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MR03-K04 Leg.4

Preliminary
Cruise Report

March, 2004

Edited by

Dr. Yasushi Yoshikawa
Dr. Takeshi Kawano

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1. Cruise Narrative (17 Feb ’04)

1.1 Highlight

WOCE　A10、R/V MIRAI Cruise MR03-K04 in the South Atlantic

Cruise Code :	MR03-K04 Leg.4
Chief Scientist :	Yasushi Yoshikawa Ocean Observation and Research Department Japan Marine Science and Technology Center 2-15, Natsushima, Yokosuka, Japan 237-0061 Takeshi Kawano Ocean Observation and Research Department Japan Marine Science and Technology Center 2-15, Natsushima, Yokosuka, Japan 237-0061
Ship :	R/V MIRAI
Ports of Call :	Santos - Capetown
Cruise Date :	Nov. 6, 2003 – Dec. 5, 2003

1.2 Cruise Summary

Cruise Track

Cruise Track and station locations are shown in Fig.1.1.

Number of Stations

A total of 111 stations were occupied using a Sea Bird Electronics 36 bottle carousel equipped with 12 liter Niskin X water sample bottles, a SBE911plus equipped with SBE35 deep ocean standards thermometer, SBE43 oxygen sensor, Seapoint sensors Inc. Chlorophyll Fluorometer and Benthos Inc. Altimeter and RDI Monitor ADCP.

Sampling and measurements

1) Measurements of temperature, salinity, oxygen ,current profile, fluorescence and using CTD/O_2 with LADCP, fluorescence meter and transmission meter
2) RMS water sampling and analysis of salinity, oxygen, nutrients, CFC11,12, 113, total alkalinity, DIC, TOC and pH. The sampling depth in db were 10, 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000, 3250, 3500, 3750, 4000, 4250, 4500, 4750, 5000, 5250, 5500, 5750 and bottom(minus 10db).
3) Sample water collection for Ar, ^{14}C, ^{13}C,, ^{137}Cs, Plutonium and ^{3}H
4) Measurements of autotropic biomass (epifluorescence and chlorophyll a) by surface LV
5) Bio-Optical measurement (scatter and transfer)
6) Underway measurements of pCO_2, temperature, salinity, nutrients, surface current, bathymetry and meteorological parameters

Floats, Drifters, Drifter

21 ARGO floats (6 SOLO floats and 15 APEX floats) were launched.

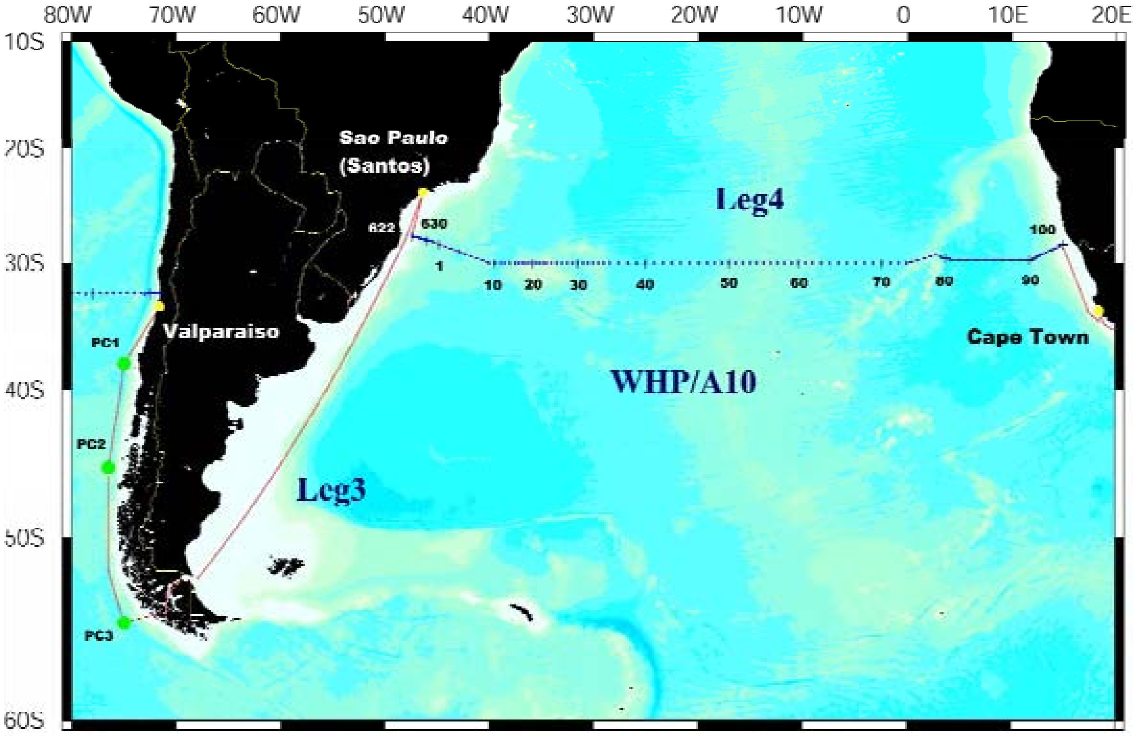


Fig.1.1 Cruise Track

1.3 Responsibility

The principal investigators responsible for major parameters are listed in Table.1.1.

Table 1.1 List of principal investigators and person in charge on the ship

Co-chief Scientist : Yasushi Yoshikawa
Co-chief Scientist : Takeshi Kawano
Chief Technologist : Satoshi Ozawa

Item	**Principal Scientists**	**Person in Charge on the Ship**
Hydrography		
CTDO	Hiroshi Uchida Masao Fukasawa Wolfgang Schneider	Mark Rosenberg Satoshi Ozawa
LADCP	Yasushi Yoshikawa	On Sugimoto Luiz Vianna Nonnato
BTL Salinity	Takeshi Kawano	Naoko Takahashi
BTL Oxygen	Shuichi Watanabe	Takayoshi Seike
Nutrients	Michio Aoyama	Junko Hamanaka
DIC	Akihiko Murata	Minoru Kamata
Alkalinity	Akihiko Murata	Fuyuki Shibata
pH	Akihiko Murata	Toru Fujiki
CFC's	Yutaka Watanabe	Katsuhiro Sagishima Kenichi Sasaki
$\Delta^{14}C$	Yuichiro Kumamoto	Akihiko Murata (collection only)
TOC	Akihiko Murata	Minoru Kamata (collection only)
Cs,Pu,^{3}H,Sr	Michio Aoyama	Sang-Han Lee (collection only)
Ar/N_2	Yutaka Watanabe	Shinichi Tanaka (collection only)
Primary Productivity	Vivian Lutz	Vivian Lutz
Chlorophyll-a	Vivian Lutz	Vivian Lutz
Underway		
ADCP	Yasushi Yoshikawa	Souichiro Sueyoshi
Bathymetry	Souichiro Sueyoshi	Souichiro Sueyoshi
Meteorology	Kunio Yoneyama	Souichiro Sueyoshi
Thermo-Salino.	Masao Fukasawa	Takayoshi Seike
PCO_2	Akihiko Murata	Minoru Kamata
Floats, Drifters		
Argo float	Kensuke Takeuchi Dean Roemmich	Miki Yoshiike Yasushi Yoshikawa

1.4 Objective of the Cruise

Objectives

a) To detect and quantify temporal changes in the Antarctic Overturn System corresponding to the global ocean and the Southern Ocean warming during this century through high quality and spatially dense observation along old WHP (World Ocean Circulation Experiment Hydrographic Program: 1991- 2002) lines.
b) To estimate the amount of anthropogenic carbon uptaken by the Antarctic Ocean.

Selected scientific priorities which lead to above interest are:
Changes in inventories of heat and freshwater
Carbon and nutrients transport
Data base for model validation
ARGO sensor calibration and its deployment in the south Atlantic.

Data Policy

All data obtained during Leg.1, Leg.2, Leg.4 and Leg.5 along WHP lines have to be quality controlled and opened through WHPO and JAMSTEC within two years after all legs.

1.5 List of Cruise Participants

Cruise participants are listed in Table 1.2.

2. Underway Measurements

2.1 Meteorological observation

2.1.1 Surface Meteorological Observation

Souichiro Sueyoshi (Global Ocean Development Inc.)
Shinya Okumura (GODI)
Katsuhisa Maeno (GODI)
Not on-board:
Kunio Yoneyama (JAMSTEC) Principal Investigator

(1) Objectives

The surface meteorological parameters are observed as a basic dataset of the meteorology. These parameters bring us the information about the temporal variation of the meteorological condition surrounding the ship.

Table 1.2 Cruise Participants

E. Braga	DO	Univ. Sao Paulo
A. Claudia	Water Sampling, Bio-optics	Univ. Sao Paulo
B. Currie	Water Sampling	MFMR
T. Fujiki	TCO_2	MWJ
J. Hamanaka	Nutrients	MWJ
J. Hashimoto	CTD Operation	MWJ
S. Ikeda	Water Sampling	MWJ
M. Kamata	TCO_2	MWJ
T. Kawano	Salinity	JAMSTEC
A. Kubo	Nutrients	MWJ
S. Lee	Cs, Pu, ^3H, Sr	IAEA
V. Lutz	Bio-optics	INIDEP
J. Madruga	Water Sampling, Bio-optics	Univ. Sao Paulo
K. Maeno	ADCP, Bathymetry, Meteorology	GODI
K. Matsumoto	DO, Water sampling	JAMSTEC
A. Murata	pH, Alkalinity, TOC, ^{14}C	JAMSTEC
L. Nonnato	LADCP, Water Sampling	Univ. Sao Paulo
S. Okumura	ADCP, Bathymetry, Meteorology	GODI
S. Ozawa	CTD	MWJ
K. Peard	Water Sampling	LMR
M. Rosenberg	CTD, DATA PROCESSING	ACE CRC
K. Sagishima	CFC	MWJ
K. Sasaki	CFC	JAMSTEC
S. Sasaki	Water Sampling	MWJ
V. Segura	Water Sampling, Bio-optics	INIDEP
T. Seike	DO	MWJ
W. Schneider	CTD	Univ. Conception
F. Shibata	pH, Alkalinity	MWJ
N. Silulwane	Water Sampling	MCM
S. Sueyoshi	ADCP, Bathymetry, Meteorology	GODI
O. Sugimoto	Water Sampling	JAMSTEC
N. Takahashi	Salinity	MWJ
S. Tanaka	CFC, Ar, N_2	Hokkaido Univ.
H. Uchida	LADCP	JAMSTEC
K. Wataki	CFC	MWJ
S. Watanabe	CFC, He	JAMSTEC
S. Yokogawa	Nutrients	MWJ
I. Yamazaki	DO	MWJ
M. Yokota	Water Sampling	MWJ
M. Yoshiike	CTD Operation, ARGO	MWJ
Y. Yoshikawa	LADCP	JAMSTEC

ACE CRC : Antarctic Climate and Ecosystems Cooperative Research Centre, Aust
MCM : Marine and Coastal Management, South Africa
INIDEP : Instituto Nacional de Investigacion y Desarrollo Pesquero, Argentina
LMR : Luederitz Marine Research, Namibia
MFMR : Ministry of Fisheries and Marine Resources, Namibia
JAMSTEC : Japan Marine Science and Technology Center
MWJ : Marine Works Japan, Ltd.
GODI : Global Ocean Development Inc.

(2) Methods

The surface meteorological parameters were observed throughout the MR03-K04 Leg.1 cruise from the departure of Santos on 6 November 2003 to arrival of Cape Town on 5 December 2003.

At this cruise, we used two systems for the surface meteorological observation.

Mirai meteorological observation system

Shipboard Oceanographic and Atmospheric Radiation (SOAR) System

(2-1) Mirai meteorological observation system

Instruments of Mirai meteorological system (SMET) are listed in Table 2.1.1 and measured parameters are listed in Table 2.1.2. Data was collected and processed by KOAC-7800 weather data processor made by Koshin-Denki, Japan. The data set has 6-second averaged.

(2-2) Shipboard Oceanographic and Atmospheric Radiation (SOAR) system

SOAR system designed by BNL consists of major 3 parts.

-Portable Radiation Package (PRP) designed by BNL – short and long wave downward radiation.

-Zeno meteorological system designed by BNL – wind, air temperature, relative humidity, pressure, and rainfall measurement.

-Scientific Computer System (SCS) designed by NOAA (National Oceanic and Atmospheric Administration, USA)- centralized data acquisition and logging of all data sets.

SCS recorded PRP data every 6 seconds, Zeno/met data every 10 seconds. Instruments and their locations are listed in Table 2.1.3 and measured parameters are listed in Table 2.1.4.

We have carried out inspecting and comparing about following three sensors, before and after the cruise.

(2-2-1) Young Rain gauge (SMet and SOAR)

Inspecting the linearity of output value from the rain gauge sensor to change input value by adding fixed quantity of test water.

(2-2-2) Barometer (SMet and SOAR)

Comparing with the portable barometer value, PTB220CASE, VAISALA.

(2-2-3) Thermometer (air temperature and relative humidity) (SMet and SOAR)

Comparing with the portable thermometer value, HMP41/45, VAISALA.

(3) Preliminary results

Fig.2.1.1 show the time series of the following parameters; Wind (SOAR), air temperature (SOAR), relative humidity (SOAR), precipitation (SOAR), short/long wave radiation (SOAR), pressure (SOAR) and significant wave height (SMET).

(4)Data archives

The raw data obtained during this cruise will be submitted to JAMSTEC Data Management Division. Corrected data sets will also be available from K. Yoneyama of JAMSTEC.

Table 2.1.1 Instruments and installations of Mirai meteorological system

Sensors	Type	Manufacturer	Location (altitude from surface)
Anemometer	KE-500	Koshin Denki, Japan	foremast (24m)
Thermometer	HMP45A	Vaisala, Finland	compass deck (21m)
	with 43408 Gill aspirated radiation shield (R.M. Young)		
	RFN1-0	Koshin Denki, Japan	4th deck (-1m, inlet -5m) SST
Barometer	F-451	Yokogawa, Japan	weather observation room captain deck (13m)
Rain gauge	50202	R. M. Young, USA	compass deck (19m)
Optical rain gauge	ORG-115DR	ScTi, USA	compass deck (19m)
Radiometer (short wave)	MS-801	Eiko Seiki, Japan	radar mast (28m)
Radiometer (long wave)	MS-202	Eiko Seiki, Japan	radar mast (28m)
Wave height meter	MW-2	Tsurumi-seiki, Japan	bow (10m)

Table 2.1.2 Parameters of Mirai meteorological observation system

	Parameter	Units	Remarks
1	Latitude	degree	
2	Longitude	degree	
3	Ship’s speed	knot	Mirai log, DS-30 Furuno
4	Ship’s heading	degree	Mirai gyro, TG-6000, Tokimec
5	Relative wind speed	m/s	6sec./10min. averaged
6	Relative wind direction	degree	6sec./10min. averaged
7	True wind speed	m/s	6sec./10min. averaged
8	True wind direction	degree	6sec./10min. averaged
9	Barometric pressure	hPa	adjusted to sea surface level 6sec. averaged
10	Air temperature (starboard side)	degC	6sec. averaged
11	Air temperature (port side)	degC	6sec. averaged
12	Dewpoint temperature (starboard side)	degC	6sec. averaged
13	Dewpoint temperature (port side)	degC	6sec. averaged
14	Relative humidity (starboard side)	%	6sec. averaged
15	Relative humidity (port side)	%	6sec. averaged
16	Sea surface temperature	degC	6sec. averaged
17	Rain rate (optical rain gauge)	mm/hr	hourly accumulation
18	Rain rate (capacitive rain gauge)	mm/hr	hourly accumulation
19	Down welling shortwave radiation	W/m^2	6sec. averaged
20	Down welling infra-red radiation	W/m^2	6sec. averaged
21	Significant wave height (fore)	m	hourly
22	Significant wave height (aft)	m	hourly
23	Significant wave period	second	hourly
24	Significant wave period	second	hourly

Table 2.1.3 Instrument and installation locations of SOAR system

Sensors	Type	Manufacturer	Location (altitude from surface)
Zeno/Met			
Anemometer	05106	R.M. Young, USA	foremast (25m)
Tair/RH	HMP45A	Vaisala, Finland	foremast (24m)
	with 43408 Gill aspirated radiation shield (R.M. Young)		
Barometer	61201	R.M. Young, USA	foremast (24m)
	with 61002 Gill pressure port (R.M. Young)		
Rain gauge	50202	R. M. Young, USA	foremast (24m)
Optical rain gauge	ORG-815DA	ScTi, USA	foremast (24m)
PRP			
Radiometer (short wave)	PSP	Epply Labs, USA	foremast (25m)
Radiometer (long wave)	PIR	Epply Labs, USA	foremast (25m)
Fast rotating shadowband radiometer		Yankee, USA	foremast (25m)

Table 2.1.4 Parameters of SOAR system

	Parameter	Units	Remarks
1	Latitude	degree	
2	Longitude	degree	
3	Sog	knot	
4	Cog	degree	
5	Relative wind speed	m/s	
6	Relative wind direction	degree	
7	Barometric pressure	hPa	
8	Air temperature	degC	
9	Relative humidity	%	
10	Rain rate (optical rain gauge)	mm/hr	reset at 50mm
11	Precipitation (capacitive rain gauge)	mm	
12	Down welling shortwave radiation	W/m^2	
13	Down welling infra-red radiation	W/m^2	
14	Defuse irradiance	W/m^2	

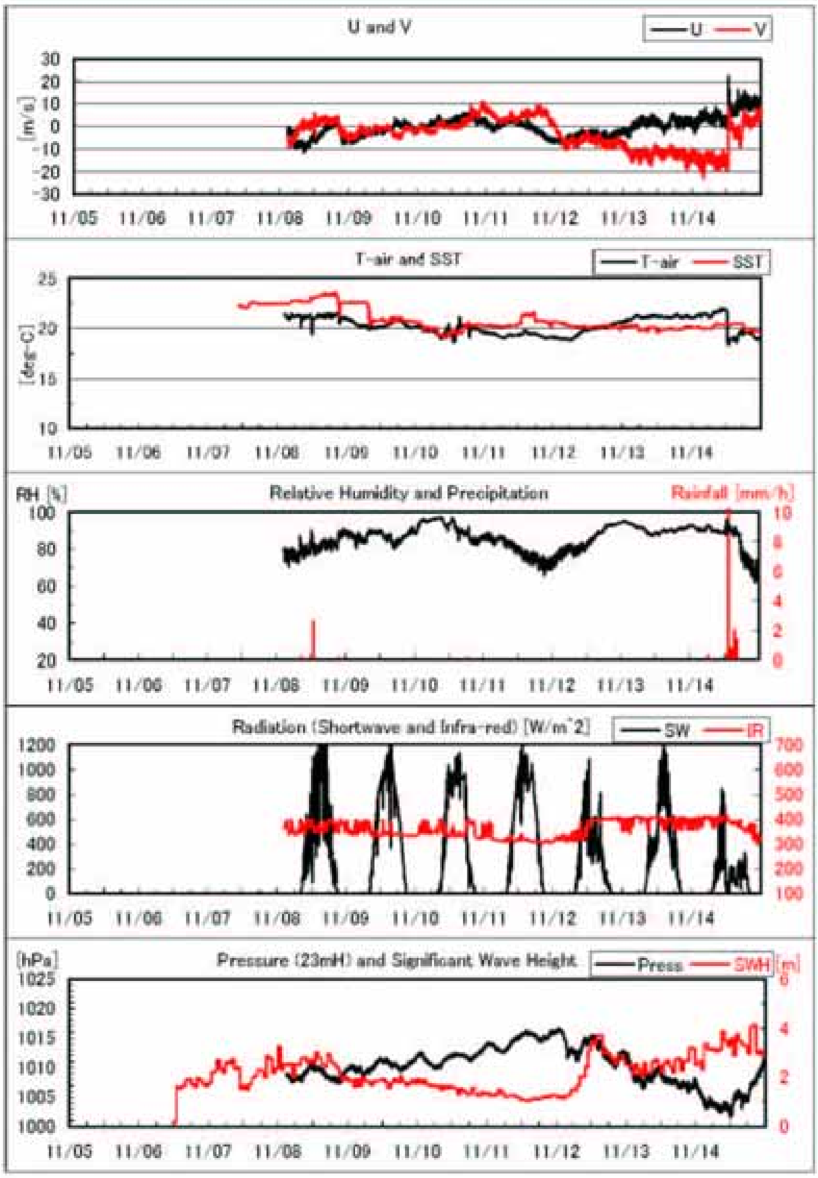


Fig.2.1.1 Time series of surface meteorological parameters during the cruise.

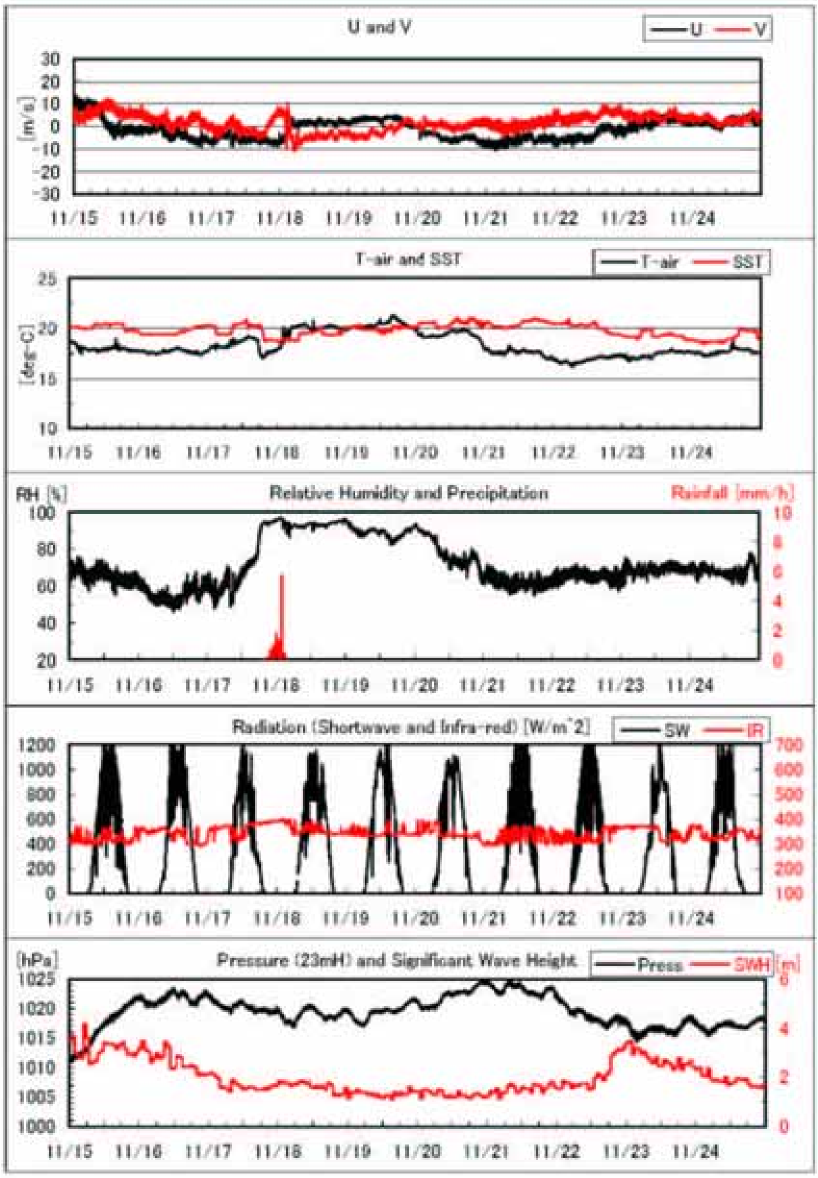


Fig.2.1.1 Continued

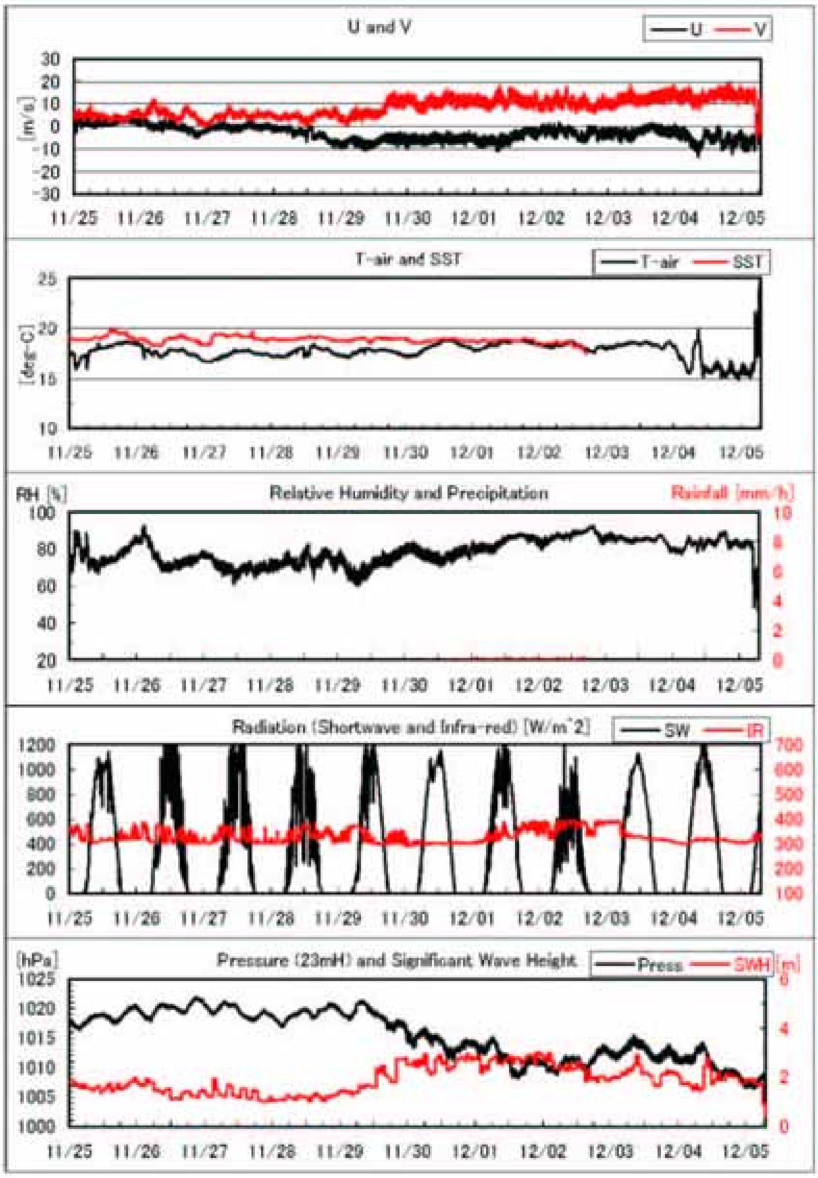


Fig.2.1.1 Continued

2.1.2 Ceilometer Observation

Souichiro Sueyoshi (Global Ocean Development Inc.)
Shinya Okumura (GODI)
Katsuhisa Maeno (GODI)
Not on-board:
Kunio Yoneyama (JAMSTEC) Principal Investigator

(1) Objectives

The information of cloud base height and the liquid water amount around cloud base is important to understand the process on formation of the cloud. As one of the methods to measure them, the ceilometer observation was carried out.

(2) Parameters

Cloud base height [m].
Backscatter profile, sensitivity and range normalized at 30 m resolution.
Estimated cloud amount [oktas] and height [m]; Sky Condition Algorithm.

(3) Methods

We measured cloud base height and backscatter profile using ceilometer (CT-25K, VAISALA, Finland) throughout the MR03-K04 Leg.4 cruise from CTD station A10-246 on 7 November 2003 to CTD station A10-100 on 2 December 2003.

Major parameters for the measurement configuration are as follows;

Laser source:	Indium Gallium Arsenide (InGaAs) Diode
Transmitting wavelength:	905±5 mm at 25 degC
Transmitting average power:	8.9 mW
Repetition rate:	5.57 kHz
Detector:	Silicon avalanche photodiode (APD) Responsibility at 905 nm: 65 A/W
Measurement range:	0 ~ 7.5 km
Resolution:	50 ft in full range
Sampling rate:	60 sec
Sky Condition	0, 1, 3, 5, 7, 8 oktas (9: Vertical Visibility) (0: Sky Clear, 1:Few, 3:Scattered, 5-7: Broken, 8: Overcast)

On the archive dataset, cloud base height and backscatter profile are recorded with the resolution of 30 m (100 ft).

(4) Preliminary results

Fig.2.1.2 shows the time series of the first, second and third lowest cloud base height.

(5) Data archives

The raw data obtained during this cruise will be submitted to JAMSTEC Data Management Division.

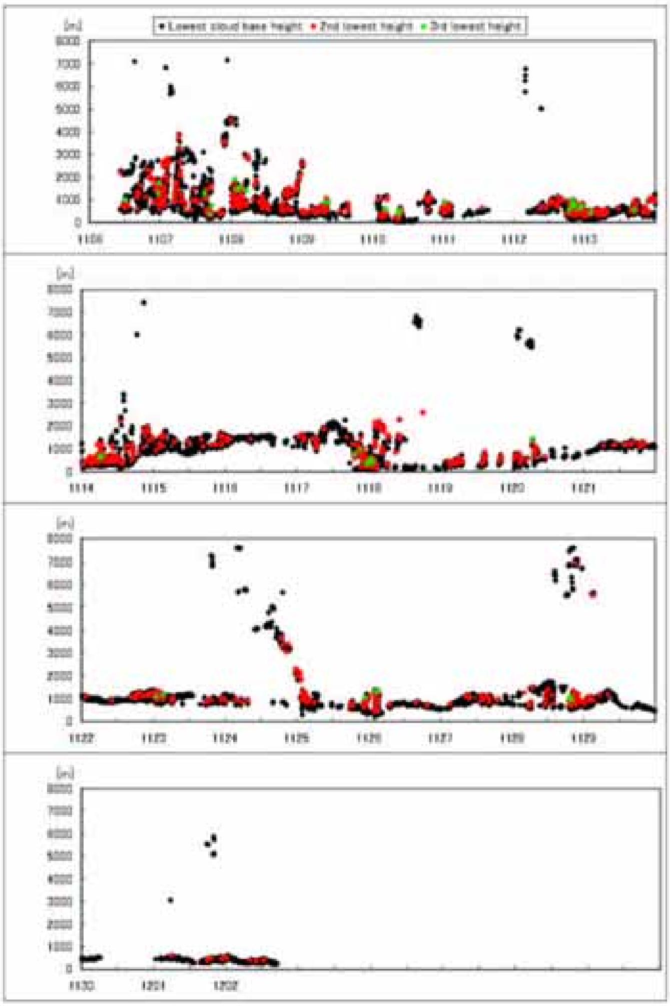


Fig.2.1.2 1st, 2nd and 3rd lowest cloud base height during the cruise.

2.1.3 Surface atmospheric turbulent flux measurement

Not on-board
Kunio Yoneyama (JAMSTEC)
Osamu Tsukamoto (Okayama Univ.)
Hiroshi Ishida (Kobe Univ.)

(1) Objective

To better understand the air-sea interaction, accurate measurements of surface heat and fresh water budgets are necessary as well as momentum exchange through the sea surface. In addition, the evaluation of surface flux of carbon dioxide is also indispensable for the study of global warming. Sea surface turbulent fluxes of momentum, sensible heat, latent heat, and carbon dioxide were measured by using the eddy correlation method that is thought to be most accurate and free from assumptions. These surface heat flux data are combined with radiation fluxes and water temperature profiles to derive the surface energy budget.

(2) Apparatus and Performance

The surface turbulent flux measurement system consists of turbulence instruments (Kaijo Co. Ltd.,) and ship motion sensors (Kanto Aircraft Instrument Co. Ltd.,). Details of each sensor are as follows. All sensors are equipped at 25 m height from sea surface.

