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MR03-K04 Leg.5

Preliminary
Cruise Report

March, 2004

Edited by

Dr. Masao Fukasawa

Dr. Takeshi Kawano

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1. Cruise Narrative (17 Feb ’04)

1.1 Highlight

WOCE　I3/I4、R/V MIRAI Cruise MR03-K04 in the Indian Ocean

Cruise Code : MR03-K04 Leg.5

Chief Scientist : Masao Fukasawa
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 : Cape Town, Tamatave, Port Luis , Fremantle

Cruise Date : Leg5a (Cape Town - Port Louise) 2003/12/09 – 2003/12/27 (19 days)
Leg5b (Port Louise - Fremantle) 2003/12/27 – 2004/01/24 (29 days)

1.2 Cruise Summary

Cruise Track

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

Number of Stations

A total of 56 and 89 stations were occupied during Leg.5a and Leg.5b, respectively, using a Sea Bird Electronics 36 bottle carousel equipped with 36 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, ^{3}He/^{4}He, ^{137}Cs, Plutonium and ^{3}H

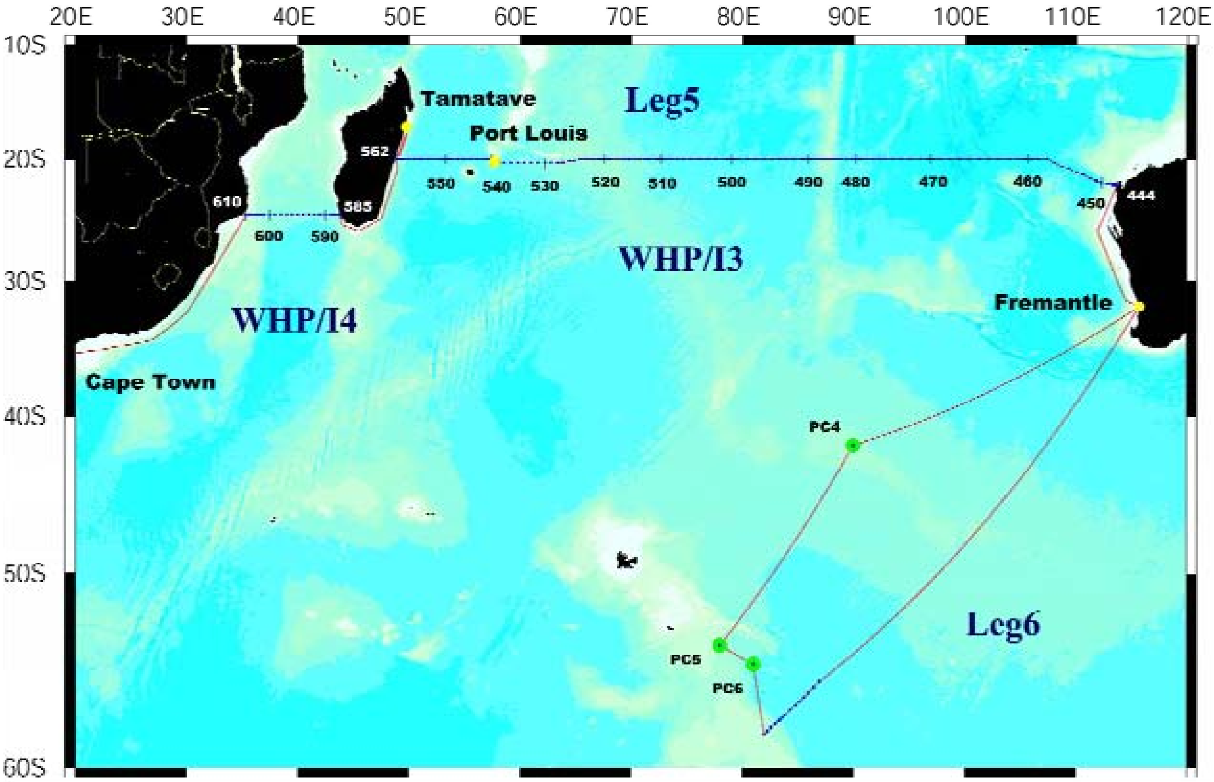
4) Measurements of autotropic biomass (epifluorescence and chlorophyll a) by surface LV

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

13 ARGO floats (APEX) were launched



1.3 Responsibility

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

Table.1.1 The principal investigators responsible for major parameters

Item	Principal Scientists	Person in Charge on the Ship
Hydrography		
CTDO	Hiroshi Uchida Wolfgang Schneider Masao Fukasawa	Satoshi Ozawa Hiroshi Matsunaga
LADCP	Yasushi Yoshikawa Andrew Forbes	Masao Fukasawa
XCTD	Tamaryn Morris Masao Fukasawa	Yasutaka Imai
BTL Salinity	Takeshi Kawano	Ken-Ichi Katayama
BTL Oxygen	Ayako Nishina	Takayoshi Seike Tomoko Miyashita
Nutrients	Michio Aoyama	Ken-Ichiro Satoh
DIC	Akihiko Murata	Mikio Kitada
Alkalinity	Akihiko Murata	Taeko Ohama
pH	Akihiko Murata	Taeko Ohama
CFC’s	Yutaka Watanabe	Yuichi Sonoyama Kenichi Sasaki
$\Delta^{14}C$	Yuichiro Kumamoto	Akihiko Murata (collection only)
TOC	Akihiko Murata	Mikio Kitada (collection only)
$^{3}He/^{4}He$	Shuichi Watanabe	Masahide Wakita (collection only)
Cs,Pu,^{3}H,Sr	Michio Aoyama	Oregioni Beniamino (collection only)
Ar/N_2	Yutaka Watanabe	Shinichi Tanaka (collection only)
Primary Productivity	Prudence Bonham	Prudence Bonham
Chlorophyll-a	Prudence Bonham	Prudence Bonham
Underway		
ADCP	Yasushi Yoshikawa	Yasutaka Imai
Bathymetry	Souichiro Sueyoshi	Yasutaka Imai
Meteorology	Kunio Yoneyama	Yasutaka Imai
Thermo-Salino.	Masao Fukasawa	Tomoko Miyashita
PCO_2	Akihiko Murata	Mikio Kitada
Floats and Drifters		
Argo float	Kensuke Takeuchi Dean Roemmich	Tomoyuki Takamori Masao Fukasawa

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 censor calibration and its deployment in the Western South Pacific and the Indian Ocean

Data Policy

All data obtained during Leg1, Leg2, Leg4 and Leg5 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

Participants of MR03-K04 Leg.5a and Leg.5b are listed in Table 1.2 (a) and (b)

Table1.2(a) Participants List of Leg.5a

Chief Scientist : Masao Fukasawa

Chief Technologist : Ken-Ichiro Sato

J. Bemiasa	Water Sampling	IHSM
P. Bonham	Bio-Optics	CSIRO
L. Bravo	Water Sampling	Univ. Conception
A. Forbes	LADCP	CSIRO
T. Fujiki	TCO_2	MWJ
M. Fukasawa	LADCP, ARGO, Thermo-salinograph	JAMSTEC
J. Githaiga-Mwicigi	Water Sampling	MCM
A. Hoguane	Water Sampling	Univ. Eduardo Mondlane
Y. Imai	ADCP, Bathymetry, Meteorology, XCTD	GODI
K. Katayama	Salinity	MWJ
T. Kawano	Salinity	JAMSTEC
M. Kawazoe	Water Sampling	MWJ
M. Kitada	TCO_2, TOC	MWJ
T. Kurokawa	Water Sampling	MWJ
M. Kyewalyanga	Water Sampling, Bio-Optics	Univ. Dar es Salaam
K. Matsumoto	Water Sampling	MWJ
H. Matsunaga	CTD	MWJ
T. Miyashita	Oxygen, Thermo-salinograph	MWJ
T. Morris	Water Sampling	MCM
A. Murata	pH, TA, pCO_2, TOC, ^{14}C	JAMSTEC
Y. Naito	Water Sampling	MWJ
A. Nisina	CTD, Oxygen	Kagoshima Univ.
T. Ohama	pH, TA	MWJ
S. Okumura	ADCP, Bathymetry, Meteorology, XCTD	GODI
B. Oregioni	Cs, Pu, ^3H, Sr	IAEA
S. Ozawa	CTD	MWJ
S. Persand	Water Sampling	MOI
T. Sagara	Water Sampling	MWJ
K. Sasaki	CFC	JAMSTEC
K. Sato	Nutrients	MWJ
W. Schneider	CTD	Univ. Conception
T. Seike	Oxygen, Thermo-salinograph	MWJ
Y. Sonoyama	CFC	MWJ
T. Takamori	CTD operation, ARGO	MWJ
S. Tanaka	CFC, Ar	Hokkaido Univ.
W. Tokunaga	ADCP, Bathymetry, Meteorology, XCTD	GODI
M. Wakita	CFC, $^3He/^4He$	JAMSTEC
T. Watanabe	Salinity	MWJ
B. Wigly	Water Sampling, Bio-Optics	Univ. Cape Town
Hirofumi Yamamoto	Water Sampling	JAMSTEC
Hideki Yamamoto	LADCP	MWJ
A. Yasuda	Nutrients	MWJ
S. Yokogawa	Nutrients	MWJ

CSIRO :	Commonwealth Scientific and Industrial Research Organization
GODI :	Global Ocean Development Inc.,
IAEA :	International Atomic Energy Agency
IHSM :	Institut Halieutique et des Sciences Marines
JAMSTEC :	Japan Marine Science and Technology Center
MCM :	Marine and Coastal Management
MOI :	Moritus Oceanography Institute
MWJ :	Marine Works Japan, Ltd.

Table1.2(b) Participants List of Leg.5b

Chief Scientist : Masao Fukasawa

Chief Technologist: Ken-Ichiro Sato

P. Bonham	Bio-Optics	CSIRO
L. Bravo	Water Sampling	Univ. Conception
A. Forbes	Bio-Optics	CSIRO
M. Fukasawa	LADCP, ARGO, Thermo-salinograph	JAMSTEC
J. Gasutaud	Cs, Pu, 3H, Sr	IAEA
Y. Imai	ADCP, Bathymetry, Meteorology, XCTD	GODI
K. Katayama	Salinity	MWJ
T. Kawano	Salinity	JAMSTEC
M. Kawazoe	Water Sampling	MWJ
R. Kimura	ADCP, Bathymetry, Meteorology, XCTD	GODI
M. Kitada	TCO2, TOC	MWJ
N. Komai	Oxygen, Thermo-salinograph	MWJ
A. Kubo	Nutrients	MWJ
T. Kurokawa	Water Sampling	MWJ
M. Kyewalyanga	Water Sampling, Bio-Optics	Univ. Dar es Salaam
K. Matsumoto	Water Sampling	MWJ
H. Matsunaga	CTD	MWJ
T. Miyashita	Oxygen, Thermo-salinograph	MWJ
M. Moro	TCO2, TOC	MWJ
A. Murata	pH, TA, pCO2, TOC, 14C	JAMSTEC
Y. Naito	Water Sampling	MWJ
A. Nisina	CTD, Oxygen	Kagoshima Univ.
T. Ohama	pH, TA	MWJ
Y. Okamoto	Water Sampling	MWJ
T. Sagara	Water Sampling	MWJ
K. Sasaki	CFC	JAMSTEC
K. Sato	Nutrients	MWJ
W. Schneider	CTD	Univ. Conception
A. Shioya	Water Sampling	MWJ
Y. Sonoyama	CFC	MWJ
T. Takamori	CTD operation, ARGO	MWJ
S. Tanaka	CFC, Ar	Hokkaido Univ.
W. Tokunaga	ADCP, Bathymetry, Meteorology, XCTD	GODI
H. Uno	CTD	MWJ
A. Wada	Water Sampling	MWJ
M. Wakita	CFC, 3He/4He	JAMSTEC
T. Watanabe	Salinity	MWJ
Hirofumi Yamamoto	Water Sampling	JAMSTEC
Hideki Yamamoto	LADCP	MWJ
A. Yasuda	Nutrients	MWJ
A. Yenluk	Water Sampling	MOI

CSIRO :	Commonwealth Scientific and Industrial Research Organization
GODI :	Global Ocean Development Inc.,
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JAMSTEC :	Japan Marine Science and Technology Center
MOI :	Moritus Oceanography Institute
MWJ :	Marine Works Japan, Ltd.

2. Underway Measurement

2.1 Meteorological observation

2.1.1 Surface Meteorological Observation

Kunio Yoneyama : JAMSTEC, Principal Investigator / Not on-board:
Yasutaka Imai : Global Ocean Development Inc.
Wataru Tokunaga : GODI
Shinya Okumura : GODI
Ryo Kimura : GODI

(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.

(2) Methods

The surface meteorological parameters were observed throughout the MR03-K04 Leg5 cruise from the departure of Cape Town on 9 December 2003 to arrival of Fremantle on 24 January 2004. At this cruise, we used two systems for the surface meteorological observation.

1) MIRAI Surface Meteorological observation (SMet) system
2) Shipboard Oceanographic and Atmospheric Radiation (SOAR) System

1) MIRAI Surface Meteorological observation (SMet) system
Instruments of SMet system 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) Shipboard Oceanographic and Atmospheric Radiation (SOAR) system
SOAR system designed by BNL (Brookhaven National Laboratory, USA) consists of major three parts.
i) Portable Radiation Package (PRP) designed by BNL – short and long wave downward radiation.
ii) Zeno Meteorological (Zeno/Met) system designed by BNL – wind, air temperature, relative humidity, pressure, and rainfall measurement.
iii) 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.
a) 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.

b) Barometer (SMet and SOAR)
Comparing with the portable barometer value, PTB220CASE, VAISALA.
c) Thermometer (air temperature and relative humidity) (SMet and SOAR)
Comparing with the portable thermometer value, HMP41/45, VAISALA.

(3) Preliminary results

Figures 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), sea surface temperature (SMet) 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.

Remarks

We did not measure sea surface temperature after 06:00UTC 21 January 2004, because we stopped pumping up surface water

Table 2.1-1 Instruments and installations of MIRAI Surface Meteorological system

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

Table 2.1-2 Parameters of MIRAI Surface Meteorological observation system

	Parmeter	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 (bow)	m	hourly
22	Significant wave height (aft)	m	hourly
23	Significant wave period (bow)	second	hourly
24	Significant wave period (aft)	second	hourly

Table 2.1-3 Instrument and installation locations of SOAR system

Sensors (*Zeno/Met*)	Type	Manufacturer	Location (altitude from surface)
Anemometer	05106	R.M. Young, USA	foremast (25 m)
Tair/RH	HMP45A	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	foremast (24 m)
Barometer	61201	R.M. Young, USA	
with 61002 Gill pressure port		R.M. Young, USA	foremast (24 m)
Rain gauge	50202	R. M. Young, USA	foremast (24 m)
Optical rain gauge	ORG-815DA	ScTi, USA	foremast (24 m)

Sensors (*PRP*)	Type	Manufacturer	Location (altitude from surface)
Radiometer (short wave)	PSP	Epply Labs, USA	foremast (25 m)
Radiometer (long wave)	PIR	Epply Labs, USA	foremast (25 m)
Fast rotating shadowband radiometer		Yankee, USA	foremast (25 m)

Table 2.1-4 Parameters of SOAR system

	Parmeter	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	
11	Precipitation (capacitive rain gauge)	mm	reset at 50 mm
12	Down welling shortwave radiation	W/m^2	
13	Down welling infra-red radiation	W/m^2	
14	Defuse irradiance	W/m^2	

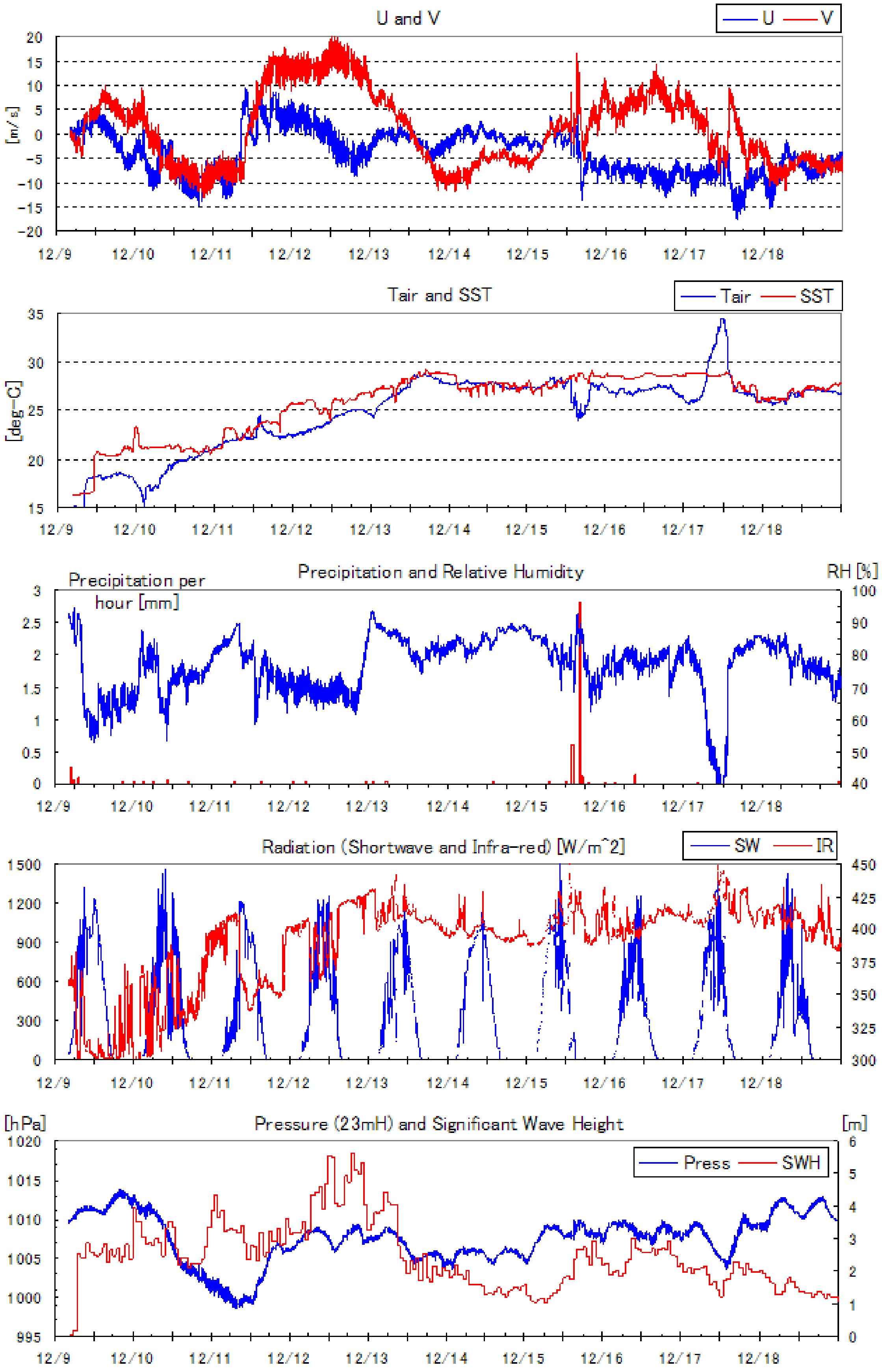

Fig. 2.1-1 Time series of surface meteorological parameters during the cruise.

