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JAPAN MARINE SCIENCE AND TECHNOLOGY CENTER

CRUISE REPORT

R/V Mirai Cruise MR03-K02

21 MAY 2003 – 6 JUNE 2003

Wake Island passage Flux Experiment (WIFE)

Edited by H Uchida

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ABSTRACT

R/V Mirai cruise MR03-K02 was carried out mainly as a part of the project, a study on the heat and material transports and their variability of the ocean general circulation, in the Ocean Observation and Research Department, Japan Marine Science and Technology Center. Wake Island passage Flux Experiment (WIFE) is designed to determine volume transport, material transports, heat storage and their variability of the abyssal water flowing into the North Pacific through the Wake Island Passage. This cruise was the first WIFE cruise.

The cruise ports ware Yokohama, Japan to Guam, USA. Five deep moorings were placed along a transect of the abyssal passage. A total of 25 CTDs and 15 current meters were deployed. And nine full-depth CTD/RMS/LADCP stations were worked with a SBE9/11plus CTD, a GO 36x12 litter Carousel Water Sampler and a RDI WorkHorse ADCP. Salinity, oxygen, silicate, nitrate, nitrite, phosphate, CFC-11, CFC-12, TCO_2 (or DIC), total alkalinity and pH were measured. Samples for ^{14}C and ^{13}C were collected.

Meteorological parameters, sea-surface temperature, salinity, oxygen, TCO_2, pCO_2/PCO_2, current profiles to 700m from a shipboard RDI 75 kHz ADCP, bottom topography, gravity acceleration, 3-component magnetic field and other continuous measurement items were measured throughout the cruise except for in the EEZ of Federated States of Micronesia.

Seven ARGO profiling floats were deployed during the cruise. A CTD/RMS/LADCP station was worked to 2000m at a point of deployment in order to calibrate the ARGO temperature and conductivity sensors.

A TRITON (Triangle Trans-Ocean Buoy Network) buoy at 8N, 156E was recovered and re-installed. Two CTD/RMS stations were worked to 1000m before the recovery and after the installation of TRITON buoy in order to calibrate the TRITON temperature and conductivity sensors.

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1 CRUISE NARRATIVE

Hiroshi Uchida (Japan Marine Science and Technology Center)

1.1 Highlights

R/V Mirai Cruise MR03-K02,
Wake Island passage Flux Experiment (WIFE)

Expedition Designation (EXPOCODE): 49MR03K02_1

Chief Scientist: Hirofumi Yamamoto,
Ocean Observation and Research Department,
Japan Marine Science and Technology Center,
2-15 Natsushima, Yokosuka,
Kanagawa 273-0061, JAPAN

Captain: Masaharu Akamine,
Global Ocean Development Inc.,
3-65 Oppamahigashi, Yokosuka,
Kanagawa 237-0063, JAPAN

Ship: R/V Mirai
Overall length: 130m
Maximum draught: 6.9m
Net tonnage: 2,601tons
Gross tonnage: 8,687tons
Propulsion: 1,838kw x 720rpm x 4 Diesel electric motors, twin screws
Cruise speed: 16knots

Ports of Call: Yokohama, Japan to Guam, USA

Cruise Dates: May 21, 2003 to June 6, 2003

1.2 Cruise Summary

Cruise Track

The cruise track and station locations are shown in Figure 1.2.1. Station locations of the WIFE with bottom topography are shown in Figure 1.2.2. Station number for the mooring (WM) and the CTD/RMS/LADCP (WC) are also shown. Bottom topography is based on a multi narrow beam used in this cruise and Smith and Sandwell (1997).

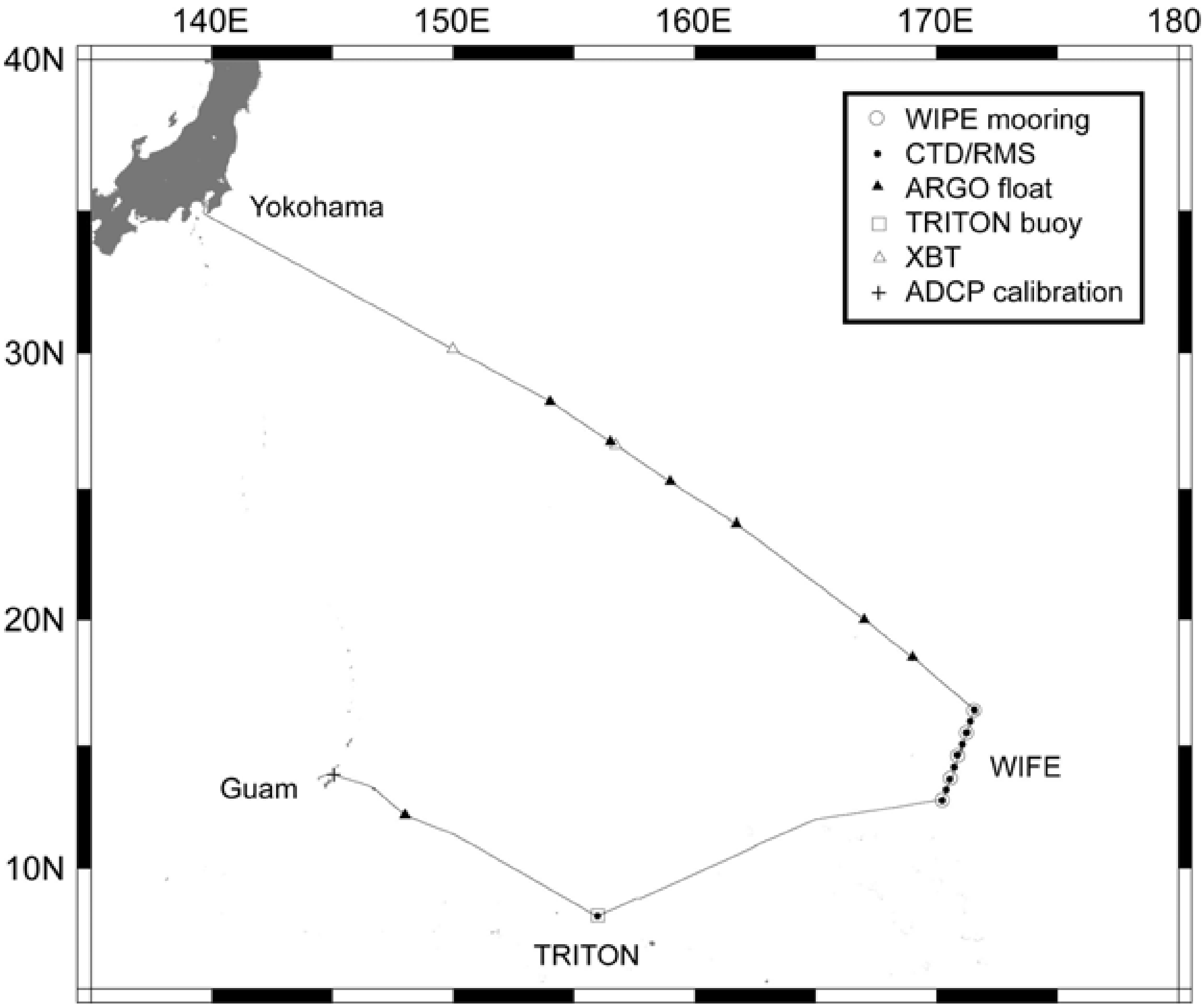


FIGURE 1.2.1: CRUISE TRACK AND STATION LOCATIONS

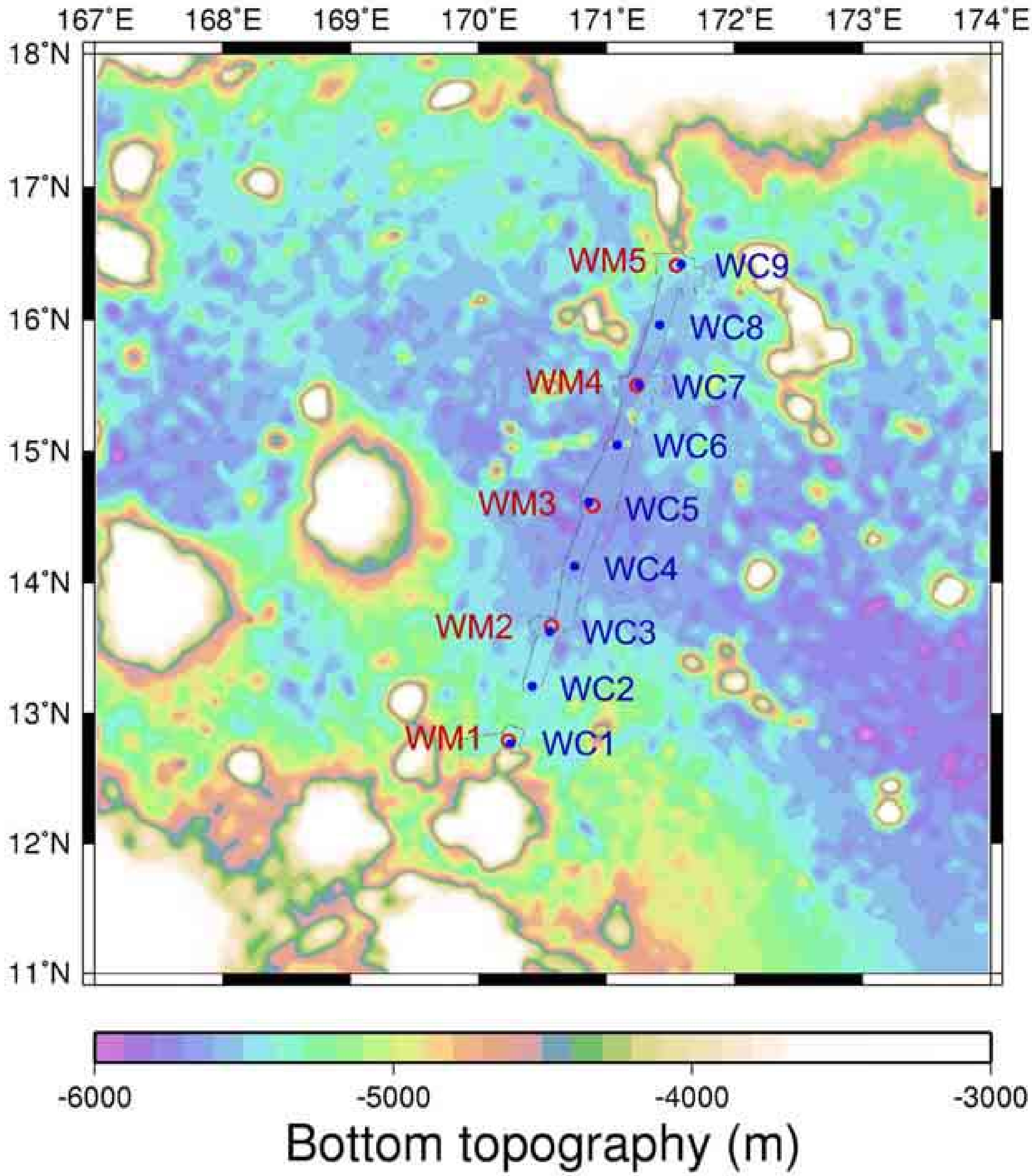


FIGURE 1.2.2: STATION LOCATIONS OF THE WIFE AND BOTTOM TOPOGRAPHY.

Cruise Log

Events of the cruise are listed in Table 1.2.1. Detailed station summary is shown in Appendix B.

TABLE 1.2.1: CRUISE LOG

Date	**Time (UTC)**		**Event**	**Latitude**	**Longitude**
2003	**Begin**	**End**			
21 May	06:15		Depart Yokohama	35 27.12' N	139 38.84' E
	10:07		Start continuous measurements	34 47.20' N	139 56.48' E
23 May	00:47		XBT (760m) for MNB calibration	30 08.68' N	149 58.54' E
	17:31		ARGO float #1 deployment	28 15.00' N	153 59.90' E
24 May	04:48		ARGO float #2 deployment	26 45.10' N	156 30.00' E
	05:50		XBT (760m) for MNB calibration	26 37.94' N	156 43.91' E
	16:21		ARGO float #3 deployment	25 16.10' N	158 58.40' E
25 May	06:46		ARGO float #4 deployment	23 40.63' N	161 43.55' E
26 May	13:10		ARGO float #5 deployment	20 00.00' N	167 00.00' E
	23:53	01:42	CTD/RMS/LADCP TR1 (2004dbar)	18 30.24' N	168 59.82' E
27 May	01:47		ARGO float #6 deployment	18 30.84' N	168 59.89' E
	15:50	19:20	CTD/RMS/LADCP WC9 (5562dbar)	16 25.04' N	171 34.98' E
	23:28	00:39	Mooring WM5 deployment	16 24.60' N	171 32.53' E
28 May	04:04	07:49	CTD/RMS/LADCP WC8 (5625dbar)	15 57.65' N	171 24.84' E
	12:08	16:01	CTD/RMS/LADCP WC7 (5703dbar)	15 30.26' N	171 15.09' E
	21:46	22:47	Mooring WM4 deployment	15 30.10' N	171 14.18' E
29 May	04:42	05:50	Mooring WM3 deployment	14 35.10' N	170 53.55' E
	06:48	10:23	CTD/RMS/LADCP WC5 (5758dbar)	14 36.72' N	170 51.66' E
	13:20	17:05	CTD/RMS/LADCP WC6 (5767dbar)	15 02.77' N	171 04.99' E
	21:19	00:45	CTD/RMS/LADCP WC4 (5719dbar)	14 07.43' N	170 44.95' E
30 May	04:15	05:20	Mooring WM2 deployment	13 40.01' N	170 34.02' E
	06:18	09:45	CTD/RMS/LADCP WC3 (5601dbar)	13 37.66' N	170 33.30' E
	12:32	16:16	CTD/RMS/LADCP WC2 (5487dbar)	13 12.47' N	170 25.01' E
	18:32	22:31	CTD/RMS/LADCP WC1 (5449dbar)	12 45.97' N	170 14.83' E
31 May	00:19	01:18	Mooring WM1 deployment	12 47.42' N	170 13.88' E
1 June	07:20	07:56	3-component magnetometer calibration	10 54.49' N	162 30.64' E
	20:00		Stop continuous measurements	09 35.52' N	159 37.66' E
2 June	21:14	22:23	CTD/RMS TC1 (1010dbar)	08 01.33' N	155 58.89' E
	22:51	01:56	TRITON buoy recovery	08 00.90' N	155 57.06' E
3 June	22:13	00:52	TRITON buoy deployment	07 57.99' N	156 01.82' E
4 June	01:26	02:35	CTD/RMS TC2 (1005dbar)	07 56.69' N	156 01.69' E
	03:03	03:42	Backup winch (TSK) test	07 56.97' N	156 01.45' E
5 June	12:00		Re-start continuous measurements	12 00.95' N	148 23.13' E
	13:37		ARGO float #7 deployment	12 10.02' N	147 59.96' E
	21:22	01:47	DYNACON cable free fall	13 12.63' N	146 45.66' E
6 June	08:20	10:45	ADCP calibration	13 48.66' N	145 02.39' E
		20:30	Stop continuous measurements	13 35.13' N	144 26.10' E
	23:00		Arrive Guam (Apra harbor)	13 26.59' N	144 39.00' E

Moorings

Five sub-surface moorings were deployed. The top buoy depths were about 3,400m. 5 CTDs and 3 current meters were attached to each mooring. Each mooring have a transponder (top) and 2 acoustic releasers (parallel). MicroCAT (SBE37-SM) with pressure sensor (Sea-Bird Electronics, Inc., USA) CTD was used to measure temperature, salinity and pressure. Acoustic Doppler current meter, 3D-ACM (Falmouth Scientific, Inc., USA), RCM-11 (Aanderaa Instruments, Norway), vector averaging current meter, RCM-8 (Aanderaa Instruments, Norway), were used to measure water current. Acoustic transponders (Benthos, Inc., USA) were used to monitor motion of the moorings during deployment. Acoustic releasers, Model-L and LII (Nichiyu Giken Kogyo Co., Ltd., Japan) were used for recovery of mooring.

Number of Stations

A total of 9 full-depth CTD/RMS/LADCP stations and a 2000m depths CTD/RMS/LADCP station were occupied using a 36 bottles SBE32 Carousel Water Sampler (Sea-Bird Electronics, Inc., USA) equipped with 36 12-liter Niskin-X (General Oceanics, Inc., USA) water sample bottles, a SBE9/11plus CTD (Sea-Bird Electronics, Inc., USA) equipped with two SBE43 oxygen sensors (Sea-Bird Electronics, Inc., USA), a fluorometer (Seapoint sensors, Inc., USA), a C-Star Transmissometer (WET Labs, Inc., USA), a PSA-900D altimeter (Benthos, Inc., USA), a SBE35 Deep Ocean Standard thermometer (Sea-Bird Electronics, Inc., USA) and a 300kHz WorkHorse ADCP (RD Instruments, Inc., USA). And two 1000m depths CTD/RMS stations were occupied using a same system mentioned above except for a LADCP in order to calibrate the TRITON temperature and conductivity sensors.

Water Sampling

The following water samples measurements were made: salinity, oxygen, silicate, nitrate, nitrite, phosphate, CFC-11, CFC-12, TCO_2, total alkalinity, pH, ^{14}C and ^{13}C. The depths in m sampled were: 10, 25, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2250, 2500, 2750, 3000, 3250, 3500, 3750, 4000, 4250, 4500, 4750, 5000, 5250, 5500 (and bottom) meters.

Floats

Seven ARGO profiling floats were deployed.

TRITON Buoys

A TRITON buoy was recovered and re-installed at 8N, 156E.

1.3 List of Principal Investigators

The principal investigators responsible for the major parameters measured on the cruise listed in Table 1.3.1. Also, the persons responsible for the tasks undertaken on the cruise are listed.

TABLE 1.3.1: PRINCIPAL INVESTIGATORS

Principal Investigator	Person in Charge	Responsibility
H. Uchida (JAMSTEC)	S. Ozawa (MWJ)	CTD
H. Uchida (JAMSTEC)	S. Ozawa (MWJ)	LADCP
H. Uchida (JAMSTEC)	N. Takahashi (MWJ)	Salinity
H. Uchida (JAMSTEC)	T. Seike (MWJ)	Oxygen
A. Murata (JAMSTEC)	K. Sato (MWJ)	Nutrients
A. Murata (JAMSTEC)	M. Kamata (MWJ)	TCO_2
A. Murata (JAMSTEC)	T. Ohama (MWJ)	pH
A. Murata (JAMSTEC)	F. Shibata (MWJ)	Total alkalinity
K. Sasaki (JAMSTEC)	K. Sagishima (MWJ)	CFC-11, CFC-12
Y. Kumamoto* (JAMSTEC)	F. Shibata (MWJ)	^{14}C, ^{13}C
H. Yoshikawa* (HU)	A. Sakamoto (HU)	^{13}C
H. Yamamoto (JAMSTEC)	H. Matsunaga (MWJ)	Moorings
H. Uchida (JAMSTEC)	H. Uchida (JAMSTEC)	MicroCAT
H. Yamamoto (JAMSTEC)	H. Yamamoto (JAMSTEC)	RCM-8, RCM-11
K. Ichikawa (KU)	K. Ichikawa (KU)	3D-ACM
N. Shikama* (JAMSTEC)	T. Takamori (MWJ)	ARGO floats
A. Ito (JAMSTEC)	T. Matsumoto (MWJ)	TRITON buoys
H. Uchida (JAMSTEC)	S. Okumura (GODI)	Navigation
H. Uchida (JAMSTEC)	S. Okumura (GODI)	Shipboard ADCP
T. Fujiwara* (JAMSTEC)	S. Okumura (GODI)	Bathymetry
T. Fujiwara* (JAMSTEC)	S. Okumura (GODI)	Gravity acceleration
T. Fujiwara* (JAMSTEC)	S. Okumura (GODI)	3-component magnetic field
H. Uchida (JAMSTEC)	T. Miyashita (MWJ)	Surface T, S
H. Uchida (JAMSTEC)	T. Miyashita (MWJ)	Surface Oxygen
A. Murata (JAMSTEC)	M. Kamata (MWJ)	Surface TCO_2
A. Murata (JAMSTEC)	M. Kamata (MWJ)	pCO_2/PCO_2
K. Yoneyama* (JAMSTEC)	Sh. Okumura (GODI)	Meteorology, SOAR
K. Yoneyama* (JAMSTEC)	Sh. Okumura (GODI)	Ceilometer
I. Asanuma* (NASDA)	K. Maeno (GODI)	Satellite image acquisition

Principal Investigator	Person in Charge	Responsibility
K. Yoneyama* (JAMSTEC)	-	Turbulent flux measurement
M. Uematsu* (ORI)	-	Carbon monoxide/Ozone monitor
T. Endo* (HU)	I. Matsui (NIES)	Sky radiometer/ Optical particle counter
N. Sugimoto* (NIES)	I. Matsui (NIES)	Mie scattering lidar
M. Sasaki* (NASDA)	-	Microwave radiometer/ Micro rain radar

Abbreviations

JAMSTEC	Japan Marine Science and Technology Center
HU	Hokkaido University
KU	Kyushu University
NASDA	National Space Development Agency of Japan
ORI	Ocean Research Institute, University of Tokyo
NIES	National Institute for Environmental Studies
MWJ	Marine Works Japan Ltd.
GODI	Global Ocean Development Inc.

Note: Person indicated by * was not on board.

1.4 Scientific Program and Methods

The principal objectives of the cruise were:

a) To place five deep moorings along a transect of deep passage near the Wake Island
b) To calibrate moored CTDs before deployment by comparing with CTD/RMS data
c) To investigate water mass characteristics on the section, and
d) To estimate volume/material transports, heat storage of the abyssal water across the section.

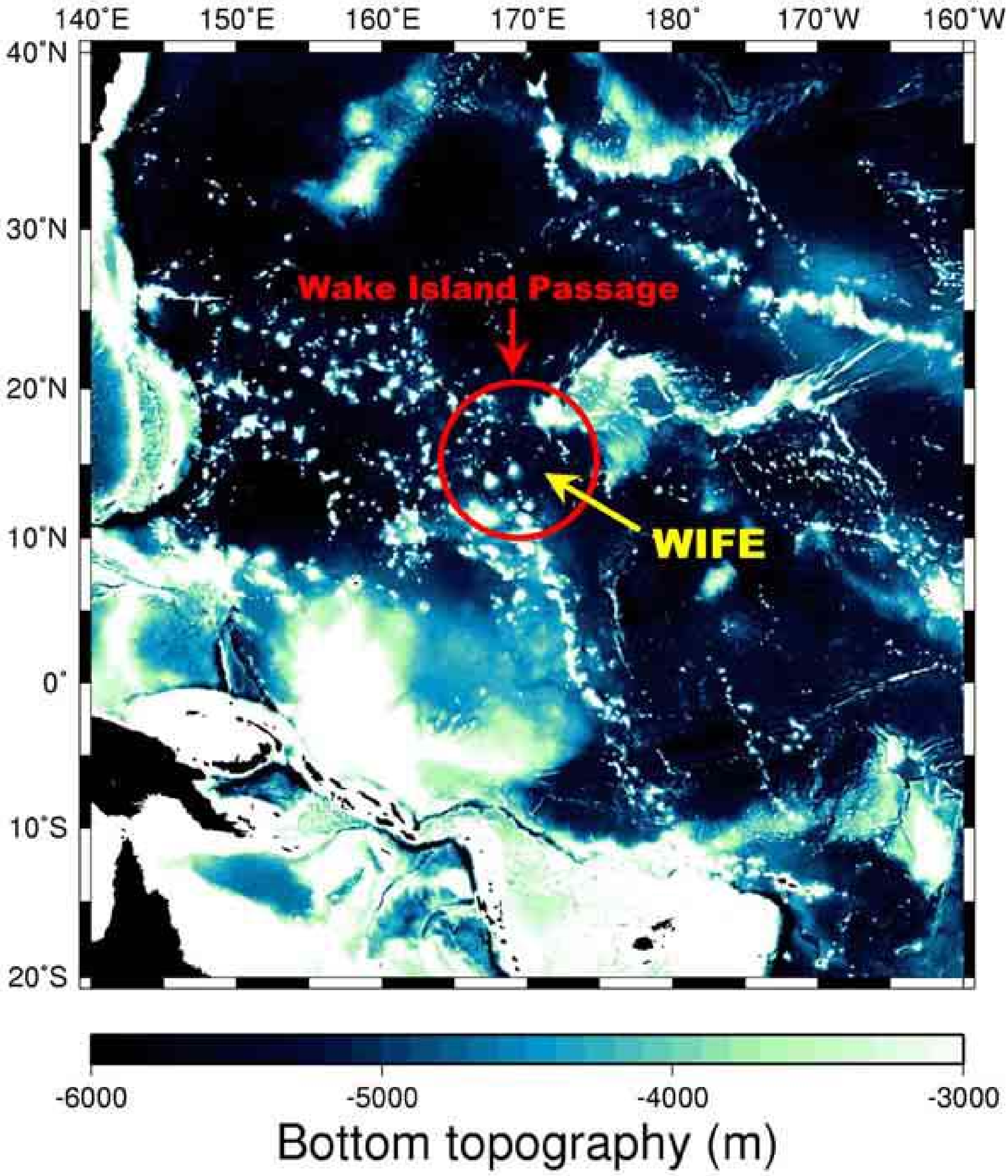


FIGURE 1.4.1: BOTTOM TOPOGRAPHY AROUND THE WIFE SECTION

In the South Pacific, volume transport of Lower Circumpolar Deep Water (LCDW) flowing northward along the western boundary was directory measured by current meter array on the Tonga-Kermadec Ridge to a point more than 10 degree further offshore (about 32S) and on the Samoa Passage (about 10S, 170E) for one to two years during WOCE (World Ocean Circulation Experiment) period. The average transport of LCDW drops from south (15.8 Sv off New Zealand; 1 Sv is 10^{-6} m^3/s) to north (10.6 Sv on the Samoa Passage). Although, in the North Pacific, volume transport of northward flowing LCDW was estimated based on a few hydrographic section data, its long-term average and variability are not yet investigated.

Wake Island passage Flux Experiment (WIFE) mooring array was designed to observe LCDW flowing into the North Pacific. Near the Wake Island Passage five deep moorings were placed along a transect of the passage. Figure 1.4.1 shows bottom topography deeper than 3,000m around the Wake Island Passage. LCDW is defined by potential temperature less than 1.2 degrees C in the Pacific. Isotherm depth of 1.2 degrees C potential temperature in the Wake Island Passage is about 3,500m depths. Each mooring of WIFE mooring array had 5 CTDs, 3 current meters, one transponder and 2 releasers. Using these instruments, temperature, salinity and pressure are measured at intervals of about 500m and current is measured at intervals of 1,000m from 3,500m depths to bottom (about 5,500m depths) for each mooring station. The moored CTDs were attached to water sampling frame at CTD/RMS casts before deployment in order to calibrate the moored CTDs by comparing with the in-situ accurate data.

CTD/RMS/LADCP stations were selected on the WIFE mooring stations and on their intermediate. The instruments of CTD/RMS/LADCP and water sample bottles were attached to 620 kg SUS frame. At some stations small or large vane was attached to the frame of the package in order to stabilize motion of the package during a cast. The CTD/RMS package wad deployed using 4.6 Ton Traction Winch System (Dynacon, Inc., USA) which was installed to the R/V Mirai in April 2001 and moved its position in April 2003. The CTD Traction Winch System with the Heave Compensation Systems (Dynacon, Inc., USA) is designed to reduce cable stress resulted from loads variation caused by wave or vessel motion. The system was 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 9 km 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.

After a cast CTD/RMS package was stored in the sampling room and all sampling was performed there. Samples were drawn followed in order by samples for oxygen, CFCs, TCO_2, pH, ^{14}C, ^{13}C, total alkalinity, nutrients and salinity. Samples for oxygen, CFCs, TCO_2, pH, total alkalinity, nutrients and salinity were analyzed on board. Samples for ^{14}C and ^{13}C are going to be analyzed after the cruise.

A description of the methods of measurement, calibration and analysis of the data obtained in the cruise will be found in following sections.

1.5 Main Results

CTD temperature, salinity and oxygen data are corrected using the Deep Ocean Standard thermometer (SBE35), bottle salinity and bottle oxygen data. Vertical sections of potential temperature, salinity and oxygen along the WIFE observation line are shown in Plate 1.5.1. Location of water samples is also shown.

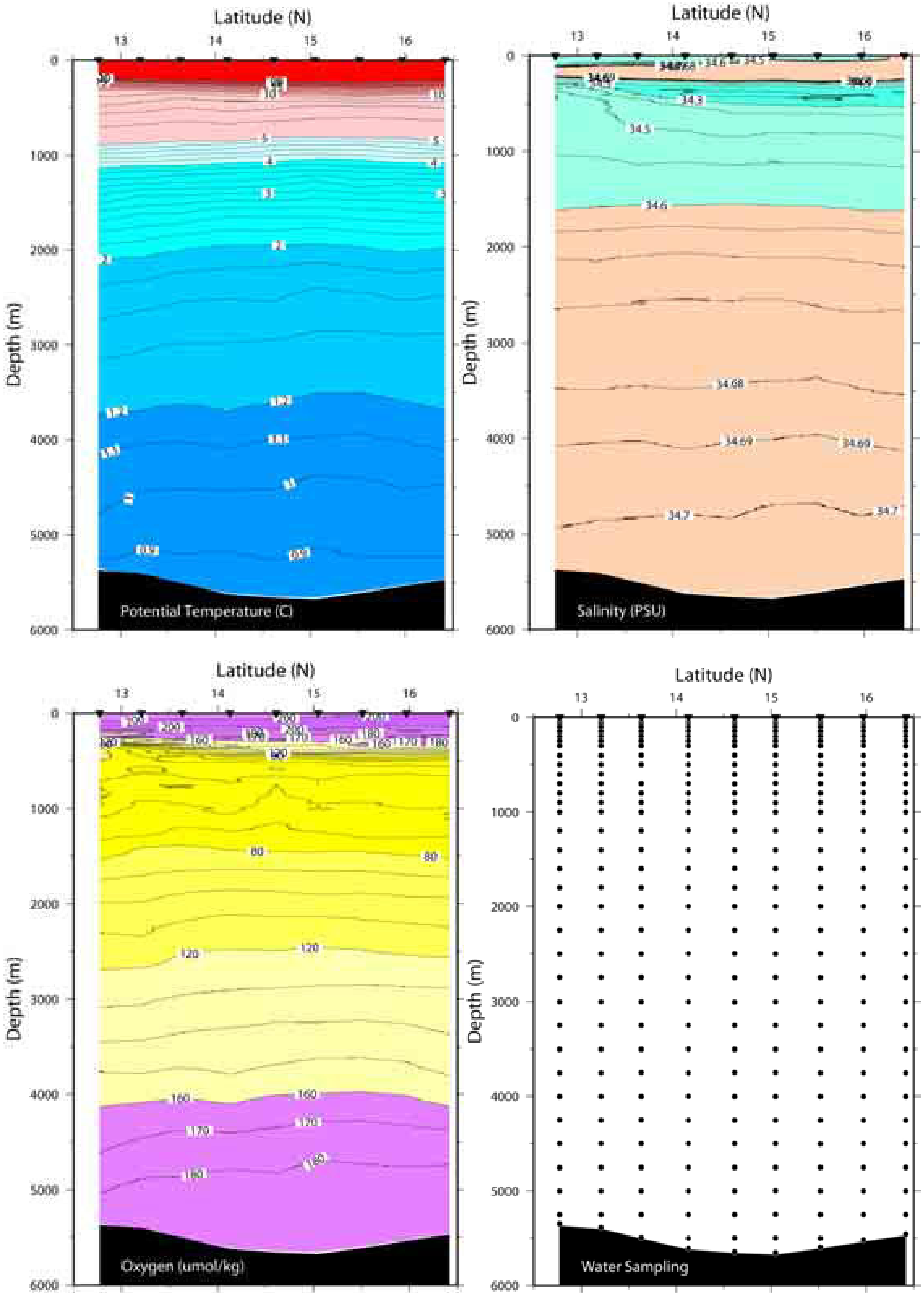


PLATE 1.5.1: VERTICAL SECTION OF TEMPERATURE, SALINITY, OXYGEN USING CALIBRATED CTD DATA AND LOCATION OF WATER SAMPLES.

Using the quality controlled CTD data, geostrophic velocity is calculated with application of a 1.2 degrees C reference surface. Vertical section of the geostrophic velocity is shown in Plate 1.5.2. Positive indicates northward current and negative indicates southward current. Using this velocity profiles, volume transport for the LCDW, defined by potential temperature colder than 1.2 degrees C, is estimated. Relatively large northward transport is observed in the western part of the WIFE observation line. At the eastern part, the LCDW may re-circulate by a baroclinic eddy. Total (net) transport of the LCDW across the WIFE section is estimated to be 2.5 Sv.

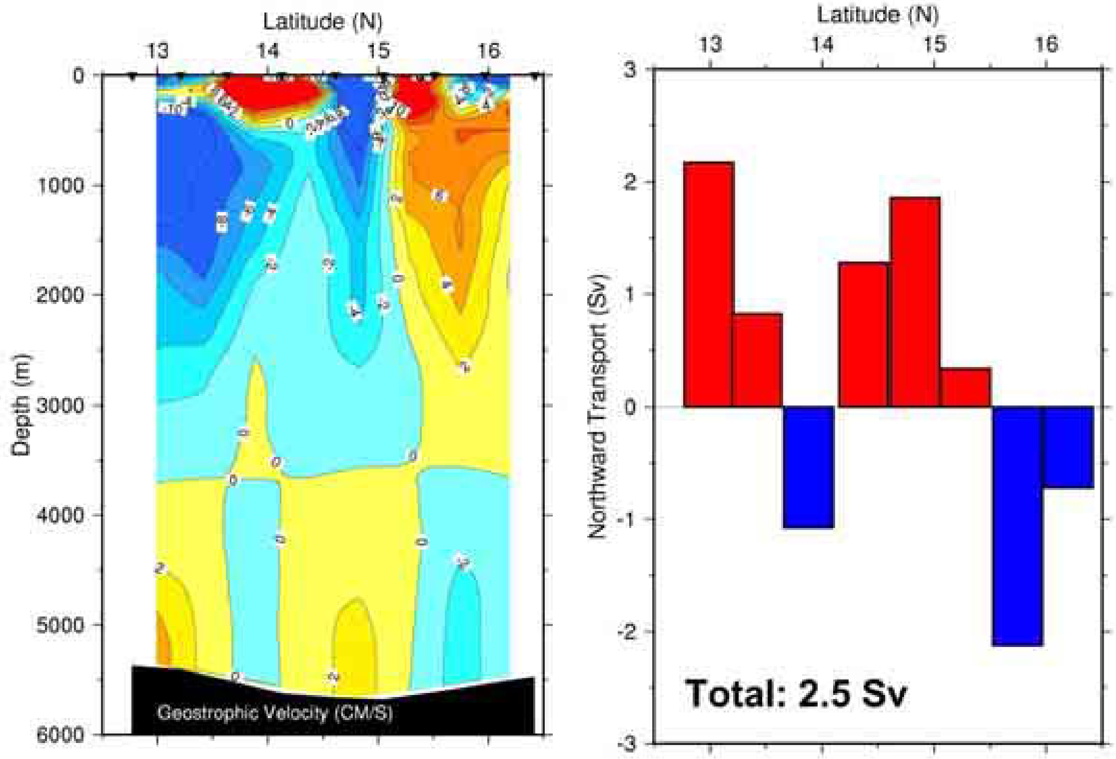


PLATE 1.5.2: VERTICAL SECTION OF GEOSTROPHIC VELOCITY AND TRANSPORT OF LCDW.