Sensor	Type / Manufacturer
Three-dimensional sonic anemometer-thermometer	Kaijo, DA-600
Infrared hygrometer	LICOR, LI-7500
Two-axis inclinometer	Applied Geomechanics, MD-900-T
Three-axis accelerometer	Applied Signal Inc., QA-700-020
Three-axis rate gyro	Systron Donner, QRS-0050-100

These signals are sampled at 10 Hz by a PC-based data logging system (Labview, National Instruments Co. Ltd.,). By obtaining the ship speed and heading information through the Mirai network system it yields the absolute wind components relative to the ground. Combining wind data with the turbulence data, turbulent fluxes and statistics are calculated in a real-time basis.

(3) Calibration

All sensors were calibrated at the manufacturer (Kaijo Co. Ltd.,) in April 2003.

After the cruise, these data will be compared with surface meteorological data obtained by another system (SOAR) to exclude unreliable data.

(4) Preliminary results

Data will be processed after the cruise at Okayama University.

(5) Data Archive

All data are archived at Okayama University, and will be open to public after quality checks and corrections. Corrected data will be submitted to JAMSTEC Data Management Division.

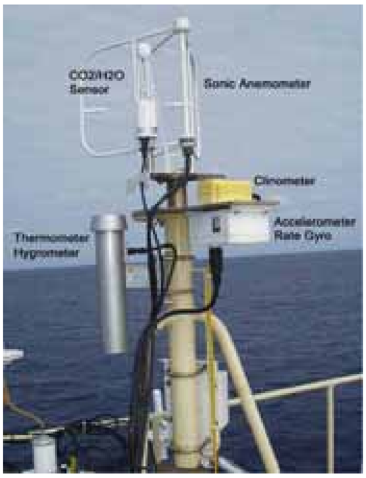


Fig.2.1.3Turbulent flux measurement system on the top deck of the foremast.

2.2 Navigation and Bathymetry

Souichiro Sueyoshi	(Global Ocean Development Inc.)
Shinya Okumura	(GODI)
Katsuhisa Maeno	(GODI)

Navigation: Ship's position was measured by Radio navigation system, made by Sena Co. Ltd., Japan. The system has two 12-channel GPS receivers (Leica MX9400N). GPS antennas located at Navigation deck, offset to starboard and portside, respectively. We switched them to choose better state of receiving when the number of GPS satellites decreased or HDOP increased. But the system sometimes lost the position while the receiving status became worse. The system also integrates gyro heading (Tokimec TG-6000), log speed (Furuno DS-30) and other navigation devices data on HP workstation. The workstation keeps accurate time using GPS Time server (Datum Tymserv2100) via NTP(Network Time Protocol). Navigation data was recorded as "SOJ" data every 60 seconds. The periods of losing the position are described in "Readme" file attached to SOJ data.

Bathymetry: R/V MIRAI equipped a Multi Narrow Beam Echo Sounding system (MNBES), SEABEAM 2112.004 (SeaBeam Instruments Inc.) The main objective of MNBES survey is collecting continuous bathymetry data along ship's track to make a contribution to geological and geophysical investigations and global datasets. We carried out bathymetric survey during the MR03-K04 Leg.4 cruise from CTD station A10-622 on 7 November 2003 to CTD station A10-100 on 2 December 2003. Data interval along ship's track was max 16 seconds at 6,000 m. To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data at the surface (6.2m) sound velocity, and the others depth sound velocity was calculated using temperature and salinity profiles from CTD data by the equation in Mackenzie (1981).

System configuration and performance of SEABEAM 2112.004,

Frequency:	12 kHz
Transmit beam width:	2 degree
Transmit power:	20 kW
Transmit pulse length:	3 to 20 msec.
Depth range:	100 to 11,000 m
Beam spacing:	1 degree athwart ship
Swath width:	150 degree (max) 120 degree to 4,500 m 100 degree to 6,000 m 90 degree to 11,000 m
Depth accuracy:	Within < 0.5% of depth or +/-1m, whichever is greater, over the entire swath. (Nadir beam has greater accuracy; typically within < 0.2% of depth or +/-1m, whichever is greater)

2.3 Acoustic Doppler Current Profiler (ADCP)

Y. Yoshikawa (JAMSTEC)
S. Sueyoshi (GODI)

The instrument used was an RDI 75kHz unit, hull-mounted on the centerline and approximately 23m aft of the bow at the water line. On this cruise the firmware version was 5.59 and the data acquisition software was RDI VMDAS Ver.1.3. Operation was made from the first CTD station (A10-622) to the last CTD station (A10-100). For most of its operation the instrument was used in the water-tracking mode, recording each 1 ping raw data in 100 x 8m bins from 18.5m to 818.5m. Bottom track mode was added in the westernmost shallow water region, giving the data to evaluate the alignment of the transducer on the hull. In the course the scale factor of ADCP was also evaluated. Compass we used was INU (Inertial Navigation Unit) instead of ship's gyrocompass. Its accuracy was 1.0mil (about 0.056 degree) and had already set on zero bias. The electronic trouble occurred at 15:33 on 24 November, between A10-67 and A10-68. Thought it recovered at 16:06, the INU compass had to be initialized. The offset was evaluated at port of Cape Town. The accuracy became 2.0mil (about 0.112 degree) after the trouble because of the initialization in open ocean.

The performance of the ADCP instrument was good throughout the cruise: on streaming, profiles were usually recorded to 500m except in heaviest weather and in whilst streaming. On station, profiles were not good because of the babbles from bow-thruster.

The first processing was evaluation both of ADCP scale factor and transducer misalignment by using the bottom track mode data between P6-246 and P6-244 along the P6 line in Leg.1. The error velocity was less than 2cm/s, and ratio ADCP/Navigation was 1.0239. Therefore the scale factor 1/1.0239=0.9766 was adapted to measured velocity magnitude of each ping. Misalignment angle was calculated as 0.76deg.

Stage 2 of the processing is applying misalignment correction to raw data and identifying of good data.

2.4 Thermo-salinograph

Takayoshi SEIKE : Marine Works Japan Co. Ltd.
Masao FUKASAWA : JAMSTEC

(1) Objective

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

(2) 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.

Specification of the each sensor in this system of listed below.

a) Temperature and Salinity sensor

SEACAT THERMOSALINOGRAPH

Model:	SBE-21, SEA-BIRD ELECTRONICS, INC.,
Serial number:	2118859-3126

Measurement range: Temperature -5 to +35degC, Conductivity 0 to 6.5 S m^{-1}
Accuracy: Temperature 0.01 degC 6month^{-1}, Conductivity 0.001 S m^{-1} month^{-1}
Resolution: Temperatures 0.001degC, Conductivity 0.0001 S m^{-1}

b) Bottom of ship thermometer
Model: SBE 3S, SEA-BIRD ELECTRONICS, INC.
Serial number: 032607
Measurement range: -5 to +35degC
Resolution: ±0.001degC
Stability: 0.002 degC year^{-1}

c) Dissolved oxygen sensor
Model: 2127A, HACH ULTRA ANALYTICS.
Serial number: 44733
Measurement range: 0 to 14 ppm
Accuracy: ±1% at 5 degC 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 chlorophyll-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 listed below.

11:07 of November 7 , 2003 – 17:05 of December 2 , 2003

(3) Preliminaly Result

Preliminary data of temperature (Bottom of ship thermometer), salinity at sea surface between this cruise are shown in Fig. 2.4.1 and 2.4.2. They show the respective trend of each distribution on the ship's track every ten minutes.

We sampled about three times every day for salinity sensor calibration. All salinity samples were collected from the course of the system while on station or from regions with weak horizontal gradients. All samples were analyzed on the Guildline 8400B. The results were shown in Table 2.4.1.

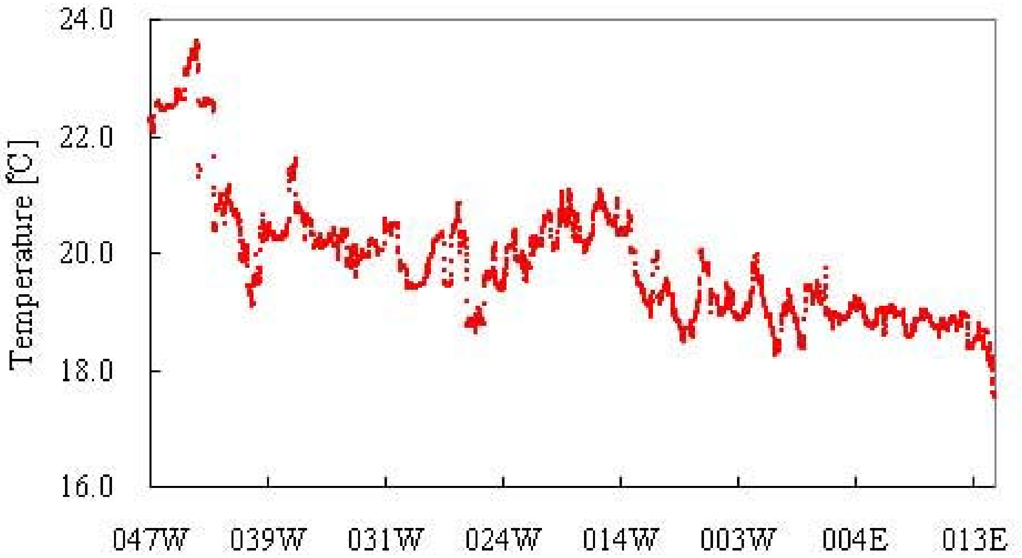


Fig.2.4.1 Time series of temperature in the sea surface water.

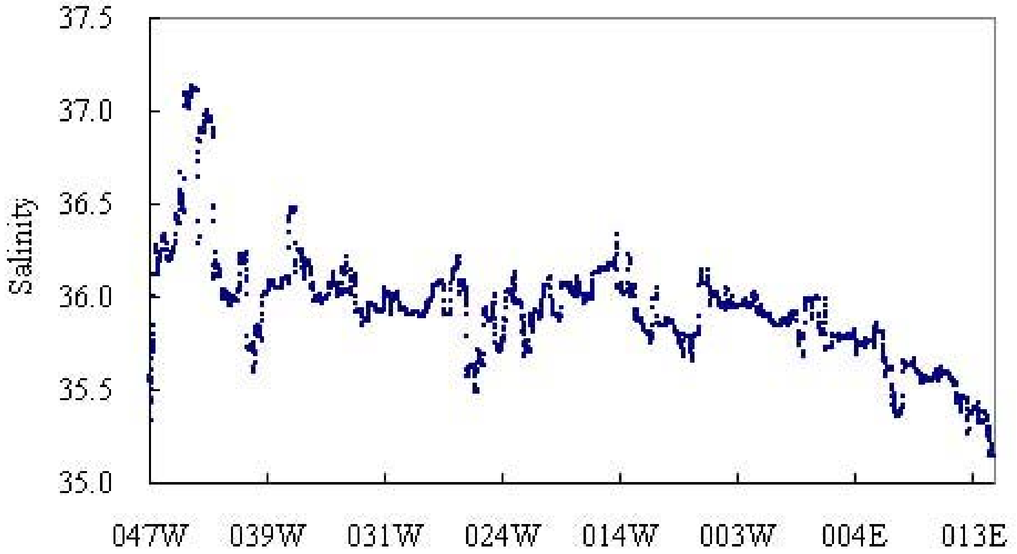


Fig.2.4.2 Time series of salinity in the sea surface water.

Table2.4.1 Comparison between salinity data from *Continuous Sea Surface Water Monitoring* and bottle salinity.

Date [UTC]	Time [UTC]	Salinity data	Bottle Salinity [PSS-78]
7-Nov-03	17:55	36.1938	36.1807
8-Nov-03	1:58	36.2261	36.2155
8-Nov-03	9:59	36.5223	36.5107
8-Nov-03	18:02	37.1111	37.1012
9-Nov-03	2:10	36.9197	36.9104
9-Nov-03	9:51	36.1602	36.1485
9-Nov-03	17:53	35.9997	35.9989
10-Nov-03	1:59	36.0251	36.0113
10-Nov-03	9:49	35.7294	35.7069
10-Nov-03	17:57	35.7728	35.7581
11-Nov-03	1:58	36.0776	36.0665
11-Nov-03	9:56	36.0963	36.0859
11-Nov-03	17:58	36.4694	36.4562
12-Nov-03	1:54	36.1788	36.1679
12-Nov-03	9:56	36.0033	35.9918
12-Nov-03	18:02	36.0591	36.0479
13-Nov-03	1:57	36.0285	36.0178
13-Nov-03	10:02	36.0261	36.0285
13-Nov-03	17:53	35.8561	35.8478
14-Nov-03	2:04	35.9495	35.9412
14-Nov-03	9:58	35.9992	35.9889
14-Nov-03	18:01	36.0190	36.0086
15-Nov-03	1:57	35.9047	35.8949
15-Nov-03	9:57	35.9049	35.8949
15-Nov-03	17:58	35.9818	35.9718
16-Nov-03	1:54	36.0762	36.0671
16-Nov-03	10:01	36.1472	36.1375
16-Nov-03	18:00	36.0770	36.0673
17-Nov-03	2:08	35.4934	35.4839
17-Nov-03	9:53	35.8994	35.8891
17-Nov-03	17:57	35.7057	35.6967
18-Nov-03	1:58	36.0270	36.0165
18-Nov-03	10:06	35.9530	35.9444
18-Nov-03	18:02	35.8323	35.8216
19-Nov-03	2:01	36.0499	36.0429
19-Nov-03	9:59	35.9020	35.8931

19-Nov-03	18:01	36.0589	36.0523
20-Nov-03	0:56	35.9941	35.9846
20-Nov-03	8:50	36.0124	36.0030
20-Nov-03	17:03	36.1284	36.1210
21-Nov-03	1:00	36.1766	36.1659
21-Nov-03	8:49	36.0655	36.0578
21-Nov-03	16:56	36.0378	36.0288
22-Nov-03	0:56	35.8476	35.8372
22-Nov-03	8:48	35.9853	35.9764
22-Nov-03	17:03	35.8738	35.8642
23-Nov-03	0:55	35.8052	35.7957
23-Nov-03	8:47	35.7842	35.7746
23-Nov-03	16:59	36.1174	36.1141
24-Nov-03	0:59	36.0071	35.9972
24-Nov-03	8:45	35.9418	35.9332
24-Nov-03	17:05	35.9580	35.9500
24-Nov-03	23:56	36.0008	35.9927
25-Nov-03	7:57	35.9606	35.9538
25-Nov-03	16:00	36.0141	36.0069
25-Nov-03	23:58	35.8938	35.8864
26-Nov-03	8:09	35.8466	35.8371
26-Nov-03	15:59	35.8641	35.8579
26-Nov-03	23:59	35.7779	35.7695
27-Nov-03	7:52	35.9645	35.9598
27-Nov-03	16:08	35.8023	35.7946
27-Nov-03	23:57	35.7883	35.7797
28-Nov-03	8:01	35.7803	35.7724
28-Nov-03	15:57	35.6961	35.6885
29-Nov-03	0:01	35.7615	35.7524
29-Nov-03	7:53	35.8114	35.8036
29-Nov-03	16:02	35.6035	35.5984
29-Nov-03	23:56	35.3958	35.3908
30-Nov-03	7:54	35.6416	35.6358
30-Nov-03	15:57	35.5562	35.5515
1-Dec-03	6:45	35.5899	35.6257
1-Dec-03	14:54	35.4484	35.4906
1-Dec-03	21:55	35.4547	35.4953
2-Dec-03	5:43	35.3556	35.3501
2-Dec-03	13:59	35.2902	35.2840

(4) Date archive

The data were stored on a magnetic optical disk, which will be submitted to the Data Management Office (DMO) JAMSTEC, and will be opened to public via“R/V MIRAI Data Web Page”in JAMSTEC homepage.

2.5 pCO_2

Akihiko Murata (JAMSTEC)
Minoru Kamata (MWJ)
Toru Fujiki (MWJ)

2.5.1 Objective

Concentrations of CO_2 in the atmosphere are now increasing at a rate of 1.5 ppmv y^{-1} owing to human activities such as burning of fossil fuels, deforestation, and cement production. It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric CO_2, and to clarify the mechanism of the CO_2 absorption, because the magnitude of the anticipated global warming depends on the levels of CO_2 in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In this cruise, we are aimed at quantifying how much anthropogenic CO_2 absorbed in the surface ocean in the Southern Hemisphere, where data for CO_2 are sparse. For the purpose, we measured pCO_2 (partial pressure of CO_2) in the atmosphere and surface seawater.

2.5.2 Apparatus and performance

Concentrations of CO_2 in the atmosphere and the sea surface were measured continuously during the cruise using an automated system with a non-dispersive infrared (NDIR) analyzer (BINOS^{TM}). The automated system was operated by on one and a half hour cycle. In one cycle, standard gasses, marine air and an air in a headspace of an equilibrator were analyzed subsequently. The concentrations of the standard gas were 270.09, 328.86, 359.10 and 409.22 ppm. The standard gases will be recalibrated after the cruise.

The marine air taken from the bow was introduced into the NDIR by passing through a mass flow controller which controlled the air flow rate at about 0.5 L/min, a cooling unit, a perma-pure dryer (GL Sciences Inc.) and a desiccant holder containing $Mg(ClO_4)_2$.

A fixed volume of the marine air taken from the bow was equilibrated with a stream of seawater that flowed at a rate of 5-6L/min in the equilibrator. The air in the equilibrator was circulated with a pump at 0.7-0.8L/min in a closed loop passing through two cooling units, a perma-pure dryer (GL Science Inc.) and a desiccant holder containing $Mg(ClO_4)_2$.

2.5.3 Results

Concentrations of CO_2 (xCO_2) of marine air and surface seawater are shown in Fig.2.5.1.

From this figure, it is found that the area acted generally as a sink for atmospheric CO_2.

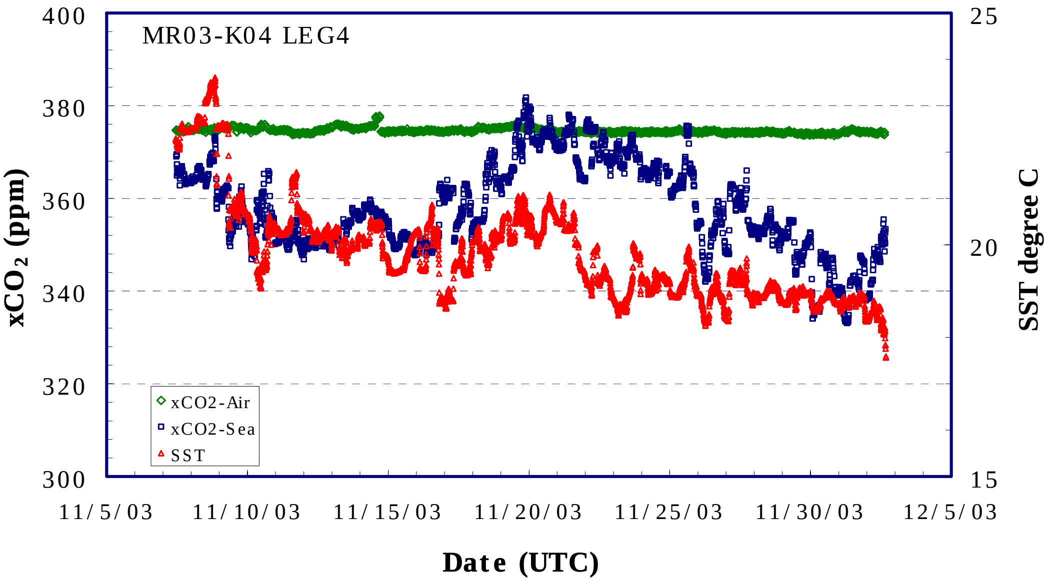


Fig.2.5.1 Concentrations of CO_2 (xCO_2) in atmosphere and surface seawater

3. Hydrography

3.1 CTDO Sampler

Hiroshi Uchida (JAMSTEC)
Masao Fukasawa (JAMSTEC) (not on board)
Wolfgang Schneider (University of Concepcion)
Mark Andrew Rosenberg (ACE CRC)
Satoshi Ozawa (MWJ)
Miki Yoshiike (MWJ)

3.1.1 Winch arrangements

The CTD package was deployed using a 4.5 Ton Traction Winch System (Dynacon, Inc., USA) which was installed on the R/V Mirai in April 2001 and moved its position several meters to stern side in April 2003. The CTD Traction Winch System with the Heave Compensation Systems (Dynacon, Inc., USA) is designed to reduce cable stress resulting from load 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 6,600 m of 9.53 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.

3.1.2 Overview of the equipment

The CTD system, SBE 911plus 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 (Hewlett Packard Vectra VL, Intel(r) Celeron(tm), Microsoft Windows98 2nd edition) 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-litre water sample bottles. Bottles were fired through the RS-232C modem connector on the back of the SBE 11plus deck unit while acquiring real time data. The 12-litre Niskin-X water sample bottle (General Oceanics, Inc., USA) is equipped externally with two stainless steel springs. 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 temperature (SBE 3F and SBE 3plus) 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 the 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. Flow speed of pumped water in standard TC duct is about 2.3 m/s. SBE’s dissolved oxygen sensor (SBE 43) was placed between the conductivity sensor module and the pump.

The system used in this cruise is summarized as follows:

Under water unit:

SBE, Inc., SBE 9plus, S/N 42423

Temperature sensor:

SBE, Inc., SBE 3-04/F, S/N 031464 (primary)

SBE, Inc., SBE 3plus, S/N 03P4188 (secondary)

Conductivity sensor:

SBE, Inc., SBE 4-04/0, S/N 041203 (primary)

SBE, Inc., SBE 4C, S/N 042435 (secondary)

Oxygen sensor:

SBE, Inc., SBE 43, S/N 430391 (primary)

SBE, Inc., SBE 43, S/N 430394 (secondary)

Pump:

SBE, Inc., SBE 5T, S/N 053575 (primary)

SBE, Inc., SBE 5T, S/N 050984 (secondary)

Altimeter:

Benthos Inc., PSA-900D, S/N 1026

Deep Ocean Standards Thermometer:

SBE, Inc., SBE 35, S/N 3533904-0045

Deck unit:

SBE, Inc., SBE 11plus, S/N 11P7030-0272

Carousel Water Sampler:

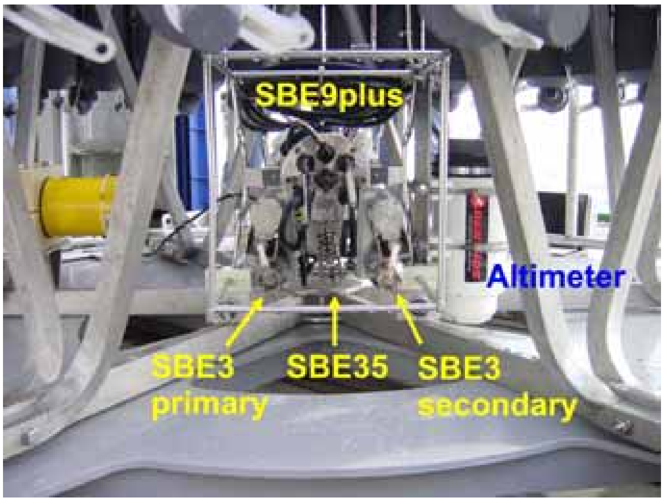
SBE, Inc., SBE 32, S/N 3227443-0391

Fluorometer:

Seapoint sensors, Inc., S/N 2579

Water sample bottle:

General Oceanics, Inc., 12-litre Niskin-X



3.1.3 Pre-cruise calibration

3.1.3.1 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:

S/N 42423 17 May, 1994
c1 = -69582.91
c2 = -1.619244
c3 = 2.34327e-02
d1 = 0.029679
d2 = 0
t1 = 28.12082
t2 = -4.595919e-04
t3 = 3.89464e-06
t4 = 0
t5 = 0

Pressure coefficients are first formulated into
c = c1 + c2 * U + c3 * U^2
d = d1 + d2 * U
t0 = t1 + t2 * U + t3 * U^2 + t4 * U^3 + t5 * U^4
where U is temperature in degrees Celsius. The pressure temperature, U, is determined according to
U (degC) = M * (12 bit pressure temperature compensation word) – B
The following coefficients were used in SEASOFT:
M = 0.01161
B = -8.32759
(in the underwater unit system configuration sheet dated on May 24, 1994)
Finally, pressure is computed as
P (psi) = c * [1 – (t0^2 / t^2)] * {1 – d * [1 – (t0^2 / t^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 calibrations 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 sensor time drift and linearity. The pressure sensor drift is known to be primarily an offset drift at all pressures rather than a change of span slope. The pressure sensor hysterisis is typically 0.2 dbar. The following coefficients for the sensor drift correction were also used in SEASOFT through the software module SEACON:

S/N 42423 April 18, 2003
slope = 0.9999112
offset = -0.0295469

The drift-corrected pressure is computed as
Drift-corrected pressure (dbar) = slope * (computed pressure in dbar) + offset

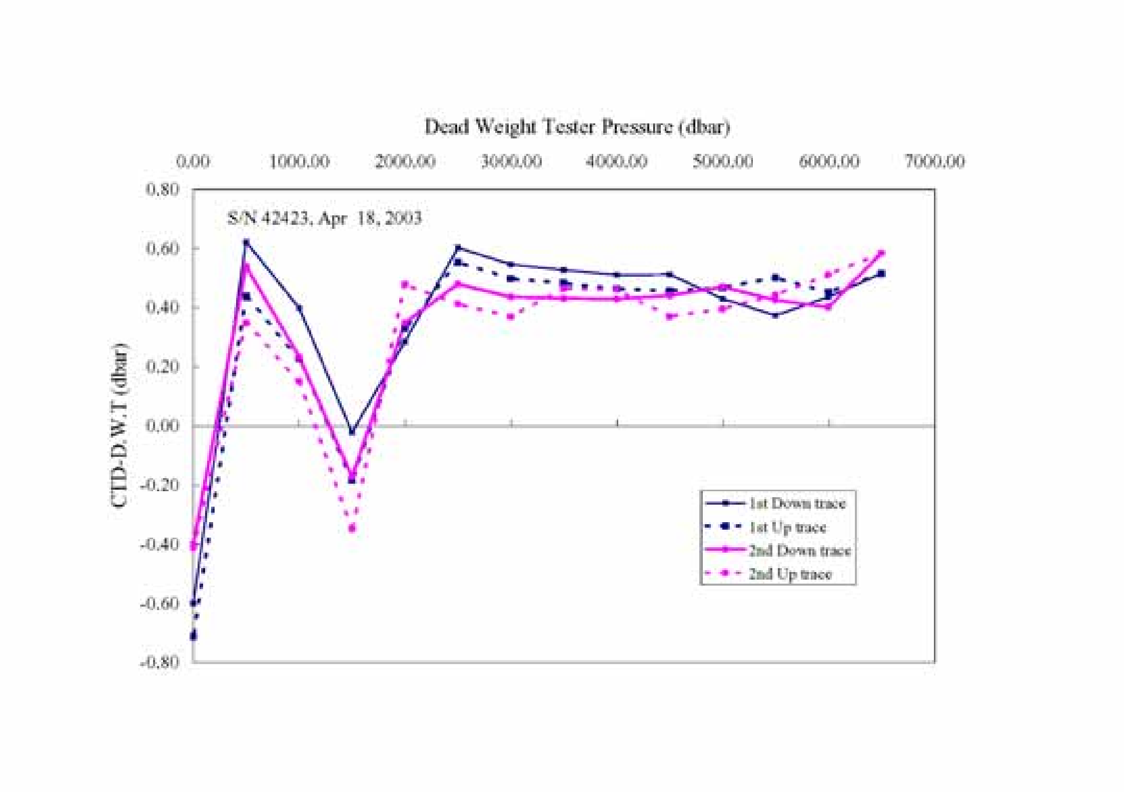


Fig.3.1.1 The residual pressures between the Dead Weight Tester and the CTD.

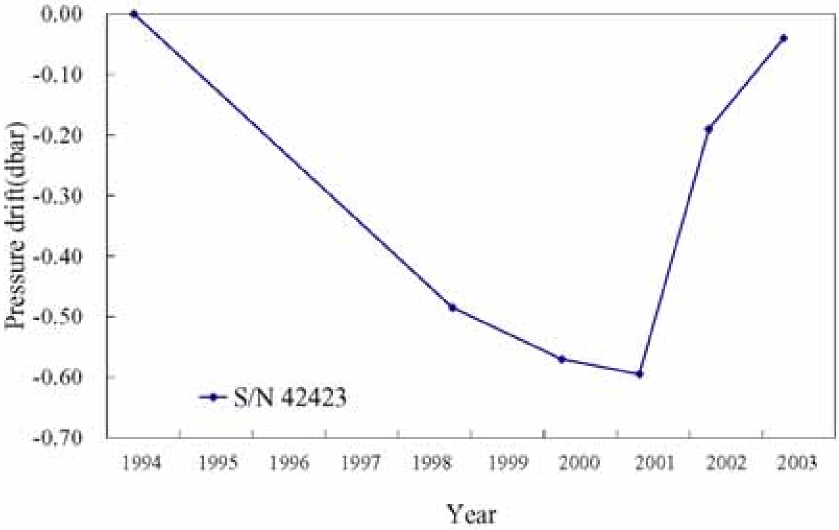


Fig.3.1.2 Drift (offset) of the pressure sensor measured by the Dead Weight Tester.

3.1.3.2 Temperature (3F and SBE 3plus)

The temperature sensing element is a glass-coated thermistor bead in a stainless steel tube, providing a pressure-free measurement at depths up to 6,800m (S/N 03P4188) and 10,500 m (S/N 031464). 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. The premium temperature sensor, SBE 3plus, is a more rigorously tested and calibrated version of standard temperature sensor (SBE 3F). A sensor is designated as an SBE 3plus only after demonstrating drift of less than 0.001 degC during a six-month screening period. In addition, the time response is carefully measured and verified to be 0.065 ± 0.010 seconds.

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

S/N 031464 (primary) 23 September, 2003

g = 4.84390595e-03

h = 6.80838076e-04
i = 2.70300539e-05
j = 2.13906165e-06
f0 = 1000.000

S/N 03P4188 (secondary)   23 September, 2003

g = 4.39869651e-03
h = 6.45292266e-04
i = 2.26138218e-05
j = 1.89143037 e-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).

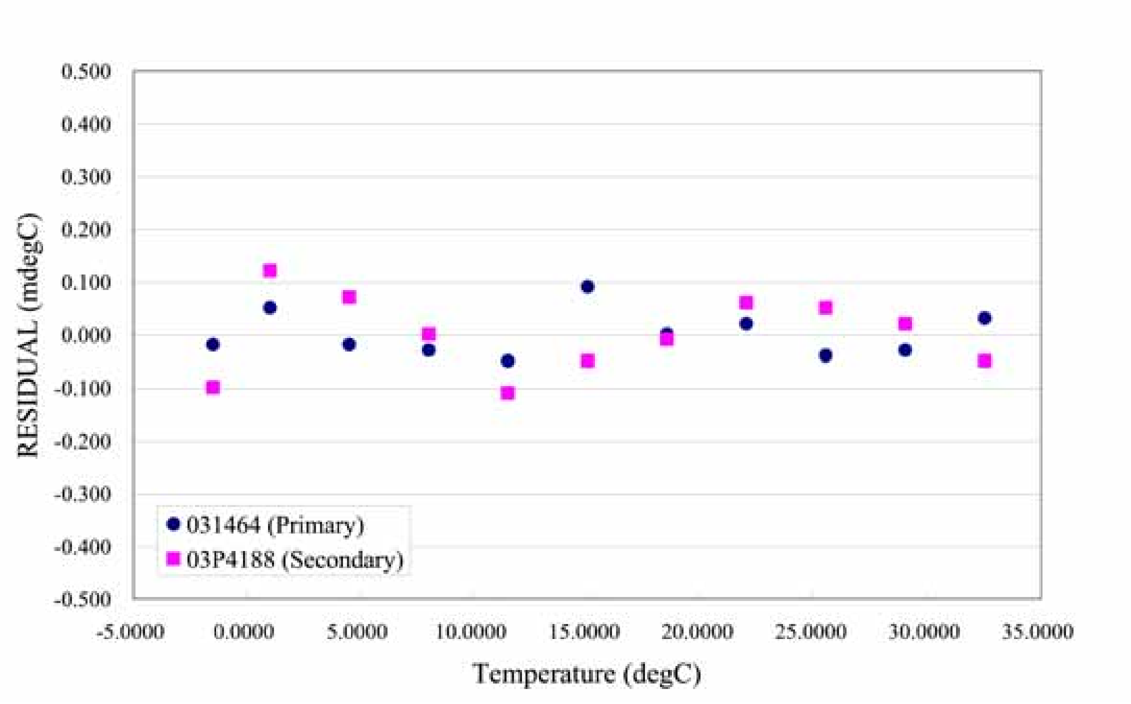


Fig.3.1.3 Residual temperature between bath and instrument temperatures.