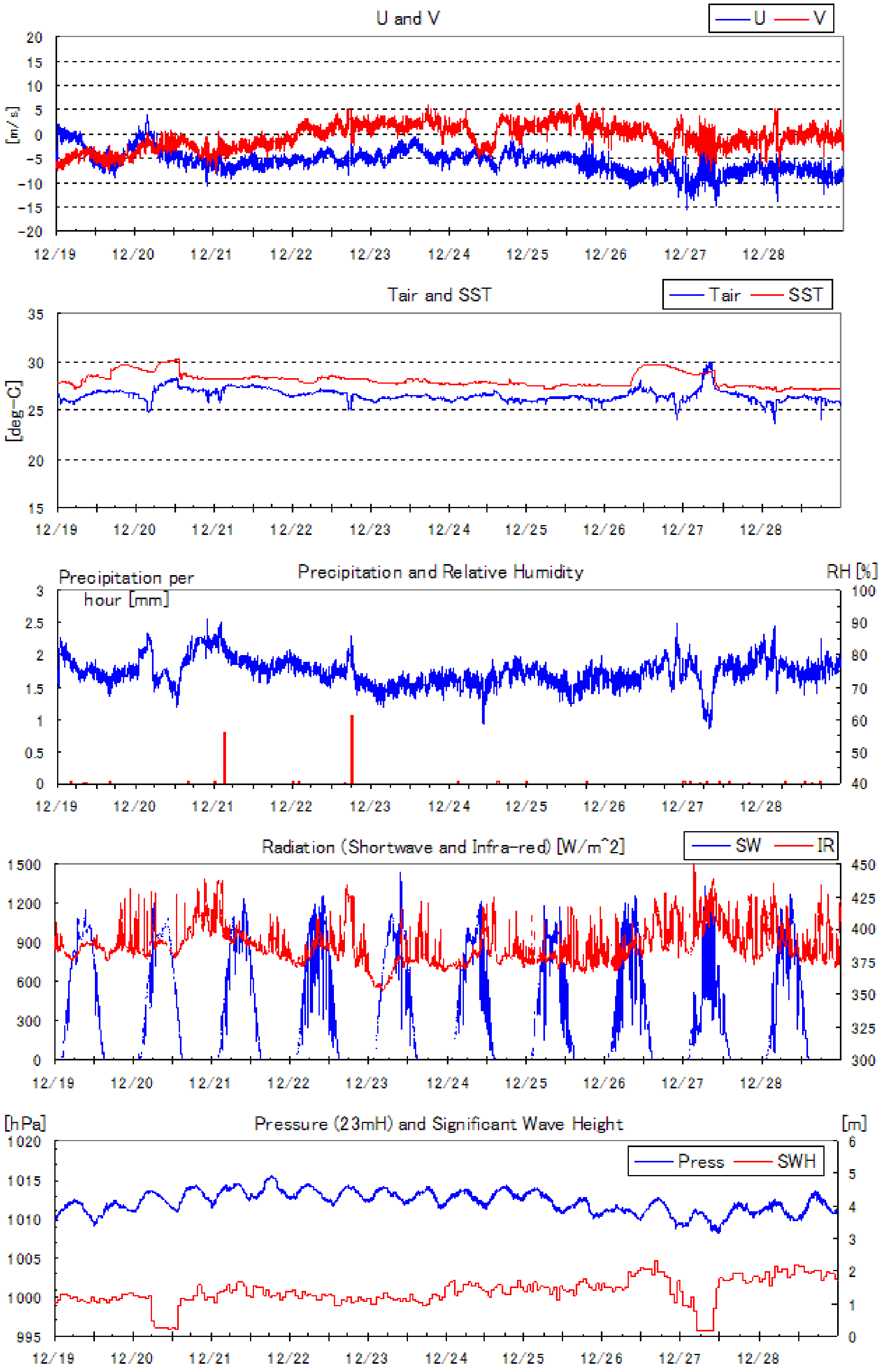

Fig. 2.1-1 Continued

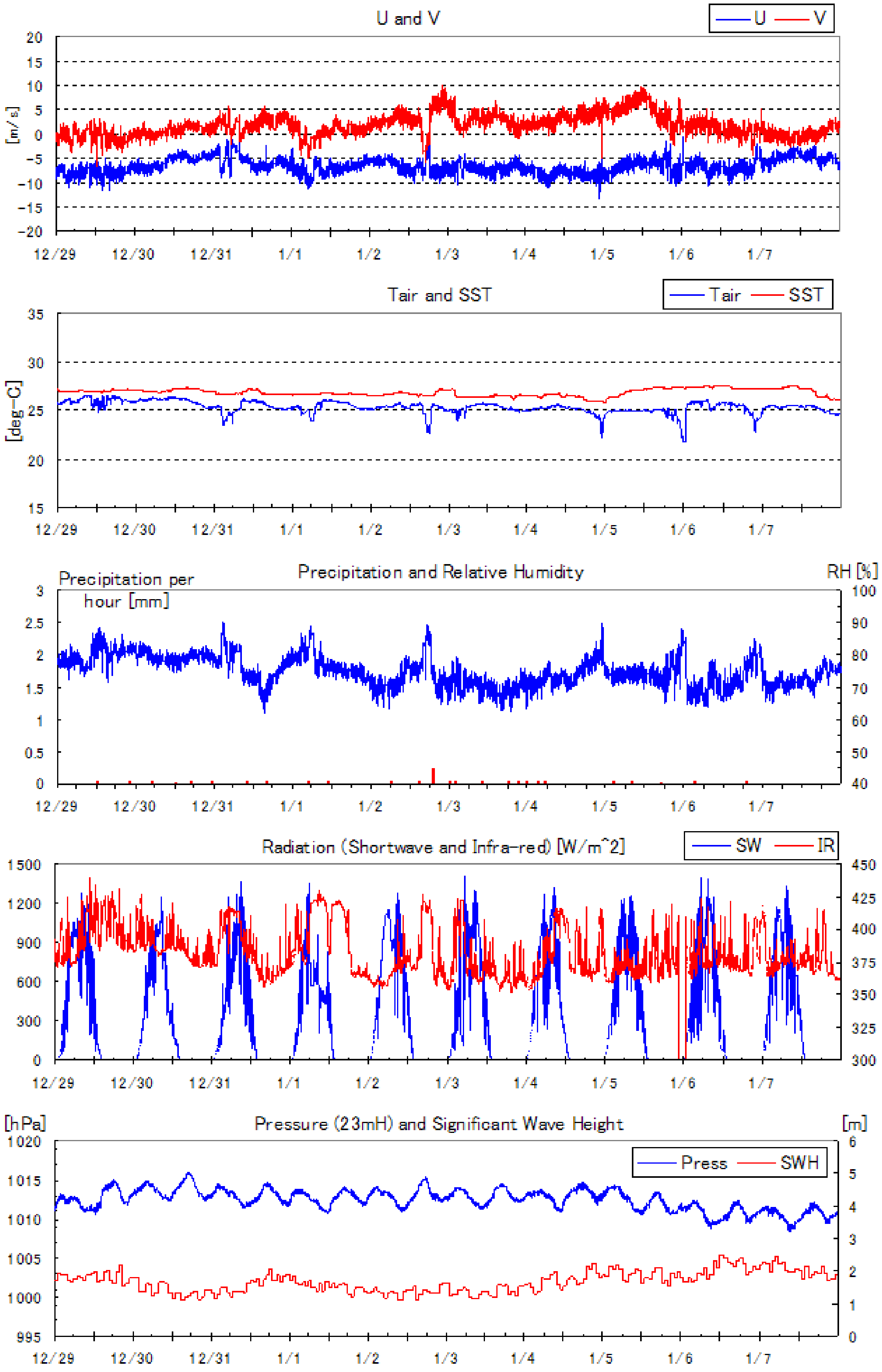

Fig. 2.1-1 Continued

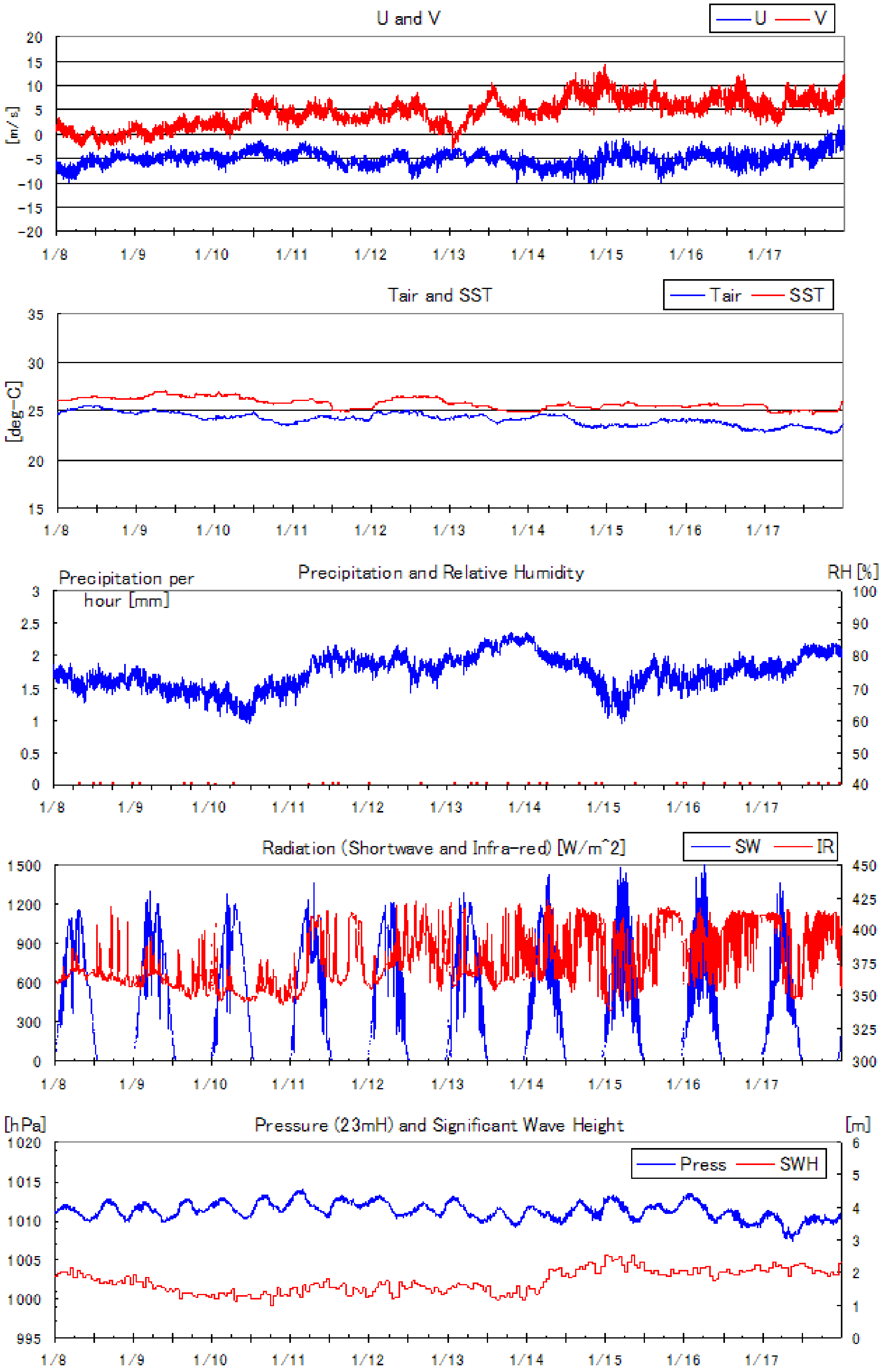

Fig. 2.1-1　Continued

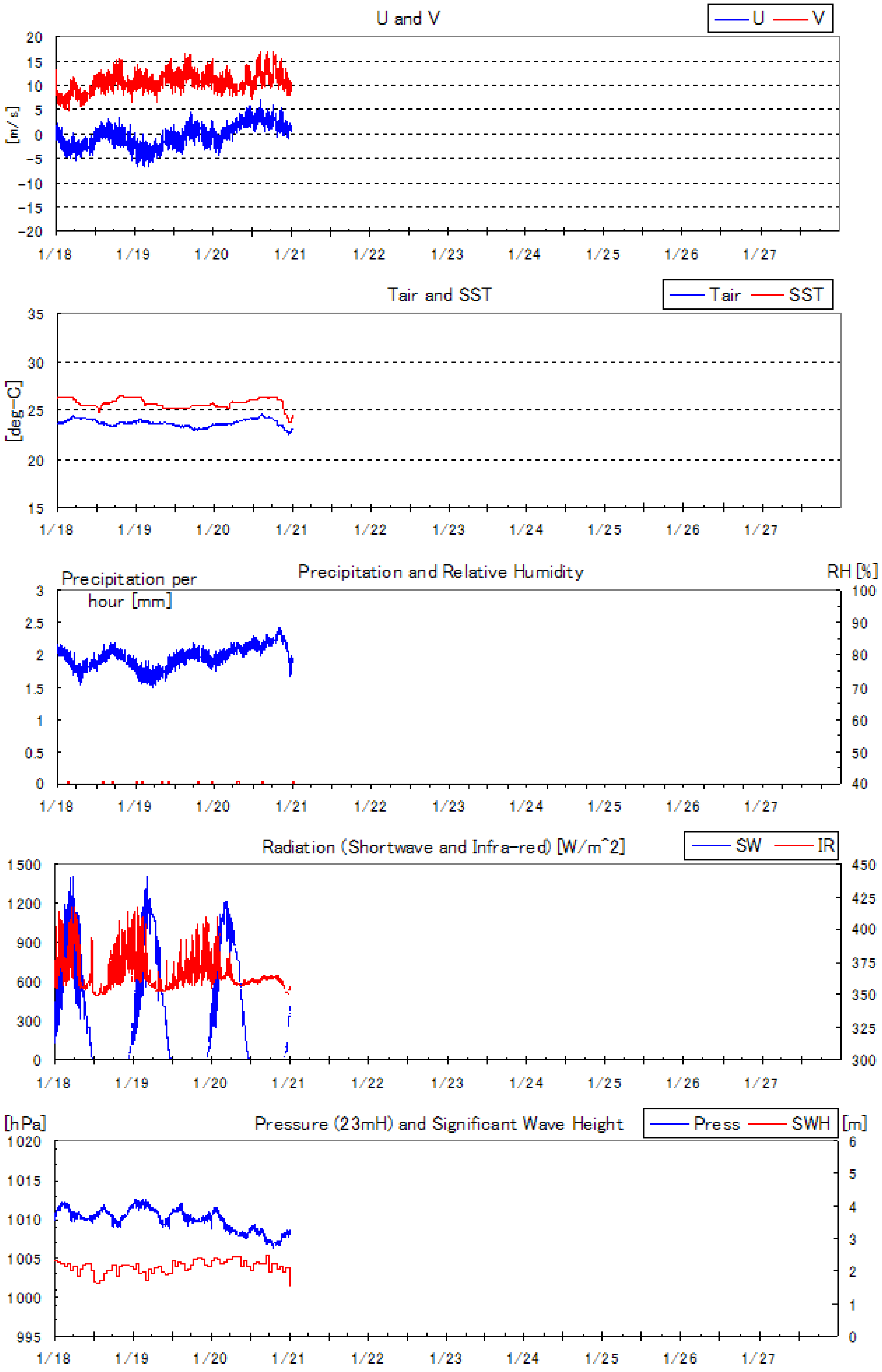

Fig. 2.1-1 Continued

2.1.2 Ceilometer Observation

Kunio Yoneyama : JAMSTEC, Principal Investigator / Not on-board
Yasutaka Imai : Global Ocean Development Inc.
Shinya Okumura : GODI
Wataru Tokunaga : GODI
Ryo Kimura : GODI

(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 Leg5 cruise from the departure of Cape town on 9 December 2004 to arrival of Fremantle on 24 January 2004.

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

The figure shows the time series of the first and second lowest cloud base height.

Remarks

1. Data record was stopped from 07:21 to 13:38, 20 Dec. 2003 because of loginng PC trouble.

2. Data record was stopped from 06:57 to 07:42 8 January 2004 because of ALARM (Receiver Failure) messages appeared. And ARLARM messages were appeared in following data terms.

YYYY/DD/MM	Time	ALARM Type
2003/12/17	09:22 to 10:24	Receiver Failure
2003/12/19	08:59 to 09:56	Receiver Failure
2004/01/08	06:18 to 06:57	Receiver Failure
2004/01/16	06:56 to 06:30	Receiver Failure
2004/01/18	05:00 to 06:02	Receiver Failure
2004/01/19	04:46 to 05:48	Receiver Failure
2004/01/20	04:32 to 05:34	Receiver Failure

3. Following records are missing.

YYYY/DD/MM	HH:MM
2003/12/21	17:03

(5) Data archives

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

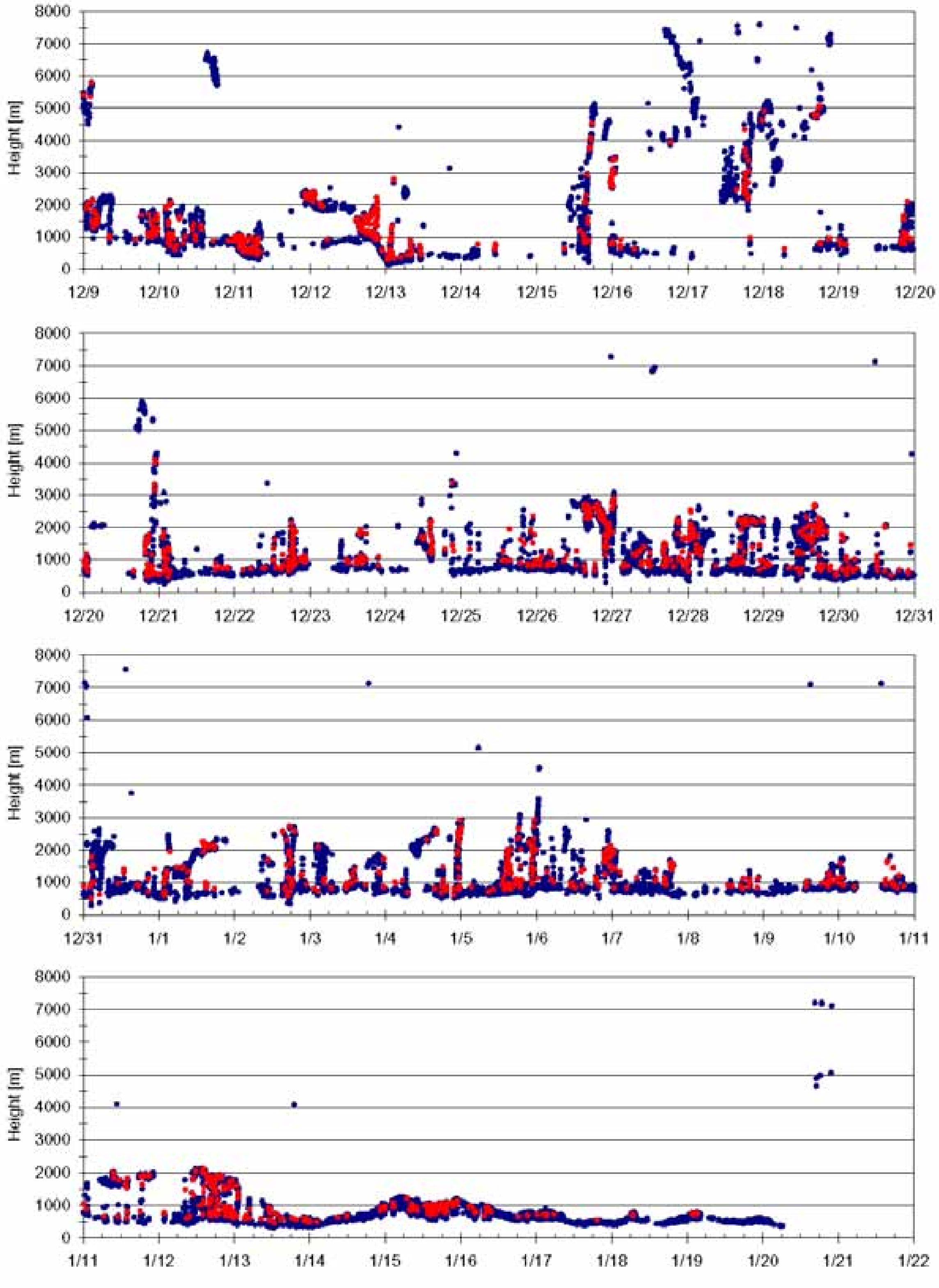
8000
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Fig.2.1.2

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.

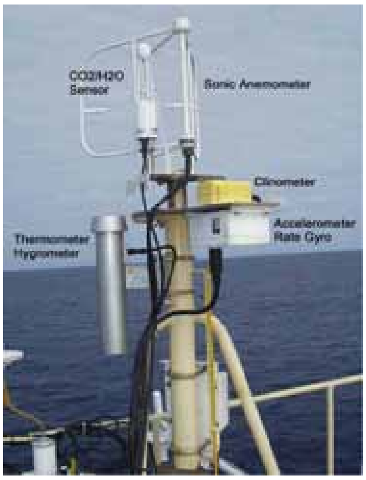

Fig.2.1.3 Turbulent flux measurement system on the top deck of the foremast.

2.2 Navigation and Bathymetry

Yasutaka Imai : Global Ocean Development Inc.
Shinya Okumura : GODI
Wataru Tokunaga : GODI
Ryo Kimura : GODI

Navigation: Ship's position was measured by 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 Leg5 cruise from CTD station I04-610 on 13 December 2003 to CTD station I03-444 on 20 January 2004. 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 the nearest 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)

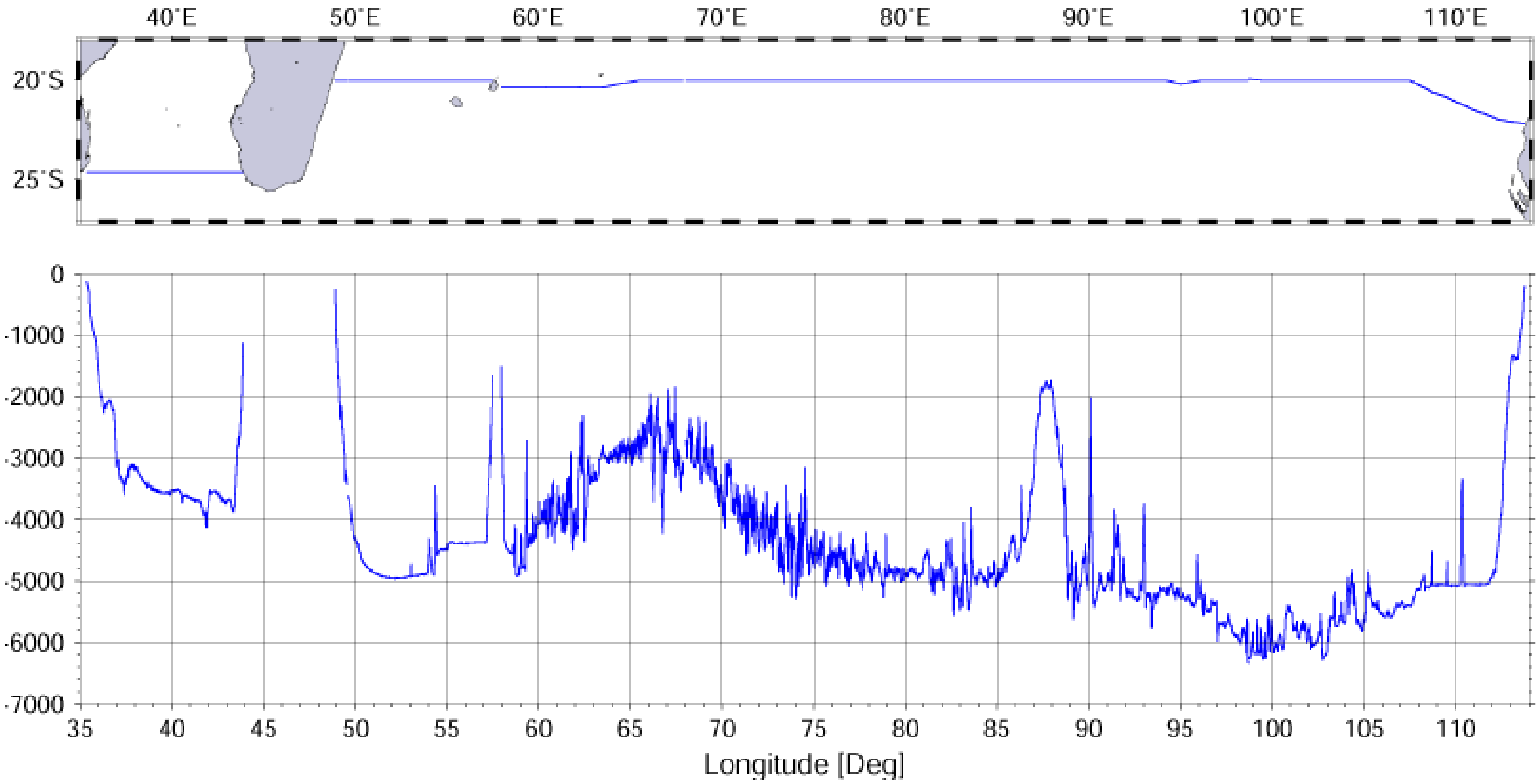

Fig.2.2.1 Bathymetry

2.3 Acoustic Doppler Current Profiler

Yasushi Yoshikawa : JAMSTEC, Principal investigator / Not onboard
Yasutaka Imai : Global Ocean Development Inc.
Wataru Tokunaga : GODI
Shinya Okumura : GODI
Ryo Kimura : GODI

Continuous upper ocean current measurement along ship’s track were made using hull-mounted Acoustic Doppler Current profiler, RD Instruments VM-75 system installed on the centerline and approximately 28m aft from the bow. The firmware version was 5.59 and the data acquisition software was VmDas Ver1.3. For most of its operation, the instrument was configured for water-tracking mode recording each ping as the raw data in 8m times 100 bins from 16.4 m to 816.4m (from transducer located 6.5 m beneath the calm water line). Bottom tracking mode, interleaved bottom-ping with water-ping, was made in shallower water region to get the calibration data for evaluating transducer misalignment angle. Raw data was recorded in beam coordinate, and then converted to the earth-coordinate.

Each coordinate using ship’s heading data from ship’s main gyrocompass (Tokimec TG-6000). The position fix data from ship’s navigation system was also recorded in NMEA0183 format and merged with ensemble data in VmDas. Additional heading data, measured by Inertial Navigation Unit, was also recorded for post-processing. Its accuracy is within 1.0mil, about 0.056 degree and had already set on zero bias.

The system performed well through the cruise. The profile range while steaming exceeded 500m, sometimes reached 600m under calm weather. But the rough sea condition made this range shorter, less than 300m. Bubbles from bow-thruster obstructed the beam and also made this range shorter on CTD stations.

ADCP data will process following steps,

1 Estimating transducer misalignment and current magnitude scale factor from bottom tracking data and apply them to all data. Heading data from INU and ship’s roll/pitch data will be used in the estimation.

2. Screening and editing bad profile.

Roughly estimated on board, misalignment error and a scale factor value were as follows;
Transducer misalignment error vs. ship’s main gyro = 1.06 deg
Scale facto: Bottom tracking magnitude/ Delta nav position = 1.03
This means that current speed should reduce about 3% from detected by ADCP during this cruise. This estimation was made using bottom track data obtained in leg2.

Preliminary Results

Processed magnitude and direction of current (5minute ensemble) is presented in Fig.1.

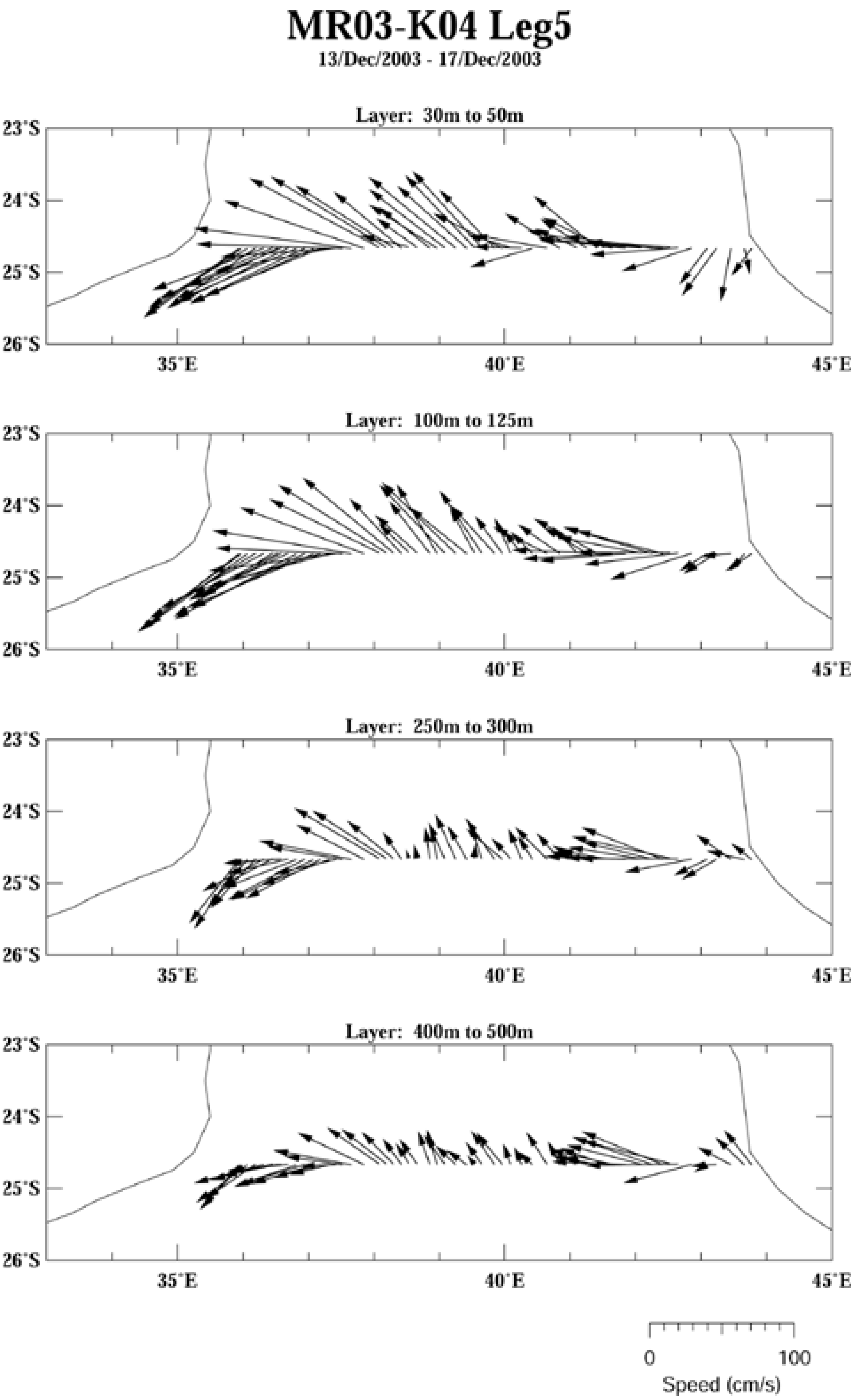

Fig.2.3.1 Magnitude and direction of current along WOCE I04 line.