1.6 Major Problems Encountered on the Cruise

Arrival time at WIFE observation line was late for the schedule for several hours due to the influence of the typhoon CHAN-HON. The last two CTD/RMS/LADCP stations (WC2 and WC1) of WIFE took more time than usual due to the winch cable trouble during the up-cast. At most CTD/RMS stations, firing of bottle #16 was not confirmed on the personal computer connected to the deck unit, although the bottle #16 was actually closed and SBE 35 temperature sensor stored data at the time when bottle #16 was fired. No other major problem was encountered on the cruise.

1.7 Other Observations of Note

The results of LADCP observations carried out before in the R/V Mirai cruises showed that CTD/RMS package was rather rotating while the package was descending than while the package was ascending. In this cruise, motion of the CTD/RMS/LADCP package during the cast was investigated using LADCP data by attaching small or large vane to the frame of the package.

In the original cruise plan, the cruise track was out of the EEZ of Federated States of Micronesia. In February 2003, the recovery/deployment of the TRITON buoy was decided to carry out in this cruise in the EEZ of Federated States of Micronesia. The decision was late for application for consent to conduct research in the EEZ except for the TRITON buoy recovery/deployment and CTD/RMS casts for the TRITON sensor calibration. Therefore continuous measurements along the cruise track were not conducted in the EEZ of Federated States of Micronesia.

As for the recovery/re-installation of the TRITION buoy, the deployment was scheduled before the recovery to avoid making gap of data. However, the recovery was conducted before the deployment taking account of lifetime of the releaser’s battery.

Backup winch (Tsurumi Seiki Co., Ltd., JAPAN) installed for the cruise MR03K04 was worked. The backup winch cable was freely fallen and the procedure of operation was checked. The disordered DYNACON winch cable was freely fallen at the Mariana trench, after all CTD stations were worked, so as to wind in order the cable.

1.8 List of Cruise Participants

The members of the scientific party are listed in Table 1.8.1, along with their main responsibilities. Abbreviations of the affiliation are same as Table 1.3.1

TABLE 1.8.1: CRUISE PARTICIPANTS

Name	**Responsibilities**	**Affiliation**
Hirofumi Yamamoto	Moorings, Moored CM	JAMSTEC
Hiroshi Uchida	Moored CTD	JAMSTEC
Akihiko Murata	Spectrophotometric pH	JAMSTEC
Takaki Hatayama	Station summary	JAMSTEC
On Sugimoto	LADCP	JAMSTEC
Ken'ichi Sasaki	CFCs	JAMSTEC
Atsuo Ito	TRITON buoys	JAMSTEC
Kaoru Ichikawa	Moored CM, LADCP	KU
Daisuke Ambe	Moored CM, Moored CTD	KU
Ai Sakamoto	TCO_2, ^{13}C	HU
Ichiro Matsui	Mie Scattering Lidar	NIES
Satoshi Ozawa	CTD operations	MWJ
Takeo Matsumoto	TRITON buoys	MWJ
Hiroshi Matsunaga	Moorings, CTD operations	MWJ
Miki Yoshiike	CTD operations	MWJ
Naoko Takahashi	Salinity, ARGO	MWJ
Tomoyuki Takamori	ARGO, TRITON buoys	MWJ
Fuyuki Shibata	Total alkalinity	MWJ
Shin'ichiro Yokokawa	Nutrients	MWJ
Katsunori Sagishima	CFCs	MWJ
Ken'ichiro Sato	Nutrients	MWJ
Taeko Ohama	pH	MWJ
Minoru Kamata	TCO_2	MWJ
Takayoshi Seike	Oxygen	MWJ
Tomoko Miyashita	Oxygen	MWJ
Yuki Otsubo	Nutrients	MWJ
Kunio Yamamori	Water sampling	MWJ
Keisuke Matsumoto	Moorings	MWJ
Satoshi Okumura	Shipboard ADCP, Bathymetry	GODI
Shinya Okumura	Meteorology, SOAR	GODI
Katsuhisa Maeno	Satellite image acquisition	GODI

1.9 List of Crew

The members of the crew are listed in Table 1.9.1.

TABLE 1.9.1: CREW OF THE CRUISE

Name	Rank
Masaharu Akamine	Master, Captain
Takaaki Hashimoto	Chief Officer
Haruhiko Inoue	1st Officer
Shingo Fujita	2nd Officer
Keitaro Inoue	3rd Officer
Akiteru Ono	Chief Engineer
Nobuya Araki	1st Engineer
Kyoichi Hashimoto	2nd Engineer
Naoto Takamori	3rd Engineer
Shuji Nakabayashi	C.R.Officer
Keiichirou Shishido	2nd R.Officer
Kenetsu Ishikawa	Boatswain
Yasuyuki Yamamoto	Able Seaman
Kenichi Torao	Able Seaman
Keiji Yamauchi	Able Seaman
Kunihiko Omote	Able Seaman
Hisao Oguni	Able Seaman
Yukiharu Suzuki	Able Seaman
Masaru Suzuki	Able Seaman
Tsuyoshi Sato	Able Seaman
Takeharu Aisaka	Able Seaman
Masashige Okada	Able Seaman
Shuji Komata	Able Seaman
Yukitoshi Horiuchi	No.1 Oiler
Kiyoharu Emoto	Oiler
Yoshihiro Sugimoto	Oiler
Toshio Matsuo	Oiler
Nobuo Boshita	Oiler
Daisuke Taniguchi	Oiler
Yasuaki Koga	Chief Steward
Koushin Hamamura	Cook
Hatsuji Hiraishi	Cook
Hitoshi Ota	Cook
Kozo Uemura	Cook
Wataru Sasaki	Cook

2 MOORING OBSERVATIONS

2.1 Deployment of Moorings

Hiroshi Uchida (Japan Marine Science and Technology Center)
Hirofumi Yamamoto (Japan Marine Science and Technology Center): Principal Investigator
Kaoru Ichikawa (RIAM, Kyushu University)
Hiroshi Matsunaga (Marine Works Japan Ltd.)
Satoshi Okumura (Global Ocean Development Inc.)

1) Mooring System

WIFE mooring array was designed to observe Lower Circumpolar Deep Water (LCDW) flowing into the North Pacific from the South Pacific. Near the Wake Island Passage five deep moorings were placed along a transect of the passage. Each mooring of WIFE mooring array had 5 CTDs, 3 current meters, one transponder and 2 releasers. Current observation was done by the cooperation with Research Institute for Applied Mechanics (RIAM), Kyushu University.

For temperature and salinity measurements, high-accuracy conductivity and temperature with optional pressure recorders, the SBE 37-SM MicroCAT (Sea-Bird Electronics, Inc., USA), are used. For current measurements, 3 types of current meters are used. For the 3,400 m layer, 3 dimensional acoustic current meters, 3D-ACM (Falmouth Scientific, Inc., USA), are used with 3-ton mooring frames. The 3D-ACMs were introduced by Kyushu University group. For the 4,400 m layer, acoustic Doppler current meters, RCM 11 (Aanderaa Instruments, NORWAY), are used. The RCM 11 measure current in the area from 0.4 to 2.2 meters from the instrument which minimizes the effect of marine fouling and local turbulence. For the 5,400 m layer, current meters, RCM 8 (Aanderaa Instruments, NORWAY), are used. The RCM 8 consists of two main parts, the vane assembly and the recording unit with a rotor.

In order to detect top depth of the mooring line from ship, acoustic transponders, 10-inch XT-6000 (Benthos, Inc., USA), are used. In order to recover the moorings as securely as possible, two (parallel) acoustic releasers, Model L and LII (Nichiyu Giken Kogyo Co., Ltd., JAPAN), are used for each mooring. The releaser applies Gas-Generation mechanism to free a hock.

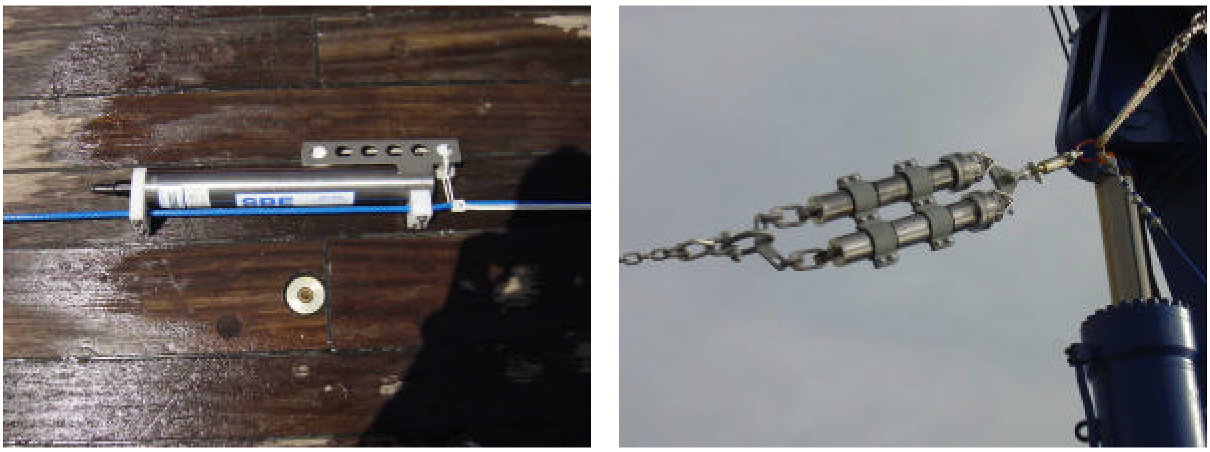


PLATE 2.1.1: PHOTOS OF A MOORED CTD AND ACOUSTIC RELEASERS.

Details of the WIFE mooring system are shown in Appendix B. Serial numbers of the instrument used for the mooring array are summarized in Table 2.1.1.

TABLE 2.1.1: SERIAL NUMBERS OF THE INSTRUMENT USED.

Instrument	*Model*	*LAYER*	*WM1*	*WM2*	*WM3*	*WM4*	*WM5*
Transponder	XT-6000	3400m	46422	50361	51276	68348	50320
	RX (kHz)		13.0	13.0	13.0	13.0	13.0
	TX (kHz)		14.5	15.0	14.0	13.5	14.5
Current Meter	3D-ACM	3400m	1573	1554	1631	1630	1633
CTD	SBE 37-SM	3400m	2750	2745	2740	2735	2755
CTD	SBE 37-SM	3900m	2751	2746	2741	2736	2756
Current Meter	RCM-11	4400m	34	28	31	30	139
CTD	SBE 37-SM	4400m	2752	2747	2742	2737	2757
CTD	SBE 37-SM	4900m	2753	2748	2743	2738	2758
Current Meter	RCM-8	5400m	10819	11033	11670	10073	11668
CTD	SBE 37-SM	5400m	2754	2749	2744	2739	2759
Acoustic Release	NICHIYU (NY)	5400m	4454-1C	4236-1H	4448-1A	4465-1D	4224-1E
	Model-L, LII		4424-3A	4232-3E	4235-1G	4459-1B	4271-3G

2) Setting of Instruments

Setup parameters and maximum operating life for the WIFE moored instruments are summarized in Table 2.1.2. Operating life time of the Aanderaa's current meter is depend on the storage capacity of the Data Storing Unit (DSU). DSU 2990E (262,100 10-bit words) is used for all RCM-11 and two RCM-8 (S/N 10073 and 11668). DSU 2990 (65,500 10-bit words) is used for the rest of the RCM-8.

TABLE 2.1.2: SETUP PARAMETERS FOR THE WIPE MOORED INSTRUMENTS.

Instrument	*Sampling Interval*	*Sampling Rate (Mode)*	*Averaging Time*	*Maximum Operating Life*
SBE 37-SM	30 minutes	one sample	-	> 2.5 years
RCM-11	60 minutes	2.5 Hz (Burst)	60 seconds	2.3 years
RCM-8	60 minutes	50/3600 Hz	60 minutes	1.2 (2.3) years*
3D-ACM	60 minutes	2 Hz	60 seconds	2.4 years
NY Model-L, LII	-	-	-	> 1 year (2 years)
XT-6000	-	-	-	> 2 years

* Maximum operating life depends on the capacity of Data Storage Units used.

3) Deployment

The moorings were deployed with the "anchor last" procedure. Date, time and locations of the deployments are listed in SUM (station summary) file. Depths of the transponders during deployment are monitored using acoustic navigation system on the R/V Mirai. Using the acoustic navigation data with some assumption, decent rate of the moorings (anchor) are estimated as 0.96 to 1.26 m/s. From bottom depth at the time of anchor released and length of the mooring line, approximate depths of the moored instruments are estimated and are summarized in Table 2.1.3.

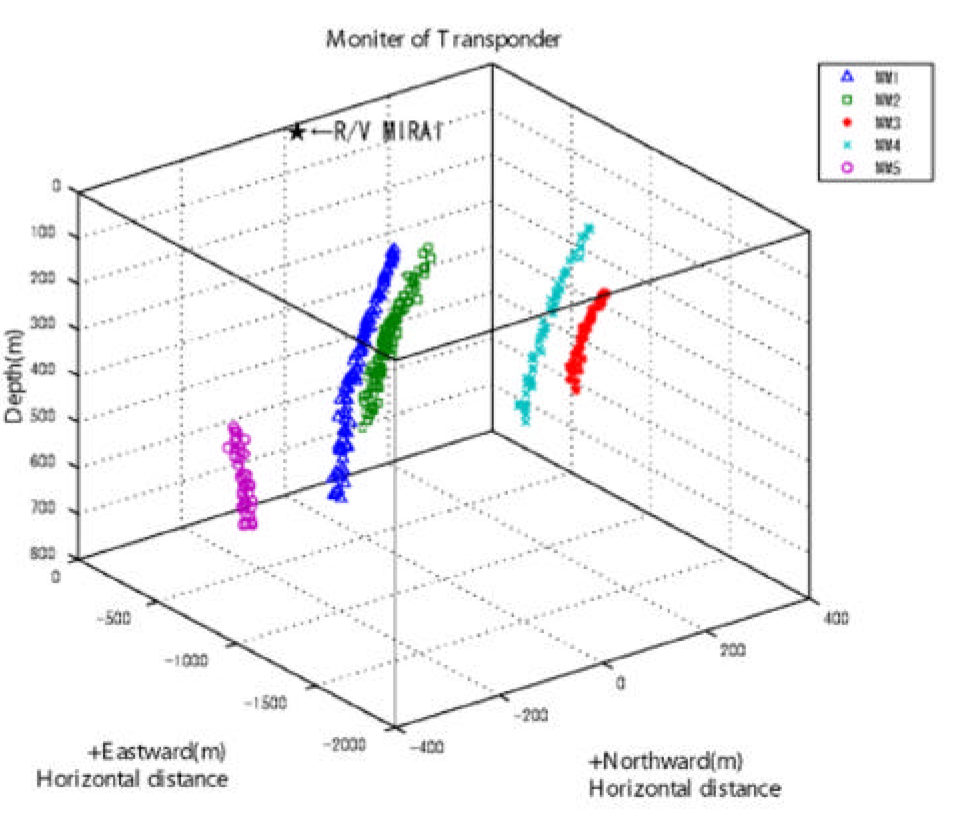


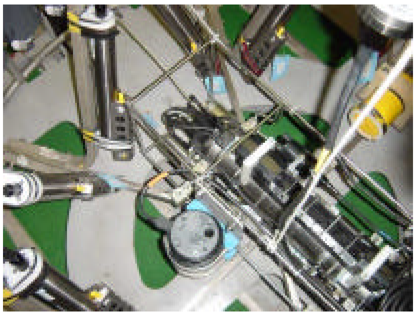
FIGURE 2.1.2: DEPTHS OF TRANSPONDERS DURING DEPLOYMENT.

TABLE 2.1.3: APPROXIMATE DEPTH OF THE MOORED INSTRUMENTS.

Instrument	*Model*	*LAYER*	*WM1*	*WM2*	*WM3*	*WM4*	*WM5*
Transponder	XT-6000	3400m	3391m	3355m	3336m	3449m	3305m
Current Meter	3D-ACM	3400m	3439m	3403m	3384m	3497m	3353m
CTD	SBE 37-SM	3400m	3441m	3405m	3386m	3499m	3355m
CTD	SBE 37-SM	3900m	3936m	3897m	3875m	3994m	3844m
Current Meter	RCM-11	4400m	4440m	4401m	4382m	4498m	4348m
CTD	SBE 37-SM	4400m	4441m	4402m	4383m	4499m	4349m
CTD	SBE 37-SM	4900m	4937m	4898m	4878m	4994m	4845m
Current Meter	RCM-8	5400m	5256m	5411m	5392m	5514m	5358m
CTD	SBE 37-SM	5400m	5259m	5414m	5395m	5517m	5361m
(Bottom depth)			5356m	5511m	5676m	5614m	5458m

2.2 Pre-deployment Calibration of CTDs

Hiroshi Uchida (Japan Marine Science and Technology Center): Principal Investigator



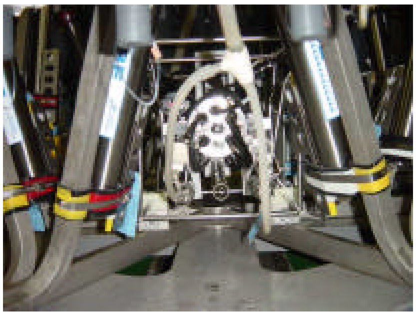


PLATE 2.2.1: PHOTOS OF MOORED CTDS ATTACHED TO THE CTD/RMS FRAME.

TABLE 2.2.1: PRE-DEPLOYMENT CALIBRATION OF MOORED CTDS

SBE-37SM Serial Number (Station)	***Laboratory Calibration Date***	***In-situ Pre-deployment Calibration Date (Station)***
S/N 2755-2759 (WM5)	January 2003	27 May 2003 (WC9)
S/N 2735-2739 (WM4)	January 2003	27 May 2003 (WC9)
S/N 2740-2744 (WM3)	January 2003	28 May 2003 (WC8)
S/N 2745-2749 (WM2)	January 2003	28 May 2003 (WC8)
S/N 2750-2754 (WM1)	January 2003	28 May 2003 (WC7)

The moored CTDs were attached to water sampling frame at a CTD/RMS cast before deployment. By comparing with the in-situ accurate CTD data, the moored CTD data are going to be calibrated. For the in-situ calibration, sampling interval of the moored CTDs was set to 6 seconds.

3 HYDROGRAPHIC MEASUREMENT TECHNIQUES AND CALIBRATIONS

3.1 Salinity

Personnel

Hiroshi Uchida (JAMSTEC): Principal Investigator
Naoko Takahashi (MWJ): Operation Reader

Objectives

Salinity Measurement of Sampled Water

Measured Parameters

Sample water salinity

Instrument and Method

The salinity analysis was carried out on R/V Mirai during the cruise of MR03-K02 by the Guildline Autosal Salinometer model 8400B (Guildline Instruments Ltd., CANADA), S/N 62827, modified with addition of a peristaltic-type intake pump (Ocean Scientific International Inc., UK). The Autosal was operated in the air-conditioned Autosal room and its bath temperature was held at 24 degrees C. An ambient temperature varied from approximately 21 to 26 degrees C. An AC power supply, PCR-1000L (Kikusui Electronics Co., JAPAN), was used for the Autosal in order to remove voltage fluctuations and irregularities in power lines.

The Autosal was standardized with the use of IAPSO Standard Seawater (Ocean Scientific International Inc., UK) before a series of measurements. The Standard Seawater was provided by 200 ml sealed glass bottles. The batch number, conductivity ratio and salinity of the Standard Seawater used in this cruise were P141, 0.99993 and 34.997, respectively. In this cruise, totally 440 samples (see Table 3.1.1) were divided to fore series of measurements. The measurement of the Standard Seawater was carried out approximately every 20 samples in order to check stability of the Autosal. Totally 36 shot bottles of the Standard Seawater were measured. The standard deviation of the salinity was 0.0002 except for two bad measurements. Drift of the Autosal was not corrected because the drift in each series of measurements was sufficiently small from 0 to 0.00001 in double conductivity ratio (2K). Sub-standard seawater was also measured every 10 samples in order to monitor the drift of the Autosal. The sub-standard seawater was deep-sea water filtered by Millipore filter (pore size of 0.45 micro m) and stored in a 20 liters container made from polyethylene.

Seawater samples were collected using 12 liter Niskin-X bottles (no Teflon coating) with O-rings. Salinity sample bottle was a 250 ml brown grass bottle with screw cap. Each salinity sample bottle was rinsed three times with the sample water, and was filled with it to the shoulder of the salinity sample bottle. Its cap was also thoroughly rinsed. The salinity sample bottles were stored longer than 24 hours in the Autosal room before the salinity measurements.

A double conductivity ratio (2K) of the salinity sample was determined as follows. Conductivity cell of the Autosal was flushed 5 times with the sampled water before the double conductivity ratio measurements. The double conductivity ratio was collected after 5 seconds from reading and stored 31 times reading during about 10 seconds automatically by a personal computer. The double conductivity ratio for the measurement was defined as median of 31 times reading. When the standard deviation of the 31 reading was greater than 0.00015, the measurement was ignored and performed again. The measurement of the double conductivity ratio was performed repeatedly at the maximum 5 times. When two measurements among the repeated measurements agreed within ±0.00001, the measurements for the salinity sample was finished and the double conductivity ratio of the salinity sample was determined as average of the two repeated measurements. When two measurements did not agreed within the criterion among the repeated 5 measurements, maximum and minimum values were ignored and the double conductivity ratio of the salinity sample was determined as average of the rest of the 3 measurements with quality "bad" flag.

TABLE 3.1.1: NUMBER OF SAMPLES.

Variety of Samples	Number of Samples
Samples for CTD	427
Samples for EPCS	9
Reference Material for DIC	4
Total	440

Result

Figure 3.1.1 shows the history of the measured double conductivity of SSW. During the measurement from the station TR1 to WC2, we measured 12 bottles of P141 and the average of the double conductivity ratio was 1.99986 and the root-mean-square was 0.000010, which is equivalent to 0.0002 in salinity. During the measurement from the station WC1 to TC2, we measured 3 bottles of P141 after standardization of the Autosal and the average of the double conductivity ratio was 1.999986.

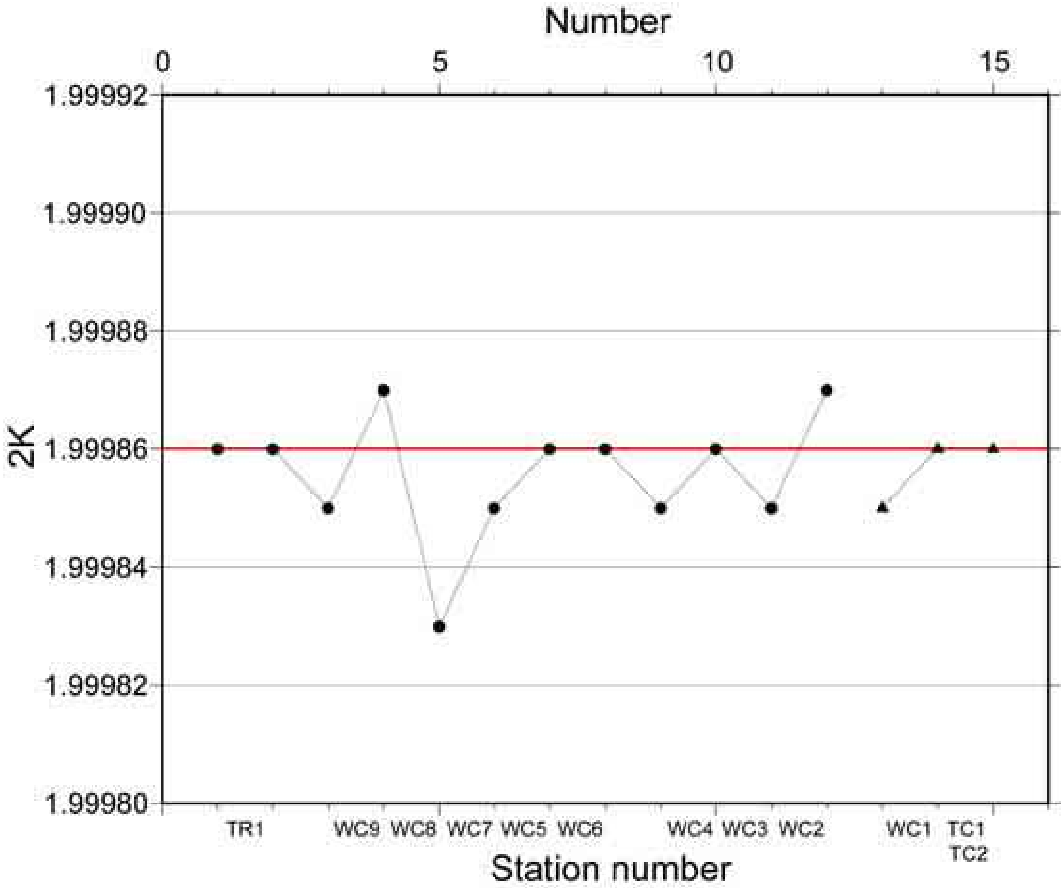


FIGURE 3.1.1: HISTORY OF THE MEASURED DOUBLE CONDUCTIVITY RATIO OF SSW.

48 pairs of replicate were collected except for bad and questionable measurements. 2 pairs were collected at 2000 m, 1 pair was collected at 1000 m, and other pairs were collected at deeper than 3500 m. Figure 3.1.2 shows the histogram of all the absolute difference between replicate samples. The average and the standard deviation of the absolute differences are 0.0003 and 0.0003, respectively in Practical Salinity Unit. Note that the standard deviation of the absolute difference between replicate samples is calculated as follows.

Standard deviation = SQRT(SUM((difference between replicates)^2) / 2N)

where N is number of replicates.

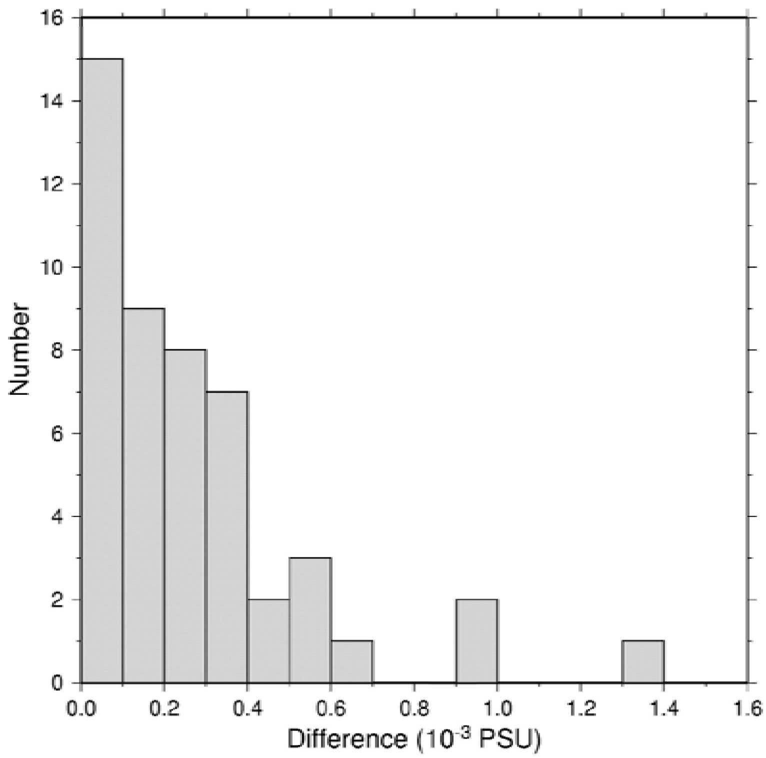


FIGURE 3.1.2: HISTOGRAM OF THE DIFFERENCE BETWEEN REPLICATE SAMPLES.

Data Archive

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

3.2 Oxygen

Personnel

Takayoshi SEIKE	(Marine Works Japan Ltd.: MWJ)
Tomoko MIYASHITA	(MWJ)
Hiroshi UCHIDA	(JAMSTEC): Principal Investigator

Objectives

Determination of dissolved oxygen in seawater by Winkler titration.

Instruments

Burette: APB-510 manufactured by Kyoto Electronic Co. Ltd. / 10 ml of titration vessel
Detector and Software: Automatic photometric titrator manufactured by Kimoto Electronic Co. Ltd.

Methods

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

36 seawater samplers were collected with Niskin bottle attached CTD-system. Seawater was transferred from Niskin sampler bottle to a calibrated clear glass bottles (ca. 100 ml) before much other water has been removed from it. Glass bottle was rinsed with three times seawater of bottle volume. Temperature was measured by digital thermometer during overflowing the sample bottle. Two reagent solutions (Reagent I, II) were added immediately each 0.5 ml after the sample is drawn. The stopper was then inserted carefully into the sample bottle. The sample bottle was then shaken vigorously to mix the contents thoroughly and to disperse the precipitate finely throughout. After the precipitate has settled at least half-way down the bottle (about 30 min), shake the bottle vigorously to disperse the precipitate. Sample bottles containing pickled samples should be stored in a cool, dark, location until they were titrated.

After precipitation remove the sample bottle stopper. Sulfuric acid solution was added 1 ml. A magnetic stirrer bar was added to the solution and began stirring. Samples were titrated by sodium thiosulfate. This normality was determined by potassium iodate solution on new reagents were made up. Temperature of sodium thiosulfate during titration was recorded by digital thermometer.

Reagents:

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

Results

1) Reproducibility of Winkler Titration Data

Replicate samples were taken on every cast; usually these were more than 10% of samples in each cast during this cruise. 63 pairs of replicate were collected except for bad and questionable measurements. Figure 3.2.1 shows the histogram of all the absolute difference between replicate samples. The average and the standard deviation of the absolute differences are 0.13 and 0.13 μmol/kg, respectively. Note that the standard deviation of the absolute difference between replicate samples is calculated the same as Section 3.1.

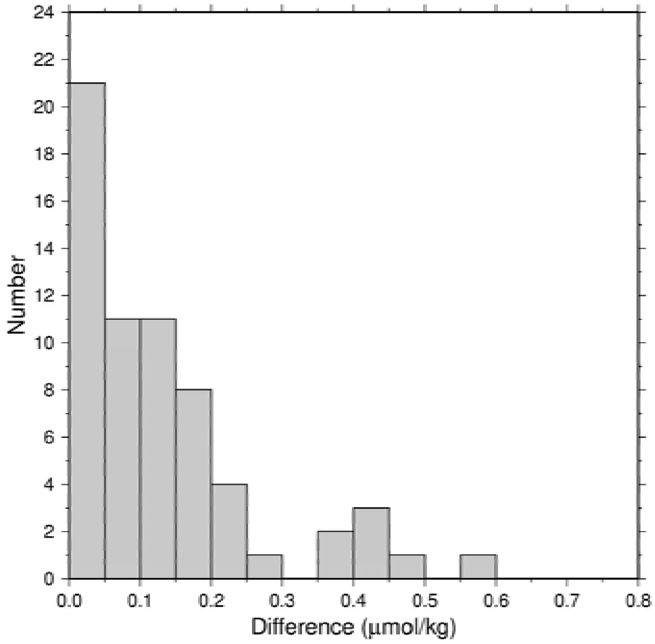


FIGURE 3.2.1: HISTOGRAM OF THE DIFFERENCE BETWEEN REPLICATE SAMPLES.

2) Vertical Section

Vertical section (16.5N to 12.75N) of dissolved oxygen in µmol/kg is shown in Fig. 3.2.1.

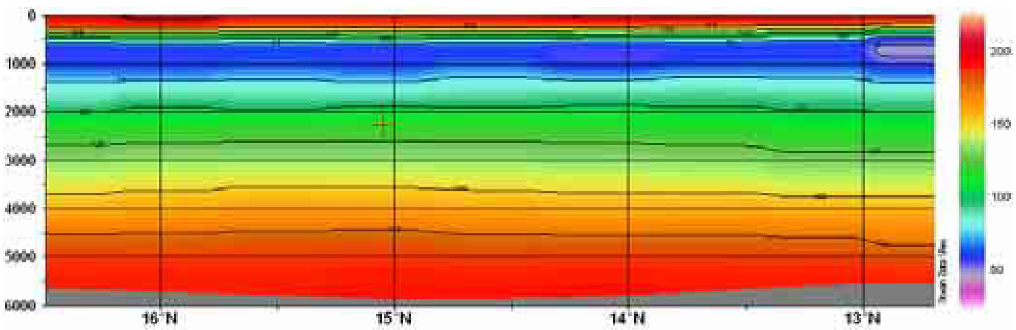


FIGURE 3.2.1: VERTICAL SECTION OF DISSOLVED OXYGEN.

Data Archive

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

References

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Murray, N., J.P. Riley and T.R.S. Wilson (1968): The solubility of oxygen in Winkler reagents used for determination of dissolved oxygen, Deep-Sea Res., 15, 237-238.

3.3 Nutrients

Kenichiro SATO	(Marine Works Japan Ltd.: MWJ)
Shinichiro YOKOGAWA	(MWJ)
Yuki OTSUBO	(MWJ)
Akihiko MURATA	(JAMSTEC): Principal Investigator

Objectives

The vertical and horizontal distributions of the nutrients are one of the most important factors on the primary production. During this cruise nutrient measurements will give us the important information on the mechanism of the primary production or seawater circulation.

Instruments and Methods

Nutrient analysis was performed on two BRAN+LUEBBE TRAACS 800 systems that have 4-channel analyzing systems for nitrate, nitrite, silicate and phosphate. The systems of analysis were improved which proposed for nutrients of seawater by BRAN+LUEBBE. The new systems are shown from Fig. 3.3.1 to Fig. 3.3.4.

The laboratory temperature was maintained between 19 - 24 deg C.

a) Measured Parameters

Nitrite:

Nitrite was determined by diazotizing with sulfanilamide and coupling with N-1-naphthyl-ethylenediamine (NED) to form a colored azo dye that was measured absorbance of 550 nm using 5 cm length cell.

Nitrate:

Nitrate in seawater is reduced to nitrite by reduction tube (Cd - Cu tube), and the nitrite determined by the method described above, but the flow cell used in nitrate analysis was 3 cm length cell. Nitrite initially present in the sample is corrected.

Silicate:

The standard AAII molybdate-ascorbic acid method was used. The silicomolybdate produced is measured absorbance of 630 nm using a 3 cm length cell.

Phosphate:

The method by Murphy and Riley (1962) was used with separate additions of ascorbic acid and mixed molybdate-sulfuric acid-tartrate. The phospho-molybdate produced is measured absorbance of 880 nm using a 5 cm length cell.

Nutrients reported in micromoles per kilogram were converted from micromoles per liter by dividing by density calculated at sample temperature.

b) Nutrients Standard

Silicate standard solution, the silicate primary standard, is obtained from Kanto Chemical CO., Inc. This standard solution is 1000 mg per litter with 0.5 M KOH and prepared for ICP analysis. Primary standard for nitrate (KNO_3), nitrite ($NaNO_2$) and phosphate (KH_2PO_4) obtained from Wako Pure Chemical Industries, Ltd.

c) Sampling Procedures

Samples were drawn into 10 ml acrylic screw-capped tubes that were rinsed three times before filling. Each sample was analyzed two times as soon as possible. Sets of 5 different concentrations of shipboard standards were analyzed at beginning, halfway and end of each group of analysis.

d) Low Nutrients Sea Water (LNSW)

Twelve containers (20 L) of low nutrients seawater were collected in February 2003 at equatorial Pacific and filtered with 0.45 μm pore size membrane filter (Millipore HA). They are used as preparing the working standard solution.

Results

Nutrient analysis of the 9 stations from the carousel was performed. Duplicate samples were collected from all bottles of each casting. Coefficient of variation (CV) of nitrate, nitrite, silicic acid, and phosphate analysis at each station were less than 0.39 % (33.16 μmol/kg), 4.53 % (0.91 μmol/kg), 0.23 % (126.27 μmol/kg) and 0.36 % (2.27 μmol/kg), respectively.

The vertical sections of nutrients along with CTD observations line are shown in Fig. 3.3.5.