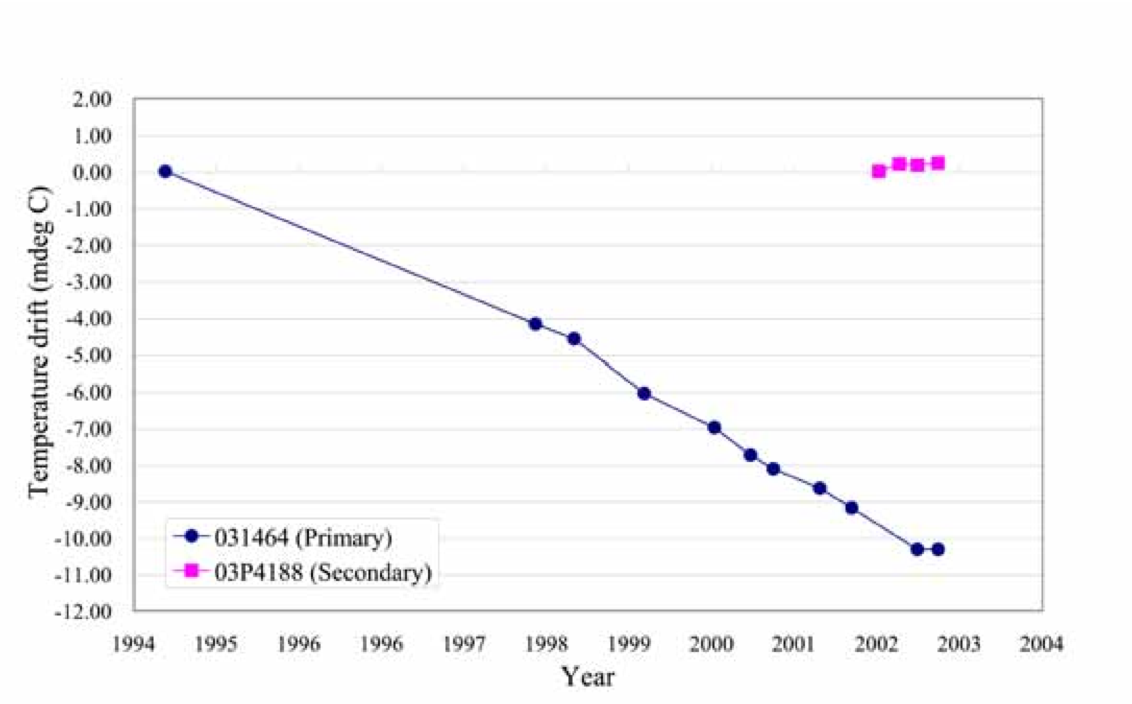


Fig.3.1.4 Drift of the temperature sensors based on laboratory calibrations.

3.1.3.3 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 of 0 to 7 S/m. The conductivity cell 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:

S/N 041203 (primary) 25 September, 2003
g = -4.05196392e+00
h = 4.93501401e-01
i = 8.12083631e-05
j = 2.24962840e-05
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

S/N 042453 (secondary)   23 September, 2003

g = -1.03013001e+00
h = 1.49755131e+00
i = 2.74099344e-04
j = 6.35607354e-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.

3.1.3.4 Deep Ocean Standards Thermometer

The SBE 35 is an accurate, ocean-range temperature sensor that can be standardized against Triple Point of Water and Gallium Melt Point cells and is also capable of measuring temperature in the ocean to depths of 6,800 m. The SBE 35 communicates via a standard RS-232 interface at 300 baud, 8 bits, no parity. The SBE 35 can be used with the SBE 32 Carousel Water Sampler and SBE 911plus CTD system. The SBE 35 makes a temperature measurement each time a bottle fire confirmation is received, and stores the value in EEPROM. Calibration coefficients stored in EEPROM allow the SBE 35 to transmit data in engineering units. Commands can be sent to SBE 35 to provide status display, data acquisition setup, data retrieval, and diagnostic test.

Following the methodology used for standards-grade platinum resistance thermometers (SPRT), the calibration of the SBE 35 is accomplished in two steps. The first step is to characterize and capture the non-linear resistance vs temperature response of the sensor. The SBE 35 calibrations are performed at SBE, Inc., in a low-gradient temperature bath and against ITS-90 certified SPRTs maintained at Sea-Bird’s primary temperature metrology laboratory. The second step is frequent certification of the sensor by measurements in thermodynamic fixed-point cells. Triple point of water (TPW) and gallium melt point (GaMP) cells are appropriate for the SBE 35. Like SPRTs, the slow time drift of the SBE 35 is adjusted by a slope and offset correction to the basic non-linear calibration equation.

Pre-cruise sensor calibrations were performed at SBE, Inc. in Bellevue, Washington, USA. The following coefficients were stored in EEPROM:

S/N 0045 27 October, 2002 (1st step: linearization)

a0 = 5.84093815e-03
a1 = -1.65529280e-03
a2 = 2.37944937e-04
a3 = -1.32611385e-05
a4 = 2.83355203e-07

Temperature (ITS-90) is computed according to

Temperature (ITS-90) =
1 / {a0 + a1 * [ln(n)] + a2 * [ln^2(n)] + a3 * [ln^3(n)]+ a4 * [ln^4(n)]} – 273.15

where n is the instrument output.

S/N 0045 26 September, 2003 (2nd step: fixed point calibration)

Slope = 1.000007
Offset = -0.000376

The SBE 35 has a time constant of 0.5 seconds. The time required per sample = 1.1 * NCYCLES + 2.7 seconds. The 1.1 seconds is total time per an acquisition cycle. NCYCLES is the number of acquisition cycles per sample. The 2.7 seconds is required for converting the measured values to temperature and storing average in EEPROM. RMS temperature noise for an SBE 35 in a Triple Point of Water cell is typically expressed as 82 / sqrt(NCYCLES) in micro K. In this cruise NCYCLES was set to 4 (acquisition time was 4.4 seconds) and the RMS noise was 0.000041 degrees C.

3.1.3.5 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. The oxygen sensor determines the dissolved oxygen concentration 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 the 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:

S/N 430391(primary)　17 July, 2003
Soc = 0.4108
Boc = 0.0000
TCor = 0.0012
PCor = 1.350e-04
Offset = -0.4851
tau = 0

S/N 430394(secondary)　06 October, 2003
Soc = 0.3003
Boc = 0.0000
TCor = 0.0016
PCor = 1.350e-04
Offset = 0.5016
tau = 0

Oxygen (ml/l) is computed as

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

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

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

3.1.3.6　Altimeter

The Benthos PSA-900 Programmable Sonar Altimeter (Benthos, Inc., USA) determines the distance of the target from the unit in almost the same way as the Benthos 2110. PSA-900 also uses the nominal speed of sound of 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 (PSA-900D) is rated to a depth of 6,000 meters.

The following scale factors were used in SEASOFT:
FSVolt * 300 / FSRange = 10
Offset = 0.0

3.1.3.7 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 2579 (unknown calibration date)
Gain setting :30X 0-5 ug/l
Offset :0.0

3.1.4 Data collection and processing

3.1.4.1 Data collection

CTD measurements were made using a SBE 9plus CTD equipped with two pumped temperature-conductivity (TC) sensors. The TC pairs were monitored to check drift and shifts by examining the differences between the two pairs. The SBE 9plus CTD (sampling rate of 24 Hz) was mounted horizontally in a 36-position carousel frame. Auxiliary sensors included altimeter, dissolved oxygen sensors, fluorometer and Deep Ocean Standards Thermometer.

The package was lowered into the water from the starboard side and held 10 m beneath the surface for about one minute in order to activate the pump. After the pump was activated the package was lifted to the surface and 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 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 board. For the up cast, the package was lifted at a rate of 1.2 m/s except for bottle firing stops. At each bottle firing stops, the bottle was fired after waiting 30 seconds and the package was stayed 7 seconds in order to sample temperature by the Deep Ocean Standards Thermometer. At 100 m from the surface, the package was stopped in order to stop the heave compensator of the crane.

Water samples were collected using a 36 bottle SBE 32 Carousel Water Sampler with 12-litre Nisken-X bottles. Niskin-X bottle samples were taken water for analysis of salinity, dissolved oxygen, nutrients, DIC, TOC, pH, total alkalinity, CFCs, radio nuclear, 14C, Argon, chlorophyll-a and primary productivity. Before a cast taken water for CFCs, the 36-bottle frame and Niskin-X bottles were wiped with acetone.

The SBE 11plus deck unit received the data signal from the CTD. Digitized data were forwarded to a personal computer running the SEASAVE module of the SEASOFT acquisition and processing software, version 5.27b. Temperature, conductivity, salinity, oxygen and descent rate profiles were displayed in real-time with the package depth and altimeter reading.

In order to acquire data for more comparison between SBE 3 and SBE 35, available bottles from which water sample was not taken were fired. CTD package was stopped and bottles were fired at additional layers (at most 5 layers) between 2,000 and 4,000 m. As a result, temperature between SBE 3 and SBE 35 can be compared at least 11 layers when the maximum depth is greater than 3,000 m.

3.1.4.2 Data collection problems

At stations A10-043 and A10-068, the same bottle was fired by mistake. Because the SEASAVE module didn’t accept firing bottles more than 36 times, a bottle was fired using a fire button of the SBE 11plus deck unit in order to close all bottles. Bottles can be fired sequentially from its home position (#1) using the fire button of the SBE 11plus deck unit. Therefore the bottle #4 for the station A10-043 and #5 for the station A10-068 were closed by pushing the fire button of the deck unit 4 and 5 times, respectively.

At station A10-089, abnormal value (greater than 37 PSU) in primary salinity was found between 60 and 100 m depths. Obtained data was carefully checked after the cast and unusual profiles in primary conductivity and primary temperature were seen. Therefore second cast was worked at the station after temperature, conductivity and oxygen sensors were washed with Triton X for 10 minutes.

When operating the SBE 911plus system with SBE 35, it was found that the deck unit (SBE 11plus) had received incorrect signal for confirmation of firing bottle #16. During this leg a module (Yoshi Ver. 1, EMS Co. Ltd., JAPAN) to correct the signal was used between the underwater unit and the deck unit.

When the SBE 35 data was uploaded by SEATERM (ver. 1.33), transmission error was appeared at all casts except for A10-98, 99 and 100. Because one character was dropped in the data file, the dropped character was estimated and the data file was corrected manually.

3.1.4.3 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 a 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 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. 5.27b) processing module sequence and specifications used in the reduction of CTD 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, depth, temperatures, conductivities, oxygen, oxygen voltage. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition. The duration was set to 4.4 seconds, and the offset was set to 0.0 seconds.

ROSSUM created a summary of the bottle data. The bottle position, date, time were output as the first two columns. Scan number, pressure, depth, temperatures, conductivities, oxygen voltage, and altitude were averaged over 4.4 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 9plus 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 a 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. This delay was compensated by 6 seconds advancing oxygen sensor output (oxygen voltage) 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 1000 scans. Data greater than 10 standard deviations were flagged. The second pass computed a standard deviation over the same 1000 scans excluding the flagged values. Values greater than 20 standard deviations were marked bad. This process was applied to pressure, temperatures, conductivities, oxygen voltage and altimeter outputs.

CELLTM used a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. Typical values used were thermal anomaly amplitude alpha = 0.03 and the time constant 1/beta = 7.0.

FILTER performed 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 a median filter to remove spikes in the Fluorometer data. A median value was determined from a window of 49 scans.

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 the starting time when the CTD package was beneath the sea-surface after activation of the pump. The maximum number was set to be the end 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 to compute oxygen.

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, potential temperature, and sigma-theta.

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

3.1.5 Post-cruise calibration

3.1.5.1 Pressure

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. In order to get the calibration data for the pre- and post-cast pressure sensor drift, the CTD deck pressure is averaged over first and last two minutes, respectively. 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 –0.80 dbar and the root-mean-square difference of 0.10 dbar. And the pre-cruise calibration (April 2003) shows that residual pressure between the Dead Weight Tester and the drift corrected CTD data at 0 dbar was –0.57 dbar. Therefore the pressure sensor drift from the pre-cruise calibration is estimated as –0.23 dbar. So the post-cruise calibration is not deemed necessary for this pressure sensor.

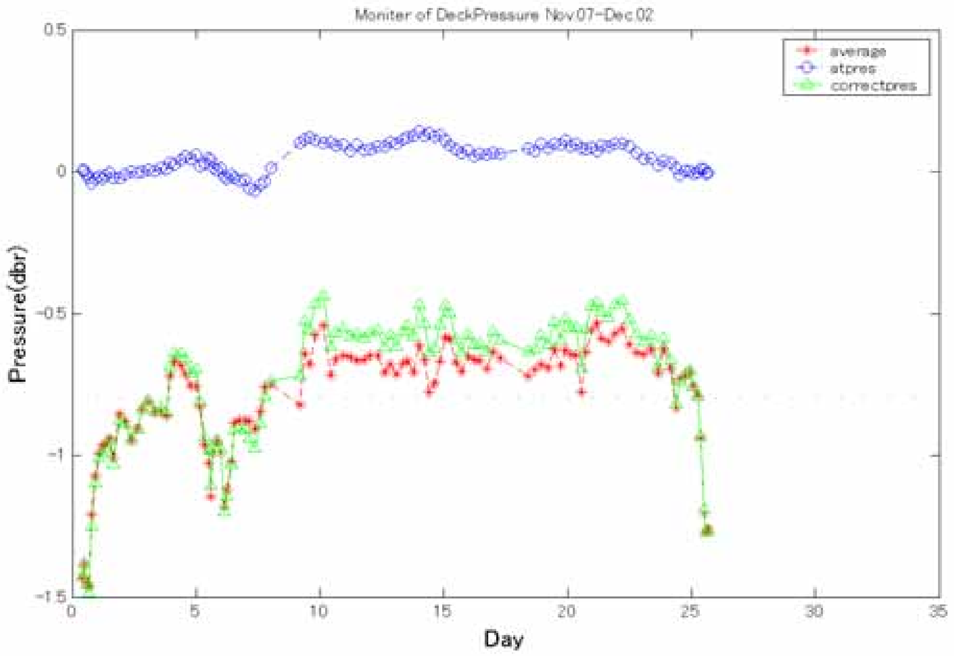


Fig.3.1.5 Time series of the CTD deck pressure.

3.1.5.2 Temperature

Post-cruise sensor calibrations are going to be performed at SBE, Inc. in Bellevue, Washington, USA. SBE 3 secondary temperature sensor (S/N 03P4188) is going to be sent to SBE immediately after the cruise. SBE 3 primary temperature sensor (S/N 031464) is going to be used in MR03-K04 Leg5 cruse as primary sensor and is going to be sent to SBE in January 2004. Using results of these calibrations and SBE 35 data, CTD temperature is going to be corrected.

SBE 3 sensors are made with a glass encased thermistor bead inside a needle. The needle protects the thermistor from seawater. If the thermistor bead is slightly large of specification it receives mechanical stress when the needle is compressed at high pressure. The pressure sensitivity for a SBE 3 sensor is usually less than 2 mK / 6000 dbar. It is somewhat difficult to measure this effect in the laboratory and it is one of the primary reasons to use the SBE 35 at sea for critical work. Also SBE 3 measurements may be affected by viscous heating that occurs in a TC duct and does not occur for un-pumped SBE 35 measurements.

SBE 35 calibrations have some uncertainty (about 0.2 mK) and SBE 3 calibrations have some uncertainty (about 1 mK). So the best corrections for CTD temperature data can be made by using a SBE 35, correcting the SBE 3 data for viscous heating and then correcting the SBE 3 to agree with the SBE 35 (a linear pressure correction and an offset for drift and/or calibration uncertainty).

Although the SBE 35 temperature must be corrected based on laboratory post-cruise calibration, the CTD temperature and the SBE 35 temperature are compared using the data deeper than 2,000 dbar. The primary temperature sensor (S/N 031464) is in good agreement with the SBE 35. Its pressure sensitivity is about –0.4 mK / 6,000 dbar and offset from the SBE 35 temperature is about +0.5 mK at surface during the cruise period. As for the secondary temperature sensor, its pressure sensitivity is about 2 mK / 6,000 dbar and offset from the SBE 35 temperature is about +0.7 mK at surface during the cruise period. And time drift of the primary and secondary temperature sensor are about +0.3 mK / month and 0 mK / month, respectively.

3.1.5.3 Salinity and dissolved oxygen

The CTD salinity and dissolved oxygen are going to be calibrated using in-situ salinity and dissolved oxygen data obtained from sampled water after the CTD temperature is calibrated.

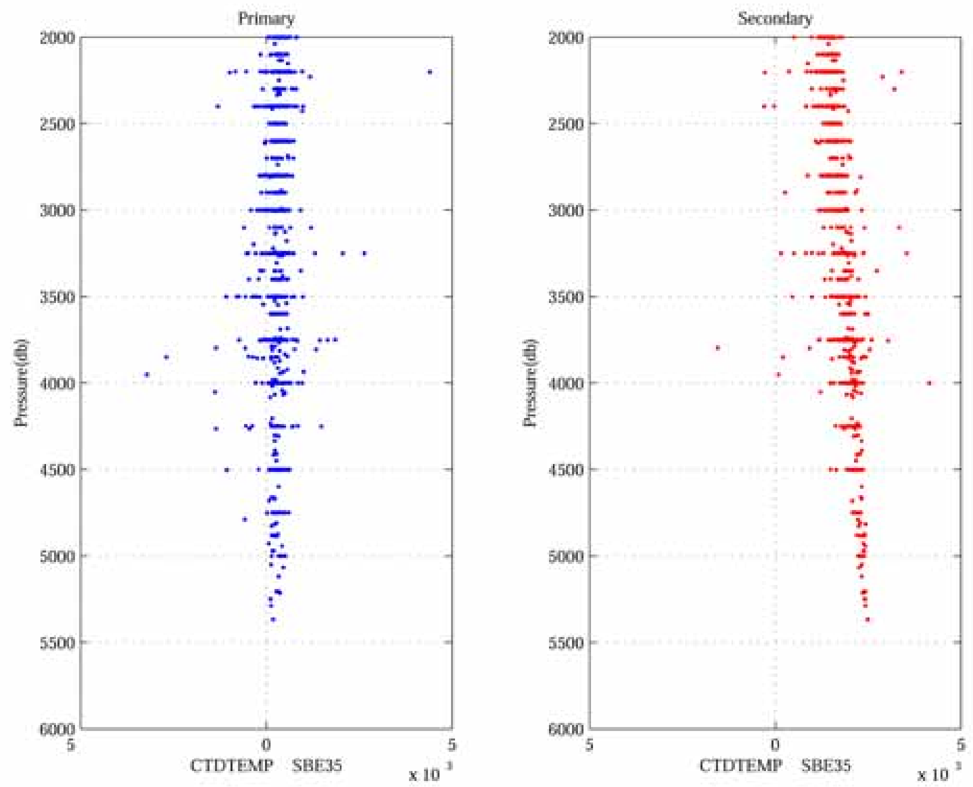


Fig.3.1.6 Comparison between SBE3 and SBE35

3.1.6 Preliminary results

Date, time and locations of the CTD casts are listed in SUM (station summary) file. In total 112 CTD casts were carried out. T-S (temperature vs salinity) diagram and vertical section of temperature, salinity, dissolved oxygen and Fluorescence are shown in Fig.3.1.6. Uncorrected CTD data are used in Fig.3.1.6.

3.1.7 Data archive

All raw and processed CTD data files will be submitted to JAMSTEC Data Management Office (DMO).

References

Schlitzer, R., Ocean Data View, http://www.awi-bremerhaven.de/GEO/ODV, 2002

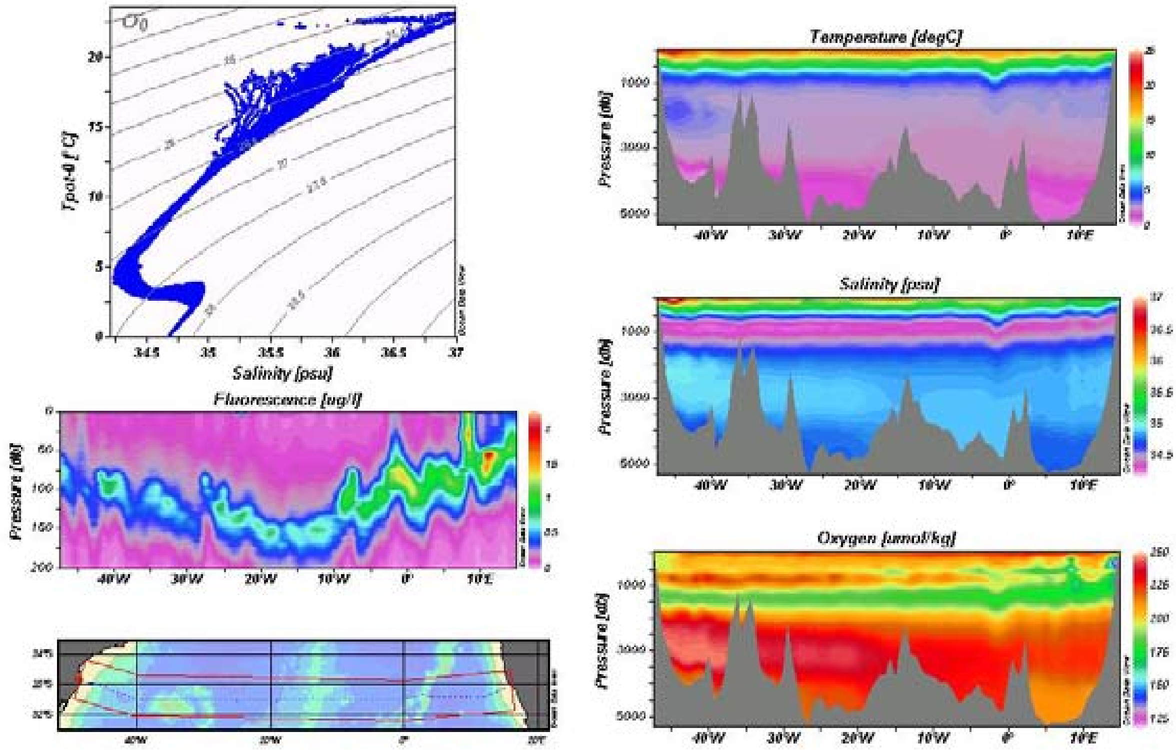


Fig.3.1.6 (a) T-S diagram, vertical section of (b) fluorescence to 200 dbar, (c) temperature, (d) salinity and (e) dissolved oxygen, and (f) Station locations.

3.2 Bottle Salinity

Takeshi Kawano (JAMSTEC) and Naoko Takahashi (MWJ)

3.2.1 Objectives

Bottle salinities were measured in order to be compared with CTD salinities to identify leaking bottles and calibrate CTD salinities.

3.2.2 Instrument and Method

3.2.2.1 Salinity Sample Collection

The bottles in which the salinity samples are collected and stored are 250 ml Phoenix brown glass bottles with screw caps. Each bottle was rinsed three times with sample water and was filled to the shoulder of the bottle. The caps were also thoroughly rinsed. Salinity samples were stored for about 24 hours in the same laboratory as the salinity measurement was made.

3.2.2.2 Instruments and Method

The salinity analysis was carried out on Guildline Autosal salinometer model 8400B (S/N 62556), which was modified by addition of an Ocean Science International peristaltic-type sample intake pump and two Guildline platinum thermometers model 9450. One thermometer monitored an ambient temperature and the other monitored a bath temperature. The resolution of the thermometers was 0.001 deg C. The measurement system was almost same as Aoyama et al (2003). The salinometer was operated in the air-conditioned ship's laboratory at a bath temperature of 24 deg C. An ambient temperature varied from approximately 19 deg C to 22 deg C, while a bath temperature is very stable and varied within +/- 0.002 deg C on rare occasion. A measure of a double conductivity ratio of a sample is taken as a median of thirty-one reading. Data collection was started after 5 seconds and it took about 10 seconds to collect 31 readings by a personal computer. Data were sampled for the sixth and seventh filling of the cell. In case the difference between the double conductivity ratio of this two fillings is smaller than 0.00003, the average value of the two double conductivity ratios was used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981). If the difference was grater than or equal to the 0.0003, we measured eighth filling of the cell. In case the double conductivity ratio of eighth filling did not satisfy the criteria above, we measured ninth and tenth filling of the cell and the median of the double conductivity ratios of five fillings are used to calculate the bottle salinity.

The measurement was conducted 16hours per day (typically from 8:00 to 24:00) and the cell was rinsed by pure water and soap every day after the measurement of the day.

3.2.3 Preliminary Result

3.2.3.1 Stand Seawater

Standardization control was set to 638 and all the measurements were done by this setting. During the whole measurement, the STANDBY was 6106 +/- 0001 and ZERO was 0.00000 to 0.00001. We used IAPSO Standard Seawater batch P142 whose conductivity ratio was 0.99991 (double conductivity ratio is 1.99982) as the standard for salinity. We measured178 ampoules of P142 and the average of the double conductivity ratio was 1.99974 and the standard deviation was 0.000009, which is equivalent to 0.0002 in salinity. Fig.3.2.1 shows the history of double conductivity ratio of the Standard Seawater batch P142. Since there was no significant trend in Fig.3.2.1 and the average of the double conductivity ratio was 1.99974, we add 0.00008 to all of the measured double conductivity ratios.

3.2.3.2 Sub-Standard Seawater

We also used sub-standard seawater which was deep-sea water filtered by pore size of 0.45 micrometer and stored in a 20 liter cubitainer made of polyethylene and stirred for at least 24 hours before measuring. It was measured every six samples in order to check the possible sudden drift of the salinometer. During the whole measurements, there was no detectable sudden drift of the salinometer.

3.2.3.3 Replicate and Duplicate Samples

We took 627 pairs of replicate and 55 pairs of duplicate samples. Fig.3.2.2 (a) and (b) shows the histogram of the absolute difference between replicate samples and duplicate samples, respectively. There were one bad measurement and five questionable measurements in replicate samples and five questionable measurements in duplicate samples. As for questionable measurements, one of the pair is extremely high. This might be cause insufficient seal of the sample bottles. Excluding these bad and questionable measurements, the standard deviation of the absolute deference of 621 pairs of replicate samples was 0.0002 in salinity and that of 50 pairs of duplicate samples was 0.0003 in salinity.

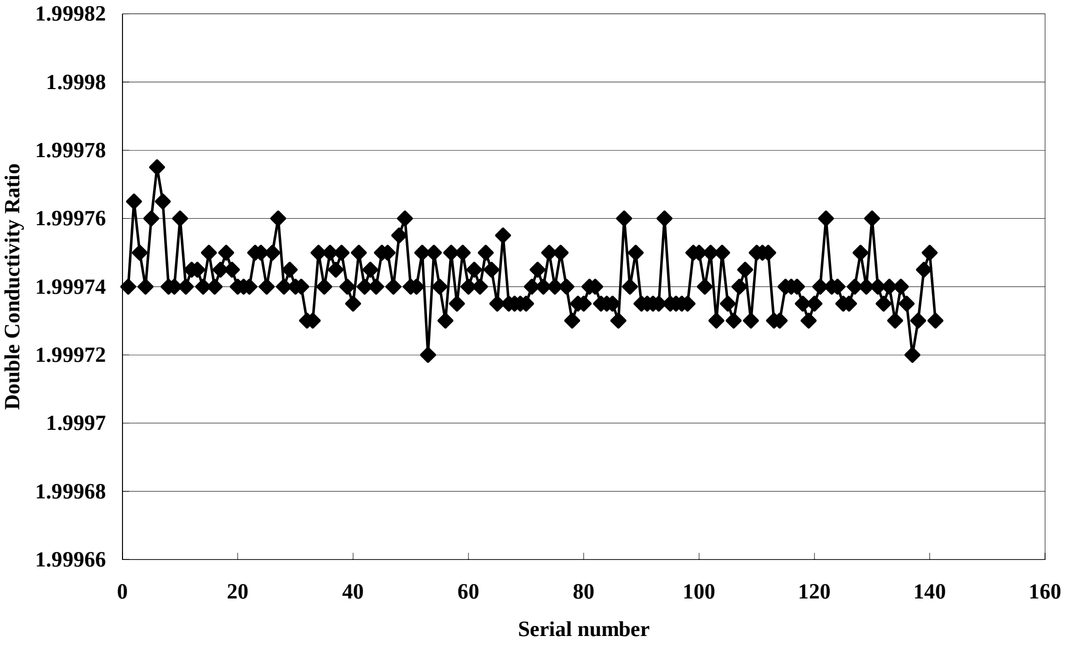


Fig.3.2.1 The history of double conductivity ratio of the Standard Seawater batch P142

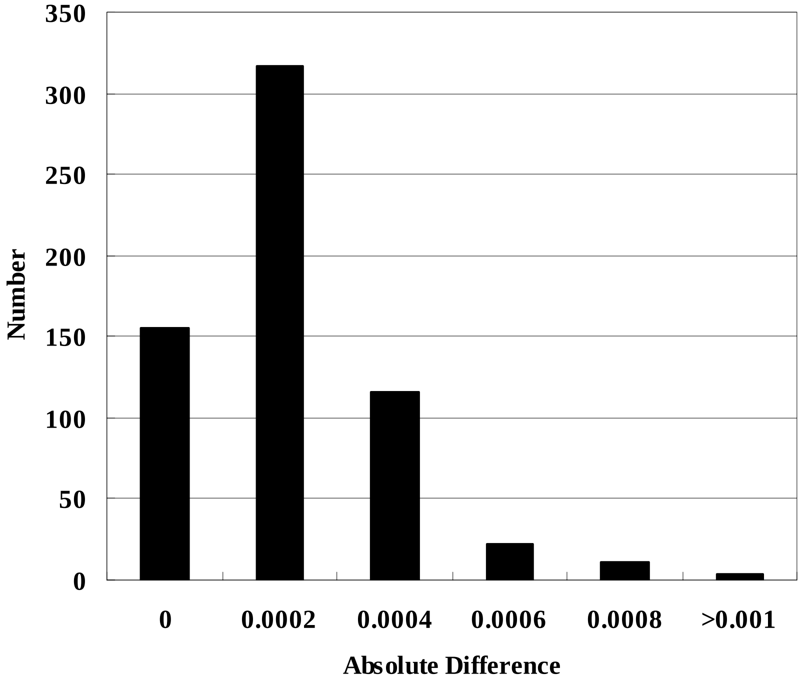


Fig.3.2.2 (a) The histogram of the absolute difference between replicate samples

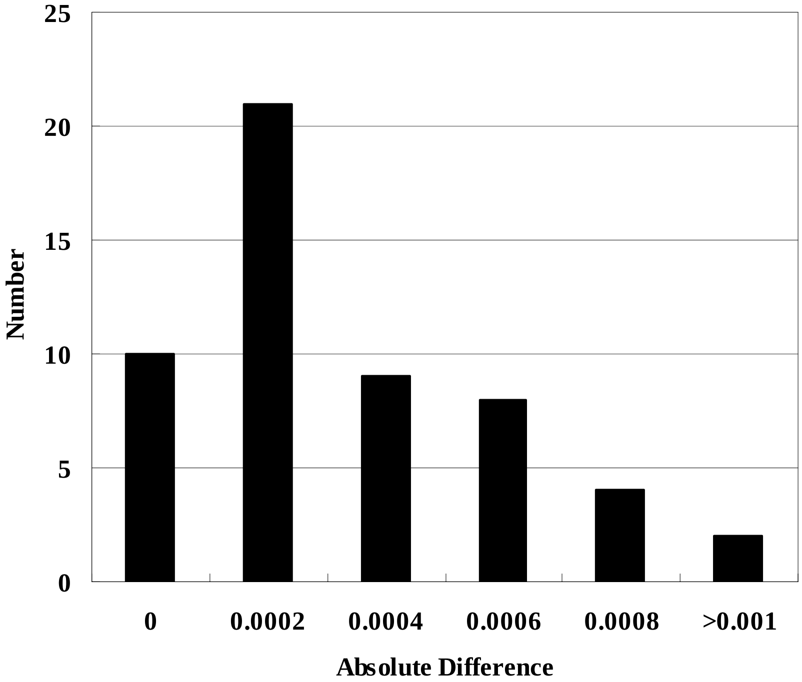


Fig.3.2.2 (b) The histogram of the absolute difference between duplicate samples.