2.4 Thermo-Salinograph (Jan.22,2004)

Tomoko MIYASHITA : Marine Works Japan Co. Ltd.
Nobuharu KOMAI : MWJ
Takayoshi SEIKE : MWJ
Masao FUKASAWA : Ocean Observation and Research Department, JAMSTEC

(1) Objective

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

(2) Methods

Surface sea water monitoring system (Nippon Kaiyo co.,Ltd.) has five kind of sensors and fluorescence photometer. Salinity, temperature, dissolved oxygen, fluorescence and particle size of plankton near surface sea water are continuously measured every 1-minute. This system is set up in the "*sea surface monitoring laboratory*" on R/V Mirai. This system is connected to shipboard LAN-system. Measured data are stored in a hard disk of PC machine every 1-minute together with time and position of ship, and displayed in the data management PC machine.

Surface sea water is continuously pumped up to the laboratory and flowed into the system. The flow rate is controlled 12L/min except with fluorometer (about 0.3L/min). The flow rate is measured with two flow meters and each values were checked everyday.

Specification of the each sensor in this system is 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 +35℃, Conductivity 0 to 6.5 S m^{-1}
Accuracy: Temperature 0.01 ℃ 6month^{-1}, Conductivity 0.001 S m^{-1} month^{-1}
Resolution: Temperatures 0.001℃, 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 +35℃
Resolution: ±0.001℃
Stability: 0.002 ℃ year^{-1}

c) Dissolved oxygen sensor

Model: 2127A, Hach Ultra Analytics Japan INC.
Serial number: 44733
Measurement range: 0 to 14 ppm
Accuracy: ±1% at 5 ℃ of correction range
Stability: 1% month^{-1}

d) Fluorometer

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

e) Particle Size sensor

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

f) Flow meter

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

The monitoring Periods (UTC) during this cruise are listed below.

09-Dec.-‘03 14:02 to 21-Jan.-’04 01:16

(3) Preliminary Result

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.

Table.2.4.1 Comparison between salinity data from *Continuous Sea Surface Water Monitoring* and bottle salinity.

Date[UTC]	Time[UTC]	Salinity data	Bottle Salinity[PSS-78]
2003/12/9	14:31	35.5513	35.5438
2003/12/10	7:03	35.6051	35.5966
2003/12/10	15:21	35.6132	35.6084
2003/12/10	23:10	35.6429	35.6401
2003/12/11	7:06	35.5615	35.5515
2003/12/11	16:43	35.4587	35.4493

2003/12/11	22:11	35.3541	35.3453
2003/12/12	5:49	35.3233	35.3163
2003/12/12	14:09	35.3667	35.3576
2003/12/13	6:05	35.1934	35.1889
2003/12/13	17:25	35.2872	35.2744
2003/12/13	21:55	35.3049	35.2942
2003/12/14	6:05	35.3170	35.3018
2003/12/14	14:29	35.3484	35.3395
2003/12/14	22:17	35.2367	35.2346
2003/12/15	6:10	35.3267	35.3150
2003/12/15	22:02	35.1947	35.1857
2003/12/16	6:03	35.2692	35.2608
2003/12/16	22:14	35.2649	35.2563
2003/12/17	6:10	35.1445	35.1364
2003/12/17	14:02	35.1797	35.1685
2003/12/17	22:09	35.2711	35.2556
2003/12/18	6:05	35.1811	35.1779
2003/12/18	14:04	34.5516	34.5406
2003/12/18	22:00	34.7189	34.7142
2003/12/19	5:42	33.9081	33.9088
2003/12/19	14:33	34.8810	34.8727
2003/12/21	5:36	35.0581	35.0529
2003/12/21	21:15	35.0091	35.0119
2003/12/22	5:24	35.0580	35.0516
2003/12/22	13:01	34.9832	34.9781
2003/12/22	21:07	35.0369	35.0310
2003/12/23	4:52	34.9513	34.9449
2003/12/23	12:59	34.9354	34.9188
2003/12/23	21:23	34.9353	34.9256
2003/12/24	5:18	34.9253	34.9196
2003/12/24	12:53	34.9528	34.9435
2003/12/24	21:06	35.0308	35.0188
2003/12/25	5:44	35.0635	35.0560
2003/12/25	13:11	35.1809	35.1728
2003/12/25	21:28	34.9931	34.9905
2003/12/26	5:00	35.0093	35.0030
2003/12/28	2:55	35.0815	35.0731
2003/12/28	11:16	34.9481	34.9407
2003/12/29	3:13	35.0996	35.0946
2003/12/29	11:13	35.1619	35.1544

2003/12/29	17:58	35.0522	35.0443
2003/12/30	3:13	35.0370	35.0297
2003/12/30	10:51	34.9865	34.9810
2003/12/30	18:54	34.8960	34.8873
2003/12/31	3:05	35.0512	35.0462
2003/12/31	10:51	34.9369	34.9289
2004/1/1	2:19	35.0381	35.0326
2004/1/1	10:01	35.0385	35.0325
2004/1/1	17:45	35.0455	35.0376
2004/1/2	2:04	35.0559	35.0509
2004/1/2	9:52	35.0417	35.0360
2004/1/2	17:53	35.1282	35.1227
2004/1/3	1:59	35.0194	35.0694
2004/1/3	9:49	35.1302	35.1237
2004/1/3	17:54	35.0556	35.0494
2004/1/4	3:54	35.2286	35.2220
2004/1/4	9:50	35.0483	35.0443
2004/1/4	17:22	35.2565	35.2510
2004/1/5	2:08	35.1113	35.1068
2004/1/5	9:49	34.8085	34.8027
2004/1/5	17:32	34.5824	34.5768
2004/1/6	2:06	34.5421	34.5342
2004/1/6	9:48	34.5069	34.5013
2004/1/6	17:08	34.5338	34.5289
2004/1/7	1:56	34.6087	34.6038
2004/1/7	9:53	34.5409	34.5364
2004/1/7	17:41	34.9639	34.9567
2004/1/8	2:08	34.9691	34.9635
2004/1/8	8:52	34.9903	34.9846
2004/1/8	16:41	34.9707	34.9652
2004/1/9	0:53	34.9801	34.9741
2004/1/9	13:03	35.0055	35.0031
2004/1/9	16:37	34.9339	34.9278
2004/1/10	0:58	34.7494	34.7441
2004/1/10	8:56	35.1022	35.0979
2004/1/10	16:46	35.0116	35.0046
2004/1/11	0:57	34.9449	34.9392
2004/1/11	8:56	35.0376	35.0314
2004/1/11	16:04	35.2834	35.2772
2004/1/12	0:59	35.1986	35.1942

2004/1/12	9:00	34.9156	34.9097
2004/1/12	16:27	34.6938	34.6848
2004/1/13	1:07	34.8813	34.8761
2004/1/13	8:50	35.0236	35.0229
2004/1/13	16:57	35.1179	35.1127
2004/1/14	0:59	35.1151	35.1101
2004/1/14	8:48	35.0928	35.0882
2004/1/14	16:36	35.0652	35.0609
2004/1/15	0:59	34.9545	34.9496
2004/1/15	8:44	34.9191	34.9075
2004/1/15	15:55	35.0167	35.0112
2004/1/16	0:10	34.9761	34.9714
2004/1/16	8:15	34.9115	34.9055
2004/1/16	16:05	34.9545	34.9495
2004/1/16	23:55	34.8065	34.7996
2004/1/17	7:42	35.0691	35.0653
2004/1/17	15:50	35.2378	35.2319
2004/1/18	0:03	34.9854	34.9813
2004/1/18	7:53	35.1433	35.1390
2004/1/18	16:05	35.2309	35.2260
2004/1/19	0:01	35.032	35.0272
2004/1/19	7:49	35.126	35.1202
2004/1/19	15:46	35.338	35.3321
2004/1/19	23:58	35.3243	35.3150
2004/1/20	7:55	35.2197	35.2148
2004/1/20	15:24	35.186	35.1802
2004/1/21	0:04	35.0948	35.0942

(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
Mikio Kitada : Marine Woks Japan Co. Ltd.
Masaki Moro : 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 ocean acted as a source for atmospheric CO_2 during the former half period of the cruise. However, it acted as a sink for or almost equilibrated with atmospheric CO_2 during the latter half period.

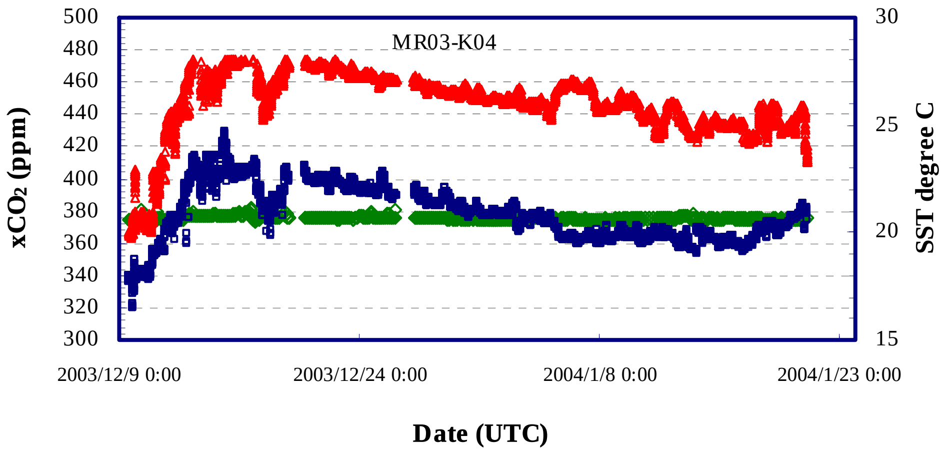

Fig.2.5.1 Concentrations of CO_2 (xCO_2) in atmosphere (green) and surface seawater (blue), and SST (red).

3. Hydrography

3.1 CTDO Sampler

Masao Fukasawa (JAMSTEC)
Hiroshi Uchida (JAMSTEC) (not on board)
Wolfgang Schneider (University of Concepcion)
Ayako Nishina (University of kagoshima)
Satoshi Ozawa (MWJ) (Leg5-1)
Hirokatsu Uno (MWJ) (Leg5-2)
Hiroshi Matsunaga (MWJ)
Tomoyuki Takamori (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 3-04/F, S/N 034323 (secondary)

Conductivity sensor:

SBE, Inc., SBE 4-04/0, S/N 041088 (primary) Stn.610 - Stn.503
SBE, Inc., SBE 4C, S/N 042435 (primary) Stn.502 – Stn.444
SBE, Inc., SBE 4-04/0, S/N 041202 (secondary)

Oxygen sensor:

SBE, Inc., SBE 43, S/N 430391 (primary)
SBE, Inc., SBE 43, S/N 430205 (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	***Stn.610 – Stn.511***
Benthos Inc., PSA-900D, S/N 0396	***Stn.510 – Stn.469 , Stn.466 –Stn.465*** ***Stn.463 – Stn.444***
Benthos Inc., Model 2110-2, S/N 206	***Stn.468,467,464***

Deep Ocean Standards Thermometer:

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

Deck unit:

SBE, Inc., SBE 11plus, S/N 11P9833-0272	***Stn.610 – Stn.467***
SBE, Inc., SBE 11plus, S/N 11P9833-0344	***Stn.466 – Stn.444***

Carousel Water Sampler:

SBE, Inc., SBE 32, S/N 3227443-0391	***Stn.610 – Stn.514***
SBE, Inc., SBE 32, S/N 3221746-0278	***Stn.513 – Stn.444***

Fluorometer:

Seapoint sensors, Inc., S/N 2579

Water sample bottle:

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

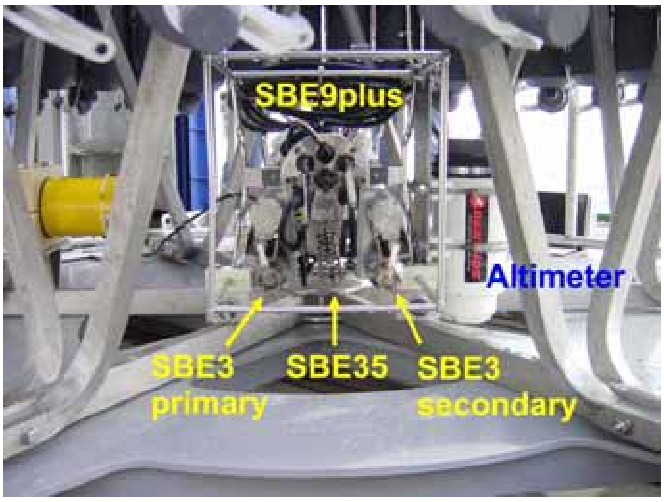

Fig.3.1.2.1 CTD

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

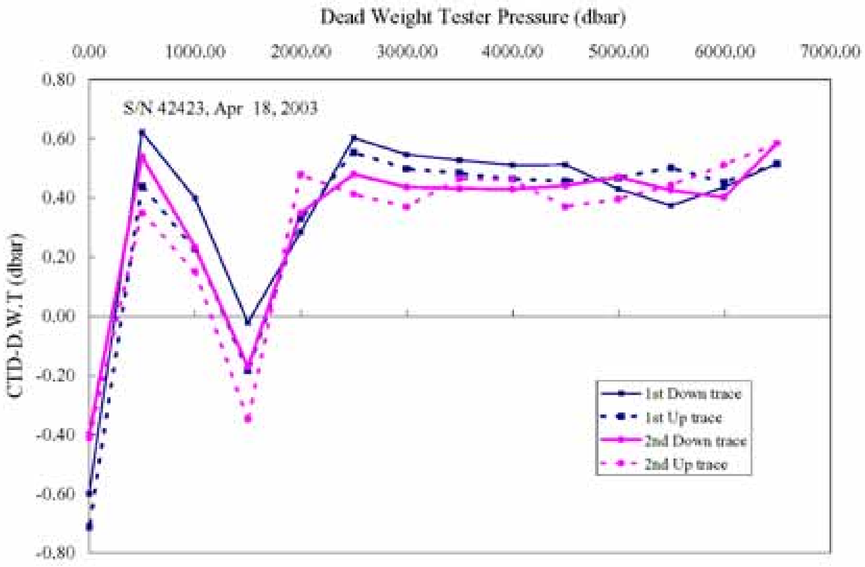

Fig.3.1.3.1: The residual pressures between the Dead Weight Tester and the CTD.

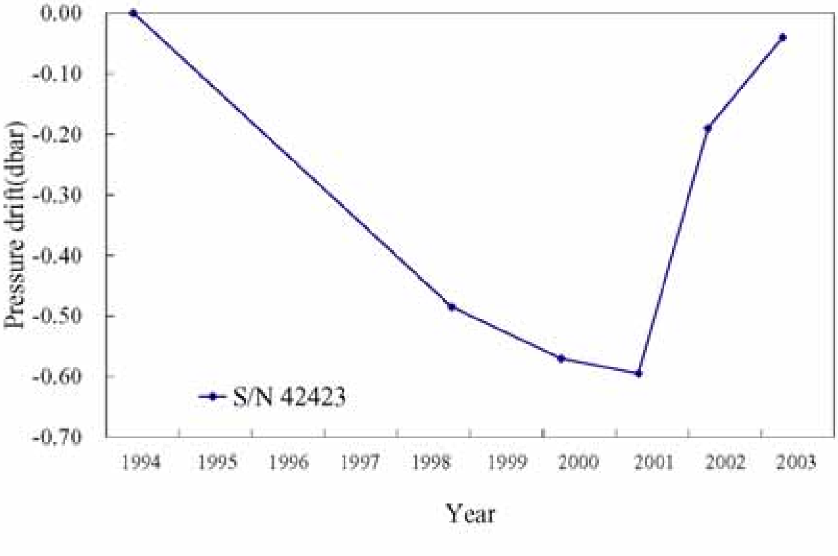

Fig.3.1.3.2: Drift (offset) of the pressure sensor measured by the Dead Weight Tester.

3.1.3.2 Temperature

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 034323) 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.

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 034323 (secondary) 29 October, 2003
g = 4.36386026e-03
h = 6.48493108e-04
i = 2.28715193e-05
j = 1.84823185 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).

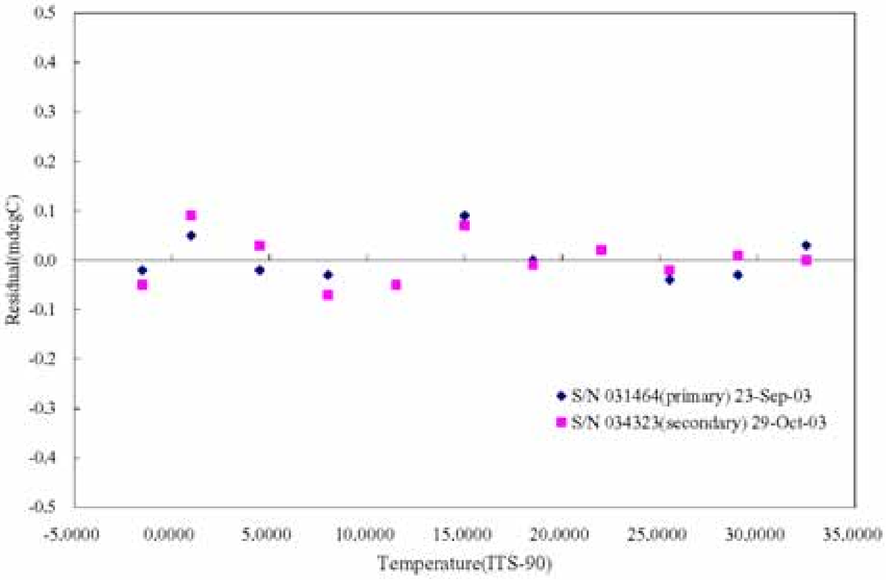

Fig.3.1.3.3: Residual temperature between bath and instrument temperatures.

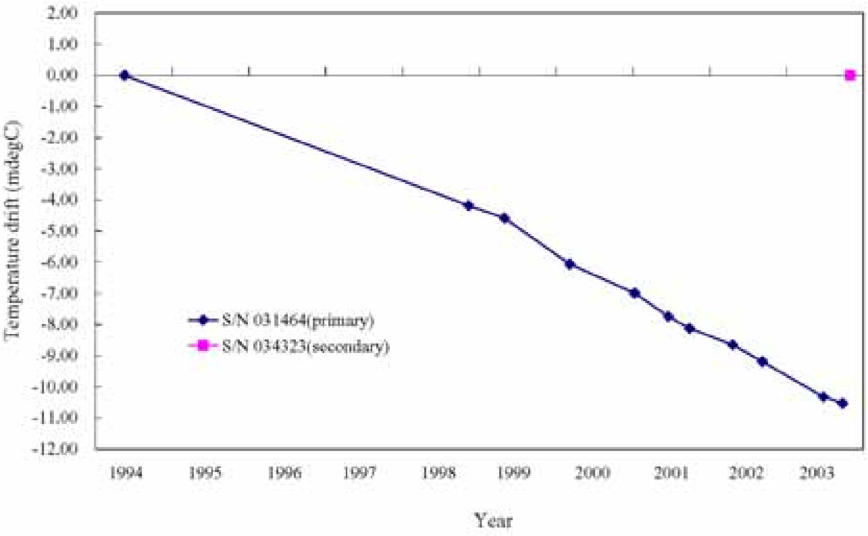

Fig.3.1.3.4: Drift of the temperature sensors based on laboratory calibrations.

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 041088 (primary Stn.610-Stn.503) 04 November, 2003
g = -4.02167245e+00
h = 5.51410012e-01
i = -2.94330837e-04
j = 4.48686818e-05
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

S/N 042453 (primary Stn.502-Stn.444) 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)

S/N 041202 (secondary) 04 November, 2003
g = -3.94477408e+00
h = 4.39537561e-01
i = -8.82455063e-05
j = 2.54499450e-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

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

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 430205(secondary) 17 November, 2003
Soc = 0.3982
Boc = 0.0000
TCor = 0.0002
PCor = 1.350e-04
Offset = -0.4808
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:

S/N 1026
  FSVolt * 300 / FSRange = 10
  Offset = 0.0

S/N 0396
  FSVolt * 300 / FSRange = 5
  Offset = 0.0

S/N 206
  FSVolt * 300 / FSRange = 15
  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)
All Station except for stn.468 and stn.464.
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 station I04-597, a fish was found in Tduct(Primary temperature sensor S/N031464) after the cast. When the data were checked, noise was found in the shallower than 800dbr of the up cast data.

At station I03-529, output from secondary conductivity sensor (S/N 041202) showed unusual value in the shallower than 3208dbr of the up cast data. After at station I03-529 , the secondary sensor show usual value.

Because there was a crack inside a Niskin-X bottle #9(NX(NC)12017) after the station I03-551 finished, we changed a Niskin-X bottle(NX(NC)12021).

After at station I03-513, carousel water sampler was replaced from S/N0391 to S/N 0278.

At station I03-513 first cast, when the package was lowered into the water from the starboard side and held 10 m, it was found that the scan number was not increased. The package coming up to surface, the SEASAVE software was re-started from the surface in order to acquire the data in a same file, 513M01.

After at station I03-511, when the altimeter data were checked, unusual (negative) value was found in the data around the bottom. So Altimeter was replaced from S/N1026 to S/N0396.

At station I03-503, primary conductivity sensor(S/N041088) showed unusual value from 4995dbr(downcast). At the same time primary and secondary oxygen sensor showed unusual value from 4995dbr to 5020dbr. After the cast primary conductivity sensor was replaced to S/N 042435.

When the CTD package was lifted to the deck after the up-cast, a hook that was connecting top and bottom caps of Niskin-X bottle by nylon line was away from the bottom cap(I03-504:#4, I03-477:#14). So we changed nylon line.

At station I03-466 first cast, the descent rate was not changing around 120 m depths in the down cast. And the update rate of the value in the fixed display and scrolled display cannot be controlled on the SEASAVE software. So the cast was aborted and the CTD package was lifted to the deck. The deck unit (SBE11plus) was replaced from S/N 11P9833-0272 to S/N 11P9833-0344 and SEASAVE software was re-started. A second cast was done at the site in order to acquire the data in a new file, 466M03.

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 –0.91 dbar and the root-mean-square difference of 0.17 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 –0.34 dbar. So the post-cruise calibration is not deemed necessary for this pressure sensor.

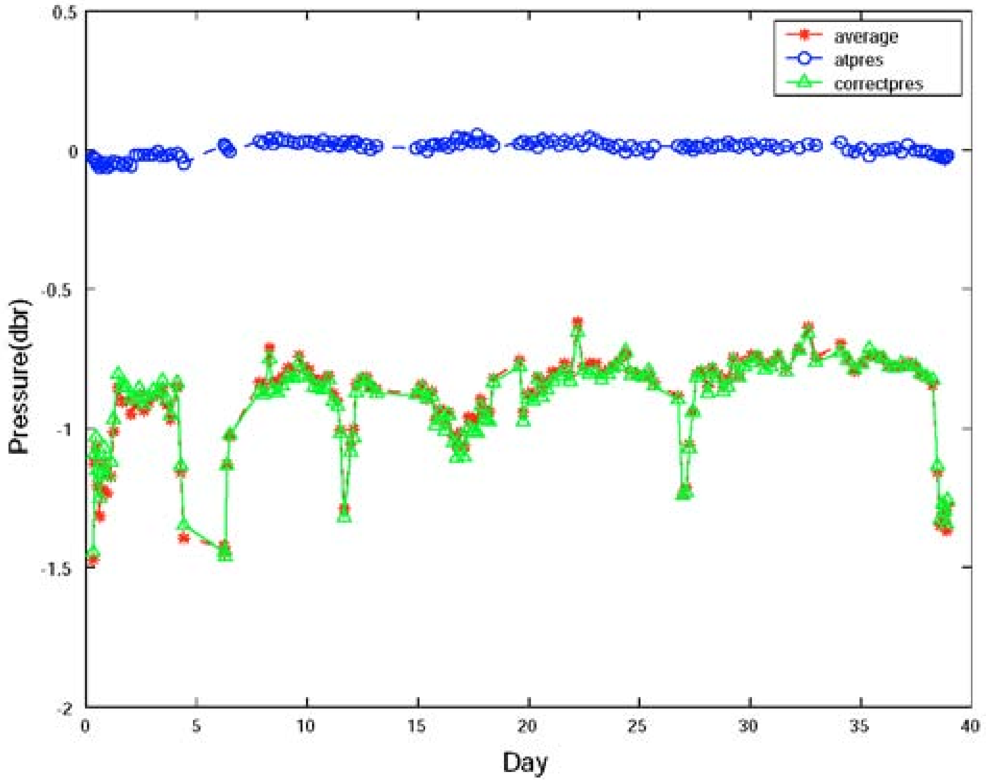

Fig.3.1.5.1: Time series of the CTD deck pressure from 12 Dec.2003 to 22 Jan.2004

3.1.5.2 Temperature

Post-cruise sensor calibrations are going to be performed at SBE, Inc. in Bellevue, Washington, USA. SBE 3 primary and secondary temperature sensor is going to be sent to SBE immediately after the cruise. 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).