Nutrient comparability

To establish comparability of nutrient analyses between other cruises, the RMNS [*Aoyama et al.*, submitted] were measured during cruises MR03-K02, KH04-4 leg 2, and MR05-05. The RMNS lots T, AN, AK, AM, O, and AH were measured during the cruise in MR03-K02 and lots AS, AT, and AU were measured during the cruise in KH04-4 leg 2. All of these lots were measured immediately before the cruise in MR05-05. Averages of nutrient (nitrate, nitrite, silicate, and phosphate) measurements for each lot from MR03-K02 and KH04-4 leg 2 agree well with those from MR05-05 except for silicate measurements in this cruise (MR03-K02). A correction factor for silicate measurements from MR03-K02 was estimated to be 1.0121 based on a linear regression of the data (Fig. 3.3.6). This systematic difference between silicate measurements in MR03-K02 and MR05-05 was probably due to a lack of accuracy in the atomic absorption spectrometry silicon standard solution (1000 mg l^{-1}, lot 402F9041; Kanto Chemical Co., Tokyo, Japan) used for the silicate standards in MR03-K02.

Data Archive

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

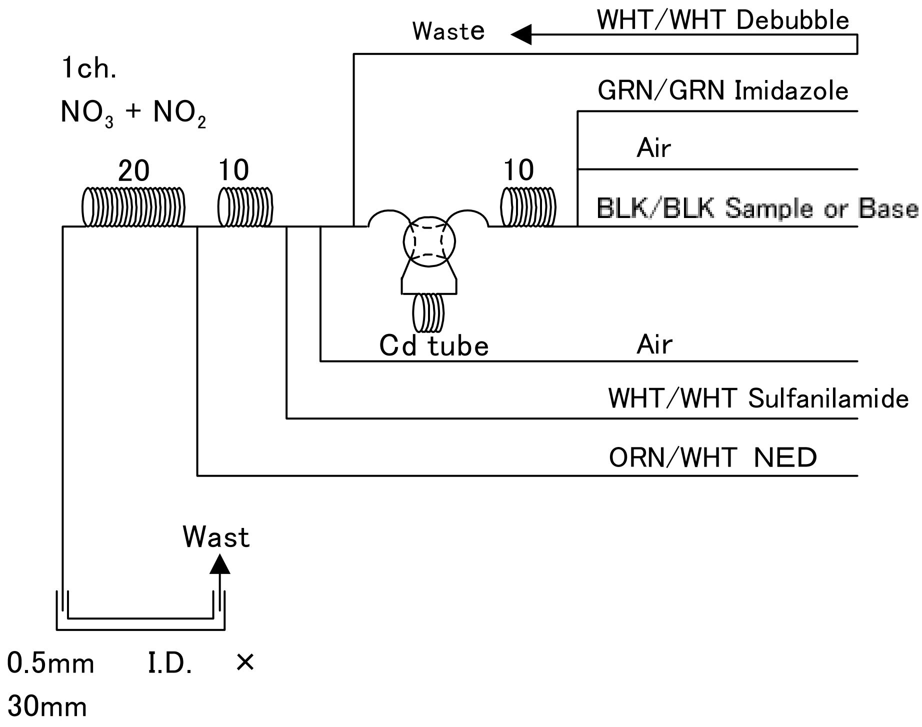

FIGURE 3.3.1: 1CH. (NO_3+NO_2) FLOW DIAGRAM.

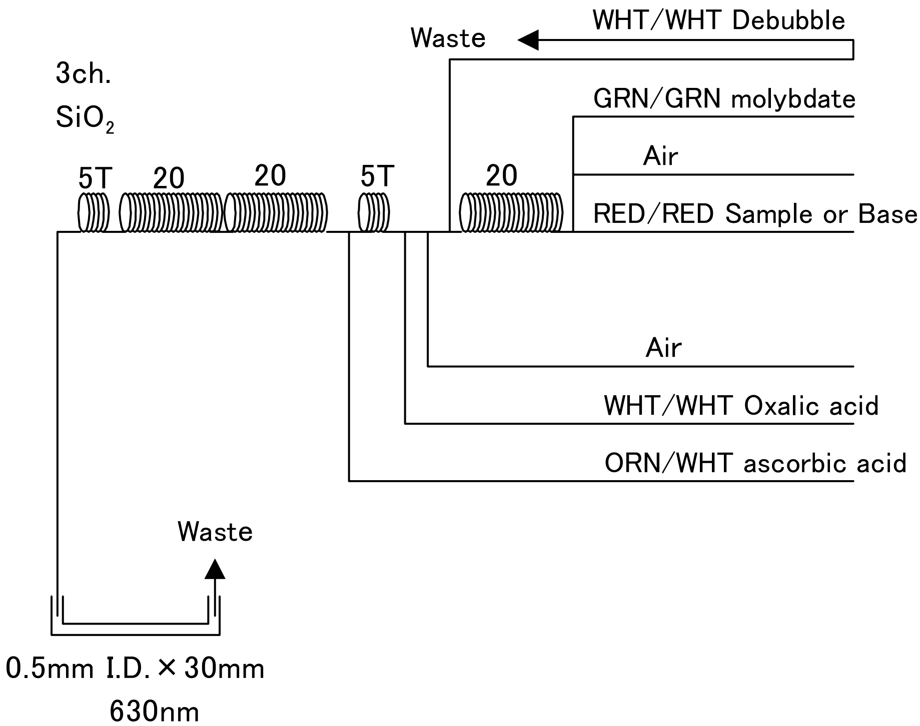

FIGURE 3.3.2: 2CH. (NO_2) FLOW DIAGRAM.

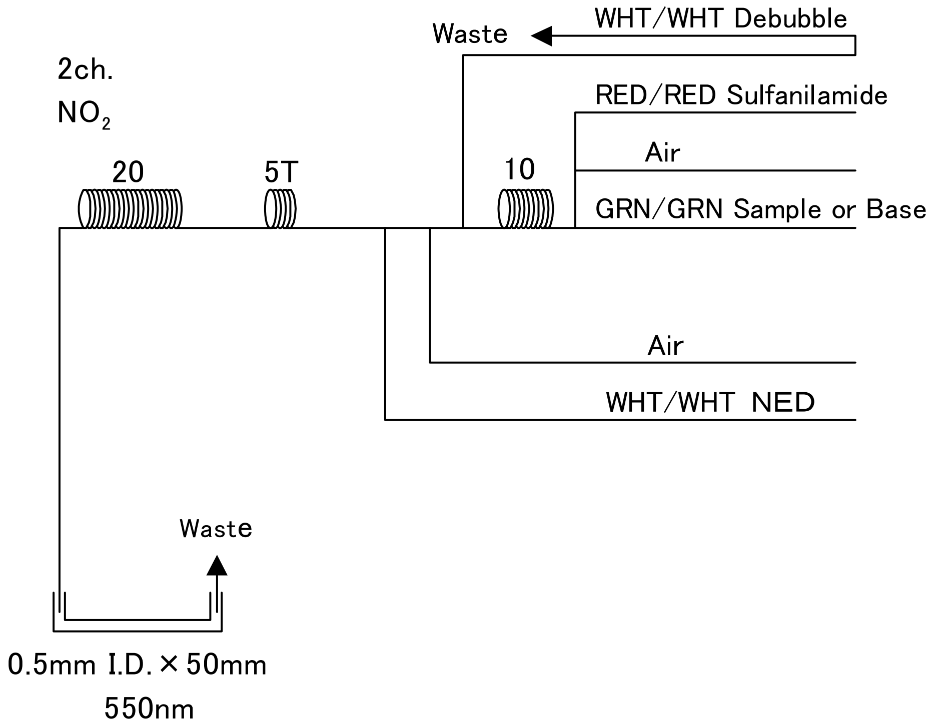

FIGURE 3.3.3: 3CH. (SIO_2) FLOW DIAGRAM.

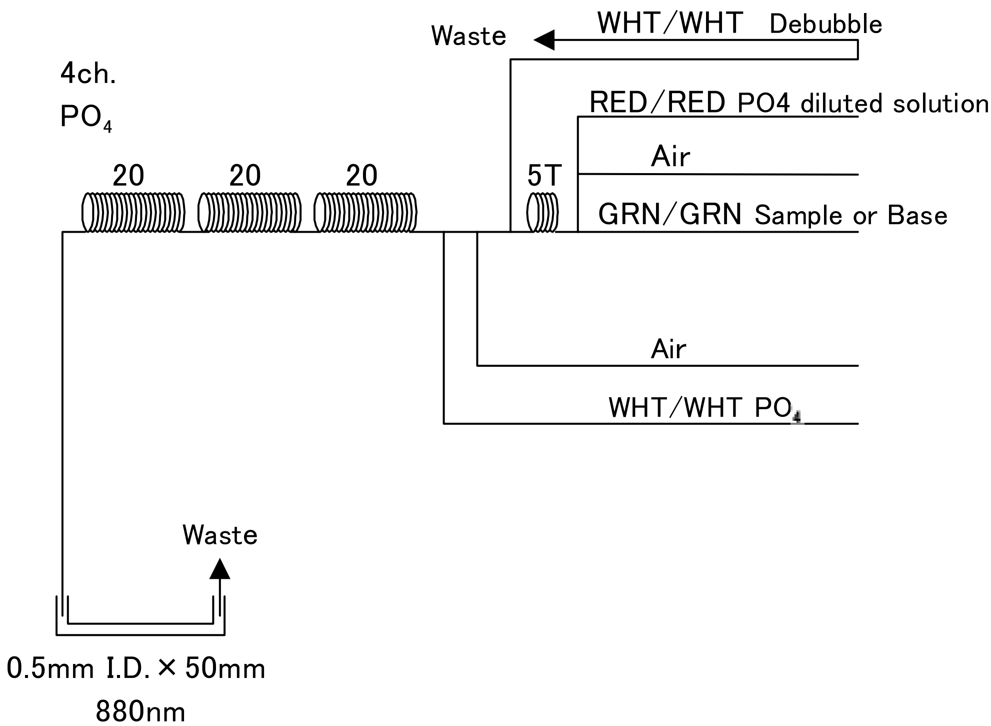

FIGURE 3.3.4: 4CH. (PO_2) FLOW DIAGRAM.

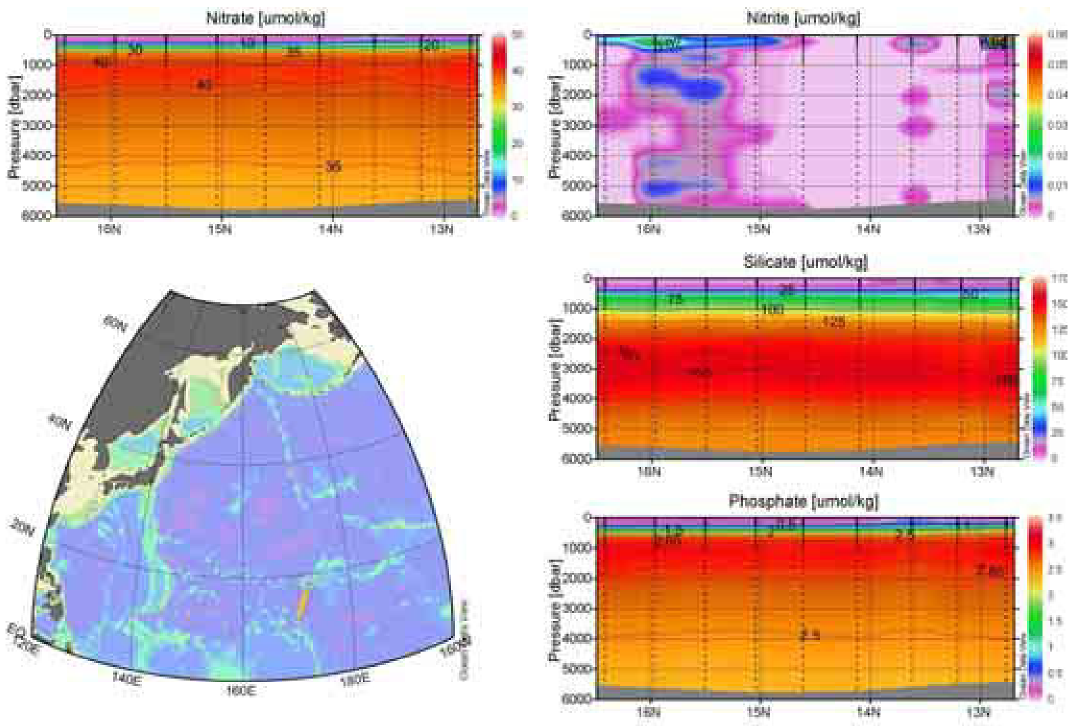

FIGURE 3.3.5: VERTICAL SECTIONS OF NUTRIENTS ALONG WITH CTD OBSERVATIONS LINE.

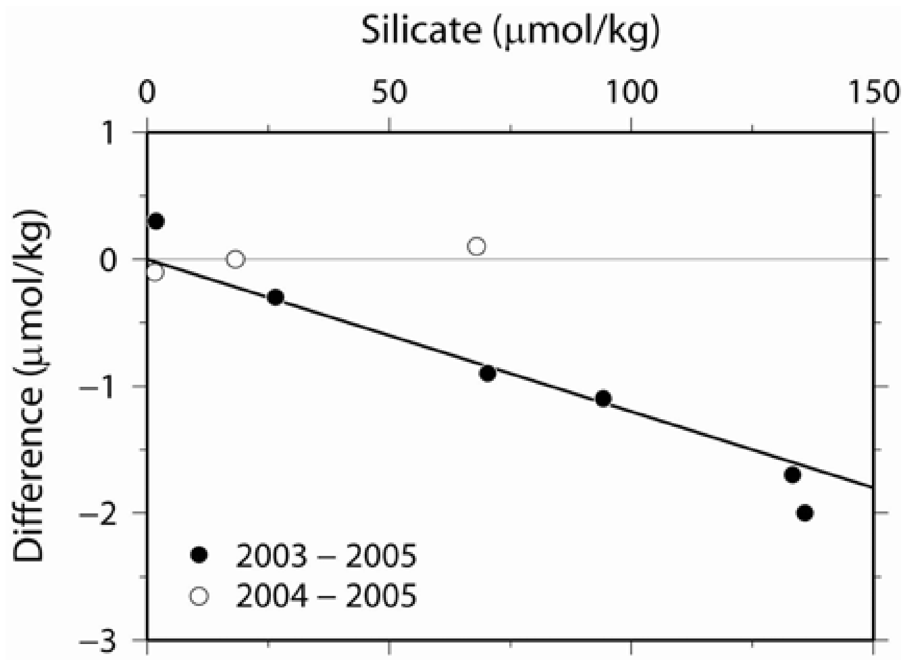

FIGURE 3.3.6: DIFFERENCE BETWEEN RMNS SILICATE MEASUREMENTS IN MR03-K02 (2003) and KH04-4 LEG 2 (2004) FROM THOSE IN MR05-05 (2005) PLOTTED AGAINST THE SILICATE MEASUREMENTS FROM 2005.

3.4 Total CO_2 (TCO_2)

Personnel

Akihiko MURATA (JAMSTEC): Principal Investigator
Minoru KAMATA (MWJ)
Taeko OHAMA (MWJ)

Objective

Global warming due to an increase of CO_2 in the atmosphere is now regarded as a social problem. Therefore understanding of CO_2 cycling is an urgent task. Because the ocean plays a major role in absorbing atmospheric CO_2, accurate estimation of CO_2 absorption by the ocean is highly important. Total CO_2 (TCO_2) indicates sum of inorganic carbon species dissolved in seawater. Therefore we can understand how much CO_2 has been absorbed and accumulated in the ocean's interior by measuring TCO_2 in the ocean.

The present investigation was carried out to estimate accumulation of CO_2 in the ocean's interior of the western North Pacific subtropical gyre.

Measured Parameters

Total CO_2 (TCO_2)

Method

Seawater samples were collected by 12L Niskin bottles at 9 stations. Seawater was sampled in a 300 ml glass bottle, which was previously soaked in 5% non-phosphoric acid detergent (pH = 13) solution for 3 hours at least and was cleaned by fresh water and Milli-Q deionized water 3 times each. The glass bottle was filled smoothly from the bottom with a drawing tube connected to the Niskin drain. Seawater was overflowed for 20 seconds with care so as not to leave any bubbles in the bottle. Prior to the analysis, 3ml of the sample (1 % of the bottle volume) was removed from the glass bottle in order to make a headspace. The samples were then poisoned with 100 μl of saturated solution of mercury chloride within 1 hour from sampling time. After poisoning, the samples were sealed using grease (Apiezon M grease) and a stopper-clip. The samples were stored in a refrigerator at approximately 5 ℃ until analysis.

Table 3.4.1 illustraties station name and the position where discrete samples were collected.

Two analyzers systems for TCO_2 measurement were mounted on board the ship. Both the systems have a PC control sampling system and a Model 5012 coulometer (Carbon Dioxide Coulometer, UIC Inc.). Concentrations of TCO_2 were measured as follows.

CO_2 standard gas (1.8 % CO_2 in N_2), 10 % phosphoric acid solution and 6 seawater samples were sequentially measured. The CO_2 standard gas was measured to confirm the constancy of the calibration factor during a run, and the phosphoric acid was measured for acid blank correction. From a sampling bottle, approximately 27 ml of seawater was taken in a pipette and was mixed with 2 ml of 10% phosphoric acid in a chamber. The mixing solution was stripped of CO_2 by bubbling N_2 gas for 10 minutes at a flow rate of 140 ml / min. The stripped CO_2 was absorbed into Cathode solution (UIC, Inc). The amout of CO_2 was determined by titrating coulometrically the hydroxyethlcarbamic acid that is formed in the mixing solution.

Calibrations of the two systems were made by Certified Reference Material (CRM batch #60; provided by Dr. A.G. Dickson, Scripps Institution of Oceanography), which were conducted at times of renewal of coulometer solutions. We also measured reference materials (RM), which were prepared by JAMSTEC (batch Q09 and BGL2) and by KANSO (batch G) to monitor response of coulometer solutions.

Preliminary Results

During the cruise, 6 CRMs and 22 RMs were analyzed. The standard deviations of absolute differences of duplicate measurements of CRMs and RMs were 0.5 and, 1.0 μmol/kg, respectively.

A duplicate seawater analysis was made on every 9th seawater sample. The average of the differences was 1.5 μmol/kg (n=37). The standard deviation was 1.4 μmol/kg.

Data Archive

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

TABLE 3.4.1: INVENTORY OF THE WATER COLUMN SAMPLES.

Station	Lat.	Lon.
WC9	16-25.0'N	171-35.0'E
WC8	15-57.5'N	171-25.0'E
WC7	15-30.0'N	171-15.0'E
WC6	15-02.5'N	171-05.0'E
WC5	14-35.0'N	170-55.0'E
WC4	14-07.5'N	170-45.0'E
WC3	13-40.0'N	170-35.0'E
WC2	13.12.5'N	170-25.0'E
WC1	12-46.0'N	159-15.0'E

3.5 pH (potentiometric)

Personnel

Akihiko Murata (JAMSTEC): Principal Investigator
Taeko Ohama (MWJ)
Fuyuki Shibata (MWJ)
Minoru Kamata (MWJ)

Objective

Global warming due to an increase of CO_2 in the atmosphere is now regarded as a social problem. Therefore understanding of CO_2 cycling is an urgent task. Because the ocean plays a major role in buffering the increase of atmospheric CO_2, studies of air-sea exchanges of CO_2 are highly important.

Measured Parameters

pH (total scale)

Methods

pH (-log[H^+]) of the seawater was measured potentiometrically in a bottle made of glass.

The e.m.f. of a glass / reference electrode was measured with a pH / Ion meter (Radiometer PHM95). Separate glass (Radiometer PHG201) and reference (Radiometer REF201) electrodes were used. To prevent seawater sample from exchanging CO_2 with atmosphere during pH measurement, the electrodes were inserted to a rubber stopper, which was fit to the mouse of a sample bottle. The sample bottle was kept at 25℃ within ±0.1℃ in a water bath during the measurement. The temperature during pH measurement was monitored with a temperature sensor (Radiometer T901).

To calibrate the electrodes, the TRIS (pH=8.0893 pH unit at 25℃, Delvalls and Dickson, 1998) and AMP (pH=6.7866 pH unit at 25℃, Dickson and Goyet, 1996) in synthetic seawater (S = 35) were used (pH_T; total scale).

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

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

where ER indicates electrode response, which is calculated as follows:

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

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

$$ER = RT\,LN(10) / F = 59.16 \text{ mV / pH unit at } 25℃$$

Preliminary Results

Figure 3.5.1 shows the vertical distribution of pH from St.WC09 to St.WC01. Absolute differences of duplicate measurements were plotted sequentially to evaluate the precision of the measurements (Fig.3.5.2). The average and repeatability (1 std) were 0.001 and 0.001pH unit, respectively.

Data Archive

All data was submitted to JAMSTEC Data Management Office (DMO) and is currently under its control.

References

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 & C. Goyet, eds. ORNS/CDIAC-74.

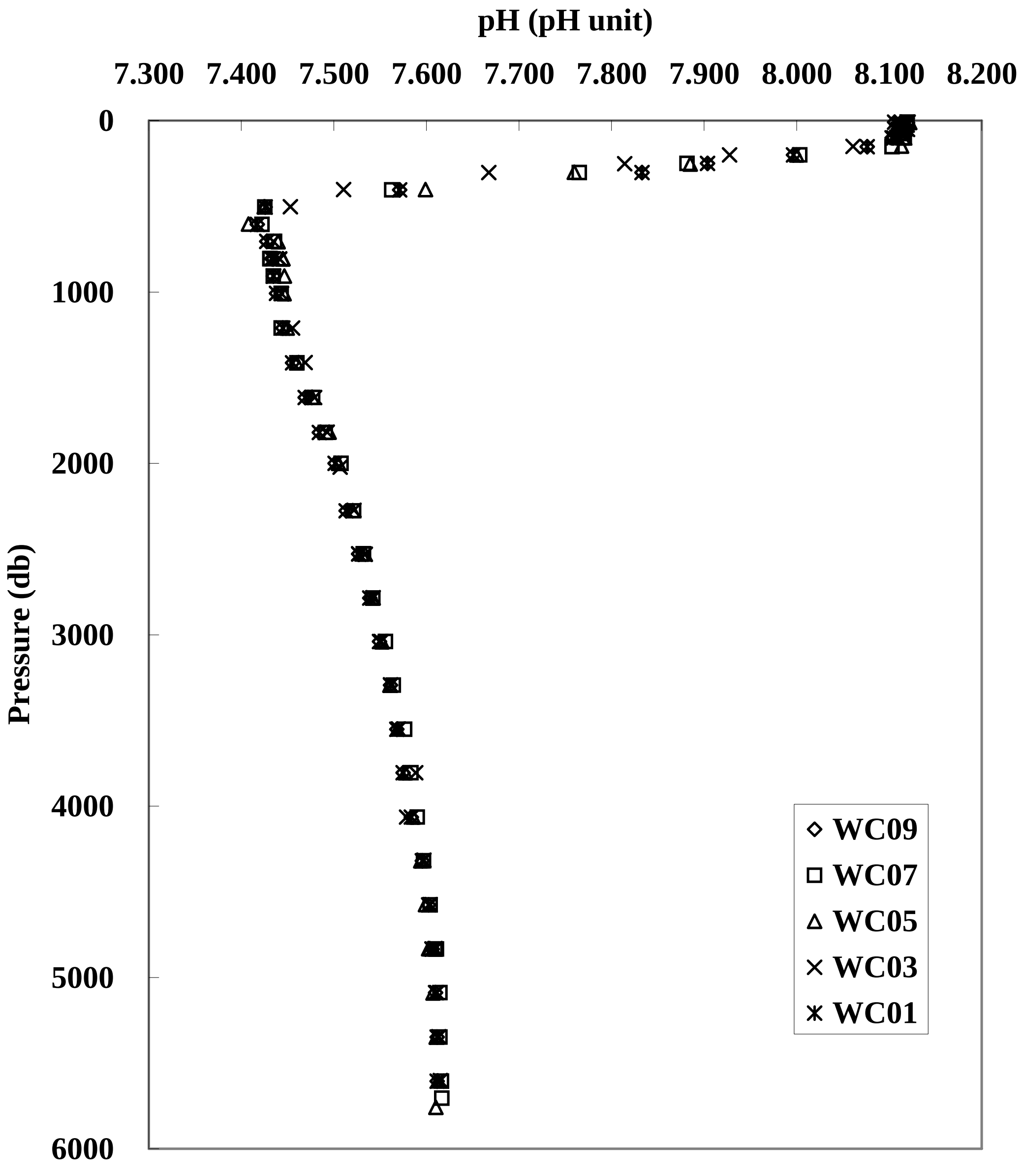

FIGURE 3.5.1: VERTICAL DISTRIBUTION OF PH FROM ST. WC09 TO ST. WC01.

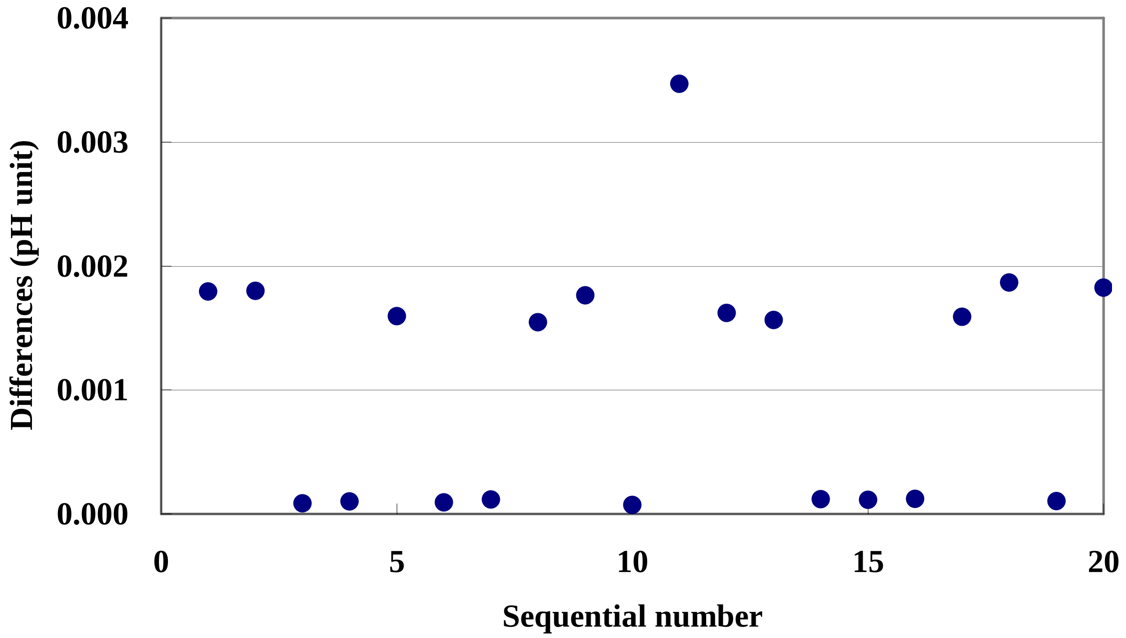

FIGURE 3.5.2: DIFFERENCES OF DUPLICATE MEASUREMENTS.

3.6 Total Alkalinity

Personnel

Akihiko Murata (JAMSTEC): Principal Investigator
Fuyuki Shibata (MWJ)
Taeko Ohama (MWJ)

Objective

Global warming due to an increase of CO_2 in the atmosphere is now regarded as a social problem. Therefore understanding of CO_2 cycling is an urgent task. Because the ocean plays a major role in absorbing atmospheric CO_2, accurate estimattion of CO_2 absorption by the ocean is highly important.

Total alkalinity (TAlk) is defined as the number of moles of hydrogen ion equivalent to the excess of proton acceptors over proton donors in 1 kg of seawater. TAlk is one of the CO_2-system parameters (other parameters are total CO_2, pCO_2 and pH), and is required to measure as accurate as possible to detect changnes of anthropogenic CO_2 in the ocean, and to use it as a tracer of oceanic circulation.

In the present survey, TAlk was measured to detect changes of anthropogenic CO_2 in the North Pacific subtropical gyre.

Measured Parameters

Total alkalinity (TAlk)

Methods

1. Seawater sampling

Seawater samples for TAlk measurement were collected by 12L Niskin bottles at 9 stations. Seawater was sampled into 125 ml glass bottles, which was previously soaked in 5% non-phosphoric acid detergent (pH = 13) solution for 3 hours at least and was cleansed by fresh water and Milli-Q deionized water 3 times each. A sampling tube was connected to a drain of Niskin bottles. The glass bottles were filled from the bottom smoothly, and seawater was overflowed for 6 seconds. The glass bottles were sealed with a plastic screw cap, and were stored in a refrigerator at approximately 5 degree C until analysis.

2. Seawater analysis

For TAlk measurement by potentiometry, we used two TAlk measuring systems (TA-1000), which were made by Nihon ANS Ltd, and were hereafter denoted as A and B, respectively. A TAlk measuring system has 6 units: a water circulaiton-titration device, an auto-sampler, an auto-burette (Metrohm), a pH meter (Thermo Orion), a thermostat bath and a PC. With the systems, first, approximately 42ml of a seawater sample was transferred into a water-jacketed pipette from a glass bottle. After that, the seawater sample was transferred into a titration cell. In the titration cell, samples were titrated with a titrant of 0.05M hydrochloric acid mixed wtih 0.65M sodium chloride. The whole titration procedure was carried out automatically.

We analyzed samples of WC9, WC8, WC7, WC6, WC4 and WC3 stations with TA1000-A, and WC5, WC2 and WC1 stations with TA1000-B. The acid used for the titration was calibrated by measuring TAlk of 4 different concentrations of Na2CO3 (0 to 2500 μmol/L) in 0.7N NaCl solutions. The Gran-plot method was applied to calculate TAlk.

Results

Four duplicate samples were taken on every station. The absolute differences between the duplicate samples were plotted on a range control chart, separately for TA1000-A and -B (see Figures 3.6.1 and 3.6.2). The averaged differences and the standard deviation of TA1000-A were 2.38 and 2.09 μmol/kg (n=24), respectively. Those for TA1000-B were 3.75 and 3.31 μmol/kg (n=12).

Data Archive

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

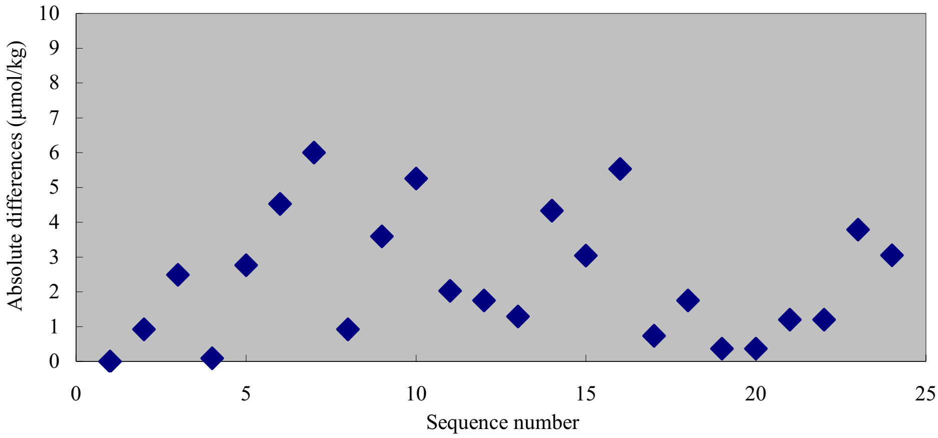

FIGURE 3.6.1: RANGE CONTROL CHART OF TA-1000-A.

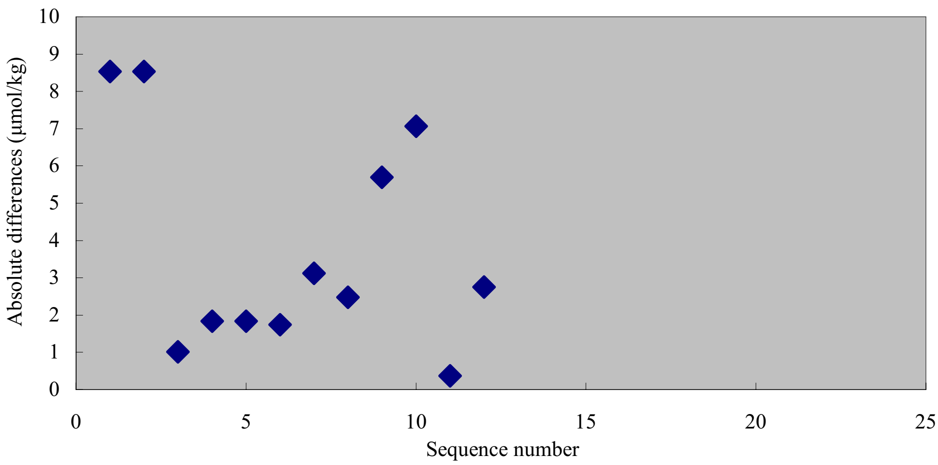

FIGURE 3.6.2: RANGE CONTROL CHART OF TA-1000-B.

3.7 Chlorofluorocarbons

Personnel

Ken'ichi Sasaki (Japan Marine Science and Technology Center): Principal Investigator
Katsunori Sagishima (Marine Works Japan Ltd.)

Objectives

Chlorofluorocarbons (hereafter CFCs) are the artificially formed gas. CFC-11 (CCl_3F), CFC-12 (CCl_2F_2) and other CFCs are very useful chemical tracers to clarify the water movement. We determine CFC-11 and CFC-12 concentrations in seawater on board.

Methods

Dissolved CFCs concentrations in seawater were determined with the electron capture detector - gas chromatograph (ECD-GC) attached the purge and trapping system. This Procedure was based on Bullister and Weiss (1988).

1) Sampling

Seawater samples for CFCs measurement were collected from 12 litter Niskin bottles to N2 purged 300ml glass bottle. Three times bottle/cylinder volumes of seawater sample were overflowed to minimize contamination with atmospheric CFCs.

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

2) Analysis

The CFCs analytical system was modified from the original design of Bullister and Weiss (1988). Sample volume was 150ml. The trap used to hold CFCs consists of a length of 1/8 in. o.d. SS tubing packed with 5 cm of Porapak T (80/100 mesh). Trapping and desorbing temperature were -45 deg-C and 130 deg-C, respectively. The trapped gas was transformed to GC system directly. Analytical conditions were bellow (Table 3.7.1).

TABLE 3.7.1: INSTRUMENTS AND ANALYTICAL CONDITIONS.

	Instruments	
	Gas Chromatograph:	GC-14B (Shimazu Ltd.)
	Detector:	ECD-14 (Shimazu Ltd)
Column		
	Pre column:	Pola PLOT – QHT (i.d.: 0.53mm, length: 1m, tick: 6.0μm)
	Main column:	Pola PLOT – QHT (i.d.: 0.53mm, length: 30m, tick: 6.0μm)
Temperature		
	Oven:	140 deg-C (constant)
	Detector:	250 deg-C
	Trapping & desorbing:	-45 deg-C & 130 deg-C
Gas flow		
	Column flow:	**3.0 ml/min**
	Detector Make UP:	14.5 ml/min
	Column Purge:	8.4 ml/min

Data Archive

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

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.

3.8 Carbon-14 and -13

18 December 2006

(1) Personnel

Yuichiro Kumamoto (IORGC, JAMSTEC)
Fuyuki Shibata (MWJ)

(2) Introduction

MR03-K02 cruise was carried out aboard the R/V MIRAI in the western North Pacific Ocean in May – June of 2003. One of the main purposes of this cruise is investigation of material transports by the abyssal water flowing into the North Pacific through the Wake Island Passage. This is the final report of $\delta^{13}C$ and $\Delta^{14}C$ measurements of dissolved inorganic carbon (DIC). Our preliminary reports are replaced by this final report.