3.2.3.4 Figures

We measured about 3,700 samples in this Leg. As a preliminary result, we will show a several figures without any interpretation. Fig.3.2.3 shows a vertical section of bottle salinity, vertical profile of bottle salinity and Sigma4-Salinity diagram produced by Ocean Data View. The same section, A10, was observed in 1992. Fig.3.2.4 shows a vertical profile of bottle salinity in 1992 plotted with the profile obtained during this cruise (Bad and questionable measurements are not omitted).

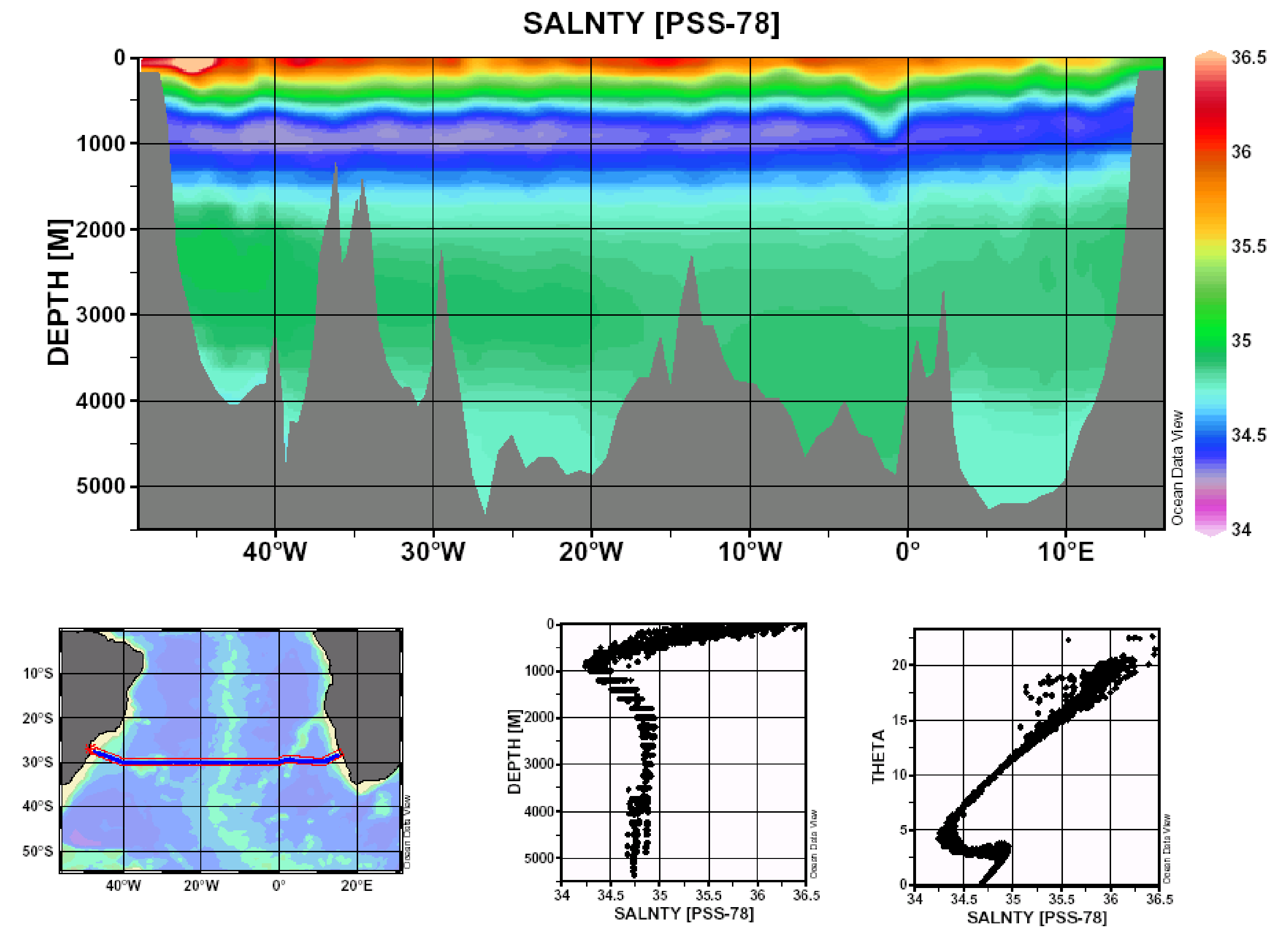
3.2.4 Further data quality check

All the data will be checked once again in detail with other parameters such as dissolved oxygen and nutrients.

3.2.5 Reference

Aoyama, M., T. Joyce, T. Kawano and Y. Takatsuki : Standard seawater comparison up to P129. Deep-Sea Research, I, Vol. 49, 1103～1114, 2002

UNESCO : Tenth report of the Joint Panel on Oceanographic Tables and Standards. UNESCO Tech. Papers in Mar. Sci., 36, 25 pp., 1981

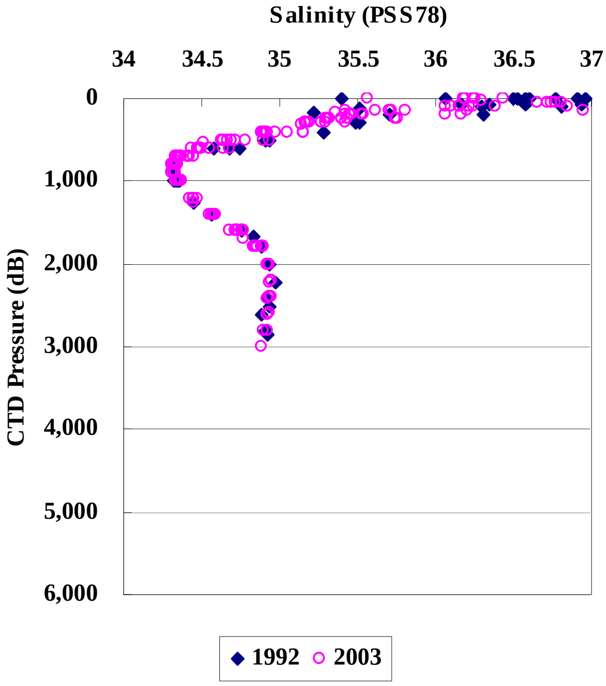


ODV5.5: C:\Documents and Settings\Administrator\ƒƒXƒNƒgƒbƒv\MR03-K04\Leg4\NewCol; C:\Documents and Settings\Administrator\ƒƒXƒNƒgƒbƒv\MR03-K04\Leg4\NewCol.cfg; C:\Documents and Settings\Administrator\ƒƒXƒNƒgƒbƒv\MR03-K04\

.

Fig.3.2.3. vertical section, vertical profile of bottle salinity and Sigma4-Salinity diagram

Station 622-632



Station 1-10

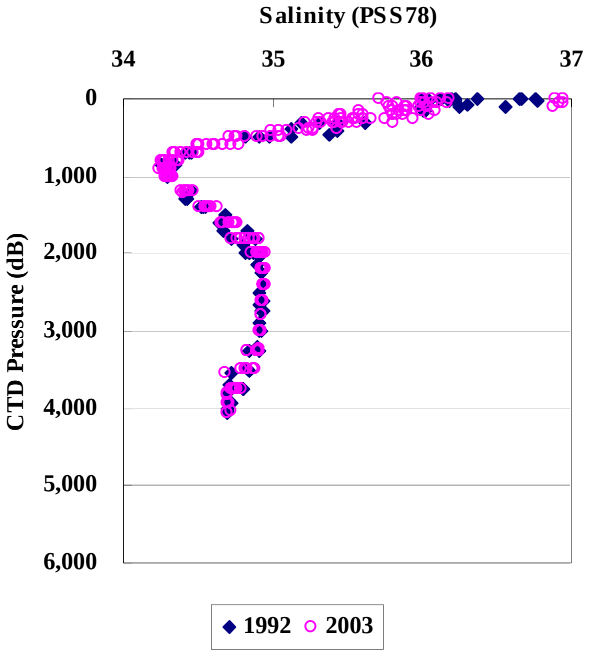
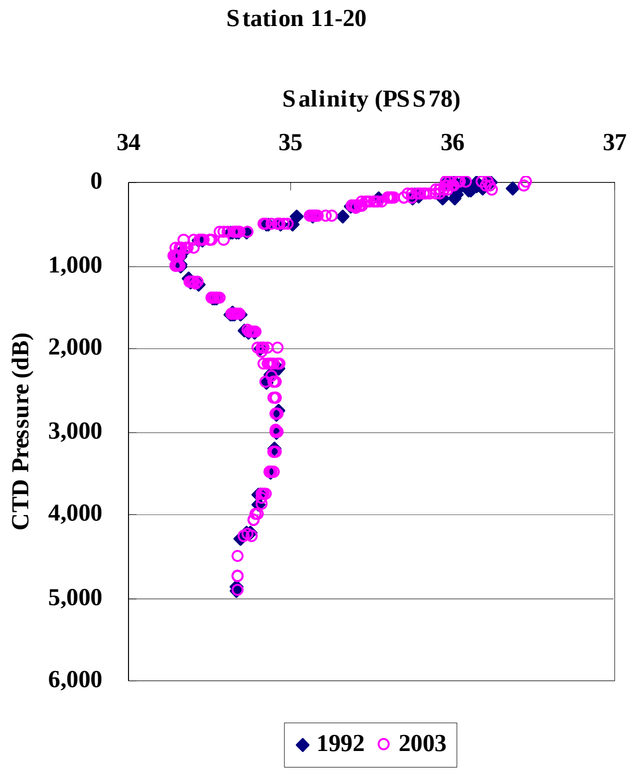


Fig.3.2.4 (a) Vertical Profile of salinity in 1992 (   ) and this cruise（○）.



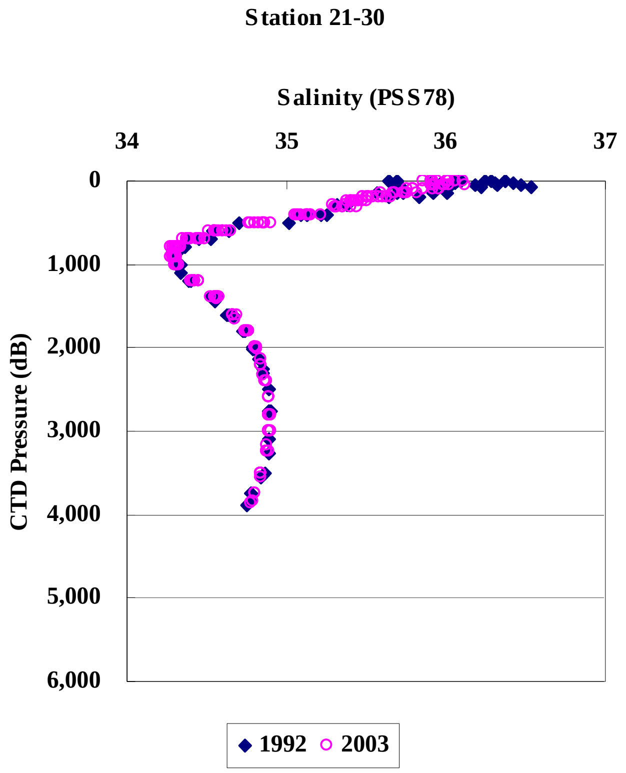
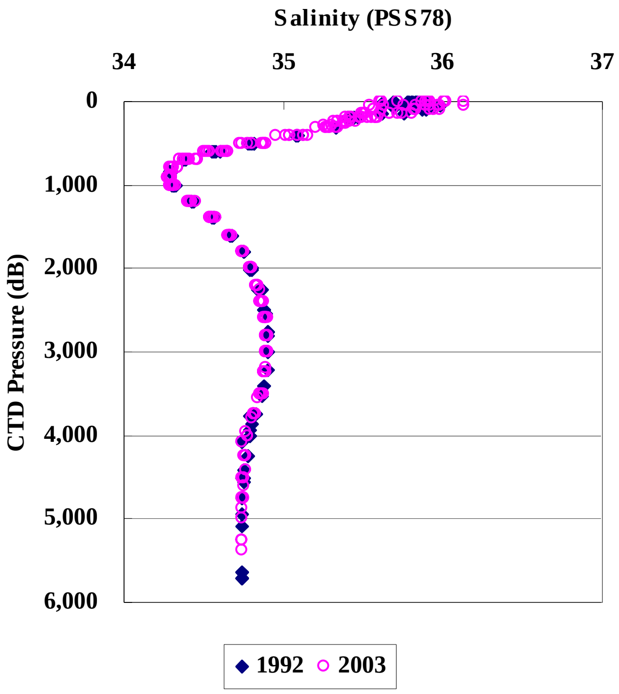


Fig.3.2.4 (b) Vertical Profile of salinity in 1992 ( ) and this cruise （○）.


Station 31-40(X16)

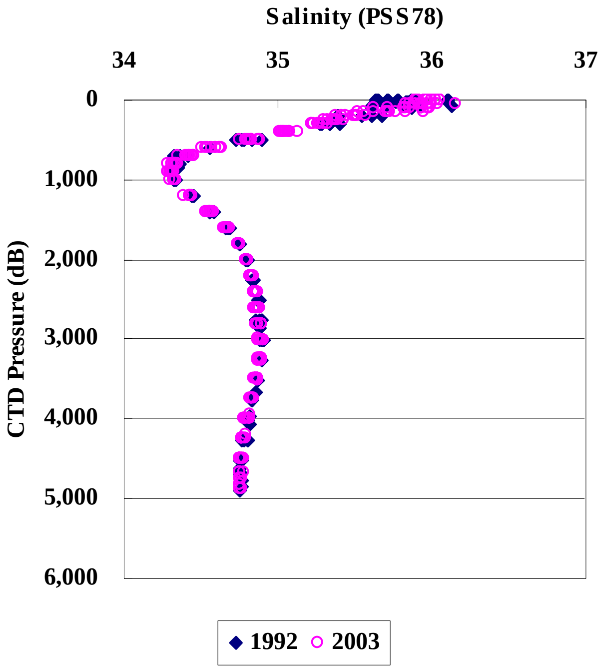
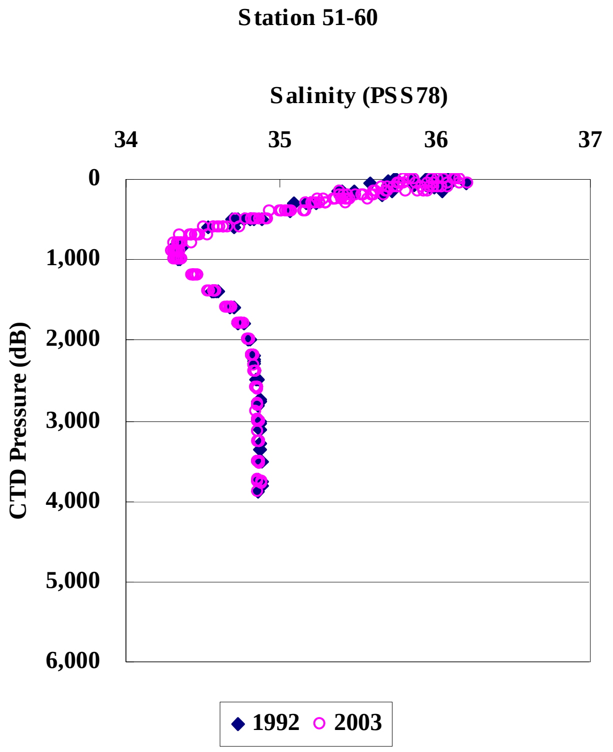

Station 41-50

Fig.3.2.4 (c) Vertical Profile of salinity in 1992 (   ) and this cruise （○）.



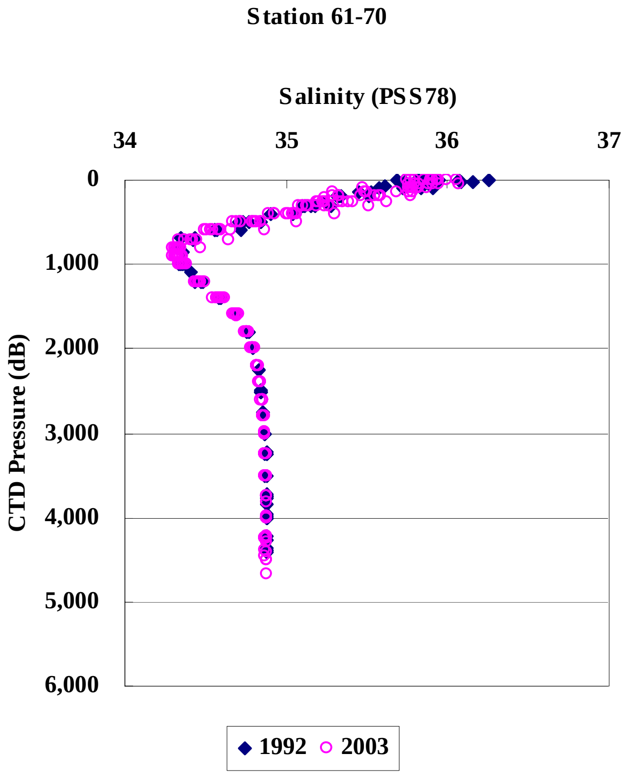
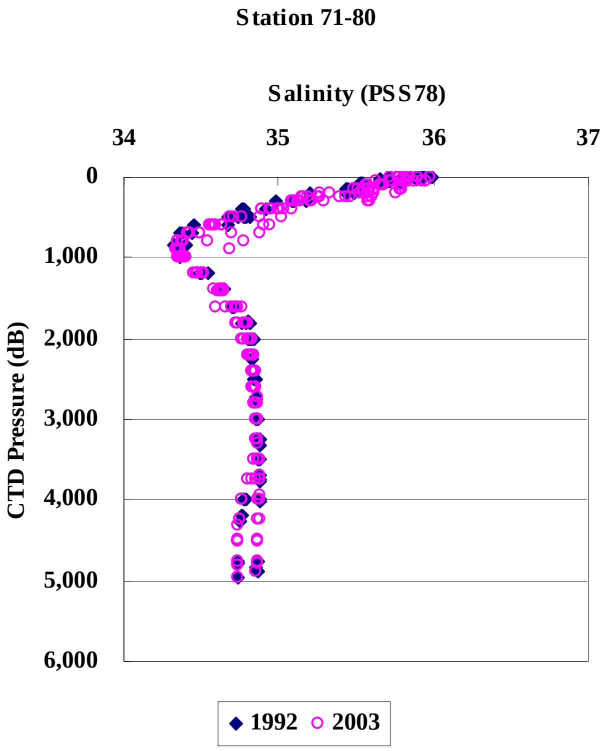


Fig.3.2.4 (d) Vertical Profile of salinity in 1992 (   ) and this cruise （○）.



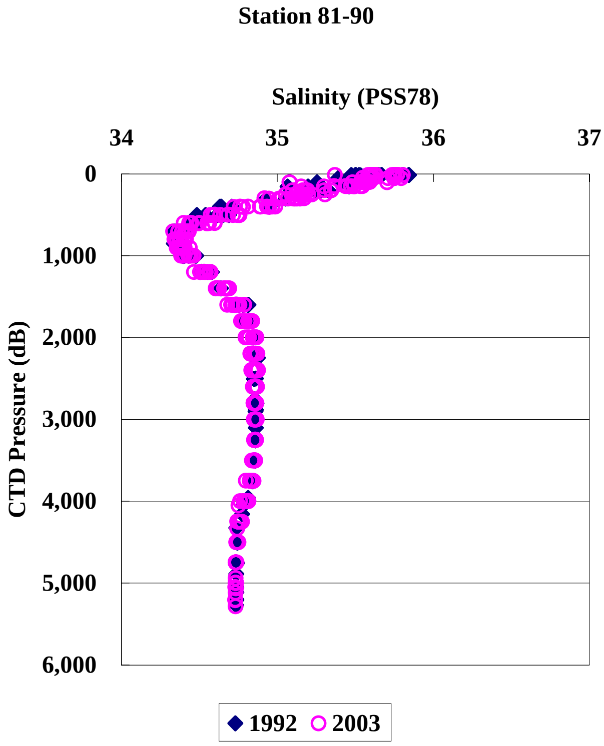


Fig.3.2.4 (e) Vertical Profile of salinity in 1992 ( ) and this cruise （○）.

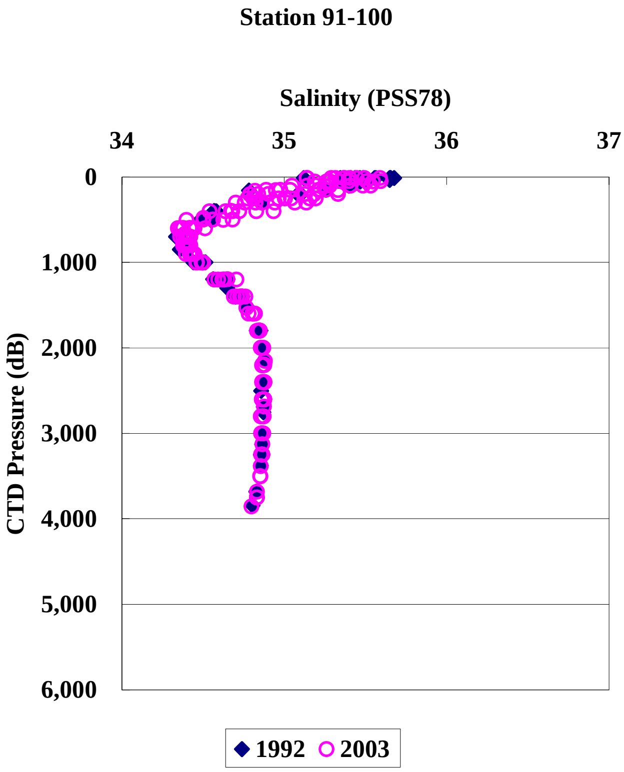


Fig.3.2.4 (f) Vertical Profile of salinity in 1992 (   ) and this cruise（○）.

3.3 Oxygen (Dec. 6, 2003)

Takayoshi Seike : Marine Works Japan Co. Ltd.
Elisabete de Santis Braga : Institution of Oceanography, University of Sao Paulo
Ichiro Yamazaki : MWJ
Kazuhiko Matsumoto : Ocean Observation and Research Department, JAMSTEC
Shuichi Watanabe : Ocean Observation and Research Department, JAMSTEC

(1) Objectives

Dissolved oxygen is one of the most significant tracers for the ocean circulation study. In this cruise (MR03-K04 Leg.4), we measured dissolved oxygen concentration at the stations along the WHP A10 section from 47.4°W to 15.0°E in the South Atlantic. Our main purpose is to compare with the past A10 cruise and to study the various water masses transport and their variability.

(2) Methods

Reagents:

Pickling Reagent I: Manganous chloride solution (3M)
Pickling Reagent II: Sodium hydroxide (8M) / sodium iodide solution (4M)
Sulfuric acid solution (5M)
Sodium thiosulfate (0.025M)
Potassium iodate (0.001667M)

Instruments:

Burette for sodium thiosulfate;
APB-510 manufactured by Kyoto Electronic Co. Ltd., / 10 cm3 of titration vessel
Burette for potassium iodate;
APB-410 manufactured by Kyoto Electronic Co. Ltd., / 20 cm3 of titration vessel
Detector and Software; Automatic photometric titrator manufactured by Kimoto Electronic Co. Ltd.

Sampling

Following procedure is based on the WHP Operations and Methods (Dickson, 1996).

Seawater samples were collected with Niskin bottle attached to the CTD-system. Seawater for oxygen measurement was transferred from Niskin sampler bottle to a volume calibrated flask (ca. 100 cm3). Three times volume of the flask of seawater was overflowed. Temperature was measured by digital thermometer during the overflowing. Then two reagent solutions (Reagent I, II) of 0.5 cm3 each were added immediately into the sample flask and the stopper was inserted carefully into the flask. The sample flask was then shaken vigorously to mix the contents and to disperse the precipitate finely throughout. After the precipitate has settled at least halfway down the flask, the flask was shaken again vigorously to disperse the precipitate. The sample flasks containing pickled samples were stored in a laboratory until they were titrated.

Sample measurement

At least two hours after the re-shaking, the pickled samples were measured on board. A magnetic stirrer bar and 1 cm3 sulfuric acid solution were added into the sample flask and stirring began. Samples were titrated by sodium thiosulfate solution whose molarity was determined by potassium iodate solution. Temperature of sodium thiosulfate during titration was recorded by a digital thermometer. During this cruise we measured dissolved oxygen concentration using two sets of the titration apparatus (DOT-1 and DOT-2). Dissolved oxygen concentration (μmol kg-1) was calculated by sample temperature during seawater sampling, salinity of the CTD sensor, and titrated volume of sodium thiosulfate solution without the blank.

Standardization and determination of the blank

Concentration of sodium thiosulfate titrant (ca. 0.025M) was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130°C. 1.7835 g potassium iodate weighed out accurately was dissolved in deionized water and diluted to final volume of 5 dm3 in a calibrated volumetric flask (0.001667M). 10 cm3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 90 cm3 of deionized water, 1 cm3 of sulfuric acid solution, and 0.5 cm3 of pickling reagent solution II and I were added into the flask in order. Amount of sodium thiosulfate titrated gave the molarity of sodium thiosulfate titrant.

The blank from the presence of redox species apart from oxygen in the reagents was determined as follows. 1 cm3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 100 cm3 of deionized water, 1 cm3 of sulfuric acid solution, and 0.5 cm3 of pickling reagent solution II and I were added into the flask in order. Just after titration of the first potassium iodate, a further 1 cm3 of standard potassium iodate was added and titrated. The blank was determined by difference between the first and second titrated volumes of the sodium thiosulfate. The oxygen in the pickling reagents I (0.5 cm3) and II (0.5 cm3) was assumed to be 3.8 x 10-8 mol (Dickson, 1996).

Table 3.3.1 shows results of the standardization and the blank determination during this cruise. The blank indicated the negative values within the range of 0.77 μmol/kg. Reproductivity (C.V.) of standardization was less than 0.06 % (n = 5).

(3) Reproducibility of sample measurement

Replicate samples were usually taken at 5 - 10 % of seawater samples of each cast during this cruise. Number of replicate sample pairs was 368 and the standard deviation was calculated to be 0.086 umol/kg. The standard deviation was calculated by a procedure (SOP23) in DOE (1994).

(4) Post-cruise calibrations

We will calibrate oxygen data that obtained on board using results of the CSK standard solution (potassium iodate solution, 0.001667M) and reassess the standardizations and the blank determinations.

(5) Preliminary results

During this cruise we measured oxygen concentration in 3,261 seawater samples. Distribution of dissolved oxygen at section A10 (from 47.4^{o}W to 15.0^{o}E along 30^{o}S,) were shown in Fig.3.3.1. North Atlantic Deep Water (NADW) was clearly shown in the west of Mid-Atlantic Ridge. Oxygen minimum layer associated with Antarctic Intermediate Water (AAIW) was shown within 1000 – 1500 m. The minimum oxygen value was found at the depth of 250 m at 8.5^{o}E with the concentration of less than 130 umol kg^{-1}. Antarctic Bottom Water (AABW) was shown in the bottom of Cape Basin. We compared our oxygen data in 2003 and those of WHP A10 in 1992 – 1993, and then we found that the distributions were similar. However, our data of concentrations were slightly lower in many parts than past A10 data. Therefore, we need more comprehensive study with other data.

Table 3.3.1 Results of the standardization and the blank determinations during MR03-K04 Leg.4

Date	Time	KIO3		DOT-1 (cm3)			DOT-2 (cm3)			Samples
(UTC)	(UTC)	#	bottle	Na2S2O3	E.P.	blank	Na2S2O3	E.P.	blank	(Stations)
11-07-03	06:09	#1	030418-47	031010-2	3.961	-0.005	031010-3	3.956	-0.007	622, 623, 624, 625
11-07-03	23:26		030418-48	031010-2	3.960	-0.005	031010-3	3.957	-0.003	626, 627, 628
11-08-03	16:33		030418-49	031010-4	3.964	-0.005	031010-5	3.963	-0.004	629, 630, 631
11-09-03	00:46		030418-50	031010-4	3.965	-0.006	031010-5	3.964	-0.003	632, 001, 002
11-09-03	14:35		030418-51	031108-1	3.965	-0.005	031108-2	3.964	-0.004	003, 004, 005
11-10-03	08:15		030418-52	031108-1	3.963	-0.004	031108-2	3.963	-0.004	006, 007, 008
11-10-03	23:27		030418-53	031108-3	3.964	-0.006	031108-4	3.962	-0.005	009, 010, 011
11-11-03	14:49		030418-54	031108-3	3.962	-0.004	031108-4	3.960	-0.004	X17, 013, 014
11-12-03	05:04		030418-55	031108-5	3.963	-0.011	031111-1	3.959	-0.004	015, 016, X.23, 018, 019
11-12-03	21:01		030418-56	031108-5	3.964	-0.006	031111-1	3.959	-0.005	020, 021, 022, 023, 024
11-13-03	15:35		030418-57	031111-2	3.964	-0.005	031111-3	3.961	-0.010	025, 026, 027
11-14-03	04:13		030418-58	031111-2	3.963	-0.004	031111-3	3.961	-0.004	028, 029, 030
11-14-03	21:52	#2	030418-61	031111-4	3.962	-0.006	031111-5	3.959	-0.004	031, 032, 033
11-15-03	15:48		030418-63	031111-4	3.959	-0.006	031111-5	3.958	-0.004	some samples of 031
11-16-03	07:14		030418-64	031111-4	3.958	-0.008	031111-5	3.954	-0.005	034, 035, 036
11-16-03	01:21		030418-65	031115-1	3.957	-0.008	031115-2	3.957	-0.004	037, 038, 039
11-17-03	18:47		030418-66	031115-1	3.956	-0.006	031115-2	3.957	-0.004	X16, 041, 042
11-18-03	18:16		030418-67	031115-3	3.960	-0.007	031115-4	3.959	-0.003	043, 044, 045
11-19-03	10:36		030418-68	031115-3	3.959	-0.006	031115-4	3.958	-0.003	046, X15, 048
11-20-03	08:01		030418-69	031115-5	3.960	-0.006	031119-1	3.956	-0.004	049, 050, 051
11-20-03	22:47		030418-70	031115-5	3.950	-0.007	031119-1	3.948	-0.004	052, 053, 054
11-21-03	14:43		030418-71	031119-2	3.957	-0.006	031119-3	3.954	-0.004	055, 056, 057, 058
11-22-03	10:19		030418-72	031119-2	3.953	-0.009	031119-3	3.952	-0.007	059, 060, 061
11-23-03	23:49		030418-75	031119-4	3.956	-0.010	031119-5	3.955	-0.007	X14, 063, 064, 065, 066, 067
11-25-03	10:00	#3	030418-76	031125-1	3.963	-0.009	031125-2	3.961	-0.007	068, 069, 070
11-26-03	07:54		030418-77	031125-1	3.959	-0.009	031125-2	3.957	-0.006	071, 072, 073
11-27-03	04:47		030418-78	031125-3	3.958	-0.008	031125-4	3.959	-0.006	074, 075, 076
11-27-03	17:17		030418-79	031125-3	3.958	-0.011	031125-4	3.959	-0.006	077, 078, 079
11-28-03	10:24		030418-80	031125-5	3.957	-0.010	031128-1	3.959	-0.007	080, 081, 082
11-29-03	01:19		030418-81	031125-5	3.955	-0.010	031128-1	3.959	-0.006	083, 084, 085
11-30-03	01:21		030418-82	031128-2	3.961	-0.011	031128-3	3.960	-0.004	086, 087, X13
11-30-03	18:09		030418-83	031128-2	3.958	-0.009	031128-3	3.960	-0.006	089, 090, 091
12-01-03	19:56		030418-84	031128-4	3.960	-0.011	031128-5	3.963	-0.004	092, 093, 094
12-02-03	06:02		030418-85	031128-4	3.962	-0.008	031128-5	3.962	-0.005	095, 096, 097, 098, 099, 100

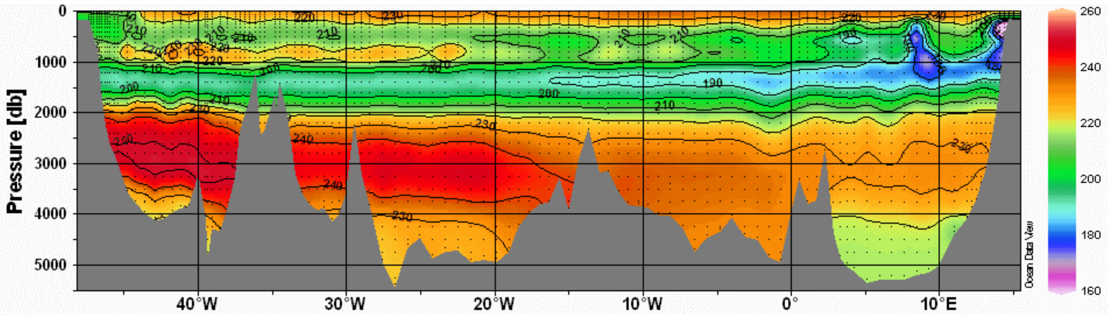


Fig.3.3.1 Dissolved oxygen concentration (umol / kg) in 2003. This figure was drawn using Ocean Data View (R. Schlitzer, http://www.awi-bremerhaven.de/GEO/ODV, 2002).