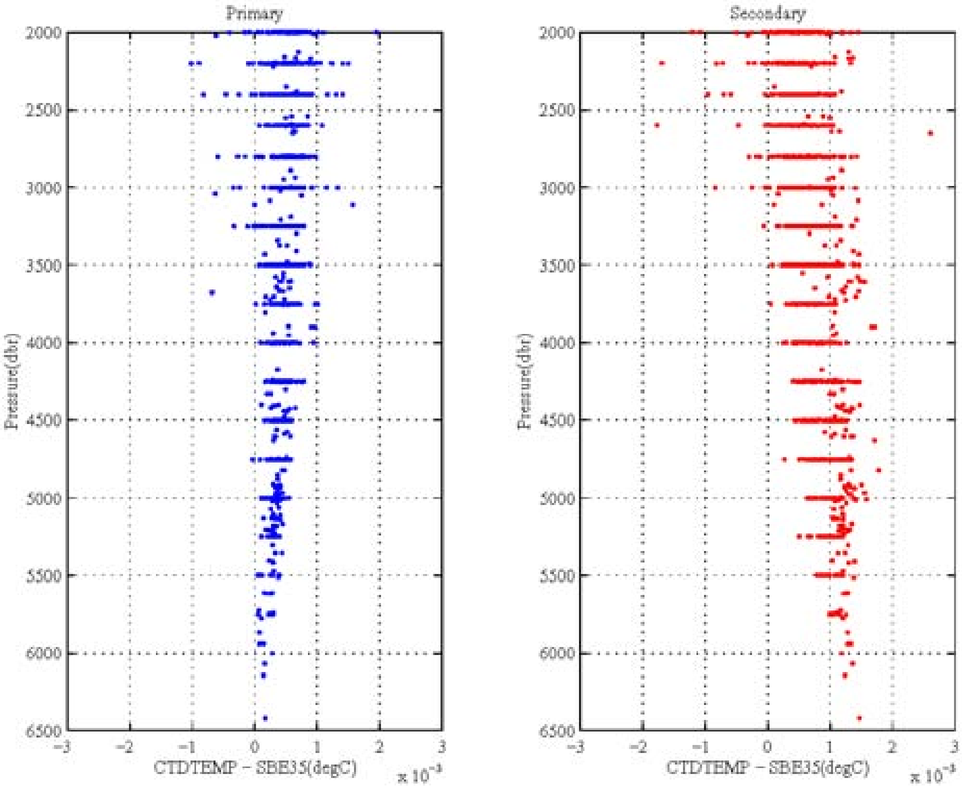

Fig.3.1.5.2: Comparison between SBE3 and SBE35 deeper than 2,000dbr

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.

3.1.6 Preliminary results

Date, time and locations of the CTD casts are listed in SUM (station summary) file. In total 145 CTD casts were carried out. Vertical section of temperature, salinity, dissolved oxygen are shown in Plate C.1.6.1. Uncorrected CTD data are used in Plate C.1.6.1.

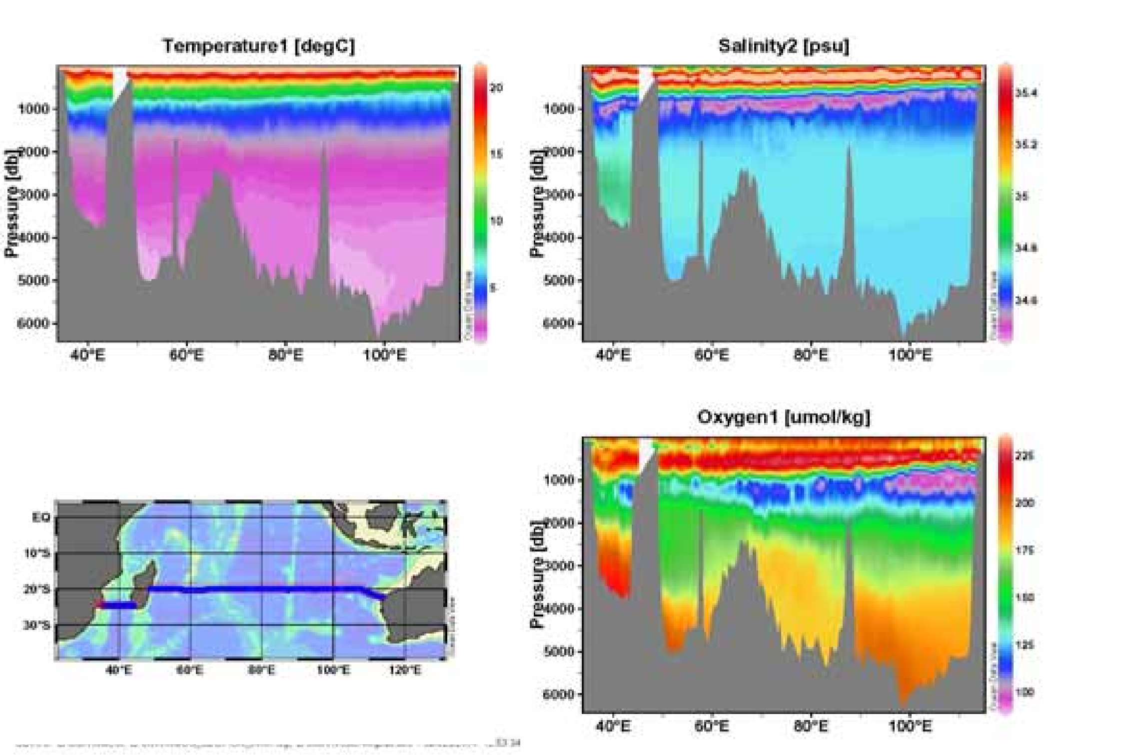

Plate C.1.6.1: section of (a) temperature, (b) salinity and (c) dissolved oxygen, and (d) Station locations.

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

3.2 Bottle Salinity

Takeshi Kawano (JAMSTEC) Kenichi Katayama(MWJ) and Tomomi Watanabe(Nagasaki Univ.)

2.1 Objectives

Bottle salinity was measured in order to compare with CTD salinity to identify leaking of the bottles and to calibrate CTD salinity.

2.2 Instrument and Method

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.

2.2.2 Instruments and Method

The salinity analysis was carried out on Guildline Autosal salinometer model 8400B with serial number of 62827 from Stn.610 to Stn.555 and Autosal with Serial number 62556 from Stn.554 to Stn.444. Both salinometers were 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 20 deg C to 23 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 taken 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 0.00002, 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 greater than or equal to 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 7:00 to 23:00) and the cell was cleaned by ethanol or soap or both after the measurement of the day.

2.3 Preliminary Result

2.3.1 Stand Seawater

Standardization control of the salinometer with serial number of 62827 and 62556 was set to 508 and 638, respectively. During the measurement, the STANDBY of 62827 was 5410 +/- 0001 and ZERO was 0.00000 to 0.00001. The STANBY of 62556 was 6107 +/- 0001 and ZERO was 0.00000 to 0.00001. We used IAPSO Standard Seawater batch P142 which conductivity ratio was 0.99991 (double conductivity ratio is 1.99982) as the standard for salinity. We measured 194 ampoules of P142. There were 7 bad ampoules whose conductivities are extremely high. Data of these 7 ampoules is not taken into consideration hereafter.

Fig.2.3.1 shows the history of double conductivity ratio of the Standard Seawater batch P142. The average of double conductivity ratio from Stn.610 to Stn.555 was 1.99977 and the standard deviation was 0.00008, which is equivalent to 0.0002 in salinity. We add 0.00005 to the measured double conductivity ratio during this period. The average from Stn.554 to Stn.444 was 1.99974 and the standard deviation was 0.00008. We add 0.00008 to the measured double conductivity ratio during this period.

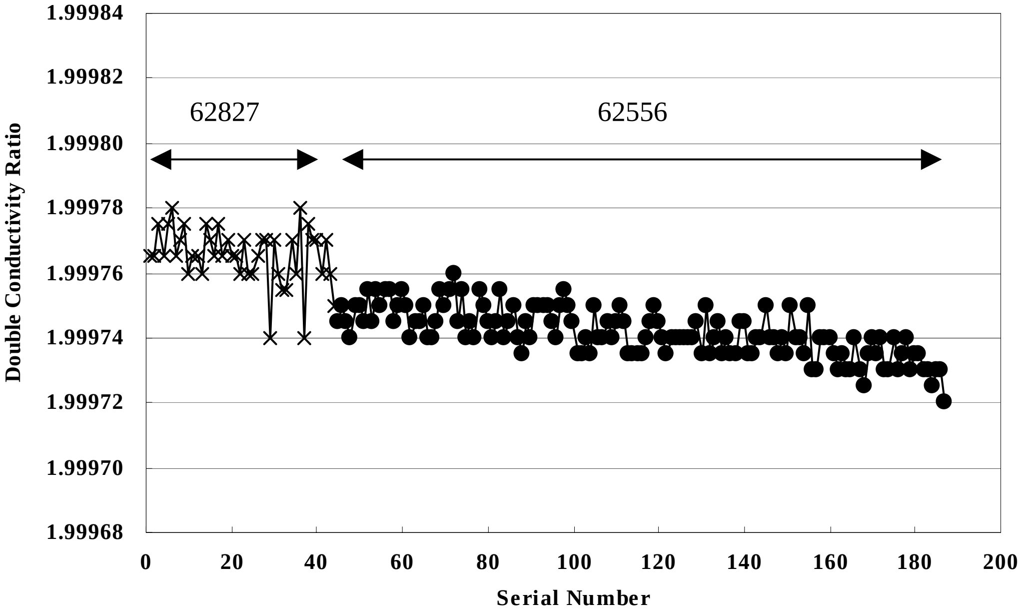

Fig.2.3.1 The history of double conductivity ratio of the Standard Seawater batch P142

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.

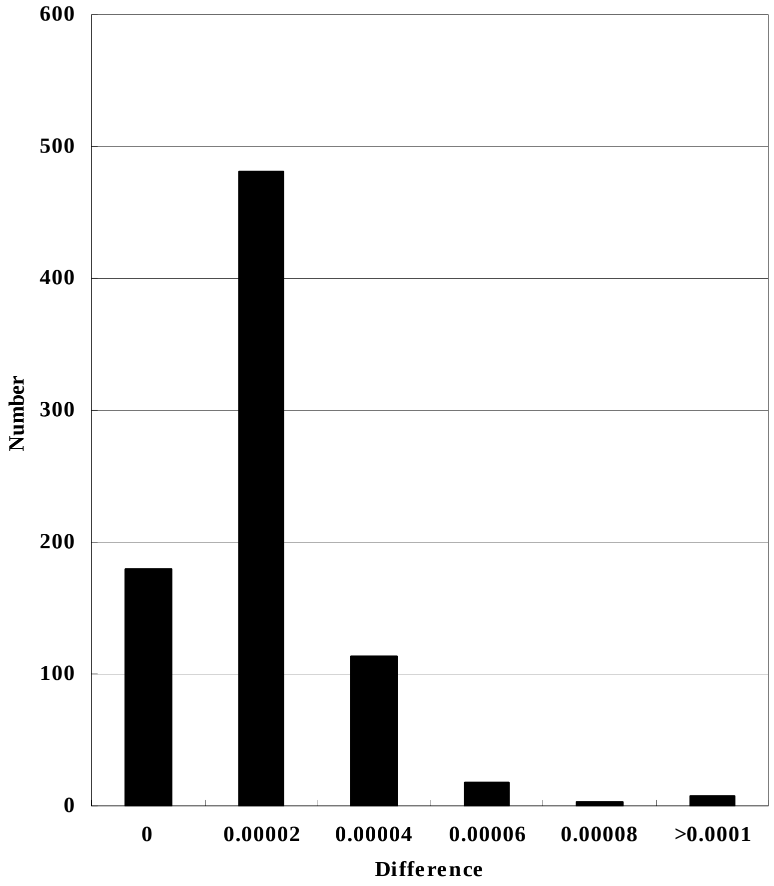

Fig.2.3.2 (a) The histogram of the absolute difference between replicate samples

2.3.3 Replicate and Duplicate Samples

We took 830 pairs of replicate and 66 pairs of duplicate samples. Fig.2.3.2 (a) and (b) shows the histogram of the absolute difference between replicate samples and duplicate samples, respectively. There were eight bad measurements and 20 questionable measurements of replicate samples and eight questionable measurements of duplicate samples. As for questionable measurements, one of the pair is extremely high (more than 0.01in salinity). This might be cause insufficient seal of the sample bottles. Excluding these bad and questionable measurements, the standard deviation of the absolute deference of 802 pairs of replicate samples was 0.0002 in salinity and that of 58 pairs of duplicate samples was 0.0003 in salinity.

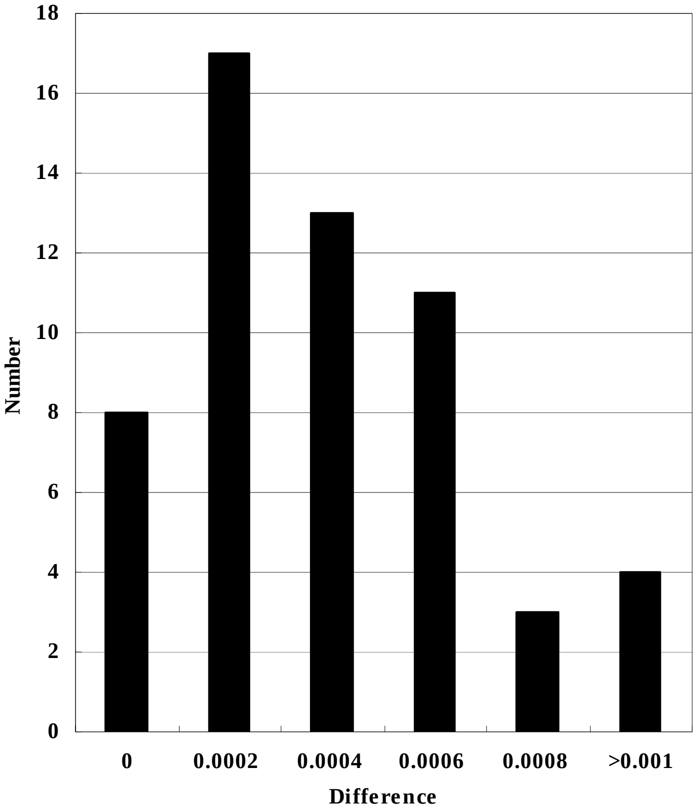

Fig.2.3.2 (b) The histogram of the absolute samples between duplicate samples.

2.3.4 Figures

We measured about 4,950 samples in this leg. As a preliminary result, we will show a several figures without any interpretation. Fig.2.3.3 shows a vertical section of bottle salinity, vertical profile of bottle salinity and Sigma4-Salinity diagram produced by Ocean Data View.

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.

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

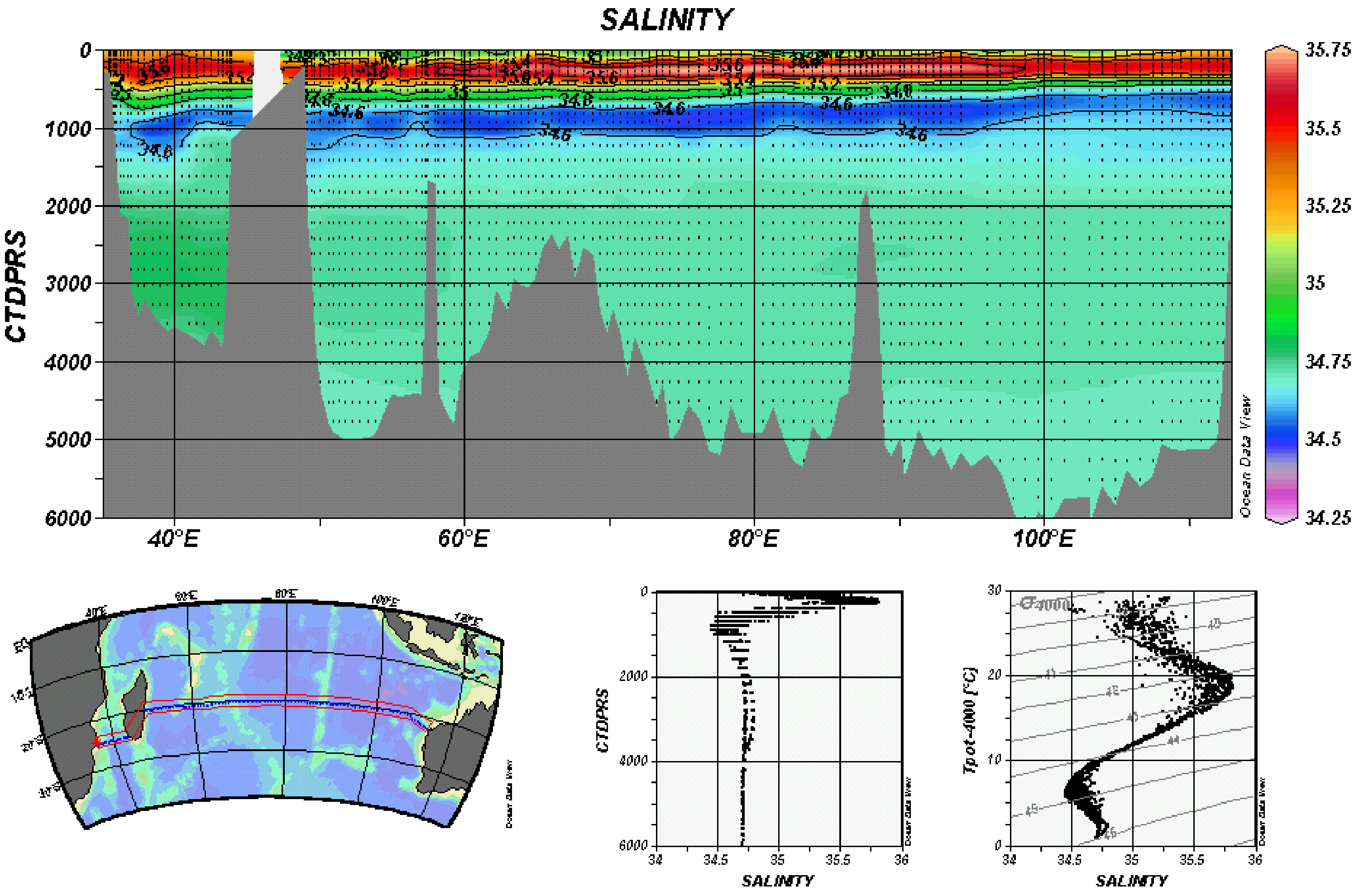

Fig.2.3.3 vertical section, vertical profile of bottle salinity and Sigma4-Salinity diagram

3.3 Oxygen (Jan. 23, 2004)

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Takayoshi SEIKE : Marine Works Japan Co. Ltd.
Tomoko MIYASHITA : MWJ
Nobuharu KOMAI : MWJ
Shuichi Watanabe : Ocean Observation and Research Department, JAMSTEC

3.3.1 Objectives

Dissolved oxygen is one of the most significant tracers for the ocean circulation study. In this cruise (MR03-K04 Leg-5), we measured dissolved oxygen concentration at the stations along the WHP I04 and I03 sections from 35.4°E to 113.5°E in the Indian Ocean. Our main purpose is to compare with the past I04 and I03 cruises and to study the various water masses transport and their variability.

3.3.2 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 cm^3 of titration vessel
Burette for potassium iodate;
  APB-410 manufactured by Kyoto Electronic Co. Ltd. / 20 cm^3 of titration vessel
Detector and Software;
  Automatic photometric titrator manufactured by Kimoto Electronic Co. Ltd.
Digital thermometer
  SK-1250MCⅢ manufactured by Sato Keiryoki MFG. Co., Ltd.

Sampling:

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

Seawater samples were collected with Niskin-X bottle attached to the CTD-system. Seawater for oxygen measurement was transferred from Niskin-X sampler bottle to a volume calibrated flask (ca. 100 cm^3). 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 cm^3 each were added immediately into the sample flask and the columnar 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 cm^3 sulfuric acid solution were added into the sample flask and stirring began. Samples were titrated by sodium thiosulfate solution which 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 dm^3 in a calibrated volumetric flask (0.001667M). 10 cm^3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 90 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 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 cm^3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 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 cm^3 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 cm^3) and II (0.5 cm^3) 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 are less than 0.012cm^3 for DOT-01 and 0.010cm^3 for DOT-02. Reproductivity (C.V.) of standardization was less than 0.06 % (n = 5).

3.3.3 Reproducibility of sample measurement

Replicate samples were usually taken at 5 - 11 % of seawater samples of each cast during this cruise. Number of replicate sample pairs was 490 and the standard deviation was calculated to be 0.076 μmol/kg. The standard deviation was calculated by a procedure (SOP23) in DOE (1994).

3.3.4 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.

3.3.5 Preliminary results

During this cruise we measured oxygen concentration in 4030 seawater samples. Distribution of dissolved oxygen at sections I03 and I04 were shown in Figure 3.3.1. The minimum oxygen value was found at the depth of 900dbar, 107.5°E which concentration was 90.6 μmol kg^{-1}. The maximum oxygen value was found at the depth of 400dbar, 113.2 °E which concentration was 243.6 μmol kg^{-1}.

Circumpoler Deep Water (CDW) was clearly shown as high oxygen water in the three areas, between South Africa and Madagascar, the east of Madagascar, and between the Ninety East Ridge and Australia. Oxygen minimum layer associated with Antarctic Intermediate Water (AAIW) was shown within 800 – 1500dbar.

