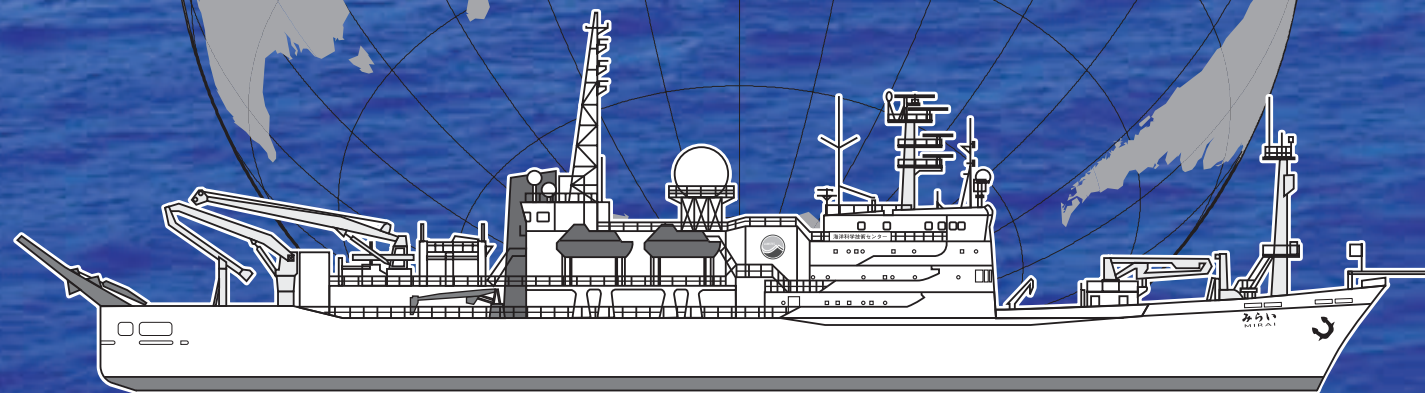


# WHP P21 REVISIT DATA BOOK

**Field Activity of JAMSTEC towards International Repeat Hydrography and Carbon Program**

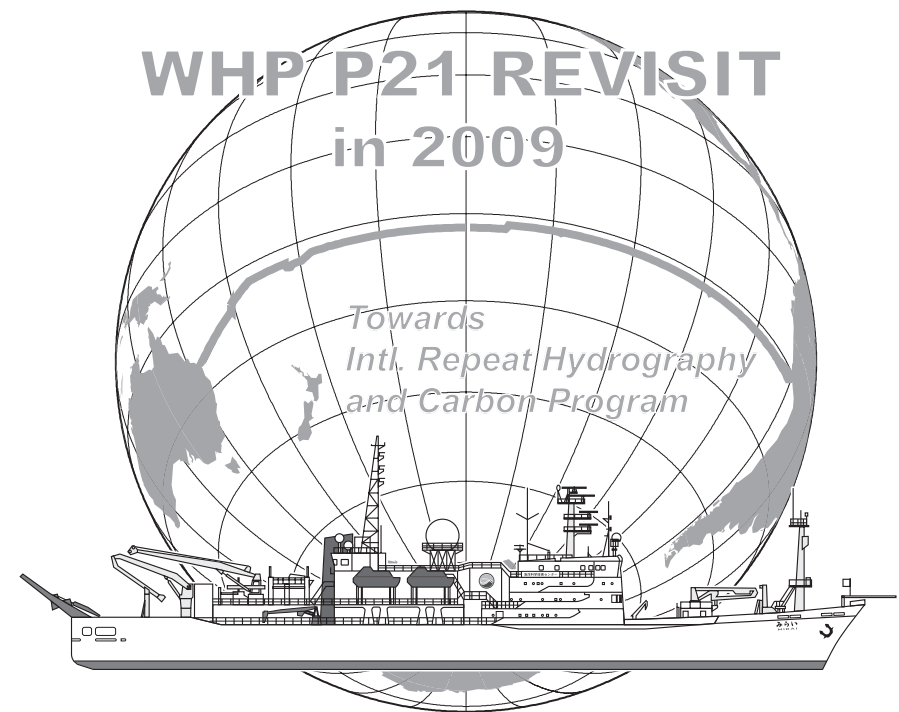
## WHP P21 REVISIT in 2009

*Towards  
Intl. Repeat Hydrography  
and Carbon Program*



# WHP P21 REVISIT DATA BOOK

*Edited by  
Hiroshi Uchida (JAMSTEC),  
Akihiko Murata (JAMSTEC),  
Toshimasa Doi (JAMSTEC)*



WHP P21 REVISIT DATA BOOK

March 25, 2011 Published

Edited by Hiroshi Uchida (JAMSTEC), Akihiko Murata (JAMSTEC) and Toshimasa Doi (JAMSTEC)

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## Preface

P21 was the WOCE one time survey line located slightly in the south of the boundary between two gyre systems of the Equatorial Counter Current and the South Equatorial Current. In 1994, WOCE hydrographic observations were carried out by United States along the line. After this cruise, P21 was not re-visited though there is a great possibility that repeat observations along this line could detect decadal or long-time scale variability of low latitudinal gyre system.

In 2008, the research system of JAMSTEC was re-organized. As the result, Institute of Observational Research for Global Change (IORGC) and Frontier Research Center for Global Change (FRCGC) were merged to form a new research organization of Research Institute for Global Change (RIGC). The General Ocean Circulation Research Program of former IORGC, which had been the main driver of CLIVAR Carbon Repeat Hydrography (CCRH) in Japan, was also developed into the Ocean Climate Change Research Program of new RIGC including Argo Group of former IORGC and Ocean assimilation Group of former FRCGC together.

P21 revisit cruise reported in this data book was the first CCRH cruise carried out under the new program of the Ocean Climate Change Research Program of RIGC. Also, it may be better to note here that this revisit-cruise was planned and proposed by bio-geochemical oceanographer in the program. One of distinct scientific outcomes from bio-geochemical researchers in the program was the discovery of the considerable acceleration in the CO<sub>2</sub> up-taking ratio and rapid increase in CO<sub>2</sub> accumulation of the South Pacific during these decades. P01, P02, P03, P10, P06 and P14 data were analyzed comprehensively but the Equator-ward extent of the CO<sub>2</sub> related issues mentioned above were left to be examined. So, this is the biggest reason why P21 was selected to be re-visited in spite of the fact that P21 was not included in the recommended repeat line in the strategy of the Global Ocean Ship-Based Hydrographic Investigation Program (GOSHIP).

After OceanObs09 in Venice, quite a few discussions were held on the sustainability of ocean observation and many proposals were published. GOSHIP strategy, which had been discussed since 2008 and was adopted

in 2010 finally, is one of answers to those discussions and proposals. The basic and important concept of the strategy is to maintain some of WOCE hydrographic lines by repeat observations along them as a strong tool of ocean monitoring to detect decadal changes in the global oceanic conditions especially in the Meridional Overturn Circulation System. We, ocean climate researchers in JAMSTEC, have carried out revisit cruises along eight WOCE one-time lines so far. However, as long as our activity concerns, P01 is the only line where we repeated observations twice. I strongly hope and believe that we will be able to have repeat observation along all of eight lines in near future to make the strategy of GO-SHIP real and effective.

On the day of Japan Northern Territory\*

Masao Fukasawa

Research Director of RIGC/JAMSTEC

\*On 7th February 1855, The Japan-Russia Treaty of Peace and Amity was ratified in which Etorofu, Kunashiri, Sikotan and Habomai islands are defined as Japan territory.



# 1 Cruise Narrative

## 1.1 Highlight

**GHPO Section Designation:** P21

**Cruise code:** MR09-01

**Expedition Designation:** 49NZ20090410  
49NZ20090521

### Chief Scientists and Affiliation:

**Leg.1: *Akihiko Murata***

akihiko.murata@jamstec.go.jp

**Leg.2: *Hiroshi Uchida***

huchida@jamstec.go.jp

**Leg.3: *Kenichi Sasaki***

ksasaki@jamstec.go.jp

Ocean Climate Change Research Program  
Research Institute for Global Change (RIGC)  
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)  
2-15 Natsushima, Yokosuka, Kanagawa, Japan 237-0061  
Fax: +81-46-867-9455

**Ship:** R/V Mirai

**Ports of Call:** Leg 1: Valparaiso, Chile - Papeete, Tahiti  
Leg 2a: Papeete, Tahiti - Papeete, Tahiti  
Leg 2b: Papeete, Tahiti - Brisbane, Australia  
Leg 3: Brisbane, Australia - Moji, Japan

**Cruise Dates:** Leg 1: April 10, 2009 - May 19, 2009  
Leg 2a: May 21, 2009 - May 24, 2009  
Leg 2b: May 25, 2009 - June 19, 2009  
Leg 3: June 20, 2009 - July 3, 2009

**Number of Stations:** 257 stations for CTD/Carousel Water Sampler  
(Leg 1: 140, Leg 2a: 8, Leg 2b: 109)

### Geographic Boundaries (for hydrographic stations):

24° 59.81'S - 15° 29.52'S  
153° 44.52'E - 75° 09.86'W

### Floats and Drifters Deployed:

5 Argo floats

### Mooring Deployed or Recovered Mooring:

None



## 1.2 Cruise Summary

### (1) Station occupied

A total of 257 stations was occupied using a Sea-Bird Electronics 36 position carousel equipped with 12 litter Niskin-X water sample bottles, a SBE 9/11plus equipped with SBE35 deep ocean standards thermometer, SBE43 oxygen sensor, AANDERAA Optode 3830 and 4330F oxygen sensors, JFE Alec RINKO oxygen sensor, Seapoint Sensors fluorometer, WET labs C-Star transmissometer, Benthos altimeter, and RDI ADCP. XCTDs were deployed at 23 stations. XMPs (eXpendable Microstructure Profiler) were also deployed at 3 stations. Cruise track and station location are shown in Figure 1.2.1.

### (2) Sampling and measurements

Water samples were analyzed for salinity, oxygen, nutrients, CFC-11, -12, -113, total alkalinity, DIC, and pH. The sampling layers are coordinated as so-called staggered mesh. Samples for  $^{14}\text{C}$ ,  $^{13}\text{C}$ , methane, nitrous oxide, carbonyl sulfide, chlorophyll a, PON, POC,  $^{15}\text{N}$ -nitrate, ammonia, and a biological study were also collected at the selected stations. The bottle depth diagram is shown in Figure 1.2.2. Underway  $\text{pCO}_2$ , temperature, salinity, oxygen, surface current, bathymetry, and meteorological measurements were conducted along the cruise track.

### (3) Floats deployment

Five ARGO floats were launched along the cruise track. The launched positions of the ARGO floats are listed in Table 1.2.1.

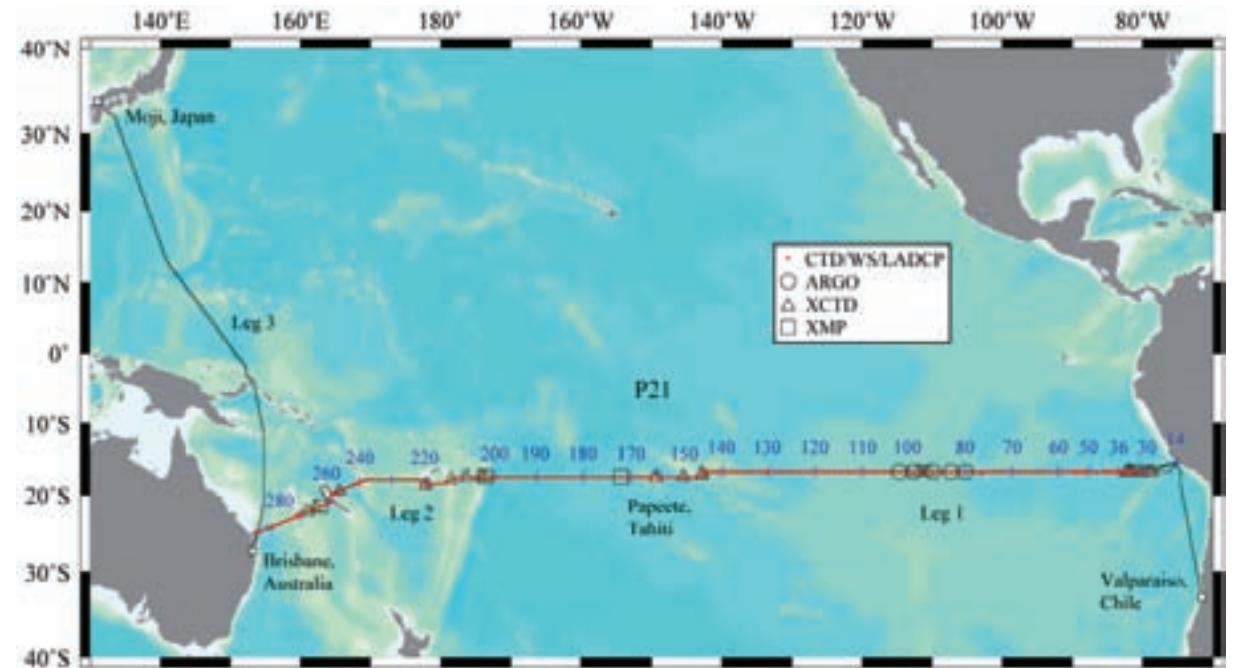


Figure 1.2.1. Cruise track and hydrographic stations.

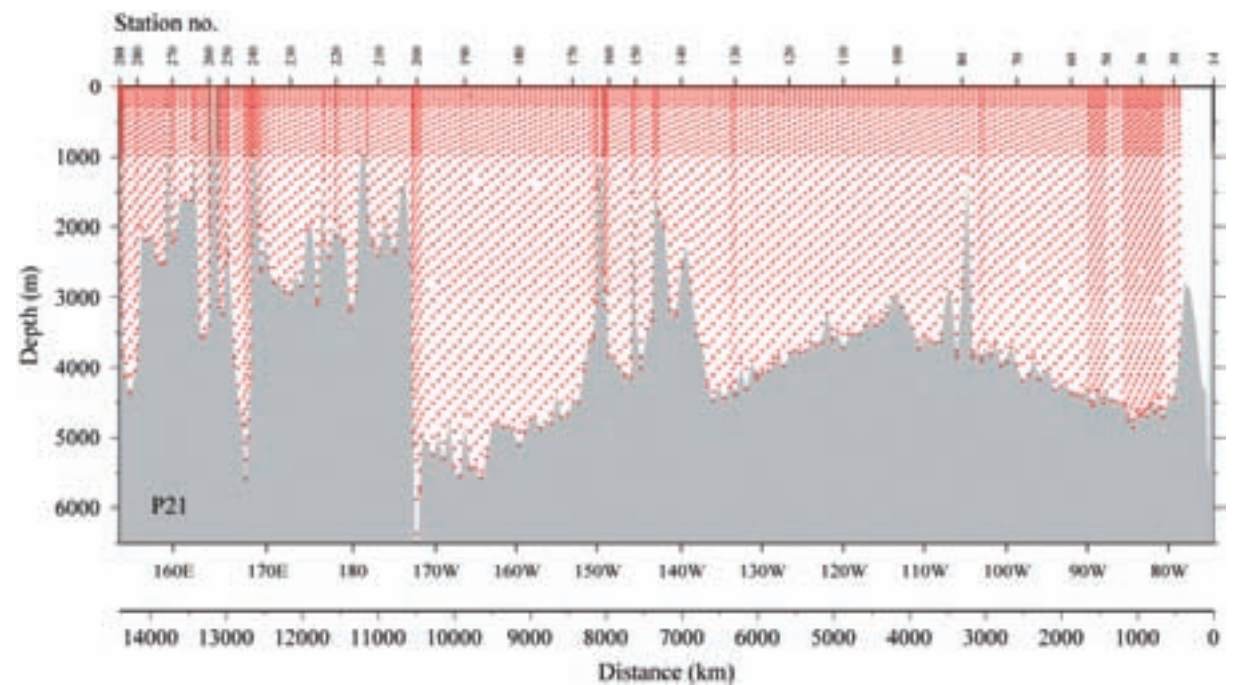


Figure 1.2.2. Bottle depth diagram.

Table 1.2.1. Launched positions of the ARGO floats.

Float S/N	ARGOS ID	Date and time of reset (UTC)	Date and time of launch (UTC)	Location of launch	CTD station no.
4099	86536	2009/05/01	2009/05/01	16-45.21 S	P21-080
		18:45	20:03	105-20.41 W	
4042	86510	2009/05/03	2009/05/03	16-44.51 S	P21-087
		08:16	09:15	107-19.90 W	
4101	86537	2009/05/04	2009/05/04	16-45.05 S	P21-095
		05:54	06:35	109-59.34 W	
4043	86511	2009/05/05	2009/05/05	16-44.99 S	P21-099
		04:05	04:52	112-41.19 W	
4102	86538	2009/05/05	2009/05/05	16-45.33 S	P21-102
		18:37	19:37	114-40.55 W	

### 1.3 List of Principal Investigator and Person in Charge on the Ship

The principal investigator (PI) and the person in charge responsible for major parameters measured on the cruise are listed in Table 1.3.1.

Table 1.3.1. List of principal investigator and person in charge on the ship.

Item	Principal Investigator	Person in Charge on the Ship
<i>Underway</i>		
ADCP	Shinya Kouketsu (JAMSTEC) skouketsu@jamstec.go.jp	Shinya Okumura (GODI) (leg 1) Satoshi Okumura (GODI) (leg 2) Souichiro Sueyoshi (GODI) (leg 3)
Bathymetry	Takeshi Matsumoto (Univ. of Ryukyus) tak@sci.u-ryukyu.ac.jp Masao Nakanishi (Chiba Univ.) nakanisi@earth.s.chiba-u.ac.jp	Shinya Okumura (GODI) (leg 1) Satoshi Okumura (GODI) (leg 2) Souichiro Sueyoshi (GODI) (leg 3)
Meteorology	Kunio Yoneyama (JAMSTEC) yoneyamak@jamstec.go.jp	Shinya Okumura (GODI) (leg 1) Satoshi Okumura (GODI) (leg 2) Souichiro Sueyoshi (GODI) (leg 3)
T-S	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamtec.go.jp	Miyo Ikeda (MWJ) (leg 1, 2) Fuyuki Shibata (MWJ) (leg 3)
pCO <sub>2</sub>	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Minoru Kamata (MWJ) (leg 1, 2) Yasuhiro Arii (MWJ) (leg 3)
<i>Hydrography</i>		
CTD/O <sub>2</sub>	Hiroshi Uchida (JAMSTEC) huchida@jamstec.go.jp	Kenichi Katayama (MWJ) (leg 1) Tomoyuki Takamori (MWJ) (leg 2)
XCTD	Hiroshi Uchida (JAMSTEC) huchida@jamstec.go.jp	Shinya Okumura (GODI) (leg 1) Satoshi Okumura (GODI) (leg 2)
LADCP	Shinya Kouketsu (JAMSTEC) skouketsu@jamstec.go.jp	Shinya Kouketsu (JAMSTEC) (leg 1) Katsuro Katsumata (JAMSTEC) (leg 2)
Salinity	Takeshi Kawano (JAMSTEC) kawanot@jamstec.go.jp	Tatsuya Tanaka (MWJ) (leg 1) Fujio Kobayashi (MWJ) (leg 2)

Oxygen	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Fuyuki Shibata (MWJ) (leg 1) Miyo Ikeda (MWJ) (leg 2)
Nutrients	Michio Aoyama (MRI) maoyama@mri-jma.go.jp	Ayumi Takeuchi (MWJ) (leg 1) Junji Matsushita (MWJ) (leg 2)
DIC	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Minoru Kamata (MWJ)
Alkalinity	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Tomonori Watai (MWJ) (leg 1) Yoshiko Ishikawa (MWJ) (leg 2)
pH	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Tomonori Watai (MWJ) (leg 1) Yoshiko Ishikawa (MWJ) (leg 2)
CFCs	Kenichi Sasaki (JAMSTEC) ksasaki@jamstec.go.jp	Kenichi Sasaki (JAMSTEC)
$\Delta^{14}\text{C}/\delta^{13}\text{C}$	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Yuichiro Kumamoto (JAMSTEC)
$\text{N}_2\text{O}/\text{CH}_4$	Osamu Yoshida (RGU) yoshida@rakuno.ac.jp	Osamu Yoshida (RGU) (leg 1) Sakae Toyoda (TITECH) (leg 2)
Biology	Ken Furuya (UT) furuya@fs.a.u-tokyo.ac.jp	Taketoshi Kodama (UT)
<i>Floats</i>		
ARGO float	Toshio Suga (JAMSTEC) sugat@jamstec.go.jp	Kenichi Katayama (MWJ)

---

GODI	Global Ocean Development Inc.
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
MRI	Meteorological Research Institute, Japan Meteorological Agency
MWJ	Marine Works Japan, Ltd.
RGU	Rakuno Gakuen University
TITECH	Tokyo Institute of Technology
UT	The University of Tokyo

## 1.4 Scientific Program and Methods

### (1) Nature and objectives of MR09-01 cruise project

It is well known that climate changes of a timescale more than a decade are influenced by changes of oceanic conditions. Among a lot of oceanic changes, we focus on transport and accumulation of anthropogenic  $\text{CO}_2$  and heat in the ocean, both of which are important for global warming. Accordingly we are aimed at clarifying temporal changes of the transport and accumulation quantitatively. In doing so, we pay a special attention to water masses of the Southern Ocean's origin, which play an important role in transporting anthropogenic  $\text{CO}_2$  and heat into the ocean's interior. With this purpose, we have so far re-occupied historical observation lines, mainly in the Pacific Ocean.