References:

Dickson, A. (1996) Dissolved Oxygen, in WHP Operations and Methods, Woods Hole, pp1-13.

DOE (1994) Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74.

3.4 Nutrients (3 Dec.. 2003)

Michio AOYAMA : Geochemical Res. Dep., Meteorological Res. Inst., Japan
Junko HAMANAKA, Asako KUBO, Shinichiro YOKOGAWA : Department of Marine Science, Marine Works Japan Ltd.

3.4.1 Objectives

The objectives of nutrients analyses during the R/V Mirai around the world cruises along ca. 30 deg. S in the Southern Hemisphere are as follows;

1) Describe the present status of nutrients in 2003-2004 in good traceability throughout the cruises. The target nutrients are nitrate, nitrite, phosphate and silicate (Although silicic acid is correct, we use silicate because a term of silicate is widely used in oceanographic community.)
2) Study the temporal and spatial variation of nutrients based on the previous high quality experiments data of WOCE, GOESECS , IGY and so on.
3) Study of temporal and spatial variation of nitrate:phosphate ratio, so called Redfield ratio.
4) Obtain more accurate estimation of total amount of nitrate, phosphate and silicate in the interested area.

5) Provide more accurate nutrients data for physical oceanographers to use as tracers of water mass movement.

3.4.2 Equipment and techniques

3.4.2.1 Analytical detail using TRAACS 800 systems (BRAN+LUEBBE)

The phosphate analysis is a modification of the procedure of Murphy and Riley (1962).

Molybdic acid is added to the seawater sample to form phosphomolybdic acid which is in turn reduced to phosphomolybdous acid using L-ascorbic acid as the reductant.

Nitrate + nitrite and nitrite are analyzed according to the modification method of Grasshoff (1970).

The sample nitrate is reduced to nitrite in a cadmium tube inside of which is coated with metallic copper. The sample stream with its equivalent nitrite is treated with an acidic, sulfanilamide reagent and the nitrite forms nitrous acid which reacts with the sulfanilamide to produce a diazonium ion. N1-Naphthylethylene-diamine added to the sample stream then couples with the diazonium ion to produce a red, azo dye. With reduction of the nitrate to nitrite, both nitrate and nitrite react and are measured; without reduction, only nitrite reacts. Thus, for the nitrite analysis, no reduction is performed and the alkaline buffer is not necessary. Nitrate is computed by difference.

The silicate method is analogous to that described for phosphate. The method used is essentially that of Grasshoff et al. (1983), wherein silicomolybdic acid is first formed from the silicic acid in the sample and added molybdic acid; then the silicomolybdic acid is reduced to silicomolybdous acid, or "molybdenum blue," using ascorbic acid as the reductant.

The flow diagrams for each parameter are shown in Fig.3.4.1 – 3.4.4.

3.4.2.2 Sampling procedures

Sampling of nutrients followed that oxygen, trace gases and salinity. Samples were drawn into two of virgin 10 ml polyacrylates vials without sample drawing tubes. These were rinsed three times before filling and vials were caped immediately after the drawing. The vials are put into water bath at 22 deg. C in 10 minutes before use to stabilize the temperature of samples.

No transfer was made and the vials were set an auto sampler tray directly. Samples were analyzed as rapidly as possible after collection, and then the samples were analyzed within 5 hours. Several samples were stored longer than usual and analyzed within 7-8 hours after collection.

3.4.2.3 Data processing.

Raw data from TRAACS800 were treated as follows;

Check baseline shift.

Check the shape of each peak and positions of peak values taken, then change the positions of peak values taken if necessary.

Carriover correction and baseline drift correction were applied to peak heights of each samples followed by sensitivity correction. Baseline correction and sensitivity correction were done basically using liner regression.

Load pressure and salinity from CTD data to calculate density of seawater.

Calibration curves to get nutrients concentration were assumed second order equations.

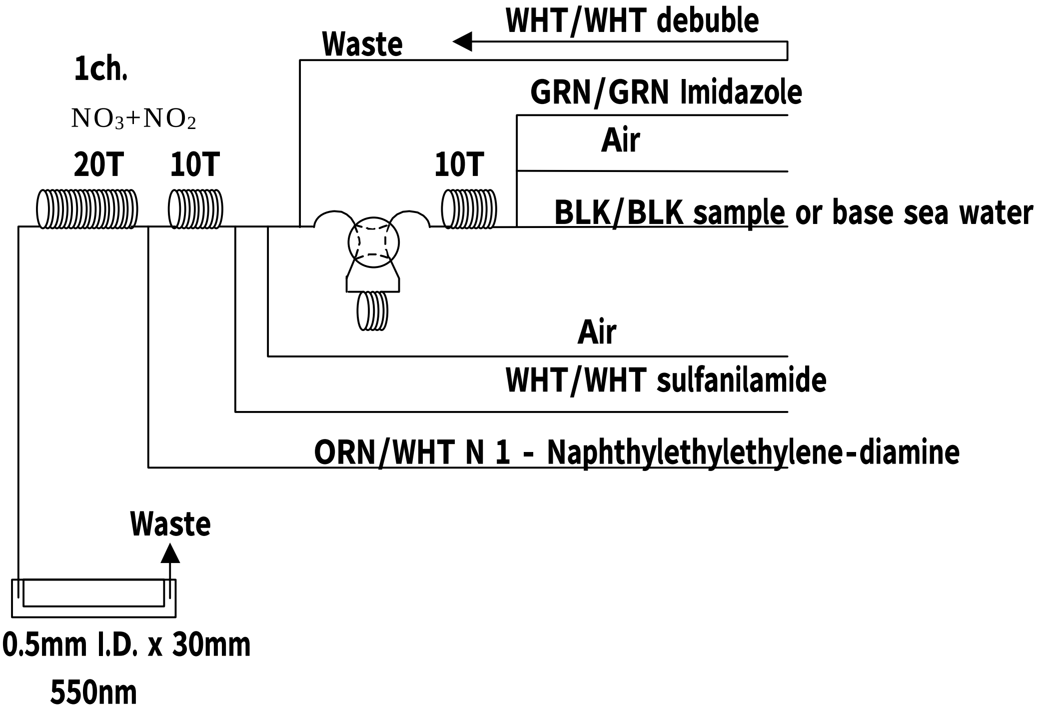


Fig.3.4.1 1ch. (NO_3+NO_2)Flow diagram.

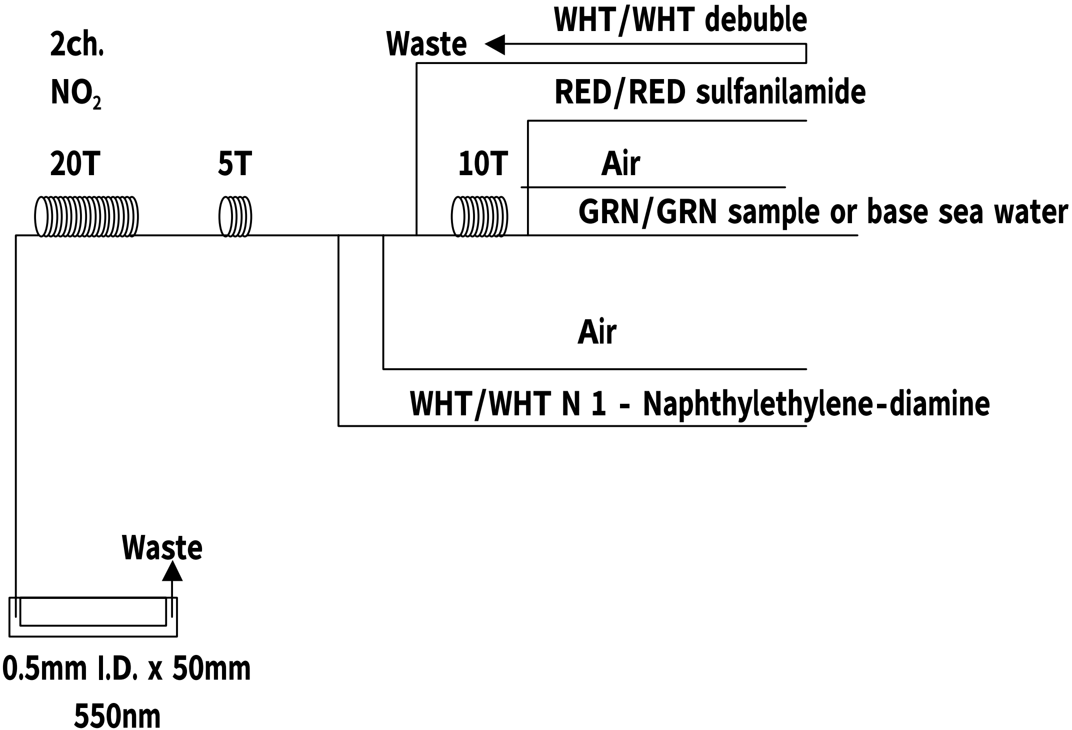


Fig.3.4.2 2ch. (NO_2) Flow diagram.

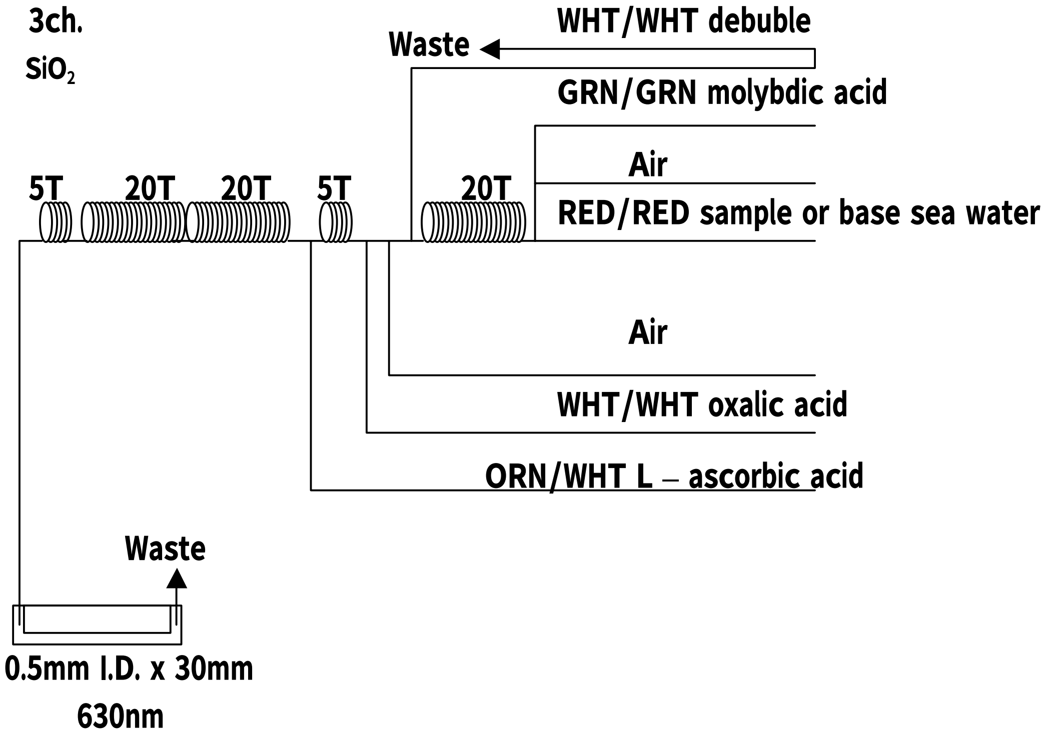


Fig.3.4.3 3ch. (SiO_2) Flow diagram.

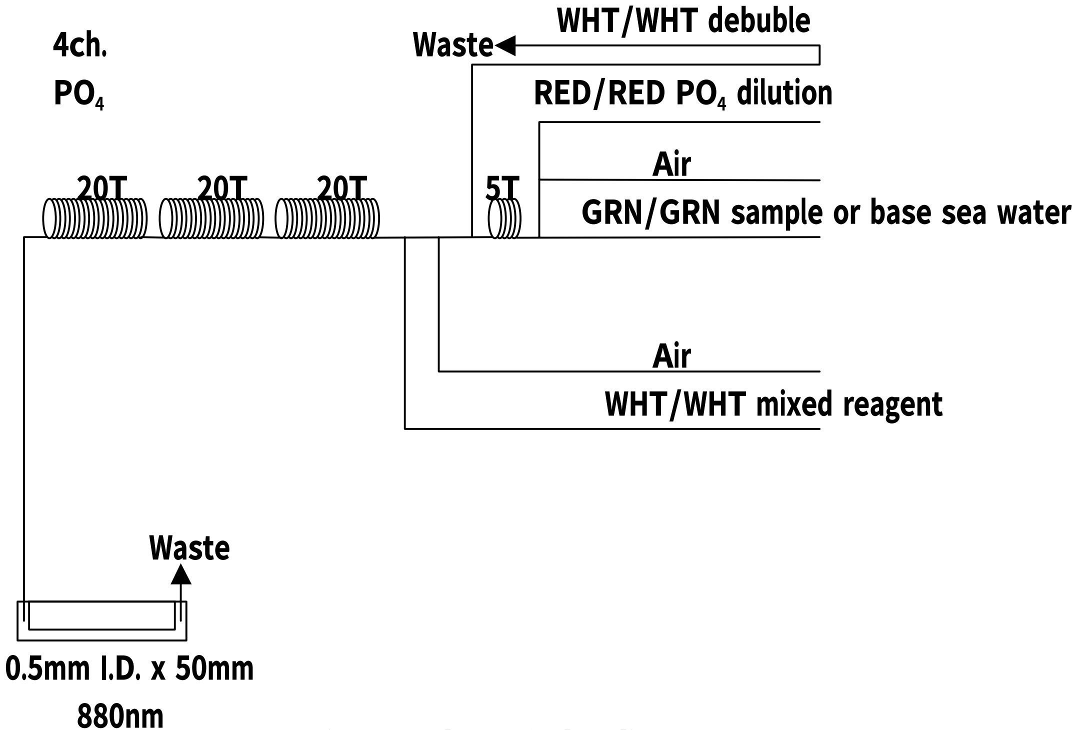


Fig.3.4.4 4ch. (PO_4) Flow diagram.

3.4.3, Nutrients standards

3.4.3.1 In-house standards

3.4.3.1-1 Volumetric Laboratory Ware.

All volumetric glass- and plastic(PMP)-ware used were gravimetrically calibrated. Plastic volumetric flasks were gravimetrically calibrated at the temperature of use within 2-3 K.

3.4.3.1-1.1 Volumetric flasks.

Volumetric flasks of Class quality (Class A) are used because their nominal tolerances are 0.05% or less over the size ranges likely to be used in this work. Class A flasks are made of borosilicate glass, and the standard solutions were transferred to plastic bottles as quickly as possible after they are made up to volume and well mixed in order to prevent excessive dissolution of silicic acid from the glass. High quality plastic (polymethylpentene, PMP, or polypropylene) volumetric flasks were gravimetrically calibrated and used only within 2-3 K of the calibration temperature.

The computation of volume contained by glass flasks at various temperatures other than the calibration temperatures were done by using the coefficient of linear expansion of borosilicate crown glass.

Because of their larger temperature coefficients of cubical expansion and lack of tables constructed for these materials, the plastic volumetric flasks were gravimetrically calibrated over the temperature range of intended use and used at the temperature of calibration within 2 K . The weights obtained in the calibration weightings were corrected for the density of water and air buoyancy.

3.4.3.1-1.2 Pipettes and pipettors.

All pipettes have nominal calibration tolerances of 0.1% or better. These were gravimetrically calibrated in order to verify and improve upon this nominal tolerance.

3.4.3.1-2 REAGENTS, GENERAL CONSIDERATIONS

3.4.3.1-2.1 General Specifications.

All reagents were of very high purity such as "Analytical Grade," "Analyzed Reagent Grade" and others. And assay of nitrite was determined according JISK8019 and assays of nitrite salts was 98.9%. We use that value to adjust the weights taken.

For the silicate standards solution, we use commercial available silicon standard solution for atomic absorption spectrometry of 1000mg L-1. Since this solution is alkaline solution of 0.5 M KOH, an aliquot of 70ml solution were diluted to 500ml as B standard together with an aliquot of 35ml of 1M HCl. Then the pH of B standard for silicate prepared to be 6.9.

3.4.3.1-2.2 Ultra pure water.

Ultra pure water (MilliQ water) freshly drawn was used for preparation of reagents, higher concentration standards and for measurement of reagent and system blanks.

3.4.3.1-2.3 Low-Nutrient Seawater (LNSW).

Surface water having low nutrient concentration was taken and filtered using 0.45 µm pore size membrane filter. This water is stored in 20 liter cubitainer with paper box. The concentrations of nutrient of this water were measured carefully in May 2003.

3.4.3.1-3 Concentrations of nutrients for A, B and C standards

Concentrations of nutrients for A, B and C standards are set as shown in Table 3.4.1. The C standard are prepared according recipes as shown in Table 3.4.2. All volumetric laboratory tools were calibrated prior the cruise as stated in chapter 3.4.3.1.1. Then the actual concentration of nutrients in each fresh standard was calculated based on the ambient, solution temperature and determined factors of volumetric lab. Wares.

Table 3.4.1 Nominal concentrations of nutrients for A, B and C standards

	A	B	C-1	C-2	C-3	C-4	C-5
NO_3(µM)	45000	1350	0.0	13.5	27.0	40.5	54.0
NO_2(µM)	4000	40	0.0	0.4	0.8	1.2	1.6
SiO_2(µM)	36000	5040	0.0	50	100	150	200
PO_4(µM)	4500	90	0.0	0.9	1.8	2.7	3.6

Table 3.4.2 Working calibration standard recipes

C-STD	B-1 STD	B-2 STD	MAT
C-1	0 ml	0 ml	40 ml
C-2	5 ml	5 ml	30 ml
C-3	10 ml	10 ml	20 ml
C-4	15 ml	15 ml	10 ml
C-5	20 ml	20 ml	0 ml

3.4.3.1-4 Renewal of in-house standard solutions.

In-house standard solutions as stated in 3.4.3.1.3 were renewed as shown in Table 3.4.3.

Table 3.4.3 Timing of renewal of in-house standards.

NO_3, SiO_2, PO_4	Renewal
A-1Std. (NO_3)	maximum 10 days
A-3Std. (SiO_2)	comercial prepared solution
A-4Std. (PO_4)	maximum 14 days
B-1Std. (mixture of A-1,3 and 4 Std.)	2 days

NO_2	**Renewal**
A-2Std. (NO_2)	**maximum 14 days**
B-2Std. (NO_2)	**maximum 14 days**

C Std	**Renewal**
C1〜C5 Std (mixture of B1 and B2 Std.)	**24 hours**

Reduction estimation	**Renewal**
D-1Std.	**when A-1renewed**
44μM NO_3	**when C-std renewed**
47μM NO_2	**when C-std renewed**

3.4.3.2 RMNS

To get the more accurate and high quality nutrients data to achieve the objectives stated above, huge number of the bottles of the reference material of nutrients in seawater (hereafter RMNS) are prepared (Aoyama et al., submitted). In the previous world wide expeditions, such as WOCE cruises, the higher reproducibility and precision of nutrients measurements were required (Joyce and Corry, 1994). Since no standards were available for the measurement of nutrients in seawater at that time, the requirements were described in term of reproducibility. The required reproducibility was 1%, 1-2%, 1-3% for nitrate, phosphate and silicate, respectively. Although nutrient data from the WOCE one-time survey was of unprecedented quality and coverage due to much care in sampling and measurements, the differences of nutrients concentration at crossover points are still found among the expeditions (Aoyama and Joyce, 1996, Mordy et al., 2000, Gouretski and Jancke, 2001). For instance, the mean offset of nitrate concentration at deep waters was 0.5 µmol kg-1 for 345 crossovers at world oceans, though the maximum was 1.7 µmol kg-1 (Gouretski and Jancke, 2001). At the 31 crossover points in the Pacific WHP one-time lines, the WOCE standard of reproducibility for nitrate of 1% was fulfilled at about half of the crossover points and the maximum difference was 7% at deeper layers below 1.6 deg. C in potential temperature (Aoyama and Joyce, 1996).

3.4.3.2-1 RMNS preparation

3.4.3.2-1.1 RMNS preparation and homogeneity for previous lots.

The study on reference material for nutrients in seawater (RMNS) on the seawater base has been carried out to establish traceability on nutrient analyses in seawater since 1994 in Japan. Autoclaving to produce RMNS has been studied (Aminot and Kerouel, 1991, 1995) and autoclaving was used to stabilize the samples for the 5th intercompariosn exercise in 1992/1993 (Aminot and Kirkwood, 1995). Aminot and Kerouel (1995) concluded that nitrate and nitrite were extremely stable throughout their 27 months storage experiment with overall standard deviations lower than 0.3% (range 5-50 µmol l-l) and 0.8% (range 0.5-5 µmol l-1), respectively. For phosphate, slight increase by 0.02-0.07 µmol l-1 per year was observed due to the leaching from the container glass. The main source of nutrient variation in seawater is believed to be microorganism activity, hence, production of RMNS depends on biological inactivation of samples. In this point of view, previous study showed that autoclaving to inactivate the biological activity is acceptable for RMNS preparation.

The seawater for RMNS production was sampled in the North Pacific Ocean at the depths of surface where the nutrients are almost depleted and 1500-2000 meters depth where the nutrients concentrations are the maximum. The seawater was gravity-filtered through a membrane filter with a pore size of 0.45 µm (Millipore HA). The latest procedure of autoclaving for RMNS preparation is that the seawater in a stainless steel container of 40 liters was autoclaved at 120 deg. C, 2 hours, 2 times during two days. The filling procedure of autoclaved seawater was basically same throughout our study. Following cooling at room temperature in two days, polypropylene bottle of 100 ml capacity were filled by the autoclaved seawater of 90 ml through a membrane filter with a pore size of 0.2 µm (Millipore HA) at a clean bench in a clean room. The polypropylene caps were immediately tightly screwed on and a label containing lot number and serial number of the bottle was attached on all of the bottles. Then the bottles were vacuum-sealed to avid potential contamination from the environment.

3.4.3.2-1.2. 180 RMNS packages and 500 bottles of lot AH for this cruise

RMNS lots T, AN, AK, AM and O are prepared to cover the nutrients concentrations in the interested sea area. About 180 sets of 5 RMNS lots are prepared. These packages will be used daily when in-house standard solutions renewed daily. 500 bottles of RMNS lot AH are prepared to use every analysis at every hydrographic stations planed about 500 during the cruise. These RMNS assignment were completely done based on random number. The RMNS bottles were stored at a room, REGENT STORE, where the temperature was maintained between 21.5 deg. C and 22.3 deg. C.

3.4.3.2-2 The homogeneity of RMNS and consensus values of the lot AH

The homogeneity of lot AH and analytical precision are shown in Table 3.4.4. These are for the assessment of the magnitude of homogeneity of the RMNS bottles those are used during the cruise. As shown in Table 3.4.4, the homogeneity of RMNS lot AH for nitrate and silicate are the same magnitude of analytical precision derived from fresh raw seawater. The homogeneity for phosphate, however, exceeded the analytical precision at about factor two. The homogeneity for lot AH is same order of magnitude for previous RMNS of lot K.

Table 3.3.4 Homogeneity of lot AH derived from 30 samples measurements and analytical precision onboard R/V Mirai in May 2003.

	Phosphate CV%	Nitrate	Silicate
RMNS			
AH	**0.83%**	**0.39%**	**0.13%**
(K)	**(1.0%)**	**(0.3%)**	**(0.2%)**
Precision	**0.39%**	**0.36%**	**0.13%**

note: N=30 x 2

3.4.4 Quality control

3.4.4.1 Precision of nutrients analyses during the cruise

Precision of nutrients analyses during the cruise was evaluated based on the 13 measurements, which are measured every 10-15 samples, during a run at the concentration of C-5. We also evaluated the reproducibility based on the replicate analyses of five samples in each run. Summary of precisions are shown in Table 3.4.5. As shown in Table 3.4.5 and Fig.3.4.5 – 3.4.7 the precisions for each parameter are generally good considering the analytical precisions estimated from the simultaneous analyses of 60 samples in May 2003. Analytical precisions previously evaluated were 0.39% for phosphate, 0.36% for nitrate and 0.13% for silicate, respectively. Then we can conclude that the analytical precisions for phosphate, nitrate and silicate were maintained throughout Leg.4.

The time series of precision are shown in Fig.3.4.5 – 3.4.7

Table 3.4.5 Summary of precision based on the replicate analyses of 13 samples in each run during Leg.4

	Nitrate CV%	Phosphate CV%	Silicate CV%
Median	**0.15**	**0.19**	**0.14**
Mean	**0.15**	**0.19**	**0.14**
Maximum	**0.21**	**0.35**	**0.24**
Minimum	**0.06**	**0.08**	**0.04**
N	**109**	**109**	**109**

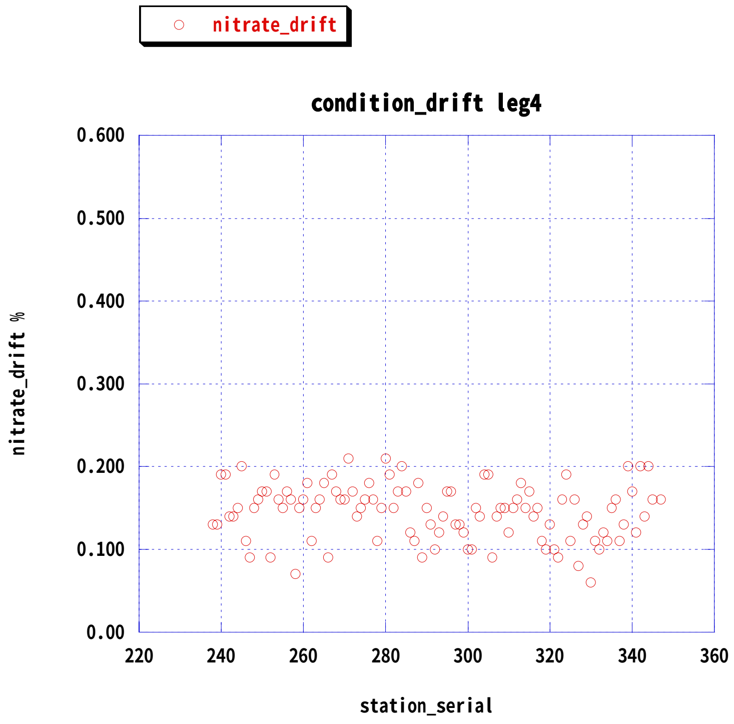


Fig.3.4.5

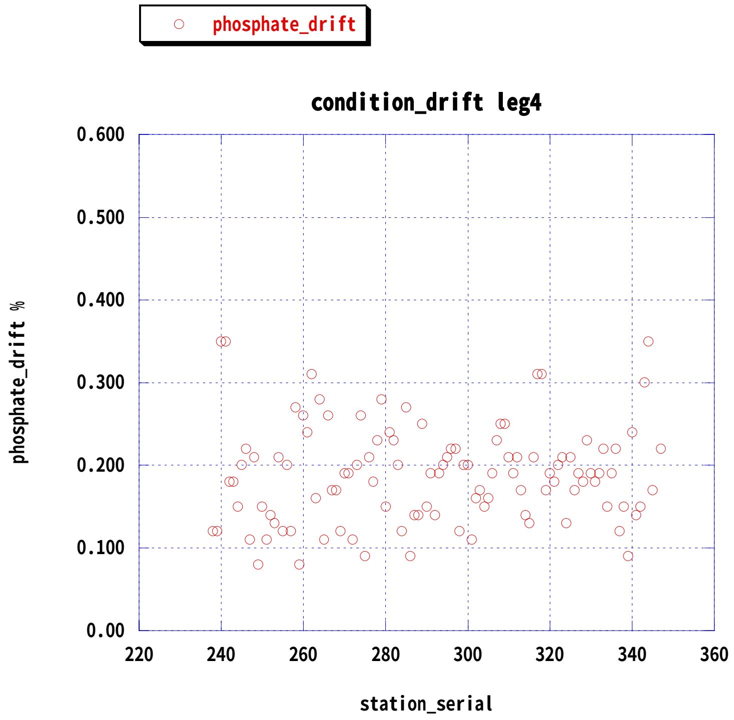


Fig.3.4.6

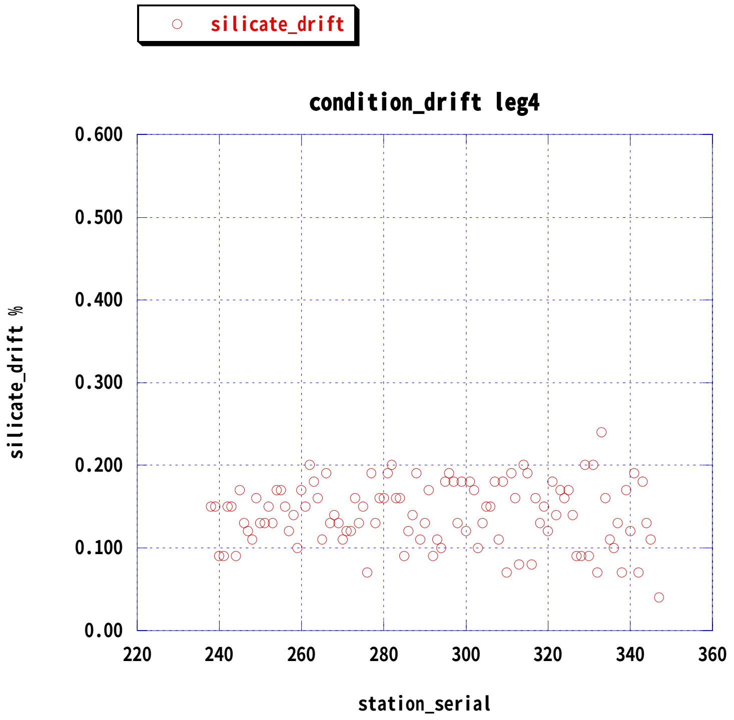


Fig.3.4.7

3.4.4.2 Carry over

We can also summarize the magnitudes of carry over throughout the cruise. These are as shown in Table 3.4.5. The average of carry over for nitrate was 0.58, which is relatively high rather than those of Phosphate and Silicate.