Table 3.3.1 Results of the standardization and the blank determinations during MR03-K04 Leg-5

Date	Time	KIO3		DOT-1			DOT-2			Stations
(UTC)	(UTC)	#	bottle	Na2S2O3	E.P.	Blank	Na2S2O3	E.P.	Blank	
12-13-03	02:32	#1	030418-91	031209-1	3.961	-0.008	031209-2	3.962	-0.006	610,609,608,607, 606,605
12-14-03	01:07		030418-92	031209-1	3.957	-0.009	031209-2	3.959	-0.007	604,603,602
12-14-03	12:06		030418-93	031209-6	3.959	-0.012	031209-7	3.960	-0.008	601,600,599
12-15-03	01:14		030418-94	031209-6	3.960	-0.011	031209-7	3.961	-0.008	598,597,596
12-16-03	00:43		030418-96	031209-6	3.958	-0.008	031209-7	3.959	-0.008	595,594
12-16-03	01:59		030418-96	031209-4	3.955	-0.011	031209-5	3.959	-0.010	593,592,591
12-16-03	15:28		030418-97	031209-4	3.957	-0.012	031209-5	3.960	-0.007	590,589,588
12-17-03	05:40		030418-98	031209-4	3.959	-0.011	031209-5	3.960	-0.008	587,586,585
12-19-03	05:30		030418-100	031215-1	3.957	-0.011	031215-2	3.959	-0.008	562,561,560,559
12-20-03	22:34		030418-102	031215-1	3.953	-0.011	031215-2	3.955	-0.009	558,557,556
12-21-03	18:52	#2	030418-106	031215-3	3.955	-0.012	031215-4	3.956	-0.008	555,554,553
12-22-03	06:22		030418-107	031215-3	3.958	-0.012	031215-4	3.958	-0.009	552,551,550
12-23-03	02:12		030418-108	031215-5	3.956	-0.012	031221-1	3.955	-0.008	549,x07,547
12-23-03	17:53		030418-109	031215-5	3.958	-0.011	031221-1	3.955	-0.009	546,545,544
12-24-03	10:01		030418-110	031221-2	3.955	-0.011	031221-3	3.957	-0.007	543,542,541,540
12-24-03	23:05		030418-111	031221-2	3.956	-0.011	031221-3	3.957	-0.007	539,538,537,536
12-25-03	21:06		030418-112	031221-4	3.956	-0.011	031221-5	3.956	-0.009	535,534,533
12-28-03	01:07		030418-114	031221-4	3.955	-0.010	031221-5	3.957	-0.008	532,531,530
12-28-03	22:01		030418-115	031224-1	3.953	-0.009	031224-2	3.954	-0.010	529,528,527
12-29-03	09:07		030418-116	031224-1	3.955	-0.011	031224-2	3.955	-0.008	526,525,524,523
12-30-03	01:45		030418-117	031224-3	3.956	-0.009	031224-4	3.957	-0.008	522,521,520
12-30-03	16:51		030418-118	031224-3	3.954	-0.009	031224-4	3.956	-0.008	519,518,517
12-31-03	05:55	#3	030418-121	031224-5	3.957	-0.012	031229-1	3.961	-0.008	516,515,514
01-01-04	15:35		030418-123	031224-5	3.954	-0.009	031229-1	3.958	-0.007	513,512,511
01-02-04	09:30		030418-124	031229-2	3.961	-0.009	031229-3	3.961	-0.007	510,509,508
01-03-04	23:45		030418-125	031229-2	3.960	-0.009	031229-3	3.959	-0.008	507,506,505
01-03-04	21:41		030418-126	031229-4	3.958	-0.010	031229-5	3.958	-0.008	504,503,502
01-04-04	17:47		030418-127	031229-4	3.959	-0.009	031229-5	3.958	-0.009	501,500,x08
01-05-04	10:36		030418-128	031229-6	3.956	-0.008	040102-1	3.958	-0.007	498,497,496
01-06-04	04:57		030418-129	031229-6	3.958	-0.009	040102-1	3.958	-0.008	495,494,493
01-07-04	01:09		030418-130	040102-2	3.960	-0.010	040102-3	3.959	-0.008	492,491,490,489
01-08-04	19:31	#4	030418-136	040102-2	3.961	-0.009	040102-3	3.961	-0.007	488,487,486,485
01-09-04	16:37		030418-137	040102-4	3.961	-0.009	040102-5	3.960	-0.008	484,483,482
01-10-04	04:46		030418-138	040102-4	3.959	-0.010	040102-5	3.959	-0.008	481,480,479
01-11-04	00:24		030418-139	040108-1	3.960	-0.009	040108-2	3.960	-0.007	478,477,476
01-11-04	17:58		030418-140	040108-1	3.959	-0.009	040108-2	3.959	-0.008	475,474,473
01-13-04	08:41		030418-142	040108-3	3.958	-0.009	040108-4	3.960	-0.007	x09,471,470,469, 468
01-14-04	04:55		030418-144	040108-5	3.956	-0.010	040112-1	3.958	-0.007	467,466,465
01-16-04	04:38		030418-146	040108-5	3.958	-0.009	040112-1	3.960	-0.008	464,463,462
01-17-04	04:00		030418-147	040112-2	3.958	-0.010	040112-3	3.959	-0.008	461,460,459
01-18-04	02:31		030418-148	040112-2	3.959	-0.010	040112-3	3.959	-0.008	458,457,456
01-19-04	01:40	#5	030418-151	040112-4	3.959	-0.008	040112-5	3.959	-0.008	455,454,x10
01-19-04	20:27		030418-152	040112-4	3.959	-0.008	040112-5	3.960	-0.008	452,451,450
01-20-04	21:05		030418-155	040112-4	3.962	-0.009	040112-5	3.961	-0.007	449,448, 447(DOT-02)
01-21-04	02:20		030418-156	040120-1	3.957	-0.009	040120-2	3.958	-0.007	447(DOT-01), 446,445,444

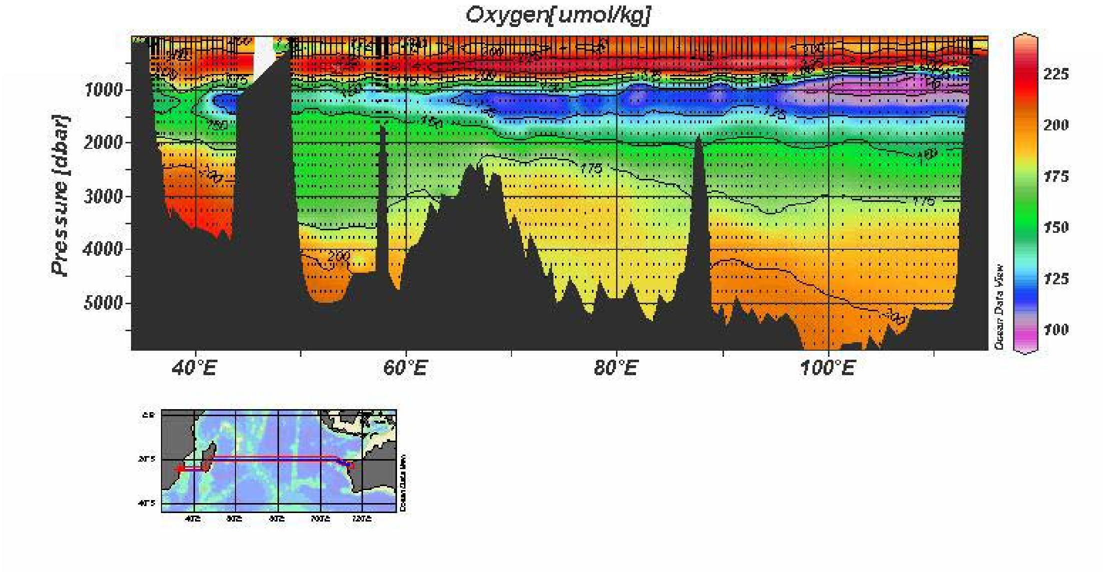

Fig.3.3.1 Dissolved oxygen concentration (μmol / kg) . This figure was drawn using Ocean Data View (R. Schlitzer, http://www.awi-bremerhaven.de/GEO/ODV, 2002).

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** (23 Jan. 2004)

Michio AOYAMA : Geochemical Res. Dep., Meteorological Res. Inst. Japan
Kennichiro SATO, Ai YASUDA, Asako KUBO : Marine Works Japan Co. 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

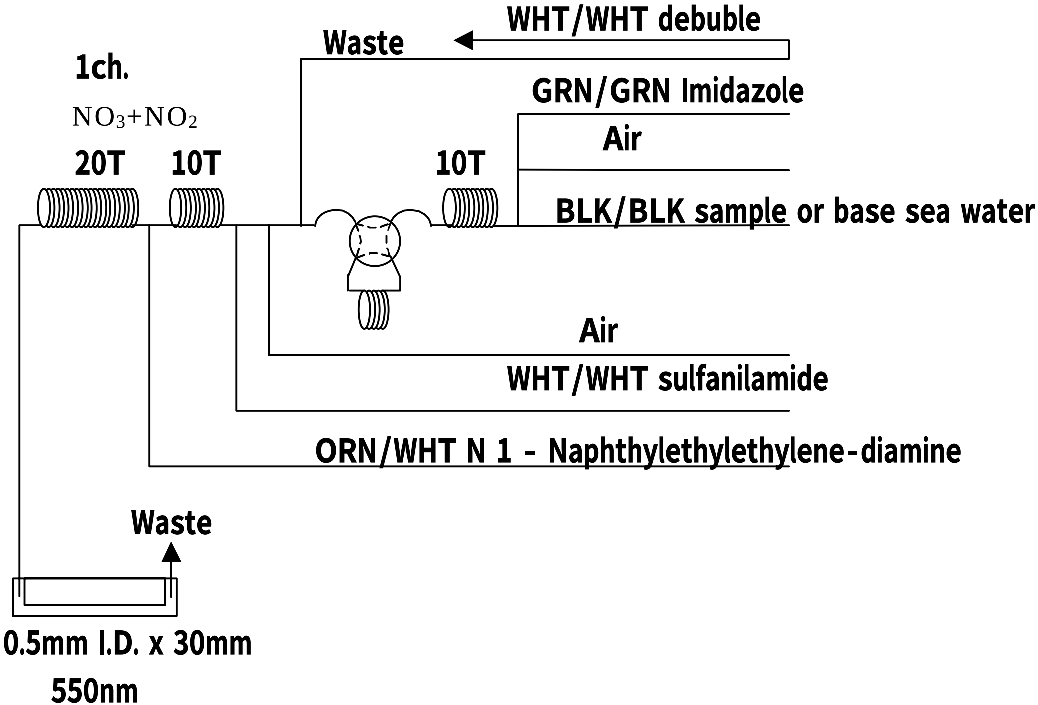

Fig. 3.4.1 1ch. (NO_3+NO_2)Flow diagram.

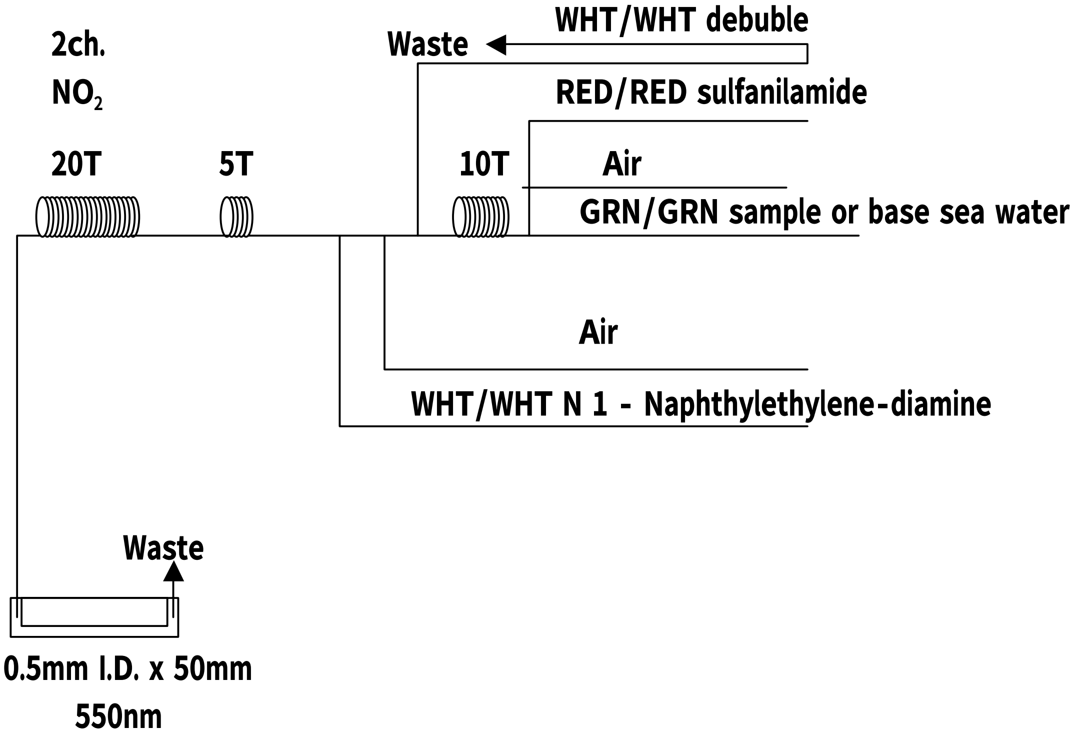

Fig. 3.4.2. 2ch. (NO_2) Flow diagram.

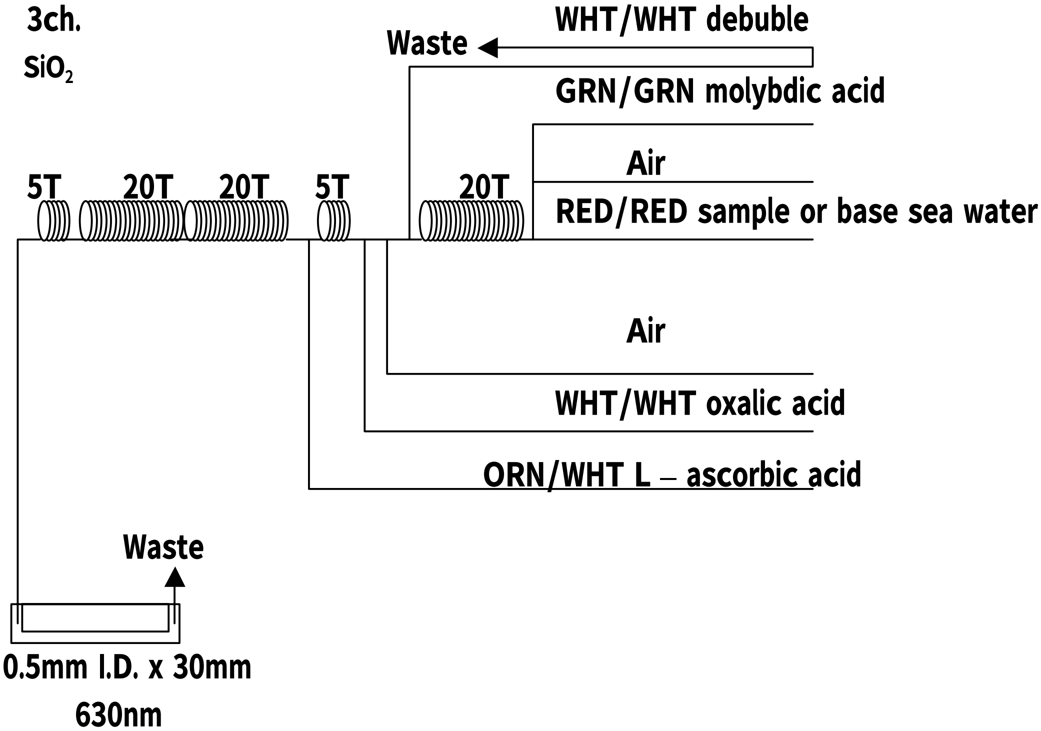

Fig. 3.4.3 3ch. (SiO_2) Flow diagram.

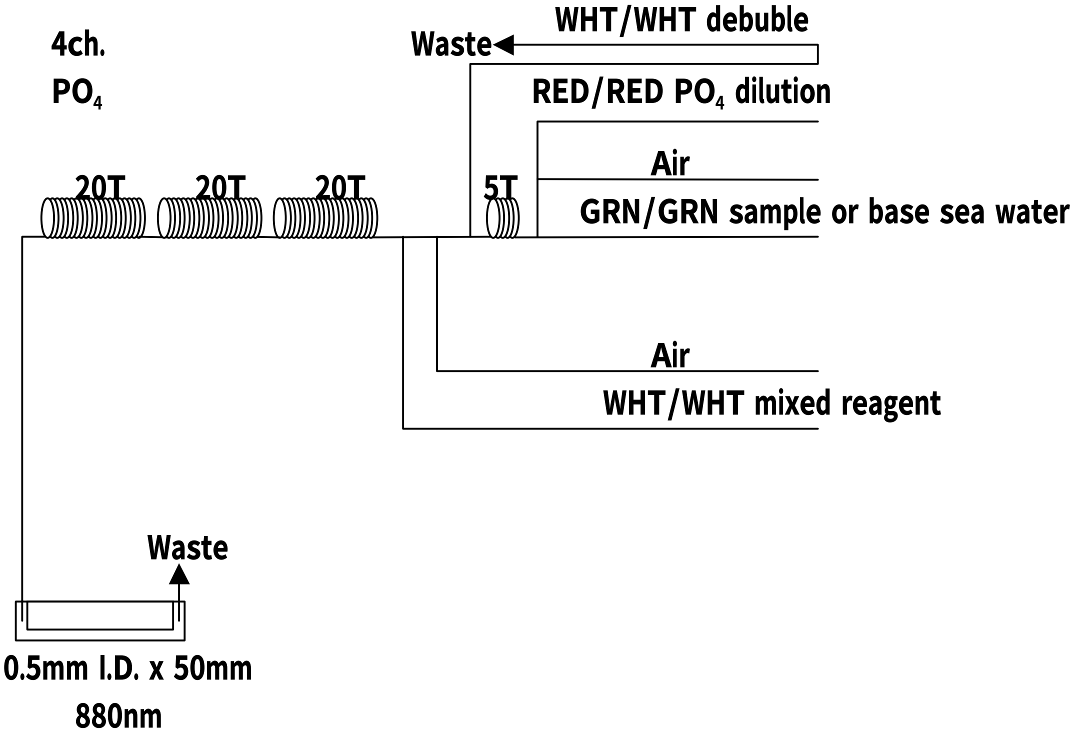

Fig. 3.4.4 4ch. (PO_4) Flow diagram.

3.4.2-2 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 23 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.

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.

3.4.3 Nutrients standards

3.4.3-1 In-house standards

3.4.3-1.1Volumetric 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

(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.

(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

(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.

(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) 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 3.1.1. 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
NO3(μ M)	45000	1350	0.0	13.5	27.0	40.5	54.0
NO2(μ M)	4000	40	0.0	0.4	0.8	1.2	1.6
SiO2(μ M)	36000	5040	0.0	50	100	150	200
PO4(μ M)	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 3.1.3 were renewed as shown in Table 3.4.3.

Table 3.4.3 Timing of renewal of in-house standards.

NO3, SiO2, PO4	Renewal
A-1 Std. (NO3)	maximum 10 days
A-3 Std. (SiO2)	comercial prepared solution
A-4 Std. (PO4)	maximum 14 days
B-1 Std. (mixture of A-1,3 and 4 Std.)	2 days

NO2	Renewal
A-2 Std. (NO2)	maximum 14 days
B-2 Std. (NO2)	maximum 14 days

C Std	Renewal
C-1～C-5 Std (mixture of B1 and	24 hours B2 Std.)

Reduction estimation	Renewal
D-1 Std.	when A-1renewed
44µM NO3	when C-std renewed
47µM NO2	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

(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.

(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 table3.3, 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 3.4.4 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 figures 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. During leg 5, analytical precisions were 0.17% for phosphate, 0.13% for nitrate and 0.12% for silicate in terms of median, respectively. Then we can conclude that the analytical precisions for phosphate, nitrate and silicate were maintained or better throughout leg 5 comparing the pre-cruise evaluations.

Table 3.4.5 Summary of precision based on the replicate analyses of 13 samples in each run during leg 5.

	Nitrate CV%	Phosphate CV%	Silicate CV%
Median	0.13	0.17	0.12
Mean	0.13	0.19	0.13
Maximum	0.40	1.00	0.40
Minimum	0.04	0.06	0.04
N	145	145	145

The time series of precision are shown in figures 3.4.5 – 3.4.7

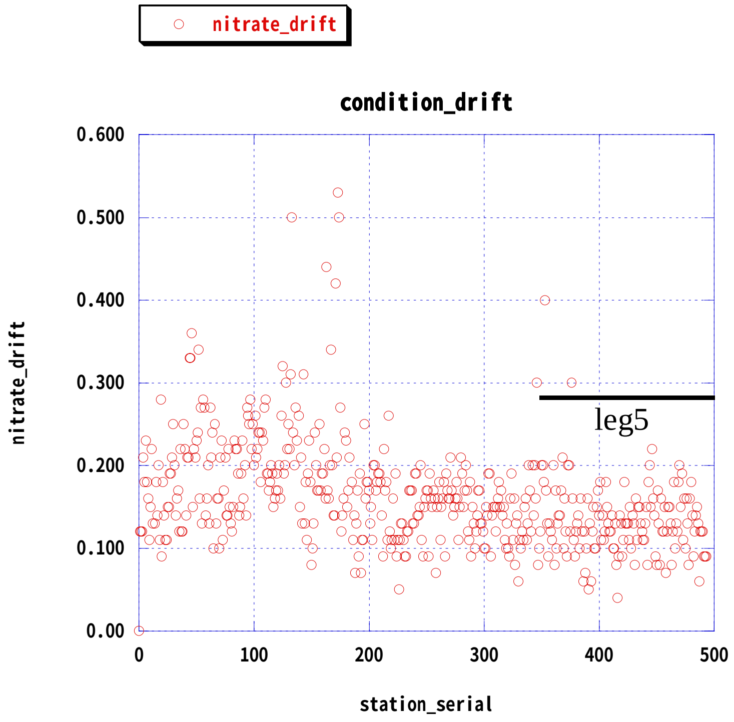

Fig.3.4.5 Time series of precision

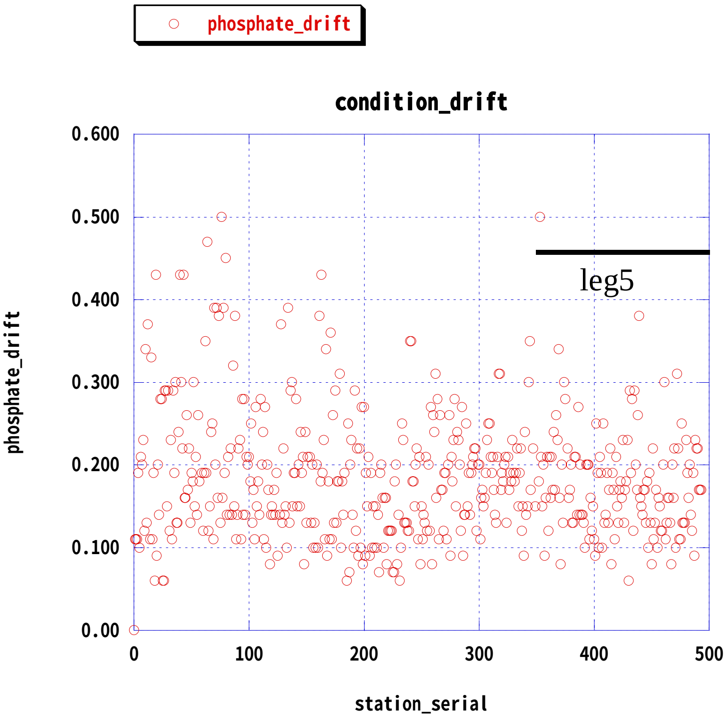

Fig.3.4.6 Time series of precision

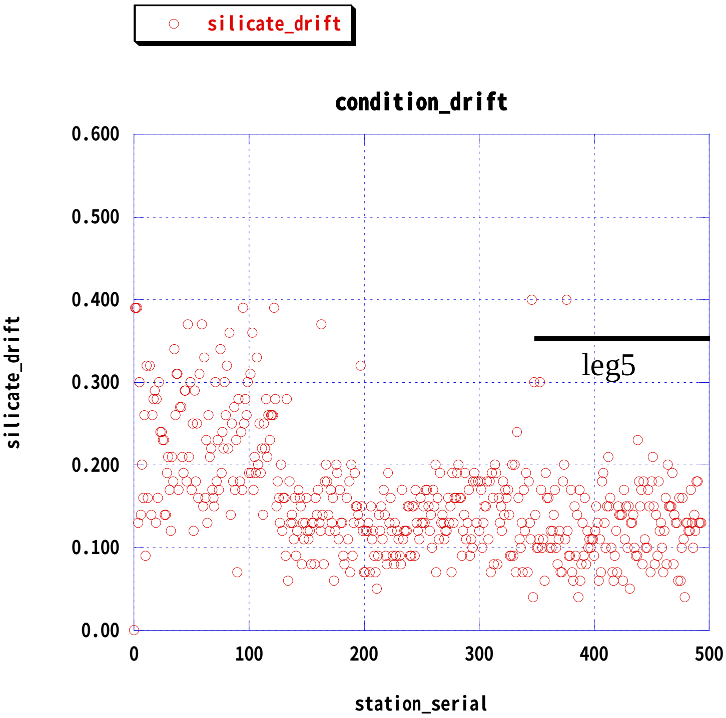

Fig.3.4.7 Time series of precision

3.4.4.2 Carry over

We can also summarize the magnitudes of carry over throughout the cruise. These are as shown in Table 3.4.6. The average of carry over for nitrate was 0.45, which is relatively high rather than those of Phosphate and Silicate.

Table 3.4.6 Summary of carry over during leg 5.

	Nitrate CV%	Phosphate CV%	Silicate CV%
Median	0.46	0.16	0.10
Mean	0.45	0.18	0.10
Maximum	0.75	0.63	0.28
Minimum	0.17	0.00	0.00
N	145	145	145

3.4.4.3 Concentrations of low nutrients seawater.

Concentrations of low nutrients seawater obtained from each measurements were summarized in Table 3.4.7. As shown in Table 3.4.7, the concentrations of low nutrients seawater used in this cruise are well reproduced against nominal concentrations given in May 2003. The phosphate concentration of low nutrients seawater was calculated as 0.15 micro mol kg-1 while nominal concentration was 0.16 micro mol kg-1. This discrepancy might be caused by the difference of automated decision process of peak positions of baseline between “base” and others. Then, we concluded that this difference as shown in Table 3.4.7 will not affect on the samples.

Table 3.4.7 Summary of low nutrients seawater during leg 5.

	Nitrate micro mol kg^{-1}	Phosphate micro mol kg^{-1}	Silicate micro mol kg^{-1}
Median	0.01	0.15	0.95
Mean	0.01	0.15	0.96
Maximum	0.11	0.17	1.33
Minimum	-0.10	0.12	0.57
Nominal	0.00	0.16	1.01

The numbers of analysis were 145 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 5. Preliminary results are shown in figures 3.4.8 – 3.4.13.

During the leg5, nitrate concentrations, phosphate concentrations and silicate concentrations were within 95% confidence level of consensus values in general, respectively.