This cruise is a reoccupation of the hydrographic section called 'WHP-P21', which was observed by an ocean science group of United States of America (USA) in 1994 as a part of World Ocean Circulation Experiment (WOCE). The dataset is included in the data base of Climate Variability and Predictability (CLIVAR) and Carbon Hydrographic Data Office (<http://whpo.ucsd.edu/>). We will compare physical and chemical properties along section WHP-P21 with those obtained in 1994 to detect and evaluate long-term changes of the marine environment in the Pacific.

Reoccupations of the WOCE hydrographic sections are now in progress by international cooperation in ocean science community, under the framework of CLIVAR, which is as part of World Climate Research Programme (WCRP) and International Ocean Carbon Coordination Project (IOCCP). Our research is planned as a contribution to this international projects supported by World Meteorological Organization (WMO), International Council for Science (ICSU) / Scientific Committee on Oceanic Research (SCOR) and United Nations Educational, Scientific and Cultural Organization (UNESCO)/Intergovernmental Oceanographic Commission (IOC), and the results and data will be published by 2010 for worldwide use.

The other purposes of this cruise are as follows:

- 1) to observe surface meteorological and hydrological parameters as a basic data of meteorology and oceanography such as studies on flux exchange, air-sea interaction and so on,

- 2) to observe sea bottom topography, gravity and magnetic fields along the cruise track to understand the dynamics of ocean plate and accompanying geophysical activities,
- 3) to observe biogeochemical parameters to study material (carbon, nitrate, etc) cycle in the ocean,
- 4) to observe greenhouse gases in the atmosphere and the ocean to study their cycle from bio-geochemical aspect, and
- 5) to estimate diapycnal diffusivity in the deep ocean.

## (2) Cruise narrative

R/V Mirai departed Valparaiso, Chile on April 10, 2009. The hydrographic cast was started at the station P21-29 on April 14, since permission of observation in the Peru's EEZ was not yet given. After the CTD station P21-33, R/V Mirai sailed towards the station P21-14 off Peru and waited for a few days in the Peru's EEZ. XCTDs were deployed at stations from P21-29 to P21-33 and the hydrographic cast was restarted at the station P21-41 on April 21.

At Papeete, Tahiti on 21 May, 2009, 34 crews and scientists who came from Japan to embark on R/V Mirai by the same plane were not allowed to embark for 7 days, because one of the scientists developed a fever of 38 °C and was suspected as a new type of flu. Therefore, we conducted 8 CTD stations without the 34 crews and scientists during leg 2a from 21 to 24 May. Then R/V Mirai departed Papeete again on May 25 and we conducted the rest of the hydrographic observations in leg 2b. R/V Mirai arrived at Brisbane, Australia on June 19, 2009.

During leg 3 from June 20 to July 3, underway observations were conducted along the cruise track.

## 1.5 List of Cruise Participants

Table 1.5.1(a). List of cruise participants for leg 1.

Name	Responsibility	Affiliation
Akihiko Murata	Chief scientist/carbon/water sampling	RIGC/JAMSTEC
Hiroshi Uchida	CTD/water sampling	RIGC/JAMSTEC
Sinya Kouketsu	LADCP/ADCP/water sampling	RIGC/JAMSTEC
Yuichiro Kumamoto	DO/thermosalinograph / $\Delta 14C$	RIGC/JAMSTEC
Kenichi Sasaki	CFCs	MIO/JAMSTEC
Hirokatsu Uno	CTD/water sampling	MWJ
Kenichi Katayama	CTD/water sampling	MWJ
Shinsuke Toyoda	CTD/water sampling	MWJ
Hiroyuki Hayashi	CTD/water sampling	MWJ
Tatsuya Tanaka	Salinity	MWJ
Akira Watanabe	Salinity	MWJ
Fuyuki Shibata	DO/water sampling	MWJ
Miyo Ikeda	DO/water sampling	MWJ
Misato Kuwahara	DO/water sampling	MWJ
Shinichiro Yokogawa	Nutrients	MWJ
Ayumi Takeuchi	Nutrients	MWJ
Kohei Miura	Nutrients	MWJ
Kenichiro Sato	Chief technologist/nutrients/water sampling	MWJ
Ai Ueda	Water sampling	MWJ
Tetsuo Aoki	Water sampling	MWJ
Rui Asakawa	Water sampling	MWJ
Masashi Inose	Water sampling	MWJ
Shinya Iwasaki	Water sampling	MWJ
Masahiro Orui	Water sampling	MWJ

Yuichi Sonoyama	CFCs	MWJ
Katsunori Sagishima	CFCs	MWJ
Shoko Tatamisashi	CFCs	MWJ
Tomonori Watai	pH/total alkalinity	MWJ
Ayaka Hatsuyama	pH/total alkalinity	MWJ
Minoru Kamata	DIC	MWJ
Yoshiko Ishikawa	DIC	MWJ
Shinya Okumura	Meteorology/geophysics/ADCP/XCTD	GODI
Ryo Kimura	Meteorology/geophysics/ADCP/XCTD	GODI
Yosuke Yuki	Meteorology/geophysics/ADCP/XCTD	GODI
Takuhei Shiozaki	Biology/water sampling	UT
Satoshi Kitajima	Biology/water sampling	UT
Taketoshi Kodama	Biology/water sampling	UT
Hiroyuki Kurotori	Biology/water sampling	UT
Osamu Yoshida	CH4 and N <sub>2</sub> O/water sampling	RGU
Sho Imai	CH4 and N <sub>2</sub> O/water sampling	RGU
Chiho Kubota	CH4 and N <sub>2</sub> O/water sampling	RGU
Wolfgang Schneider	CTD/water sampling	COPAS
Lorena Graciela Márquez Ismodes	Observer	Peruvian Navy

COPAS	Center for Oceanographic Research in the eastern South Pacific, University of Concepcion, Chile
GODI	Global Ocean Development Inc.
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
MIO	Mutsu Institute of Oceanography
MWJ	Marine Works Japan, Ltd.
RGU	Rakuno Gakuen University
RIGC	Research Institute for Global Change
UT	The University of Tokyo

Table 1.5.1(b). List of cruise participants for leg 2a.

Name	Responsibility	Affiliation
Hiroshi Uchida	Chief Scientist/CTD/water sampling	RIGC/JAMSTEC
Shinya Kouketsu	LADCP/ADCP/water sampling	RIGC/JAMSTEC
Yuichiro Kumamoto	DO/thermosalinograph / $\Delta^{14}\text{C}$	RIGC/JAMSTEC
Toshimasa Doi	LADCP /water sampling	RIGC/JAMSTEC
Katsuro Katsumata	XMP/LADCP/water sampling	RIGC/JAMSTEC
Kenichi Sasaki	CFCs	MIO/JAMSTEC
Hirokatsu Uno	CTD/water sampling	MWJ
Kenichi Katayama	CTD/water sampling	MWJ
Shinsuke Toyoda	CTD/water sampling	MWJ
Hiroyuki Hayashi	CTD/water sampling	MWJ
Tatsuya Tanaka	Salinity	MWJ
Akira Watanabe	Salinity	MWJ
Fuyuki Shibata	DO/water sampling	MWJ
Miyo Ikeda	DO/water sampling	MWJ
Misato Kuwahara	DO/water sampling	MWJ
Shinichiro Yokogawa	Nutrients	MWJ
Ayumi Takeuchi	Nutrients	MWJ
Kohei Miura	Nutrients	MWJ
Kenichiro Sato	Chief technologist/nutrients/water sampling	MWJ
Ai Ueda	Water sampling	MWJ
Yuichi Sonoyama	CFCs	MWJ
Katsunori Sagishima	CFCs	MWJ
Shoko Tatamisashi	CFCs	MWJ
Tomonori Watai	pH/total alkalinity	MWJ
Ayaka Hatsuyama	pH/total alkalinity	MWJ
Minoru Kamata	DIC	MWJ
Yoshiko Ishikawa	DIC	MWJ



Shinya Okumura	Meteorology/geophysics/ADCP/XCTD	GODI
Ryo Kimura	Meteorology/geophysics/ADCP/XCTD	GODI
Yosuke Yuki	Meteorology/geophysics/ADCP/XCTD	GODI
Takuhei Shiozaki	Biology/water sampling	UT
Satoshi Kitajima	Biology/water sampling	UT
Taketoshi Kodama	Biology/water sampling	UT
Hiroyuki Kurotori	Biology/water sampling	UT
Sho Imai	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	RGU
Chiho Kubota	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	RGU
Wolfgang Schneider	CTD/water sampling	COPAS
Camillia Pauline Garae	Observer	DGMWR
Harish Pratap	Observer	FMS
DGMWR	Department of Geology Mines and Water Resources, Vanuatu	
FMS	Fiji Meteorological Services, Fiji	

Table 1.5.1(c). List of cruise participants for leg 2b.

Name	Responsibility	Affiliation
Hiroshi Uchida	Chief scientist/CTD/water sampling	RIGC/JAMSTEC
Yuichiro Kumamoto	DO/thermosalinograph/ $\Delta^{14}\text{C}$	RIGC/JAMSTEC
Toshimasa Doi	LADCP/water sampling	RIGC/JAMSTEC
Katsuro Katsumata	XMP/LADCP/water sampling	RIGC/JAMSTEC
Kenichi Sasaki	CFCs	MIO/JAMSTEC
Fujio Kobayashi	Salinity	MWJ
Akira Watanabe	Salinity	MWJ
Miyo Ikeda	DO/water sampling	MWJ
Misato Kuwahara	DO/water sampling	MWJ
Masanori Enoki	DO/water sampling	MWJ
Ayumi Takeuchi	Nutrients	MWJ
Kohei Miura	Nutrients	MWJ
Junji Matsushita	Nutrients	MWJ
Satoshi Ozawa	Chief technologist /CTD/water Sampling	MWJ
Ai Ueda	Water sampling	MWJ
Yuichi Sonoyama	CFCs	MWJ
Katsunori Sagishima	CFCs	MWJ
Shoko Tatamisashi	CFCs	MWJ
Yoshiko Ishikawa	pH/total alkalinity	MWJ
Ayaka Hatsuyama	pH/total alkalinity	MWJ
Minoru Kamata	DIC	MWJ
Yasuhiro Arii	DIC	MWJ
Tomoyuki Takamori	CTD/water sampling	MWJ
Hiroshi Matsunaga	CTD/water sampling	MWJ
Masayuki Fujisaki	CTD/water sampling	MWJ
Shungo Oshitani	CTD/water sampling	MWJ
Tatsuya Ando	Water sampling	MWJ



Tomomi Watanabe	Water sampling	MWJ
Kanako Yoshida	Water sampling	MWJ
Mami Kawai	Water sampling	MWJ
Hideki Yamamoto	Water sampling	MWJ
Satoshi Okumura	Meteorology/geophysics/ADCP/XCTD	GODI
Kazuho Yoshida	Meteorology/geophysics/ADCP/XCTD	GODI
Harumi Ota	Meteorology/geophysics/ADCP/XCTD	GODI
Takuhei Shiozaki	Biology/water sampling	UT
Satoshi Kitajima	Biology/water sampling	UT
Taketoshi Kodama	Biology/water sampling	UT
Hiroyuki Kurotori	Biology/water sampling	UT
Sho Imai	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	RGU
Chiho Kubota	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	RGU
Wolfgang Schneider	CTD/water sampling	COPAS
Camillia Pauline Garae	Observer	DGMWR
Harish Pratap	Observer	FMS
Sakae Toyoda	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	TITECH
Taku Watanabe	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	TITECH
TITECH	Tokyo Institute of Technology	

Table 1.5.1(d). List of cruise participants for leg 3.

Name	Responsibility	Affiliation
Kenichi Sasaki	Chief scientist	MIO/JAMSTEC
Fujio Kobayashi	Technician	MWJ
Sinsuke Toyoda	Technician	MWJ
Fuyuki Shibata	Technician	MWJ
Sinichiro Yokogawa	Technician	MWJ
Shoko Tatamisashi	Technician	MWJ
Hideki Yamamoto	Technician	MWJ
Nironori Sato	Technician	MWJ
Yasuhiro Aarii	Technician	MWJ
Ryo Kimura	Meteorology/geophysics/ADCP/XCTD	GODI
Soichiro Sueyoshi	Meteorology/geophysics/ADCP/XCTD	GODI
Takuhei Shiozaki	Biology	UT
Satoshi Kitajima	Biology	UT
Taketoshi Kodama	Biology	UT
Hiroyuki Kurotori	Biology	UT
Taku Watanabe	CH <sub>4</sub> and N <sub>2</sub> O	TITECH
Sho Imai	CH <sub>4</sub> and N <sub>2</sub> O	RGU
Chiho Kubota	CH <sub>4</sub> and N <sub>2</sub> O	RGU
Hiroshi Furutani	Air sampling	ORI
Jinyoung Jung	Air sampling	ORI
ORI	Ocean Research Institute, The University of Tokyo	

## 2 Underway Observation

### 2.1 Navigation and Bathymetry

September 9, 2009

#### 2.1.1 Navigation

##### (1) Personnel

*Shinya Okumura* (GODI) : Leg 1

*Satoshi Okumura* (GODI) : Leg 2

*Souichiro Sueyoshi* (GODI) : Leg 3

*Ryo Kimura* (GODI) : Leg 1, Leg 3

*Yousuke Yuuki* (GODI) : Leg 1

*Kazuho Yoshida* (GODI) : Leg 2

*Harumi Ota* (GODI) : Leg 2

##### (2) Overview of the equipment

Ship's position, speed and course were provided by Radio Navigation System on R/V MIRAI. The system integrates GPS position, Log speed, Gyro heading and other basic data on a workstation. Ship's course and speed over ground are calculated from GPS position. The workstation clock is synchronized to reference clock using NTP (Network Time Protocol). Navigation data, called "SOJ data", is distributed to client computer every second, and recorded every 60 seconds.

Navigation devices are listed below.

1. GPS receiver (2sets): Trimble DS-4000 9-channel receiver, the antennas are located on Navigation deck, port and starboard side. GPS position from each receiver is converted to the position of radar mast.
2. Doppler log: Furuno DS-30, which use three acoustic beam for current measurement
3. Gyrocompass: Tokimec TG-6000, sperry mechanical gyrocompass
4. Reference clock: Symmetricom TymServ2100, GPS time server

5. Workstation

Hewlett-Packard ZX2000 running HP-UX ver.11.22

##### (3) Data period

MR09-01 Leg 1: 17:58UTC 09 Apr. 2009 to 23:59 UTC 19 May 2009 (UTC)

MR09-01 Leg 2: 00:00 UTC 21 May 2009 to 02:00 UTC 19 Jun. 2009 (UTC)

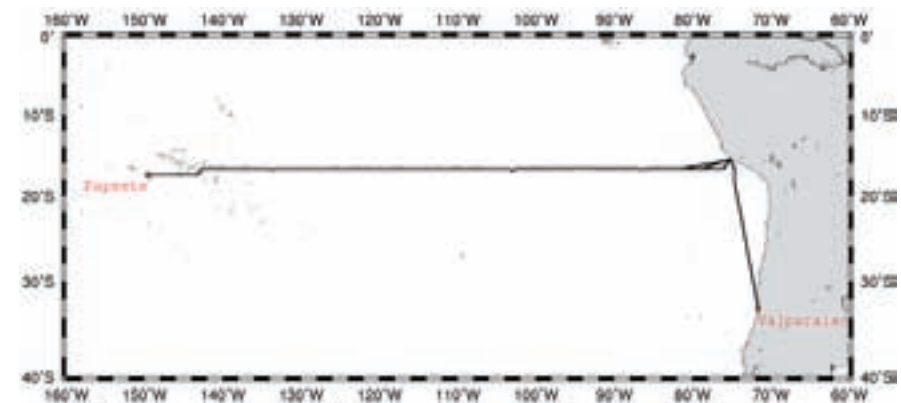


Figure 2.1.1. Cruise Track of MR09-01 Leg 1.

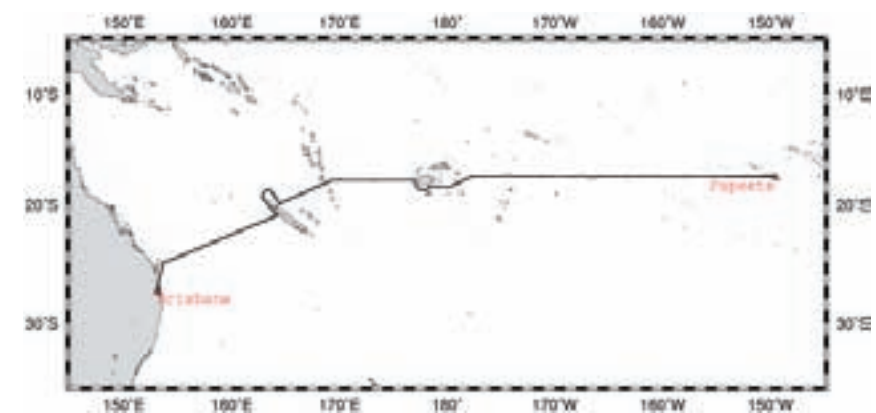


Figure 2.1.2. Cruise Track of MR09-01 Leg 2.