(3) Sample collection

The sampling stations are summarized in Table 3.8.1. A total of 330 seawater samples, including 11 replicate samples, were collected between surface (about 10 m depth) and near bottom at nine stations using 12-liter X-Niskin bottles. The seawater in the X-Niskin bottle was siphoned into a 250 cm^3 glass bottle with enough seawater to fill the glass bottle 2 times. Immediately after sampling, 10 cm^3 of seawater was removed from the bottle and poisoned by 50 µl of saturated $HgCl_2$ solution. Then the bottle was sealed by a glass stopper with Apiezon M grease and stored in a cool and dark space on board.

Table 3.8.1 The sampling locations, date, number of samples, and maximum sampling pressure.

Station	Date (UTC)	Latitude N degree	Longitude E degree	Number of samples	Number of replicates	Max. sampling pressure /db
WC1	5/30/03	12.771	170.248	35	0	5449
WC2	5/30/03	13.208	170.417	35	0	5487
WC3	5/30/03	13.631	170.550	35	0	5601
WC4	5/29/03	14.127	170.746	36	0	5719
WC5	5/29/03	14.616	170.861	36	0	5758
WC6	5/29/03	15.048	171.086	36	0	5767
WC7	5/28/03	15.516	171.251	36	0	5703
WC8	5/28/03	15.971	171.413	35	0	5625
WC9	5/27/03	16.419	171.581	35	11	5562
Total				319	11	

(4) Sample preparation

In our laboratory, DIC in the seawater samples were stripped cryogenically and split into three aliquots: Accelerator Mass Spectrometry (AMS) ^{14}C measurement (about 200 µmol), ^{13}C measurement (about 100 µmol), and archive (about 200 µmol). Efficiency of the CO_2 stripping from seawater sample was more than 95 % that was calculated from concentration of DIC in the seawater samples. The stripped CO_2 gas for ^{14}C was then converted to graphite catalytically on iron powder with pure hydrogen gas. Yield of graphite powder from CO_2 gas was estimated to be more than 70 % by weighing of sample graphite powder. Details of these preparation procedures were described by Kumamoto et al. (2000).

(5) Sample measurements

$\delta^{13}C$ of the sample CO_2 gas was measured using Finnigan MAT252 mass spectrometer. The $\delta^{13}C$ value was calculated by a following equation:

$$\delta^{13}C\ (‰) = (R_{sample} / R_{standard} - 1) \times 1000. \quad (1)$$

where R_{sample} and $R_{standard}$ denote ^{13}C / ^{12}C ratios of the sample CO_2 gas and the standard CO_2 gas, respectively. The working standard gas was purchased from Oztech Gas Co. with assigned $\delta^{13}C$ value of -3.64 ‰ versus VPDB (Lot No. SHO-873C). The gas has been calibrated relative to the appropriate internationally accepted IAEA primary standards. $\Delta^{14}C$ in the graphite sample was measured in AMS facilities of Institute of Accelerator Analysis Ltd in Shirakawa (Pelletron 9SDH-2, NEC) and Japan Atomic Energy Agency (3 MV Tandetron, HVEE) in Mutsu, Japan. The $\Delta^{14}C$ value was calculated by:

$$\delta^{14}C\ (‰) = (R_{sample} / R_{standard} - 1) \times 1000, \quad (2)$$

$$\Delta^{14}C\ (‰) = \delta^{14}C - 2\ (\delta^{13}C + 25)\ (1 + \delta^{14}C / 1000), \quad (3)$$

where R_{sample} and $R_{standard}$ denote, respectively, ^{14}C / ^{12}C ratios of the sample and the international standard, NIST Oxalic Acid SRM4990-C (HOxII). $R_{standard}$ was corrected for decay since A.D. 1950 (Stuiver and Polach, 1977; Stuiver, 1983). Equation 3 is normalization for isotopic fractionation. When quality of $\delta^{13}C$ data was not "good", $\Delta^{14}C$ was calculated by interpolated $\delta^{13}C$ value from data at just above and below layers. Finally $\Delta^{14}C$ value was corrected for radiocarbon decay between the sampling and the measurement. Individual errors of $\delta^{13}C$ were given by standard deviation of repeat measurements. Errors of $\Delta^{14}C$ were derived from larger of the standard deviation of repeat measurements and the counting error. Means of the $\delta^{13}C$ and $\Delta^{14}C$ errors were calculated to be 0.003 ‰ and 3.4 ‰ that probably correspond to "repeatabilities" of our $\delta^{13}C$ and $\Delta^{14}C$ measurements, respectively. It should be noted that these errors did not include error due to sample preparation.

(6) Replicate measurements

Nine pairs of replicate samples were collected at Station WC9. Results of the replicate samples are shown in Table 3.8.2. The standard deviation of the $\delta^{13}C$ and $\Delta^{14}C$ replicate analyses in good measurement was calculated to be 0.017 ‰ (n = 8) and 3.3 ‰ (n = 11), respectively. The results of replicate measurements suggested that "reproducibilities" of our $\delta^{13}C$ and $\Delta^{14}C$ measurements including errors due to the sample preparation were less than 0.02 ‰ and 3.5 ‰, respectively.

Table 3.8.2 Summary of replicate analyses

Station	Btl	$\delta^{13}C$ / ‰				$\Delta^{14}C$ / ‰			
		$\delta^{13}C$	Error[a]	E.W.Mean[b]	Uncertainty[c]	$\Delta^{14}C$	Error[d]	E.W.Mean[b]	Uncertainty[c]
WC9	12	0.061	0.001	0.061	0.006	-226.7	3.5	-227.7	2.5
		0.069	0.004			-228.7	3.5		
WC9	11	0.089	0.001	0.090	0.015	-227.1	3.4	-224.7	2.4
		0.110	0.005			-222.1	3.5		
WC9	10	0.151	0.003	0.156	0.005	-222.6	3.4	-221.3	2.4
		0.158	0.002			-219.9	3.5		
WC9	9	-	-	-	-	-219.8	3.5	-223.6	5.4
		-	-			-227.4	3.5		
WC9	8	-	-	-	-	-212.2	3.5	-214.1	2.6
		-	-			-215.9	3.4		
WC9	7	-	-	-	-	-204.8	3.5	-202.6	3.1
		-	-			-200.4	3.4		
WC9	6	0.282	0.004	0.304	0.030	-200.9	3.6	-197.3	5.0
		0.325	0.004			-193.8	3.5		
WC9	5	0.346	0.003	0.353	0.018	-198.2	3.5	-195.9	3.3
		0.371	0.005			-193.5	3.6		
WC9	4	0.400	0.002	0.400	0.002	-190.9	3.5	-190.5	2.5
		0.399	0.003			-190.1	3.6		
WC9	3	0.415	0.004	0.415	0.003	-181.8	3.8	-179.7	2.8
		0.415	0.004			-177.8	3.6		
WC9	2	0.403	0.005	0.434	0.030	-185.7	3.5	-183.3	3.4
		0.445	0.003			-180.9	3.5		

a. Standard deviation of several time measurements
b. Error weighted mean of the replicate pair
c. Larger of the standard deviation and the error weighted standard deviation of the replicate pair
d. Larger of the standard deviation and the counting error

(7) Quality control flag assignment

Quality flag values were assigned to all $\delta^{13}C$ and $\Delta^{14}C$ measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev.2 section 4.5.2 (Joyce et al., 1994). $\Delta^{14}C$ measurements of 142 seawater samples collected at stations WC2, WC4, WC6, and WC8 have not finished yet because of a lack of funding (flag 1). Except those unmeasured samples, measurement flags of 2, 3, 4, and 6 have been assigned (Table 3.8.3). For the choice between 2 (good), 3 (questionable) or 4 (bad), we basically followed a flagging procedure that described by Key et al. (1996) as listed below:

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

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

c. Vertical sections against depth were prepared using the Ocean Data View (Schlitzer, 2006). If a datum was anomalous on the section plots, datum flag was degraded from 2 to 3, or from 3 to 4.

Table 3.8.3 Summary of assigned quality control flags

Flag	Definition	Number	
		$\delta^{13}C$	$\Delta^{14}C$
1	Not reported	0	142
2	Good	291	163
3	Questionable	10	3
4	Bad	10	0
6	Replicate	8	11
Total		319	319

(8) Data Summary

Figure 3.8.1 shows transects of $\delta^{13}C$ and $\Delta^{14}C$. In deep and bottom waters, there are no obvious differences in vertical profiles of $\delta^{13}C$ and $\Delta^{14}C$ among all the stations. We compared our deep $\delta^{13}C$ and $\Delta^{14}C$ data with historical ones (Kroopnick, 1985; Key et al., 2004) at stations closed to our observation line and found no systematic sifts between them. In the thermocline, there were some variations in $\delta^{13}C$ and $\Delta^{14}C$ by stations. In the upper thermocline (- 500 m depth), $\Delta^{14}C$ in northern stations were higher than those in southern stations. At the two southernmost stations, WC1 and WC2, $\delta^{13}C$ in the lower thermocline (500 - 1,000 m depth) were relatively high.

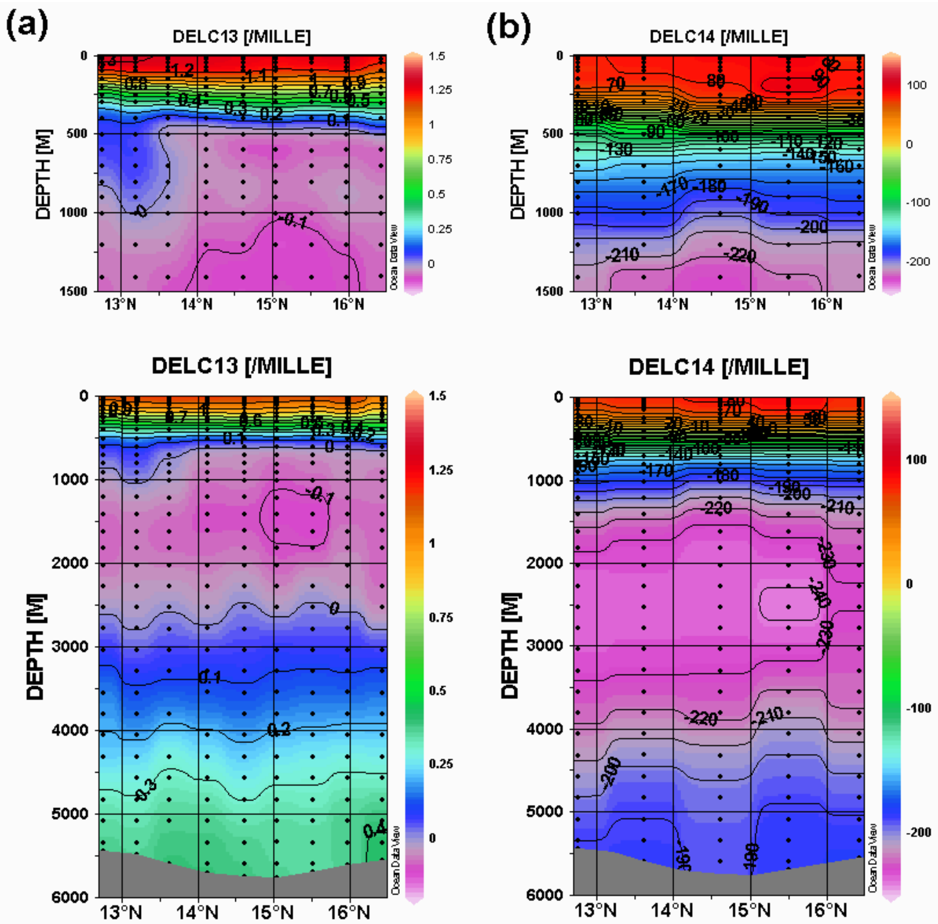

Figure 3.8.1 Transects of $\delta^{13}C$ (a) and $\Delta^{14}C$ (b) in dissolved inorganic carbon along the Wake Island Passage in 2003.

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3.9 TCO_2 and ^{13}C Discrete Water Samples

Personnel

Hisayuki Yoshikawa (Hokkaido University): Principal Investigator
Ai Sakamoto (Hokkaido University)

Objective

To clarify the N_2 fixation occurring in the North Pacific Subtropical Gyre

Parameters

Total inorganic carbon (TCO_2) and ^{13}C of TCO_2

Methods

We took discrete samples for measurements of TCO_2 and ^{13}C of TCO_2 in seawater from Niskin bottles on carousel sampling system at station WC1, 3, 5, 6, 7, 8 and 9, and from an outlet of fresh surface seawater which were used for underway measurements of pCO_2 and TCO_2 (typically, 4 samples per day). At each station, 72 seawater samples for measurements of TCO_2 and ^{13}C were stored in 100 cm^3 glass bottles, and poisoned with 0.04cm^3 of saturated $HgCl_2$ solution. Measurements of TCO_2 and ^{13}C will be made at Hokkaido University.

Results

Data analysis will be made after measurements of TCO_2 and ^{13}C of collected samples.

Data Archive

The original data will be archived at Hokkaido University, Sapporo, Japan. Data will be submitted to Data Management Office of JAMSTEC within three years.

3.10 CTD Measurements

Personnel

Hiroshi Uchida (JAMSTEC): Principal Investigator
Satoshi Ozawa (MWJ): Operation Leader
Miki Yoshiike (MWJ)
Tomoyuki Takamori (MWJ)

3.10.1 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 up to 10 km 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.

3.10.2 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 34,560 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 911plus 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 ware 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 3) 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 (3,000 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 2.4 m/s. SBE's dissolved oxygen sensor (SBE 43) was placed between the conductivity sensor module and the pump. Auxiliary sensors, Deep Ocean Standards Thermometer (SBE 35), altimeter, fluorometer and Transmissometer were also used with the SBE 9plus underwater unit. The SBE 35 position in regard to the SBE 3 is shown in Figure 3.10.1.

It is known that the CTD temperature data is influenced by the motion (pitching and rolling) of the CTD package. In order to reduce the motion of the CTD package, a heavy stainless frame (total weight of the CTD package without sea water in the bottles is about 1,000 kg) was used and an aluminum plate was attached to the frame (see Appendix C).

Summary of the system used in this cruise:

Deck unit:

SBE, Inc., SBE 11plus, S/N 0344

Under water unit:

SBE, Inc., SBE 9plus, S/N 0357 (Pressure sensor: S/N 42423)

Temperature sensor:

SBE, Inc., SBE 3plus, S/N 4188, (primary)

SBE, Inc., SBE 3plus, S/N 4216, (secondary)

Conductivity sensor:

SBE, Inc., SBE 4-02/0, S/N 1088, (primary)

SBE, Inc., SBE 4-04/0, S/N 1203, (secondary)

Oxygen sensor:

SBE, Inc., SBE 43, S/N 0390, (primary)

SBE, Inc., SBE 43, S/N 0391, (secondary)

Pump:

SBE, Inc., SBE 5T, S/N 3575, (primary)

SBE, Inc., SBE 5T, S/N 3576, (secondary)

Altimeter:

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

Deep Ocean Standards Thermometer:

SBE, Inc., SBE 35, S/N 0022

Fluorometer:

Seapoint Sensors, Inc., S/N 2148

Transmissometer:

WET Labs, Inc., C Star Transmissometer, S/N CST-207RD

Carousel Water Sampler:

SBE, Inc., SBE 32, S/N 0278

Water sample bottle:

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

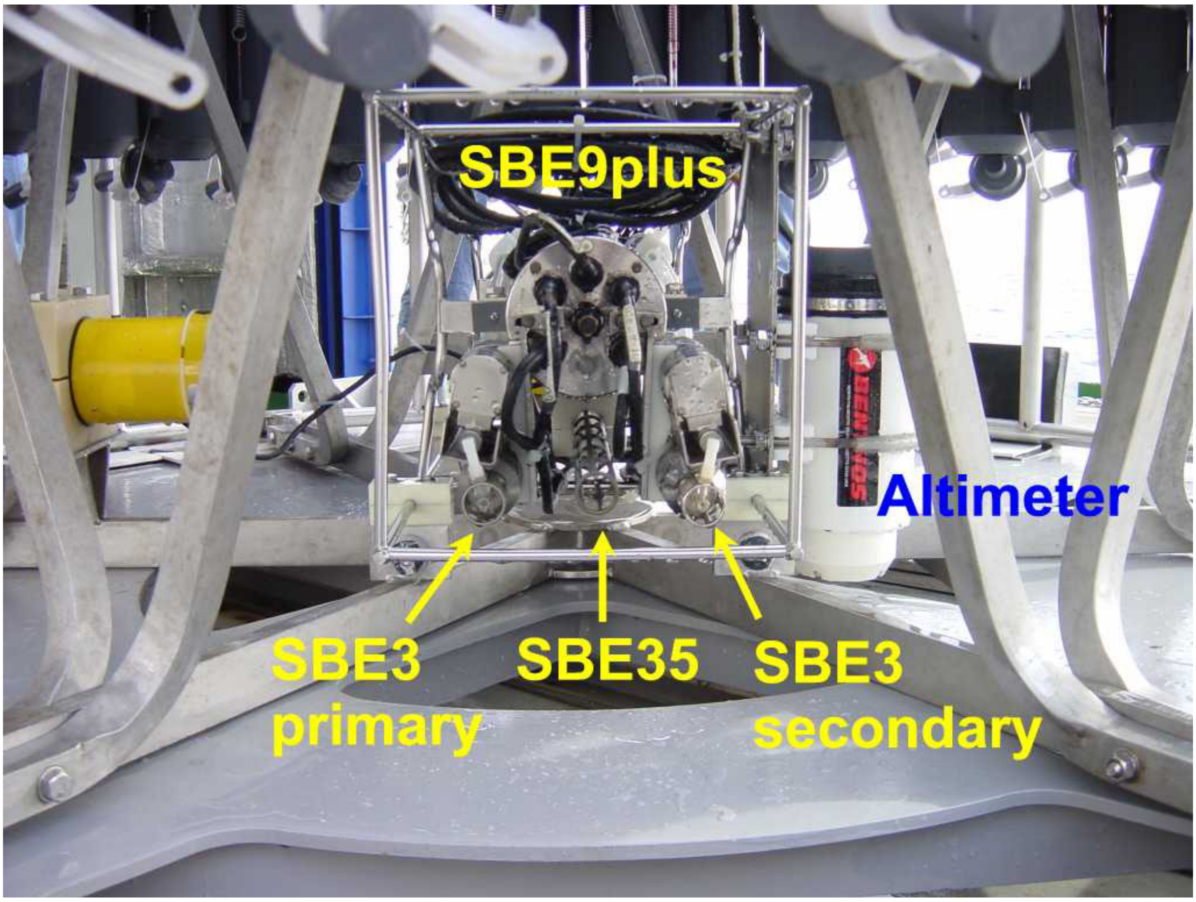

FIGURE 3.10.1: THE SBE 35 POSITION IN REGARD TO THE SBE 3 TEMPERATURE SENSOURS.

3.10.3 Pre-cruise calibration

1) Pressure

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

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

S/N 42423 May 17, 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

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

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

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

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 (Bundenberg Gauge Co. Ltd., UK; Model 480DA, S/N 23906) are performed at JAMSTEC (Yokosuka, Kanagawa, JAPAN) by Marine Works Japan Ltd. (MWJ), 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:

S/N 42423 April 18, 2003

slope = 0.9999112

offset = -0.0295469

The drift-corrected pressure is computed as

$$\text{Drift-corrected pressure (dbar)} = \text{slope} * \text{(computed pressure in dbar)} + \text{offset}$$

Result of the pressure sensor calibration against the dead weight piston gauge is shown in Figure 3.10.2.

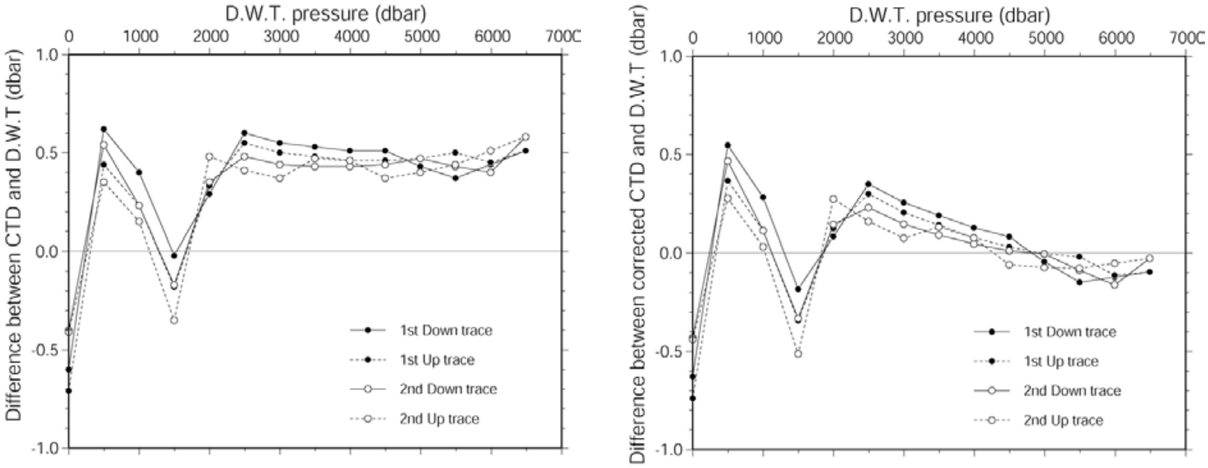

FIGURE 3.10.2: RESIDUAL PRESSURES BETWEEN THE CTD AND THE DEAD WEIGHT TESTER. LEFT IS FOR THE RESIDUAL BEFORE THE DRIFT-CORRECTION AND RIGHT IS FOR THE RESIDUAL AFTER THE DRIFT-CORRECTION.

2) Temperature (SBE 3)

The temperature sensing element is a glass-coated thermistor bead in a stainless steel tube, providing a pressure-free measurement at depths up to 10,500 (6,800) meters by titanium (aluminum) housing. The sensor output frequency ranges from approximately 5 to 13 kHz corresponding to temperature from –5 to 35 degC. The output frequency is inversely proportional to the square root of the thermistor resistance, which controls the output of a patented Wien Bridge circuit. The thermistor resistance is exponentially related to temperature. The SBE 3F thermometer has a nominal accuracy of 0.001 degC, typical stability of 0.0002 degC/month and resolution of 0.0002 degC at 24 samples per second. The premium temperature sensor, SBE 3plus, is a more rigorously tested and calibrated version of standard temperature sensor (SBE 3F). A sensor is designated as an SBE 3plus only after demonstrating drift of less than 0.001 degC during a six-month screening period. In addition, the time response is carefully measured and verified to be 0.065 ± 0.010 seconds.

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

S/N 4188 (primary) April 05, 2003 (SBE 3plus, aluminum)

g = 4.39869443e-003
h = 6.45278631e-004
i = 2.25999059e-005
j = 1.88773787e-006
f0 = 1000.000

S/N 4216 (secondary) April 05, 2003 (SBE 3plus, aluminum)

g = 4.35980548e-003
h = 6.46149426e-004
i = 2.29065636e-005
j = 1.95269986e-006

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).

Time drift of the SBE 3 temperature sensors based on the laboratory calibrations is shown in Figure 3.10.3.

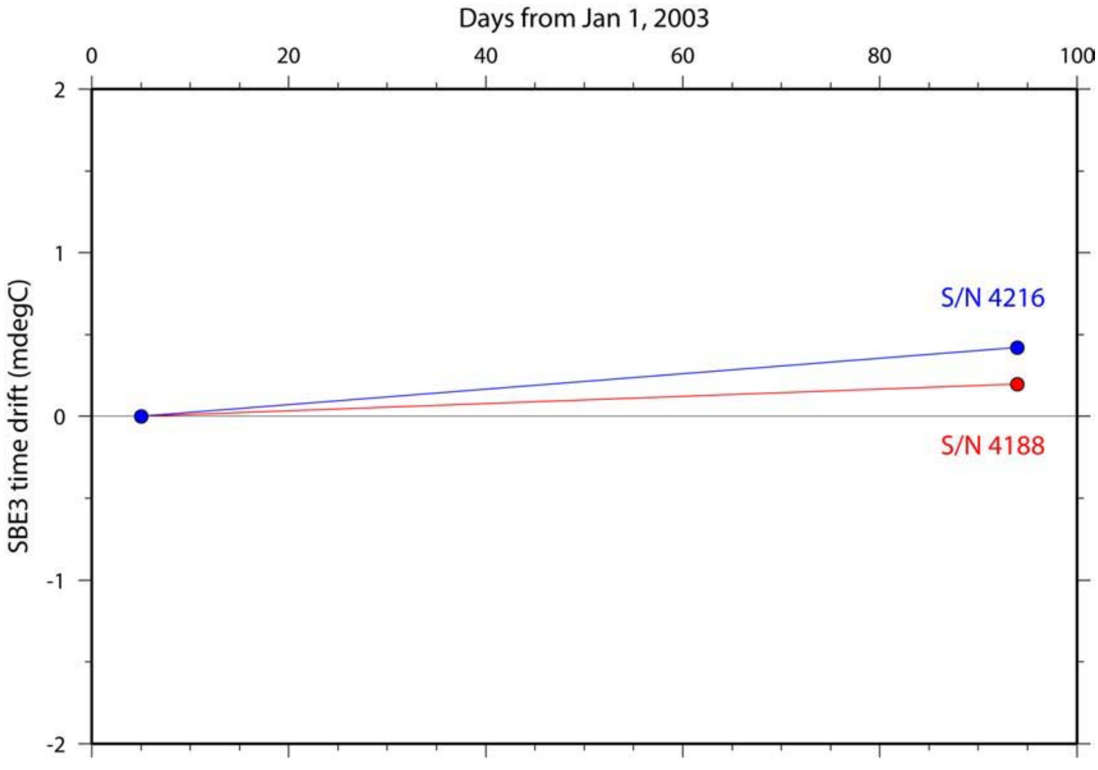

FIGURE 3.10.3: TIME DRIFT OF SBE 3 TEMPERATURE SENSORS (S/N 4188 AND S/N 4216) BASED ON LABORATORY CALIBRATIONS PERFORMED BY SBE, INC.

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., USA. The following coefficients were used in SEASOFT:

S/N 1088 (primary) November 01, 2002

g = -4.19904478e+000

h = 5.75495715e-001

i = -1.82243044e-004

j = 4.07824209e-005

CPcor = -9.57e-08 (nominal)

CTcor = 3.25e-06 (nominal)

S/N 1203 (secondary) April 10, 2003

g = -4.05452764e+000

h = 4.94066669e-001

i = -3.17163389e-005

j = 2.77491660e-005

CPcor = -9.57e-08 (nominal)

CTcor = 3.25e-06 (nominal)

Conductivity of a fluid in the cell is expressed as:

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

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

4) Deep Ocean Standards Thermometer

The Deep Ocean Standards Thermometer (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.

Temperature is determined by applying an AC excitation to reference resistances and an ultrastable aged thermistor with a drift rate of less than 0.001 °C/year. Each of the resulting outputs is digitized by a 20-bit A/D converter. The reference resistor is a hermetically sealed, temperature-controlled VISHAY. The switches are mercury wetted reed relays with a stable contact resistance. AC excitation and ratiometric comparison using a common processing channel removes measurement errors due to parasitic thermocouples, offset voltages, leakage currents, and gain errors. Maximum power dissipated in the thermistor is 0.5 µwatts, and contributes less than 200 µK of overheat error.

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 using terminal software.

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. The SBE 35 resolves temperature in the fixed-point cells to approximately 25 µK. 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 0022 October 12, 1999 (1st step: linearization)

a0 = 4.320725498e-3
a1 = -1.189839279e-3
a2 = 1.836299593e-3
a3 = -1.032916769e-5
a4 = 2.225491125e-7

Temperature (ITS-90) is computed according to

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

where n is the instrument output. Then the SBE 35 is certified by measurements in thermodynamic fixed-point cells of the TPW (0.0100 °C) and GaMP (29.7646 °C). Like SPRTs, the slow time drift of the SBE 35 is adjusted by periodic recertification corrections.

S/N 0022 26 March, 2003 (2nd step: fixed point calibration)

Slope = 1.000012
Offset = 0.000052

Temperature (ITS-90) is calibrated according to

Temperature (ITS-90) = Slope * Linearized temperature + Offset

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.

Time drift of the SBE 35 based on the fixed point calibrations is shown in Figure 3.10.4.

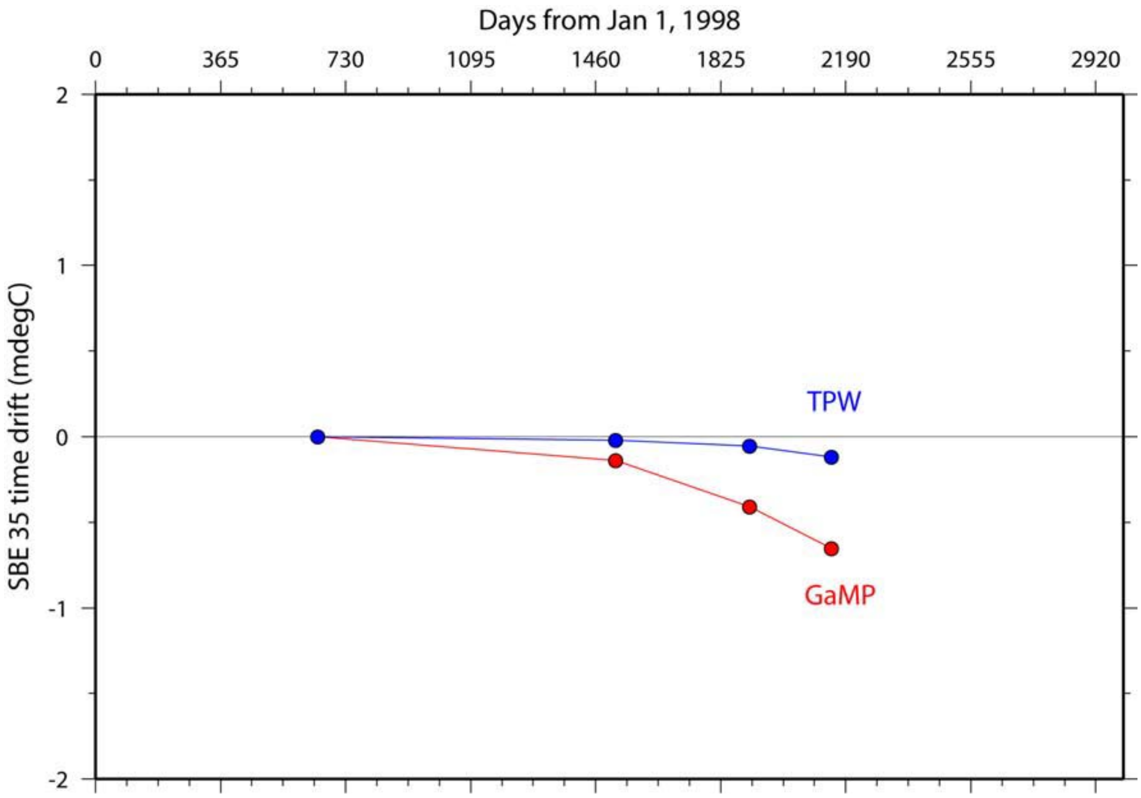

FIGURE 3.10.4: TIME DRIFT OF SBE 35 (S/N 0022) BASED ON LABORATORY FIXED POINT CALIBRATIONS (TRIPLE POINT OF WATER, TPW AND GALLIUM MELT POINT, GAMP) PERFORMED BY SBE, INC.

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) compared with the previous oxygen sensor (SBE 13). 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. 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.

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

S/N 430390 (primary)   April 07, 2003

Soc = 3.7710e-001

TCor = 0.0014

PCor = 1.350e-04

Offset = -0.5027

S/N 430391 (secondary)   April 07, 2003

Soc = 4.0140e-001

TCor = 0.0014

PCor = 1.350e-04

Offset = -0.4827

Oxygen (ml/l) is computed as

Oxygen (ml/l) = Soc * (v + offset)

* 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))]

A1 = -173.4292

A2 = 249.6339

A3 = 143.3483

A4 = -21.8482

B1 = -0.033096

B2 = -0.00170

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.

6) Altimeter

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

The following scale factors were used in SEASOFT:

FSVolt * 300 / FSRange = 10

Offset = 0.0

7) Fluorometer

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

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

S/N 2148 (unknown calibration date)

Gain = 5.0 (Gain setting = 30X 0-5 ug/l)

Offset = 0.0

Chlorophyll-a concentration is computed as

Chlorophyll-a (ug/l) = (Voltage * Range / Gain) + Offset

8) Transmissometer

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

The following coefficients were used in SEASOFT:

S/N CST-207RD May 19, 1998

M = 19.6410

B = -1.3940

Path length (m) = 0.25

The beam transmittance (Tr) iscomputed as

Tr (%) = M * voltage + B

3.10.4 Data collection and processing

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. Dissolved oxygen sensor was placed between the conductivity sensor module and the pump. Auxiliary sensors included altimeter, Deep Ocean Standards Thermometer, Fluorometer and Transmissometer. The SBE 9plus (sampling rate of 24 Hz) was mounted horizontally in a 36-position carousel frame.

CTD system was powered on at least two minutes in advance of the operation and was powered off at least two minutes after the operation in order to acquire pressure data on ship's deck.

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 1.0 m/s or 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 1.0 m/s or 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 5 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. 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 data acquisition software. Temperature, salinity, oxygen and descent rate profiles were displayed in real-time with the package depth and altimeter reading.

The following software was used in this cruise.

SBE, Inc., SEASAVE-Win32, version 5.27b

2) Data collection problems

When operating the SBE 911 system with SBE 35, it was found that the deck unit (SBE 11plus) frequently could not receive correct signal for confirmation of firing bottle #16. This problem occurred at station TR1 (750 dbar), WC9, WC7, WC5 (2,000 dbar), WC6, WC2 (1,800 dbar), WC1 (Bottom), TC1 and TC2 (no water sample). These bottle firing times are estimated using SBE 35 data and the bottle data are created after the cruise.

After the cruise, it was found that the altimeter setting was incorrect (FSVolt * 300 / FSRange = 5) during the cruise. The altimeter reading showed a distance twice of a true distance. So the altimeter reading was corrected after the cruise.

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 data processing module sequence and specifications used in the reduction of CTD data in this cruise.

Data processing software

SBE, Inc., SEASOFT-Win32, version 5.29b

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 3,000-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 temperature.

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 and oxygen voltage.

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

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.

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 for estimation of 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.

3.10.5 Post-cruise calibration

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 –0.73 dbar and the root-mean-square difference of 0.21 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 –0.16 dbar. So the post-cruise calibration is not deemed necessary for this pressure sensor.