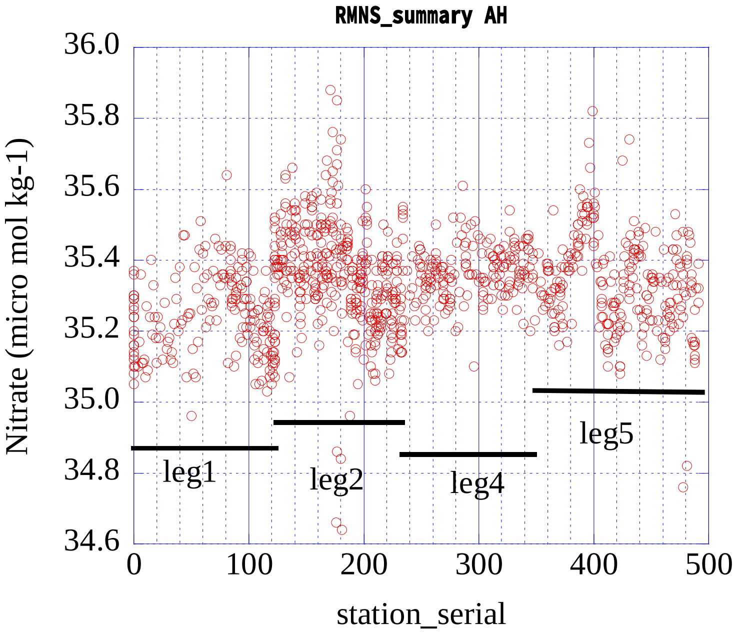

Fig.3.4.8

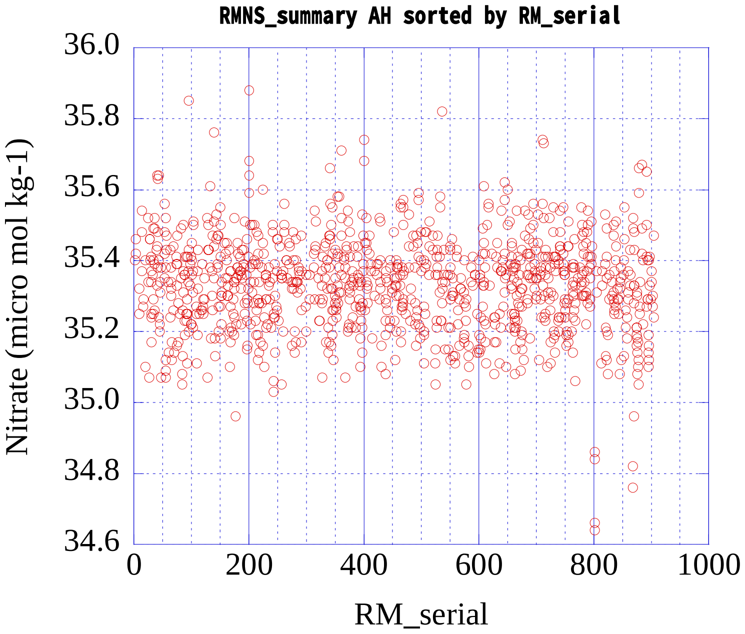

Fig.3.4.9

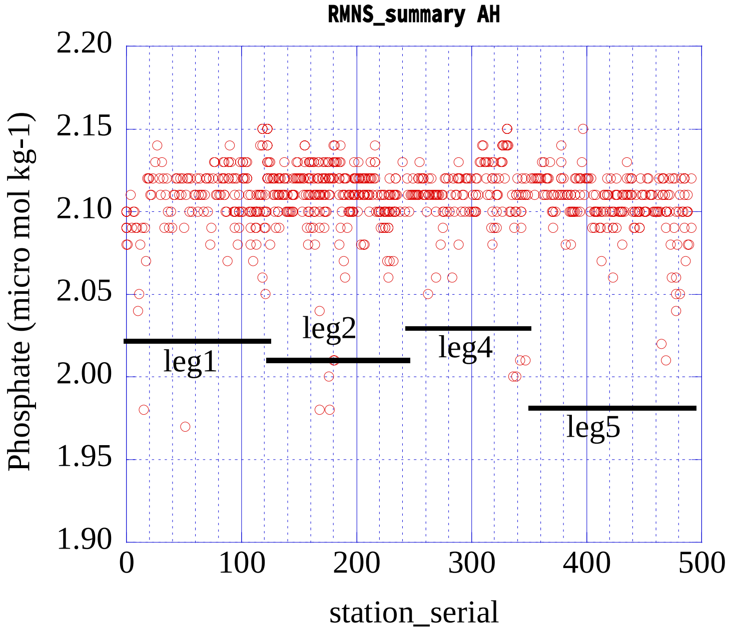

Fig.3.4.10

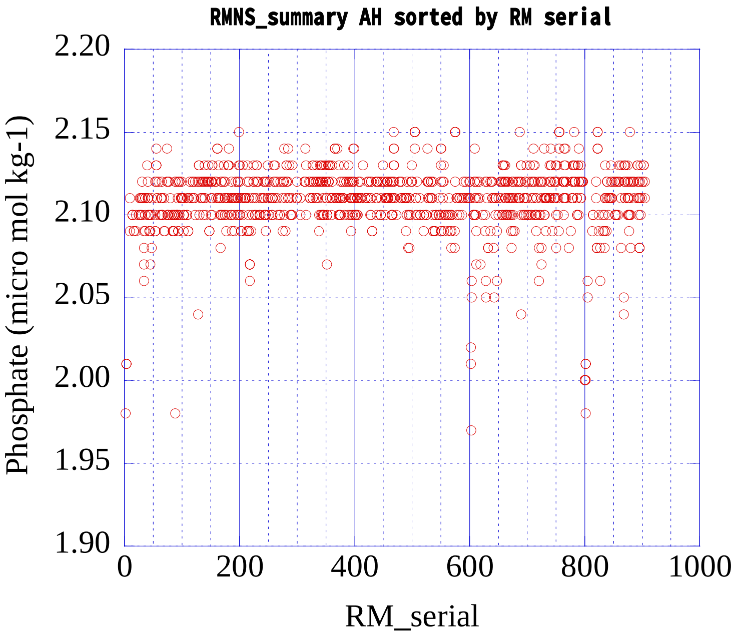

Fig.3.4.11

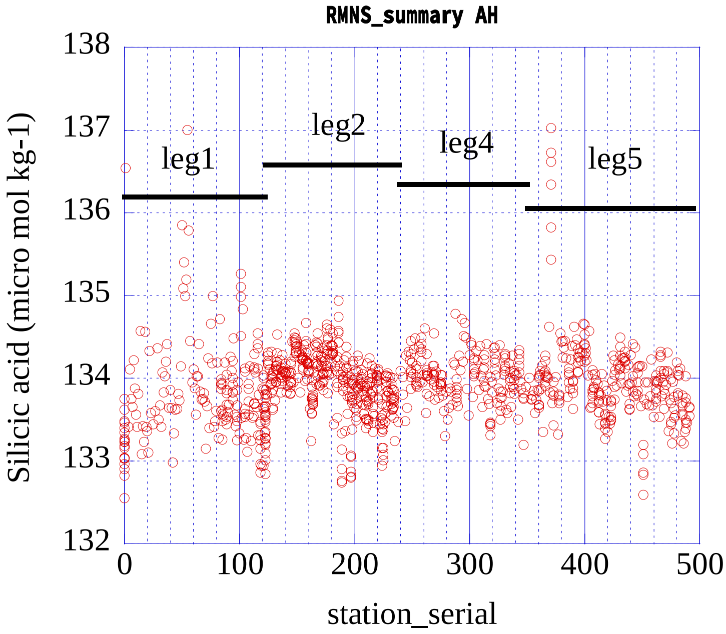

Fig.3.4.12

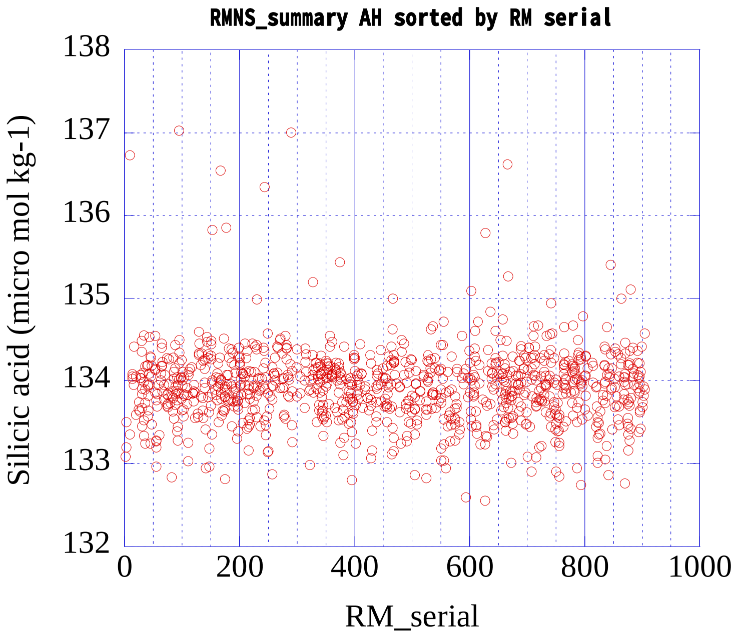
RMNS_summary AH sorted by RM serial
138
137
136
135
134
133
132
Silicic acid (micro mol kg-1)
0
200
400
600
800
1000
RM_serial

Fig.3.4.13

3.4.6 Leg-to-leg traceability

Table 3.4.8 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

	NO3_leg5	SiO2_leg5	PO4_leg5
median	**35.34**	**133.93**	**2.11**
average	**35.34**	**133.95**	**2.11**
stdev	**0.13**	**0.51**	**0.02**
cv%	**0.38**	**0.38**	**1.14**
max	**35.82**	**137.02**	**2.39**
min	**34.76**	**131.99**	**2.01**
max-min	**1.06**	**5.03**	**0.38**
count	**267**	**267**	**267**

Table 3.4.7 Summary of leg-to-leg traceability

	Nitrate	Phosphate	Silicate
leg1	**35.25**	**2.11**	**133.75**
leg2	**35.37**	**2.11**	**134.00**
leg4	**35.37**	**2.11**	**134.02**
leg5	**35.34**	**2.11**	**133.93**

Leg-to-leg traceability were examined based on the results of the statistics of RMNS-AH concentrations. As shown in Table 3.4.6 and 3.4.7, the medians and averages of the nutrients concentration of RMNS-AH were in good agreement among leg1,leg2, leg4 and leg5. The deviation among four 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.

Nothing occurred.

3.5 Freons

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Yuichi SONOYAMA : Marine Works Japan Co. Ltd.
Hideki YAMAMOTO : MWJ

3.5.1 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, Film thickness: 20µm)
Main column:	Pola BOND Q
	(i. d.: 0.53mm, length: 25m, Film thickness: 10µm)
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:	～220 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 N_2 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 100 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 temperatures 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 in 2120 samples at 69 stations (all C-stations). The precisions of CFCs (CFC-11, -12 and –113) measurements estimated from replicate analyses were 0.01 pmol/kg (n = 125). In the CFC-113 data for surface samples, there is a problem that comes from unknown interference peak. The chromatograms should additionally be analyzed for CFC-113 data. We found the maximum concentrations of CFC-11 and CFC-12 (>3.5 pmol/kg and >1.5 pmol/kg, respectively) at around 500 m depth on the I04 and I03 sections. These concentrations steeply decrease around 1000 m depth. We found change in CFCs penetration depth at I03 and I04 sections. This was to be shallower at east of I03 section than west of the section and I04 section.

(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

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Mikio Kitada : Marine Works Japan Co. Ltd.
Taeko Ohama : MWJ
Masaki Moro : MWJ
Fujiki Toru : 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 - 2 °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.).

(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.

(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 °C as soon as possible after the water sampling.

TOC will be measured in a laboratory on land.

3.4.3 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 for systems A and B were estimated to be 1.0 (n = 113 pairs) and 0.9 (n = 107 pairs) µmol kg^{-1}, respectively. The combined result was 1.0 µmol kg^{-1} (n = 220 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 1.8 µmol kg^{-1} (n = 217 pairs).

(3) pH

The system had worked well with no troubles. The average of absolute differences between replicate samples were 0.0007 pH unit (n = 208 pairs).

3.4.4 Results

Cross sections of C_T, A_T and pH along WOCE I04 and I03 lines are illustrated in Fig. 3.6.1.

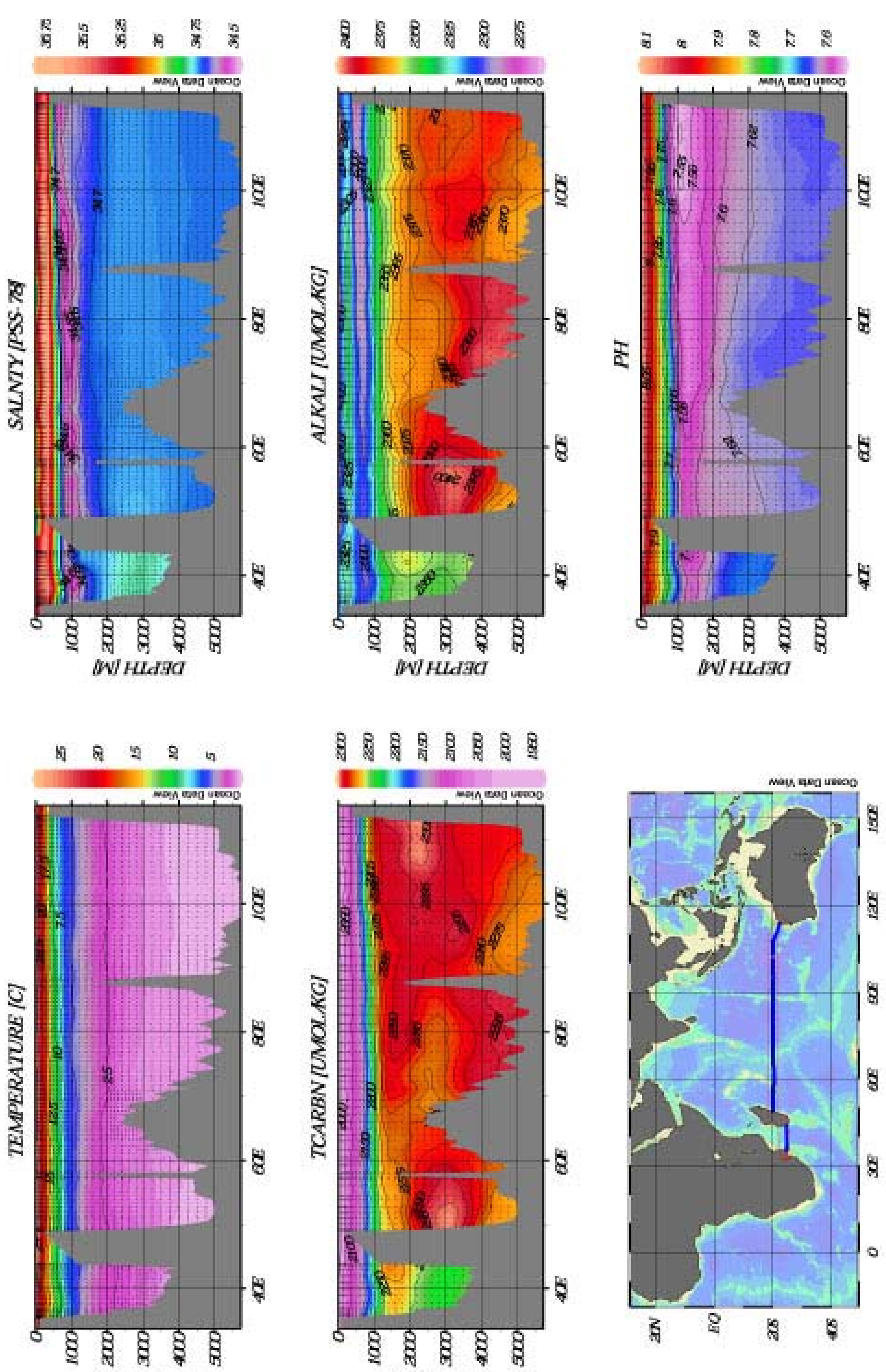

Fig.3.6.1 Distributions of temperature, C_T, salinity, A_T and pH.

3.7 Samples taken for other chemical measurement

3.7.1 Nitrogen/Argon

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(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 N_2,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 N_2, Ar and oxygen in the ocean, it is possible to estimate more accurate oxygen utilization.

N_2 Ar, and O_2 are main component gases of atmosphere and N_2 and Ar has non reactive gases in the ocean. The saturation of N_2 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 N_2 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.5, Indian 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 N_2 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 16 stations using the Niskin bottle

Station I04-603,595,551,543,530,525,517,512,505,498,491,480,471,464,459,452.

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 50 μl 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.3.7.1-1). Each gases analytical precision has below 0.1%.

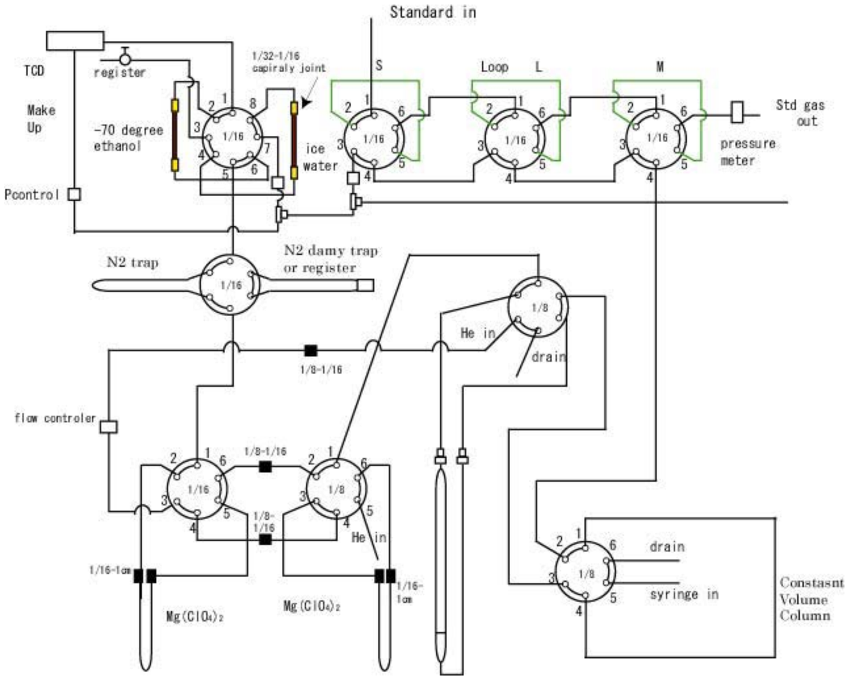

Fig.3.7.1-1 TCD-GC system

3.7.2 Carbon-14, carbon-13 (Feb. 3, 2004)

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 3.7.2.1. 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 μl of saturated $HgCl_2$ solution. Then the bottle was sealed by a glass stopper with Apiezon M grease and stored in a cool and dark space on board.

(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 3.7.2.1. The sampling stations and number of samples for carbon isotope ratios.

Station	No. samples	No. replicate samples	Max. sampling pressure /db
I04-601	25	3	3,084
I04-595	27	3	3,578
I04-589	28	3	3,725
I03-557	31	3	4,401
I03-551	34	3	5,002
I03-545	31	3	4,441
I03-535	33	3	4,823
I03-531	28	3	3,650
I03-525	27	2	2,935
I03-519	23	2	2,541
I03-513	30	3	4,240
I03-507	33	3	5,032
I03-503	34	3	5,168
I03-X08	34	3	4,928
I03-495	34	3	5,305
I03-491	33	3	4,951
I03-487	20	2	2,022
I03-480	35	3	5,251
I03-474	35	3	5,410
I03-470	35	3	5,419
I03-466	36	3	6,067
I03-463	36	3	5,751
I03-459	36	3	5,617
I03-455	34	3	5,140
I03-451	33	3	5,019
Total	785	72	

3.7.3 Radionuclides (April. 2004)

Michio AOYAMA : Geochemical Res. Dep. Meteorological Res. Inst., Japan
Ben OREGIONI (Leg5-1) : International Atomic Energy Agency, Marine Environment Laboratory
Janine GASTAUD (Leg5-2) : International Atomic Energy Agency, Marine Environment Laboratory

3.7.3.1, 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

3.7.3.2, 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.

3.7.3.3, 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.

3.7.3.4-1, Samples accomplished during leg 5-1

Samples for the surface seawater were collected at the 8 stations. At the 6 stations, a total of (80) samples (1766 L) were collected for water column and stored at room temperature. The filter papers are stored in the refrigerator in a frozen state.

3.7.3.4-2, Samples accomplished during leg 5-2 from Port-Louis to Fremantle

Samples for the surface seawater were collected at the 14 stations. At 11 stations, a total of (178) samples (2969 L) were collected for water column and stored at room temperature. The filter papers are stored in the refrigerator in a frozen state.

5, Problem occurred and solutions.

Any problem does not happened.

Leg5-1

combined sampling summary

Station	Lat.	Lon.	seawater		box type and number				
			depth	volume	total	20L	10L	5L	1L
IO4-606	24°40.04' S	37°53.46' E	0db	81L	80L	4			1
IO4-600	24°40.00' S	37°30.07' E	0db	81L	80L	4			1
			100db	8L	7L			2	1
			200db	20L	19L	1			1
			400db	8L	7L				1
			600db	19L	18L	1			1
			800db	18L	17L	1			1
			1000db	14L	13L	1			1
			1200db	9L	8L			2	1
			1400db	9L	8L			2	1
			2000db	20L	19L	1			1
			2400db	9L	8L			2	1
			3000db	21L	20L	1			1
			3383db	19L	18L	1			1
IO4-594	24°39.98' S	40°30.01' E	0db	81L	80L	4			1
			100db	9L	8L			2	1
			200db	21L	20L	1			1
			400db	9L	8L				1
			600db	19L	18L	1			1
			800db	21L	20L	1			1
			1000db	21L	20L	1			1
			1200db	9L	8L			2	1
			1400db	8L	7L			2	1
			2000db	20L	19L	1			1
			2400db	9L	8L			2	1
			3000db	21L	20L	1			1
			3551db	21L	20L	1			1
IO4-588	24°39.78' S	43°20.21' E	0db	81L	80L	4			1
			100db	8L	7L			2	1
			200db	21L	20L	1			1
			400db	8L	7L			2	1
			600db	21L	20L	1			1
			800db	21L	20L	1			1
			1000db	21L	20L	1			1
			1200db	8L	7L			2	1
			1400db	9L	8L			2	1
			2000db	21L	20L	1			1
			2400db	8L	7L			2	1
			3000db	21L	20L	1			1
			3500db	8L	7L	1		2	1
			3837db	21L	20L	1			1
IO3-557	20°00.08' S	50°03.95' E	0db	81L	80L	4			1
IO3-550	19°59.95' S	53°20.00' E	0db	81L	80L	4			1
			100db	9L	8L			2	1

Station	Lat.	Lon.	seawater		box type and number				
			depth	volume	total	20L	10L	5L	1L
			200db	21L	20L	1			1
			400db	8L	7L			2	1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	21L	20L	1			1
			1200db	8L	7L			2	1
			1400db	9L	8L			2	1
			2000db	6L	5L	1			1
			2400db	8L	7L			2	1
			3000db	8L	7L	1			1
			3500db	9L	8L	1		2	1
			4000db	9L	8L	1			1
			4500db	9L	8L	1			1
			4869db	21L	20L	1		2	1
IO3-544	20°00.11' S	56°37.93' E	0db	81L	80L	4			1
			100db	8L	7L			2	1
			200db	21L	20L	1			1
			400db	9L	8L			2	1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	21L	20L	1			1
			1200db	8L	7L			2	1
			1400db	8L	7L			2	1
			2000db	21L	20L	1			1
			2400db	8L	7L			2	1
			3000db	9L	8L	1			1
			3500db	9L	8L	1		2	1
			4000db	21L	20L	1			1
			4342db	21L	20L	1			1
IO3-536	20°22.00' S	58°37.04' E	0db	81L	80L	4			1
			100db	8L	7L			2	1
			200db	21L	20L	1			1
			400db	8L	7L			2	1
			600db	21L	20L	1			1
			800db	7L	6L	1			1
			1000db	21L	20L	1			1
			1200db	7L	6L			2	1
			1400db	8L	7L			2	1
			2000db	21L	20L	1			1
			2400db	8L	7L			2	1
			3000db	9L	8L	1			1
			3500db	9L	8L	1		2	1
			4000db	21L	20L	1			1
			4414db	21L	20L	1			1
Leg-5 小計			-	1766L	1678L	82L	0L	66L	88L

Leg5-2

combined sampling summary

Station	Lat.	Lon.	seawater		box type and number				
			depth	volume	total	20L	10L	5L	1L
IO3-530	20°22.12' S	62°14.23' E	0db	81L	80L	4			1
			100db	8L	7L			2	1
			200db	21L	20L	1			1
			400db	8L	7L			2	1
			600db	21L	20L	1			1
			800db	8L	7L			2	1
			1000db	21L	20L	1			1
			1200db	8L	7L			2	1
			1400db	8L	7L			2	1
			2000db	21L	20L	1			1
			2400db	6L	5L			2	1
			3000db	13L	12L	1			1
			3045db	21L	20L	1			1
IO3-525	20°05.56' S	64°55.98' E	0db	81L	80L	4			1
IO3-518	20°00.03' S	68°47.98' E	0db	81L	80L	4			1
			100db	8L	7L			2	1
			200db	21L	20L	1			1
			400db	8L	7L			2	1
			600db	21L	20L	1			1
			800db	21L	20L	1			1
			1000db	21L	20L	1			1
			1200db	8L	7L			2	1
			1400db	8L	7L			2	1
			2000db	21L	20L	1			1
			2400db	8L	7L			2	1
			2620db	21L	20L	1			1
IO3-512	20°00.13' S	71°41.97' E	0db	81L	80L	4			1
			100db	8L	7L			2	1
			200db	21L	20L	1			1
			400db	8L	7L			2	1
			600db	21L	20L	1			1
			800db	21L	20L	1			1
			1000db	21L	20L	1			1
			1200db	8L	7L			2	1
			1400db	8L	7L			2	1
			2000db	21L	20L	1			1
			2400db	8L	7L			2	1
			3000db	21L	20L	1		2	1
			3500db	8L	7L			2	1
			3485db	21L	20L	1			1
IO3-507	20°00.02' S	74°10.05' E	0db	81L	80L	4			1
IO3-502	19°59.99' S	77°37.97' E	0db	81L	80L	4			1
			100db	9L	8L	1			1
			200db	9L	8L	1			1