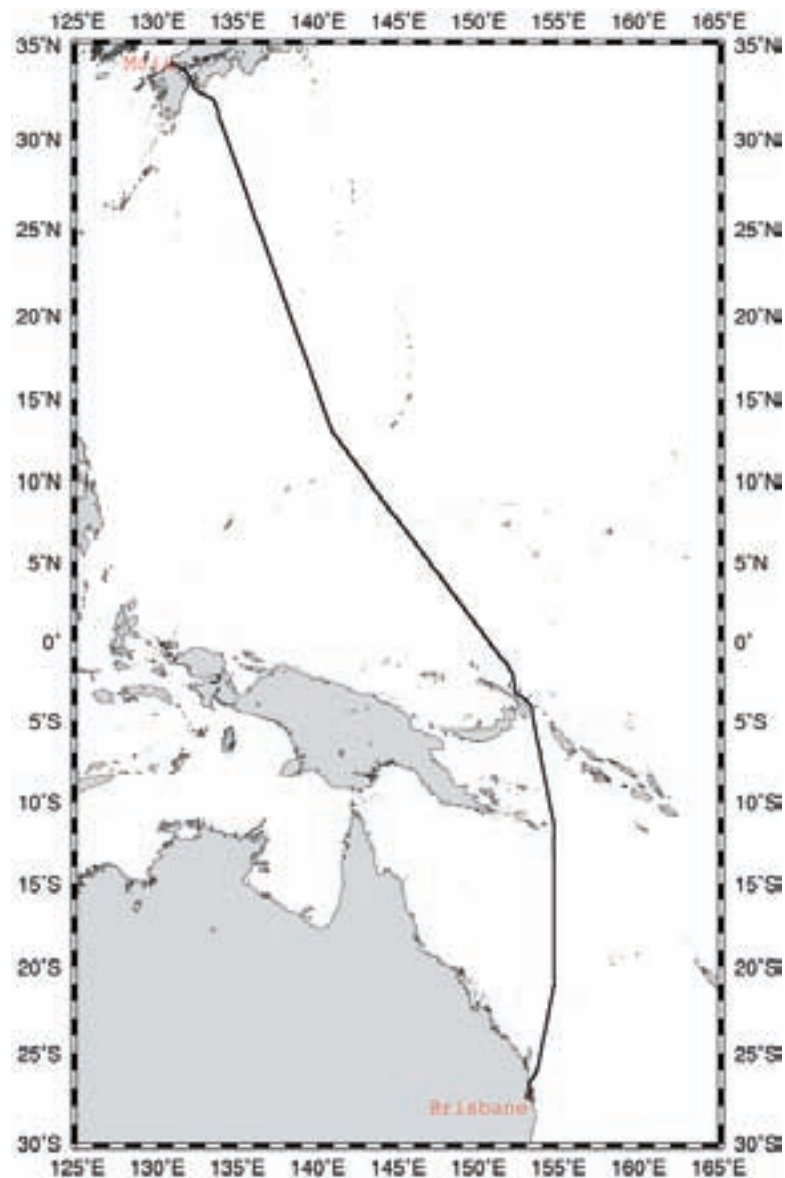


Figure 2.1.3. Cruise Track of MR09-01 Leg 3.

## 2.1.2 Bathymetry

### (1) Personnel

<i>Takeshi Matsumoto</i>	<i>(University of the Ryukyus)</i>	<i>: Principal investigator / Not on-board</i>
<i>Masao Nakanishi</i>	<i>(Chiba University)</i>	<i>: Principal investigator / Not on-board</i>
<i>Shinya Okumura</i>	<i>(GODI)</i>	<i>: Leg1</i>
<i>Satoshi Okumura</i>	<i>(GODI)</i>	<i>: Leg2</i>
<i>Souichiro Sueyoshi</i>	<i>(GODI)</i>	<i>: Leg3</i>
<i>Ryo Kimura</i>	<i>(GODI)</i>	<i>: Leg1, Leg3</i>
<i>Yousuke Yuuki</i>	<i>(GODI)</i>	<i>: Leg1</i>
<i>Kazuho Yoshida</i>	<i>(GODI)</i>	<i>: Leg2</i>
<i>Harumi Ota</i>	<i>(GODI)</i>	<i>: Leg2</i>

### (2) Overview of the equipments

R/V MIRAI equipped with a Multi Beam Echo Sounding system (MBES), SEABEAM 2112.004 (SeaBeam Instruments Inc.) The main objective of MBES survey is collecting continuous bathymetry data along ship's track to make a contribution to geological and geophysical investigations and global datasets. Data interval along ship's track was max 17 seconds at 6,000 m. To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data to get the sea surface (6.2 m depth) sound velocity, and the deeper depth profiles were calculated using temperature and salinity profiles from the nearest CTD data by the equation in Mackenzie (1981).

System configuration and performance of SEABEAM 2112.004,

Frequency:	12 kHz
Transmit beam width:	2 degree
Transmit power:	20 kW
Transmit pulse length:	3 to 20 msec.
Depth range:	100 to 11,000 m

Beam spacing:	1 degree athwart ship
Swath width:	150 degree (max)
	120 degree to 4,500 m
	100 degree to 6,000 m
	90 degree to 11,000 m
Depth accuracy:	Within < 0.5% of depth or $\pm 1$ m, whichever is greater, over the entire swath. (Nadir beam has greater accuracy; typically within < 0.2% of depth or $\pm 1$ m, whichever is greater)

### (3) Data Period

MR09-01 Leg1: P21-029 on 14 April 2009 to P21-033 on 16 April 2009,  
P21-014 on 17 April 2009 to P21-156 on 18 May 2009  
MR09-01 Leg2: P21-157 on 21 May 2009 to P21-288 on 19 June 2009  
MR09-01 Leg3: 20 June 2009 to 1 July 2009  
(except for the territorial waters of Papua New Guinea)

### (4) Data processing

#### i. Sound velocity correction

The continuous bathymetry data are split into small areas around each CTD station. For each small area, the bathymetry data are corrected using a sound velocity profile calculated from the CTD data in the area. The equation of Mackenzie (1981) is used for calculating sound velocity. The data processing is carried out using “mbbath” command of MBsystem.

#### ii. Editing and Gridding

Gridding for the bathymetry data are carried out using the HIPS software version 6.1 Service Pack 2 (CARIS, Canada). Firstly, the bathymetry data during Ship’s turning is basically removed before “BASE surface” is made. A spike noise of each swath data is also removed using “swath editor” and “subset editor”. Then the bathymetry data are gridded by “Interpolate” function of the software with following parameters.

BASE surface resolution:	50 m
Interpolate matrix size:	5 × 5
Minimum number of neighbors for interpolate:	10

Finally, raw data and interpolated data are exported as ASCII data, and converted to 150 m grid data using “xyz2grd” utility of GMT (Generic Mapping Tool) software.

#### (5) Data Archive

Bathymetry data obtained during this cruise was submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and archived there.

#### (6) Tectonic history of the Pacific Plate

The Pacific Plate is the largest oceanic lithospheric plate on the Earth. The Pacific Plate was born around 190 Ma, Middle Jurassic (Nakanishi et al., 1992). The tectonic history of the Pacific Plate has been exposed by many studies based on magnetic anomaly lineations. However, the tectonic history in some periods is still obscure because of lack of geophysical data. To reveal the entire tectonic history of the Pacific Plate from Middle Jurassic to the present, increase in geophysical data is indispensable.

Identification of magnetic anomaly lineations has been the most common method for tectonic studies of oceanic plates. After improvement of the multi-narrow beam echo sounder, we become able to describe lineated abyssal hills for the tectonic studies in detail. Abyssal hills are related to the nature of the mid-ocean ridges at

which they form (e.g. Goff et al., 1997). For example, abyssal hills heights and widths tend to correlate inversely with spreading rates. Abyssal hills also change morphology depending on crustal thickness and magma supply, factors which can vary within a single ridge segment and/or can vary from one ridge segment to another. Abyssal hills are therefore an off-axis indicator of mid-ocean ridge spreading history.

We collected bathymetric data using SeaBeam 2112 during the cruise. Figures 2.1.4 and 2.1.5 show examples of abyssal hills. Figure 2.1.4 is the bathymetric map near the East Pacific Rise (EPR). The crest of the EPR has about 2600 m depth and about 350 m higher than its foot. The depth of the seafloor near the edges of Figure 2.1.4a is about 3500 m. Most of the abyssal hills have the similar strike as the EPR, but some have different strikes from the EPR. The height of abyssal hills is 50 m near the EPR and is more than 200 m around 114°W.

Figure 2.1.5 is the bathymetric map of the seafloor south of the Manihiki Plateau and crosses the East Manihiki Scarp, which is a remarkably linear feature extending more than 700 km from the northeastern corner of the Manihiki plateau. Previous works (e.g., Viso et al., 2005; Downey et al., 2007) show the existence of the abyssal hills with an E-W strike in this area. The abyssal hills originate from the Pacific-Phoenix Ridge in the mid-Cretaceous. The abyssal hills with an E-W strike exist west of 164°W (Figure 2.1.5b). The height of the abyssal hills is ~100 m. Several knolls with depression exist around 165°15'W. The height of the knolls is about 600 m. The abyssal hills east of the East Manihiki Scarp (EMS) have an NE-SW strike (Figure 2.1.5a, c). The height of abyssal hills is more than 100 m. The pattern of the abyssal hills near the EMS is similar to that around 2.5°S reported by Viso et al. (2005). They interpret these abyssal hills as intratransform spreading centers resulting from transtensional strain across the EMS. Thus, the abyssal hills east of the EMS in Figure 2.1.5(c) derive from the same mechanism.

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- Searle, R. (1984): GLORIA survey of the East Pacific Rise Near 3.5°S: Tectonic and volcanic characteristics of a fast spreading mid-ocean rise, *Tectonophysics*, 101, 319-344.
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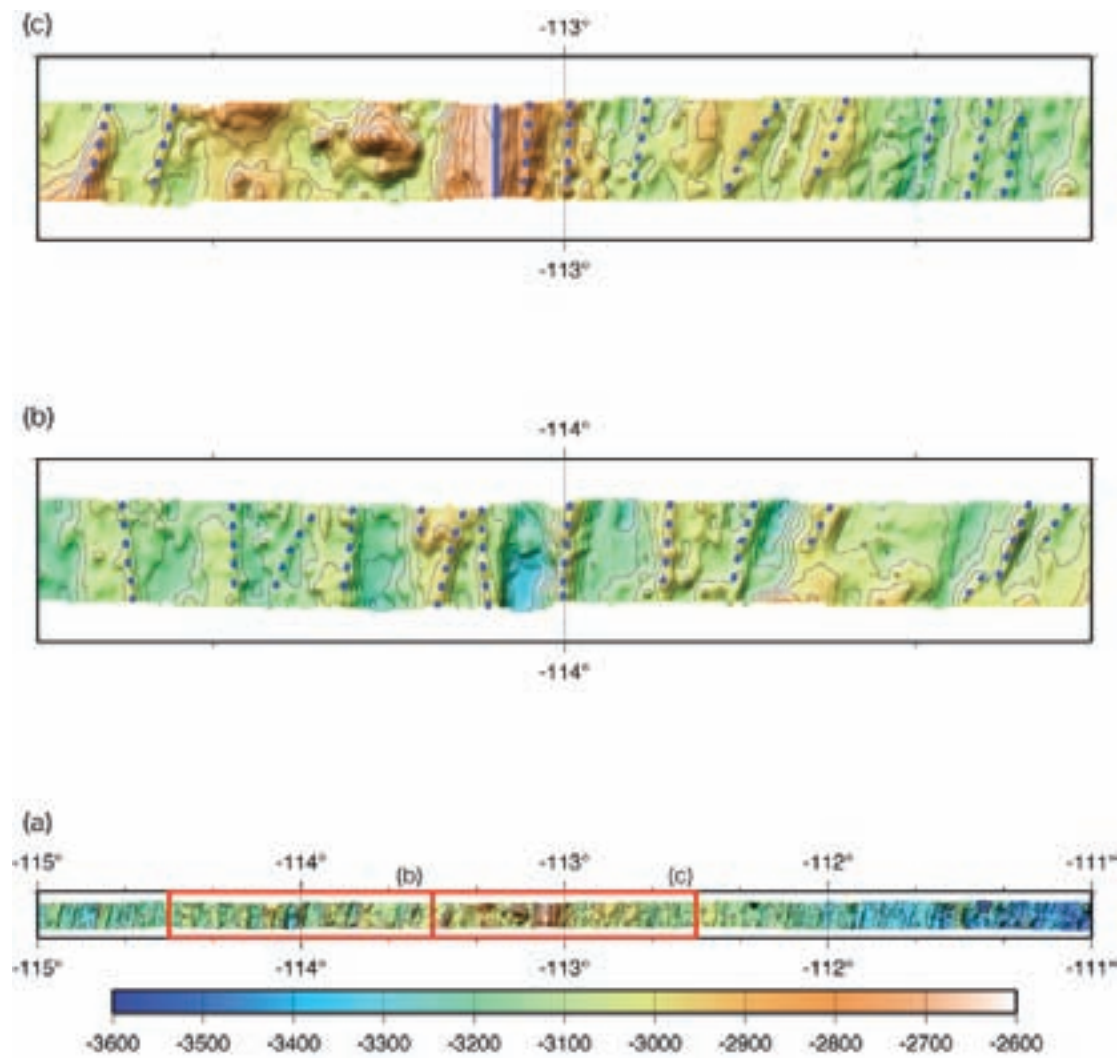


Figure 2.1.4. Bathymetric Map around the East Pacific Rise. Contour interval is 50 m. Bathymetry is illuminated from the northwest. Red rectangles in (a) represent the areas of (b) and (c). Blue dotted lines represent abyssal hills. A blue line shows the crest of the East Pacific Rise.

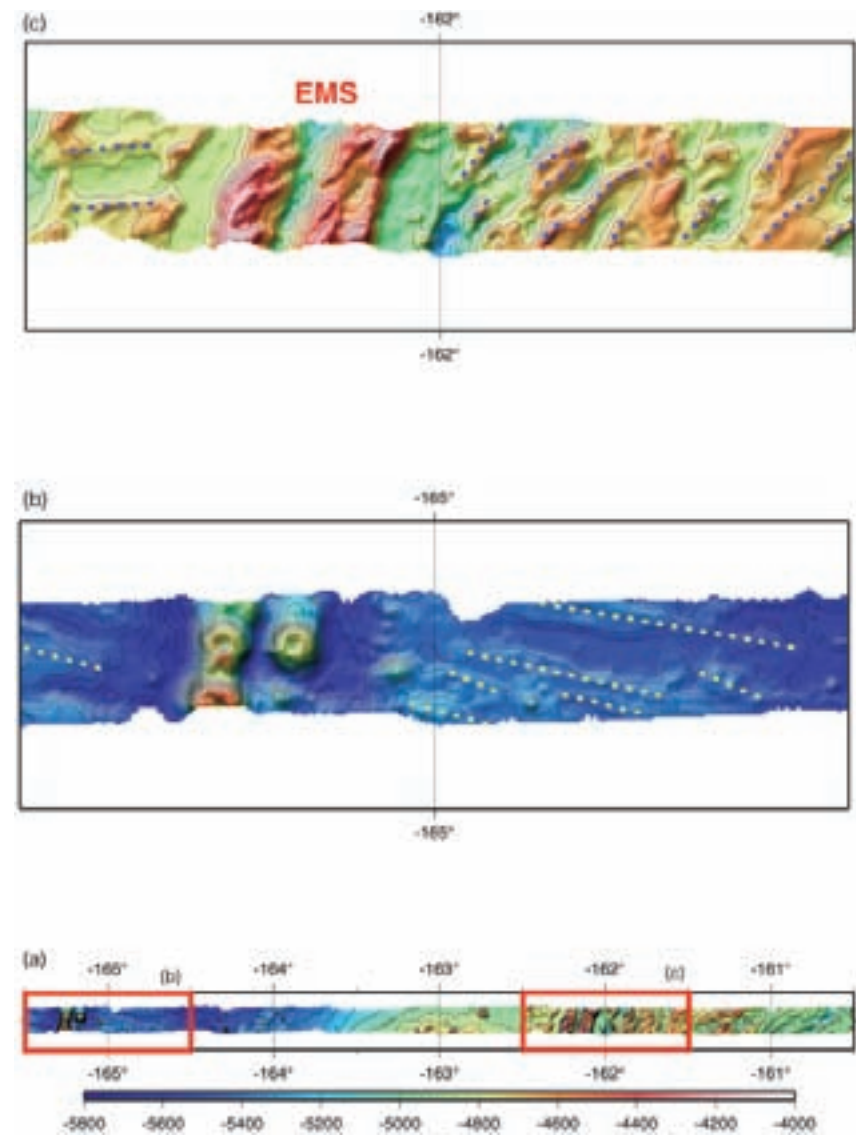


Figure 2.1.5. Bathymetric Map of the seafloor south of the Manihiki Plateau. Contour interval is 50 m. Bathymetry is illuminated from the northwest. Red rectangles in (a) represent the areas of (b) and (c). Yellow and blue dotted lines represent abyssal hills. EMS represents the East Manihiki Scarp.



## 2.2 Surface Meteorological Observation

January 13, 2010

### (1) Personnel

*Kunio Yoneyama* (JAMSTEC)

*Satoshi Okumura* (GODI)

*Souichiro Sueyoshi* (GODI)

*Shinya Okumura* (GODI)

*Ryo Kimura* (GODI)

*Kazuho Yoshida* (GODI)

*Harumi Ota* (GODI)

*Yousuke Yuuki* (GODI)

### (2) Objective

As a basic dataset that describes weather conditions during the cruise, surface meteorological observation was continuously conducted.

### (3) Methods

There are two different surface meteorological measurement systems on board the R/V MIRAI. One is the MIRAI surface meteorological observation system (SMET), and the other is the Shipboard Oceanographic and Atmospheric Radiation measurement system (SOAR).

Instruments of SMET are listed in Table 2.2.1. All SMET data were collected and processed by KOAC-7800 weather data processor made by Koshin Denki, Japan. Note that although SMET contains rain gauge, anemometer and radiometers in their system, we adopted those data from not SMET but SOAR due to the following reasons; 1) Since SMET rain gauge is located near the base of the mast, there is a possibility that its capture rate might be affected, 2) SOAR's anemometer has better starting threshold wind speed ( $1 \text{ m s}^{-1}$ )

comparing to SMET's anemometer ( $2 \text{ m s}^{-1}$ ), and 3) SMET's radiometers record data with  $10 \text{ W/m}^2$  resolution, while SOAR takes high resolution data of  $1 \text{ W/m}^2$ .

SOAR system was designed and constructed by the Brookhaven National Laboratory (BNL), USA, for an accurate measurement of solar radiation on the ship (cf. <http://www.gim.bnl.gov/soar/>). SOAR consists of 1) Portable Radiation Package (PRP) that measures short and long wave downwelling radiation, 2) Zeno meteorological system that measures pressure, air temperature, relative humidity, wind speed/direction, and rainfall, and 3) Scientific Computer System (SCS) developed by the National Oceanic and Atmospheric Administration (NOAA), USA, for data collection, management, real-time monitoring, and so on. Information on sensors used here is listed in Table 2.2.2.

Table 2.2.1. Instruments and locations of SMET.

Sensor	Parameter	Manufacturer / type	Location / height from sea level
Thermometer* <sup>1</sup>	air temperature relative humidity	Vaisala, Finland / HMP45A	compass deck* <sup>2</sup> / 21 m
Thermometer	sea temperature	Sea-Bird Electronics, Inc., USA/SBE3S* <sup>3</sup>	4th deck / -5 m
Barometer	pressure	Setra Systems Inc., USA / 370	captain deck / 13 m

\*<sup>1</sup> Gill aspirated radiation shield 43408 made by R. M. Young, USA is attached.

\*<sup>2</sup> There are two thermometers at starboard and port sides.

\*<sup>3</sup> Sea surface temperature data were taken from EPCS surface water monitoring system.

Table 2.2.2. Instruments and locations of SOAR.

Sensor	Parameter	Manufacturer / type	Location / height from sea level
Anemometer	wind speed/direction	R. M. Young, USA / 05106	foremast / 25 m
Rain gauge	rainfall accumulation	R. M. Young, USA / 50202	foremast / 24 m
Radiometer	short wave radiation	Eppley, USA / PSP	foremast / 24 m
	long wave radiation	Eppley, USA / PIR	foremast / 24 m

#### (4) Data processing and data format

All raw data were recorded every 6 seconds. Datasets produced here are 1-minute mean values (time stamp at the end of the average). These values are the simple mean of 8 samples, after removing maximum/minimum values from 10 samples to exclude singular/erroneous data. Linear interpolation onto missing values was applied only when their interval is less than 5 minutes.

Since the thermometers are equipped on both starboard/port sides on the deck, we adopted air temperature/relative humidity data taken at upwind side. Dew point temperature was produced from relative humidity and air temperature data.

Any adjustment to a certain height was not applied except pressure data to the sea level.

Data are stored as ASCII format and contains following parameters. Time in UTC expressed as YYYYMMDDHHMM, time in Julian day (1.0000 = January 1, 0000Z), longitude (°E), latitude (°N), pressure (hPa), air temperature (°C), dew point temperature (°C), relative humidity (%), sea surface temperature (°C), zonal wind component (m/sec), meridional wind component (m/sec), precipitation (mm/hr), downwelling shortwave radiation ( $W/m^2$ ), and downwelling longwave radiation ( $W/m^2$ ).