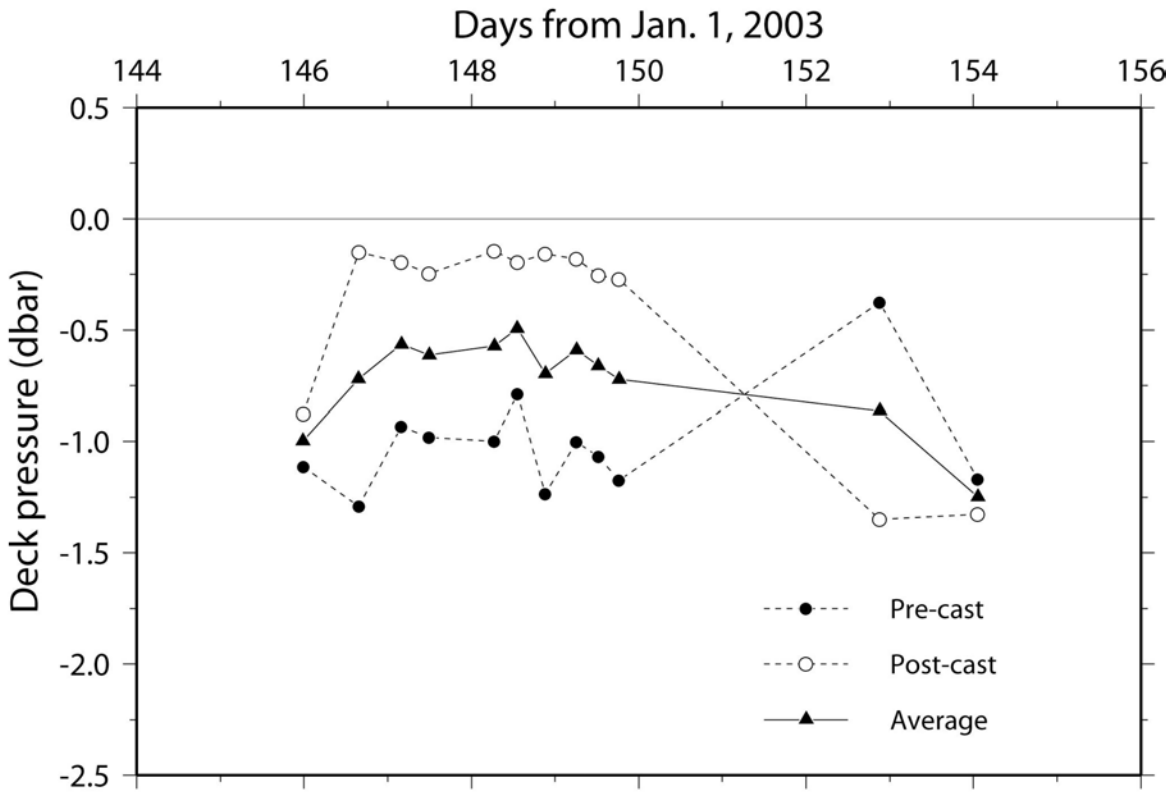

FIGURE 3.10.5: TIME SERIES OF THE CTD DECK PRESSURE. CORRECTION FOR THE ATMOSPHERIC PRESSURE DEVIATION IS APPLIED.

2) Temperature

The CTD temperature sensor (SBE 3) is 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 (Budeus and Schneider, 1998). The pressure sensitivity for a SBE 3 sensor is usually less than +2 m°C / 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 (about +0.5 m°C) that occurs in a TC duct and does not occur for un-pumped SBE 35 measurements (Larson and Pederson, 1996). Furthermore the SBE 35 calibrations have some uncertainty (about 0.2 m°C) and SBE 3 calibrations have some uncertainty (about 1 m°C). So the practical corrections for CTD temperature data can be made by using a SBE 35, correcting the SBE 3 to agree with the SBE 35 (a linear pressure correction, a viscous heating correction and an offset for drift and/or calibration uncertainty).

Post-cruise sensor calibration for the SBE 35 was performed at SBE, Inc., USA.

S/N 0022, 19 November 2003 (2nd step: fixed point calibration)

Slope = 1.000018

Offset = 0.000116

Offset of the SBE 35 data from the pre-cruise calibration are estimated to be –0.1 m°C for temperature less than 4 °C. So the post-cruise correction of the SBE 35 temperature data is not deemed necessary for the SBE 35.

The discrepancy between the CTD temperature and the SBE 35 is considered to be a function of pressure and time. Effect of the viscous heating is assumed to be constant. Since the pressure sensitivity is thought to be constant in time at least during observation period and observation period (3 days) is too short to estimate time drift during the period, the CTD temperature is calibrated as

$$\text{Calibrated temperature} = T - (c_0 * P + c_1)$$

where T is CTD temperature in °C, P is pressure in dbar, and c_0 and c_1 are calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation from the SBE 35 data. The fortran subroutine DMINF1 of the Scientific Subroutine Library II (Fujitsu Ltd., JAPAN) is used to determine the sets. The DMINF1 uses the revised quasi-Newton method.

The calibration is performed for the secondary temperature (S/N 4216) data. The CTD data created by the software module ROSSUM are used. The deviation of CTD temperature from the SBE 35 temperature at depth shallower than 2,000 dbar is large for determining the coefficients with sufficient accuracy since the vertical temperature gradient is too large in the regions. So the coefficients are determined using the data for the depth deeper than 1,950 dbar.

The number of data used for the calibration (from station WC9 to WC1), the mean absolute deviation from the SBE 35 and the calibration coefficients are listed in Table 3.10.1. Mean and standard deviation of the difference between the CTD temperature and the SBE 35 after the post-cruise calibration are listed in Table 3.10.2. The results of the post-cruise calibration for the CTD temperature are summarized in Table 3.10.3 and shown in Figure 3.10.6.

TABLE 3.10.1: CALIBRATION COEFFICIENTS FOR THE CTD TEMPERATURE (SECONDARY).

S/N	*Number*	*ADEV (m°C)*	*c_0 (°C/dbar)*	*c_2 (°C)*
4216	141	0.18	6.9351e-8	0.11e-3

TABLE 3.10.2: DIFFERENCE BETWEEN THE CTD TEMPERATURE AND THE SBE 35 AFTER THE POST-CRUISE CALIBRATION. MEAN AND STANDARD DEVIATION (SDEV) ARE CALCULATED FOR THE DATA BELOW AND ABOVE 1,950 DBAR.

S/N	*Pressure < 1,950 dbar*			*Pressure >= 1,950 dbar*		
	Num	*Mean (m°C)*	*Sdev(m°C)*	*Num*	*Mean (m°C)*	*Sdev (m°C)*
4216	276	0.40	13.17	156	0.02	0.32

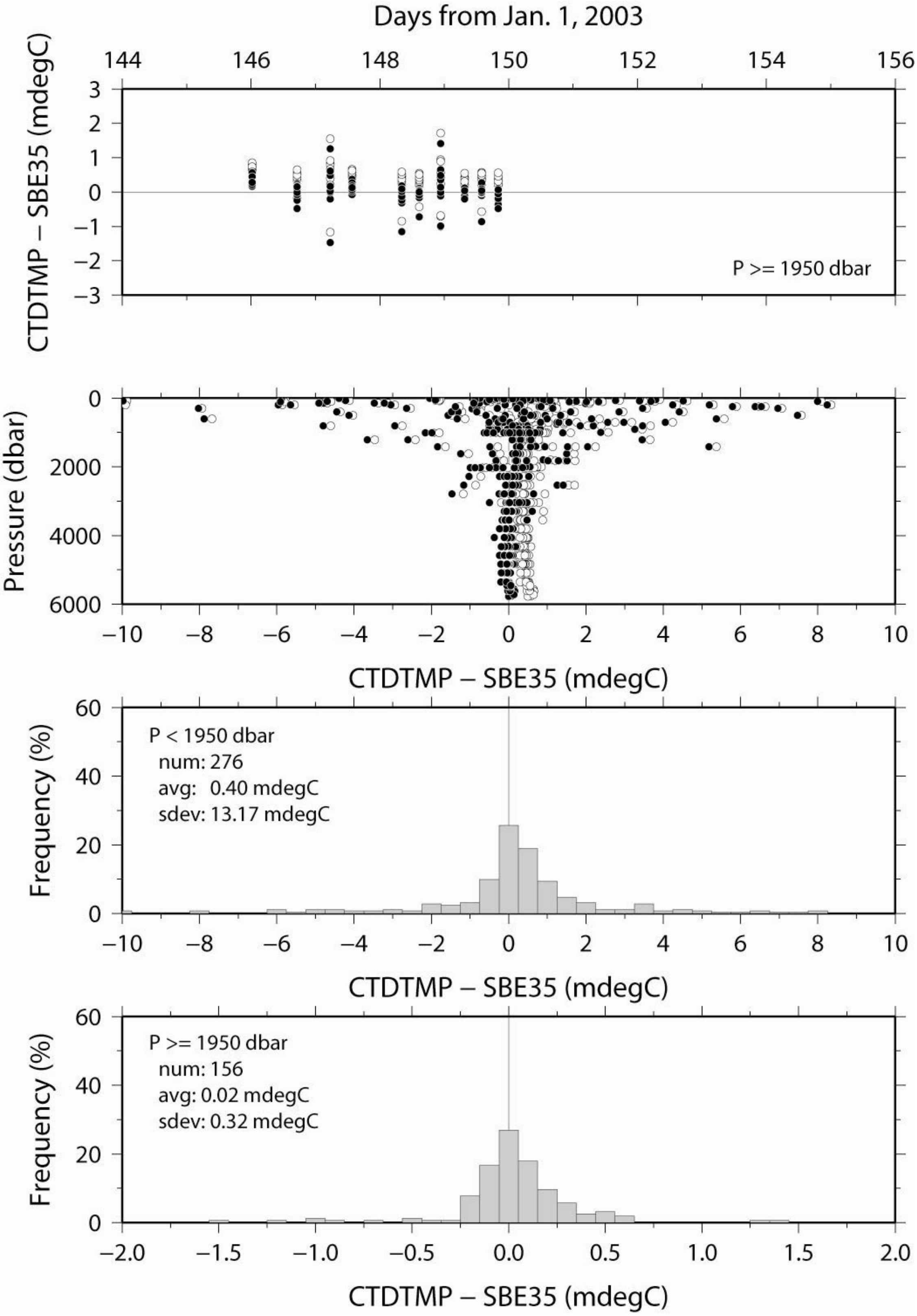

FIGURE 3.10.6: DIFFERENCE BETWEEN THE CTD TEMPERATURE (SECONDARY) AND THE SBE 35. OPEN AND CLOSED CIRCLES INDICATE BEFORE AND AFTER THE POST-CRUISE CALIBRATION USING THE SBE 35 DATA, RESPECTIVELY. LOWER TWO PANELS SHOWS HISTOGRAM OF THE DIFFERENCE AFTER THE CALIBRATION.

3) Salinity

The discrepancy between the CTD salinity and the bottle salinity is considered to be a function of conductivity and pressure. The CTD salinity is calibrated as

$$\text{Calibrated salinity} = S - (c_0 * P + c_1 * C + c_2 * C * P + c_3)$$

where S is CTD salinity, P is pressure in dbar, C is conductivity in S/m and c_0, c_1, c_2 and c_3 are calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation with a weight from the bottle salinity data. The fortran subroutine DMINF1 of the Scientific Subroutine Library II (Fujitsu Ltd., JAPAN) is used to determine the sets. The weight is given as a function of pressure as

$$\text{Weight} = \min[10, \exp\{\log(10) * P / PR\}]$$

where PR is threshold of pressure (1,000 dbar). When pressure is large (small), the weight is large (small) at maximum (minimum) value of 10 (1).

The calibration is performed for the salinity derived from the secondary temperature and secondary conductivity sensors. The CTD data created by the software module ROSSUM are used after the post-cruise calibration for the CTD temperature. The calibration coefficients are determined for grouped stations.

The results of the post-cruise calibration for the CTD salinity are summarized in Table 3.10.4 and shown in Figure 3.10.7. And the calibration coefficients and the number of the data (NUM) used for the calibration are listed in Table 3.10.5.

TABLE 3.10.4: DIFFERENCE BETWEEN THE CTD SALINITY AND THE BOTTLE SALINITY AFTER THE POST-CRUISE CALIBRATION. MEAN AND STANDARD DEVIATION (SDEV) ARE CALCULATED FOR THE DATA BELOW AND ABOVE 1,000 DBAR.

Pressure < 1,000 dbar			***Pressure >= 1,000 dbar***		
Num	***Mean***	***Sdev***	***Num***	***Mean***	***Sdev***
179	–0.0013	0.0167	185	0.0000	0.0005

TABLE 3.10.5: CALIBRATION COEFFICIENTS FOR THE CTD SALINITY. THE NUMBER OF DATA (NUM) USED FOR THE CALIBRATION IS ALSO SHOWN.

Station	***Num***	***c0***	***c1***	***c2***	***c3***
TR1	23	-4.80974e-5	4.99536e-4	1.64214e-5	-6.20274e-3
WC1-9	299	5.32578e-6	-4.71760e-4	-1.54552e-6	2.49370e-3
TC1-2	31	-3.73661e-6	-6.81139e-3	-2.85383e-7	2.80237e-2

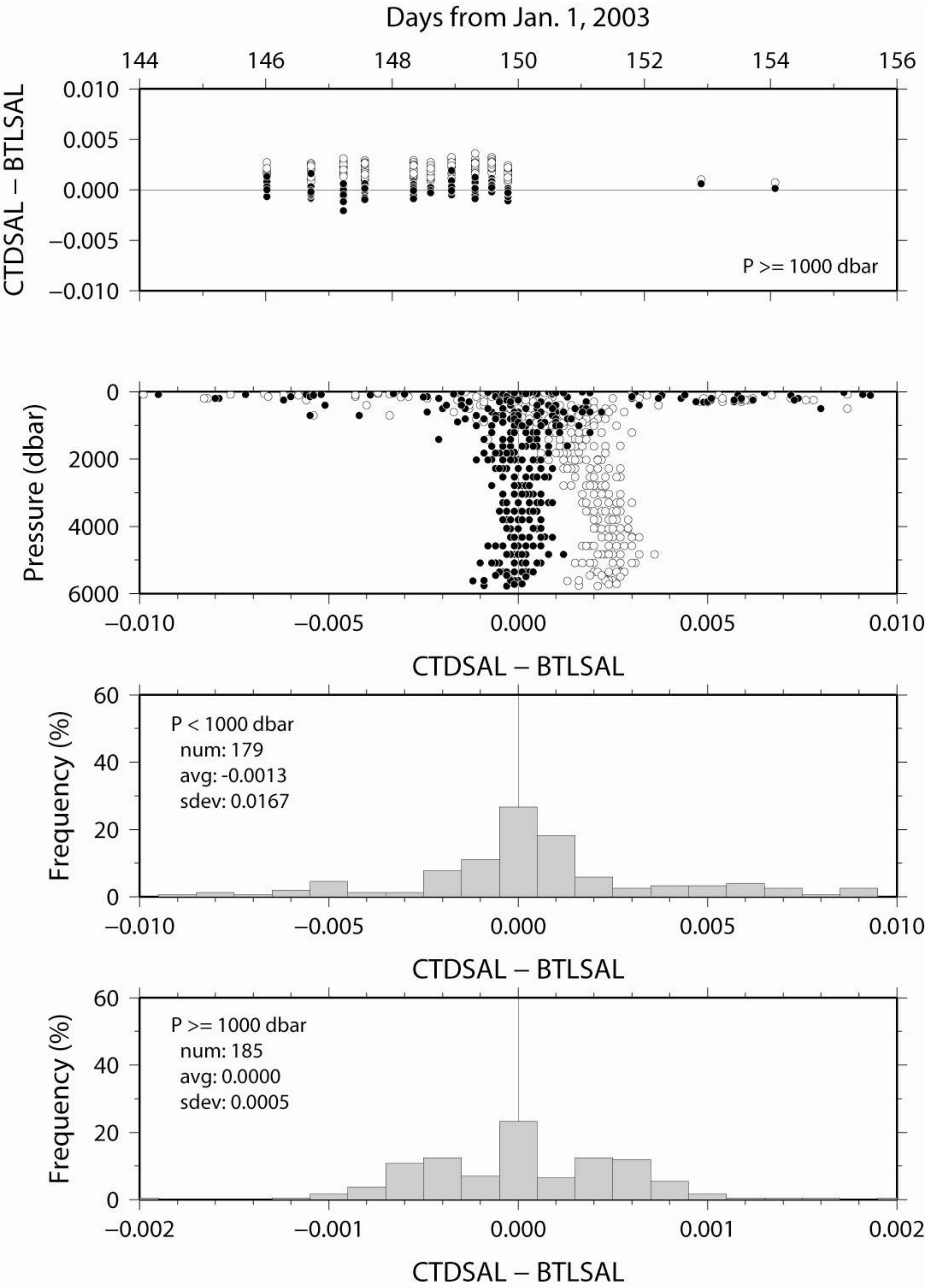

FIGURE 3.10.7: DIFFERENCE BETWEEN THE CTD SALINITY (SECONDARY) AND THE BOTTLE SALINITY. OPEN AND CLOSED CIRCLES INDICATE BEFORE AND AFTER THE POST-CRUISE CALIBRATION USING THE BOTTLE SALINITY DATA, RESPECTIVELY. LOWER TWO PANELS SHOWS HISTOGRAM OF THE DIFFERENCE AFTER THE CALIBRATION.

4) Oxygen

The CTD oxygen is calibrated using the oxygen model (see section 3.10.3) as

Calibrated oxygen (ml/l)

= Soc * (v + offset) * exp(TCor * t + PCor * p) * Oxsat(t, s)

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 (see section 3.10.3). Soc, offset, TCor and PCor are the calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation with a weight from the bottle oxygen data. The fortran subroutine DMINF1 of the Scientific Subroutine Library II (Fujitsu Ltd., JAPAN) is used to determine the sets. The weight is given as a function of pressure as

Weight = min[10, exp{log(10) * P / PR}]

where PR is threshold of pressure (1,000 dbar). When pressure is large (small), the weight is large (small) at maximum (minimum) value of 10 (1).

The calibration is performed for the output from the secondary oxygen sensor. The down-cast CTD data sampled at same pressure of the CTD data created by the software module ROSSUM are used after the post-cruise calibration for the CTD temperature and salinity. The coefficients are basically determined for each station.

The results of the post-cruise calibration for the CTD oxygen are summarized in Table 3.10.6 and shown in Figure 3.10.8. And the calibration coefficients and the number of the data (NUM) used for the calibration are listed in Table 3.10.7.

TABLE 3.10.6: DIFFERENCE BETWEEN THE CTD OXYGEN AND THE BOTTLE OXYGEN AFTER THE POST-CRUISE CALIBRATION. MEAN AND STANDARD DEVIATION (SDEV) ARE CALCULATED FOR THE DATA BELOW AND ABOVE 1,000 DBAR.

Pressure < 1,000 dbar			***Pressure >= 1,000 dbar***		
Num	***Mean (umol/kg)***	***Sdev(umol/kg)***	***Num***	***Mean (umol/kg)***	***Sdev (umol/kg)***
176	0.54	3.92	191	0.04	0.55

TABLE 3.10.7: CALIBRATION COEFFICIENTS FOR THE CTD OXYGEN. THE NUMBER OF DATA (NUM) USED FOR THE CALIBRATION IS ALSO SHOWN.

Station	***Num***	***Soc***	***offset***	***TCor***	***PCor***
TR1	19	0.454298	-0.523607	-1.52994e-3	1.11519e-4
WC1	30	0.426220	-0.494082	1.08846e-3	1.33495e-4
WC2	30	0.415282	-0.494365	1.97838e-3	1.38047e-4
WC3	30	0.418571	-0.494008	1.62393e-3	1.36535e-4
WC4	29	0.449117	-0.526772	-3.39453e-4	1.33898e-4
WC5	29	0.433512	-0.508566	1.90090e-4	1.33897e-4
WC6	30	0.438596	-0.520490	3.53086e-4	1.35414e-4
WC7	27	0.402646	-0.475128	2.59647e-3	1.36684e-4
WC8	23	0.444342	-0.517461	-1.89580e-4	1.30379e-4
WC9	23	0.409509	-0.498658	2.20189e-3	1.39555e-4
TC1	13	0.374538	-0.483420	5.13935e-3	2.08388e-4
TC2	13	0.405014	-0.491340	2.79051e-3	1.53990e-4

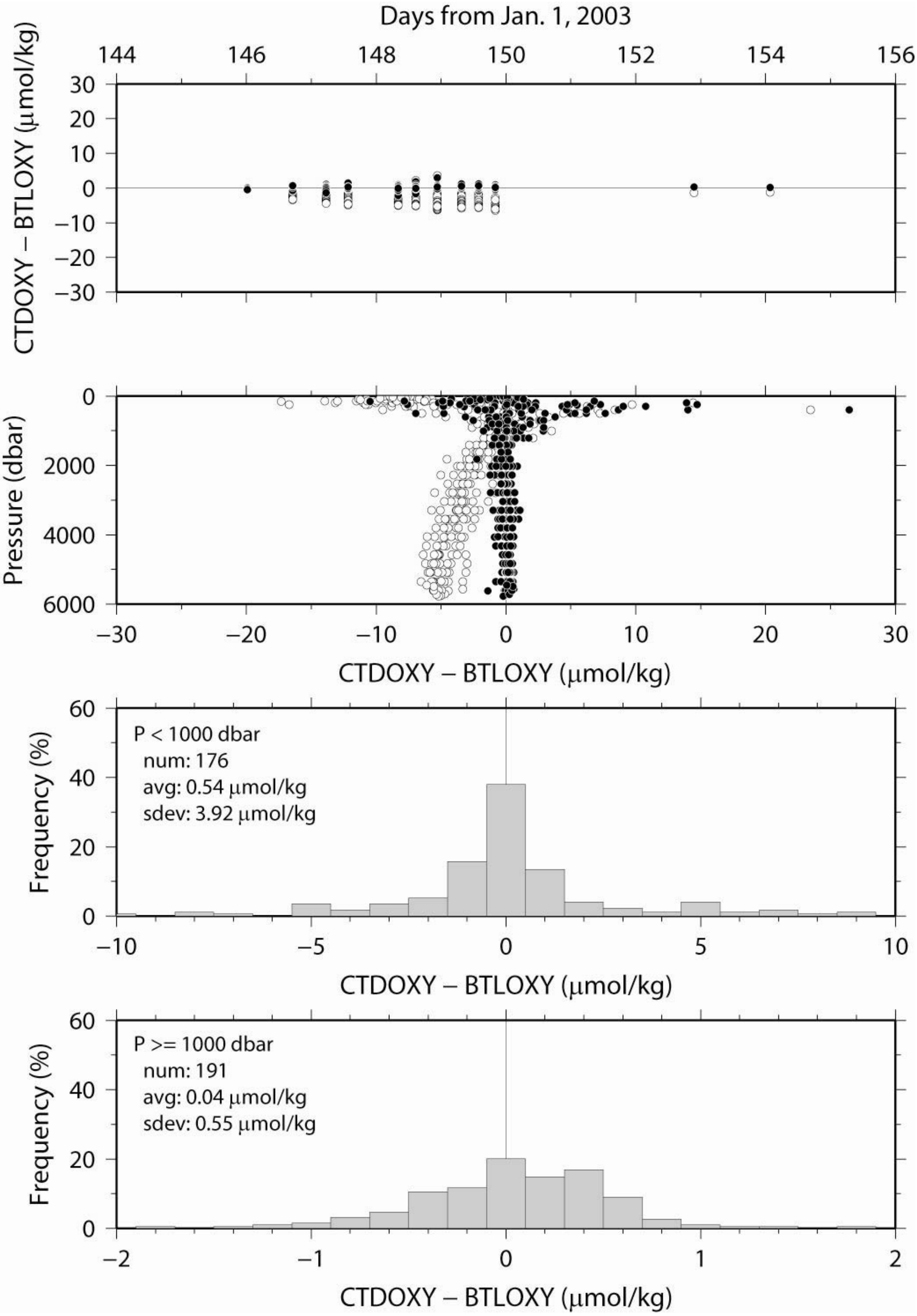

FIGURE 3.10.8: DIFFERENCE BETWEEN THE CTD OXYGEN (SECONDARY) AND THE BOTTLE OXYGEN. OPEN AND CLOSED CIRCLES INDICATE BEFORE AND AFTER THE POST-CRUISE CALIBRATION USING THE BOTTLE OXYGEN DATA, RESPECTIVELY. LOWER TWO PANELS SHOWS HISTOGRAM OF THE DIFFERENCE AFTER THE CALIBRATION.

3.10.6 Results

Date, time and locations of the CTD casts are listed in SUM (station summary) file (see Appendix A). In total 12 CTD casts were carried out. Vertical section of temperature, salinity and dissolved oxygen are shown in Section 1.5.

References

Budeus, G. and W. Schneider (1998): In-situ temperature calibration: A remark on instruments and methods, *Intl. WOCE Newsletter*, 30, 16-18.

Larson, N. and A. Pederson (1996): Temperature measurements in flowing water: Viscous heating of sensor tips, 1st IGHEM Meeting, Montreal, Canada. (http://www.seabird.com/technical_references/paperindex.htm)

3.11 Lowered Acoustic Doppler Current Profiler

Personnel

Hiroshi Uchida (JAMSTEC): Principal Investigator
Kaoru Ichikawa (RIAM, Kyushu University)
On Sugimoto (JAMSTEC)
Satoshi Ozawa (MWJ): Operation Leader

3.11.1 Overview of the equipment

A 307.2 kHz RD Instruments acoustic Doppler current profiler (ADCP) was integrated with the CTD/RMS package. The lowered ADCP (LADCP) rated to 6,000 m and 4 downward facing transducers with 20-degree beam angles. The LADCP makes direct current measurements at the depth of the CTD, thus providing a full profile of velocity. The LADCP is powered during casts by a 54 volts rechargeable battery pack housed in a second pressure case horizontally mounted near the bottom of the frame. The shipboard data acquisition system for the LADCP permits data acquisition on a laptop PC. Unlike the CTD sensors that are sending a continuous flow of data to the computer onboard, the LADCP unit is set for recording internally prior to deployment then the communication socket is sealed off with a blanking plugs. Prior to each cast the instrument was sent a configuration command-file, which determines the mode of operation. After each cast the configuration command-file and the observed data were uploaded to the computer onboard.

The system used in this cruise is as follows.
Lowered Acoustic Doppler Current Profiler:
RD Instruments, USA, WHM300HP, S/N 2553

3.11.2 Data collection

The instrument was set to water and bottom tracking mode with following configuration for the whole cruise.

Bin size: 8.0 m
Number of bins: 24
Pings per ensemble: 1
Ping interval: 1.0 sec

A total of one test station (TR1) and 9 CTD stations (WC1 to WC9) were occupied, in depths ranging from 2004 dbar to 5767 dbar.

By combining the measured velocity of the ocean with respect to the instrument, the measured vertical shear, and accurate shipboard navigation at the start and end of the station, absolute velocity profiles can be obtained (Fisher and Visbeck, 1993).

4 ARGO FLOAT DEPLOYMENT

Personal

Nobuyuki Shikama	(FORSGC): Principal Investigator (not on board)
Naoko Takahashi	(MWJ): Technical staff
Tomoyuki Takamori	(MWJ): Technical staff
Eitarou Oka	(FORSGC): not on board

Objective

The objective of deployment is to clarify variations of temperature and salinity in association with interannual variations such as ENSO events and intraseasonal variations.

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 variations mentioned above with time scales much smaller than those in the previous studies.

Measured parameters

Water temperature, salinity, and pressure

Methods

We launched 7 APEX floats manufactured by Webb Research Ltd (Figure 4.1). Each floats equips SBE41 CTD sensor manufactured by Sea-Bird Electronics Inc.

These floats usually drift at a depth of 1500 or 2000 dbar (called the parking depth), and rise up to the sea surface every ten days by increasing their volume and changing the buoyancy. During the ascent, they measure temperature, salinity, and pressure. They stay at the sea surface for approximately nine hours, transmitting their positions and the CTD data to the land via the ARGOS system, and then return to the parking depth by decreasing volume. The status of floats and their launches are shown in Table 4.1.

Comparison Between ARGO and CTD Station Data

Figure 4.2 shows results of comparison between ARGO (S/N 924) 1st, 2nd and 3rd time observed data and CTD station (TR1) data. Temperature and salinity profiles and T-S relationship are compared. The ARGO data are in good agreement with the CTD station data.

Data Archive

All data acquired through the ARGOS system is stored at FORSGC. The real-time data are provided to meteorological organizations via Global Telecommunication System (GTS) and utilized for analysis and forecasts of sea conditions.

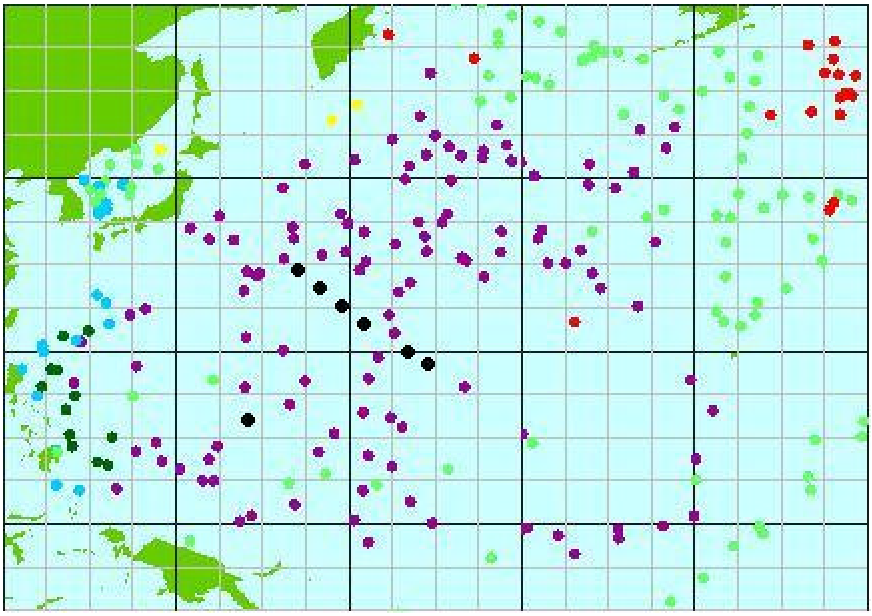

FIGURE 4.1: LOCATIONS OF FLOAT LAUNCH IN THIS CRUISE (BIG BLACK CIRCLES). THE SMALL CIRCLES SHOWS THE DISTRIBUTION OF ARGO FLOATS ON 4 MAY JUST BEFORE THE START OF THIS CRUISE (PURPLE-JAPAN, LIGHT GREEN-US, RED-CANADA, YELLOW-RUSSIA, GREEN-CHINA, CYAN-KOREA).

TABLE 4.1: STATUS OF FLOATS AND THEIR LAUNCHES.

Floats

Floats Type	APEX floats manufactured 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	1500 or 2000 dbar

Launches

Float S/N	ARGOS PTT ID	Date and Time of Reset (UTC)	Date and Time of Launch (UTC)	Location of Launch
790	20813	16:49 May,23	17:31 May,23	29-15.00N, 153-59.90E
791	20839	03:59 May,24	04:48 May,24	26-45.10N, 156-30.00E
792	20932	15:34 May,24	16:21 May,24	25-16.10N, 158-58.40E
793	21043	06:16 May,25	06:46 May,25	23-40.63N, 161-43.55E
794	21044	11:54 May,26	13:10 May,26	20-00.00N, 167-00.00E
924	25140	00:28 May,27	01:47 May,27	18-30-84N, 168-59.89E
925	25152	12:11 Jun, 05	13:37 Jun, 05	12-10.02N, 147-59.96E

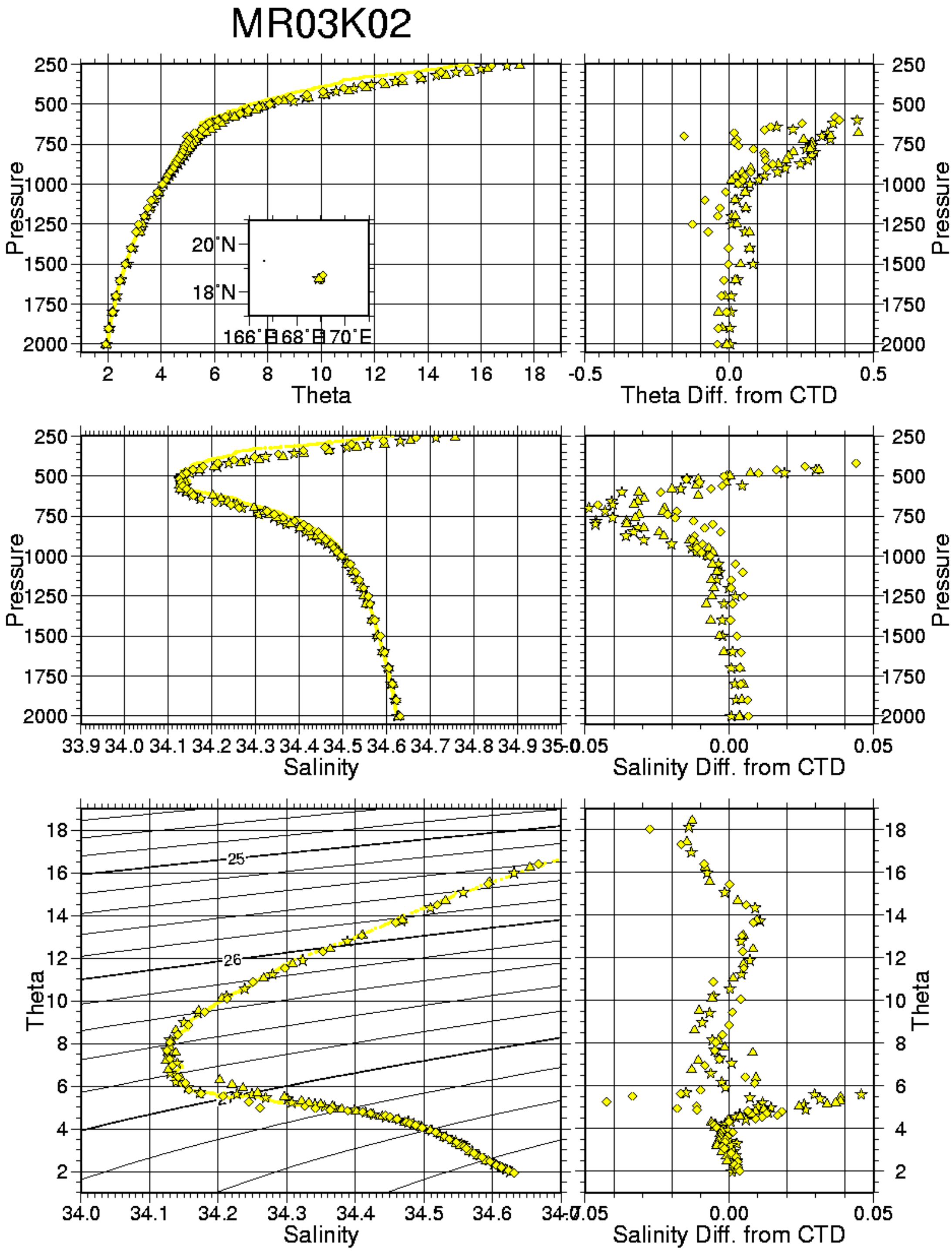

FIGURE 4.2: COMPARISON BETWEEN ARGO (S/N 924) AND CTD STATION DATA. SOLID YELLOW LINE INDICATES CTD STATION DATA. STARS, TRIANGLES AND DIAMONDS INDICATE ARGO 1ST, 2ND AND 3RD TIME OBSERVED DATA, RESPECTIVELY.

5 TRITON MOORING OPERATION

Personnel

Atsuo Ito	(JAMSTEC): Principal Investigator
Satoshi Ozawa	(MWJ): Technical staff
Takeo Matsumoto	(MWJ): Operation leader
Hiroshi Matsunaga	(MWJ): Technical staff
Miki Yoshiike	(MWJ): Technical staff
Naoko Takahashi	(MWJ): Technical staff
Takamori Tomoyuki	(MWJ): Technical staff
Sinichiro Yokogawa	(MWJ): Technical staff
Kenichiro Sato	(MWJ): Technical staff
Takayoshi Seike	(MWJ): Technical staff
Yuki Otsubo	(MWJ): Technical staff
Keisuke Matsumoto	(MWJ): Technical staff
Kunio Yamamori	(MWJ): Technical staff

Objectives

The large-scale air-sea interaction over the warmest sea surface temperature region in the western tropical Pacific Ocean called warm pool affects the global atmosphere and causes El Nino phenomena. The formation mechanism of the warm pool and the air-sea interaction over the warm pool has not been well understood. Long-term data sets of temperature, salinity, currents, and so on have been required at fixed locations. In particular, the oceanic change due to the surface winds over the western tropical Pacific is important to study the relation with El Nino and rainfall over the ocean is also important parameter to study El Nino and Asia-Australian Monsoon. The TRITON program aims to obtain the basic data to improve the predictions of El Nino and variations of Asia-Australian Monsoon system.