Station	Lat.	Lon.	seawater		box type and number				
			depth	volume	total	20L	10L	5L	1L
			400db	9L	8L	1			1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	9L	8L	1			1
			1200db	9L	8L	1			1
			1400db	9L	8L	1			1
			2000db	9L	8L	1			1
			2400db	9L	9L	1			
			3000db	9L	8L	1			
			3500db	9L	8L			2	
			4000db	9L	8L			2	
			4500db	9L	9L			2	
			5000db	9L	9L			2	
			5080db	21L	20L	1			1
IO3-494	20°00.00' S	83°23.98' E	0db	81L	80L	4			1
			100db	10L	9L	1			1
			200db	10L	9L	1			1
			400db	10L	9L	1			1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	9L	8L	1			1
			1200db	9L	8L	1			1
			1400db	9L	8L	1			1
			2000db	9L	8L	1			1
			2400db	8L	8L			2	
			3000db	8L	8L			2	
			3500db	9L	9L			2	
			4000db	9L	9L			2	
			4500db	9L	9L			2	
			5000db	9L	9L			2	
			5140db	21L	20L	1			1
IO3-487	20°00.03' S	87°19.95' E	0db	81L	80L	4			1
IO3-479	19°59.99' S	90°48.93' E	0db	81L	80L	4			1
			100db	9L	8L	1			1
			200db	9L	8L	1			1
			400db	9L	8L	1			1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	21L	20L	1			1
			1200db	9L	8L	1			1
			1400db	9L	8L	1			1
			2000db	8L	8L			2	1
			2400db	6L	6L			2	
			3000db	9L	9L			2	
			3500db	9L	9L			2	
			4000db	8L	8L			2	
			4500db	9L	9L			2	

Station	Lat.	Lon.	seawater		box type and number				
			depth	volume	total	20L	10L	5L	1L
			5000db	8L	8L			2	
			5500db	8L	8L			2	
			5095db	21L	20L	1			1
IO3-473	20°00.04' S	94°18.02' E	0db	81L	80L	4			1
			100db	9L	8L	1			1
			200db	9L	8L	1			1
			400db	9L	8L	1			1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	9L	8L	1			1
			1200db	9L	8L	1			1
			1400db	8L	8L			2	1
			2000db	7L	7L			2	1
			2400db	8L	8L			2	
			3000db	9L	9L			2	
			3500db	7L	7L			2	
			4000db	8L	8L			2	
			4500db	8L	8L			2	
			5000db	8L	8L			2	
			5073db	21L	20L	1			1
IO3-467	20°00.11' S	99°35.07' E	0db	81L	80L	4			1
			100db	10L	9L	1			1
			200db	9L	8L	1			1
			400db	8L	7L	1			1
			600db	8L	7L	1			1
			800db	8L	7L	1			1
			1000db	8L	7L	1			1
			1200db	8L	7L			2	1
			1400db	9L	8L			2	1
			2000db	9L	8L			2	1
			2400db	8L	8L			2	
			3000db	8L	8L			2	
			3500db	7L	7L			2	
			4000db	8L	8L			2	
			4500db	8L	8L			2	
			5000db	9L	9L			2	
			5500db	9L	9L			2	
			5770db	8L	7L			2	1
IO3-462	19°59.96' S	104°00.05' E	0db	81L	80L	4			1
			100db	9L	8L	1			1
			200db	9L	8L	1			1
			400db	9L	8L	1			1
			600db	9L	8L	1			1
			800db	9L	8L	1			1
			1000db	8L	7L	1			1
			1200db	7L	6L			2	1
			1400db	8L	7L			2	1

Station	Lat.	Lon.	seawater		box type and number				
			depth	volume	total	20L	10L	5L	1L
			2000db	8L	7L			2	1
			2400db	7L	7L			2	
			3000db	9L	9L			2	
			3500db	8L	8L			2	
			4000db	8L	8L			2	
			4500db	8L	8L			2	
			5000db	8L	8L			2	
			5500db	8L	8L			2	
			5575db	21L	20L	1			1
IO3-454	21°09.03' S	110°08.97' E	0db	81L	80L	4			1
			100db	9L	8L	1			1
			200db	9L	8L	1			1
			400db	8L	7L	1			1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	8L	7L	1			1
			1200db	10L	9L	1			1
			1400db	9L	8L			2	1
			2000db	9L	8L			2	1
			2400db	6L	6L			2	
			3000db	6L	6L			2	
			3500db	6L	6L			2	
			4000db	8L	8L			2	
			4500db	9L	9L			2	
			5000db	8L	8L			2	
			5030db	21L	20L	1			
IO3-450	22°00.10' S	112°22.86' E	0db	81L	80L	4			1
			100db	10L	9L	1			1
			200db	21L	20L	1			1
			400db	8L	7L	1			1
			600db	21L	20L	1			1
			800db	9L	8L	1			1
			1000db	21L	20L	1			1
			1200db	8L	7L	1			1
			1400db	8L	7L	1			1
			2000db	21L	20L	1			1
			2400db	8L	8L	1			
			3000db	8L	8L			2	
			3500db	8L	8L			2	
			4000db	9L	9L			2	
			4240db	21L	20L	1			
Leg 5B				2969L	2839L	146		152	128
Total				10338L	9901L	442L	87L	300L	425L

3.7.4 Helium Isotopes in seawater

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(1) Objective

Helium isotope ratio is one of important chemical tracers for discussion of water movement. Helium-3 is mainly diffused from earth interior and produced by decay of tritium (Clark, Beg and Craig, 1969). In southern hemisphere, former helium-3 is important. Distribution of helium-3 in mid-depth ocean indicates the source of helium-3 is hydrothermal activity in mid-ocean ridge and is spreading in the deep ocean waters (for example, Craig and Lupton, 1981, Lupton, 1998). Its distribution in the shallow ocean is related with tritium distribution. This helium is important to discuss mixing and transport to deeper ocean (for example, Jenkins, 1998).

In this leg, water samples for helium isotope analysis were collected at I03-547, I03-498 and I03-460 to discuss the lateral transport of deep ocean water in the Indian Ocean.

(2) Procedure

(2-1) Sampling method

Water sampling method is according to the WOCE Hydrographic Operation manual (Jenkins *et al*., 1991). Seawater samples were transferred from the Niskin bottle to the annealed copper tubing (o.d.: 3/8 inches, thickness: 1.5 mm, length: about 1 m) through plastic tubing. The seawater volume flushed through the copper tubing was about 6 times sample volume. During flushing, copper tubing was hit with wooden hummer and air babbles were removed completely. Plastic tubing both side of copper tubing was clipped with stopper. The copper tubing was clamped both side with special clamps inside of laboratory on board and these samples were kept inside room.

(2-2) Analysis

Helium isotopes are analyzed with static mass spectrometer after dissolved helium is degassed from seawater and purified. The determination of helium isotopes will be ordered to specialist.

References

Clark, W., M. A. Beg and H. Craig (1969) Excess ^{3}He in the sea: evidence for terrestrial primordial helium. *Earth Planet. Sci. Lett.*, **6**, 213-220.

Craig, H. and J. E. Lupton (1981) Helium-3 and mantle volatiles in the ocean and the oceanic crust. *The Sea, 7: The Oceanic Lithosphere*. Ed. C. Emiliani, Wily and Son, New York, 391-428.

Jenkins W. J.(1998) Studying subtropical thermocline ventilation and circulation using tritium and ^{3}He. *J. Geophys. Res.*, **103**, 15817-15831.

Jenkins W. J., D. E. Lott, M. W. Davis, S. P. Birdwhistell and M. O. Matthewson (1991) Measuring Helium Isotopes and Tritium in Seawater Samples. In: *WOCE hydrographic Operations and Methods, WOCE Operations Manual*, 3, Section 3.1, Part 3.1.3, WHP Office Report WHPO 91-1, WOCE Report No. 68/91, 21pp.

Lupton, J. E. (1998) Hydrothermal Helium Plumes in the Pacific Ocean. *J. Geophys. Res.*, **103**, 15853-15863.

3.8 Lowered Acoustic Doppler Current Profiler

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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 142 operations was made with the CTD observations. Because the depth was too deep, LADCP was not operated at the station I3_468. One ping raw data were recorded in 32 bins. Bin length was set for 8 m. Each sampling interval was 1.20 second. The accuracy is 2 cm/s in 8m-bin. Bottom-tracking mode was used and it succeeded to capture the bottom during the instrument was within 200m above the bottom. For the calculation of sound speed, we set salinity as constant value, 34 psu.

The performance of the LADCP instrument was good in the shallow ocean, where profiles were obtained over 100 m. In the deep ocean it reached almost 60 m. The performance looks as unchanged during the leg. Data transfer errors were often occurred during upload process from LADCP to PC.

The data will be analyzed by using the method of Visbeck (2002) with CTD and navigation data.

3.9 XCTD

Masao Fukasawa : JAMSTEC Principal Investigator
Tamaryn Morris : Marine and Coastal Management Principal Investigator
Yasutaka Imai : Global Ocean Development Inc.
Wataru Tokunaga : GODI
Shinya Okumura : GODI

(1) Observation

We observed the vertical profiles of sea water temperature and conductivity using TSK digital XCTD system developed by Tsurumi Seiki, Co. The system consists of an expendable probe, a launcher, the MK-100 data acquisition unit, and a computer. The probe contains a conductivity sensor, a temperature sensor, a battery, and system electronics. Conductivity is measured with an inductive cell that detects induced electromotive force in a toroid due to changes in seawater conductivity. Salinity is derived using this conductivity. Temperature is measured with a thermistor that changes resistance as a function of seawater temperature. Depth is calculated from the well known drop rate of the probe. Temperature and conductivity data from the sensor is transmitted to the surface by wire. It is in digital format and is collected and stored by the data acquisition system. The measurement range and accuracy of parameters are shown in Table 3.9.1. Mapped stations are presented in Fig.3.9.1. Information of the stations are summarized in Table 3.9.2.

Table 3.9.1 Measuring range and accuracy

Parameter	Range	Accuracy
Conductivity	0–60[mS/cm]	+/-0.03 [mS/cm]
Temperature	-2-32[deg-C]	+/-0.02 [deg-C]

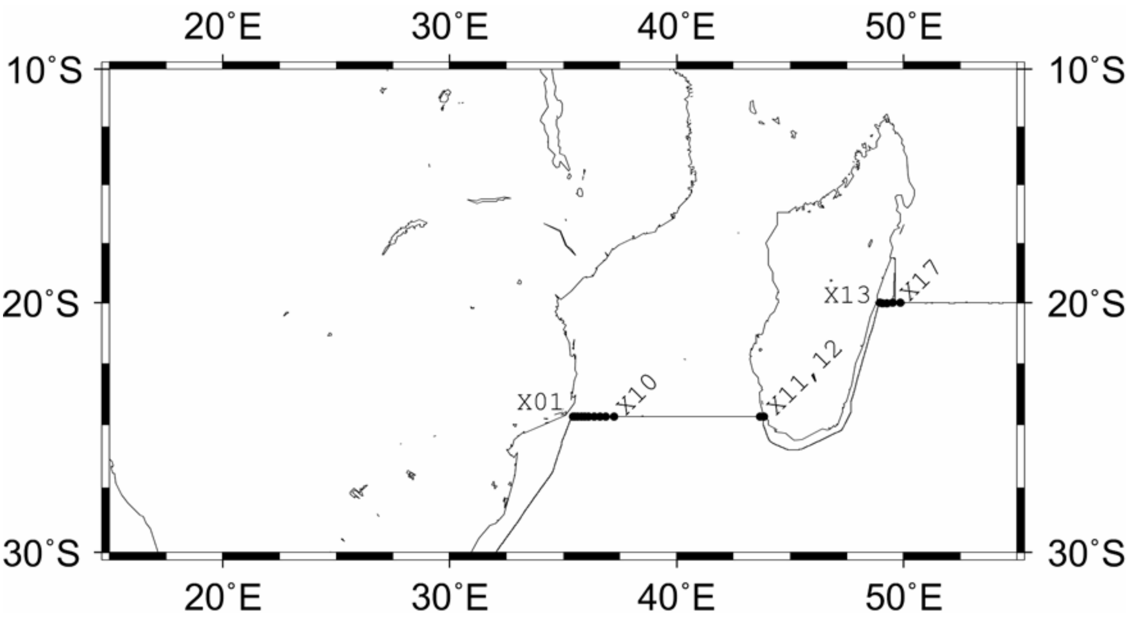


Fig.3.9.1 XCTD stations

Table 3.9.2 XCTD Observations

Station	Date	Time	Latitude	Longitude	SST [deg-C]	SSS [PSU]	Measured Depth[m]	Water Depth[m]	Serial Number
X01	2003/12/13	09:38	24-39.99S	35-25.71E	27.63	35.151	203	208	03022178
X02	2003/12/13	10:43	24-40.12S	35-31.09E	27.74	35.182	406	412	03022196
X03	2003/12/13	12:24	24-40.09S	35-38.18E	27.73	35.229	787	798	03022177
X04	2003/12/13	14:28	24-39.98S	35-48.14E	28.31	35.312	1022	1033	03022202
X05	2003/12/13	16:55	24-40.28S	35-56.74E	28.67	35.297	1035	1479	03022198
X06	2003/12/13	20:06	24-39.92S	36-07.45E	28.49	35.291	1034	1936	03022199
X07	2003/12/13	23:23	24-39.62S	36-22.55E	28.33	35.303	1034	2144	03022197
X08	2003/12/14	02:28	24-39.76S	36-37.54E	27.80	35.266	1035	2052	03022201
X09	2003/12/14	05:51	24-40.11S	36-52.59E	26.72	35.525	1035	2432	03022200
X10	2003/12/14	10:17	24-40.01S	37-15.09E	27.26	35.331	1035	3356	03022203
X11	2003/12/17	07:12	24-40.19S	43-40.66E	28.19	35.210	1035	2700	03022205
X12	2003/12/17	10:08	24-39.94S	43-50.28E	28.12	35.240	1035	1614	03022204
X13	2003/12/19	07:26	20-00.03S	48-57.25E	27.34	34.473	884	909	03022166
X14	2003/12/19	09:21	20-00.13S	49-04.26E	28.06	34.650	1035	1665	03022167
X15	2003/12/19	12:23	20-00.09S	49-16.23E	28.20	34.835	1034	2444	03022165
X16	2003/12/19	15:42	20-00.01S	49-30.75E	27.70	34.857	1035	3367	03022168
X17	2003/12/21	00:51	20-00.02S	49-51.02E	27.71	34.954	1035	4098	03022169

SST: Sea surface temperature [deg-C] measured by continuous sea surface monitoring system

SSS: Sea surface salinity [PSU] measured by continuous sea surface monitoring system

3.10 Bio-Optics Group

Principal Investigator : Dr Shubha Sathyendranath (Canada)
Scientist in charge on board : Pru Bonham (Australia)
POGO Trainees: : Dr Margareth Serapio Kyewalyanga (Tanzania)
Benjamin Wigley (South Africa)
(from Cape Town - Port Louis only)

With assistance from:
Cape Town - Port Louis
John Bemiasa (JAMSTEC observer for Madagascar)
Prof Dr Antonio Mubango Hoguane (Mozambique)
Jean Mwicigi (South Africa)
Port Louis - Fremantle
Dr Andrew Forbes (CSIRO Australia)

3.10.1 Introduction

The **B**lue **EA**rth **GL**obal **E**xpedition 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). The detailed objectives are:

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 the old WHP (World Ocean Circulation Experiment Hydrographic Program 1991-2002) lines.

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

3.10.2 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 achieve this objective, measurements of radiation (seawater reflectance) are being taken with a variety of radiometers (Simbad, Simbada, Ocean Optics.)
Samples are taken for the analysis of chlorophyll *a* and phaeopigments 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 picoplankton by flow-cytometry are also being collected.
Results from these analyses are expected to contribute to the validation and calibration, and to assist in the development of regional algorithms, for satellite-derived products (e.g., chlorophyll *a*) by sensors such as SeaWiFS, MODIS, and MERIS.

- To provide a training environment in which trainees could get hands-on experience in collecting phytoplankton related samples and bio-optical data.

- To gain basic knowledge about some of the analysis and processing of bio-optical data.

3.10.3 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 were taken at the surface, or near surface, of the ocean, except for a second set of samples for chlorophyll analysis which were generally taken at the depth of the fluorescence maximum. Analysis of chlorophyll *a* and phaeopigments concentrations, particulate and CDOM absorption, and P&I incubations were performed on board, while HPLC, flow cytometry and ^{13}C (for the calculations of P&I parameters), as well as a duplicate set of particulate absorption samples, are going to be processed in different laboratories (in Canada, Australia, South Africa and Chile) after the end of the cruise. A preliminary processing of some of the data available was developed onboard during Leg 4, and continued on Leg 5.

3.10.4 Features of Leg 5

During leg 5, the main focus was again on chemical and physical oceanography. A total of 146 CTD casts were performed.

For the bio-optical sampling, either one or two stations a day were occupied. Initially, it was intended to sample one station close to noon and another about 4 hours earlier or later. However, on several days, the CTD casts were extremely deep – up to 6300m. Often there was an extensive time delay between casts and it was only possible to sample one station. Additionally there were only two scientists in the Bio-optical team for most of Leg 5, with occasional help from a third scientist, and it was not always feasible to sample two stations a day.

Whenever possible, seawater samples were taken from Niskin bottles at the 5m depth. At several deeper stations, there were not enough Niskin bottles for all the required sampling, and a bucket was used to collect surface water samples. An extra sample for determining the concentration of chlorophyll and phaeopigments was taken from the depth of the fluorescence maximum (indicated by the *in situ* fluorometer attached to the CTD). Again, on the deeper section, it was not always possible to fire a bottle at the chlorophyll maximum, and a sample was taken from the bottle depth closest to the chlorophyll maximum.

Radiation measurements (seawater reflectance) were performed about one hour before the rosette sampling, or approximately one hour after the bucket sampling.

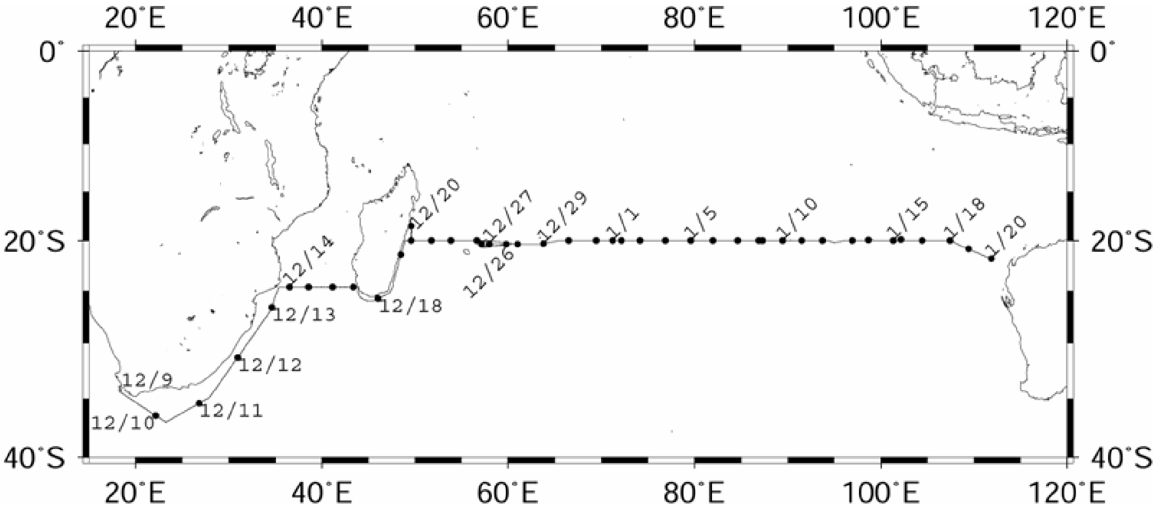


Fig.3.10.1 R/V Mirai cruise track, BEAGLE expedition 2003-2004, Leg 5

I. BIOLOGICAL SAMPLING

On Leg 5, 50 complete sets of biological samples were collected, sampling the following parameters. Stored data records are generally divided into week1-7, starting on Mondays.

Photosynthesis v/s Irradiance (PI) Experiments

Each day 1 or 2 experiments were carried out. 42 bottles (and 3 dark bottles) were incubated with 13C in a Larsen box for 3 hours. The contents of 3 bottles, incubated at similar light intensities, were filtered through a single filter and dried at 52ºC. Light intensities in the 42 positions in the box were measured daily and recorded. The filters are to be analysed by mass spectrometry at University of Concepcion (Chile.)
Storing: filters were dried and stored in sets of 15 labelled envelopes. Light intensity results are in folder: JAMSTEC/ Leg5/reports&summaries/PIlightleg5

CDOM

Water samples for the determination of coloured-dissolved-organic-matter were filtered through 0.2 μm polycarbonate membrane filters, and immediately scanned in a 10 cm quartz cuvette in a CARY BIO 50 UV/VIS spectrophotometer. Absorption was measured from 250-750nm with a 50mm pathlength.
Storing: no samples were stored. Results are in folder: JAMSTEC/CDOM/Leg5/week/dailyfolder ("a" and "b" if two samples were taken in one day.)

Chlorophyll and Phaeopigments concentration

Triplicate water samples from the surface and chlorophyll maximum (or the closest depth) were filtered through 25 mm GF/F glass fibre filters immediately after sampling, extracted in 90:10 acetone, and stored overnight in a freezer. Chlorophyll-*a* and phaeopigments concentrations were measured onboard using a digital Turner Designs 10-AU fluorometer.

Storing: no samples were stored. Results are in folder: JAMSTEC/Leg5/chlorophylls/week/daily files

Phytoplankton Particulate Absorption

Duplicate samples were collected and filtered through 25 mm GF/F glass fibre filters for the determination of particulate absorption. One sample was immediately scanned on board in a CARY BIO 50 UV/VIS spectrophotometer, and the other will be analysed at the Bedford Institute of Oceanography. Ten replicates were read from each particulate sample filter and a blank filter. The sample and blank were then treated with methanol and rescanned.

Storing: The duplicate samples were frozen in liquid nitrogen in a labelled cryogenic vial and then stored in a deep freezer (-80^{o}C). Results of the samples analysed on board are in folder: JAMSTEC/Absorption/Leg5/week/dailyfolder (“a” and “b” if two samples were taken in one day.)

High Performance Liquid Chromatography

Two samples were collected and filtered through 25mm GF/F glass fibre filters for the determination of phytoplankton pigment composition by HPLC. These samples will be analysed in two different laboratories: University of Cape Town (South Africa) and CSIRO Marine Research Hobart (Australia) by Bio-optical specialist Lesley Clementson.

Storing: Both samples were frozen in liquid nitrogen and then stored in two separate labelled aluminium foil envelopes in a deep freezer (-80^{o}C).

Picoplankton

Two samples were collected from surface seawater, fixed with paraformaldehyde, and frozen for later analysis by flow cytometry at Bedford Institute of Oceanography.

Storing: Both samples were frozen in liquid nitrogen and then stored in two separate labelled cryotubes in a deep freezer (-80^{o}C).

II. OPTICAL SAMPLING

SIMBAD

The SIMBAD-03 radiometer had stopped working in the first week of the previous leg (leg 4) It is hoped that the bio-optical specialist on leg 6 may be able to repair it.

Storing: no results for SIMBAD from Leg 5

SIMBADA_21

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 taken are 1 Dark, 3 Sun, 6 Sea, 3 Sun, and 1 Dark. One set of Simbada measurements was taken while on station, as close to noon as possible. On the days of deeper CTD stations, readings were usually made about 09.30-10.00 as filtering PI samples took preference later, and the ship was often not on station nearer to noon.

On Leg 5, there appear to be some problems with the Simbada_21 functioning after the change to the New

Year. The date record is incorrect, and the sun, sea and dark files are all in similar format to the normal "dark" files.Probably the data are retrievable by someone with expertise in the Simbada programming. We continued to collect data until the end of Leg 5.

Storing: The files are in the folder JAMSTEC/Leg5/simbada21/week/dailyfolder.

Hyperspectral radiometer (Ocean Optics)

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 grey plaque that diffuses the incident irradiance.

One set of Ocean Optics measurements was taken while on station, as close to noon as possible. On the days of deeper CTD stations, readings were usually made about 09.30-10.00 as filtering PI samples took preference later, and the ship was often not on station nearer to noon.

Note: The Ocean Optics reader is designed with an operating temperature of around 20°C. On deck temperatures on Leg 5 were always above 25°C, and above 30°C at the western end of the Leg. To bring the reader down to operating temperature, a double plastic tub was used, with the outer box containing freezer bricks and iced water. The OO reader was placed in an inner, dry plastic box. Trial and error proved that the fastest way to bring the reader down to operating temperature on deck was to cool the boxes for at least 30 minutes and place the reader in the cooler box about 5 minutes before taking it on deck. Usually the OO reader then reached operating temperature in about 5 minutes.