Missing values are expressed as “9999”.

#### (5) Data Quality

To ensure the data quality, each sensor was calibrated as follows. Since there is a possibility for fine time resolution data sets to have some noises caused (generated) by turbulence, it is recommended to filter them out (ex. hourly mean) from this 1-minute mean data sets depending on the scientific purpose.

T/RH sensor:

Temperature and humidity probes were calibrated before/after the cruise by the manufacturer. Certificated accuracy of T/RH sensors are better than  $\pm 0.2$  °C and  $\pm 2$  %, respectively.

We also checked T/RH values using another calibrated portable T/RH sensor (Vaisala, HMP45A) before and after the cruise. The results are,

Temperature (°C)

Mean difference between T (SMET) and T (portable) is

$-0.08 \pm 0.17$  (°C) at port side,  $-0.26 \pm 0.33$  (°C) at starboard side.

Relative Humidity (%)

Mean difference between RH (SMET) and RH (portable) is

$1.3 \pm 0.5$  (%) at port side,  $1.3 \pm 1.6$  (%) at starboard side.

Sea surface temperature sensor:

Temperature sensor was calibrated before the cruise at the manufacturer. Certificated accuracy is better than  $0.002$ °C/year.

Pressure sensor:

Using calibrated portable barometer (Vaisala, Finland / PTB220, certificated accuracy is better than  $\pm 0.1$  hPa), pressure sensor was checked before/after the cruise. Mean difference of SMET pressure sensor and portable sensor is  $0.06 \pm 0.05$  hPa.

Precipitation:

Before the each leg, we checked the linearity of rain gauge value in response to water amount in the gauge.

The results are as follows, and data have already been corrected using this relationship.

	Leg-1	Leg-2	Leg-3
minimum input water volume (cc)	0.0	0.0	0.0
maximum input water volume (cc)	505.0	505.7	503.7
minimum measured value (mm)	0.47	0.25	0.47
maximum measured value (mm)	50.23	48.75	49.79

Radiation sensors:

Short wave and long wave radiometers were calibrated by the manufacturer, Remote Measurement and Research Company, USA, prior to the cruise (February 2009).

#### (6) Data periods

Leg-1	1300 UTC, April 10, 2009	-	0000 UTC, May 20, 2009
Leg-2	0100 UTC, May 21, 2009	-	0100 UTC, June 19, 2009
Leg-3	2300 UTC, June 19, 2009	-	2350 UTC, July 2, 2009

#### (7) Point of contact

Kunio Yoneyama (yoneyamak@jamstec.go.jp)  
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 2-15, Natsushima, Yokosuka 237-0061, Japan

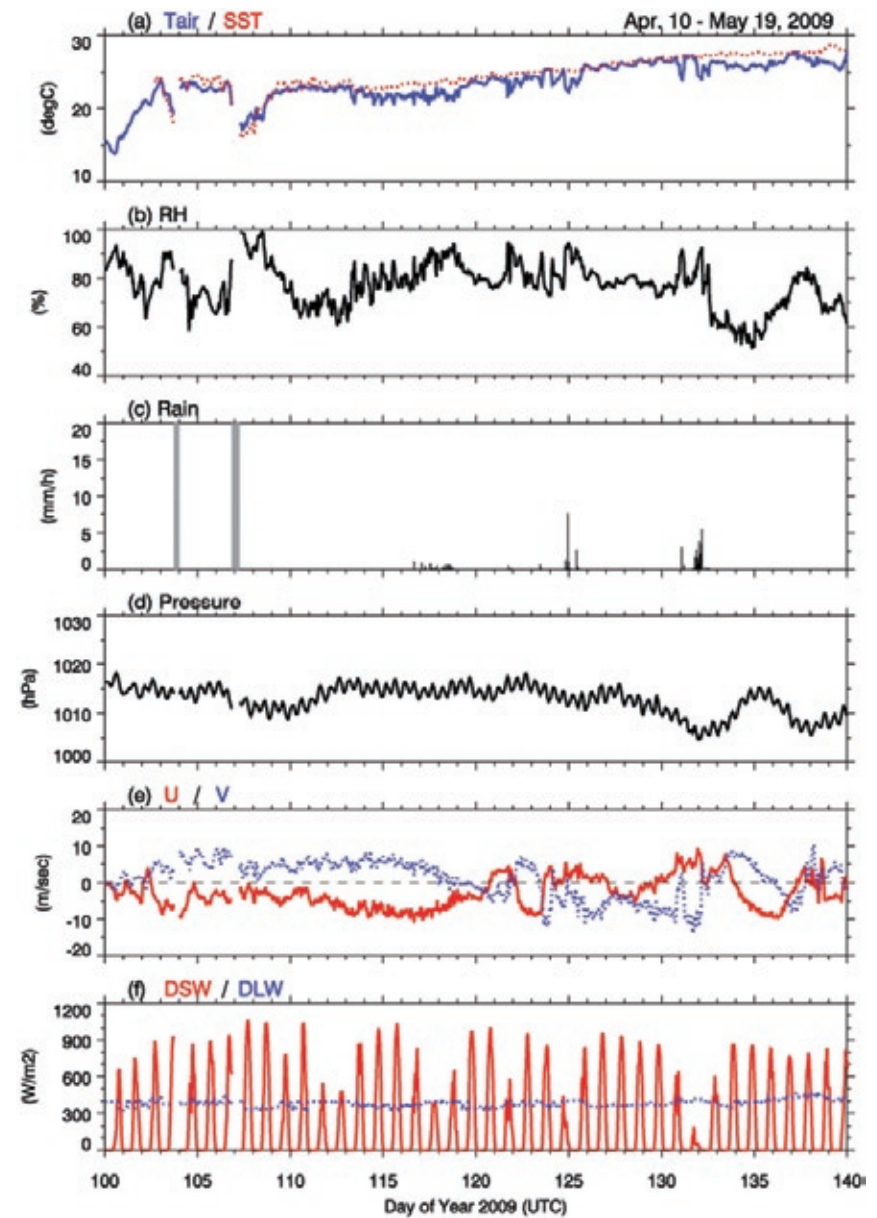


Figure 2.2.1. Time series of surface (a) air/sea temperature, (b) relative humidity, (c) precipitation, (d) pressure, (e) zonal and meridional wind components, and (e) short and long wave radiation for Leg-1. Day 100 corresponds to April 10, 2009.

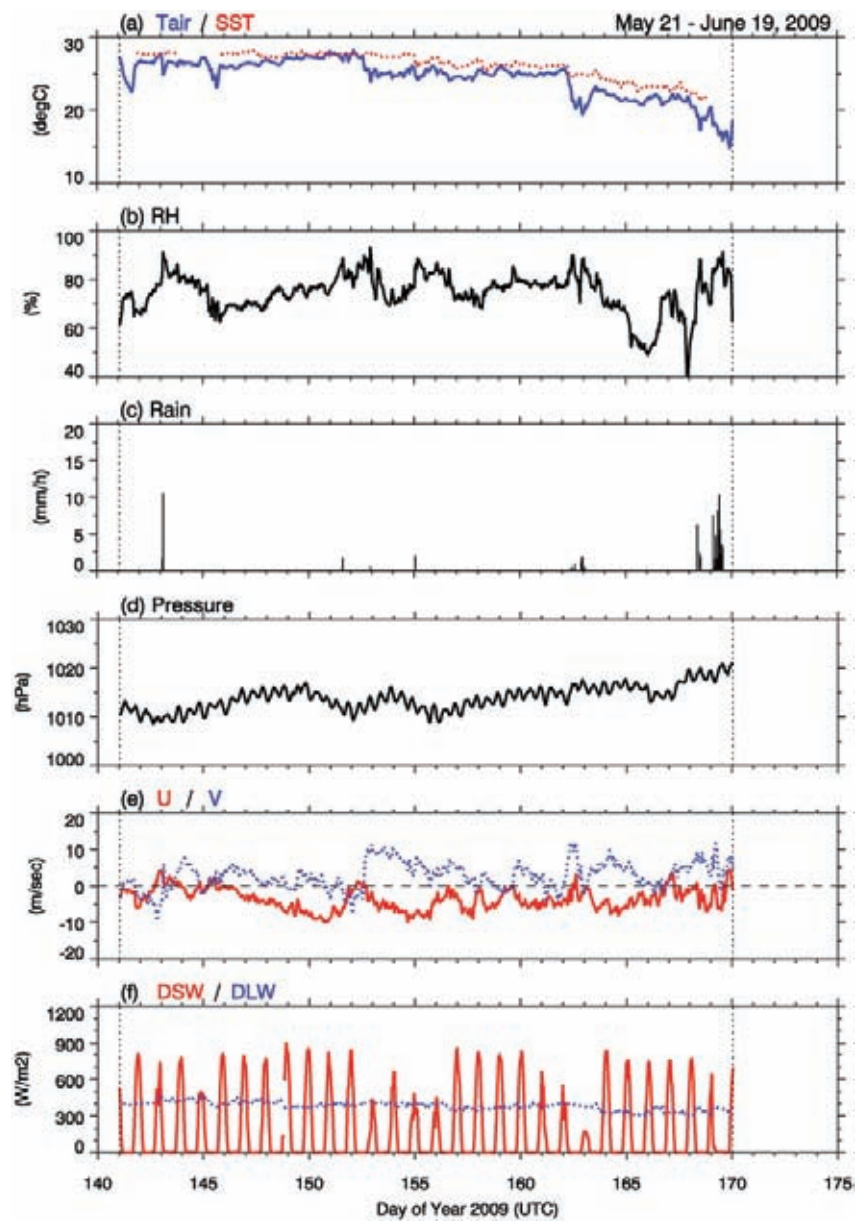


Figure 2.2.2. Same as Figure 2.2.1, but for Leg 2. Day 141 corresponds to May 21, 2009.

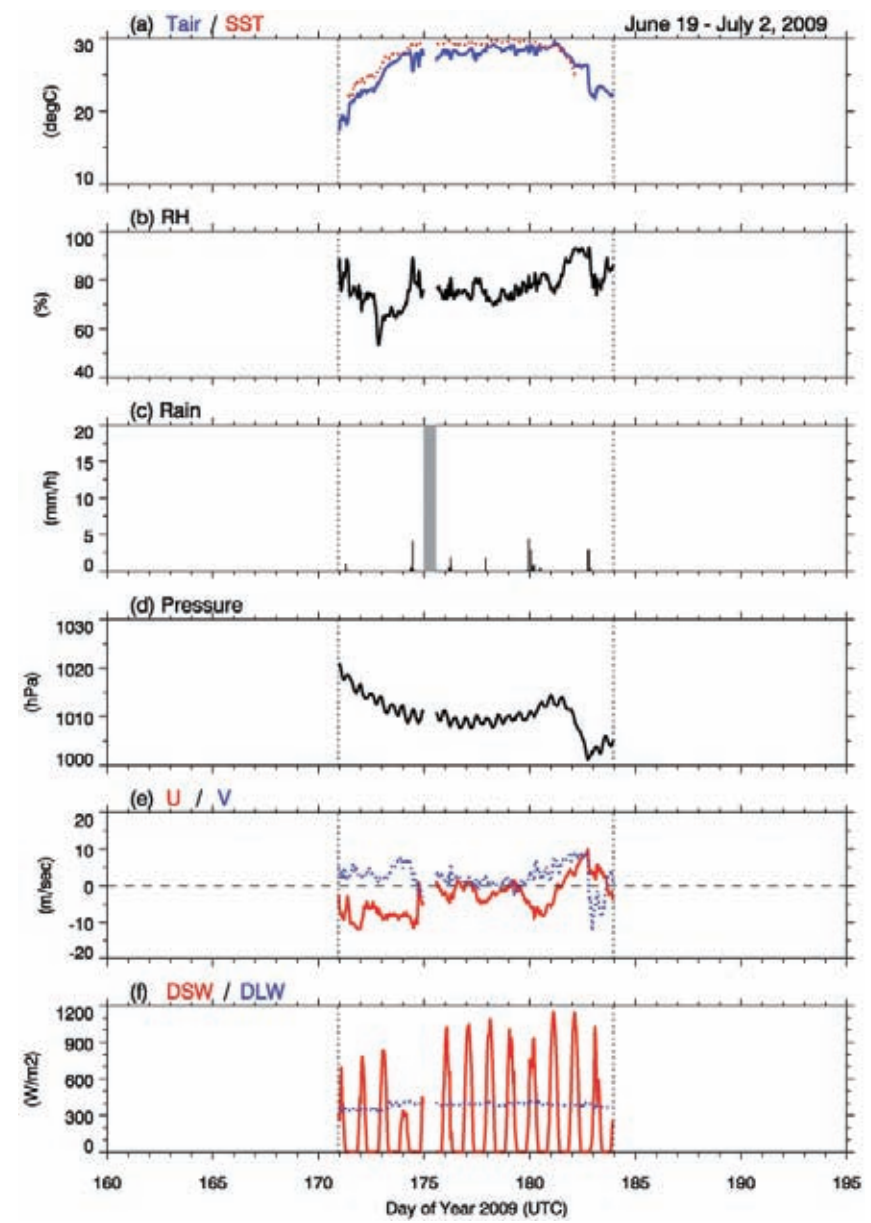


Figure 2.2.3. Same as Figure 2.2.1, but for Leg 3. Day 171 corresponds to June 19, 2009.

## 2.3 Thermo-Salinograph and Related Measurements

July 31, 2010

### (1) Personnel

*Yuichiro Kumamoto (JAMSTEC)*

*Miyo Ikeda (MWJ)*

*Fuyuki Shibata (MWJ)*

*Masanori Enoki (MWJ)*

*Misato Kuwahara (MWJ)*

### (2) Objective

Our purpose is to obtain salinity, temperature, dissolved oxygen, and fluorescence data continuously in near-sea surface water during MR09-01 cruise.

### (3) Methods

The Continuous Sea Surface Water Monitoring System (Nippon Kaiyo Co. Ltd.), including the thermo-salinograph, has five sensors and automatically measures salinity, temperature, dissolved oxygen, and fluorescence in near-sea surface water every one minute. This system is located in the sea surface monitoring laboratory and connected to shipboard LAN system. Measured data, time, and location of the ship were stored in a data management PC (IBM NetVista 6826-CBJ). The near-surface water was continuously pumped up to the laboratory from about 4 m water depth and flowed into the system through a vinyl-chloride pipe. The flow rate of the surface seawater was adjusted to be 12 dm<sup>3</sup>/min except for a fluorometer (about 0.4 dm<sup>3</sup>/min). Specifications of the each sensor in this system are listed below.

#### a) Temperature and salinity sensors

SEACAT THERMOSALINOGRAPH

Model: SBE-21, SEA-BIRD ELECTRONICS, INC.

Serial number: 2126391-3126

Measurement range: Temperature -5 to +35°C (ITS-90), Salinity 0 to 7.0 S m<sup>-1</sup>

Accuracy: Temperature 0.01°C 6month<sup>-1</sup>, Salinity 0.001 S m<sup>-1</sup> month<sup>-1</sup>

Resolution: Temperatures 0.001°C, Salinity 0.0001 S m<sup>-1</sup>

#### b) Bottom of ship thermometer (RMT)

Model: SBE 3S, SEA-BIRD ELECTRONICS, INC.

Serial number: 032175

Measurement range: -5 to +35°C (ITS-90)

Resolution: ±0.001°C

Stability: 0.002°C year<sup>-1</sup>

#### c) Dissolved oxygen sensor

Model: 2127A, HACH ULTRA ANALYTICS JAPAN, INC.

Serial number: 61230

Measurement range: 0 to 14 ppm

Accuracy: ±1% at 5°C of correction range

Stability: 1% month<sup>-1</sup>

#### d) Fluorometer

Model: 10-AU-005, TURNER DESIGNS

Serial number: 5562 FRXX

Detection limit: 5 ppt or less for chlorophyll-a

Stability: 0.5% month<sup>-1</sup> of full scale



e) Flow meter

Model: EMARG2W, Aichi Watch Electronics LTD.

Serial number: 8672

Measurement range: 0 to 30 l min<sup>-1</sup>

Accuracy: ±1%

Stability: ±1% day<sup>-1</sup>

#### (4) Measurements

Periods of measurement, maintenance, and events during MR09-01 are listed in Table 2.3.1.

Table 2.3.1. Events list of the thermo-salinograph during MR09-01.

System Date [UTC]	System Time [UTC]	Events	Remarks
09-Apr.-14	12:47	All the measurements started.	Leg-1 start
09-Apr.-15	23:59	All the measurements stopped due to entering in the Peruvian EEZ.	
09-Apr.-21	00:00		
09-Apr.-22	01:40	Lost of all the data due to reboot of the data management PC.	
09-Apr.-22	02:04		
09-May-18	07:06	All the measurements stopped.	Leg-1 finish
09-May-21	20:18	All the measurements started.	Leg-2a start
09-May-23	20:44	All the measurements stopped.	Leg-2a finish
09-May-25	20:19	All the measurements started.	Leg-2b start
09-Jun.-13	17:07	Lost of all the data due to error on program.	
09-Jun.-13	17:18		
09-Jun.-17	19:36	All the measurements stopped.	Leg-2b finish
09-Jun.-20	10:01	All the measurements started.	Leg-3 start
09-Jun.-23	22:59	Lost of all the data..	
09-Jun.-24	14:03		
09-Jul.-01	04:23	All the measurements stopped.	Leg-3 finish

#### (5) Calibrations

We collected the surface seawater samples for salinity sensor calibration during Leg-1 and Leg-2 (Table 2.3.2). The seawater was collected approximately twice a day using a 250 ml brown glass bottle. The samples

were stored in the sea surface monitoring laboratory and then measured using the Guildline 8400B at the end of the legs after all the measurements of the hydrocast bottle samples.

Table 2.3.2. Comparison of the sensor salinity with the bottle salinity.