TRITON buoy array is integrated with the existing TAO (Tropical Atmosphere Ocean) array, which is presently operated by the Pacific Marine Environmental Laboratory/National Oceanic and Atmospheric Administration of the United States. TRITON is a component of international research program of CLIVAR (Climate Variability and Predictability), which is a major component of World Climate Research Program sponsored by the World Meteorological Organization, the International Council of Scientific Unions, and the Intergovernmental Oceanographic Commission of UNESCO. TRITON will also contribute to the development of GOOS (Global Ocean Observing System) and GCOS (Global Climate Observing System).

The TRITON buoy have been successfully recovered during this R/V Mirai cruise, and deployed one TRITON buoy.

Measured Parameters

Meteorological parameters:	wind speed, direction, atmospheric pressure, air temperature, relative humidity, radiation and precipitation
Oceanic parameters:	water temperature and conductivity at 1.5m, 25m, 50m, 75m, 100m, 125m, 150m, 200m, 300m, 500m 750m, pressure at 300m and 750m, and current at 10m

Instruments

1) CTD and CT

SBE-37 IM MicroCAT

A/D cycles to average:	4
Sampling interval:	600 sec
Measurement range Temperature:	-5～+35 degree-C
Measurement range Conductivity:	0～+7 S/m
Measurement range Pressure:	0～full scale range

2) CRN (Current meter)

SonTek Argonaut ADCM

Sensor frequency:	1500 kHz
Sampling interval:	1200 sec
Average interval:	120 sec

3) Meteorological sensors

Precipitation

SCTI ORG-115DX

Atmospheric Pressure

PARPSCIENTIFIC. Inc. DIGIQUARTZ FLOATING BAROMETER 6000SERIES

Relative Humidity/Air Temperature, Shortwave Radiation, Wind Speed/Direction

Woods Hole Institution ASIMET

Sampling interval:	60 sec
Data analysis:	600 sec averaged

Locations of TRITON Buoy

1) TRITON buoy deployed

Nominal location	8N, 156E
ID number at JAMSTEC	01006
Number on surface float	T04
ARGOS PTT number	03593
ARGOS backup PTT number	24242
Deployed date	04 Jun. 2003
Exact location	07 - 58.09Ｎ, 156 - 01.52Ｅ
Depth	4853 m

2) TRITON buoy recovered

Nominal location	8N, 156E
ID number at JAMSTEC	01005
Number on surface float	T01
ARGOS PTT number	11823
ARGOS backup PTT number	11584
Deployed date	28 Feb. 2002
Recovered date	02 Jun. 2003
Exact location	08-01.21Ｎ, 155 - 54.71Ｅ

*: Dates are UTC and represent anchor drop times for deployments and release time for recoveries, respectively.

Details of Deployed

We had deployed a TRITON buoy, described them details in Table 5.1.

TABLE 5.1: TRITON BUOY DEPLOYMENT.

Observation No.	Location	Details
01006	8N, 156E	Deploy at full spec.

Data Archive

Those hourly averaged data transmitted through ARGOS satellite data transmission system in near real time. The real time data are provided to meteorological organizations via Global Telecommunication System and utilized for daily weather forecast. The data will be also distributed world wide through Internet from JAMSTEC and PMEL home pages. All data will be archived at the JAMSTEC Mutsu Institute.

TRITON Homepage: http://www.jamstec.go.jp/jamstec/triton

6 UNDERWAY OBSERVATIONS

6.1 Navigation

Satoshi Okumura (Global Ocean Development Inc.)

Ship's position and velocity was provided from Radio Navigation System to all equipments throughout the cruise. Radio Navigation System integrates GPS position data (from Leica MX9400 GPS receiver), log speed (from Furuno DS-300, Doppler sonar), gyro heading (from Tokimec TG-6000, ship's main gyrocompass) and other basic data for navigation, and then calculated and distributed speed over ground and course over ground. These data were logged on network server as "SOJ" data.

SkyFix differential GPS system has also installed, but no chance to use this system because of few reference stations were available, more than 2,000 km from the ship, almost all the time during this cruise.

Specifications:

Doppler Sonar (Furuno DS-30)

Frequency: 440 kHz
Number of beams: 3 beams
Range: Fore-aft -10 to +40 knots
Port-stbd –9.99 to +9.99 knots
Accuracy (ground tracking): +/-0.4 % or 0.01 m/sec, whichever is greater
Accuracy (water tracking): +/-1 % or 0.1 knot, whichever is greater

Gyrocompass (TokimecTG-6000)

Settling time: within 2 hours
Settling point error: Less than +/-0.3 deg.
RMS value of the differences: Less than 0.1 deg.
Follow-up speed: 360 deg. /15 sec.
Band of speed error correction: 0-50 knot / Latitude 0-70 deg.

6.2 Shipboard ADCP

Hiroshi Uchida (JAMSTEC) Principal investigator
Satoshi Okumura (Global Ocean Development Inc.)
Shinya Okumura (GODI)
Katsuhisa Maeno (GODI)

Parameters

Current velocity of each depth cell (mm/s)

Methods

Upper ocean current measurements were made throughout MR03-K02 cruise from the departure of Yokohama on 21 May 2003 to arrival of Guam on 6 Jun 2003 using the hull-mounted Acoustic Doppler Current Profiler (ADCP) system that is permanently installed on the R/V Mirai.

The system consists of following components;

1. a 75 kHz Broadband (coded-pulse) profiler with 4-beam Doppler sonar operating at 75 KHz (RD Instruments, USA), mounted with beams pointing 30 degrees from the vertical and 45 degrees azimuth from the keel;
2. the Ship's main gyro compass (Tokimec, Japan), continuously providing ship's heading measurements to the ADCP;
3. a GPS navigation receiver (Leica MX9400) providing position fixes;
4. a personal computer running data acquisition software (VmDas version 1.3; RD Instruments, USA). The clock of the logging PC is adjusted to GPS time every 5 minutes.

The ADCP was configured for 8-m pulse length, 8-m processing bin, and a 8-m blanking interval. The sound speed is calculated from temperature (thermistor near the transducer faces), salinity (constant value; 35.0 psu) and depth (6.5 m; transducer depth) by equation in Medwin (1975). The transducer depth was 6.5 m; 100 velocity measurements were made at 8-m intervals starting 23 m below the surface. Each 1 ping was recorded as raw ensemble data. Also, 60 seconds and 300 seconds average data were recorded as short-term average (STA) and long-term average (LTA) data. Major parameters for the measurement (Direct Command) are shown in the table 6.2.1.

To estimate the transducer offset, we carried out bottom track calibration (comparing the ship's displacement measured from bottom tracking with that determined from navigation data) for the following period; 6 June 2003 08:17 to 6 June 2003 10:44.

Preliminary Results

Horizontal velocity along the ship's track is presented in figure 6.2.1. The ADCP data will be processed using more accurate heading data from ring laser gyro installed for Doppler radar antenna control in the near future.

Data Archives

These data obtained in this cruise will be submitted to the JAMSTEC DMD (Data Management Division), and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

Remarks

We did not collect data in the EEZ of Federated States of Micronesia (from 1 June 20:00 to 5 June 12:00).

TABLE 6.2.1: MAJOR PARAMETERS.

Bottom-Track Commands

BP000 -------------------- Ping per Ensemble

BP001 -------------------- Ping per Ensemble

(bottom track calibration; 6 June 2003 08:17 to 6 June 2003 10:4

Environmental Sensor Commands

EA = +00000 -------------------- Heading Alignment (1/100 deg)

EB = +00000 -------------------- Heading Bias (1/100 deg)

ED = 00065 -------------------- Transducer Depth (0-65535dm)

EF = +0001 -------------------- Pitch/Roll Division/Multiplier (pos/neg) [1/99-99]

EH = 00000 -------------------- Heading (1/100 deg)

ES = 35 -------------------- Salinity (0-40 pp thousand)

EX = 11000 -------------------- Coord Transform (Xform; Type; Tilts; 3Bm; Map)

EZ = 1020001 -------------------- Sensor Source(C; D; H; P; R; S; T)

Timing Commands

TE = 00000200 -------------------- Time per Ensemble (hrs; min; sec; sec/100)

TP = 000200 -------------------- Time per Ping (min: sec; sec/100)

Water Track Commands

WA = 255 -------------------- False Target Threshold (Max) (0-255 counts)

WB = 1 -------------------- Mode 1 Bandwidth Control (0=Wid, 1=Med, 2=Nar)

WC = 064 -------------------- Low Correlation Threshold (0-255)

WD = 111111111 -------------------- Data Out (V; C; A; PG; St; Vsum; Vsum^2; #G; P0)

WE = 5000 -------------------- Error Velocity Threshold (0-5000 mm/s)

WF = 0800 -------------------- Blank After Transmit (cm)

WG = 001 -------------------- Percent Good Minimum (0-100%)

WM = 1 -------------------- Profiling Mode (1-8)

WN = 100 -------------------- Number of Depth Cells (1-128)

WP = 00001 -------------------- Pings per Ensemble (0-100%)

WS = 0800 -------------------- Depth Cell Size (cm)

WV = 999 -------------------- Mode 1 Ambiguity Velocity (cm/s radial)

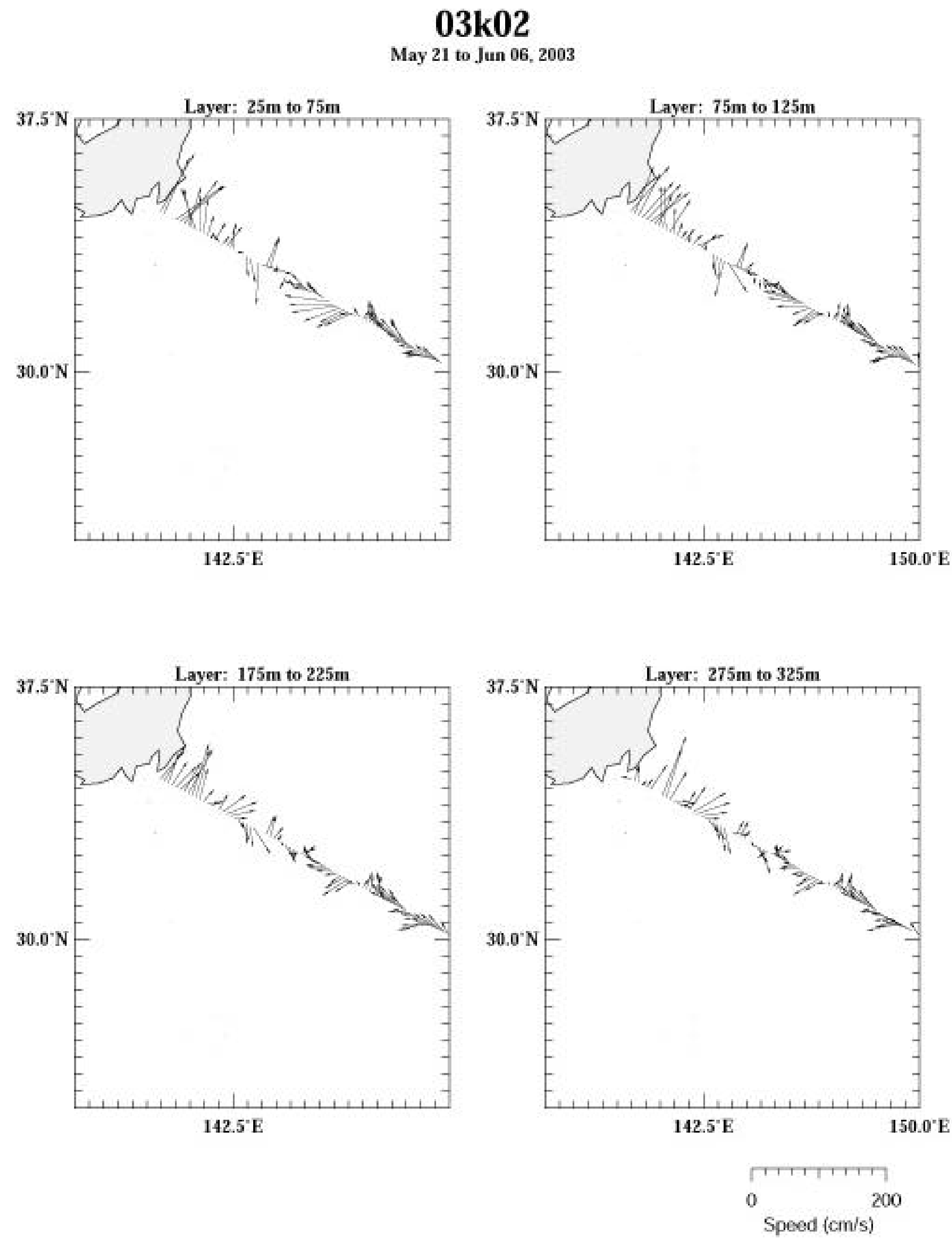

FIGURE 6.2.1: HORIZONTAL VELOCITY ALONG CRUISE TRACK.

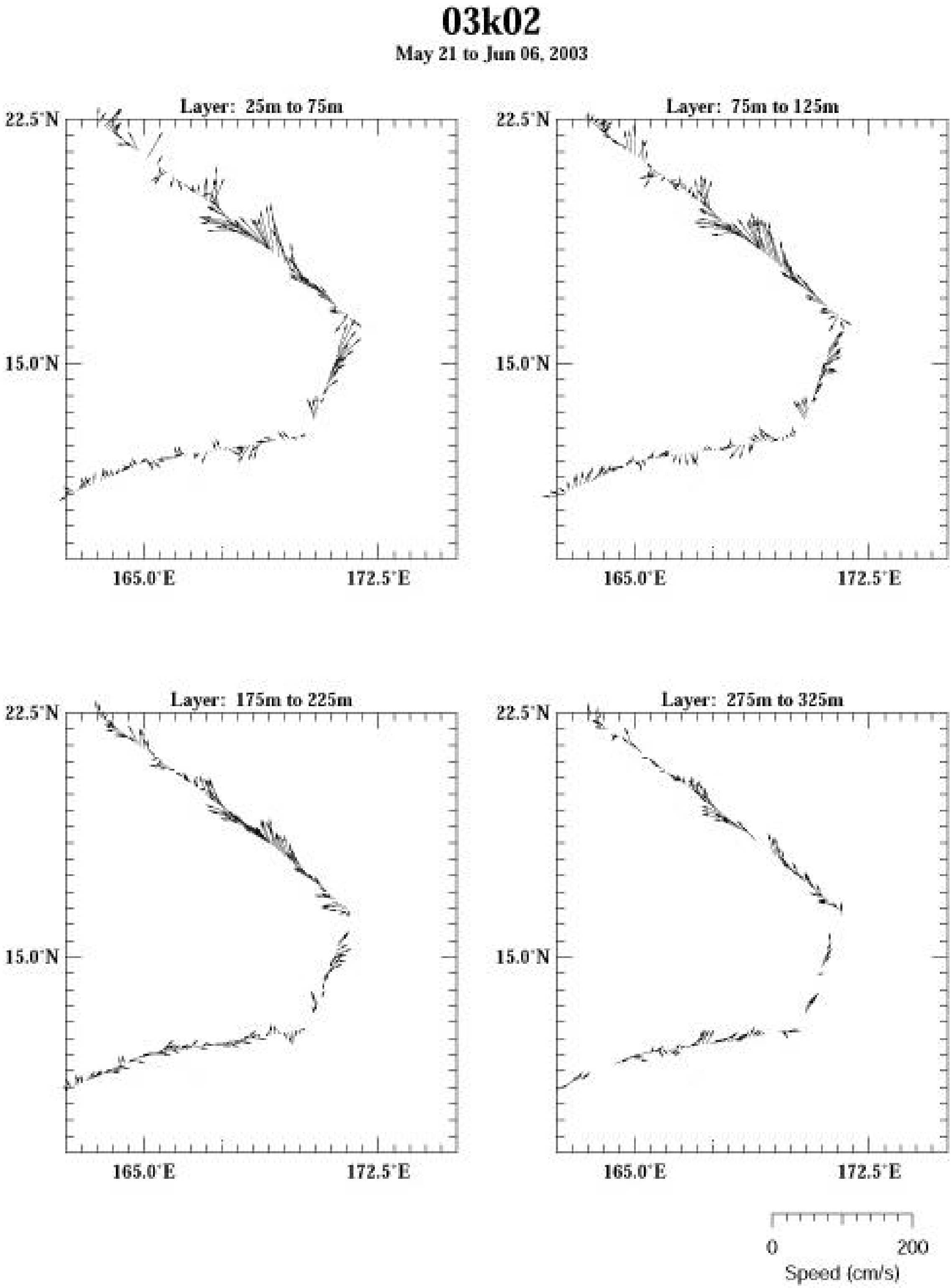

FIGURE 6.2.1: CONTINUED.

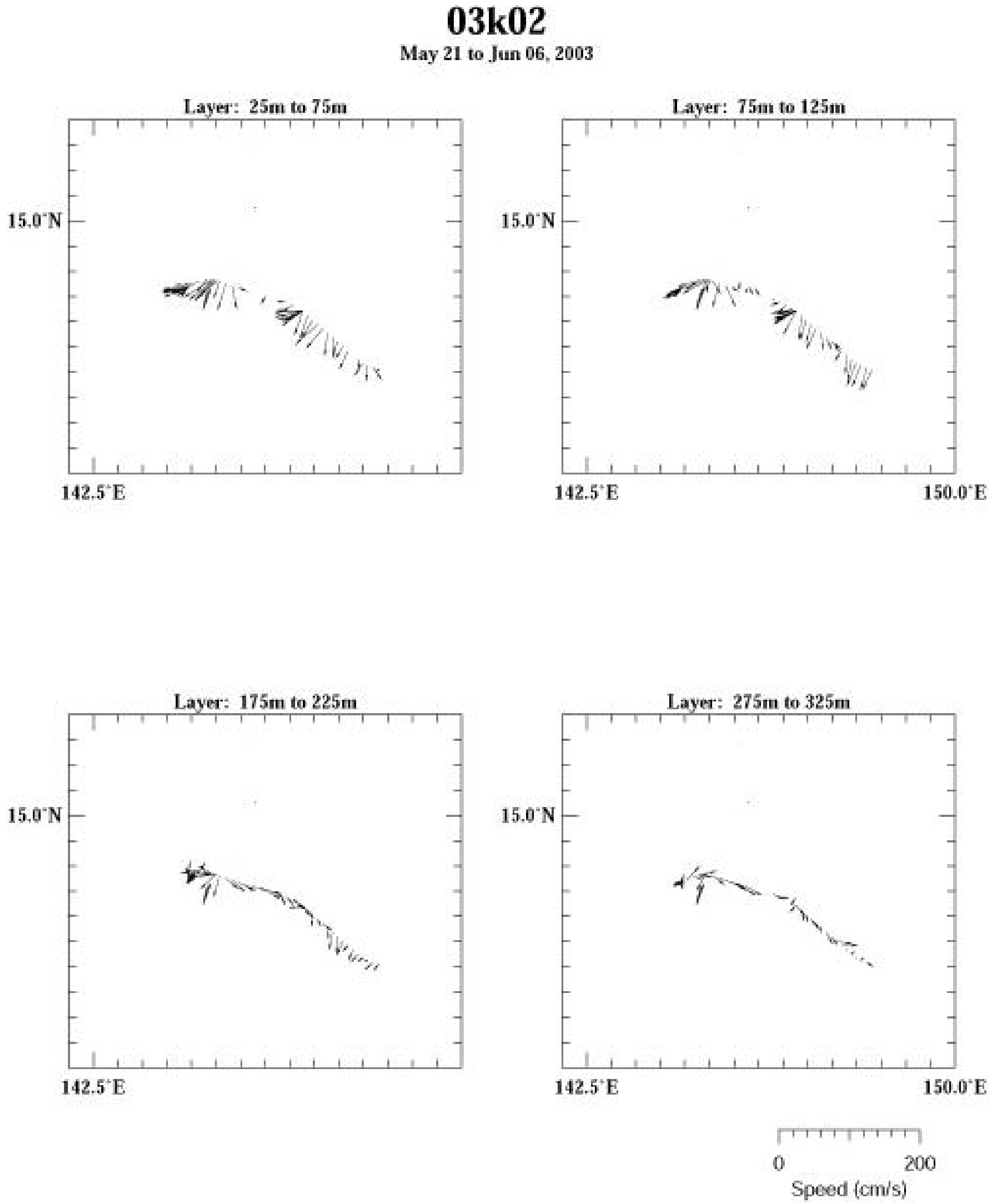

FIGURE 6.2.1: CONTINUED.

6.3 Swath Bathymetry

Satoshi Okumura	(Global Ocean Development Inc.)
Shinya Okumura	(GODI)
Katsuhisa Maeno	(GODI)
Toshiya Fujiwara	(JAMSTEC) Principal investigator; Not on-board

Introduction

R/V Mirai equipped a multi narrow beam echo sounding system (MNBES), SeaBeam 2112.004 (SeaBeam Inc., USA). 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 had carried out bathymetric survey from Yokohama on 21 May 2003 to Guam on 6 Jun 2003.

In addition, the survey performed at the station WM1, 2, 3, 4, and 5 for determination of mooring system deployment position. The results of the survey are shown in Figure 6.3.1.

Data Acquisition

The "SeaBeam 2100" on R/V Mirai was used for bathymetry mapping during the MR03-K02 cruise. To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used temperature and salinity profiles from CTD data during the cruise and calculated sound velocity 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 width:	3 msec to 20 msec
Depth range:	100 to 11,000 m
Beam spacing:	1° athwart ship
Swath width:	max 150°
	120° to 4,500 m
	100° to 6,000 m
	90° to 11,000 m
Depth accuracy:	Within < 0.5 % of depth or ± 1 m,
	(whichever is greater, over the entire swath)

Preliminary Results

The results will be published after primary processing.

Data Archives

Bathymetry data obtained during this cruise will be submitted to the JAMSTEC Data Management Office, and archived there.

Remarks

We did not collect data in the EEZ of Federated States of Micronesia (from 1 June 20:00 to 5 June 12:00).

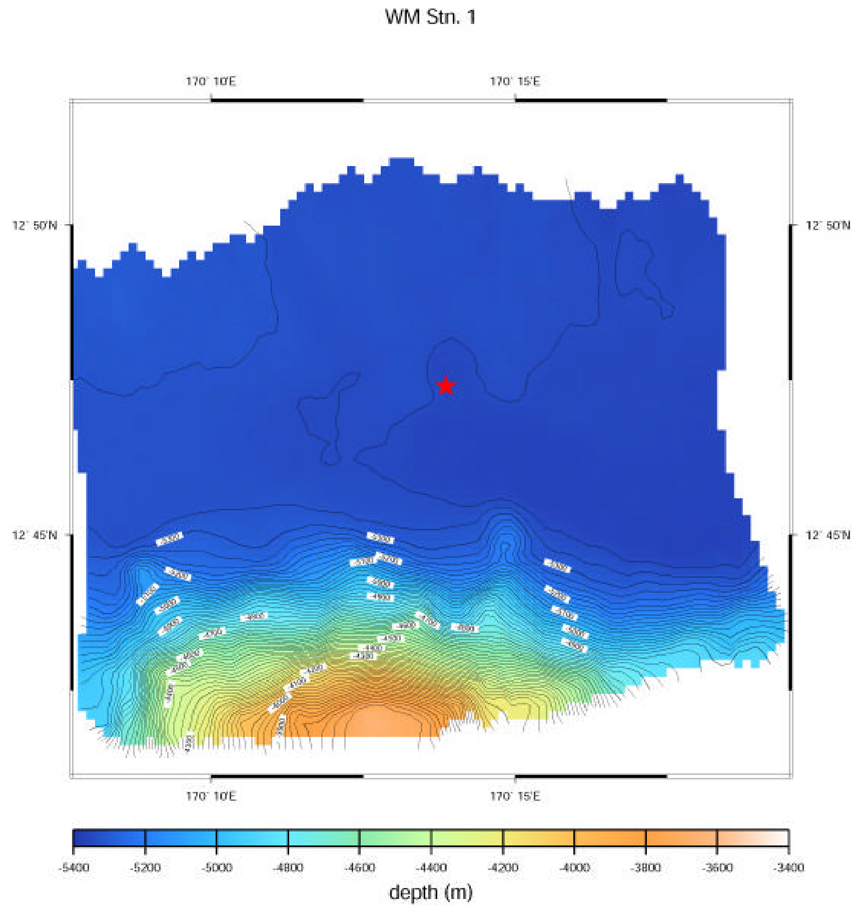

FIGURE 6.3.1: BATHYMETRY AROUND THE MOORING STATION WM1.

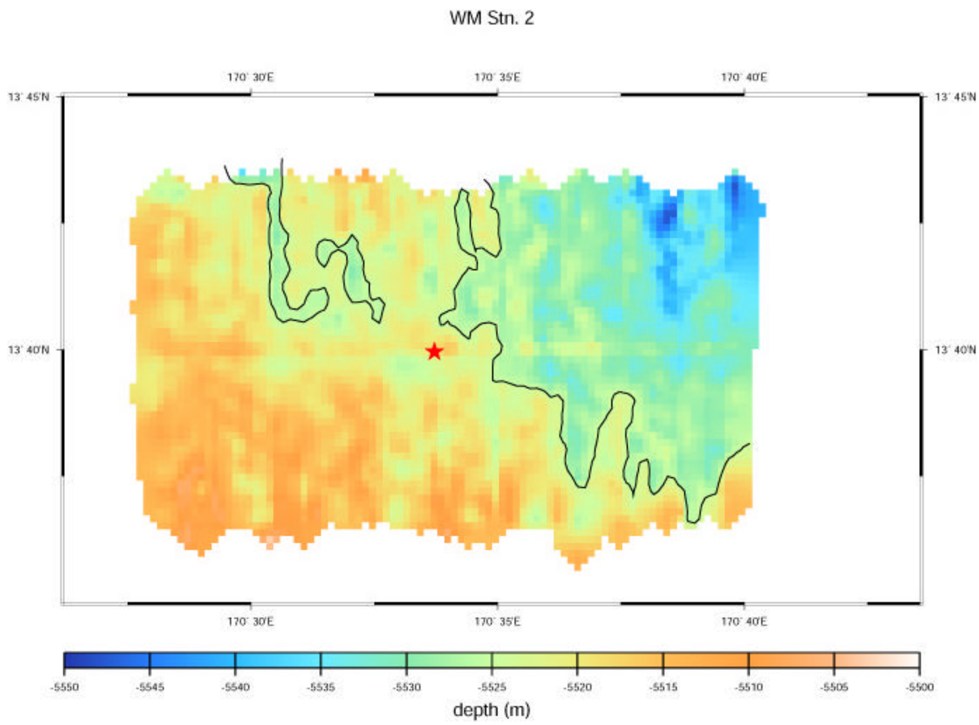

FIGURE 6.3.1: CONTINUED (WM2).

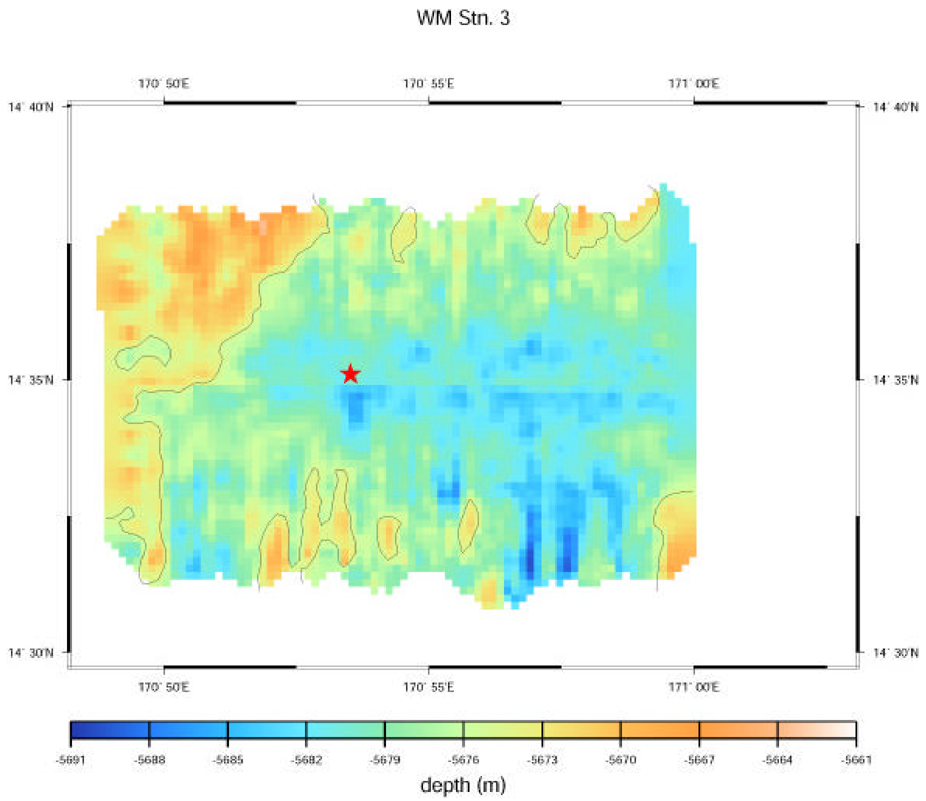

FIGURE 6.3.1: CONTINUED (WM3).

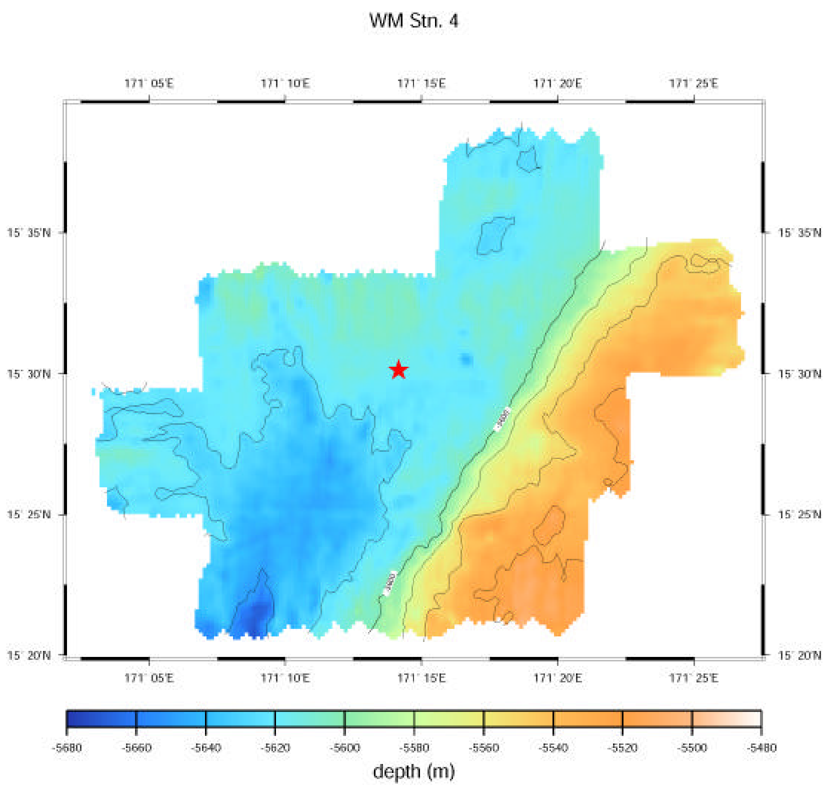

FIGURE 6.3.1: CONTINUED (WM4).

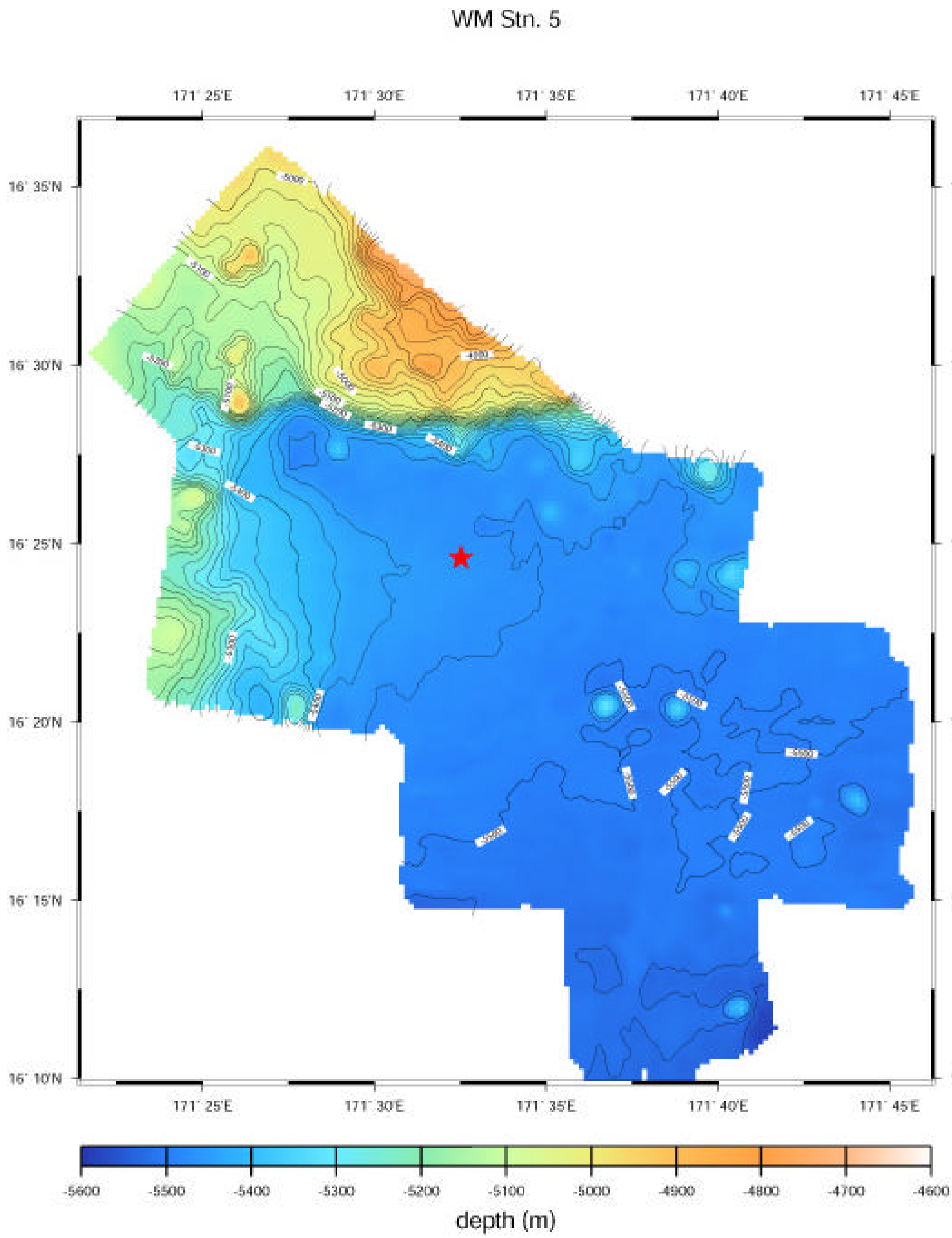

FIGURE 6.3.1: CONTINUED (WM5).

6.4 Sea Surface Gravity

Satoshi Okumura (Global Ocean Development Inc.)
Shinya Okumura (GODI)
Katsuhisa Maeno (GODI)
Toshiya Fujiwara (JAMSTEC) Principal investigator; Not on-board

Introduction

The difference of local gravity is an important parameter in geophysics and geodesy. We collected gravity data at the sea surface during the MR03-K02 cruise from Yokohama on 21 May 2003 to Guam on 6 Jun 2003.

Parameters

Gravity (mGal)

Data Acquisition

We have measured relative gravity using LaCoste-Romberg onboard gravity meter S-116 during the MR03-K02 cruise. To convert the relative gravity to absolute one, we measured gravity, using portable gravity meter (Scintrex gravity meter CG-3M), at Sekinehama Port and Yokohama Port as reference points.

Preliminary Results

Absolute gravities at ports on call are shown in Table 6.4.1.

