) Y. Kumamoto's responsibilities

Moved Surface Nutrients report from section 2.6 to section 2.3.

Updated top 2 plots of Figure 13.

Updated section 3.7 an Carbon Isotope Ratios:

• Changed section on Sample Collection

• Updated Table 1

• Changed section called "Equipment and technique for sample preparation" to "Sample preparation" and deleted last sentence

• Added sections on delta 13C and DELTA 14C

• Replaced scatter plots of delta 13C and DELTA 14C preliminary scatter plots with delta 13C and DELTA 14C against depth vertical sections.

• Added Table 2: Summary of replicate analyses

• Added new section: "Quality control samples"

• Added Table 3: Summary of quality control samples (QCS)

• Added section on quality control flag assignment

• Added Data Summary

• Expanded References

Updated most figures for greater clarity

Expanded these Data Processing Notes