Date [UTC]	Time [UTC]	Latitude	Longitude	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Difference [Sen. - Bot.]
2009/4/14	13:48	16-44.97580S	078-42.43970W	35.4984	35.4950	0.0034
2009/4/14	21:56	16-45.17830S	079-19.83920W	35.5812	35.5769	0.0043
2009/4/15	8:56	16-44.40370S	080-39.63650W	35.5748	35.5725	0.0023
2009/4/15	22:04	16-40.73990S	080-59.80990W	35.4099	35.4083	0.0016
2009/4/21	8:19	16-44.92050S	080-25.69800W	35.4962	35.4981	-0.0019
2009/4/21	21:10	16-44.52540S	082-00.27190W	35.5029	35.5088	-0.0059
2009/4/22	10:00	16-44.93300S	082-59.85970W	35.5844	35.5889	-0.0045
2009/4/22	10:02	16-44.91210S	082-59.85080W	35.5842	35.5890	-0.0048
2009/4/22	21:29	16-45.09040S	083-40.05760W	35.5448	35.5507	-0.0059
2009/4/23	8:51	16-44.56640S	084-20.09390W	35.6529	35.6570	-0.0041
2009/4/23	21:08	16-45.11350S	085-19.65940W	35.5000	35.5058	-0.0058
2009/4/24	9:52	16-49.99990S	086-23.16600W	35.7428	35.7466	-0.0038
2009/4/24	21:11	16-44.71580S	087-40.33490W	35.7371	35.7444	-0.0073
2009/4/25	10:36	16-45.00120S	088-39.82020W	35.7708	35.7750	-0.0042
2009/4/25	10:38	16-45.00260S	088-39.84800W	35.7718	35.7744	-0.0026
2009/4/25	20:55	16-44.78260S	089-20.05120W	35.7637	35.7691	-0.0054
2009/4/26	10:09	16-44.73750S	090-08.14720W	35.7523	35.7574	-0.0051
2009/4/26	21:41	16-44.78340S	091-28.27440W	35.7917	35.7951	-0.0034
2009/4/27	9:19	16-44.80660S	092-49.23870W	35.8304	35.8362	-0.0058
2009/4/27	21:37	16-43.85810S	094-21.16550W	35.8251	35.8318	-0.0067
2009/4/28	9:21	16-45.33650S	095-47.60370W	35.8719	35.8724	-0.0005
2009/4/28	9:23	16-45.34400S	095-48.13740W	35.8679	35.8707	-0.0028
2009/4/28	21:52	16-44.73560S	097-20.31890W	35.8107	35.8161	-0.0054
2009/4/29	9:38	16-44.79350S	098-40.12210W	35.9412	35.9454	-0.0042
2009/4/29	22:07	16-44.05720S	100-00.30900W	36.0435	36.0471	-0.0036
2009/4/30	10:07	16-44.61130S	101-28.24690W	35.9749	35.9805	-0.0056
2009/4/30	10:09	16-44.62880S	101-28.76720W	35.9771	35.9820	-0.0049
2009/4/30	21:57	16-59.19030S	102-58.24090W	35.9857	35.9880	-0.0023



Table 2.3.2. (continued)

Date [UTC]	Time [UTC]	Latitude	Longitude	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Difference [Sen. - Bot.]
2009/5/1	11:09	16-45.46850S	104-00.09040W	36.0785	36.0822	-0.0037
2009/5/1	23:39	16-45.03880S	106-00.04450W	36.0361	36.0432	-0.0071
2009/5/2	11:08	16-44.97480S	106-54.64000W	36.0931	36.0988	-0.0057
2009/5/3	1:48	16-45.49220S	107-15.05250W	36.1222	36.1272	-0.0050
2009/5/3	10:31	16-44.96970S	107-37.76710W	36.1409	36.1453	-0.0044
2009/5/3	23:03	16-45.14510S	109-19.99040W	36.1931	36.1985	-0.0054
2009/5/3	23:04	16-45.14910S	109-19.98920W	36.1924	36.1974	-0.0050
2009/5/4	11:33	16-45.13740S	110-40.38760W	36.2194	36.2242	-0.0048
2009/5/4	23:32	16-45.29100S	112-00.07440W	36.1544	36.1630	-0.0086
2009/5/5	10:47	16-45.25910S	113-37.45760W	36.3165	36.3205	-0.0040
2009/5/5	21:52	16-45.46490S	115-13.33820W	36.2483	36.2538	-0.0055
2009/5/6	11:27	16-44.98470S	116-42.80650W	36.3767	36.3807	-0.0040
2009/5/6	23:06	16-45.17100S	118-25.21730W	36.2563	36.2622	-0.0059
2009/5/7	11:36	16-45.09820S	120-00.16570W	36.2863	36.2924	-0.0061
2009/5/7	11:38	16-45.10700S	120-00.17050W	36.2868	36.2924	-0.0056
2009/5/8	7:21	16-45.09310S	122-39.65920W	36.2948	36.3001	-0.0053
2009/5/8	11:20	16-44.85160S	122-57.81300W	36.3801	36.3857	-0.0056
2009/5/8	23:17	16-45.11080S	124-39.69490W	36.4907	36.4951	-0.0044
2009/5/9	10:59	16-45.02640S	126-00.21060W	36.3923	36.3965	-0.0042
2009/5/9	23:45	16-45.30990S	127-20.52890W	36.3225	36.3272	-0.0047
2009/5/10	12:35	16-45.01200S	129-05.41100W	36.3609	36.3641	-0.0032
2009/5/10	12:37	16-45.01500S	129-05.91430W	36.3552	36.3591	-0.0039
2009/5/11	2:11	16-45.46310S	130-39.68820W	36.3718	36.3788	-0.0070
2009/5/11	12:12	16-45.05740S	131-59.97770W	36.4767	36.4823	-0.0056
2009/5/12	2:21	16-45.29710S	133-20.19320W	36.3381	36.3432	-0.0051
2009/5/12	11:51	16-45.56450S	134-00.34900W	36.2077	36.2137	-0.0060
2009/5/13	11:58	16-45.31040S	136-39.87070W	36.4252	36.4293	-0.0041
2009/5/13	12:00	16-45.30590S	136-39.85740W	36.4246	36.4307	-0.0061
2009/5/13	17:28	16-44.96630S	137-20.15810W	36.3616	36.3693	-0.0077
2009/5/14	0:08	16-45.09200S	138-22.38950W	36.3073	36.3105	-0.0032
2009/5/14	12:56	16-44.92430S	140-02.89960W	36.3949	36.4020	-0.0071
2009/5/15	0:27	16-44.56690S	141-43.14970W	36.2809	36.2862	-0.0053
2009/5/15	14:26	17-18.00390S	143-01.90900W	36.2908	36.2964	-0.0056
2009/5/16	0:40	17-29.56580S	144-09.39550W	36.3152	36.3204	-0.0052

Table 2.3.2. (continued)

Date [UTC]	Time [UTC]	Latitude	Longitude	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Difference [Sen. - Bot.]
2009/5/16	14:32	17-29.82400S	145-44.07210W	36.3189	36.3234	-0.0045
2009/5/16	14:34	17-29.85300S	145-44.45950W	36.3190	36.3243	-0.0053
2009/5/17	1:06	17-29.80410S	146-55.62150W	36.3267	36.3310	-0.0043
2009/5/17	12:53	17-30.21460S	148-28.58790W	36.2912	36.2957	-0.0045
2009/5/18	2:28	17-30.00190S	149-10.30590W	36.2251	36.2292	-0.0041
2009/5/18	7:03	17-29.95660S	149-19.96200W	36.2223	36.2345	-0.0122
2009/5/22	0:57	17-29.84320S	150-05.34030W	36.1993	36.1916	0.0077
2009/5/22	13:27	17-29.91300S	151-16.85460W	36.1192	36.1159	0.0033
2009/5/23	1:14	17-30.41760S	152-43.27130W	36.038	36.0309	0.0071
2009/5/23	13:20	17-30.39290S	154-03.86520W	35.9694	35.9629	0.0065
2009/5/23	19:06	17-30.73690S	154-19.15890W	35.9772	35.9698	0.0074
2009/5/26	0:33	17-30.27460S	150-56.34070W	36.148	36.1428	0.0052
2009/5/26	7:46	17-28.15840S	152-47.88450W	36.0207	36.0145	0.0062
2009/5/26	7:48	17-28.15860S	152-48.39390W	36.0187	36.0123	0.0064
2009/5/27	2:22	17-29.71150S	155-39.65110W	35.935	35.9279	0.0071
2009/5/27	12:43	17-30.14850S	156-59.98330W	35.9856	35.9789	0.0067
2009/5/28	2:43	17-30.05130S	158-21.80860W	35.6579	35.6521	0.0058
2009/5/28	13:17	17-29.60850S	159-40.16600W	35.7293	35.7217	0.0076
2009/5/29	3:15	17-29.62850S	161-00.53220W	35.7593	35.7527	0.0066
2009/5/29	12:44	17-29.84780S	162-20.19010W	35.5213	35.5153	0.0060
2009/5/29	12:46	17-29.84070S	162-20.19980W	35.5218	35.5148	0.0070
2009/5/30	0:51	17-29.71710S	163-40.22410W	35.5298	35.5240	0.0058
2009/5/30	13:14	17-29.86090S	165-00.09660W	35.658	35.6523	0.0057
2009/5/31	2:37	17-29.50610S	166-20.56290W	35.3233	35.3168	0.0065
2009/5/31	12:34	17-29.75890S	167-19.39840W	35.2629	35.2559	0.0070
2009/6/1	2:10	17-30.02270S	168-57.87450W	35.1326	35.1238	0.0088
2009/6/1	2:12	17-30.01870S	168-58.38400W	35.1286	35.1222	0.0064
2009/6/1	13:19	17-30.12720S	169-57.96900W	35.6192	35.6121	0.0071
2009/6/2	2:06	17-30.09560S	171-19.29490W	35.3532	35.3447	0.0085
2009/6/2	13:53	17-29.47620S	172-09.08020W	35.3759	35.3695	0.0064
2009/6/3	2:19	17-29.86830S	172-39.93180W	35.3979	35.3921	0.0058
2009/6/3	13:42	17-29.76370S	172-59.95610W	35.4848	35.4781	0.0067
2009/6/4	1:57	17-29.15390S	174-53.24790W	35.1388	35.1300	0.0088
2009/6/4	2:00	17-29.24690S	174-54.02150W	35.1391	35.1312	0.0079

Table 2.3.2. (continued)

Date [UTC]	Time [UTC]	Latitude	Longitude	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Difference [Sen. - Bot.]
2009/6/4	14:06	17-29.84240S	176-29.21680W	35.4266	35.4206	0.0060
2009/6/5	1:48	17-45.08660S	178-15.00220W	35.5201	35.5144	0.0057
2009/6/5	14:08	18-24.86800S	179-39.44760W	35.0543	35.0458	0.0085
2009/6/6	4:37	18-25.14400S	178-19.77450E	34.7175	34.7105	0.0070
2009/6/6	15:05	18-34.43890S	177-15.01060E	34.8111	34.8052	0.0059
2009/6/7	3:07	17-49.80500S	176-20.13720E	34.8422	34.8366	0.0056
2009/6/7	3:09	17-49.80020S	176-20.14540E	34.8446	34.8362	0.0084
2009/6/7	14:51	17-49.96720S	174-30.44490E	34.7476	34.7396	0.0080
2009/6/8	3:29	17-50.20620S	172-57.74250E	34.7886	34.7854	0.0032
2009/6/8	16:16	17-50.03360S	171-00.02810E	34.8332	34.8284	0.0048
2009/6/9	3:14	17-49.98500S	169-39.81200E	34.8549	34.8498	0.0051
2009/6/9	14:51	18-08.76050S	168-35.87720E	34.8734	34.8673	0.0061
2009/6/9	14:54	18-08.72630S	168-35.86890E	34.8733	34.8673	0.0060
2009/6/10	3:33	18-28.98480S	167-48.94890E	34.8825	34.8751	0.0074
2009/6/10	15:10	18-41.83330S	167-18.97920E	34.668	34.6618	0.0062
2009/6/11	4:30	19-09.22850S	166-15.30210E	34.6166	34.6111	0.0055
2009/6/11	15:48	19-35.14790S	165-13.44460E	34.8688	34.8621	0.0067
2009/6/12	4:20	19-55.09680S	164-26.87740E	34.7665	34.7596	0.0069
2009/6/12	4:23	19-55.03730S	164-27.09530E	34.7686	34.7604	0.0082
2009/6/12	14:15	18-41.18910S	163-27.76470E	34.7966	34.7912	0.0054
2009/6/13	5:09	20-52.28470S	164-12.34210E	34.9014	34.8964	0.0050
2009/6/13	15:40	20-58.30450S	164-05.86780E	35.1654	35.1531	0.0123
2009/6/14	4:12	21-28.99900S	162-45.98240E	34.894	34.8870	0.0070
2009/6/14	15:44	22-05.92740S	161-12.07260E	35.2426	35.2314	0.0112
2009/6/15	4:55	22-43.07240S	159-39.05030E	35.2074	35.1999	0.0075
2009/6/15	4:57	22-43.07120S	159-39.05450E	35.2077	35.2009	0.0068
2009/6/15	15:44	23-15.94420S	158-15.27150E	35.2435	35.2369	0.0066
2009/6/16	4:18	23-52.07610S	156-43.12080E	35.3243	35.3164	0.0079
2009/6/16	16:06	24-20.93430S	155-30.04440E	35.2284	35.2212	0.0072
2009/6/17	5:24	24-46.82500S	154-19.41980E	35.437	35.4248	0.0122
2009/6/17	18:53	25-02.01130S	153-38.93560E	35.3601	35.3536	0.0065

## 2.4 Underway pCO<sub>2</sub>

December 4, 2010

### (1) Personnel

*Akihiko Murata* (RIGC, JAMSTEC)

*Minoru Kamata* (MWJ)

*Yoshiko Ishikawa* (MWJ)

*Yasuhiro Arie* (MWJ)

### (2) Introduction

Concentrations of CO<sub>2</sub> in the atmosphere are now increasing at a rate of 1.9 ppmv y<sup>-1</sup> due to human activities such as burning of fossil fuels, deforestation, cement production, etc. It is an urgent task to estimate as accurately as possible the absorption capacity of the ocean against the increased atmospheric CO<sub>2</sub>, and to clarify the mechanism of the CO<sub>2</sub> absorption, because the magnitude of the predicted global warming depends on the levels of CO<sub>2</sub> in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In the P21 revisit cruise, we were aimed at quantifying how much anthropogenic CO<sub>2</sub> is absorbed in the surface ocean in the Pacific. For the purpose, we measured pCO<sub>2</sub> (partial pressures of CO<sub>2</sub>) in the atmosphere and in the surface seawater.

### (3) Apparatus and shipboard measurement

Continuous underway measurements of atmospheric and surface seawater pCO<sub>2</sub> were made with the CO<sub>2</sub> measuring system (Nippon ANS, Ltd) installed in the R/V Mirai of JAMSTEC. The system comprises of a non-dispersive infrared gas analyzer (NDIR; BINOS<sup>®</sup> model 4.1, Fisher-Rosemount), an air-circulation module and a showerhead-type equilibrator. To measure concentrations (mole fraction) of CO<sub>2</sub> in dry air (xCO<sub>2</sub>a), air sampled from the bow of the ship (approx. 30 m above the sea level) was introduced into the NDIR through a dehydrating

route with an electric dehumidifier (kept at ~2 °C), a Perma Pure dryer (GL Sciences Inc.), and a chemical desiccant (Mg(ClO<sub>4</sub>)<sub>2</sub>). The flow rate of the air was 500 ml min<sup>-1</sup>. To measure surface seawater concentrations of CO<sub>2</sub> in dry air (xCO<sub>2</sub>s), the air equilibrated with seawater within the equilibrator was introduced into the NDIR through the same flow route as the dehydrated air used in measuring xCO<sub>2</sub>a. The flow rate of the equilibrated air was 600 – 800 ml min<sup>-1</sup>. The seawater was taken by a pump from the intake placed at the approx. 4.5 m below the sea surface. The flow rate of seawater in the equilibrator was 500 – 800 ml min<sup>-1</sup>.

The CO<sub>2</sub> measuring system was set to repeat the measurement cycle such as 4 kinds of CO<sub>2</sub> standard gases (Table 2.4.1), xCO<sub>2</sub>a (twice), xCO<sub>2</sub>s (7 times). This measuring system was run automatically throughout the cruise by a PC control.

### (4) Quality control

Concentrations of CO<sub>2</sub> of the standard gases are listed in Table 2.4.1, which were calibrated by the JAMSTEC primary standard gases. The CO<sub>2</sub> concentrations of the primary standard gases were calibrated by C.D. Keeling of the Scripps Institution of Oceanography, La Jolla, CA, USA.

Since differences of concentrations of the standard gases between before and after the cruise were allowable (< 0.1 ppmv), the averaged concentrations (Table 2.4.1) were adopted for the subsequent calculations.

In actual shipboard observations, the signals of NDIR usually reveal a trend. The trends were adjusted linearly using the signals of the standard gases analyzed before and after the sample measurements.

Effects of water temperature increased between the inlet of surface seawater and the equilibrator on xCO<sub>2</sub>s were adjusted based on Gordon and Jones (1973), although the temperature increases were slight, being ~0.3 °C.

We checked values of xCO<sub>2</sub>a and xCO<sub>2</sub>s by examining signals of the NDIR on recorder charts, and by plotting the xCO<sub>2</sub>a and xCO<sub>2</sub>s as a function of sequential day, longitude, sea surface temperature and sea surface salinity.

## Reference

Gordon, L. I. and L. B. Jones (1973) The effect of temperature on carbon dioxide partial pressure in seawater.  
Mar. Chem., 1, 317-322.

Table 2.4.1. Concentrations of CO<sub>2</sub> standard gases used during MR09-01 cruise.

Cylinder no.	Concentrations (ppmv)
CQC00742	270.22
CQC00739	330.43
CQC00740	360.04
CQC00741	420.32

## 2.5 Acoustic Doppler Current Profiler (ADCP)

November 1, 2010

### (1) Personnel

<i>Shinya Kouketsu</i>	<i>(JAMSTEC)</i>	
<i>Shinya Okumura</i>	<i>(Global Ocean Development Inc., GODI)</i>	<i>-leg1-</i>
<i>Ryo Kimura</i>	<i>(GODI)</i>	<i>-leg1, 3-</i>
<i>Yousuke Yuki</i>	<i>(GODI)</i>	<i>-leg1-</i>
<i>Satoshi Okumura</i>	<i>(GODI)</i>	<i>-leg2-</i>
<i>Kazuho Yoshida</i>	<i>(GODI)</i>	<i>-leg2-</i>
<i>Harumi Ohta</i>	<i>(GODI)</i>	<i>-leg2-</i>
<i>Souichiro Sueyoshi</i>	<i>(GODI)</i>	<i>-leg3-</i>

### (2) Objective

To obtain continuous measurement of the current profile along the ship's track.

### (3) Methods

Upper ocean current measurements were made throughout MR09-01 cruise, using the hull mounted Acoustic Doppler Current Profiler (ADCP) system. For most of its operation, the instrument was configured for water-tracking mode recording. Bottom-tracking mode, interleaved bottom-ping with water-ping, was made in shallower water region to get the calibration data for evaluating transducer misalignment angle.

The system consists of following components;

- 1) R/V MIRAI has installed the Ocean Surveyor for vessel-mount (acoustic frequency 75 kHz; Teledyne RD Instruments). It has a phased-array transducer with single ceramic assembly and creates 4 acoustic beams electronically. We mounted the transducer head rotated to a ship-relative angle of 45 degrees

azimuth from the keel.

- 2) For heading source, we use ship's gyro compass (Tokimec, Japan), continuously providing heading to the ADCP system directory. Additionally, we have Inertial Navigation System (INS) which provide high-precision heading, attitude information, pitch and roll, are stored in ".N2R" data files with a time stamp.
- 3) GPS navigation receiver (Trimble DS4000) provides position fixes.
- 4) We used VmDas version 1.4.2 (TRD Instruments) for data acquisition.
- 5) To synchronize time stamp of ping with GPS time, the clock of the logging computer is adjusted to GPS time every 1 minute.
- 6) The sound speed at the transducer does affect the vertical bin mapping and vertical velocity measurement, is calculated from temperature, salinity (constant value; 35.0 psu) and depth (6.5 m; transducer depth) by equation in Medwin (1975).

The data was configured for 4 m processing bin, 4 m intervals and starting 20 m below the surface. Every ping was recorded as raw ensemble data (.ENR). Also, 60 seconds and 300 seconds averaged data were recorded as short term average (.STA) and long term average (.LTA) data, respectively. We changed the major parameters, and showed the date and time that we changed command file.

### (4) Data processing

We processed ADCP data as described below. ADCP-coordinate velocities were converted to the earth-coordinate velocities using the ship heading from the INU. The earth-coordinate currents were obtained by subtracting ship velocities from the earth-coordinate velocities. Corrections of the misalignment and scale factors were made using the bottom track data. The misalignment angle calculated was 0.15, the scale factor was 1.00.

**(5) Remarks**

The profile with bad quality is included between 200 m in depth and 400 m while in this cruise corresponding to weak echo intensities (Fig. 2.5.1 causes of the weak echo intensity may be considered during data processing after cruise).

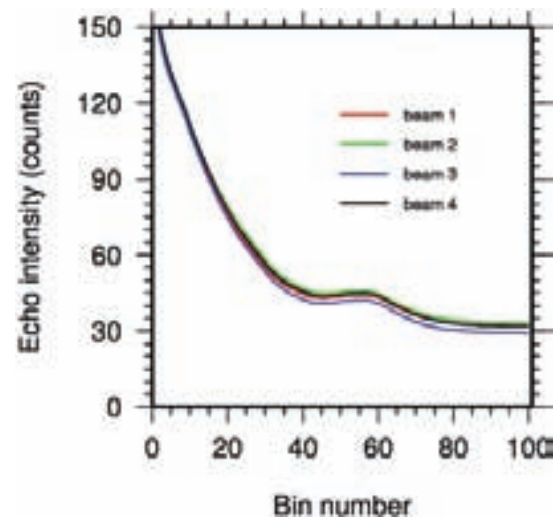


Figure 2.5.1. Cruise-averaged echo intensities.