TABLE 6.4.1: ABSOLUTE GRAVITIES.

No.	Date	UTC	Port	Absolute Gravity (mGal)	Sea Level (cm)	Draft (cm)	Gravity at Sensor (mGal)	L&R (mGal)
1	2003/May/18	00:52	Sekinehama	980371.85	238	605	980372.62	12666.6
2	2003/May/20	06:17	Yokohama	979741.25	321	665	979742.30	12036.7
3	2003/Jun/06	23:00	Guam	-	232	654	-	10815.2

・Gravity at sensor = Absolute gravity + sea level*0.3086/100 + (Draft－530)/100*0.0431
・L&R: LaCoste - Romberg onboard gravity meter S-116

Differential	G at sensor		L&R value
No.1-No.2	-630.24 mGal ---(a)		-629.9 mGal ---(b)
L&R drift value (b)-(a)	-0.34 mGal	2.23 days	
Daily drift ratio	**-0.15 mGal/day**		

Data archives

Gravity data obtained during this cruise will be submitted to the JAMSTEC Data Management Division, and archived there.

Remarks

We did not collect data in the EEZ of Federated States of Micronesia (from 1 June, 20:00 to 5 June, 12:00).

6.5 Sea Surface Three-Component Magnetic Field

Satoshi Okumura (Global Ocean Development Inc.)
Shinya Okumura (GODI)
Katsuhisa Maeno (GODI)
Toshiya Fujiwara (JAMSTEC) Principal investigator; Not on-board

Introduction

Measurements of magnetic force on the sea is required for the geophysical investigations of marine magnetic anomaly caused by magnetization in upper crustal structure. We measured geomagnetic field using a three-component magnetometer during the MR03-K02 cruise.

Parameters

Three-component magnetic force (nT)
Ship’s attitude (1/100deg)

Data Acquisition

A sensor of three-component fluxgate magnetometer is set on the top of foremast. Sampling is controlled by a 1pps (pulse per second) standard clock of GPS signals. Every one-second record is composed of navigation information, 8 Hz three-component of magnetic forces, and vertical reference unit (VRU) data. For calibration of the ship's magnetic effect, we made a sail like a "figure of 8" (a pair of clockwise and anti-clockwise rotation). This calibration carried out from 1 June 2003 07:22 to 1 June 2003 07:52.

Preliminary Results

The results will be published after primary processing.

Data Archives

Magnetic force data obtained during this cruise will be submitted to the JAMSTEC, and archived there.

Remarks

We did not collect data in the EEZ of Federated States of Micronesia (from 1 June 20:00 to 5 June 12:00).

6.6 Sea Surface Water Monitoring

Tomoko Miyashita (Marine Works Japan Ltd.)
Takayoshi Seike (Marine Works Japan Ltd.)
Hiroshi Uchida (JAMSTEC): Principal Investigator

Objective

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

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., USA
Serial number:	2118859-2641
Measurement range:	Temperature -5 to +35℃, Salinity0 to 6.5 S m^{-1}
Accuracy:	Temperature 0.01 ℃ $6month^{-1}$, Salinity0.001 S m^{-1} $month^{-1}$
Resolution:	Temperatures 0.001℃, Salinity0.0001 S m^{-1}

b) Bottom of Ship Thermometer

Model:	SBE 3S, Sea-Bird Electronics, Inc., USA
Serial number:	032607
Measurement range:	-5 to +35℃
Resolution:	±0.001℃
Stability:	0.002 ℃ $year^{-1}$

c) Dissolved Oxygen Sensor

Model:	2127A, Orbisphere Laboratories Japan, Inc., JAPAN
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, USA
Serial number:	5562 FRXX
Detection limit:	5 ppt or less for chlorophyll a
Stability:	0.5% month-1 of full scale

e) Particle Size Sensor

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

f) Flow Meter

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

The monitoring periods during this cruise is from 21 May 10:07 to 1 June 19:51 (UTC).

Preliminary Result

Time series of salinity, temperature, fluorescence, dissolved oxygen are shown in Figure 6.6.1. The results of comparison for salinity and dissolved oxygen between measurements by sensor and water sample analysis are shown in Figure 6.6.2.

Date Archive

The data obtained during this cruise will be submitted to the JAMSTEC Data Management Division, and archived there.

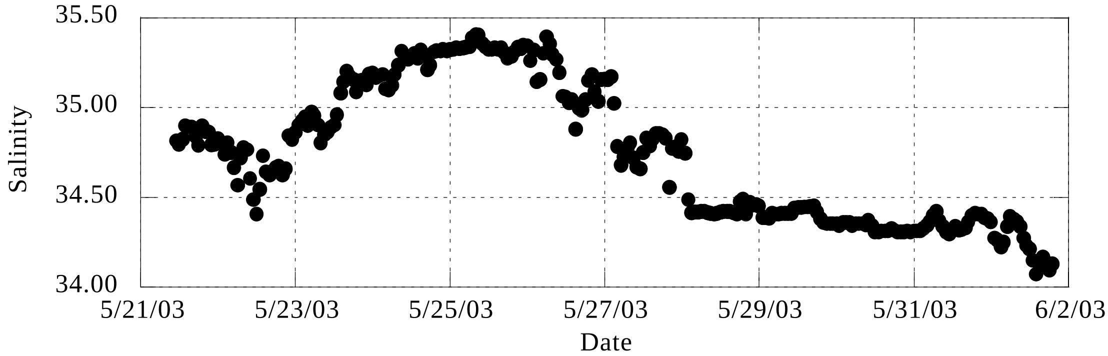

FIGURE 6.6.1: TIME SERIES OF SEA SURFACE SALINITY.

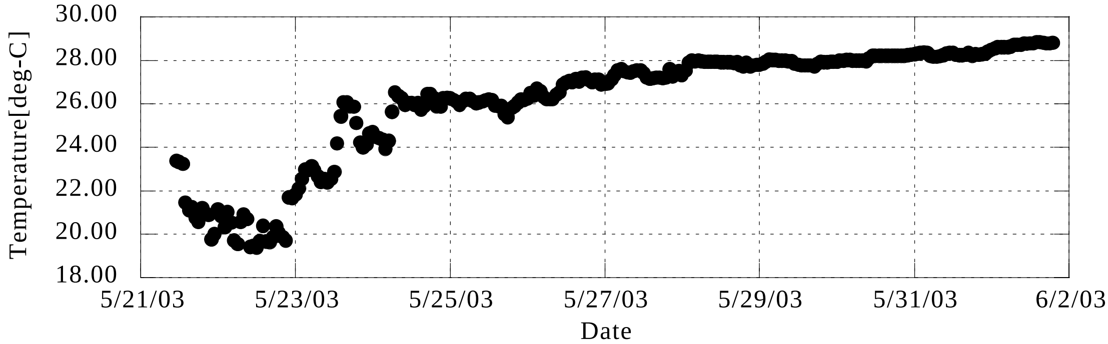

FIGURE 6.6.1: CONTINUED (TEMPERATURE).

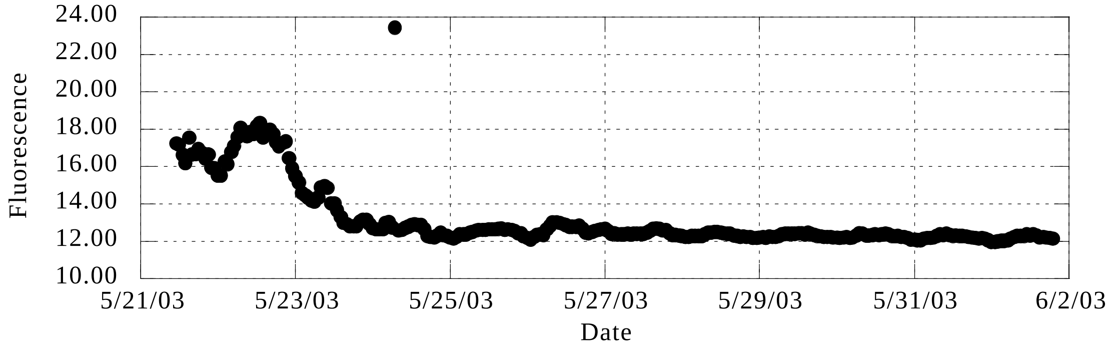

FIGURE 6.6.1: CONTINUED (FLUORESCENCE).

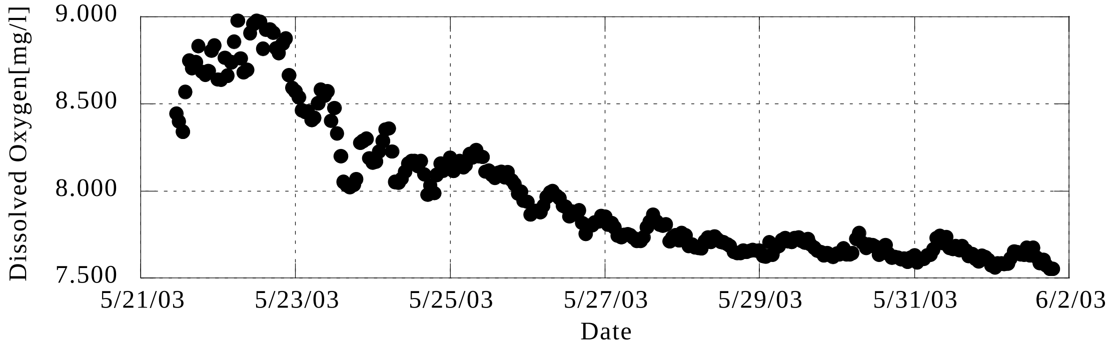

FIGURE 6.6.1: CONTINUED (DISSOLVED OXYGEN).

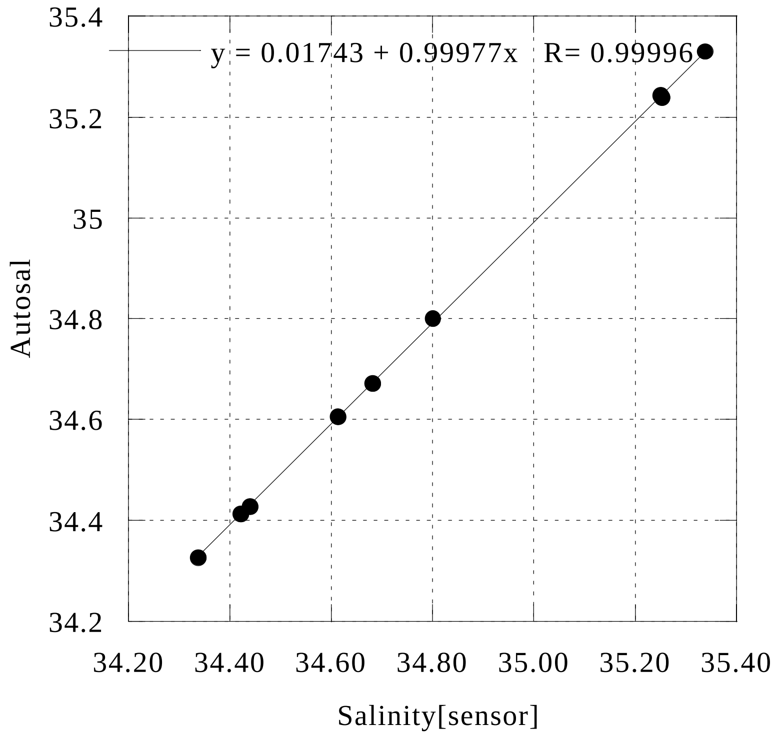

FIGURE 6.6.2: COMPARISON BETWEEN SENSOR AND ANALYSIS FOR SALINITY.

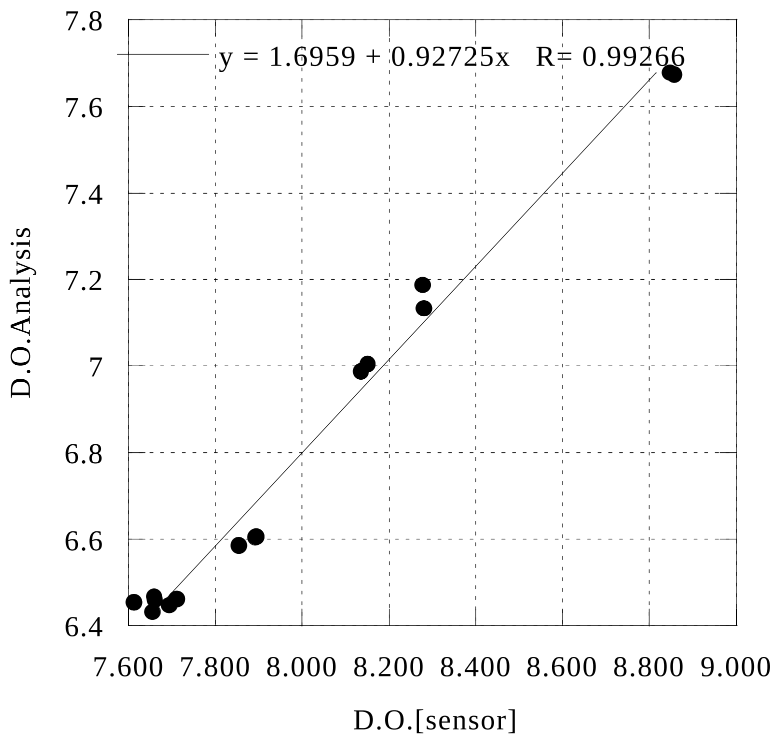

FIGURE 6.6.2: CONTINUED (DISSOLVED OXYGEN).

6.7 Underway Total CO_2 (TCO_2)

Personnel

Akihiko MURATA (JAMSTEC): Principal Investigator
Minoru KAMATA (MWJ)

Objective

Global warming due to an increase of CO_2 in the atmosphere is now regarded as a social problem. Therefore understanding of CO_2 cycling is an urgent task. Because the ocean plays a major role in absorbing atmospheric CO_2, accurate estimation of CO_2 absorption by the ocean is highly important.

Total CO_2 (TCO_2) indicates sum of inorganic carbon species dissolved in seawater. Therefore we can understand how much CO_2 has been absorbed and accumulated in the ocean's interior by measuring TCO_2 in the ocean.

The present investigation was carried out to estimate accumulation of CO_2 in the surface ocean of the western North Pacific subtropical gyre.

Measured Parameter

Total CO_2

Method

Surface seawater was continuously collected from 21st May 2003 to 1st June 2003 during this cruise. Surface seawater was collected by a pump from bottom of the ship (4.5m deep). TCO_2 of the introduced surface seawater was measured coulometerically. The coulometric measurement was almost the same as used for discrete seawater samples.

Preliminary Results

During the cruise, 5 RMs (batch Q09) were analyzed in order to monitor drift of a calibration factor, which was determined by CRM (batch 60). The standard deviation of the absolute differences of duplicate measurements was 1.1 μmol/kg (n = 5).

Data Archive

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

6.8 Partial Pressure of CO_2 (pCO_2)

Personnel

Akihiko MURATA (JAMSTEC): Principal Investigator
Minoru KAMATA (MWJ)

Objective

Global warming due to an increase of CO_2 in the atmosphere is now regarded as a social problem. Therefore understanding of CO_2 cycling is an urgent task. Because the ocean plays a major role in buffering the increase of atmospheric CO_2, studies of air-sea exchanges of CO_2 are highly important.

The present investigation was carried out to estimate air-sea exchanges of CO_2 in the western North Pacific subtropical gyre.

Measured Parameters

Partial pressure of CO_2 in the atmosphere and surface seawater

Method

Concentrations of CO_2 in the atmosphere and surface seawaer were measured continuously during the cruise using an automated system with a non-dispersive infrared (NDIR) analyzer (BINOS^{TM}). The automated system was operated with half an hour cycle of subsequent measurements of 4 standard gases, ambient air sample and a headspace air in an equilibrator. The concentrations of the standard gases used to calibrate the analyzer were 270.09, 328.86, 359.10 and 409.22 ppm.

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

Ambient 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 an air pump at 0.7-0.8L/min in a closed loop of two cooling units, a perma-pure dryer (GL Science Inc.) and a desiccant holder containing $Mg(ClO_4)_2$.

Results

Figure 6.8.1 shows CO_2 concentration (xCO_2) of ambient air and surface seawater.

Data Archive

All data was submitted to JAMSTEC Data Management Office (DMO) and is currently under its control.

Reference

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 & C. Goyet, Eds., ORNS/CDIAC-74.

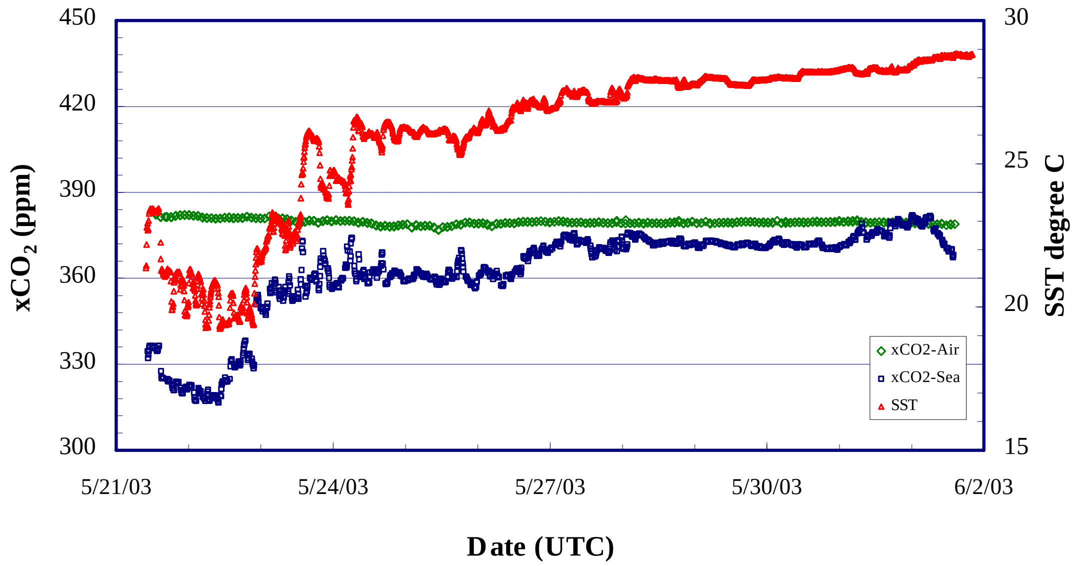

FIGURE 6.8.1: CO_2 CONCENTRATIONS (xCO_2) IN THE ATMOSPHERE AND SURFACE WATER.

6.9 Surface Meteorological Observation

Satoshi Okumura	(Global Ocean Development Inc.) Operation Leader
Shinya Okumura	(GODI)
Katsuhisa Maeno	(GODI)
Kunio Yoneyama	(JAMSTEC) Principal Investigator; Not on-board
R. Michael Reynolds	(Brookhaven National Laboratory, USA); Not on-board

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.

Methods

The surface meteorological parameters were observed throughout the MR03-K02 cruise from the departure of Yokohama on 21 May 2003 to arrival of Guam on 6 Jun 2003. Note that, however, the period within the EEZ of the Federated States of Micronesia is not included.

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

1. Mirai meteorological observation system
2. Shipboard Oceanographic and Atmospheric Radiation (SOAR) System

1. Mirai Meteorological Observation System

Instruments of Mirai meteorological system (SMET) are listed in Table 6.9.1 and measured parameters are listed in Table 6.9.2. Data was collected and processed by KOAC-7800 weather data processor made by Koshin-Denki, Japan. The data set has 6-second averaged and 10-minute averaged.

2. Shipboard Oceanographic and Atmospheric Radiation (SOAR) System

SOAR system designed by BNL consists of major 3 parts.

a) Portable Radiation Package (PRP) designed by BNL – short and long wave downward radiation.
b) Zeno meteorological system designed by BNL – wind, air temperature, relative humidity, pressure, and rainfall measurement.
c) 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 6.9.3 and measured parameters are listed in Table 6.9.4.

Preliminary Results

Figure 6.9.1 show the time series of the following parameters; Wind (SOAR), air temperature (SOAR), sea surface temperature (EPCS), relative humidity (SMET), precipitation (SMET), short/long wave radiation (SOAR), pressure (SOAR) and hourly significant wave height (SMET).

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

1. We did not sample the data within the EEZ of Federated States of Micronesia (from 1 June 2003, 20:00 UTC to 5 June 2003, 12:00 UTC).
2. Radiometers for the upwelling radiation measurement of R/V Mirai meteorological observation system were not installed during this cruise.
3. We used EPCS (external machine for SST), and had run during this cruise from 21 May, 09:37 UTC to 1 June, 19:51 UTC.

TABLE 6.9.1: INSTRUMENTS AND INSTALLATION LOCATIONS OF SMET.

Sensors	Type	Manufacturer	Location (altitude from surface)
Anemometer	KE-500	Koshin Denki, Japan	foremast (24 m)
Thermometer	RFN1-0	Koshin Denki, Japan	4th deck (-1 m, inlet -5 m) SST
	HMP45A	Vaisala, USA	compass deck (21 m)
		with 43408 Gill aspirated shield (R.M. Young)	
Barometer	F-451	Yokogawa, Japan	weather observation room captain deck (13 m)
Rain gauge	50202	R.M. Young, USA	compass deck (19 m)
Optical rain gauge	ORG-115DR	Osi, 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 6.9.2: PARAMETERS OF SMET.

	Parameter	Units	Remarks
1	Latitude	degree	
2	Longitude	degree	
3	Ship's speed	knot	Mirai log, DS-30 Furuno
4	Ship's heading	degree	Mirai Gyro, TG-60000, tokimec
5	Relative wind speed	m/s	6 sec./ 10 min. averaged
6	Relative wind direction	degree	6 sec./ 10 min. averaged
7	True wind speed	m/s	6 sec./ 10 min. averaged
8	True wind direction	degree	6 sec./ 10 min. averaged
9	Barometric pressure	hPa	adjusted to the sea surface level 6 sec./ 10 min. averaged
10	Air temperature (starboard side)	degC	6 sec./ 10 min. averaged
11	Air temperature (port side)	degC	6 sec./ 10 min. averaged
12	Dewpoint temperature (starboard side)	degC	6 sec./ 10 min. averaged
13	Dewpoint temperature (port side)	degC	6 sec./ 10 min. averaged
14	Relative humidity (starboard side)	%	6 sec./ 10 min. averaged
15	Relative humidity (port side)	%	6 sec./ 10 min. averaged
16	Sea surface temperature	degC	6 sec./ 10 min. 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 radiometer	W/m^2	6 sec./ 10 min. averaged
20	Down welling infra-red radiometer	W/m^2	6 sec./ 10 min. averaged
21	Significant wave height (fore)	m	hourly
22	Significant wave height (aft)	m	hourly
23	Significant wave period (fore)	second	hourly
24	Significant wave period (aft)	second	hourly

TABLE 6.9.3: INSTRUMENT INSTALLATION LOCATIONS OF SOAR SYSTEM.

Sensors	Type	Manufacturer	Location (altitude from baseline)
Zeno/Met			
Anemometer	5106	R.M. Young, USA	foremast (25 m)
Tair/RH	HMP45A	Vaisala, USA	foremast (24 m)
	with 43408 Gill aspirated shield (R.M. Young)		
Barometer	61201	R.M. Young, USA	foremast (24 m)
	with 61002 Gill pressure (R.M. Young)		
Rain gauge	50202	R.M. Young, USA	foremast (24 m)
Optical rain gauge	ORG-815DA	Osi, USA	foremast (24 m)
PRP			
Radiometer (short wave)	PSP	Eppley labs, USA	foremast (25 m)
Radiometer (long wave)	PIR	Eppley labs, USA	foremast (25 m)
Fast rotating shadowband radiometer		Yankee, USA	foremast (25 m)

TABLE 6.9.4: PARAMETERS OF SOAR SYSTEM.

	Parameter	Units	Remarks
1	Latitude	degree	
2	Longitude	degree	
3	Sog	knot	
4	Cog	degree	
5	Relative wind speed	m/s	
6	Relative wind direction	degree	
7	Barometric pressure	hPa	
8	Air temperature	degC	
9	Relative humidity	%	
10	Rain rate (optical rain gauge)	mm/hr	
11	Precipitation (capacitive rain gauge)	mm	reset at 50 mm
13	Down welling shortwave radiometer	W/m2	
14	Down welling infra-red radiometer	W/m2	
15	Defuse irradiation	W/m2	

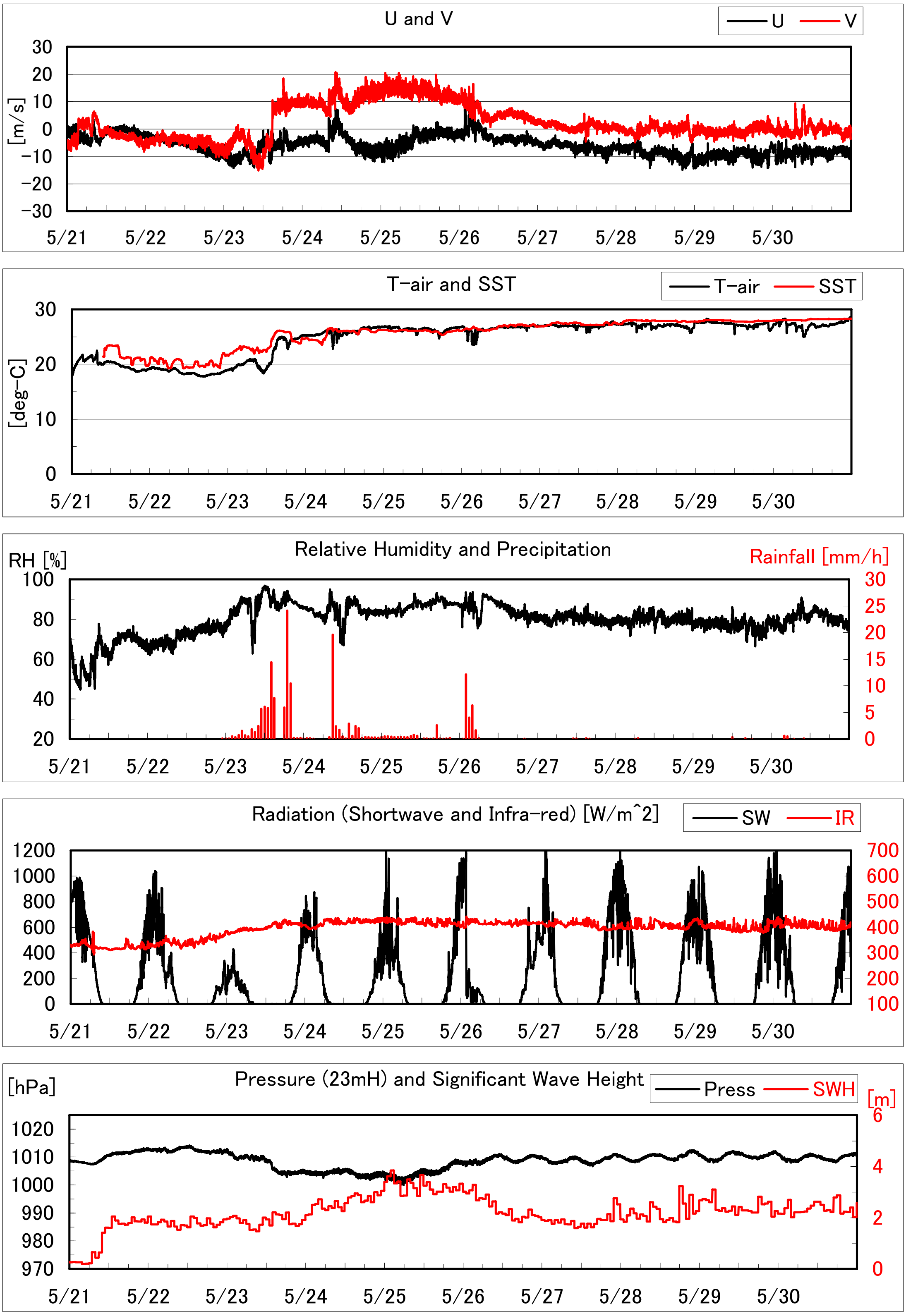

FIGURE 6.9.1: TIME SERIES OF MEASURED PARAMETERS.

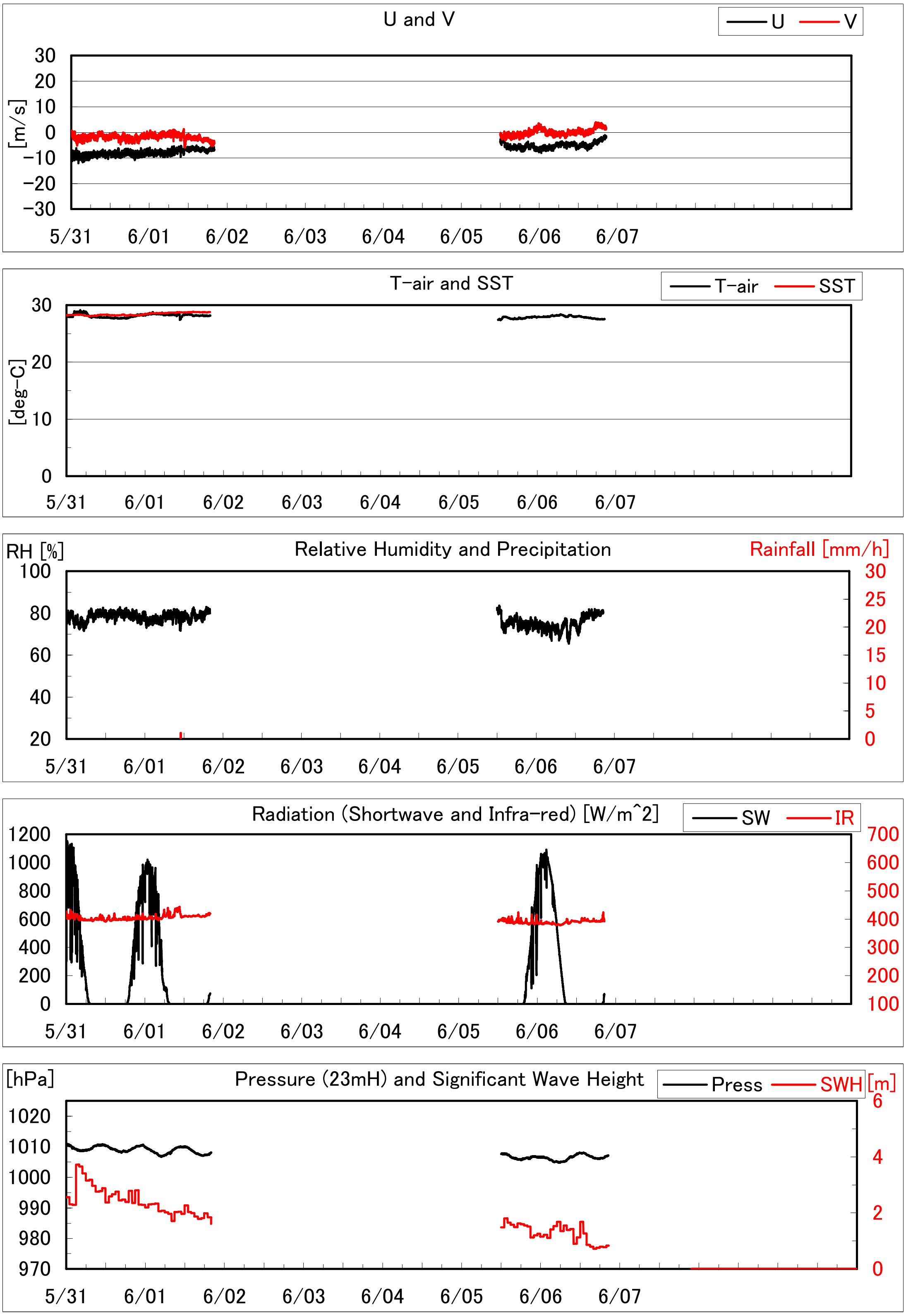

FIGURE 6.9.1: CONTINUED.

6.10 Ceilometer Observation

Satoshi Okumura	(Global Ocean Development Inc.) Operation Leader
Shinya Okumura	(GODI)
Katsuhisa Maeno	(GODI)
Kunio Yoneyama	(JAMSTEC) Principal Investigator; Not on-board

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.

Parameters

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

Methods

We measured cloud base height and backscatter profile using ceilometer (CT-25K, VAISALA, Finland) throughout the MR03-K02 cruise from the departure of Yokohama on 21 May 2003 to arrival of Guam on 6 Jun 2003. Note that, however, the period within the EEZ of Federated States of Micronesia is not included.

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).

Preliminary Results

Figure 6.10.1 shows the time series of the first, second and third lowest cloud base height.

Data Archives

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

Remark

We did not sample the data within the EEZ of Federated States of Micronesia (from 01 June 2003, 2000 UTC to 5 June 2003, 1200 UTC).

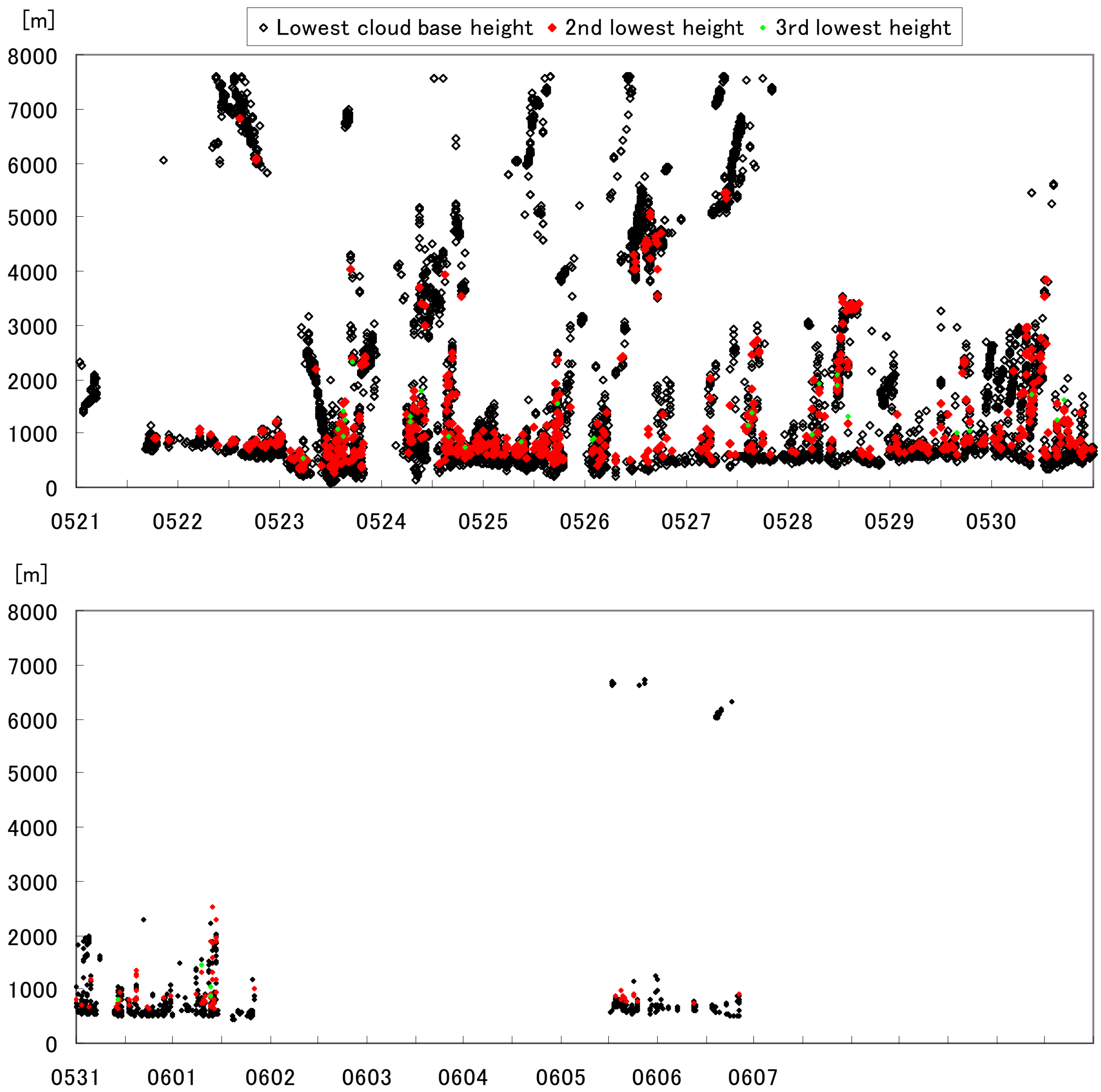

FIGURE 6.10.1: TIME SERIES OF THE CLOUD BASE HEIGHTS.