Storing: Files are in folder JAMSTEC/Leg5/OO-processed/week/dailyfolder

Photosynthetically 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/Leg5/PAR_sensor_data/PAR_Leg5.txt

3.10.6 Pogo Trainees Activities

On leg 5, the bio-optical team had two official POGO/IOCCG trainees, Margareth Serapio Kyewalyanga (Tanzania) and Ben Wigley (South Africa). Initially they were both scheduled to participate in Bio-optical sampling from Cape Town to Fremantle, however Ben had to leave the ship in Port Louis for medical reasons.

In his brief time on Mirai, when he was well enough to work, Ben assisted with general laboratory analysis, some radiation measurements and data processing. His skills in gathering photographic records of activities, and performing data backups, were particularly appreciated. We think Ben enjoyed the CTD sampling watches and was able to relate well to the MWJ and Jamstec scientists. We enjoyed working with Ben and wish him all the best for his future studies.

Margareth already had considerable experience in many of the bio-optical techniques during her PhD studies. Her knowledge was a significant assistance to the program, complementing some of the areas in which I, as a general phytoplankton biologist rather than a Bio-optical specialist, had less experience. The collection of 50 sets of Bio-optics samples on Leg 5 would not have been possible without Margareth's skills, attention to detail, energy and enthusiasm for her work. In particular, Margareth's experience in Fortran programming meant that processing of particulate absorption data could be continued on leg 5.

Trainees Remarks

Margareth Serapio Kyewalyanga (Tanzania)

This cruise was a very unique opportunity for me! I am happy and proud that I got a golden chance to attend part of the prestigious BEAGLE 2003 Expedition. Working onboard the RV Mirai was an eye-opener to modern oceanographic equipment and facilities. The experience gained will be an asset to me, and my Institute, in our future research plans.

I have learned some new techniques such as determination of downwelling and water-leaving irradiance using modern Instruments (Simbada and Hyperspectral Radiometer); determination of coloured dissolved organic matter, using a spectrophotometer; and how to collect an array of samples from the CTD for water chemistry analysis. In addition, it was refreshing to do again some of the measurement, which I was familiar with (such as PI incubations and particulate absorption).

All the above wouldn’t have been possible without the generous sponsorship by POGO, to which I am very grateful. Working with Pru Bonham was a delight; she is full of energy, enthusiasm and teamwork sprit. This made even the hard work seem easy. I would like to thank the JAMSTEC staff for their support and cooperation. The help provided by MWJ technical staff is highly appreciated. Last, but not least, I would like to thank the Captain of RV Mirai, the Officers and Crew Members, who worked so hard to make our day-to-day life on board so smooth!

Ben Wigley

A report was requested from Ben, but it had not arrived by the date of compiling my report. Possibly it has been sent directly to POGO, or to my CSIRO email address. If so, I will forward to Dr Venetia Stuart when I return to Hobart.

3.10.7 Data Processing

A series of Fortran routines developed by Dr Vivian Lutz and colleagues during Leg 3 and extended during Leg 4, were used to process the absorption data. Phytoplankton concentrations were again extremely low during Leg 5.

Results can be found in the directory /JAMSTEC/Leg5/data-process.

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.

Ocean Optics data were processed on board into daily Excel worksheets. Additionally, Microcal Origin software was utilised to produce four preliminary graphs for most files:

- L_m (sea), L_{sky}, L_{spec} radiances
- water-leaving radiance L_W
- downwelling radiance E_D
- and Remote Sensing Reflectance (RRS).

The only preliminary data control was the removal of negative outlier data points in some graphs. A

comment worksheet and key to these files has been provided in:
/JAMSTEC/Leg5/OO-processed/OOprocessed-Leg5summary.xls.

Some of the initial files show the sky radiance peaking over 4000. This has been noted. Later in the cruise more experience with the software and determination of integration times largely avoided this. However there were still occasions when the integration time was set appropriately for the conditions, but highly variable solar radiation during the reading caused the readings to run over the limit.

Note: The collecting and processing of Ocean Optics data was made much more difficult by the slow speed and unreliability of the Toshiba laptop computer. Each Excel worksheet is about 6MB in size and the laptop often had difficulty using Excel and Origin software routines, causing it to "hang up" regularly. Also, it is slow to start up and frequently "hung up" when used on deck, or was very slow to react to operator input such as changed integration times. This often made the on-deck procedures more prolonged than necessary.

3.10.8 Preliminary Results

This is a preliminary analysis of some of the results obtained on Leg 5. The cruise track is shown in figure 1.

Chlorophyll and phaeopigments: During this leg chlorophyll concentrations were extremely low (Table 3.10.1). The exception was the final sample collected on Leg 5, which was collected just off the Australian coast. This sample does not have a matching absorption or CDOM sample and has not been included in the average.

Chlorophyll concentration and Particulate Absorption (these paragraphs have been contributed by Dr Margareth Kyewalyanga. I have not reproduced the figures which she has attached to her individual report.)

Although 1.5 litres of seawater were filtered, some of the particulate absorption data lay close to the limit of detection of the spectrophotometer. This caused those spectra to look very noisy. 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.

Surface chlorophyll concentrations were very low; ranging from 0.016 to 0.142,
with an average of 0.037 mg m^{-3} (excluding the final sample collected.). Relatively high values were only observed close to the coast of South Africa and Australia (concentration greater than 0.05 mg m^{-3}). Owing to such low concentrations of chlorophyll-*a*, the resultant absorption spectra of phytoplankton was noisy, despite taking 10 spectra of each for averaging. The shapes, and in most cases the magnitude, of the total particulate absorption and phytoplankton absorption were always similar, suggesting that there was less detrital materials in these waters. Thus, these are case 1 waters, where light absorption by particulate matters is dominated by phytoplankton, albeit of low concentration.

It is also assumed that the waters are dominated by picoplanktonic cells, which easily pass through the GF/F filter. This is further supported by high values of specific absorption coefficient of phytoplankton, which ranged from 0.053-0.294 (average 0.181), with about 50% of the total data being above 0.2 m^2.mg chl-a^{-1}. Hopefully, results from flow cytometry analysis will be able to shed light on the cell size composition in the waters.

In two cases (21st December 03; ID 264371 and 6th January 2004: ID 264396),
the water filtered through the Millipore filter (0.2µm) showed some orange-brownish colouration. As a result, although the sample (filtered through GF/F filter) was not coloured, the blanks became coloured because they were rinsed with the 0.2µm filtered sea-water. This completely altered the shapes and magnitude of the spectra (so that the blanks had much higher absorbance than the samples) resulting into

complete negative absorption values. We hypothesize that the smaller cells present in the water were probably delicate and burst during filtration, resulting in the observed colouration. This hypothesis could only be proved after analysis of HPLC and Flow Cytometry samples.

3.10.9 Acknowledgements

We would like to thank all those responsible at POGO, IOCCG and JAMSTEC, also the Chief and staff at CSIRO Marine Research, for giving us the opportunity of being able to participate in the BEAGLE 2003-04 expedition. We appreciate the support and leadership of the Chief Scientist on Leg 5, Prof. Masao Fukasawa. We particularly acknowledge his support and kindness in allowing Margareth to cease CTD watches so that she could concentrate on sampling, after our Bio-optics team was reduced to two scientists from Port Louis to Fremantle. We also record our thanks to the chief sampling scientist and the sampling teams for their cooperation and assistance in this matter.

From Cape Town to Port Louis, when one of the trainees, Ben Wigley, was unable to work due to illness for most of the period, we are extremely grateful to the following people who gave us considerable assistance in sampling and processing:

John Bemiasa (JAMSTEC observer), Institut Halieutique Sciences Marines, Madagascar,
Prof Dr Antonio Mubango Hoguane, Universidade Eduardo Mondlane, Mozambique,
and Jean Mwicigi, University of Cape Town, South Africa

After Port Louis, Dr Andrew Forbes (CSIRO Marine Research, Australia) volunteered to assist the Bio-optics group. His support with Fortran programming and data backup, plus on deck assistance with the solar radiation measurements, was invaluable, because it allowed Margareth and myself more time for laboratory analysis.

Special thanks to Principal Investigator Shubha Sathyendranath, and Bio-optical specialists Lesley Clementson, Venetia Stuart and Vivian Lutz for their support during Leg 5. Thanks especially to Vivian for the provision of shorter guides and her excellent training before Leg 5. Eric Madsen and Brian Griffiths (CSIRO Marine Research) have provided a replacement Turner Fluorometer cable for Leg 6.

It has been a privilege and a unique experience for us to work on this vessel and participate in this research expedition. We sincerely appreciate the professional collaboration and cooperation received from Prof Masao Fukosawa, Dr Takeshi Kawano, the entire scientific and sampling team from JAMSTEC and Marine Works Japan, as well as Captain Akamine Masaharu, the officers and crew of the *R/V Mirai*.

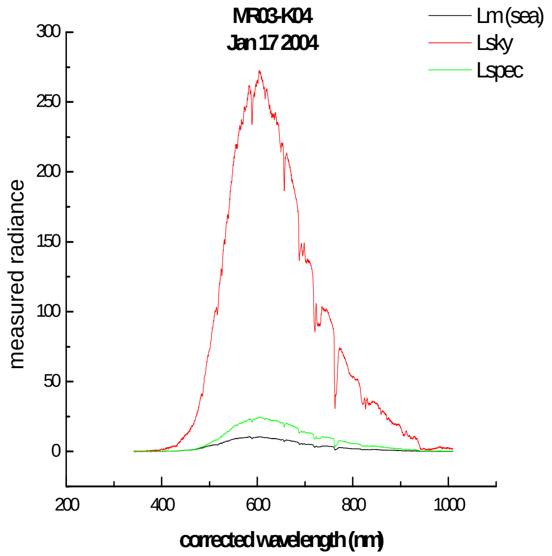
Table 3.10.1 Summary of chlorophyll-*a* and phaeophytin-*a* results from Leg 5

Station ID	Sample ID	Depth(m)	Chl-*a* (mg m^{-3})	phaeo-*a* (mg m^{-3})	Comments
AI04-610N	264362	0	0.097	-0.006	
	264362	45	0.985	0.138	
AI04-602N	264363	0	0.075	-0.012	
	264363	90	0.329	0.337	
AI04-596N	264365	0	0.066	-0.002	
	264365	75	0.585	0.179	
AI04-592N	264366	0	0.071	-0.001	
	264366	60	0.867	0.251	
AI04-591C	264367	0	0.064	0.001	
	264367	55	0.289	0.060	
AI04-586C	264368	0	0.142	0.004	
	264368	65	0.313	0.046	
I03-562N	264369	0	0.092	-0.005	
	264369	60	0.313	0.100	
I03-560N	264370	0	0.040	-0.003	
	264370	95	0.121	0.046	
I03-557N	264371	0	0.037	-0.003	
	264371	120	0.185	0.116	
I03-556N	264372	0	0.033	-0.002	
	264372	100	0.240	0.081	
I03-553N	264373	0	0.035	0.004	
	264373	100	0.267	0.123	
I03-552N	264374	0	0.046	-0.004	
	264374	115	0.209	0.136	
I03-X07C	264375	0	0.039	-0.001	
	264375	110	0.193	0.088	
I03-547N	264376	0	0.030	-0.001	
	264376	100	0.192	0.076	
I03-542C	264377	0	0.028	-0.002	
	264377	100	0.196	0.074	
I03-538C	264379	0	0.039	-0.003	
	264379	115	0.088	0.020	
I03-533C	264381	0	0.037	-0.003	
	264381	110	0.174	0.088	
I03-531C	264382	0	0.029	0.001	
	264382	115	0.149	0.081	
I03-530N	264383	0	0.016	0.002	
	264383	120	0.116	0.093	
I03-526N	264384	0	0.024	0.004	
	264384	110	0.179	0.109	
I03-521C	264385	0	0.031	0.001	
	264385	115	0.136	0.062	
I03-520N	264386	0	0.019	-0.002	
	264386	120	0.134	0.072	
I03-516N	264387	0	0.019	0.000	
	264387	130	0.130	0.062	
I03-515N	264388	0	0.016	0.000	
	264388	130	0.141	0.100	
I03-511C	264389	0	0.018	-0.002	
	264389	125	0.128	0.057	
I03-510N	264390	0	0.016	-0.002	
	264390	125	0.088	0.034	
I03-506N	264391	5	0.016	0.000	
	264391	145	0.129	0.080	
I03-503C	264392	0	0.019	-0.001	
	264392	110	0.142	0.059	

I03-502N	264393	0	0.017	0.000	
	264393	135	0.146	0.105	
I03-X08C	264394	0	0.018	0.001	
	264394	120	0.101	0.042	
I03-498N	264395	5	0.019	0.001	
	264395	140	0.139	0.110	
I03-495C	264396	0	0.027	-0.003	
	264396	100	0.172	0.090	
I03-492N	264398	0	0.030	0.000	
	264398	115	0.139	0.087	
I03-491C	264399	0	0.020	0.002	
	264399	80	0.146	0.010	
I03-487C	264400	5	0.023	0.000	
	264400	130	0.130	0.063	
I03-486N	264401	5	0.021	0.001	
	264401	100	0.108	0.024	
I03-481N	264402	0	0.025	0.003	
	264402	115	0.156	0.090	
I03-480C	264403	0	0.018	0.001	
	264403	145	0.134	0.080	
I03-477C	264404	0	0.021	0.003	
	264404	85	0.137	0.029	
I03-476N	264405	0	0.019	0.001	
	264405	125	0.150	0.108	
I03-473N	264406	0	0.025	0.000	
	264406	110	0.212	0.093	
I03-470C	264407	0	0.029	-0.001	
	264407	115	0.153	0.086	
I03-469N	264408	0	0.025	-0.001	
	264408	100	0.111	0.053	No chl max bottle
I03-467N	264409	0	0.027	-0.003	
	264409	150	0.074	0.041	No chl max bottle
I03-464C	264410	0	0.029	0.004	
	264410	100	0.151	0.101	Chl max not known
I03-461C	264411	0	0.033	0.003	
	264411	100	0.163	0.063	No chl max bottle
I03-458N	264412	0	0.035	0.000	
	264412	85	0.213	0.090	
I03-454N	264413	0	0.052	-0.003	
	264413	90	0.210	0.118	
I03-451C	264414	0	0.067	-0.008	
	264414	75	0.304	0.157	
I03-450N	264415	0	0.057	-0.005	
	264415	85	0.367	0.235	
I03-444N	264416	0	1.538	-0.123	
	264416	45	1.505	-0.049	

Fig.3.10.2 Preliminary Hyperspectral radiometer (Ocean Optics) results

Ocean Optics files from a day with heavy overcast, January 17, 2004



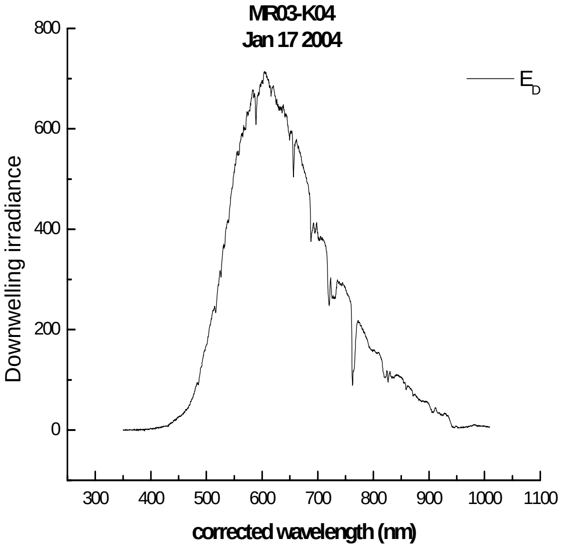
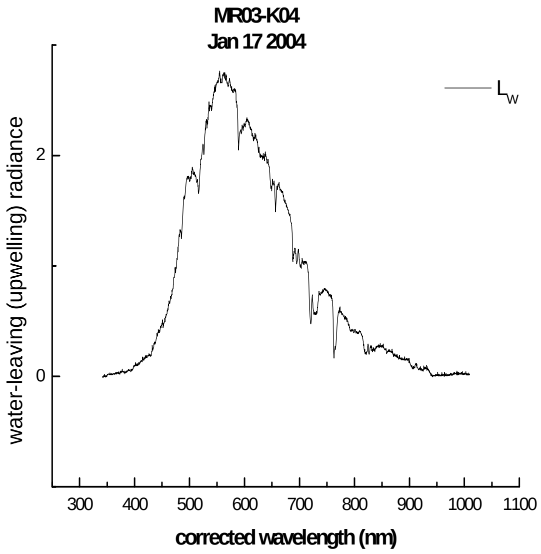


Fig.3.10.2a. Measured radiances from sea, sky and spectralon	Fig.3.10.2b. Downwelling radiance measured with spectralon



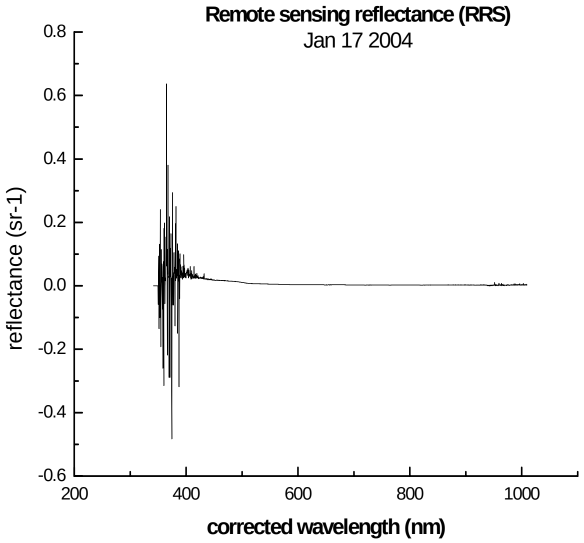
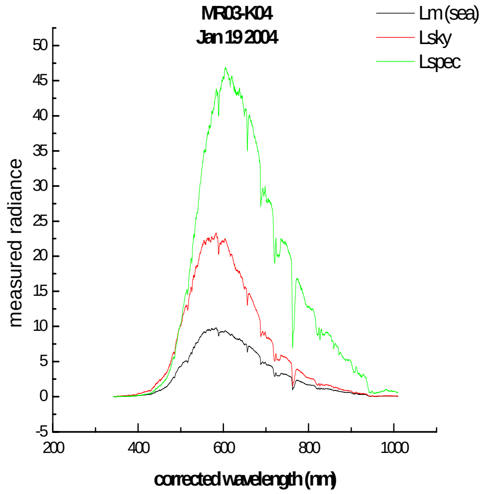


Fig.3.10.2c. Water leaving radiance L_W	Fig.3.10.2d. Remote sensing reflectance RRS

Fig.3.10.3 Preliminary Hyperspectral radiometer (Ocean Optics) results

Ocean Optics files from a sunny day, January 19, 2004



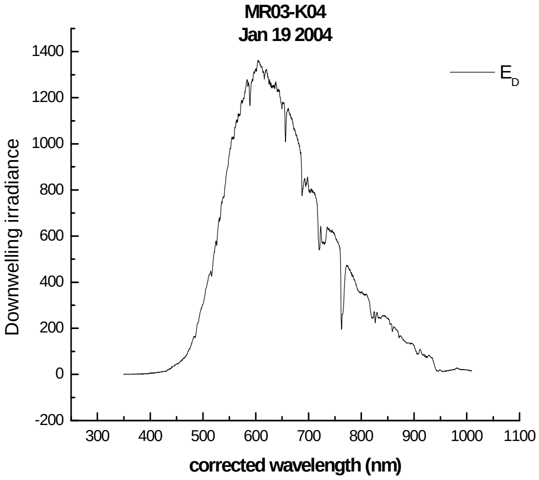
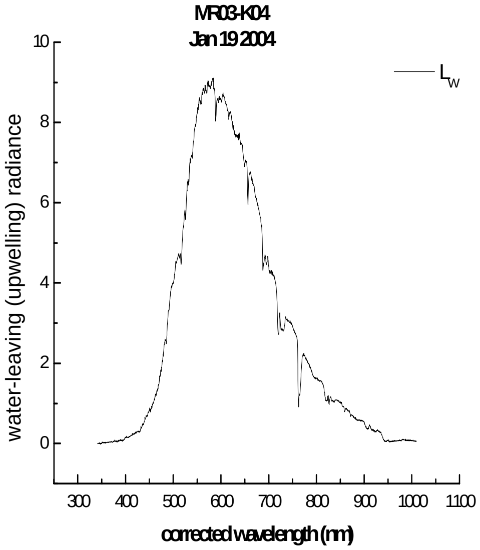


Fig.3.10.3a. Measured radiances from sea, sky and spectralon	Fig.3.10.3b. Downwelling radiance measured with spectralon



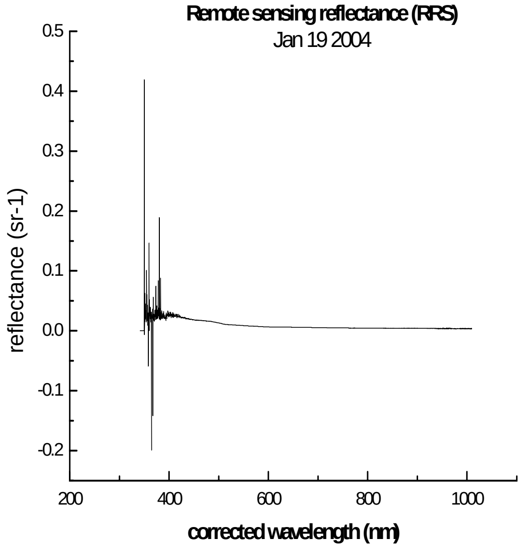


Fig.3.10.3c. Water leaving radiance L_W	Fig.3.10.3d. Remote sensing reflectance RRS

4. Floats and Drifters

4.1 Argo float

Nobie Shikama : FORSGC, Principal Investigator (not on board)
Eitarou Oka : FORSGC, not on board
Mizue Hirano : FORSGC, not on board
Hiroshi Matsunaga : MWJ, Technical Staff
Tomoyuki Takamori : MWJ, Technical Staff

4.1.1 Objectives

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

The profiling floats launched in this cruise measure 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 in previous studies.

4.1.2 Parameters

・water temperature, salinity, and pressure

4.1.3 Methods

1) Profiling float deployment

We launched 13 APEX floats manufactured by Webb Research Ltd. These floats equip an SBE41 CTD sensor manufactured by Sea-Bird Electronics Inc.

The 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 the CTD data to the land via the ARGOS system, and then return to the parking depth by decreasing volume. The status of floats and their launches are shown in Table 13.1-1.

4.1.4 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 floats and their launches

Float

Float Type	**APEX floats manufactured by Webb Research Ltd.**
CTD sensor	**SBE41 manufactured by Sea-Bird Electronics Inc.**
Cycle	**10 days (approximately 9 hours at the sea surface)**
ARGOS transmit interval	**30 sec**
Target Parking Pressure	**2000 dbar**
Sampling layers	**110 (1950, 1900, 1850, 1800, 1750, 1700, 1650, 1600, 1550, 1500, 1450, 1400, 1350, 1300, 1250, 1200, 1150, 1100, 1050, 1000, 975, 950, 925, 900, 875, 850, 825, 800, 775, 750, 725, 700, 675, 650, 625, 600, 580, 560, 540, 520, 500, 490, 480, 470, 460, 450, 440, 430, 420, 410, 400, 390, 380, 370, 360, 350, 340, 330, 320, 310, 300, 290, 280, 270, 260, 250, 240, 230, 220, 210, 200, 195, 190, 185, 180, 175, 170, 165, 160, 155, 150, 145, 140, 135, 130, 125, 120, 115, 110, 105, 100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, 4 dbar)**

Launches

Float S/N	ARGOS PTT ID	Date and Time of Reset (UTC)	Date and Time of Launch (UTC)	Location of Launch	CTD St. No.
1077	20647	00:21, Dec. 26	01:49, Dec. 26	20-22.87 S, 059-49.40 E	I03-534
1078	20724	16:45, Dec. 28	17:47, Dec. 28	20-21.16 S, 062-51.36 E	I03-529
1080	20773	18:42, Dec. 29	20:24, Dec. 29	19-59.85 S, 065-58.88 E	I03-523
1079	20725	17:37, Dec. 30	18:48, Dec. 30	19-59.81 S, 068-47.65 E	I03-518
1097	21997	20:16, Jan. 01	21:50, Jan. 01	19-58.97 S, 071-41.65 E	I03-512
1098	22083	05:47, Jan. 03	06:15, Jan. 03	19-59.11 S, 074-43.92 E	I03-506
1075	20590	07:39, Jan. 04	09:05, Jan. 04	19-59.74 S, 077-37.42 E	I03-502
1076	20644	09:53, Jan. 05	11:18, Jan. 05	19-58.41 S, 080-32.71 E	I03-498
1094	21341	12:04, Jan. 06	13:28, Jan. 06	19-59.53 S, 083-24.76 E	I03-494
1073	20572	18:39, Jan. 07	20:00, Jan. 07	19-58.51 S, 086-28.15 E	I03-489
947	26426	04:45, Jan. 10	06:20, Jan. 10	19-59.53 S, 089-59.70 E	I03-481
946	26080	14:05, Jan. 11	15:58, Jan. 11	19-58.80 S, 092-48.40 E	I03-475
1096	21561	18:35, Jan. 12	20:10, Jan. 12	19-59.36 S, 096-04.02 E	I03-471