## 2.6 XCTD

February 8, 2011

### (1) Personnel

*Hiroshi Uchida* (JAMSTEC)

#### Leg 1

*Shinya Okumura* (GODI)

*Ryo Kimura* (GODI)

*Yosuke Yuki* (GODI)

#### Leg 2

*Satoshi Okumura* (GODI)

*Kazuho Yoshida* (GODI)

*Harumi Ota* (GODI)

### (2) Objectives

In this cruise, XCTD (eXpendable Conductivity, Temperature and Depth profiler) measurements were carried out to examine short-term changes in temperature and salinity profiles, and to evaluate fall rate equations by comparing with CTD (Conductivity, Temperature and Depth profiler) measurements and bottom topography measurements.

### (3) Instrument and Method

The XCTDs used were XCTD-1 and XCTD-2 (Tsurumi-Seiki Co., Ltd., Yokohama, Kanagawa, Japan) with an MK-130 deck unit (Tsurumi-Seiki Co., Ltd.). The manufacturer's specifications are listed in Table 2.6.1. In this cruise, seven XCTD-1 probes and twenty-three XCTD-2 probes were deployed by using 8-loading automatic launcher (Tsurumi-Seiki Co., Ltd.) (Table 2.6.2). Ship's speed was slowed down to 3 knot during the XCTD-2 measurement. For the comparison with CTD, XCTD was deployed at about 5 minutes for XCTD-1 and at about

10 minutes for XCTD-2 after the beginning of the down cast of the CTD.

Table 2.6.1. Manufacturer's specifications of XCTD-1 and XCTD-2.

Parameter	Range	Accuracy
Conductivity	0 ~ 60 mS cm <sup>-1</sup>	±0.03 mS cm <sup>-1</sup>
Temperature	-2 ~ 35 °C	±0.02 °C
Depth	0 ~ 1000 m (for XCTD-1) 0 ~ 1850 m (for XCTD-2)	5 m or 2%, whichever is greater * 5 m or 2%, whichever is greater *

\* Depth error is shown in Kizu et al (2008).

### (4) Data Processing and Quality Control

The XCTD data were processed and quality controlled based on a method by Uchida et al. (2011). Thermal bias (+0.016 °C) of the XCTD data reported by Uchida et al. (2011) was not corrected. Depth error of the XCTD data was corrected by using the estimated terminal velocity error (-0.0428 m s<sup>-1</sup>) (Uchida et al., 2011). Salinity biases of the XCTD data were estimated by using temperature and salinity relationships in the deep ocean obtained from the post-cruise calibrated CTD data (Table 2.6.2). For the XCTD data of the station P21\_29\_1, salinity bias could not be estimated because the maximum depth was too shallow to estimate the salinity bias.

Vertical section of potential temperature is shown in Fig. 2.6.1 for stations between 29 and 33. Comparison with the CTD data shows short-term fluctuation in temperature between the observation periods 6 days apart.

**References**

Kizu, S., H. Onishi, T. Suga, K. Hanawa, T. Watanabe, and H. Iwamiya (2008): Evaluation of the fall rates of the present and developmental XCTDs. *Deep-Sea Res I*, **55**, 571-586.

Uchida, H., K. Shimada, and T. Kawano (2011): A method for data processing to obtain high quality XCTD data. *J. Atmos. Oceanic Technol.*, accepted.

Table 2.6.2. Serial number and probe type of the XCTD. Water depth, ship intake temperature (SST) and salinity (SSS; not corrected), and maximum pressure for the XCTD data are shown. Salinity offset applied to the XCTD data and reference salinity estimated from the CTD data are also shown.

Station	Serial number (type)	Depth [m]	SST [°C]	SSS [PSU]	Max pressure [dbar]	Salinity offset [PSU]	Reference salinity [PSU]
<i>Leg 1</i>							
29_1 *	08112315 (2)	3798	23.759	35.444	187 **	-	NA
29_2 *	08112312 (2)	3816	23.725	35.430	1967	0.009	34.6215 @ 2.5°C
30_1 *	08112308 (2)	4462	24.249	35.432	1967	0.021	34.6215 @ 2.5°C
31_1 *	08112304 (2)	4441	24.815	35.497	1913	0.022	34.6215 @ 2.5°C
32_1 *	08112309 (2)	4713	23.453	35.480	1917	0.007	34.6215 @ 2.5°C
33_1 *	08112306 (2)	4442	23.787	35.538	1967	0.014	34.6215 @ 2.5°C
41_1	03022164 (1)	4659	23.975	35.456	1036	0.023	34.5219 @ 4.5°C
41_2	08112305 (2)	4659	23.977	35.455	1967	0.007	34.6215 @ 2.5°C
34_1	08112307 (2)	4536	24.030	35.505	1967	0.012	34.6215 @ 2.5°C
34_2	07022711 (1) ***	4537	24.029	35.505	1037	0.000	34.5219 @ 4.5°C
42_1	03022159 (1)	4558	23.544	35.584	1037	-0.017	34.5219 @ 4.5°C

42_2	08112310 (2)	4572	23.547	35.585	1967	0.015	34.6215 @ 2.5°C
96_1	03022156 (1)	3732	25.612	36.217	1036	0.005	34.5219 @ 4.5°C
96_2	08112311 (2)	3751	25.610	36.218	1967	0.007	34.6215 @ 2.5°C
97_1	03022162 (1)	3462	25.592	36.166	1037	0.012	34.5219 @ 4.5°C
97_2	08112313 (2)	3453	25.591	36.166	1967	0.010	34.6215 @ 2.5°C
98_1	03022157 (1)	3287	25.649	36.149	1037	0.002	34.5219 @ 4.5°C
98_2	08112314 (2)	3297	25.659	36.162	1967	0.010	34.6215 @ 2.5°C
145_1	08112319 (2)	1505	28.117	36.244	1464	0.007	34.5665 @ 3.0°C
146_1	08112316 (2)	1530	27.918	36.291	1520	0.020	34.5665 @ 3.0°C
151_1	08112322 (2)	1531	28.009	36.315	1518	0.005	34.5665 @ 3.0°C
156_1	03022155 (1)	943	28.339	36.223	943	0.008	34.4726 @ 4.5°C
<i>Leg 2</i>							
205_1	08112325 (2)	1365	28.097	35.430	1356	0.014	34.4781 @ 3.5°C
206_1	08112317 (2)	1484	27.978	35.548	1470	0.037	34.5512 @ 3.0°C
209_1	08112318 (2)	1924	27.032	35.260	1286 **	0.008	34.4911 @ 3.5°C
213_1	08112327 (2)	991	26.979	35.232	985	0.016	34.4238 @ 4.5°C
221_1	08112320 (2)	1883	26.466	34.783	1911	-0.004	34.6094 @ 2.5°C
250_1	08112321 (2)	1716	25.045	34.938	1700	0.013	34.5710 @ 3.0°C
266_1	08112324 (2)	1638	24.094	34.950	1631	-0.001	34.5860 @ 3.0°C
268_1	08112323 (2)	1562	23.496	35.227	1551	0.014	34.5860 @ 3.0°C

\* Not for simultaneous measurements with CTD

\*\* Failure of measurements due to noise or lost contact

\*\*\* Relatively large (about 30 minutes) time difference between CTD and XCTD measurements

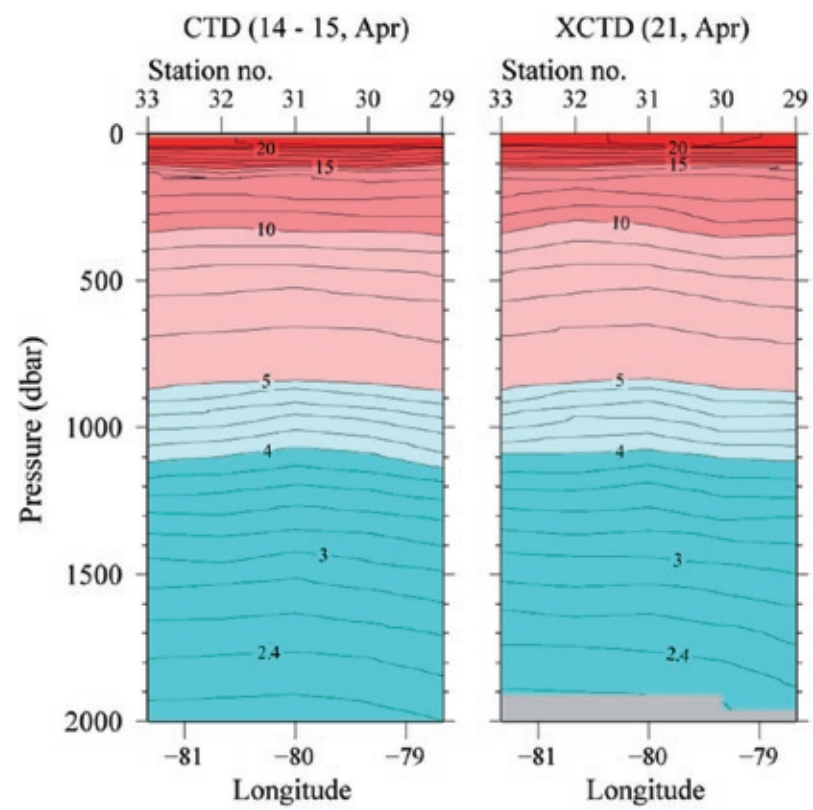


Figure 2.6.1. Vertical sections of potential temperature measured by CTD (left) and XCTD (right).

## 3 Hydrographic Measurement Techniques and Calibrations

### 3.1 CTDO<sub>2</sub> Measurements

February 16, 2010

#### (1) Personnel

<i>Hiroshi Uchida</i>	<i>(JAMSTEC)</i>
<i>Wolfgang Schneider</i>	<i>(University of Concepcion, Chile)</i>
<i>Leg 1 and leg 2a</i>	
<i>Kenichi Katayama</i>	<i>(MWJ)</i>
<i>Shinsuke Toyoda</i>	<i>(MWJ)</i>
<i>Hirokatsu Uno</i>	<i>(MWJ)</i>
<i>Hiroyuki Hayashi</i>	<i>(MWJ)</i>
<i>Leg 2b</i>	
<i>Tomoyuki Takamori</i>	<i>(MWJ)</i>
<i>Hiroshi Matsunaga</i>	<i>(MWJ)</i>
<i>Masayuki Fujisaki</i>	<i>(MWJ)</i>
<i>Shungo Oshitani</i>	<i>(MWJ)</i>
<i>Satoshi Ozawa</i>	<i>(MWJ)</i>

#### (2) Winch arrangements

The CTD package was deployed by using 4.5 Ton Traction Winch System (Dynacon, Inc., Bryan, Texas, USA), which was installed on the R/V Mirai in April 2001 (Fukasawa et al., 2004). Primary system components include a complete CTD Traction Winch System with up to 8000 m of 9.53 mm armored cable (Rochester Wire & Cable).

#### (3) Overview of the equipment

The CTD system was SBE 911plus system (Sea-Bird Electronics, Inc., Bellevue, Washington, USA). The SBE 911plus system controls 36-position SBE 32 Carousel Water Sampler. The Carousel accepts 12-litre Niskin-X water sample bottles (General Oceanics, Inc., Miami, Florida, USA). The SBE 9plus was mounted horizontally in a 36-position carousel frame. SBE's temperature (SBE 3) and conductivity (SBE 4) sensor modules were used with the SBE 9plus underwater unit. 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 modular unit of underwater housing pump (SBE 5T) flushes water through sensor tubing at a constant rate independent of the CTD's motion, and pumping rate (3000 rpm) remain nearly constant over the entire input voltage range of 12-18 volts DC. Flow speed of pumped water in standard TC duct is about 2.4 m/s. Two sets of temperature and conductivity modules were used. An SBE's dissolved oxygen sensor (SBE 43) was placed between the primary conductivity sensor and the pump module. Auxiliary sensors, a Deep Ocean Standards Thermometer (SBE 35), an altimeter (PSA-916T; Teledyne Benthos, Inc., North Falmouth, Massachusetts, USA), three oxygen optodes (Oxygen Optode 3830 and 4330F; Aanderaa Data Instruments AS, Bergen, Norway, and a prototype of RINKO-III; JFE Alec Co., Ltd, Kobe Hyogo, Japan), a fluorometer (Seapoint sensors, Inc., Kingston, New Hampshire, USA), and a transmissometer (C-Star Transmissometer; WET Labs, Inc., Philomath, Oregon, USA) were also used with the SBE 9plus underwater unit. To minimize motion of the CTD package, a heavy stainless frame (total weight of the CTD package without sea water in the bottles is about 1000 kg) was used with an aluminum plate (54 × 90 cm).

#### Summary of the system used in this cruise

Deck unit:

SBE 11plus, S/N 0272

Under water unit:

SBE 9plus, S/N 79511 (Pressure sensor: S/N 0677)

Temperature sensor:

SBE 3plus, S/N 4815 (primary)

SBE 3, S/N 1525 (secondary)

Conductivity sensor:

SBE 4, S/N 2854 (primary)

SBE 4, S/N 1203 (secondary: stations from P21\_14\_1 to P21\_86\_1)

SBE 4, S/N 3261 (secondary: stations from P21\_87\_1 to P21\_288\_1)

Oxygen sensor:

SBE 43, S/N 0394 (stations from P21\_14\_1 to P21\_76\_1)

SBE 43, S/N 0330 (stations from P21\_X18\_1 to P21\_288\_1)

AANDERAA Oxygen Optode 3830, S/N 612 (foil batch no. 1707)

AANDERAA Oxygen Optode 4330F, S/N 143 (foil batch no. 2808F)

JFE Alec RINKO-III, S/N 006 (foil batch no. 131002A)

Pump:

SBE 5T, S/N 4598 (primary)

SBE 5T, S/N 4595 (secondary)

Altimeter:

PSA-916T, S/N 1100

Deep Ocean Standards Thermometer:

SBE 35, S/N 0045

Fluorometer:

Seapoint Sensors, Inc., S/N 3054

Transmissometer:

C-Star, S/N CST-207RD

Carousel Water Sampler:

SBE 32, S/N 0391

Water sample bottle:

12-litre Niskin-X model 1010X (no TEFLON coating)

\* without Oxygen Optode 4330F, fluorometer, and transmissometer at station P21\_200\_1

**(4) Pre-cruise calibration**

**i. Pressure**

The Paroscientific series 4000 DigiQuartz high pressure transducer (Model 415K-187; Paroscientific, Inc., Redmond, Washington, 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 15000 psia (0 to 10332 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 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). 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 automatically.

Pre-cruise sensor calibrations for linearization were performed at SBE, Inc.

S/N 0677, 4 May 2007

The time drift of the pressure sensor is adjusted by periodic recertification corrections against a dead-weight piston gauge (Model 480DA, S/N 23906; Bundenberg Gauge Co. Ltd., Irlam, Manchester, UK). The corrections are performed at JAMSTEC, Yokosuka, Kanagawa, Japan by Marine Works Japan Ltd. (MWJ), Yokohama, Kanagawa, Japan, usually once in a year in order to monitor sensor time drift and linearity.

S/N 0677, 9 December 2008

slope = 0.99977580

offset = -0.02383

Result of the pre-cruise pressure sensor calibration against the dead-weight piston gauge is shown in Fig. 3.1.1.

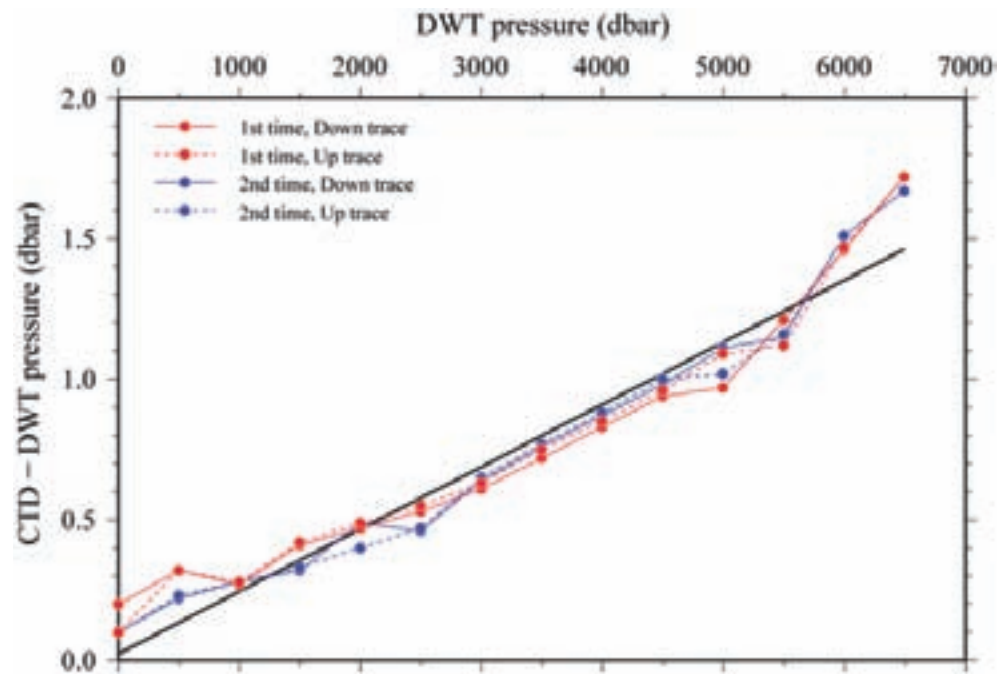


Figure 3.1.1. Difference between the dead-weight piston gauge and the CTD pressure. The calibration line (black line) is also shown.

## ii. 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 10500 (6800) m by titanium (aluminum) housing. The SBE 3 thermometer has a nominal accuracy of 1 mK, typical stability of 0.2 mK/month, and resolution of 0.2 mK at 24 samples per second. The premium temperature sensor, SBE 3plus, is a more rigorously tested and calibrated version of standard temperature sensor (SBE 3).

Pre-cruise sensor calibrations were performed at SBE, Inc.

S/N 4815, 26 November 2008

S/N 1525, 25 November 2008

Pressure sensitivity of SBE 3 was corrected according to a method by Uchida et al. (2007), for the following

sensor.

S/N 4815,  $-3.45974716e-7$  [°C/dbar]

S/N 1525,  $5.92243e-9$  [°C/dbar]

Time drift of the SBE 3 temperature sensors based on the laboratory calibrations is shown in Fig. 3.1.2.

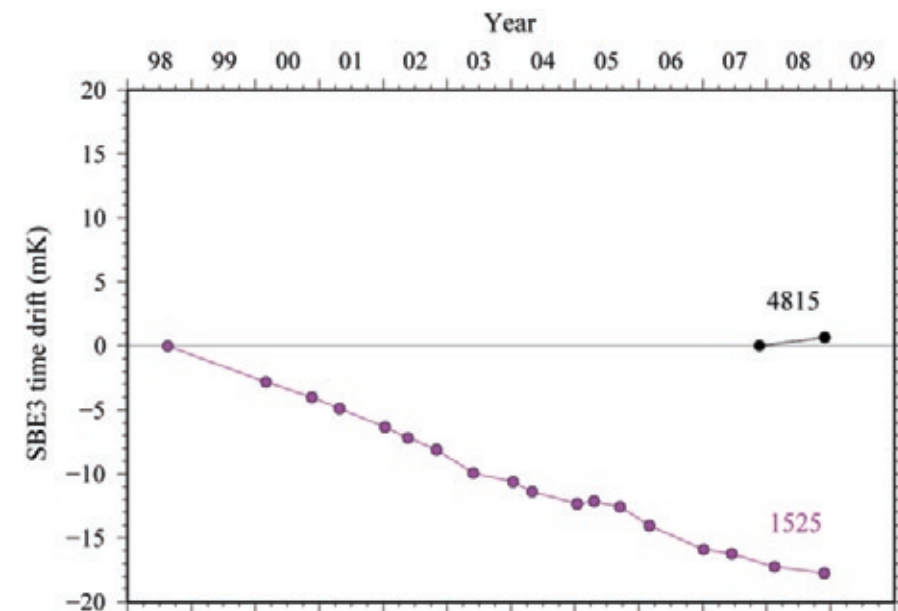


Figure 3.1.2. Time drift of SBE 3 temperature sensors based on laboratory calibrations.