6.11 Surface Atmospheric Turbulent Flux

Personnel

Shinya Okumura (GODI): On-board collaborator
On-shore scientists:
Kunio Yoneyama (JAMSTEC): Principal Investigator
Osamu Tsukamoto (Okayama University)
Hiroshi Ishida (Kobe University of Mercantile Marine)

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.

Methods

The surface turbulent flux measurement system consists of turbulence instruments (Kaijo Co., Ltd.) and ship motion sensors (Kanto Aircraft Instrument Co., Ltd.). The turbulence sensors include a three-dimensional sonic anemometer-thermometer (Kaijo, DA-600) and an infrared hygrometer (LICOR, LI-7500). The sonic anemometer measures three-dimensional wind components relative to the ship. The ship motion sensors include a two-axis inclinometer (Applied Geomechanics, MD-900-T), a three-axis accelerometer (Applied Signal Inc., QA-700-020), and a three-axis rate gyro (Systron Donner, QRS-0050-100). LI7500 is a CO2/H2O turbulence sensor that measures turbulent signals of carbon dioxide and water vapor simultaneously. Figure 6.11.1 shows the installation of the instruments at the top of the foremast.

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.

Results

Data will be processed after the cruise at Okayama University.

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.

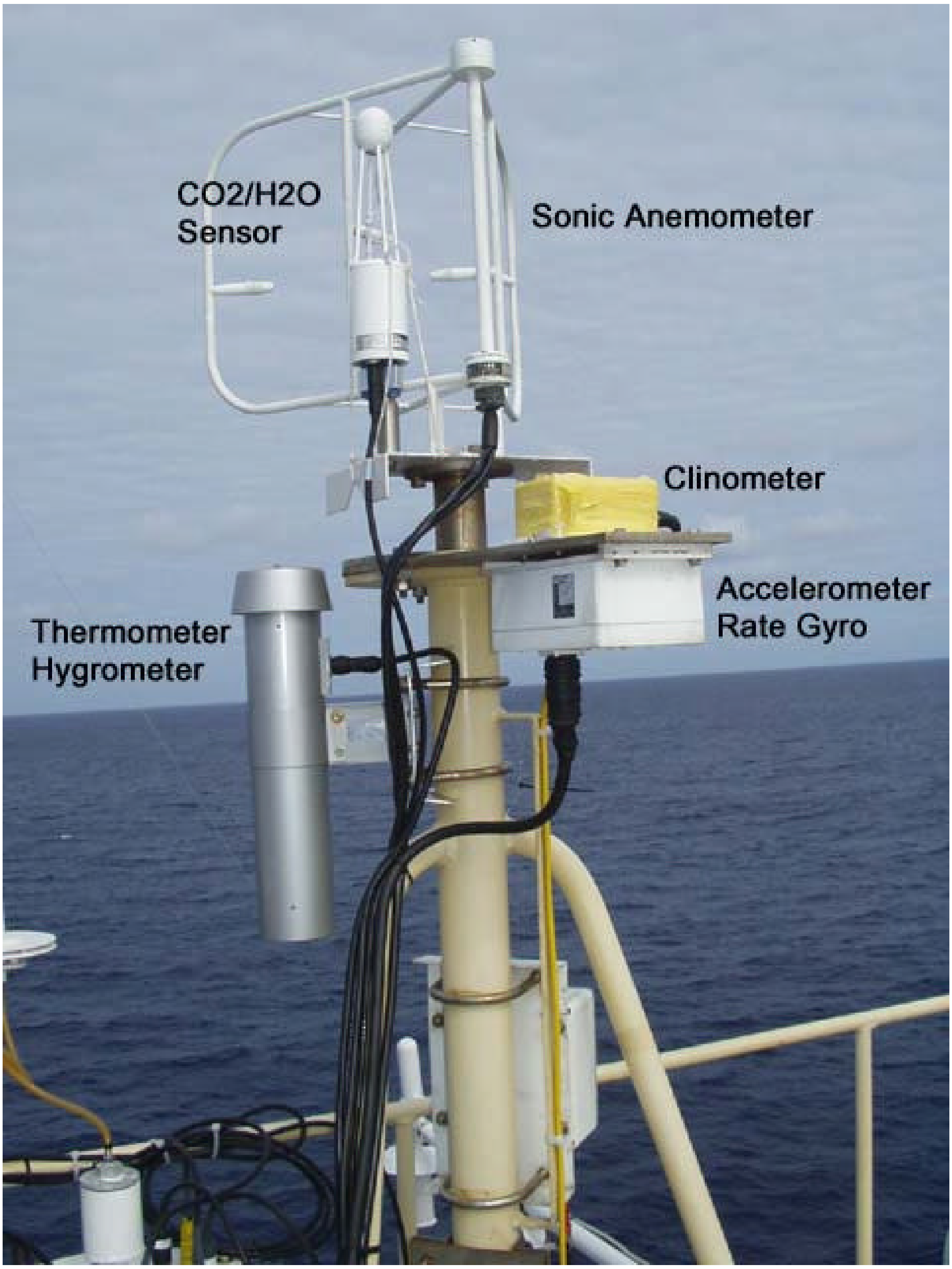

FIGURE 6.11.1: TURBULENT FLUX MEASUREMENT SYSTEM ON THE TOP DECK OF THE FOREMAST.

6.12 Satellite Image Acquisition

6.12.1 Ocean Color

Ichio Asanuma (JAMSTEC): Principal Investigator
Satoshi Okumura (Global Ocean Development Inc.)
Shinya Okumura (GODI)
Katsuhisa Maeno (GODI)

Objectives

It is our objectives to collect data of chlorophyll-a distribution in a high spatial resolution mode from the Sea Wide Field of View Sensor (SeaWiFS) on the OrbView-2 polar orbit satellite and to build a time and depth resolved primary productivity model.

Method

We receive the down link High Resolution Picture Transmission (HRPT) signal from the OrbView-2 by the HRPT receiving station on the R/V Mirai. Our receiving station is the TeraScan receiving system, which has 1.2 m antenna in the redome, the down converter, the bit synchronizer, the frame synchronizer, and the workstation to control antenna and to process received. An encrypted SeaWiFS data were decrypted by the decryption key assigned by the Goddard Space Flight Center (GSFC) of the National Aero Space Agency (NASA). The level-1a data were generated on the R/V Mirai.

We received and processed SeaWiFS data throughout MR03-K02 cruise from the departure of Yokohama on 21 May 2003 to arrival of Guam on 6 June 2003.

The higher product, chlorophyll-a distribution, will be generated at the laboratory using the SeaWiFS Data Analysis System (SEADAS) with the algorithms dedicated for the SeaWiFS. The algorithm called MSL12 in the SeaDAS is the basic function to generate chlorophyll-a distribution as a level-2 data.

The chlorophyll-a distribution data will be applied for the time and depth resolved primary productivity model to determine a standing stock of phytoplankton as a function of chlorophyll-a.

Preliminary Results

The results will be public after the analysis.

Data Archives

The raw data obtained during this cruise will be submitted to JAMSTEC Data Management Division and will be under their control based on the agreement between NASA and JAMSTEC in 1993.

Data List

The level-la data is available on the notation rule as follows. The L1A_HMIR.hdf is the file format of the SeaWiFS level-1a, of which information is available form the web site, http://seawifs.gsfc.nasa.gov.

Syyyydddhhmmss.L1A_HMIR.hdf.Z,

where yyyy is a year, ddd is a Julian day of the year, hhmmss is an hour, a minute and a second when data received.

S2003134022748.L1A_HMIR.hdf.Z
S2003134040534.L1A_HMIR.hdf.Z
S2003135030808.L1A_HMIR.hdf.Z
S2003135044720.L1A_HMIR.hdf.Z
S2003136034854.L1A_HMIR.hdf.Z
S2003137025234.L1A_HMIR.hdf.Z
S2003137043017.L1A_HMIR.hdf.Z
S2003138033239.L1A_HMIR.hdf.Z
S2003139023651.L1A_HMIR.hdf.Z
S2003139041514.L1A_HMIR.hdf.Z
S2003140031750.L1A_HMIR.hdf.Z
S2003140045830.L1A_HMIR.hdf.Z
S2003141022111.L1A_HMIR.hdf.Z
S2003141035835.L1A_HMIR.hdf.Z
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S2003143034410.L1A_HMIR.hdf.Z
S2003144024627.L1A_HMIR.hdf.Z
S2003146023242.L1A_HMIR.hdf.Z

6.12.2 NOAA HRPT (Sea surface temperature and IR)

Ichio Asanuma (JAMSTEC): Principal Investigator
Satoshi Okumura (Global Ocean Development Inc.)
Shinya Okumura (GODI)
Katsuhisa Maeno (GODI)

Objectives

It is our objectives to collect data of sea surface temperature in a high spatial resolution mode from the Advance Very High Resolution Radiometer (AVHRR) on the NOAA polar orbiting satellites and to build a time and depth resolved primary productivity model.

Method

We receive the down link High Resolution Picture Transmission (HRPT) signal from NOAA satellites by the same way as the signal of OrbView-2. We processed the HRPT signal with the inflight calibration and computed the sea surface temperature by the multi-channel sea surface temperature (MCSST) method. A daily composite map of MCSST data is processed for each day on the R/V Mirai for the area, where the R/V Mirai located. A raw data on the pass disk for each pass is also processed into the local area coverage (LAC) formatted data.

We received and processed NOAA data throughout MR03-K02 cruise from the departure of Yokohama on 21 May 2003 to arrival of Guam on 6 June 2003.

The sea surface temperature data will be applied for the time and depth resolved primary productivity model to determine a temperature field for the model.

Preliminary results

The results will be public after the analysis.

Data Archives

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

a) MCSST Composite Data

The MCSST composite data is available on the notation rule as follows. The file type of ".cmp" is the composite data of TeraScan system with information on the MCSST and the projection.

yymmdd.cmp,

where yy is a year, mm is a month, and dd is a day.

b) LAC Data

The LAC data is available on the notation rule as follows.

noaaNN.yyyymmdd.hhmm.nnnn.lac.gz,

where NN is the satellite number as 15, 16, 17, yyyy is a year, mm is a month, dd is a day, hhmm is an hour and a minute, and nnnn is a number of scan lines.

6.13 Particulate Carbonaceous Substances and Ozone

Personnel

Mitsuo Uematsu (Ocean Research Institute, The University of Tokyo): Principal Investigator
Kiyoshi Matsumoto (Ocean Research Institute, The University of Tokyo/
Japan Science and Technology Corporation)

Objectives

The potential influence of increasing tropospheric aerosols on negative radiative forcing in the atmosphere has attracted considerable attention, since these aerosols may have a cooling effect through direct and indirect radiative processes, thus mitigating the global warming. In order to understand the effects of carbonaceous aerosols on climate, it is necessary to determine their geographical distributions and seasonal changes, especially over the remote ocean. In this cruise, continuous measurements of particulate carbonaceous substances were conducted over the western Pacific Ocean. Ozone concentrations were also measured during this cruise, since ozone is a good indicator of air mass alternation and photochemical activities.

Methods

The concentrations of carbonaceous substances, organic carbon (OC) and elemental carbon (EC), in aerosols were measured for every 4 hours by using an Ambient Carbon Particulate Monitor (Rupprechet & Patashnick Co. Inc., Model 5400). This instrument can automatically measure the concentrations of OC and EC in aerosols by a thermal analysis. Only ambient aerosols with diameter < 2.5μm were introduced into the instrument using a PM2.5 cyclone (with a 50% effective cut-off diameter of 2.5μm) to eliminate coarse aerosols such as sea-salt particles. The inlet tube was heated at 50°C to avoid dewfall. Aerosols were collected with an impactor (with a 50% effective cut-off diameter of 0.14μm) at a flow rate of 16.7L min^{-1}. The collection plate of the impactor was heated at 50°C in order to minimize the adsorption of gaseous organic matter during sampling; therefore, large fraction of the particulate carbonaceous matters evolved below 50°C may have been lost from our measurements. The collected samples of carbonaceous matters were volatilized by heating the collection plate and then transformed to CO_2 by combustion at 750°C with an afterburner. The concentration of CO_2 was then measured by an NDIR CO_2 sensor. The heating temperatures of the collection plate were set at four stages, 200°C, 250°C, 340°C and 750°C. In this study, OC and total carbon (TC) were defined as the carbonaceous matters evolved below 340°C and below 750°C, respectively. And then, the difference between the amounts of TC and OC yielded the amount of EC.

Our preliminary experiments found that this instrument overestimates particulate OC concentration, probably due to the adsorption of organic vapors on the collection plate that is called “positive artifact”. In order to avoid the positive artifact, a parallel plate organic denuder, which is produced by Sunset Laboratory Inc., was installed at the inlet of the monitor.

The concentration of ozone was measured at 12-second intervals by using an ozone monitor (Dylec, Model 1150).

The inlets of air were located on the compass deck (about 17m above the sea surface).

Results

Figure 6.13.1 shows the preliminary results of the concentrations of particulate OC and EC during MR03-K02 cruise. In future, the data of ozone concentration and wind direction should be analyzed to eliminate the influence of some contaminations from the ship.

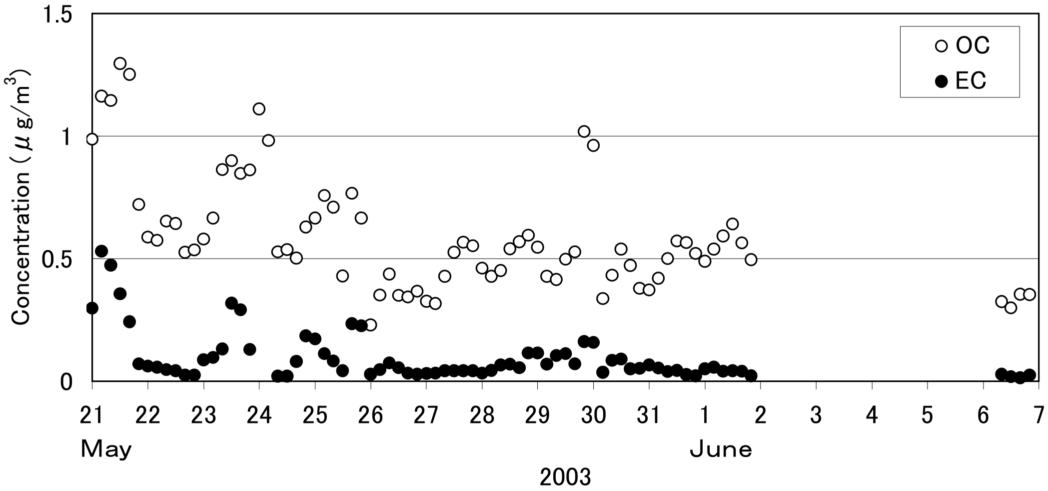

FIGURE 6.13.1: TEMPORAL VARIATIONS IN THE CONCENTRATIONS OF PARTICULATE OC AND EC.

Data Archives

The data of the concentrations of carbonaceous aerosols and ozone obtained in this cruise will be archived at Ocean Research Institute (ORI), the University of Tokyo.

6.14 Horizontal Distribution and Optical Properties of Aerosols

Personnel

Principal Investigator not on board:
Tatsuo Endoh (Tottori University of Environmental Studies) Professor
On board scientist:
Ichiro Matsui (National Institute for Environmental Studies, Japan) Research Scientist
Co-workers not on board:
Sachio Ohta (Engineering environmental resource laboratory,
Graduate school of engineering, Hokkaido University) Professor
Tamio Takamura (Center of environmental remote sensing science, Chiba University) Professor
Teruyuki Nakajima (Center of climate system research, University of Tokyo) Professor
Nobuo Sugimoto (National Institute for Environmental Studies, Japan) Chief Research Scientist

Objective Theme

Investigation of horizontal distribution on the concentration and size distribution and optical properties of atmospheric aerosols at the surface and optical thickness of columnar aerosol over the ocean

Objects

To clear and solve the problems of horizontal distribution and optical properties of aerosols, some observations were carried out over the central region of the Notthern Pacific Ocean. Furthermore, collections of the data for calibration and validation to the remote sensing data were performed simultaneously.

Summery

To obtain the data for calibration and validation between remote sensing and surface measurements over the ocean, a series of simultaneous observations has been carried out about optical properties like as scattering and absorption coefficients and radiative properties as optical properties of atmospheric aerosols, the concentration and size distribution of surface aerosols over the Central region of North Pacific Ocean for 18 days from 22 May 2003 to 8 June 2003. In addition of that, a sky radiometer was examined for to a fully automated ship-borne instrument and improved to the practical usage on same board.

Objects/Introduction

One of the most important objects is the collection of calibration and validation data from the surface (Nakajima et al.1996, 1997 and 1999). It may be considered for the observation over the widely opening of the huge ocean to be desired ideally because of horizontal homogeneity. Furthermore, the back ground values of aerosol concentration are easily obtained over there (Ohta et al.1996, Miura et al. 1997 and Takahashi et al. 1996) and vertical profile of aerosol concentration are obtained by means of extrapolation up to the scale height. It is desired to compare the integrated value of these profile of aerosol concentration with optical thickness observed by the optical and radiative measurement (Hayasaka et al. 1998, Takamura et al.1994). Facing this object, the optical and radiative observations were carried out by mean of the Sky Radiometer providing more precise radiation data as the radiative forcing for global warming.

Measuring Parameters

a) Atmospheric optical thickness, Ångström coefficient of wave length efficiencies,
b) Direct irradiating intensity of solar, and forward up to back scattering intensity with scattering angles of 2-140degree and seven different wave lengths
c) GPS provides the position with longitude and latitude and heading direction of the vessel, and azimuth and elevation angle of sun. Horizon sensor provides rolling and pitching angles.
d) Concentration and size distribution of atmospheric aerosol.

Methods

The instruments used in this work are shown as following in Table 6.14.1.

Sky Radiometer was measuring irradiating intensities of solar radiation through seven different filters with the scanning angle of 2-140 degree. These data will provide finally optical thickness, Ångström exponent, single scattering albado and size distribution of atmospheric aerosols with a kind of retrieval method.

Optical Particle Counter was measuring the size of large aerosol particle and counting the number concentration with laser light scattering method and providing the size distribution in 0.3,0.5,1.0,2.0 and 5.0 micron of diameter with real time series display graphically.

Results

Information of data and sample obtained are summarized in Table 6.14.2. The sky radiometer has been going well owing to more calm and silent condition and circumstances about shivering problems provided by the R/V Mirai whose engines are supported by well defined cushions. Therefore, measured values will be expected to be considerably stable and provide good calculated parameters in higher quality. However, some noise waves were found to interfere the 16,13 and 12channel marine bands of VHF from sky radiometer. Fortunately the origin and source were identified by using a VHF wide band receiver and the interference waves were kept by fairly separating from two VHF antennae and decreased to recovery of 100%.

Aerosols size distribution of number concentration have been measured by the Particle Counter and data obtained are displayed in real time by a kind of time series *in situ* with 5stages of size range of 0.3, 0.5, 1.0, 2.0, and 5.0 micron in diameter.

Data Archive

This aerosol data by the Particle Counter will be able to be archived soon and anytime. However, the data of other kind of aerosol measurements are not archived so soon and developed, examined , arranged and finally provided as available data after a certain duration. All data will archived at ILTS (Endoh), Hokkaido University, CCSR (Nakajima), University of Tokyo and CEReS (Takamura), Chiba University after the quality check and submitted to JAMSTEC within 3-year.

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Data inventory

TABLE 6.14.1: INFORMATION OF OBTAINED DATA INVENTORY (METHOD).

Item, No. data	Name	Instrument	Site position
Optical Thickness Ångström Exponent	T.Endoh	Sky Radiometer (Prede, POM-01MK2)	roof of stabilizer
Aerosol Size Distribution	T.Endoh	Particle Counter (Rion, KC-01C)	compass deck (inlet) & environmental research laboratory

TABLE 6.14.2: DATA AND SAMPLE INVENTORY.

Data/Sample	Rate	Site	Object	Name	State	Remarks
Sun & Sky Light	1/5min (fine& daytime)	roof of stabilizer	optical thickness Ångström expt.	T.Endoh	land analysis	05/22-06/08

6.15 Mie Scattering Lidar Observation

Personnel

Ichiro Matsui *, (* indicates on board personnel)
Atsushi Shimizu,
Nobuo Sugimoto (National Institute for Environmental Studies): Principal Investigator

Objectives

To study distribution and optical characteristics of aerosols and clouds using a two-wavelength dual polarization lidar

Measured Parameters

- Vertical profiles of backscattering coefficient at 532 nm and 1064 nm.
- Vertical profile of depolarization ratio at 532 nm.

Method

A lidar using a compact flashlamp pumped second-harmonics Nd:YAG laser. Mie scattering at 1064 nm and 532 nm, and depolarization ratio at 532 nm were recorded. Major specifications of the lidar are as follows;

Laser: Quantel Ultra CFR
  Output power: 532nm 20mJ/Pulse, 1064nm 30mJ/pulse
  Repetiton rate: 10Hz, Beam div.: 0.5mrad
Receiver: Schmidt cassegrainian
  Diameter: 200mm, Field of view: 1mrad
Detector: PMT (532nm), APD (1064nm)
Data collection: LeCroy LT344
Measurement range: 0-24km, Range resolution: 6m
Temporal resolution: 5minute

Results

Figure 6.15.1 shows a temporal variation of vertical profile during this cruise. A rang-corrected lidar signal at 532 nm is indicated with gray scale. At the beginning of the cruise to May 27th, the distribution of the cloud by the effect of the typhoon was observed. After, the lower clouds at 600m are continuously observed over western Pacific Ocean. Also higher cirrus around 10km is detected.

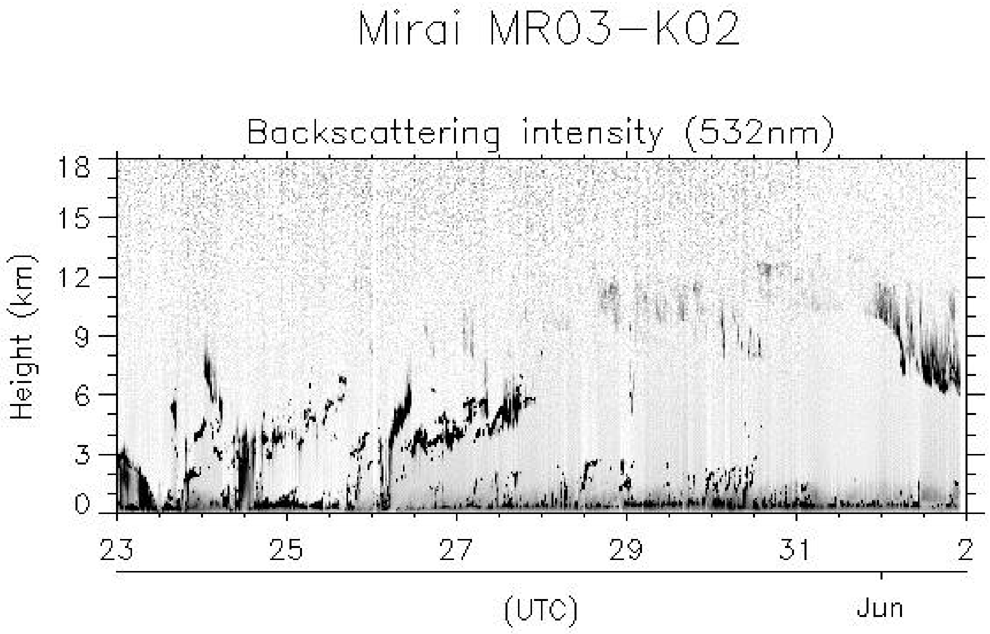

FIGURE 6.15.1: RANGE-CORRECTED SIGNAL AT 532 NM.

Data Archive

- raw data

lidar signal at 532 nm (parallel polarization)

lidar signal at 532 nm (perpendicular polarization)

lidar signal at 1064 nm

temporal resolution 15 min.

vertical resolution 6 m.

processed data

cloud base height, apparent cloud top height, cloud phase

cloud fraction

boundary layer height (aerosol layer upper boundary height)

backscatter coefficient of aerosols

aerosol depolarization ratio

6.16 AMSR/AMSR-E Validation Observation

Personnel

Masayuki Sasaki (NASDA/EORC*): Principal Investigator (not on board)
Yozo Takayama (JMA/MRI**)

Objectives

The satellite-borne microwave radiometers are the powerful device to obtain the spatial and temporal variation of the water vapor, cloud liquid water, sea surface temperature, rain rate, etc, especially over the ocean where the ground-based observation is poor. To validate the products of AMSR (Advanced Mircowave Scanning Radiometer) / ADEOS-II and AMSR-E / EOS Aqua, brand-new satellite-borne microwave radiometer, the R/V Mirai basic observation system installed on the vessel and continuous observation is carried out.

Methods

The micro rain radar MRR-2 (METEK GmbH) and the microwave radiometer WVR-1100 (Radiometrics Co.) are used for this observation.

The radar is a compact 24 GHz FM-CW-radar for the measurement of profiles of drip size distribution and rain rates, liquid water content and characteristic falling velocity of the raindrops. The transmitter power is 50 mW. In this observation, the data is obtained every 60 seconds, at every 200-m range gate to 6000-m height.

The radiometer obtained brightness temperature data for the two frequencies, 23GHz and 31GHz. The brightness temperature data is converted to the vertically integrated water vapor amount and cloud liquid water amount.

The observation was performed continuously from 23 May to, 12 June 2003.

Match-up data between AMSR/AMSR-E products and R/V Mirai observation data will be created.

a) Water Vapor; AMSR/AMSR-E vs. Microwave Radiometer
b) Liquid Water Content; AMSR/AMSR-E vs. Microwave Radiometer
c) Rain Rate; AMSR/AMSR-E vs. Micro rain radar

Preliminary Results

The observed data will be checked and analyzed after the cruise. Sample plots of data retrieved from Micro Rain Radar are shown in Figure 6.16.1 to Figure 6.16.4.

Data Archive

No original data.

*NASDA/EORC: National Space Development Agency of JAPAN / Earth Observation Research Center
**JMA/MRI : Japan Meteorological Agency / Meteorological Research Institute

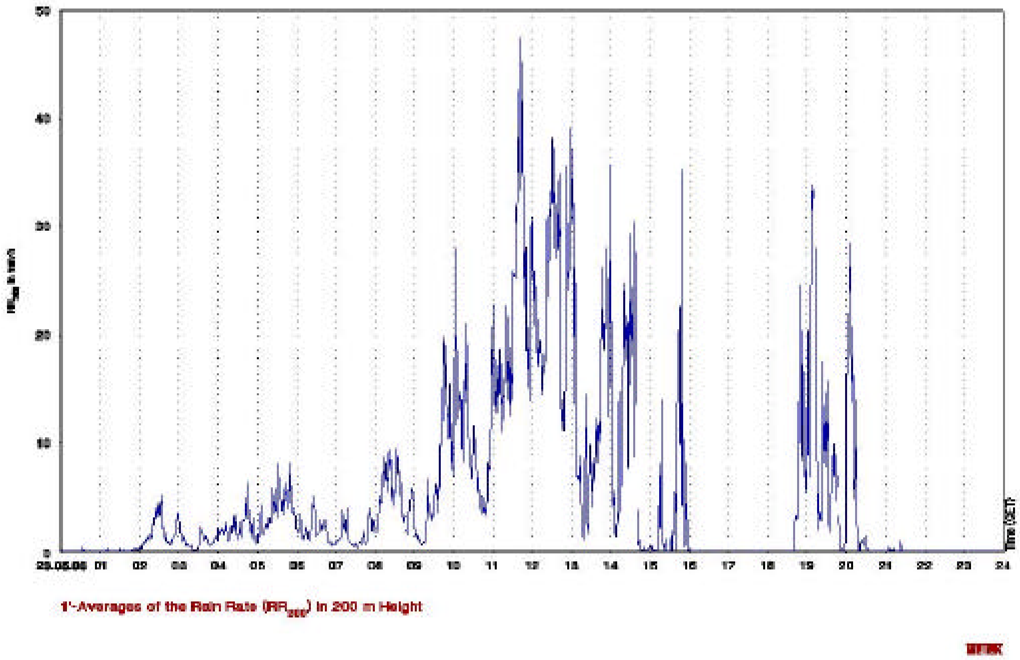

FIGURE 6.16.1: RAIN RATE RETRIEVED FROM MICRO RAIN RADAR (2003.05.23).

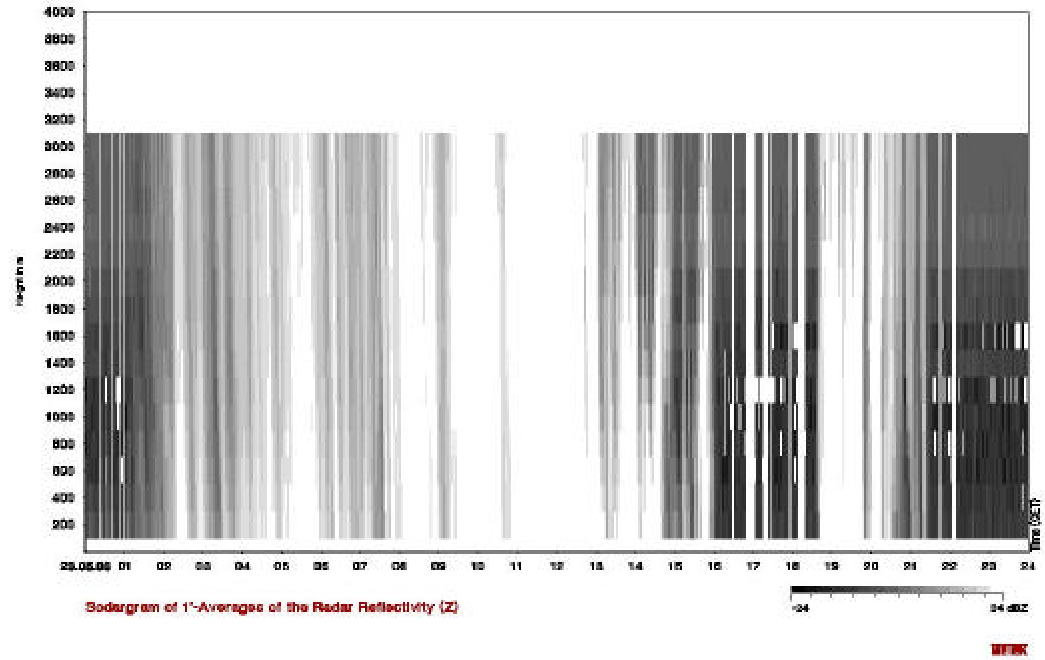

FIGURE 6.16.2: RADAR REFRECTIVITY (2003.05.23).

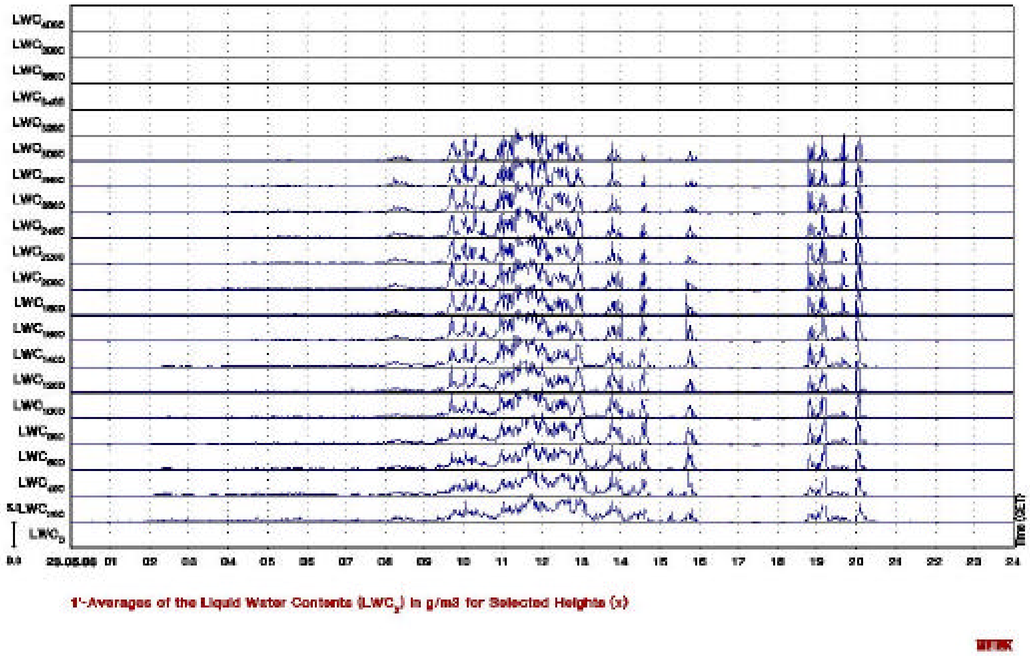

FIGURE 6.16.3: LIQUID WATER CONTENT RETRIEVED FROM MICRO RAIN RADAR (2003.05.23).

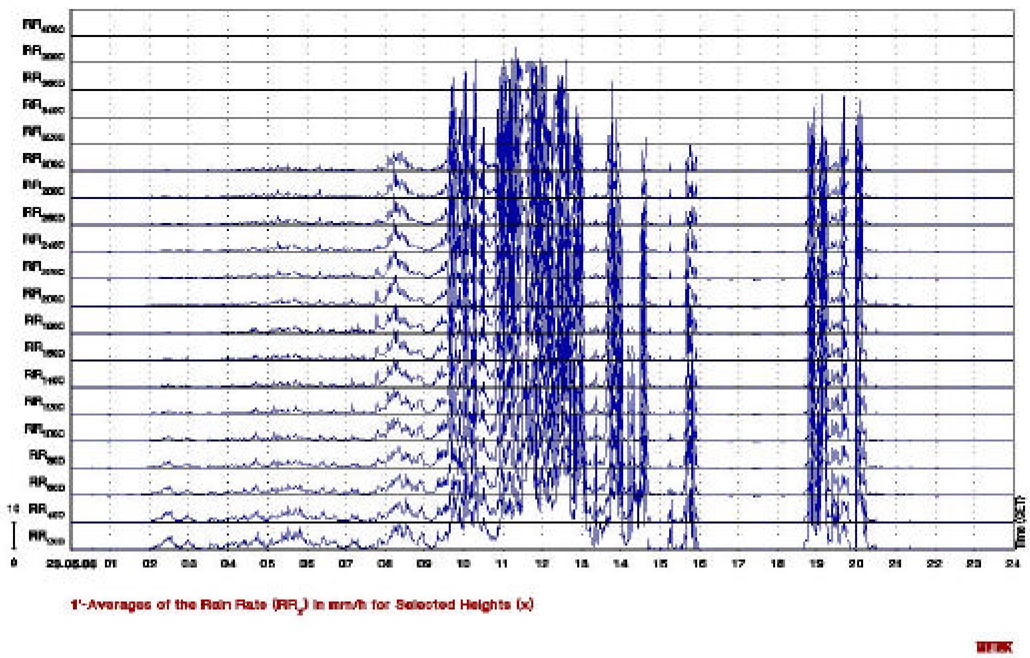

FIGURE 6.16.4: RAIN RATE RETRIEVED FROM MICRO RAIN RADAR (2003.05.23).

Acknowledgements

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