Table 3.4.5 Summary of carry over during Leg.4

	Nitrate CV%	Phosphate CV%	Silicate CV%
Median	0.59	0.21	0.10
Mean	0.58	0.21	0.12
Maximum	0.94	0.78	0.24
Minimum	0.35	0.00	0.00
N	109	109	109

3.4.4.3 Concentrations of low nutrients seawater.

Concentrations of low nutrients seawater obtained from each measurements were summarized in Table 3.4.6. As shown in Table 3.4.6, the concentrations of low nutrients seawater used in this cruise are well reproduced against nominal concentrations given in May 2003.

Table 3.4.6 Summary of low nutrients seawater during Leg.4

	Nitrate micro mol kg-1	Phosphate micro mol kg-1	Silicate micro mol kg-1
Median	0.03	0.15	0.99
Mean	0.02	0.15	0.99
Maximum	0.08	0.17	1.31
Minimum	-0.05	0.13	0.57
Nominal	0.00	0.16	1.01

The numbers of analysis were 109 for three parameters.

3.4.5, Evaluation of trueness of nutrients concentrations using RMNSs

We have been using RMNS for all runs, then, we can evaluate the trueness of nutrients concentration throughout Leg.4. Preliminary results are shown in Fig.3.4.8 – 3.4.10. During the leg4, nitrate concentrations, phosphate concentrations and silicate concentrations were within 95% confidence level of consensus values in general, respectively.

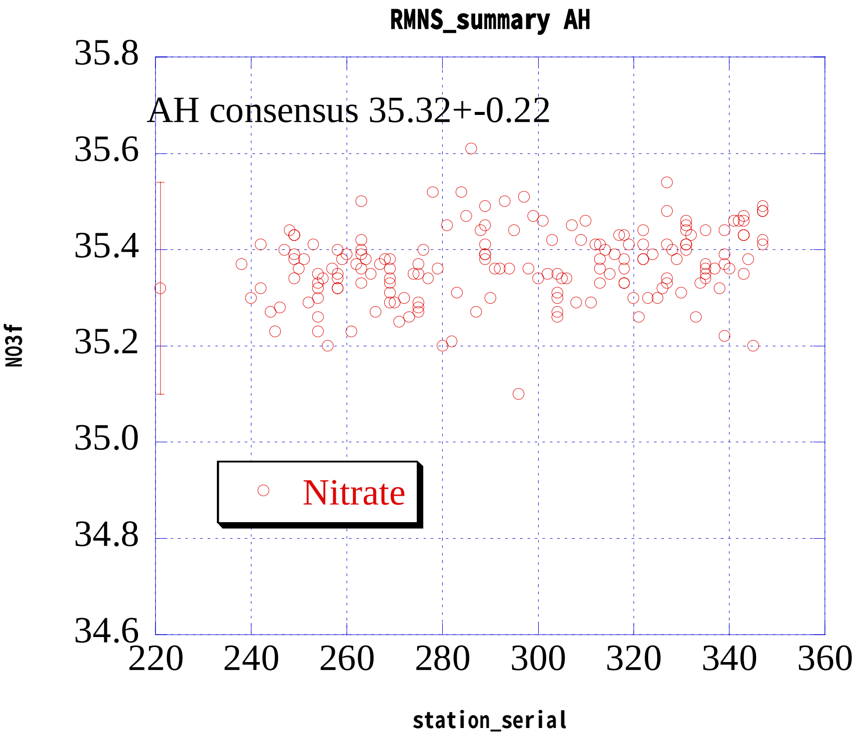


Fig.3.4.8

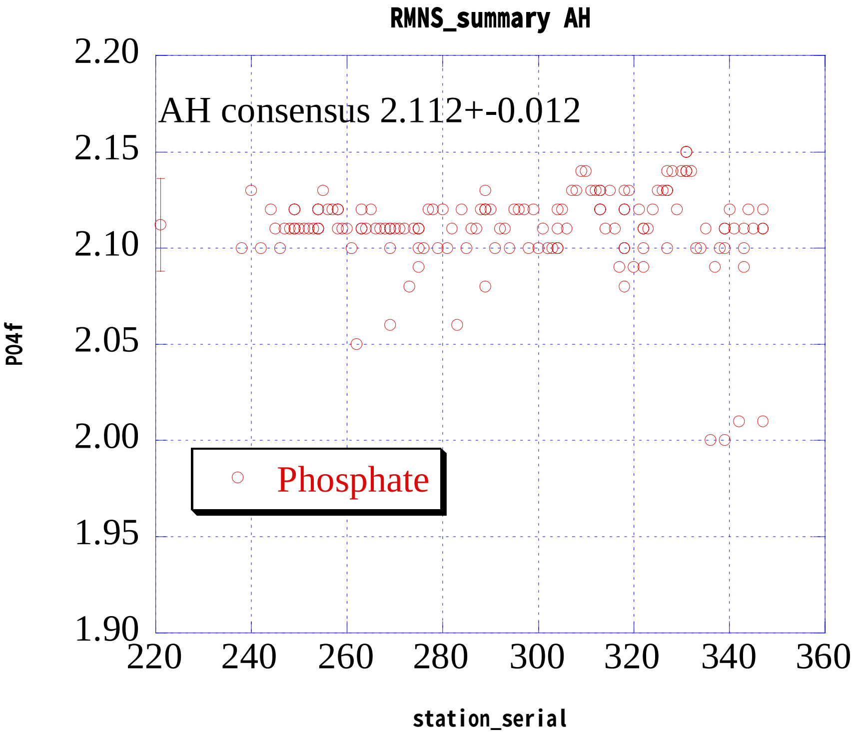


Fig.3.4.9

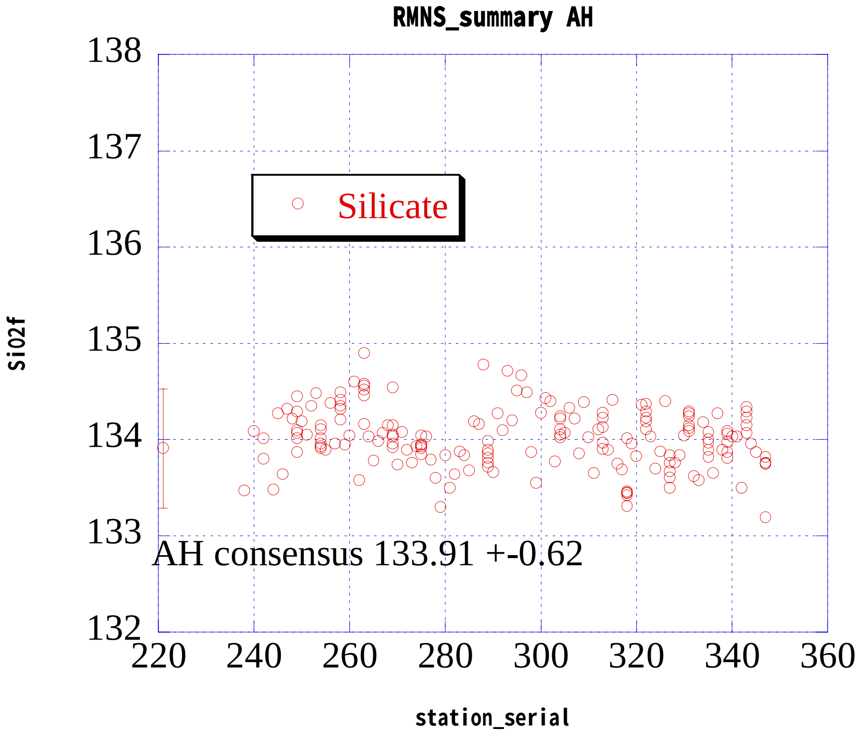


Fig.3.4.10

3.4.6 Leg-to-leg traceability

Table 3.4.7 Results of the statistics of RMNS-AH concentrations

	NO3_Pacific	SiO2_Pacific	PO4_Pacific
median	35.33	133.95	2.11
mean	35.32	133.94	2.11
stdev	0.15	0.45	0.02
CV%	0.42	0.34	1.00
max	35.88	137	2.15
min	34.64	132.74	1.97
max-min	1.24	4.26	0.18
count	537	535	535

	NO3_leg1	SiO2_leg1	PO4_leg1
median	35.25	133.75	2.11
mean	35.25	133.88	2.11
stdev	0.12	0.62	0.02
CV%	0.33	0.46	1.13
max	35.64	137	2.15
min	34.96	132.86	1.97
max-min	0.68	4.14	0.18
count	166	165	165

	NO3_leg2	SiO2_leg2	PO4_leg2
median	35.37	134.00	2.11
mean	35.36	133.96	2.11
stdev	0.15	0.35	0.02
CV%	0.43	0.26	0.94
max	35.88	134.94	2.15
min	34.64	132.74	1.98
max-min	1.24	2.2	0.17
count	371	370	370

	NO3_leg4	SiO2_leg4	PO4_leg4
median	35.37	134.02	2.11
mean	35.37	134.02	2.11
stdev	0.07	0.30	0.02
CV%	0.21	0.23	1.02
max	35.61	134.90	2.15
min	35.10	133.19	2.00
max-min	0.51	1.71	0.15
count	181	183	183

Leg-to-leg traceability were examined based on the results of the statistics of RMNS-AH concentrations. As shown in Table 3.4.7, the medians and averages of the nutrients concentration of RMNS-AH were in good agreement among Leg.1, Leg.2 and Leg.4. The deviation among three Legs were less than 0.3% for nitrate, 0.2 % for silicate and 0% for phosphate, respectively.

3.4.7 Problems/improvements occurred and solutions.

1) Lower phosphate concentration for a few RMNS-AH bottles.

We found that phosphate concentrations for 4 bottles of RM-AH during Leg.4 were unreasonably low comparing the concentrations of RMNS bottles. Those are AH-4, 720, 801 and 805, respectively.

2) Simultaneous base line shift at 3 and 4 ch, silicate and phosphate channels, of #2 machine of TRAACS800.

Simultaneous base line shift at 3 and 4 ch, silicate and phosphate channels, of #2 machine of TRAACS800 were occurred seven times during Leg.4. Although, #2 machine of TRAACS800 were checked at Tahiti and a board, two cables and a drive belt were replaced and base line shift becomes less, these simultaneous base line shift may be caused by different reason.

3) Preventive replacements of pump tubes and flow cells, and careful treatment of the peak position determination might contribute excellent results on analytical precision.

We did preventive replacements of pump tubes before baseline noise would increase due to the aging of pump tubes. We also did preventive replacements of flow cells to maintain good condition of the TRAACS800s.

We pay more attention to determine peak positions before the calculation of concentrations of nutrients.

3.5 Freons

Ken'ichi SASAKI : Ocean Observation and Research Department, JAMSTEC
Katsunori SAGISHIMA : Marine Works Japan Co. Ltd
Shinichi TANAKA : Graduate School of Environmental Earth Science, Hokkaido University
Keisuke WATAKI : MWJ
Shuichi WATANABE : Ocean Observation and Research Department, JAMSTEC

(1) Objectives

Freons (Chlorofluorocarbons, hereafter CFCs) are the artificially formed gases. CFC-11 (CCl_3F), CFC-12 (CCl_2F_2) , CFC-113 ($C_2Cl_3F_3$) are very useful chemical tracers to clarify the water movement. We determined dissolved CFC-11, CFC-12, CFC-113 concentrations in seawater on board.

(2) Apparatus

Dissolved CFCs concentrations in seawater were determined with an electron capture detector - gas chromatograph (ECD-GC) attached the purge and trapping system.

Table 3.5.1 Instruments and analytical conditions

Instruments	
Gas Chromatograph:	GC-14B (Shimadzu Ltd.)
Detector:	ECD-14 (Shimadzu Ltd)
Column:	
Pre column:	Pola PLOT – QHT (i. d.: 0.53mm, length: 2m, tick: 6.0μm)
Main column:	Pola BOND – Q (i. d.: 0.53mm, length: 25m, tick: 6.0μm)
Temperature	
Oven:	95 deg-C (Constant)
Detector:	290 deg-C
Trapping & desorbing:	-45 deg-C & 130 deg-C
Gas flow rate	
Carrier gas:	27 ml/min
Detector Make UP:	～28 ml/min
Column Purge:	>15 ml/min
Sample purge:	～300 ml/min

(3) Procedures

(3-1) Sampling

Seawater samples for CFCs measurement were collected from 12 litter Niskin bottles to 300ml glass bottles attached the custom made Swagelok unions. The sample bottles were purged by N2 gas before each sampling. The Niskin bottles were cleaned by an acetone solution (1+2) before the CTD casts. Two times bottle volumes of seawater sample were overflowed to minimize contamination with atmospheric CFCs. Replicate samples were collected at 250 m and 1000 m depth.

Air samples for CFCs measurement were collected to 100ml glass cylinder at the navigation deck on R/V “MIRAI”.

(3-2) Analysis

The CFCs analytical system was modified from the original design of Bullister and Weiss (1988). Sample volume was 150 ml. The trap used to hold CFCs consists of a length of 1/8 in. o.d. SS tubing packed with 5 cm of Porapak T (80/100 mesh). Trapping and desorbing temperature were - 45 deg-C and 130 deg-C, respectively.

(4) Performance

The two analytical systems were used in this cruise. The analysis time of each system was 20 min on a sample. The standard gases used in this cruise will be calibrated to SIO scale standard gases after the cruise, and then the data will be corrected.

(5) Results

Dissolved CFCs were measured at 54 stations (all C-stations). The precisions CFC-11, CFC-12 and CFC-113 measurements estimated from replicate analyses were 0.03 pmol/kg (n = 96), 0.02 pmol/kg (n = 96), 0.02 pmol/kg (n = 66), respectively. In the CFC-113 data, there are many problems that come from fate of an automatic chromatogram analysis. The chromatograms should additionally be analyzed for CFC-113 data. We found the maximum concentrations of CFC-11 and CFC-12 (～3 pmol/kg and ～1.5 pmol/kg, respectively) at 300 m depth on the A10 section. These concentrations steeply decrease around 1000 m depth. In the bottom water of west of A10 section, we found relatively high concentrations of CFCs (around 0.2 pmol/kg).

(6) Data archive

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

(7) Reference

Bullister, J.L and Weiss R.F. 1988. Determination of CCl_3F and CCl_2F_2 in seawater and air. Deep Sea Research, 35, 839-853.

3.6 Carbon items

Akihiko Murata (JAMSTEC)
Fuyuki Shibata (MWJ)
Minoru Kamata (MWJ)
Toru Fujiki (MWJ)

3.6.1 Objectives

Concentrations of CO_2 in the atmosphere are now increasing at a rate of 1.5 ppmv y^{-1} owing to human activities such as burning of fossil fuels, deforestation, and cement production. It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric CO_2, and to clarify the mechanism of the CO_2 absorption, because the magnitude of the anticipated global warming depends on the levels of CO_2 in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In this cruise, we are aimed at quantifying how much anthropogenic CO_2 absorbed in the Southern Oceans, where intermediate and deep waters are formed, are transported and redistributed in the Pacific, Atlantic and Indian Oceans. For the purpose, we measured CO_2-system parameters such as dissolved inorganic carbon (C_T), total alkalinity (A_T) and pH. For a carbon budget study, we also collected seawater samples for total organic carbon (TOC).

3.6.2 Apparatus

(1) C_T

Measurements of C_T was made with two total CO_2 measuring systems (systems A and B; Nippon ANS, Inc.,), which are slightly different from each other. The systems comprise 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 20 ml volume by PC control. The pipette was kept at 20 °C by a water jacket, in which water from a water bath set at 20 °C is circulated.

CO_2 dissolved in a sea water sample is 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, a heating wire kept at 40 °C was rolled from the bottom to a 1/3 height of the stripping chamber. The acid is 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 is made with nitrogen gas (99.9999 %). After the acid is transferred to the stripping chamber, a sea water sample kept in a pipette is introduced to the stripping chamber by the same method as in adding an acid. The sea water reacted with phosphoric acid is 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 is carried by the nitrogen gas (flow rates of 130 ml min^{-1} and 140 ml min^{-1} for systems A and B, respectively) to the coulometer through a dehydrating module. For system A, the module consists of two electric dehumidifiers (kept at 1 °C) and a chemical desiccant ($Mg(ClO_4)_2$). For system B, it cosists of three electric dehumidifers with a chemical desiccant.

The measurement sequence such as system blank (phosphoric acid blank), 2 % CO_2 gas in a nitrogen base, sea water samples (6) was programmed to repeat. The measurement of 2 % CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc.,).

To check systematic differences of C_T measurements, we measured in-house reference materials at every stations, and certified reference material (CRM, Bach #60) provided by Prof. A.G. Dickson of Scripps Institution of Oceanography.

(2) A_T

Measurement of A_T was made using a titration systems (Nippon ANS, Inc.,). The systems comprise of a water dispensing unit, an auto-burette (Metrohm) and a pH meter (Thermo Orion), which are automatically controlled by a PC.

A seawater of approx. 40 ml is transferred from a sample bottle (brosilicate glass bottle; 130 ml) into a water-jacketed (25 °C), and is introduced into a water-jacketed (25 °C) titration cell. The seawaters are titrated by a acid titrant, which was 0.05 M HCl in 0.65 M NaCl in this cruise.

Calibration of the acid titrant was made by measuring A_T of 5 solutions of Na_2CO_3 in 0.7 M 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 0.05 M) should be a linear function of the A_T contributed by the Na_2CO_3. The line was fitted by the method of least squares. 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

Calculation of A_T was made based on a modified Gran approach.

To check systematic differences of C_T measurements, we measured in-house reference materials at every stations, and certified reference material (CRM, Bach #60) provided by Prof. A.G. Dickson of Scripps Institution of Oceanography.

(3) pH

Measurement of pH was made by a pH measuring system (Nippon ANS, Inc.), which adopts a method for the spectrophotometric determination. The system comprises of a water dispensing unit and a spectrophotometer (Carry 50 Scan, Varian). For an indicator, *m*-cresol purple (2 mM) was used.

Seawater was transferred from borosilicate glass bottle (300 ml) to a sample cell in the spectrophotometer. The length and volume of the cell are 8 cm and 13 ml, respectively, and the sample cell was kept at 25.00 ± 0.05 ºC in a thermostated compartment. First, absorbances of seawater only were measured at three wavelengths (730, 578 and 434 nm). Then the indicator was injected and circulated for about 4 minutes. to mix the indicator and seawater sufficiently. After the pump was stopped, the absorbances of seawater + indicator were maeasured at the same wavelengths. The pH was calculated based on the following equation (Clayton and Byrne, 1993):

$$pH = pK_2 + \log\left(\frac{A_1 / A_2 - 0.00691}{2.2220 - 0.1331(A_1 / A_2)}\right),$$

where A_1 and A_2 indicate absorbances at 578 and 434 nm, respectively, and pK_2 is calculated as a function of water temperature and salinity.

Reference

Clayton T.D. & R.H. Byrne (1993) Spectrophotometric seawater pH measurements: total hydrogen ion concentrtaion scale calibration of m-cresol purple and at-sea results. Deep-Sea Research 40, 2115-2129.

(4) TOC

Seawaters for TOC measurement were collected at every 4th to 5th stations.

The seawater was collected into a test tube from Niskin bottles (approx. 50 ml) without a drawing tube. The seawater was frozen at approx. –20 ºC as soon as possible after the water sampling.

TOC will be measured in a laboratory on land.

3.6.3 Performances

(1) C_T

The two systems had worked well during the leg without a major malfunction. Replicate analysis was made on every 9th seawater sample. The repeatability was estimated to be 1.0 µmol kg^{-1} (n = 168 pairs).

(2) A_T

The systems conducted a high speed titration (5-6 min.) compared to systems used in previous studies A few replicate samples were taken on every station. The repeatability was estimated to be 1.9 μmol kg^{-1} (n = 161 pairs).

(3) pH

The system had worked well with no troubles. The repeatability was estimated to be 0.0008 pH unit (n = 155 pairs).

3.6.4 Results

Cross sections of C_T, A_T and pH are illustrated in Fig. 3.6.1.

One maximum of C_T (approx. 2220 μmol kg^{-1}) existed at a depth of about 1500 m, distinctly in the western half of the section. The other maximum was found at depths greater than 4000 m. For A_T, the maximum (> 2350 μmol kg^{-1}) and minimum (< 2290 μmol kg^{-1}) were found in the surface layer and in the layer of about 800 m, respectively. In bottom waters greater than 4000 m, A_T was often in excess of 2350μmol kg^{-1}. The pH was about 8.0 in the surface layers, and decreased gradually with increasing depths, showing the minimum (approx. 7.60) in the layers from 1200 to 1400 m. From the depths, pH increased gradually to the depth, reaching 7.6 – 7.7 in the bottom waters.

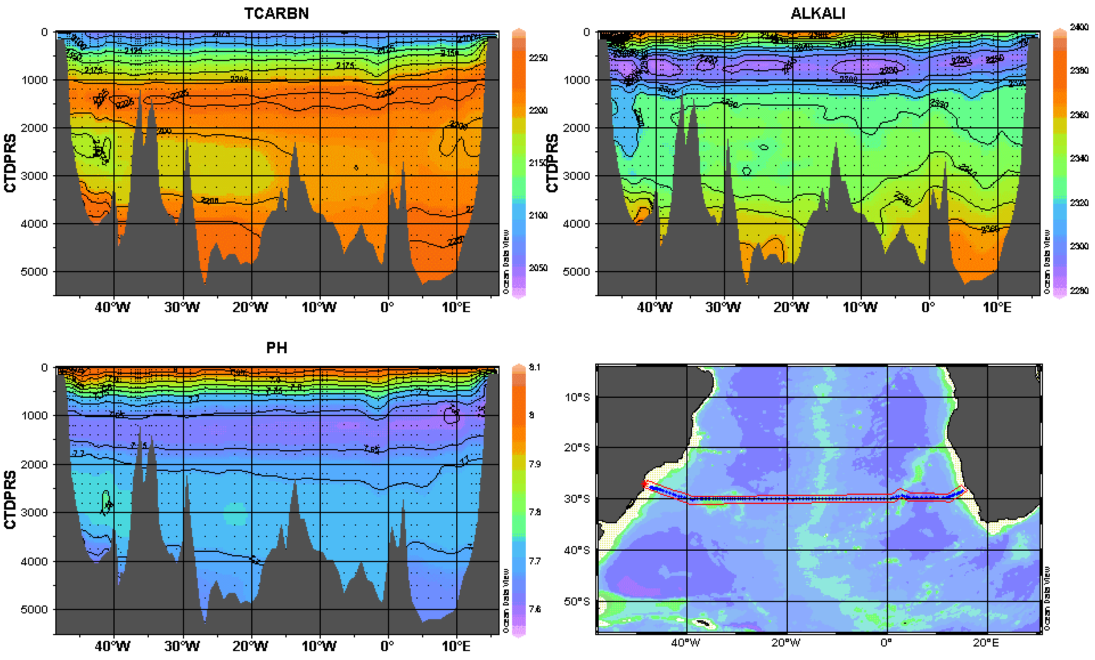


Fig.3.6.1 Cross sections of C_T, A_T and pH along the WOCE A10 line.

3.7 Samples taken for other chemical measurements

3.7.1 Nitrogen/Argon

Shinichi Tanaka and Yutaka Watanabe
Marin & Atmosphere Geochemistry Lab.,Division of Ocean & Atmospheric Science,
Graduate School of Environmental Earth Science, Hokkaido University

(1)Objective

(a) Detection for the change of air-sea interaction due to the climate change of the evidence.

To detect a signal of oceanic change due to the climate change, we have focused the recent change of air-sea gases exchange. Oceanic interior water is almost formed by the vertical convection at the winter surface. If we observe a time series gases concentrations in the oceanic interior, we can find the evidence for the change of air-sea gases exchange process due to the climate change. We here find the evidence for dissolved N2,Ar concentration as a tracer to clarify and collected these samples in this cruise.

(b) Improved method for accurate oxygen utilization in the ocean

To estimate marine biological activity, we usually use a concept of Apparent Oxygen Utilization (AOU) based on the difference between saturated and observed oxygen concentration. However, this concept has larger uncertainty because the oxygen content is saturated when water mass stayed in the surface mixed layer. If we can use saturation ratio among N2, Ar and oxygen in the ocean, it is possible to estimate more accurate oxygen utilization.

N2 Ar, and O2 are main component gases of atmosphere and N2 and Ar has non reactive gases in the ocean. The saturation of N2 and Ar could indicate of air-sea gases exchange in the winter surface (starting point of water masses). Therefore, we can possible estimate more accurate oxygen utilization in the ocean using the saturation ratio of N2 and Ar to oxygen.

Moreover, we will reconstruct preformed nutrient contents according to the above this study results.

(2) Sea area

The observation area in MR03-K04 Leg.4, South Atrantic Ocean, has variant sea water masses and it is very important through way of southward – northward thermohaline circulations. It is expected that dissolved concentration of N2 and Ar in the water masses have evidence of the change of air-sea gases interaction due to the climate change.

(3) Method

(a) Sampling

We collected Water samples at 15 stations using the Niskin bottles.

Station P06C-117,109,99,89,85,75,P06E-67,59,51,42,X19,29,21,15,11.

Each sample was collected in a 50ml-glass bottle. At each sampling site, seawater was allowed to overflow more than four times the bottle volume. A 50µl aliquot of saturated HgCl2 solution was added to each sample to avoid biological activity after sampling and it was stored in refrigerator.

(b) Analysis

We will analyze these sample onshore laboratory use by TCD-GC system. (Fig.3.7.1). Each gases analytical precision has below 0.1%.

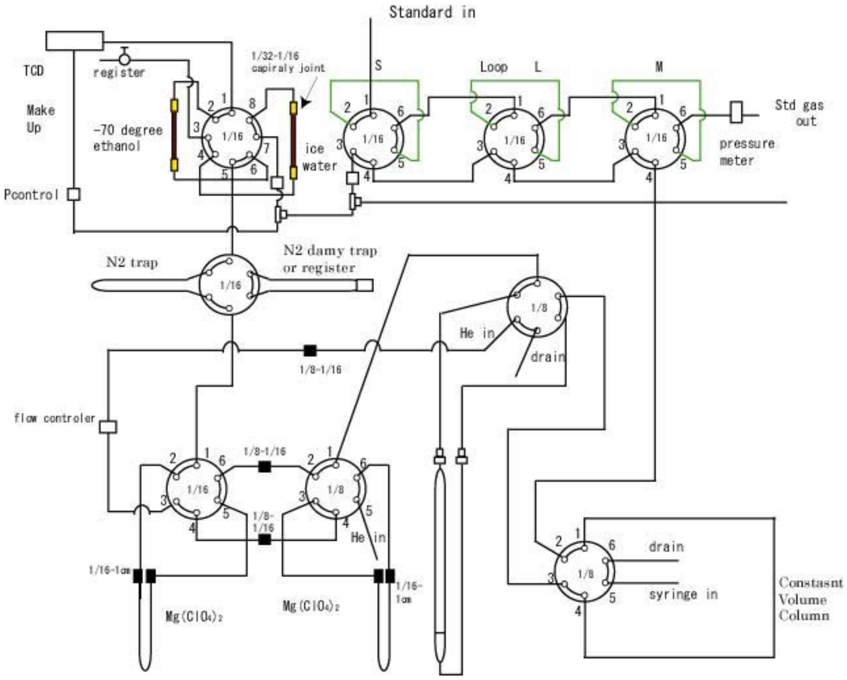


Fig.3.7.1 TCD-GC system

3.7.2 Carbon-14, carbon-13 (Dec. 8, 2003)

Yuichiro KUMAMOTO : Ocean Observation and Research Department, JAMSTEC

(1) Objective

In order to investigate water circulation and carbon cycle in the south Atlantic, seawater for carbon-14 (radiocarbon) and carbon-13 (stable carbon isotope) of total dissolved inorganic carbon (TDIC) was collected by the hydrocasts from surface to bottom.

(2) Sample collection

The sampling stations and number of samples are summarized in Table 3.7.1. All samples for carbon isotope ratios were collected at 23 stations using 12 liter Niskin bottles. The seawater sample was siphoned into a 250 cm^3 glass bottle with enough seawater to fill the glass bottle 3 times. Immediately after sampling, 10 cm^3 of seawater was removed from the bottle and poisoned by 0.05 cm^3 micro-L 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.

(3) Sample preparation and measurements

In our laboratory, dissolved inorganic carbon in the seawater samples will be stripped cryogenically and split into three aliquots: radiocarbon measurement (about 200 µmol), carbon-13 measurement (about 100 µmol), and archive (about 200 µmol). The extracted CO_2 gas for radiocarbon will be then converted to graphite catalytically on iron powder with pure hydrogen gas. The carbon-13 of the extracted CO_2 gas will be measured using Finnigan MAT252 mass spectrometer. The carbon-14 in the graphite sample will be measured by Accelerator Mass Spectrometry (AMS).

Table 3.7.1. The sampling stations and number of samples for carbon isotope ratios.

Station	No. samples	No. replicate samples	Max. sampling pressure /db
A10-629	22	2	2,429
A10-003	28	3	3,935
A10-007	28	3	3,835
A10-X17	30	3	4,249
A10-021	22	2	2,328
A10-029	28	3	3,862
A10-035	26	3	3,199
A10-038	35	3	5,368
A10-X16	31	3	4,411
A10-043	32	3	4,660
A10-X15	31	3	4,671
A10-051	28	3	3,741
A10-055	22	2	2,317
A10-059	28	3	3,767
A10-X14	29	3	3,981
A10-067	31	3	4,302
A10-071	32	3	4,789
A10-075	28	3	3,747
A10-079	32	3	4,816

A10-083	34	3	5,204
A10-087	34	3	5,067
A10-093	28	3	3,250
Total	639	63	

3.7.3 Radionuclides (Dec. 2003)

Michio AOYAMA : Geochemical Res. Dep., Meteorological Res. Inst., Japan
Sang-Han Lee : International Atomic Energy Agency, Marine Environment Laboratory

(1) Objectives

1) Study on the present distribution of artificial radioactivity originated mainly from atmospheric nuclear weapons tests in the 1950-60s in the world oceans.
2) Application of artificial radionuclides database for general circulation model validation

(2) Target radionuclides

Main target radionuclides are ^{137}Cs, Plutonium and tritium(^{3}H).
For some samples, the other parameters such as ^{90}Sr and ^{129}I will be measured.

(3) Sampling procedures

Sampling of seawater samples for radionuclides analysis in water column were done after following that all chemical and physical parameters. In all station, 5-7 additional bottles were available, then, the samples volumes for water column varied from 6 liter to 20 liter. Samples were drawn into 20liter cubitainers from the Niskin bottles. These samples were filtered using 0.45 um pore size filter and filled into appropriate size of cubitaners (6L to 20L) and bottle (1L). Filters were also archived. Concentrated Nitric Acid was added to the samples to keep pH1.6 except for tritium samples.

Surface water samples (about 80-90 liter) were drawn through intake pump in the lab below several meters from the surface and were filtered with the appropriate amounts of acid (Nitric Acid), which will be analysed for the determination of ^{137}Cs, Pu and ^{90}Sr. For the tritium, seawater of 1 liter was collected.

(4) Samples accomplished during Leg.4

Samples for the surface seawater were collected at the 20 stations. At the 13 stations, a total of 175 samples were collected for water column. Consequently, a total amount of the samples might be estimated around 4000kg and stored at room temperature. The filter papers are stored in the refrigerator in a frozen state.

(5) Problem occurred and solutions.

Any problem did not happen.