## iii. 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 10500 (6800) m by titanium (aluminum) housing. The 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.

S/N 2954, 25 November 2008 (new cell preventing a stress concentration)

S/N 1203, 12 December 2008 (new cell preventing a stress concentration)



S/N 3261, 17 December 2008 (new cell preventing a stress concentration)

The value of conductivity at salinity of 35, temperature of 15 °C (IPTS-68) and pressure of 0 dbar is 4.2914 S/m.

#### iv. Oxygen (SBE 43)

The SBE 43 oxygen sensor uses a Clark polarographic element to provide in-situ measurements at depths up to 7000 m. The range for dissolved oxygen is 120 % of surface saturation in all natural waters, nominal accuracy is 2 % of saturation, and typical stability is 2 % per 1000 hours.

Pre-cruise sensor calibrations were performed at SBE, Inc.

S/N 0394, 20 December 2008

S/N 0330, 20 December 2008

#### v. Deep Ocean Standards Thermometer

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 6800 m. The SBE 35 was used to calibrate the SBE 3 temperature sensors in situ (Uchida et al., 2007).

Pre-cruise sensor linearization was performed at SBE, Inc.

S/N 0045, 27 October 2002

Then the SBE 35 is certified by measurements in thermodynamic fixed-point cells of the TPW (0.01 °C) and GaMP (29.7646 °C). The slow time drift of the SBE 35 is adjusted by periodic recertification corrections. Pre-cruise sensor calibration was performed at SBE, Inc.

S/N 0045, 23 December 2008 (slope and offset correction)

The time required per sample =  $1.1 \times \text{NCYCLES} + 2.7$  seconds. The 1.1 seconds is total time per an acquisition cycle. NCYCLES is the number of acquisition cycles per sample and was set to 4. The 2.7 seconds is required for converting the measured values to temperature and storing average in EEPROM.

When using the SBE 911 system with SBE 35, the deck unit receives incorrect signal from the under water unit for confirmation of firing bottle #16. In order to correct the signal, a module (Yoshi Ver. 1; EMS Co. Ltd., Kobe, Hyogo, Japan) was used between the under water unit and the deck unit.

Time drift of the SBE 35 based on the fixed point calibrations is shown in Fig. 3.1.3.

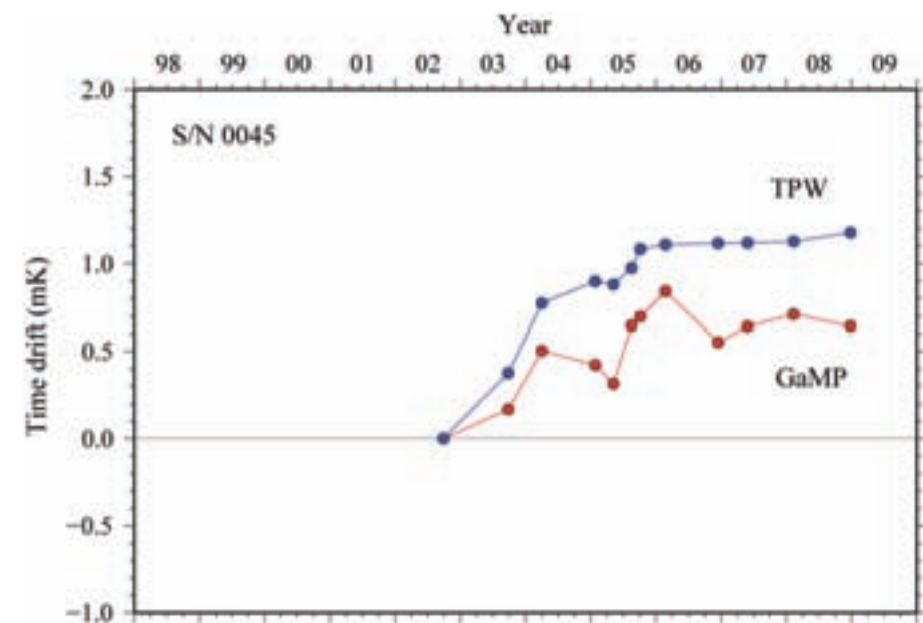


Figure 3.1.3. SBE35 time drift based on laboratory fixed point calibrations (triple point of water, TPW and gallium melt point, GaMP) performed by SBE, Inc.

#### vi. Altimeter

Benthos PSA-916T Sonar Altimeter (Teledyne Benthos, Inc.) determines the distance of the target from the unit by generating a narrow beam acoustic pulse and measuring the travel time for the pulse to bounce back from the target surface. It is rated for operation in water depths up to 10000 m. The PSA-916T uses the nominal speed of sound of 1500 m/s.

## vii. Oxygen Optode

### (a) Oxygen Optode 3830

Oxygen Optode 3830 (Aanderaa Data Instruments AS) is based on the ability of selected substances to act as dynamic fluorescence quenchers. In order to use with the SBE 911plus CTD system, an analog adaptor (3966) is connected to the oxygen optode (3830). The analog adaptor is packed into titanium housing made by Alec Electronics Co., Ltd. The sensor is designed to operate down to 6000 m. The range for dissolved oxygen is 120 % of surface saturation in all natural waters, nominal accuracy is less than 8  $\mu\text{M}$  or 5 % of saturation which ever is greater and setting time (63%) is shorter than 25 seconds.

### (b) Oxygen Optode 4330F

Oxygen Optode 4330F (Aanderaa Data Instruments AS) is based on the ability of selected substances to act as dynamic fluorescence quenchers. In order to use with the SBE 911plus CTD system, an analog adaptor (3966) with titanium housing for Oxygen Optode 3975 is connected to the oxygen optode (4330F). The sensor is designed to operate down to 6000 m. The range for dissolved oxygen is 150 % of surface saturation in all natural waters, nominal accuracy is less than 8  $\mu\text{M}$  or 5 % of saturation which ever is greater and setting time (63%) is shorter than 8 seconds.

### (c) RINKO

RINKO (JFE Alec Co., Ltd.) is based on the ability of selected substances to act as dynamic fluorescence quenchers. RINKO model III is designed to use with a CTD system which accept an auxiliary analog sensor, and is designed to operate down to 7000 m.

Outputs from Optode 3830 and RINKO are the raw phase shift data. Raw phase shift data for Optode 4330F can be back calculated from the outputs (oxygen concentration and temperature). The optode oxygen can be calibrated by the Stern-Volmer equation, according to a method by Uchida et al. (2008) with slight modification:

$$O_2 (\mu\text{mol/l}) = [(V_0 / V)^2 - 1] / K_{sv}$$

where V is voltage, V<sub>0</sub> is voltage in the absence of oxygen and K<sub>sv</sub> is Stern-Volmer constant. The V<sub>0</sub> and the K<sub>sv</sub> are assumed to be functions of temperature as follows.

$$K_{sv} = C_0 + C_1 \times T + C_2 \times T^2$$

$$V_0 = 1 + C_3 \times T$$

$$V = C_4 + C_5 \times V_b$$

where T is CTD temperature ( $^{\circ}\text{C}$ ) and V<sub>b</sub> is raw output (volts). V<sub>0</sub> and V are normalized by the output in the absence of oxygen at 0 $^{\circ}\text{C}$ . The oxygen concentration is calculated using temperature data from the first responding CTD temperature sensor instead of temperature data from slow responding optode temperature sensor. The pressure-compensated oxygen concentration O<sub>2c</sub> can be calculated as follows.

$$O_{2c} = O_2 (1 + C_p p / 1000)^{1/3}$$

where p is CTD pressure (dbar) and C<sub>p</sub> is the compensation coefficient. Since the sensing foil of the optode is permeable only to gas and not to water, the optode oxygen must be corrected for salinity. The salinity-compensated oxygen can be calculated by multiplying the factor of the effect of salt on the oxygen solubility (García and Gordon, 1992). García and Gordon (1992) have recommended the use of the solubility coefficients derived from the data of Benson and Krause.

The calibration coefficients were preliminary determined by using the bottle oxygen data obtained in this cruise, and used during the cruise.

## viii. Fluorometer

The Seapoint Chlorophyll Fluorometer (Seapoint Sensors, Inc., Kingston, New Hampshire, USA) provides in-situ measurements of chlorophyll-a at depths up to 6000 m. 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.

## ix. Transmissometer

The C-Star Transmissometer (WET Labs, Inc., Philomath, Oregon, 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.

### (5) Data collection and processing

#### i. Data collection

CTD system was powered on at least 20 minutes in advance of the data acquisition and was powered off at least two minutes after the operation in order to acquire pressure data on the ship's deck.

The package was lowered into the water from the starboard side and held 10 m beneath the surface in order to activate the pump. After the pump was activated, the package was lifted to the surface and lowered at a rate of 1.0 m/s to 200 m (or 300 m when significant wave height is high) then the package was stopped to operate the heave compensator of the crane. The package was lowered again at a rate of 1.2 m/s to the bottom. For the up cast, the package was lifted at a rate of 1.1 m/s except for bottle firing stops. At each bottle firing stop, the bottle was fired after waiting from the stop for 30 seconds (20 seconds from station P21\_23\_1) and the package was stayed at least 5 seconds for measurement of the SBE 35. At 200 m (or 300 m) from the surface, the package was stopped to stop the heave compensator of the crane.

Water samples were collected using a 36-bottle SBE 32 Carousel Water Sampler with 12-litre Niskin-X bottles. Before a cast taken water for CFCs, the 36-bottle frame and Niskin-X bottles were wiped with acetone.

#### *Data acquisition software*

SEASAVE-Win32, version 7.18c

## ii. Data collection problems

### (a) Temperature and conductivity sensors

Since differences of temperature-salinity relationship calculated from the secondary sensors between downcast and upcast were larger than that calculated from the primary sensors, the secondary conductivity sensor S/N 1203 was replaced with the conductivity sensor S/N 3261 after the station P21\_86\_1. However, the differences were still larger than that calculated from the primary sensors. The results suggest that the secondary temperature sensor S/N 1525 may have a pressure hysteresis relatively larger than the primary temperature sensor.

At the station P21\_16\_1, the primary temperature and conductivity data were noisy probably due to jellyfish in the primary TC duct. Therefore, the second cast P21\_16\_2 was carried out.

At the station P21\_26\_1, the primary temperature and conductivity data were noisy probably due to jellyfish in the primary TC duct. Since the second cast was not carried out, the secondary temperature and conductivity data must be used for this station.

### (b) SBE43 oxygen sensor

Since differences between downcast and upcast profiles near the surface gradually became large, the SBE43 oxygen sensor S/N 0394 was replaced with the oxygen sensor S/N 0330 after the station P21\_76\_1.

### (c) Miss trip and miss fire

Niskin bottles did not trip correctly at the following stations.

Miss trip

Miss fire

P21_33_1, #13	P21_61_1, #14
P21_18_1, #13	P21_69_1, #15
P21_36_1, #15	P21_177_1, #21
	P21_185_1, #21
	P21_188_1, #21
	P21_255_1, #33

**(d) Problem of the Niskin bottle #13**

Discrepancies between CTD salinity and bottle sampled salinity data for the bottle #13 (about 3000 dbar) were slightly larger (about 0.001) than that obtained from neighboring bottles during leg 1. Bottle salinity data were obtained from a different bottle at the same depth of following stations, and were compared with the bottle salinity data obtained from the bottle #13.

Bottle #2 of P21\_47\_1

Bottle #3 of P21\_131\_1, P21\_132\_1, P21\_133\_1, P21\_135\_1, P21\_137\_1

Bottle #9 of P21\_136\_1

Mean difference with standard error between CTD salinity and bottle salinity data are  $-0.0021 \pm 0.0002$  and  $-0.0013 \pm 0.0001$  for the bottle #13 and for the duplicate bottles, respectively. Salinity data from bottle #13 were significantly smaller than the other bottles probably due to slight leakage, although leak was not found for the bottle #13 at the water sampling. Therefore, the Niskin bottle #13 (S/N X12013) was replaced with the Niskin bottle S/N X12014 after the station P21\_141\_1, and the bottle flags of #13 for stations from P21\_29\_1 to P21\_141\_1 were set to 7 (unknown problem). For the other water sampling parameters, significant difference was not detected for the duplicate bottle comparison (#2 and #13) at the station P21\_47\_1.

**(e) Errors of bottle sampled oxygen data from nitrites**

During the determination of dissolved oxygen by using the Winkler method, errors from nitrites were introduced at the time the solution was made acidic with sulfuric acid (Wetzel and Gene, 2000). Therefore, the

bottle sampled oxygen data were corrected when the nitrite concentration was high ( $> 0.5 \mu\text{mol/kg}$ ) as follows and used for the CTD oxygen calibration.

$$O_{2c} = O_2 - 0.25 \text{NO}_2$$

If the nitrite concentration was higher than  $5 \mu\text{mol/kg}$ , the bottle sampled oxygen data was not used, because the error was significantly greater than  $0.25 \text{NO}_2$ .

**(f) Other incidents of note**

At the station P21\_200\_1, Oxygen Optode 4330F, fluorometer, and transmissometer were removed from the CTD system, because the maximum pressure (6500 dbar) for the cast was beyond the proof pressure of these sensors (6000 m).

To gain more observation time, the bottle was fired after waiting from the stop for 20 seconds at each bottle firing stops from station P21\_23\_1. Immediately after the bottle firing stop, water around the instruments can be contaminated by the wake effect (Uchida et al., 2007). Although the wake effect is usually large within the first 20 seconds of the stop, the data may somewhat contaminated by the wake effect.

At the station P21\_97\_1, the cast was aborted at 285 dbar of the down cast due to a bad condition of the winch system, and the second cast P21\_97\_2 was carried out. At the station P21\_118\_1, the cast was aborted at 54 dbar of the down cast due to a mistake of the parameter setting for the LADCP, and the second cast P21\_118\_2 was carried out.

**iii. Data processing**

SEASOFT consists of modular menu driven routines for acquisition, display, processing, and archiving of oceanographic data acquired with SBE equipment. Raw data are acquired from instruments and are stored as unmodified data. The conversion module DATCNV uses instrument configuration and calibration coefficients to create a converted engineering unit data file that is operated on by all SEASOFT post processing modules. The following are the SEASOFT and original software data processing module sequence and specifications used in the reduction of CTD data in this cruise.

### *Data processing software*

SEASOFT-Win32, version 7.18c

DATCNV converted the raw data to engineering unit data. 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 second. The hysteresis correction for the SBE 43 data (voltage) was applied for both profile and bottle information data.

TCORP (original module, version 1.1) corrected the pressure sensitivity of the SBE 3 for both profile and bottle information data.

RINKOCOR (original module, version 1.0) corrected the time-dependent, pressure-induced effect (hysteresis) of the RINKO for both profile data.

RINKOCORROS (original module, version 1.0) corrected the time-dependent, pressure-induced effect (hysteresis) of the RINKO for bottle information data by using the hysteresis-corrected profile data.

BOTTLESUM created a summary of the bottle data. The data were averaged over 4.4 seconds.

ALIGNCTD converted the time-sequence of sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9plus CTD with the ducted temperature and conductivity sensors and a 3000-rpm pump, the typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit was set to advance the primary and the secondary conductivity for 1.73 scans ( $1.75/24 = 0.073$  seconds). 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 5 seconds advancing oxygen sensor output (voltage) relative to the temperature data. Delay of the RINKO data was also compensated by 1 second advancing sensor output (voltage) relative to the temperature data.

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, temperature, conductivity and SBE 43 output.

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

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

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

SECTIONU (original module, version 1.1) 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 start 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 depth of the package was 1 dbar below the surface. The minimum and maximum numbers were automatically calculated in the module.

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

DESPIKE (original module, version 1.0) removed spikes of the data. A median and mean absolute deviation was calculated in 1-dbar pressure bins for both down- and up-cast, excluding the flagged values. Values greater than 4 mean absolute deviations from the median were marked bad for each bin. This process was performed 2 times for temperature, conductivity, SBE 43, Optode 3830, and RINKO output.

DERIVE was used to compute oxygen (SBE 43).

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 exist every dbar.

OPTBACKCAL (original module, version 1.0) calculated raw phase shift data of the Optode 4330F from the Optode 4330F outputs (oxygen concentration and temperature data). For bottle information data, this module

was applied before applying the module BOTTLESUM.

DERIVE was re-used to compute salinity, potential temperature, and density ( $\sigma_\theta$ ).

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

Remaining spikes in the CTD data were manually eliminated from the 1-dbar-averaged data. The data gaps resulting from the elimination were linearly interpolated with a quality flag of 6.

## (6) Post-cruise calibration

### i. Pressure

The CTD pressure sensor offset in the period of the cruise was estimated from the pressure readings on the ship deck. For best results the Paroscientific sensor was powered on for at least 20 minutes before the operation. In order to get the calibration data for the pre- and post-cast pressure sensor drift, the CTD deck pressure was averaged over first and last one minute, respectively. Then the atmospheric pressure deviation from a standard atmospheric pressure (14.7 psi) was subtracted from the CTD deck pressure. The atmospheric pressure was measured at the captain deck (20 m high from the base line) and sub-sampled one-minute interval as a meteorological data. Time series of the CTD deck pressure is shown in Fig. 3.1.4.

The CTD pressure sensor offset was estimated from the deck pressure obtained above. Mean of the pre- and the post-casts data over the whole period gave an estimation of the pressure sensor offset from the pre-cruise calibration. Mean residual pressure between the dead-weight piston gauge and the calibrated CTD data at 0 dbar of the pre-cruise calibration was subtracted from the mean deck pressure. Estimated mean offset of the pressure data is listed in Table 3.1.1. The post-cruise correction of the pressure data is not deemed necessary for the pressure sensor.

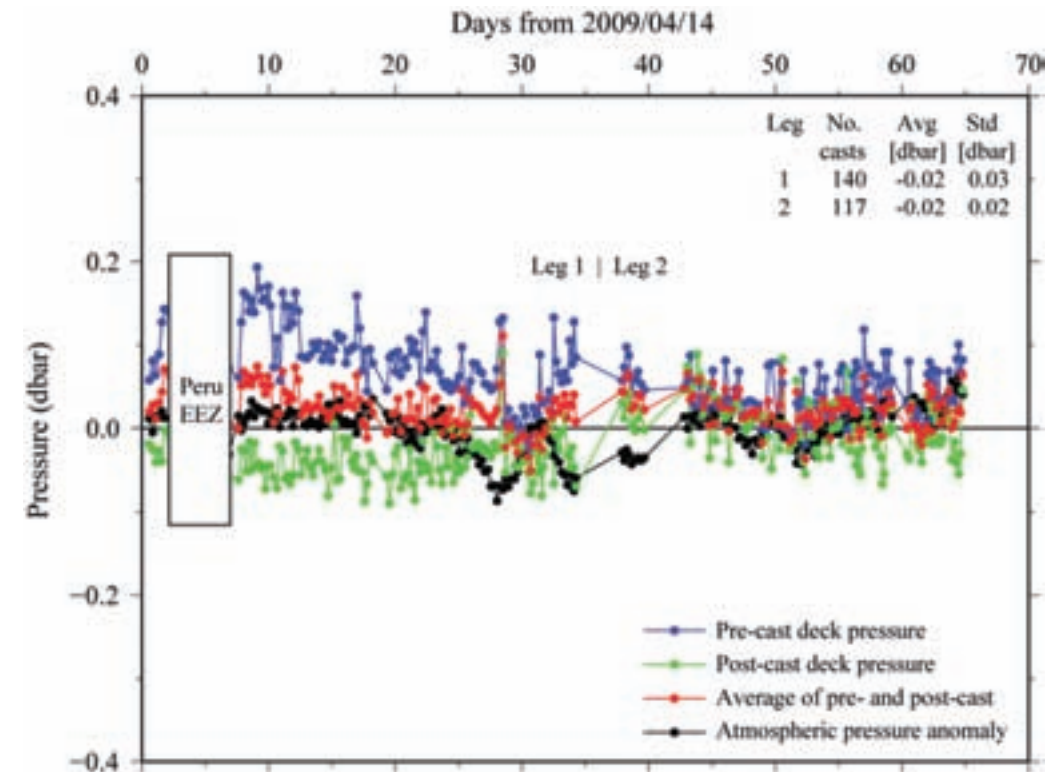


Figure 3.1.4. Time series of the CTD deck pressure. Black dot indicates atmospheric pressure anomaly. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dot indicates an average of the pre- and the post-cast deck pressures.