Table.3.7.2 SAMPLING RESULTS (1/4)

Stn.	LATITUDE	LONGITUDE	seawater		FILTER		REMARKS
			depth	volume	pore size	umbe	
A10-629	28 ° 02.69' S	46 ° 07.60' W	0db	86L	0.45μm	1	Cs137,Pu,H3,Sr
A10-004	29 ° 02.20' S	42 ° 54.60' W	0db	no samp	0.45μm	1	Cs137,Pu,H3,Sr
A10-008	29 ° 48.50' S	40 ° 35.00' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	6L	0.45μm	1	Cs137,Pu,H3
			200db	20L	0.45μm	1	Cs137,Pu,H3
			400db	10L	0.45μm	1	Cs137,Pu,H3
			600db	20L	0.45μm	1	Cs137,Pu,H3
			800db	10L	0.45μm	1	Cs137,Pu,H3
			1000db	20L	0.45μm	1	Cs137,Pu,H3
			1200db	10L	0.45μm	1	Cs137,Pu,H3
			1400db	10L	0.45μm	1	Cs137,Pu,H3
			2000db	20L	0.45μm	1	Cs137,Pu,H3
			2400db	10L	0.45μm	1	Cs137,Pu
			3000db	20L	0.45μm	1	Cs137,Pu,H3
			3500db	10L	0.45μm	1	Cs137,Pu
			3781db	20L	0.45μm	1	Cs137,Pu,H3
A10-013	30 ° 00.00' S	38 ° 30.19' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	11L	0.45μm	1	Cs137,Pu,H3
			200db	21L	0.45μm	1	Cs137,Pu,H3
			400db	9L	0.45μm	1	Cs137,Pu,H3
			600db	21L	0.45μm	1	Cs137,Pu,H3
			800db	9L	0.45μm	1	Cs137,Pu,H3
			1000db	21L	0.45μm	1	Cs137,Pu,H3
			1200db	9L	0.45μm	1	Cs137,Pu,H3
			1400db	9L	0.45μm	1	Cs137,Pu,H3
			2000db	21L	0.45μm	1	Cs137,Pu,H3
			2400db	9L	0.45μm	1	Cs137,Pu
			3000db	11L	0.45μm	1	Cs137,Pu,H3
			3500db	11L	0.45μm	1	Cs137,Pu
			4220db	21L	0.45μm	1	Cs137,Pu,H3
A10-022	29 ° 59.94' S	35 ° 10.09' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	9L	0.45μm	1	Cs137,Pu,H3
			200db	21L	0.45μm	1	Cs137,Pu,H3
			400db	9L	0.45μm	1	Cs137,Pu,H3
			600db	21L	0.45μm	1	Cs137,Pu,H3
			800db	21L	0.45μm	1	Cs137,Pu,H3
			1000db	21L	0.45μm	1	Cs137,Pu,H3
			1200db	11L	0.45μm	1	Cs137,Pu,H3
			1400db	11L	0.45μm	1	Cs137,Pu,H3
			2000db	21L	0.45μm	1	Cs137,Pu,H3
			2152db	21L	0.45μm	1	Cs137,Pu
A10-025	29 ° 59.81' S	33 ° 59.89' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
A10-030	29 ° 59.98' S	31 ° 30.22' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	8L	0.45μm	1	Cs137,Pu,H3
			200db	20L	0.45μm	1	Cs137,Pu,H3
			400db	8L	0.45μm	1	Cs137,Pu,H3
			600db	20L	0.45μm	1	Cs137,Pu,H3
			800db	20L	0.45μm	1	Cs137,Pu,H3
			1000db	20L	0.45μm	1	Cs137,Pu,H3
			1200db	10L	0.45μm	1	Cs137,Pu,H3
			1400db	9L	0.45μm	1	Cs137,Pu,H3
			2000db	20L	0.45μm	1	Cs137,Pu,H3
			2400db	9L	0.45μm	1	Cs137,Pu
			3000db	20L	0.45μm	1	Cs137,Pu
			3500db	8L	0.45μm	1	Cs137,Pu
			3855db	20L	0.45μm	1	Cs137,Pu

Table.3.7.2 SAMPLING RESULTS (2/4)

Stn.	LATITUDE	LONGITUDE	seawater		FILTER		REMARKS
			depth	volume	pore size	umbe	
A10-036	29 ° 59.77' S	28 ° 25.08' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	9L	0.45μm	1	Cs137,Pu,H3
			200db	21L	0.45μm	1	Cs137,Pu,H3
			400db	9L	0.45μm	1	Cs137,Pu,H3
			600db	21L	0.45μm	1	Cs137,Pu,H3
			800db	9L	0.45μm	1	Cs137,Pu,H3
			1000db	21L	0.45μm	1	Cs137,Pu,H3
			1200db	8L	0.45μm	1	Cs137,Pu,H3
			1400db	10L	0.45μm	1	Cs137,Pu,H3
			2000db	21L	0.45μm	1	Cs137,Pu,H3
			2400db	8L	0.45μm	1	Cs137,Pu
			3000db	20L	0.45μm	1	Cs137,Pu
			3500db	8L	0.45μm	1	Cs137,Pu
			3770db	20L	0.45μm	1	Cs137,Pu
A16C-317	30 ° 13.20' S	25 ° 02.80' W	0db	91L	0.45μm	1	Cs137,Pu,H3,Sr
A10-044	30 ° 00.00' S	21 ° 37.00' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	10L	0.45μm	1	Cs137,Pu,H3
			200db	20L	0.45μm	1	Cs137,Pu,H3
			400db	7L	0.45μm	1	Cs137,Pu,H3
			600db	20L	0.45μm	1	Cs137,Pu,H3
			800db	9L	0.45μm	1	Cs137,Pu,H3
			1000db	20L	0.45μm	1	Cs137,Pu,H3
			1200db	11L	0.45μm	1	Cs137,Pu,H3
			1400db	10L	0.45μm	1	Cs137,Pu,H3
			2000db	20L	0.45μm	1	Cs137,Pu,H3
			2400db	9L	0.45μm	1	Cs137,Pu
			3000db	9L	0.45μm	1	Cs137,Pu
			3500db	9L	0.45μm	1	Cs137,Pu
			4000db	9L	0.45μm	1	Cs137,Pu
			4845db	11L	0.45μm	1	Cs137,Pu
A15-105	30 ° 06.60' S	19 ° 00.03' W	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
A10-052	30 ° 00.04' S	15 ° 40.00' W	0db	101L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	9L	0.45μm	1	Cs137,Pu,H3
			200db	20L	0.45μm	1	Cs137,Pu,H3
			400db	8L	0.45μm	1	Cs137,Pu,H3
			600db	20L	0.45μm	1	Cs137,Pu,H3
			800db	20L	0.45μm	1	Cs137,Pu,H3
			1000db	20L	0.45μm	1	Cs137,Pu,H3
			1200db	8L	0.45μm	1	Cs137,Pu,H3
			1400db	9L	0.45μm	1	Cs137,Pu,H3
			2000db	20L	0.45μm	1	Cs137,Pu,H3
			2400db	9L	0.45μm	1	Cs137,Pu
			3000db	20L	0.45μm	1	Cs137,Pu
			3280db	20L	0.45μm	1	Cs137,Pu
A10-055	30 ° 00.17' S	13 ° 39.90' W	0db	90L	0.45μm	1	Cs137,Pu,H3,Sr

Table.3.7.2 SAMPLING RESULTS (3/4)

Stn.	LATITUDE	LONGITUDE	seawater		FILTER		REMARKS
			depth	volume	pore size	umbe	
A10-060	29 ° 59.80' S	10 ° 19.80' W	0db	81L	0.45 μ m	1	Cs137,Pu,H3,Sr
			100db	9L	0.45 μ m	1	Cs137,Pu,H3
			200db	20L	0.45 μ m	1	Cs137,Pu,H3
			400db	8L	0.45 μ m	1	Cs137,Pu,H3
			600db	20L	0.45 μ m	1	Cs137,Pu,H3
			800db	9L	0.45 μ m	1	Cs137,Pu,H3
			1000db	20L	0.45 μ m	1	Cs137,Pu,H3
			1200db	8L	0.45 μ m	1	Cs137,Pu,H3
			1400db	8L	0.45 μ m	1	Cs137,Pu,H3
			2000db	20L	0.45 μ m	1	Cs137,Pu,H3
			2400db	9L	0.45 μ m	1	Cs137,Pu
			3000db	20L	0.45 μ m	1	Cs137,Pu
			3500db	9L	0.45 μ m	1	Cs137,Pu
			3840db	20L	0.45 μ m	1	Cs137,Pu
A10-072	30 ° 00.96' S	0 ° 43.89' W	0db	81L	0.45 μ m	2	Cs137,Pu,H3,Sr
			100db	8L	0.45 μ m	1	Cs137,Pu,H3
			200db	20L	0.45 μ m	1	Cs137,Pu,H3
			400db	8L	0.45 μ m	1	Cs137,Pu,H3
			600db	20L	0.45 μ m	1	Cs137,Pu,H3
			800db	8L	0.45 μ m	1	Cs137,Pu,H3
			1000db	20L	0.45 μ m	1	Cs137,Pu,H3
			1200db	8L	0.45 μ m	1	Cs137,Pu,H3
			1400db	8L	0.45 μ m	1	Cs137,Pu,H3
			2000db	10L	0.45 μ m	1	Cs137,Pu,H3
			2400db	8L	0.45 μ m	1	Cs137,Pu
			3000db	8L	0.45 μ m	1	Cs137,Pu
			3500db	8L	0.45 μ m	1	Cs137,Pu
			4000db	9L	0.45 μ m	1	Cs137,Pu
			4500db	9L	0.45 μ m	1	Cs137,Pu
			4851db	20L	0.45 μ m	1	Cs137,Pu
A10-075	29 ° 43.94' S	1 ° 07.97' E	0db	81L	0.45 μ m	1	Cs137,Pu,H3,Sr
A10-080	29 ° 36.69' S	3 ° 46.74' E	0db	81L	0.45 μ m	2	Cs137,Pu,H3,Sr
			100db	9L	0.45 μ m	1	Cs137,Pu,H3
			200db	9L	0.45 μ m	1	Cs137,Pu,H3
			400db	9L	0.45 μ m	1	Cs137,Pu,H3
			600db	20L	0.45 μ m	1	Cs137,Pu,H3
			800db	9L	0.45 μ m	1	Cs137,Pu,H3
			1000db	20L	0.45 μ m	1	Cs137,Pu,H3
			1200db	9L	0.45 μ m	1	Cs137,Pu,H3
			1400db	8L	0.45 μ m	1	Cs137,Pu,H3
			2000db	9L	0.45 μ m	1	Cs137,Pu,H3
			2400db	8L	0.45 μ m	1	Cs137,Pu
			3000db	9L	0.45 μ m	1	Cs137,Pu
			3500db	7L	0.45 μ m	1	Cs137,Pu
			4000db	9L	0.45 μ m	1	Cs137,Pu
			4500db	6L	0.45 μ m	1	Cs137,Pu
			4927db	20L	0.45 μ m	1	Cs137,Pu

Table.3.7.2 SAMPLING RESULTS (4/4)

Stn.	LATITUDE	LONGITUDE	seawater		FILTER		REMARKS
			depth	volume	pore size	umbe	
A10-084	29 ° 45.05' S	6 ° 46.65' E	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	8L	0.45μm	1	Cs137,Pu,H3
			200db	9L	0.45μm	1	Cs137,Pu,H3
			400db	8L	0.45μm	1	Cs137,Pu,H3
			600db	20L	0.45μm	1	Cs137,Pu,H3
			800db	9L	0.45μm	1	Cs137,Pu,H3
			1000db	20L	0.45μm	1	Cs137,Pu,H3
			1200db	9L	0.45μm	1	Cs137,Pu,H3
			1400db	8L	0.45μm	1	Cs137,Pu,H3
			2000db	9L	0.45μm	1	Cs137,Pu,H3
			2400db	9L	0.45μm	1	Cs137,Pu
			3000db	9L	0.45μm	1	Cs137,Pu
			3500db	9L	0.45μm	1	Cs137,Pu
			4000db	8L	0.45μm	1	Cs137,Pu
			4500db	9L	0.45μm	1	Cs137,Pu
			4750db	9L	0.45μm	1	Cs137,Pu
			5000db	8L	0.45μm	1	Cs137,Pu
			5190db	20L	0.45μm	1	Cs137,Pu
A10-087	29 ° 44.73' S	9 ° 17.30' E	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
A10-091	29 ° 37.28' S	12 ° 10.20' E	0db	81L	0.45μm	1	Cs137,Pu,H3,Sr
			100db	1L	0.45μm	1	Cs137,Pu,H3
			200db	15L	0.45μm	1	Cs137,Pu,H3
			400db	1L	0.45μm	1	Cs137,Pu,H3
			600db	15L	0.45μm	1	Cs137,Pu,H3
			800db	15L	0.45μm	1	Cs137,Pu,H3
			1000db	17L	0.45μm	1	Cs137,Pu,H3
			1200db	1L	0.45μm	1	Cs137,Pu,H3
			1400db	1L	0.45μm	1	Cs137,Pu,H3
			2000db	15L	0.45μm	1	Cs137,Pu,H3
			2400db	1L	0.45μm	1	Cs137,Pu
			3000db	15L	0.45μm	1	Cs137,Pu
			3500db	1L	0.45μm	1	Cs137,Pu
			3820db	15L	0.45μm	1	Cs137,Pu
Total			-	3659L	-		

3.8 Lowered Acoustic Doppler Current Profiler

Y. Yoshikawa (JAMSTEC)
L. Nonnato (University of Sao Paulo)

Direct flow measurement from sea surface to bottom was carried out by using a lowered acoustic Doppler current profiler (LADCP). The instrument used was an RDI Monitor 307.2 kHz unit. The instrument was attached on CTD/RMS frame, and oriented downward. CPU firmware version was 16.20.

A total of 111 operations were made with the CTD observations. One ping raw data were recorded in 32 bins with 8 m of bin length. Each sampling interval was 1.29 second. The accuracy of each ping was 2 cm/s. Bottom-tracking mode was used and it succeeded to capture the bottom. For the calculation of sound speed, we set salinity as constant value, 34 psu. We replace the instrument at A10-37 because we found one of the four beams sounded weak signal (beam 2). A pressure sensor was also added to the first instrument.

The performance of the LADCP instrument was not good for first instrument. Profiles were obtained less than 40 m in deeper depth. Three beam solution was obtained before A10-37. After the replacement the profile was obtained about 60 m in deeper depth, as a four beam solution. The sea bottom was recognized during the instrument was lowered less than 200 m above the bottom.

The data was analyzed in the ship by using the method of Visbeck (2002) with CTD and navigation data. The following figure is a sample of results at station 11 and X23, in the sea east off the Brazil. Bottom tracking was valid even if the sound did not reach so long.

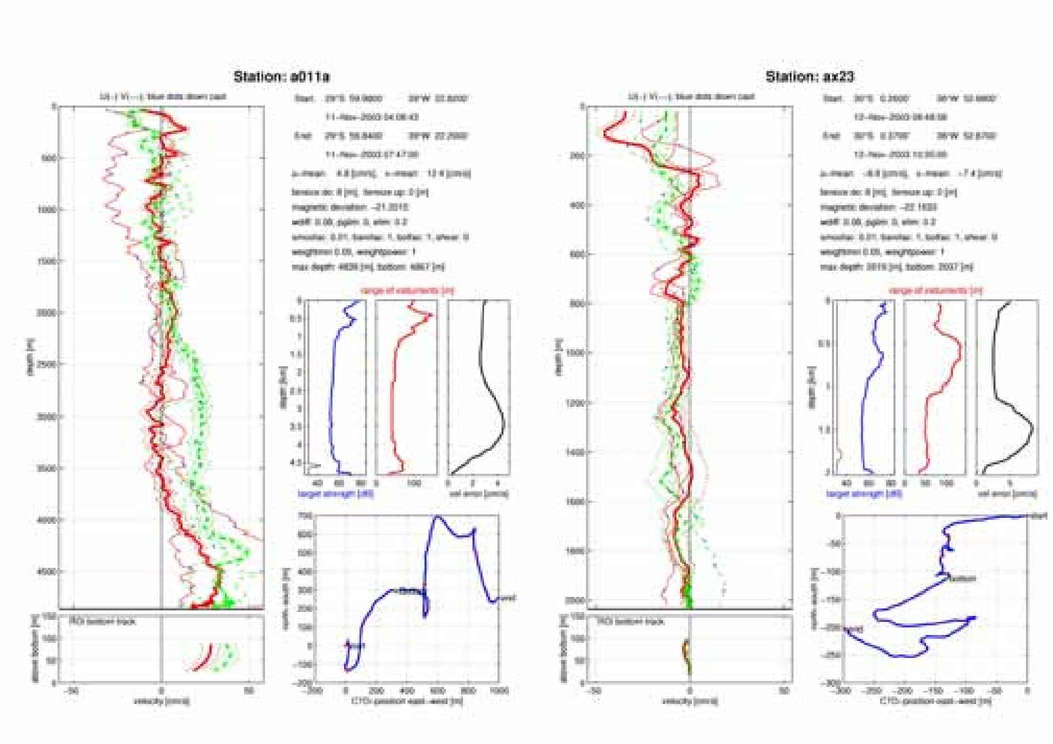


Fig.3.8.1 Sample of results at stations 11 and X23.

3.9 Bio-optics

Principal Investigator : Shubha Sathyendranath (Canada)
Specialist in charge on board : Vivian Lutz (Argentina)
POGO Trainees : Valeria Segura (Argentina)
Jaqueline Leal Madruga (Brasil)
Observer for South Africa : Nonkqubela Silulwane (South Africa)

(1) Introduction

The Blue EArth GLobal Expedition 2003, 'BEAGLE 2003', is an oceanographic research program developed by Japan Marine Science and Technology Centre (JAMSTEC). The principal objective of this project is to enhance oceanographic research activities in the Southern Hemisphere, in accordance with the Sao Paulo Declaration (POGO, 2000). These are pointed out as follows:

1) To detect and quantify temporal changes in the Antarctic Overturn System corresponding to the global ocean and the Southern Ocean warming during this century through high quality and spatially dense observation along old WHP (World Ocean Circulation Experiment Hydrographic Program 1991-2002) lines.

2.). To estimate the amount of anthropogenic carbon uptaken by the Antarctic Ocean.

3.) To provide a training environment in which trainees could get a hand-on experience in collecting biological, optical samples and optical data.

(2) Bio-optical Objectives

The general objectives of the bio-optical project on this expedition are:

-To generate an important database of bio-optical measurements and primary production from the under-sampled Southern Ocean.

-To reach this objective, measurements of radiation (seawater reflectance) are being measured with a variety of radiometers (Simbad, Simbada, Ocean Optics), samples are taken for the analysis of chlorophyll a concentration, and for the determination of absorption properties of particulate (phytoplankton and detritus) and coloured-dissolved-organic-matter (CDOM); P&I experiments are also performed for the estimation of primary production parameters. Samples for the determination of phytoplankton pigment composition by HPLC, as well as for the quantification and identification of the small-sized phytoplankton by flow-cytometry are also being collected. Results from these analysis are expected to contribute to the validation and calibration, and probably to develop regional algorithms, for satellite-derived products (eg., chlorophyll a) by sensors such as SeaWiFS, MODIS, and MERIS.

-To provide a training environment in which trainees could get a hands-on experience in collecting phytoplankton related samples and bio-optical data. To get a first knowledge about some of the analysis and processing of bio-optical data.

(3) Sampling and Methods

Protocols for the sampling and methods being used for the optical measurements and analysis of biological samples can be consulted in the URL of IOCCG (http://www.ioccg.org/training/pogo_ioccg/protocols/protocols.html). Most of the samples are taken at the surface, or near surface, of the ocean, except for a second set of samples for chlorophyll analysis which are taken at the depth of the fluorescence maximum. Analysis of chlorophyll concentrations, particulate and CDOM absorption, and P&I incubations are performed on board, while HPLC, flow cytometry and ^{13}C (for the calculations of P&I parameters), as well as a duplicate of particulate absorption samples are going to be processed in different laboratories (in Canada, Chile, South Africa, and Australia) after the end of the cruise. A preliminary processing of some of the data available is being developed onboard.

(4) Peculiarities of Leg.4

During this leg the main focus of the expedition was on chemical and physical oceanography. A total of 111 CTD casts were performed. For all the bio-optical sampling two stations a day were occupied, one close to noon and another about 4 hs earlier or later. Whenever possible seawater samples were taken from Niskin bottles at 5 m depth, or 10 m (when the weather was too windy). In a few occasions, when there were not enough Niskin bottles for all the required sampling, samples were taken from the surface using a bucket. An extra sample for the analysis of chlorophyll concentration, was taken from the depth of the fluorescence maximum (indicated by the in situ fluorometer attached to the CTD).

Radiation measurements (seawater reflectance) were performed about one hour before the rosette sampling. Unfortunately, after the first week of the cruise one of the radiometers, SIMBAD-03, stopped working.

I. BIOLOGICAL SAMPLING

-Photosynthesis v/s Irradiance (PI) Experiments

Everyday 1 or 2 experiments were carried out onboard. 42 bottles (+ 3 dark) were incubated with ^{13}C in a Larsen box for 3 hours, then filtered and dried.
Storing: filters were labelled and stored in sets of 15 envelopes.

-CDOM

Water for the determination of coloured-dissolved-organic-matter were filtered through 0.2 μm membranes, and immediately scanned in a 10 cm quartz cuvette in a CARY spectrophotometer.
Storing: no samples were stored. Results are in folder JAMSTEC/CDOM/Leg4/dailyfolder

-Chlorophyll Concentration

Chlorophyll-a and phaeopigments concentrations were measured onboard using a digital Turner Designs fluorometer.
Storing: no samples were stored. Results are in folder JAMSTEC/Leg4/Chl/daily files

-Particulate Absorption

Two samples were collected and filtered through GF/F glass fiber filters for the determination of particulate absorption. One sample was immediately scanned on board in a CARY spectrophotometer, and the other will be analysed at the Bedford Institute of Oceanography (Att: Dr. Venetia Stuart).
Storing: Results of samples analysed on board are in folder JAMSTEC/Absorption/Leg4/dailyfolder. Duplicate samples were frozen in liquid nitrogen into a labelled cryogenic vial and then stored in a deep freezer (-80 degC).

-High Performance Liquid Chromatography

Two samples were collected and filtered through GF/F glass fiber filters for the determination of phytoplankton pigment composition by HPLC. These samples will be analysed in 2 different laboratories: Cape Town (South Africa) and Hobart (Australia).

Storing: Both samples were frozen in liquid nitrogen and then stored in 2-separated labelled aluminium foil envelopes into a deep freezer (-80degC).

II. OPTICAL SAMPLING

-SIMBAD

The hand-held battery operated radiometer collects data in five spectral bands that are centred at 443, 490, 560, 670, 870 nm. This instrument has an external GPS antenna and measures direct sunlight intensity and water leaving radiance. The GPS must first find the instruments position before readings can be made. The sequence of measurements are 1 Dark, 3 Sun, 6 Sea, 3 Sun, and 1 Dark.

Storing: The files are in the folder JAMSTEC/Leg4/simbad03/dailyfolder.

-SIMBADA

This instrument is an above-water radiometer and it measures water-leaving radiance and aerosol optical thickness in 11 spectral bands. The bands are centred at 350, 380, 412, 443, 490, 510, 565, 620, 670, 750 and 870 nm. The instrument has an internal GPS antenna that must home in on 3 or more satellites before readings can be taken. The sequence of measurements are 1 Dark, 3 Sun, 6 Sea, 3 Sun, and 1 Dark.

Storing: The files are in the folder JAMSTEC/Leg4/simbada21/dailyfolder.

-Hyperspectral radiometer

This instrument measures irradiance from 350 to 1000 nm at 0.5 nm intervals and has a special fibre optic that collects the irradiance from the sky and the sea surface. The downwelling irradiance is measured using a spectralon that diffuses the incident irradiance.

Storing: Files are in folder JAMSTEC/Leg4/HyperSp/dailyfolder.

-Photosynthetic Active Radiation (PAR)

The PAR sensor is mounted outside, above the Atmospheric Observation laboratory. The Licor 1400 data logger connected to the sensor reads measurements every 60 seconds and records hourly average on the hour. Data are downloaded at the end of the Leg to be later processed at BIO in Canada.

Storing: Files are in folder JAMSTEC/Leg4/PAR_sensor_data/PAR_Leg4.txt

(5) Pogo Trainees Activities

In this Leg apart from the two official POGO trainees, Valeria Segura and Jaqueline Leal Madruga, we have to thank the participation of Nonkqubela Silulwane (observer for South Africa), who joined the bio-optical team. Valeria and Nonkqubela worked very hardly and enthusiastically learning all the bio-optical techniques. Jaqueline, concentrated on light measurements and some light-data processing.

Trainees Remarks

Nonkqubela Silulwane

It was an exciting challenge and experience to be onboard R/V Mirai and to be part of a bio-optic research team. Although I have been to a couple of research cruises before, I believe that this cruise is a major highlight of my sea-going experiences.

I got hands-on training in different studies such as P&I experiments, particulate absorption, CDOM, light measurements, as well as extensive CTD sampling. Such an excellent training came at a crucial time of my career when I am faced with a major challenge of starting my own research project in South Africa. With so much that I have learnt, now it is even difficult to choose which experiments to consider for my research project from the set of experiments that I conducted onboard as they are all important and of interest to me.

The hard work, perseverance and dedication from Dr Vivian Lutz making sure that I followed the sampling protocols and her clear explanations when I could not understand deserve a mention. Furthermore, it was such a pleasure and a privilege for me to conduct the experiments and be able to learn so much because of the other enthusiastic bio-optic team member (Valeria Segura) with high team spirit.

Special thanks goes to JAMSTEC for their financial support and giving me the opportunity to be onboard R/V Mirai. The training provided under POGO programme is highly appreciated.

Valeria Segura

My experience on R/V Mirai was incredible and unique not only because I got professional training as a scientist but because I was also exposed and obtained a personal experience in living in an environment with people from different cultures, and this I will never forget.

I learnt a lot about biological and optical measurements because I worked with Dr. Vivian Lutz who has a lot of experience in this discipline and she is good as a teacher. In addition, I learnt how to take water samples from a CTD for different measurement such as Dissolved Oxygen, CFCs, Salinity, PH, Total Dissolved Carbon, Alkalinity, Nutrients, Total Organic Carbon, etc.

I would like to thank POGO for giving me the opportunity to be trained onboard this fantastic research vessel because I have learnt a lot of things about routine sea measurements. I am also grateful to JAMSTEC for their wonderful research collaboration.

Jaqueline Leal Madruga

My participation in BEAGLE 2003 was very important for my training in new technologies and methodologies about light measurements. This opportunity permits a integration with researchers of other countries of South America and South Africa that is very important to improve our relationship of work.

The PAR and ocean optics data set could be very useful in the validation of BRAZILSR Radiative Transference Model that estimates the PAR in Brazilian coast. This model was adapted for Brazilian coast by National Institute of Space Research, but it isn’t validated yet.

I intend to use the light measurements background in the ANTARES Project that is a pionner project to install fixed oceanographic stations in the coast of South America.

(6) Data Processing

A series of Fortran routines developed during Leg 3, were used to process the absorption data. The only modification to the routines is step (7), which applies a running average to try to smooth even more the data, since phytoplankton concentrations were extremely low during this Leg. They can be found in the directory /JAMSTEC/Leg4/data-process. These data can be later reprocessed to make any necessary adjustments, for example choosing a more appropriate Beta factor (once HPLC pigments would be available; see Stuart et al., 1998). This modification could be even more relevant for the data of Leg.4, where we could expect to find abundance of small cells, including perhaps some Prochlorophytes.

In the case of the particulate absorption, the first routine ‘absorption_n.for’ retrieves the optical density values (OD) from the ASCII files produced by the Cary spectrophotometer in a format which can be read by Fortran. The second routine ‘absorption_f.for’ processes the OD values following the steps described in the protocols. Basically:

- it subtracts the value of absorption at 750 nm from the whole spectrum;
- it averages the 10 replicates of each type of measurement;
- it subtracts the averaged blank from the averaged sample absorption;
- it organises the spectrum from the lower to the higher wavelength;
- it corrects the spectrum for the Beta factor (using the equation proposed by Hoepffner & Sathyendranath, 1992; see reference in protocols);
- it transforms OD into absorption (passing from log10 to loge and considering the area and volume of filtration);
- it smoothes the data by doing a running average every 5 nm;
- it subtracts the detritus from the total to retrieve the phytoplankton absorption;
- it calculates the specific absorption coefficient of phytoplankton (dividing the phytoplankton absorption by the chlorophyll a concentration of the sample).

The program generates four output files with the results of the processing:

SampleID+ABT.txt
SampleID+ABD.txt
SampleID+ABPHY.txt
SampleID+ABSPHY.txt

CDOM data was not corrected on board. It will be processed after the cruise using the routines developed during Leg.3.

(7) Preliminary Results

This is just a preliminary analysis of some of the results obtained on Leg.4. The cruise track is shown in Fig.3.9.1. During this leg chlorophyll concentrations were extremely low (Table 3.9.1). As a result, although ~ 2 litters of seawater were filtered, some of the particulate absorption data lay close to the limit of detection of the spectrophotometer. This cause that spectra look somehow noisy (Fig.3.9.2). It is expected that duplicate samples, to be ran at the Bedford Institute (Canada) using a more sophisticated spectrophotometer (double beam and with an integrating sphere), may show a better resolution. Nevertheless, the data processed on board show some conspicuous features. This data set, consistent of 45 samples, showed no huge differences in their main characteristics. It was noticeable that total absorption coefficients, at their maximum in the blue, were one order of magnitude lower than spectra on Leg.3. The maximum value of total particulate absorption (ABT ~ 0.022 at 440 nm) occurred at stations A10-626 and A10-631 (close to the Brazilian coast), were similar to the lowest values found on Leg.3. Most stations showed low detritus absorption, indicating that total particulate absorption was dominated by phytoplankton absorption, typical of case 1 waters.

The specific absorption coefficients of phytoplankton ($a^*_{ph}(\lambda)$, ABPHY/Chla), were higher than those estimated for Leg.3. The values of $a^*_{ph}(\lambda)$ (Fig.3.9.3), oscillated between ~ 0.1 and 0.2 for the maximum at the blue. This, would indicate the predominance of small cells, less affected by the packaging effect, in the phytoplanktonic community. Flow cytometric data of the samples collected will provide and excellent tool to identify and quantify this small fraction of the plankton.

Acknowledgements

We would like to thank people at POGO, IOCCG and JAMSTEC for giving us the opportunity of being able to participate in this exciting BEAGLE2003 expedition, especially to Prof. Masao Fukasawa for his support and overall leadership of the whole expedition. The experience will be most useful to us in our future work. The good will and effort of Ana Claudia de Paula (official Brazilian observer) allowed us to obtain the necessary permit to sample in Brazilian waters. The ‘engineering’ support received from Luiz Nonnato, was invaluable: Muito obrigado. We want to thank Kathleen Peard and Bronwen Currie from Namibia, for their support on board. Special thanks go to Shubbha Sathyendranath, Venetia Stuart, Tony Paysant, Marie Helene Forget, Robert Frouin and Brian Irwin for their long distance support. We sincerely appreciate the collaboration received on board from Yasushi Yoshikawa, chief scientist, Shuichi Watanabe, the whole sampling-team of JAMSTEC and MWJ, as well as the captain and crew of the R/V Mirai.

Table 3.9.1 Chlorophyll a concentrations in the samples of Leg.4

Number (Fig.2)	Station #	Sample ID	Depth (m)	Chla (mg m^{-3})
1	A10-623	264314	0	0.094
			5	0.12
2	A10-626	264315	0	0.148
			75	0.292
3	A10-631	264316	0	0.141
			70	0.179
4	A10-632	264317	5	0.112
5	A10-003	264318	5	0.075
			100	0.181
6	A10-004	264319	5	0.074
			130	0.13

7	A10-007	264320	0	0.071
			95	0.284
8	A10-008	264321	0	0.057
			105	0.201
9	A10X17-C	264322	5	0.067
			100	0.307
10	A10-013	264323	0	0.065
			100	0.215
11	A10 X23C	264325	5	0.067
			110	0.164
12	A10-18-C	264326	10	0.059
			125	0.204
13	A10-25-C	264327	5	0.076
			100	0.324
14	A10-26-N	264328	5	0.061
			130	0.192
15	A10-30-N	264329	0	0.066
			120	0.204
16	A10-31-C	264330	10	0.078
			130	0.157
17	A10-35-C	264331	5	0.06
			150	0.163
18	A10-36-N	264332	0	0.058
			150	0.159
19	A10-39-N	264333	5	0.053
			120	0.133
20	A10-X16-C	264334	0	0.056
			120	0.183
21	A10-42-N	264335	5	0.057
			130	0.233
22	A10-43-C	264336	5	0.044
			135	0.265
23	A0-46-N	264338	5	0.037
			150	0.171
24	A10-X15-C	264339	5	0.032
			160	0.213
25	A10-50-N	264340	5	0.034
			160	0.217
26	A10-51-C	264341	5	0.031
			150	0.163
27	A10-55-C	264342	5	0.033
			150	0.207
28	A10-56-N	264343	5	0.037
			155	0.215

29	A10-59-C	264344	5	0.033
			150	0.187
30	A10-60-N	264345	0	0.028
			122	0.196
31	A10-63-N	264346	5	0.038
			105	0.315
32	A10-64-N	264347	5	0.028
			90	0.328
33	A10-67-C	264348	5	0.035
			120	0.192
34	A10-68-N	264349	5	0.034
			100	0.265
35	A10-72-N	264350	5	0.103
			50	0.241
			75	0.237
36	A10-71-C	264351	0	0.052
			50	0.116
37	A10-76-N	264352	5	0.04
			100	0.274
38	A10-77-C	264353	5	0.053
			115	0.222
39	A10-80-N	264354	0	0.048
			50	0.155
40	A10-81-C	264355	5	0.053
			80	0.21
41	A10-84-N	264356	0	0.059
			100	0.274
42	A10-85-C	264357	0	0.118
			90	0.251
43	A10-X13-C	264358	10	0.082
			75	0.229
44	A10-89-N	264359	10	0.085
			55	0.164
45	A10-91-N	264360	0	0.133
			50	0.256

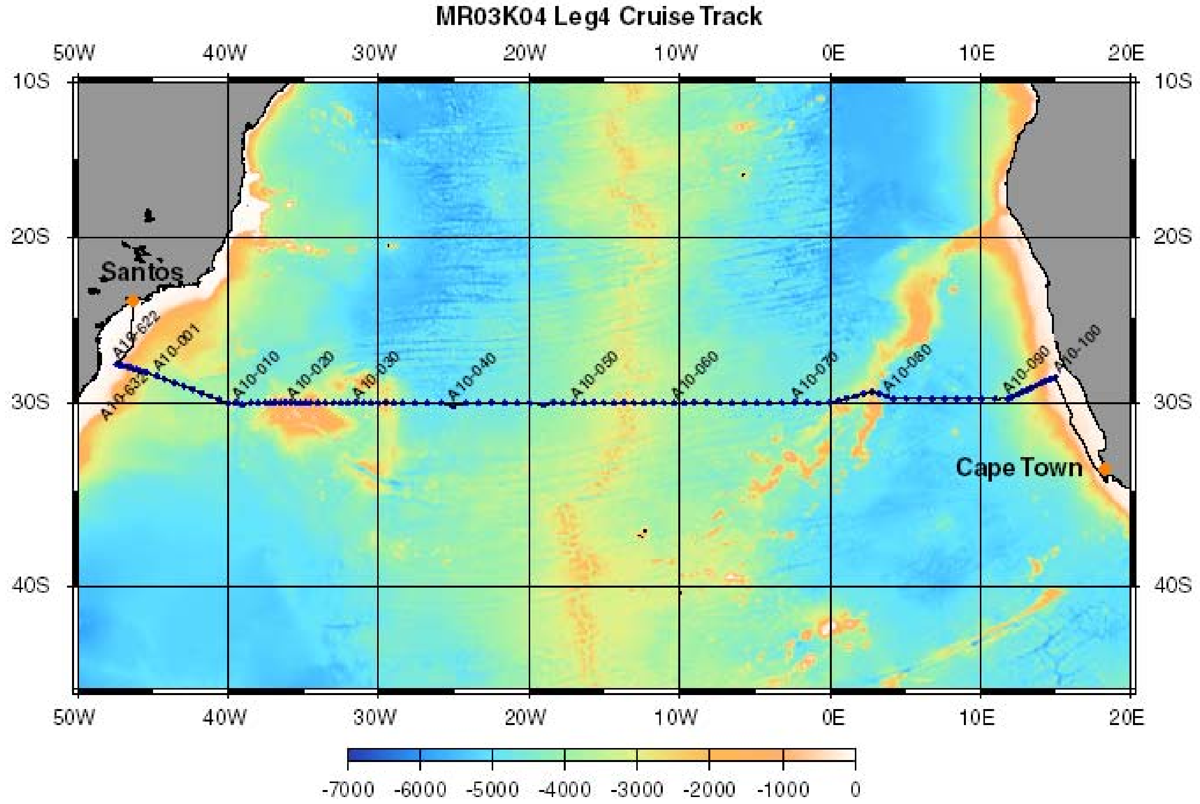


Fig.3.9.1 Cruise track, and stations positions in Leg.4

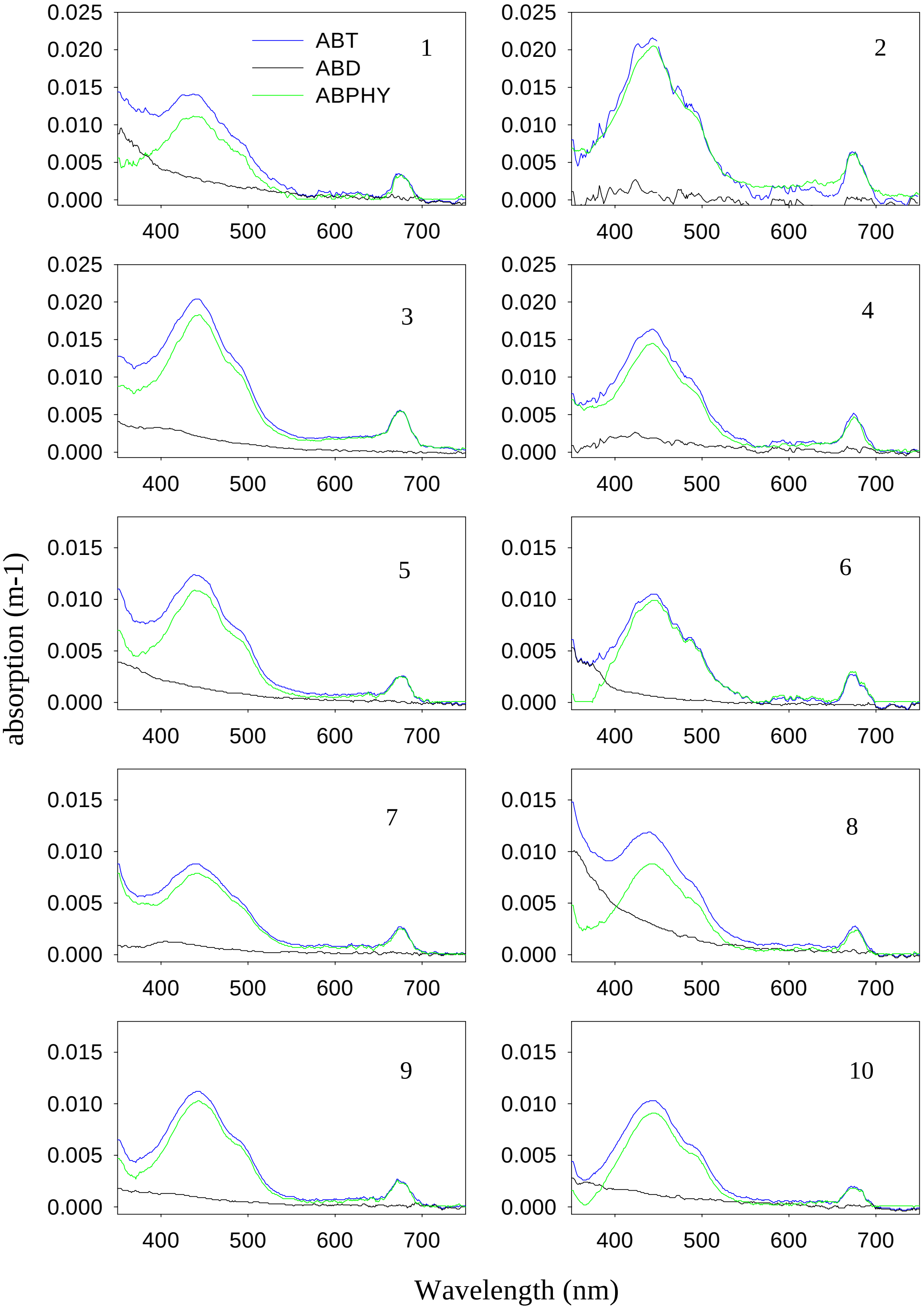


Fig.3.9.2 Absorption coefficients of total particulate material, ABT, detritus, ABD, and phytoplankton, ABPHY, in the samples of Leg.4

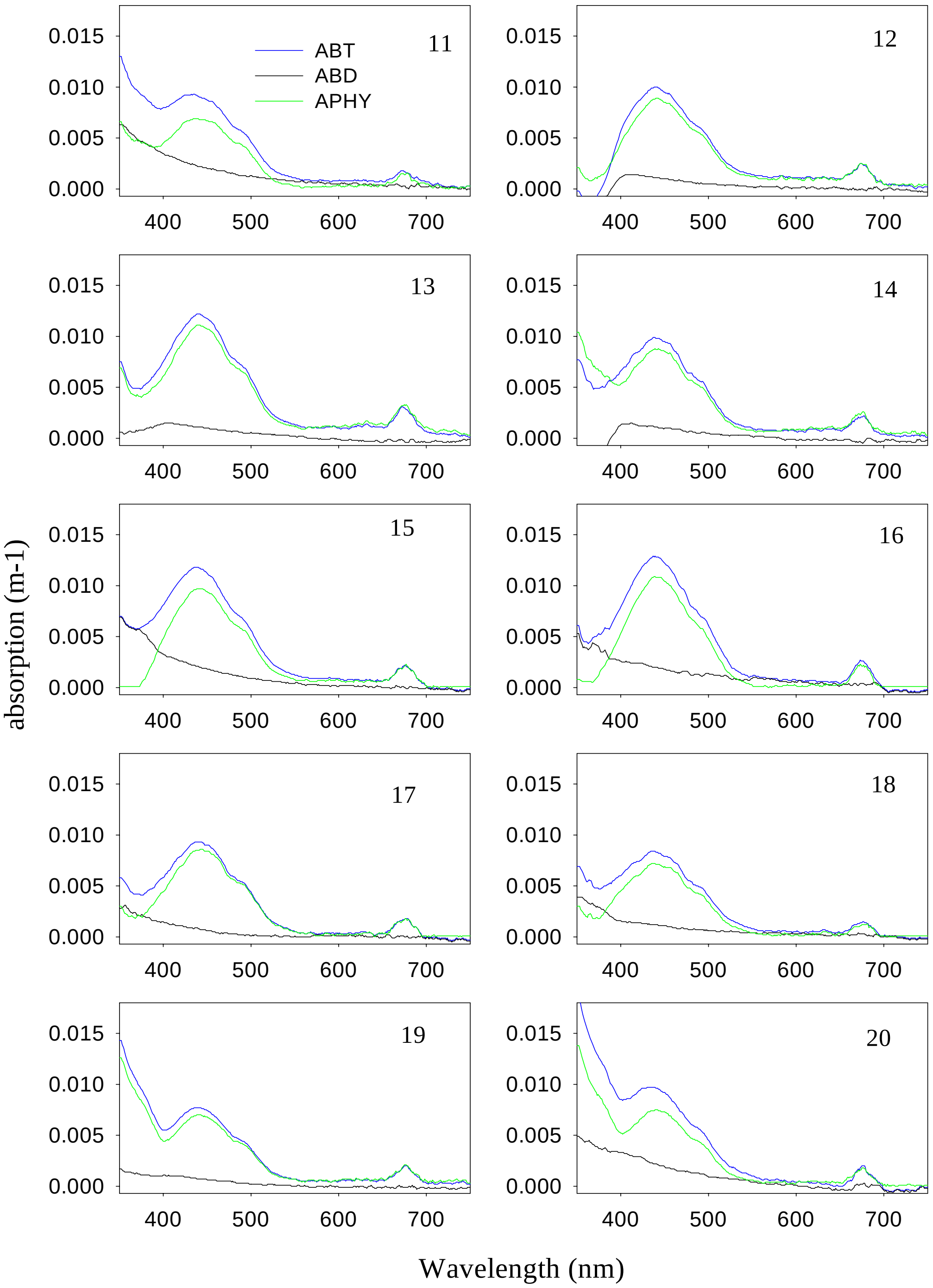


Fig.3.9.2 Continued

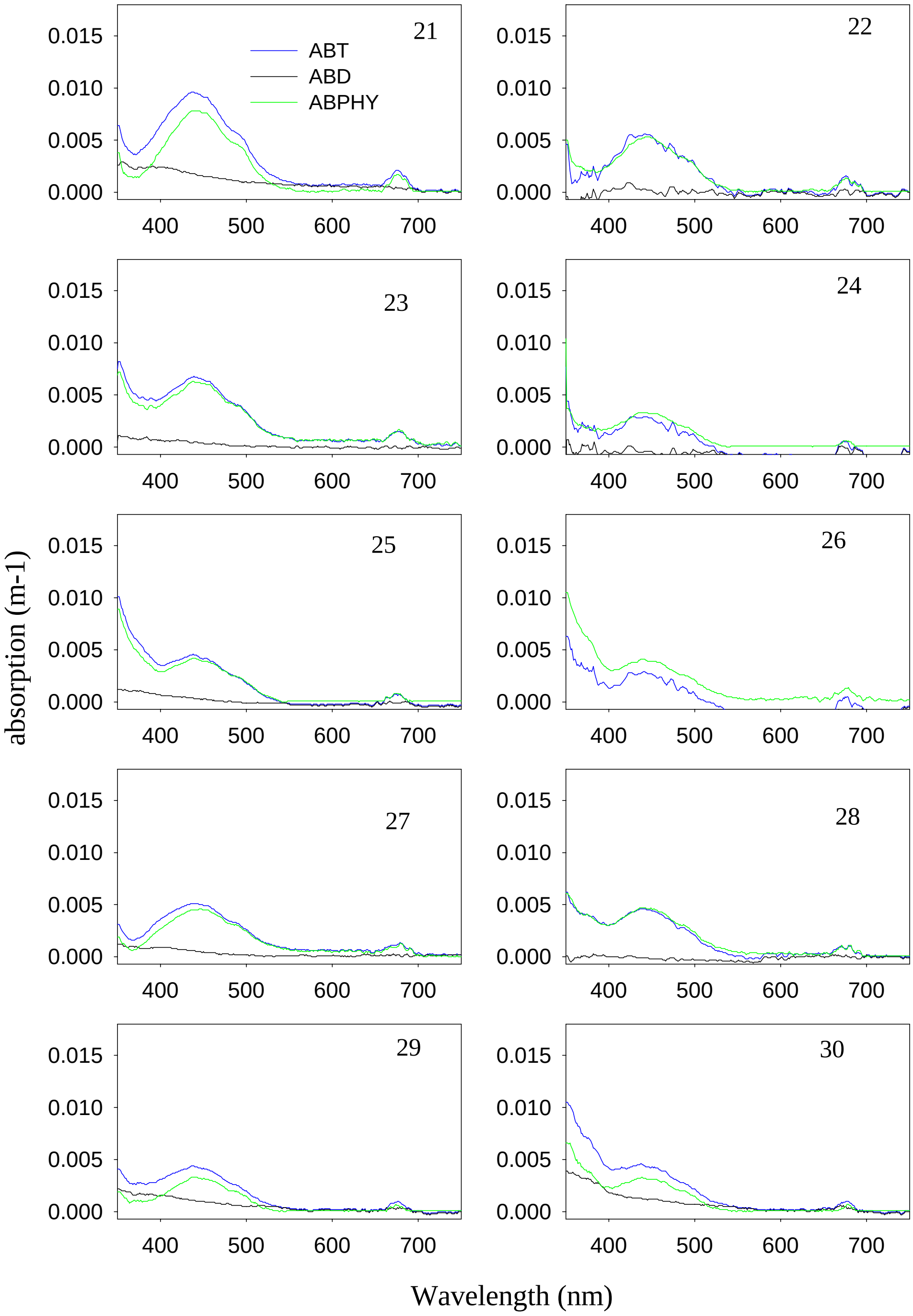


Fig.3.9.2 Continued

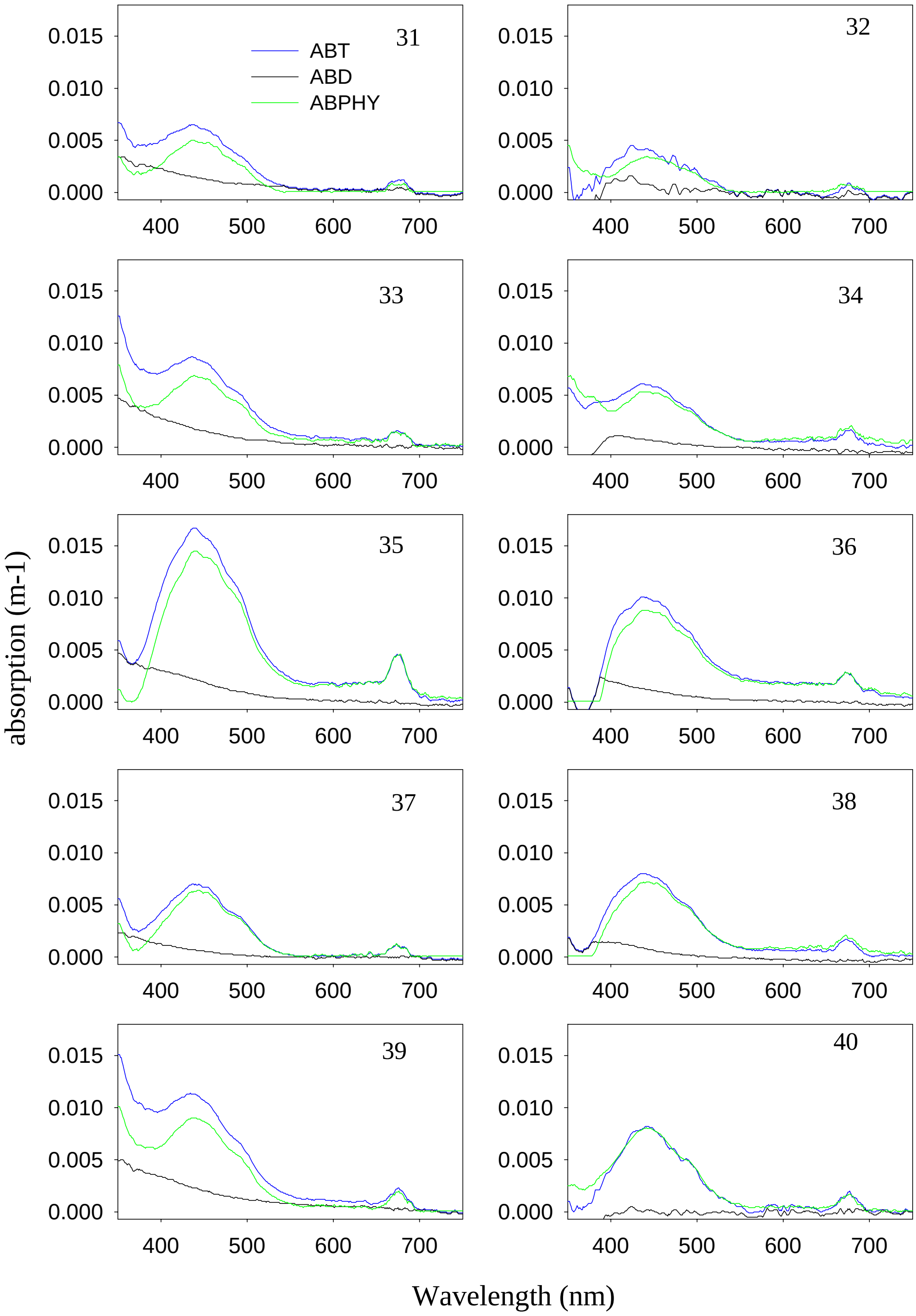


Fig.3.9.2 Continued

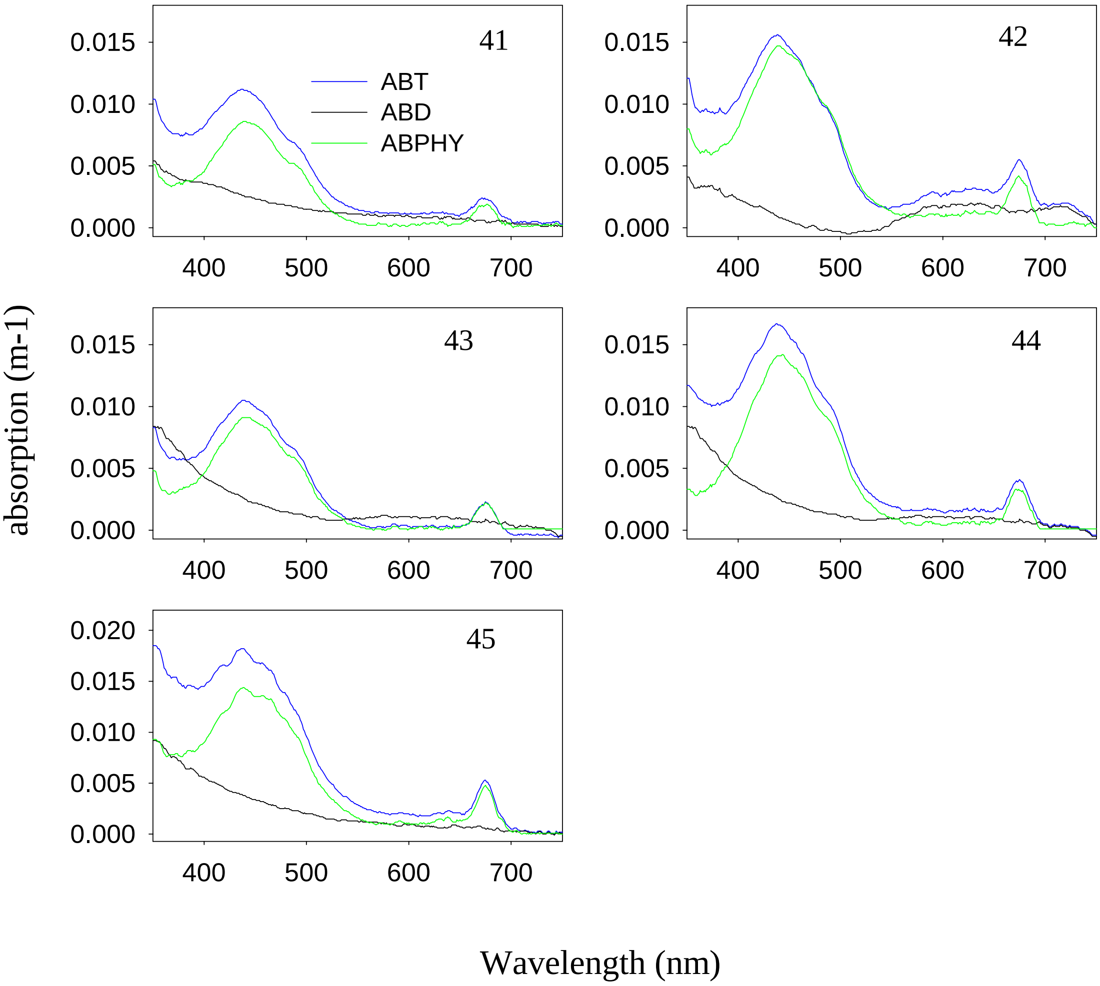


Fig.3.9.2 Continued

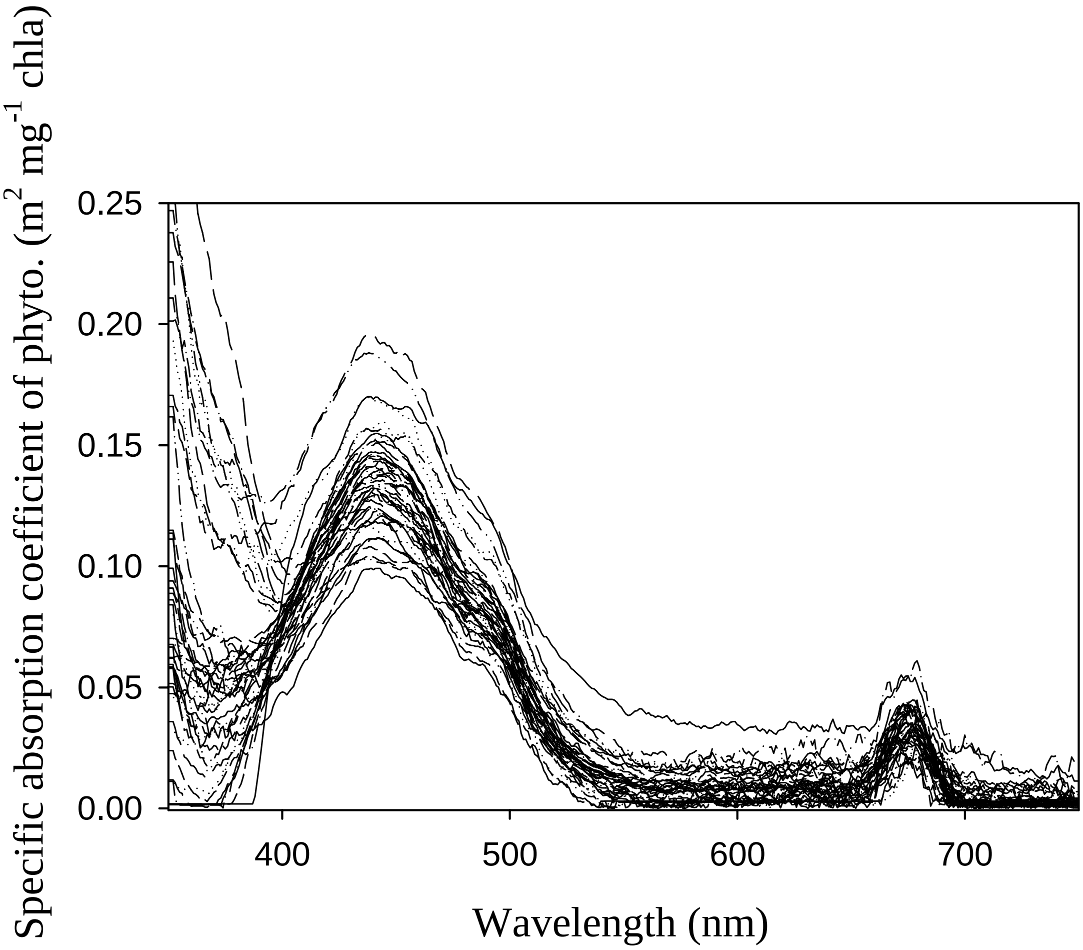


Fig.3.9.3 Specific absorption coefficient of phytoplankton, $a^*_{ph}(\lambda)$ in the samples.

4. Floats and Drifters

4.1 Argo float deployment

Nobuyuki Shikama	(FORSGC): Principal Investigator (not on board)
Eitarou Oka	(FORSGC): not on board
Miki Yoshiike	(MWJ): Technical staff
Makito Yokota	(MWJ): Technical staff

(1) Objectives

The objective of deployment is to clarify the structure and temporal/spatial variability of water masses in the subtropical South Atlantic such as the South Atlantic Subtropical Mode Water.

The profiling floats launched in this cruise obtain vertical profiles of temperature and salinity automatically every ten days. The data from the floats will enable us to understand the phenomenon mentioned above with time/spatial scales much smaller than those in the previous studies.

(2)Parameters

water temperature, salinity, and pressure

(3)Methods

Profiling float deployment

We launched 6 SOLO-type floats of the Atlantic Oceanographic and Meteorological Laboratory (AOML) of the National Oceanic and Atmospheric Administration (NOAA) in USA and 15 APEX-type floats of the Southampton Oceanography Centre (SOC) in UK. The SOLO floats equip an FSI CTD sensor manufactured by Falmouth Scientific, Inc., and the APEX flaots an SBE41 CTD sensor manufactured by Sea-Bird Electronics Inc.,.

These floats usually drift at a depth of 2000 dbar (called the parking depth), rising up to the sea surface every ten days by increasing their volume and thus changing the buoyancy. During the ascent, they measure temperature, salinity, and pressure. They stay at the sea surface for approximately nine hours, transmitting their positions and the CTD data to the land via the ARGOS system, and then return to the parking depth by decreasing volume. The status of float launches is shown in Table 4.1.1.

(4) Data archive

The real-time data are provided to meteorological organizations via Global Telecommunication System (GTS) and utilized for analysis and forecasts of sea conditions.

Table 4.1.1 Status of float launches

Launches

Owner	Type	S/N	Date and Time of Reset (UTC)	Date and Time of Launch (UTC)	Location of Launch	CTD St. No.
AOML	SOLO	262	04:47, Nov. 10	06:24, Nov. 10	29-23.73 S, 041-44.59 W	A10-006
AOML	SOLO	260	11:15, Nov. 11	12:32, Nov. 11	30-05.90 S, 039-01.21 W	A10-X17
AOML	SOLO	264	12:15, Nov. 17	13:46, Nov. 17	29-59.34 S, 025-51.76 W	A10-039
AOML	SOLO	261	08:15, Nov. 18	09:44, Nov. 18	30-00.19 S, 023-18.64 W	A10-042
AOML	SOLO	263	10:50, Nov. 19	12:03, Nov. 19	29-59.69 S, 019-53.28 W	A10-046
AOML	SOLO	265	09:55, Nov. 20	11:22, Nov. 20	29-59.02 S, 017-01.38 W	A10-050
SOC	APEX	865	06:35, Nov. 21	08:32, Nov. 21	29-59.55 S, 014-19.74 W	A10-054
SOC	APEX	1190	21:48, Nov. 21	23:10, Nov. 21	29-58.61 S, 012-18.93 W	A10-057
SOC	APEX	1191	13:26, Nov. 22	15:17, Nov. 22	29-59.65 S, 010-19.76 W	A10-060
SOC	APEX	1192	07:02, Nov. 23	08:54, Nov. 23	29-59.62 S, 008-09.22 W	A10-063
SOC	APEX	886	20:44, Nov. 23	21:52, Nov. 23	30-00.33 S, 006-28.91 W	A10-065
SOC	APEX	1193	09:07, Nov. 24	10:27, Nov. 24	29-59.70 S, 004-48.50 W	A10-067
SOC	APEX	1194	01:17, Nov. 26	02:39, Nov. 26	30-01.98 S, 002-18.17 W	A10-070
SOC	APEX	1195	14:10, Nov. 26	15:13, Nov. 26	29-58.98 S, 000-43.56 W	A10-072
SOC	APEX	1196	05:05, Nov. 27	06:51, Nov. 27	29-43.13 S, 001-08.20 E	A10-075
SOC	APEX	887	01:47, Nov. 28	02:53, Nov.28	29-27.83 S, 003-19.07 E	A10-079
SOC	APEX	1197	18:58, Nov. 28	20:17, Nov. 28	29-44.82 S, 005-07.75 E	A10-082
SOC	APEX	1198	08:07, Nov. 29	09:30, Nov. 29	29-43.79 S, 006-47.35 E	A10-084
SOC	APEX	1199	22:12, Nov. 29	23:30, Nov. 29	29-44.65 S, 008-29.14 E	A10-086
SOC	APEX	1200	10:39, Nov. 30	12:42, Nov. 30	29-43.97 S, 009-58.78 E	A10-X13
SOC	APEX	1201	06:25, Dec. 01	07:46, Nov. 01	29-44.47 S, 011-47.97 E	A10-090