Table 3.1.1. Offset of the pressure data. Mean and standard deviation are calculated from time series of the average of the pre- and the post-cast deck pressures.

Number of cast	Mean deck pressure [dbar]	Standard deviation [dbar]	Residual pressure [dbar]	Estimated offset [dbar]
<i>Leg 1</i>				
140	0.02	0.03	0.13	-0.11
<i>Leg 2</i>				
117	0.02	0.02	0.13	-0.11

**ii. Temperature**

The CTD temperature sensors (SBE 3) were calibrated with the SBE 35 under the assumption that discrepancies between SBE 3 and SBE 35 data were due to pressure sensitivity, the viscous heating effect, and time drift of the SBE 3, according to a method by Uchida et al. (2007).

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

*S/N 0045, 19 August 2009 (2nd step: fixed point calibration)*

$$\text{Slope} = 1.000013$$

$$\text{Offset} = -0.001173$$

Offset of the SBE 35 data from the pre-calibration was estimated to be smaller than 0.1 mK for temperature smaller than 4.5C. So the post-cruise correction of the SBE 35 temperature data was not deemed necessary for the SBE 35.

The CTD temperature was preliminary calibrated as

$$\text{Calibrated temperature} = T - (c_0 \times P + c_1 \times t + c_2)$$

where T is CTD temperature in °C, P is pressure in dbar, t is time in days from pre-cruise calibration date of the

CTD temperature and  $c_0$ ,  $c_1$ , and  $c_2$  are calibration coefficients. The coefficients were determined using the data for the depths deeper than 1950 dbar.

The primary temperature data were basically used for the post-cruise calibration. The secondary temperature sensor was also calibrated and used instead of the primary temperature data for the station P21\_26\_1. The number of data used for the calibration and the mean absolute deviation from the SBE 35 are listed in Table 3.1.2 and the calibration coefficients are listed in Table 3.1.3. The results of the post-cruise calibration for the CTD temperature are summarized in Table 3.1.4 and shown in Figs. 3.1.6 and 3.1.7.

Table 3.1.2. Number of data used for the calibration (pressure  $\geq$  1950 dbar) and mean absolute deviation between the CTD temperature and the SBE 35.

Leg	Serial number	Number	Mean absolute deviation	Note
1	4815	1315	0.1 mK	
1	1525	1315	0.1 mK	for station P21_26_1
2	4815	834	0.1 mK	
2	1525	834	0.1 mK	Not used

Table 3.1.3. Calibration coefficients for the CTD temperature sensors.

Leg	Serial number	$c_0$ (°C/dbar)	$c_1$ (°C/day)	$c_2$ (°C)
1	4815	1.03996e-8	2.23793e-6	-0.0000
1	1525	-7.61078e-9	1.76847e-6	0.0005
2	4815	-4.16502e-8	3.67354e-7	-0.0003
2	1525	1.76844e-8	-1.01065e-5	0.0024

Table 3.1.4. 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 1950 dbar. Number of data used is also shown.

Serial number	Pressure $\geq$ 1950 dbar			Pressure $<$ 1950 dbar		
	Number	Mean (mK)	Sdev (mK)	Number	Mean (mK)	Sdev (mK)
<i>Leg 1</i>						
4815	1315	-0.01	0.2	2647	-0.03	8.7
1525	1315	-0.01	0.2	2647	0.46	9.8
<i>Leg 2</i>						
4815	834	-0.00	0.3	2171	-0.42	4.8
1525	834	-0.02	0.5	2171	-0.00	5.2

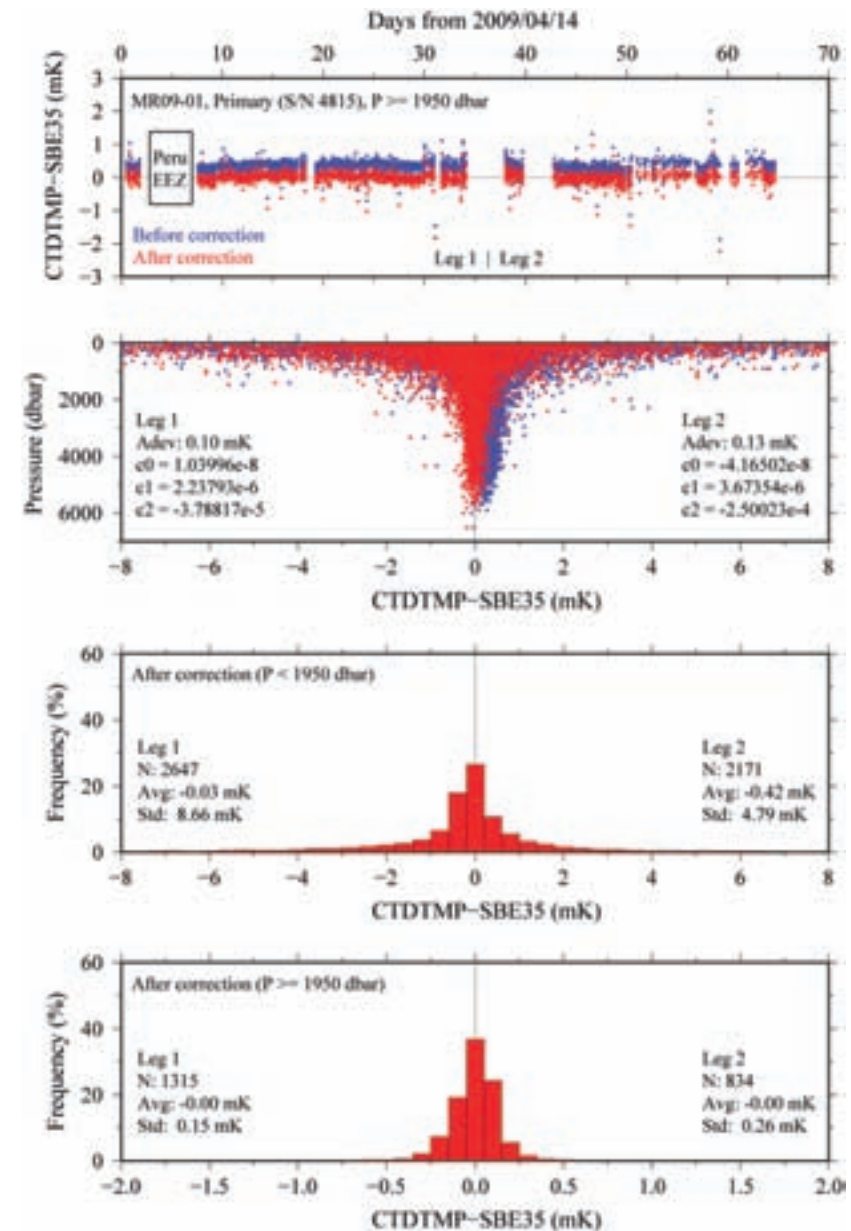


Figure 3.1.5. Difference between the CTD temperature and the SBE 35. Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Lower two panels show histogram of the difference after the calibration. Results from the primary temperature sensor (S/N 4815) are shown.

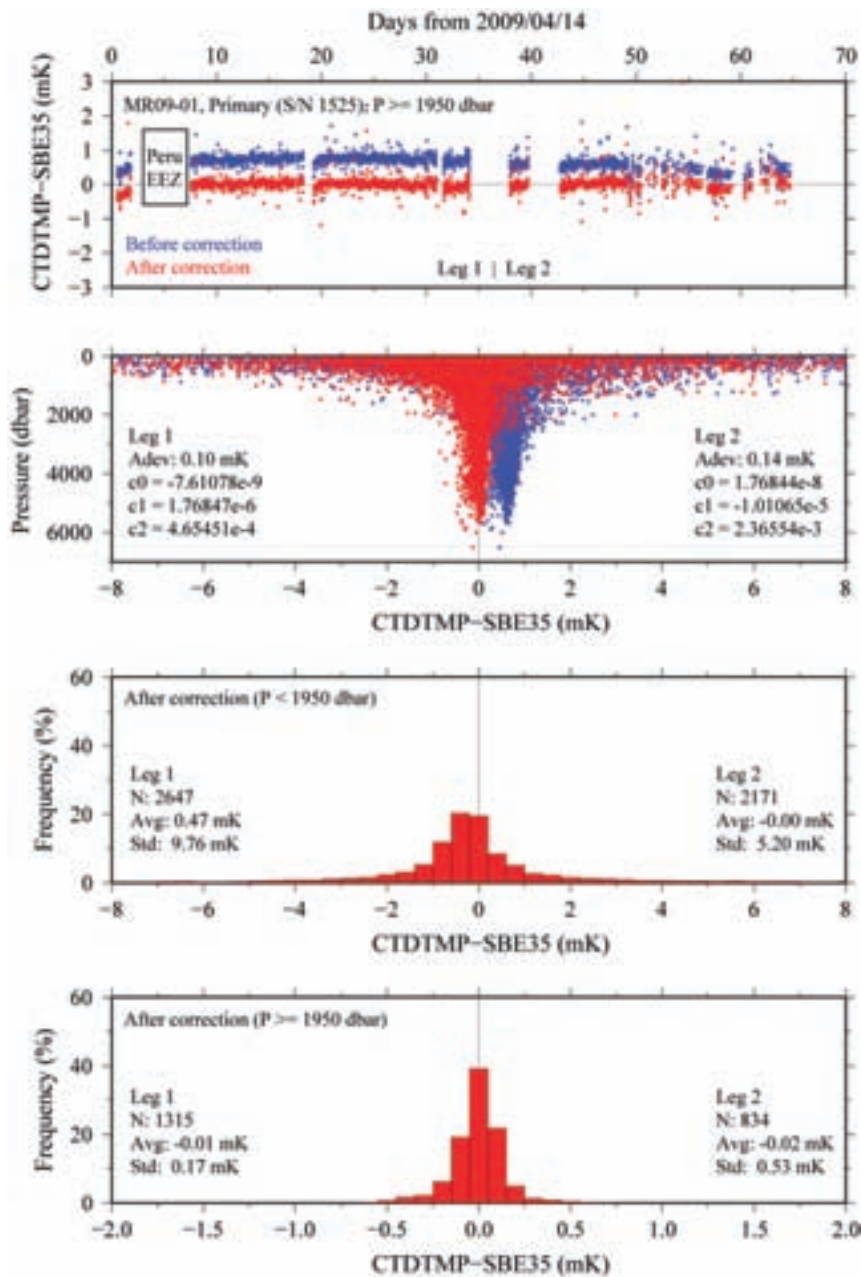


Figure 3.1.6. Same as Fig. 3.1.5, but for the secondary temperature sensor (S/N 1525).

### iii. Salinity

The discrepancy between the CTD conductivity and the conductivity calculated from the bottle salinity data with the CTD temperature and pressure data is considered to be a function of conductivity, pressure and time. The CTD conductivity was calibrated as

$$\text{Calibrated conductivity} = c_0 \times C + c_1 \times P + c_2 \times C \times P + c_3 \times t + c_4$$

where C is CTD conductivity in S/m, P is pressure in dbar, t is time in days from 14 April 2009 and  $c_0, c_1, c_2, c_3$  and  $c_4$  are calibration coefficients. The best fit sets of coefficients were determined by a weighted least square technique to minimize the deviation from the conductivity calculated from the bottle salinity data. The revised quasi-Newton method (FORTRAN subroutine DMINF1 from the Scientific Subroutine Library II, Fujitsu Ltd., Kanagawa, Japan) was used to determine the sets. The weight was given as a function of pressure as

$$\text{Weight} = \min[100, \exp\{\log(100) \times P / PR\}]$$

where PR is threshold of the pressure (950 dbar). When pressure is large (small), the weight is large (small) at maximum (minimum) value of 100 (1).

The primary conductivity data created by the software module ROSSUM were basically used after the post-cruise calibration for the temperature data. For the station P21\_26\_1, the secondary conductivity data was used, because the primary conductivity data was not able to be used for the station. Data from the station P21\_14\_1 to P21\_27\_1 were used for the calibration of the secondary conductivity. The coefficients were determined for each leg. The calibration coefficients are listed in Table 3.1.5. The results of the post-cruise calibration for the CTD salinity are summarized in Table 3.1.6 and shown in Fig. 3.1.7.

Table 3.1.5. Calibration coefficients for the CTD conductivity sensors.

Number	$c_0$	$c_1$ [S/(m dbar)]	$c_2$ (1/dbar)	$c_3$ [S/(m day)]	$c_4$ (S/m)	Note
<i>Leg 1</i>						
3743	1.00015	3.00883e-8	-9.60863e-8	4.24710e-6	-4.86614e-4	S/N 2854
330	0.999985	1.87529e-7	-6.74291e-8	5.33449e-5	-9.41355e-5	S/N 1203
<i>Leg 2</i>						
2849	1.00021	-3.50016e-8	5.62948e-9	-1.22961e-6	-4.63040e-4	S/N 2854

Table 3.1.6. Difference between the CTD salinity and the bottle salinity after the post-cruise calibration. Mean and standard deviation (Sdev) (in  $10^{-3}$ ) are calculated for the data below and above 950 dbar. Number of data used is also shown.

Leg (Serial no.)	Pressure $\geq$ 950 dbar			Pressure $<$ 950 dbar		
	Number	Mean	Sdev	Number	Mean	Sdev
Leg 1 (2854)	1933	-0.02	0.42	1810	0.15	5.57
Leg 1 (1203)	163	-0.00	0.40	167	0.13	3.20
Leg 2 (2854)	1347	0.00	0.39	1502	0.05	4.58

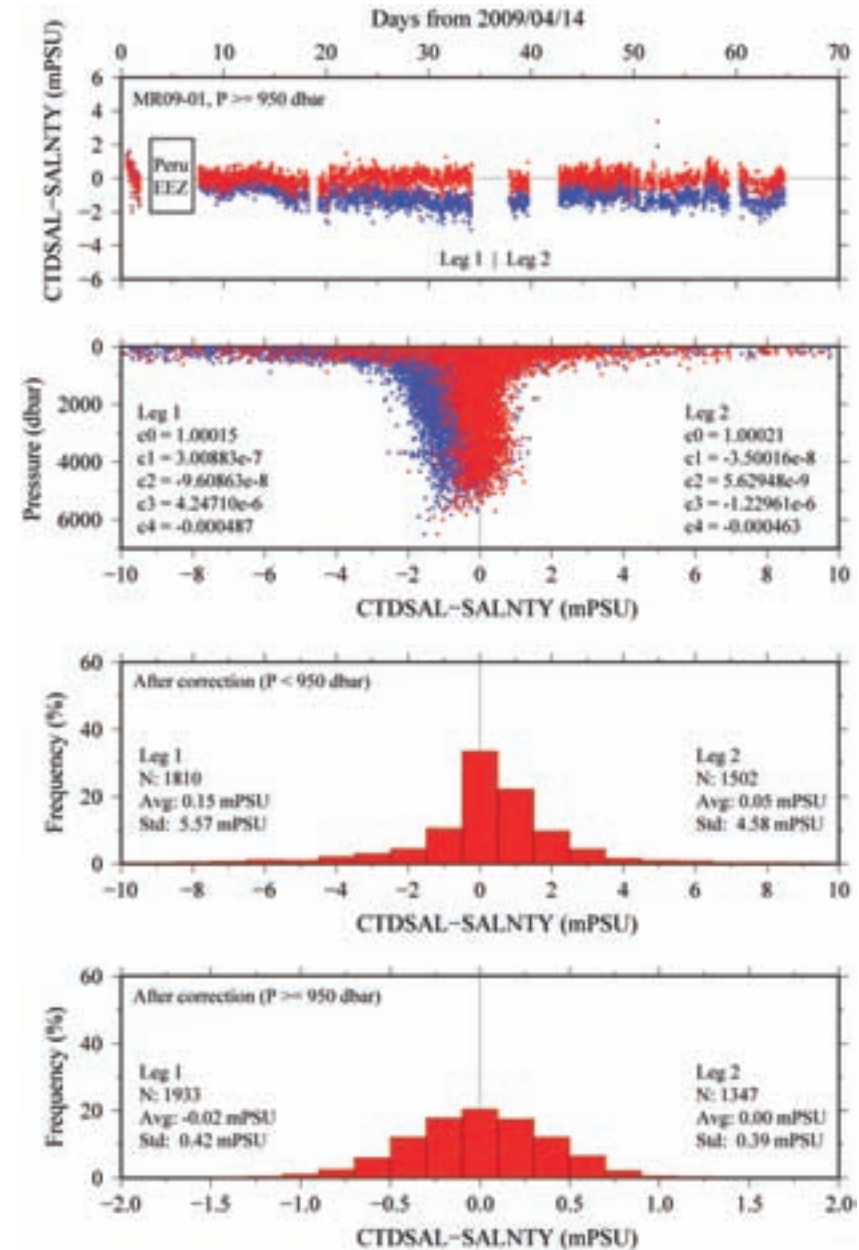


Figure 3.1.7. Difference between the CTD salinity and the bottle salinity. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration. Results from the primary conductivity sensor (S/N 2854) are shown.



#### iv. Oxygen

The RINKO oxygen optode was calibrated and used as the CTD oxygen data, since the RINKO has a fast time response. However, the time-dependent, pressure-induced effect on the sensing foil was large for the RINKO, as was observed for the SBE 43. Data from the RINKO was corrected for the time-dependent, pressure-induced effect by means of the same method as that developed for the SBE 43 (Sea-Bird Electronics, 2009). The calibration coefficients, H1 (amplitude of hysteresis correction), H2 (curvature function for hysteresis), and H3 (time constant for hysteresis) were determined empirically as:

$$H1 = 0.0065$$

$$H2 = 5000 \text{ dbar}$$

$$H3 = 2000 \text{ seconds.}$$

Difference between the up and down cast oxygen was quite small for the pressure-hysteresis corrected RINKO data (Fig. 3.1.8).

The pressure-hysteresis corrected RINKO data was calibrated by the Stern-Volmer equation, basically according to a method by Uchida et al. (2008) with modification:

$$[O_2] (\mu\text{mol/l}) = [(V_0 / V)^2 - 1] / K_{sv}$$

and

$$K_{sv} = C_0 + C_1 \times T + C_2 \times T^2$$

$$V_0 = 1 + C_3 \times T$$

$$V = C_4 + C_5 \times V_b + C_6 \times t + C_7 \times t \times V_b$$

where  $V_b$  is the RINKO output (voltage),  $V_0$  is voltage in the absence of oxygen,  $T$  is temperature in  $^{\circ}\text{C}$ , and  $t$  is exciting time (days) integrated from the first CTD cast. Time drift of the RINKO output was corrected. The pressure-compensation coefficient ( $C_p$ ) was estimated to be 0.058. The coefficient for the  $V_0$  ( $C_3 = -0.00076$ ) was estimated from laboratory experiments on August 6, 2009. The remaining seven coefficients ( $C_0, C_1, C_2, C_4, C_5, C_6,$  and  $C_7$ ) were determined by minimizing the sum of absolute deviation with a weight from the bottle oxygen data. The revised quasi-Newton method (DMINF1) was used to determine the sets. The weight was given as a function of pressure as

$$\text{Weight} = \min[20, \exp\{\log(20) \times P / PR\}], \text{ when } [O_2] \geq 5 \mu\text{mol/kg}$$

$$\text{Weight} = 20, \text{ when } [O_2] < 5 \mu\text{mol/kg},$$

where PR is threshold of the pressure (950 dbar).

The post-cruise calibrated temperature and salinity data were used for the calibration. The coefficients were determined for some groups of the CTD stations. The calibration coefficients are listed in Table 3.1.7. The results of the post-cruise calibration for the RINKO oxygen are summarized in Table 3.1.8 and shown in Fig. 3.1.9.

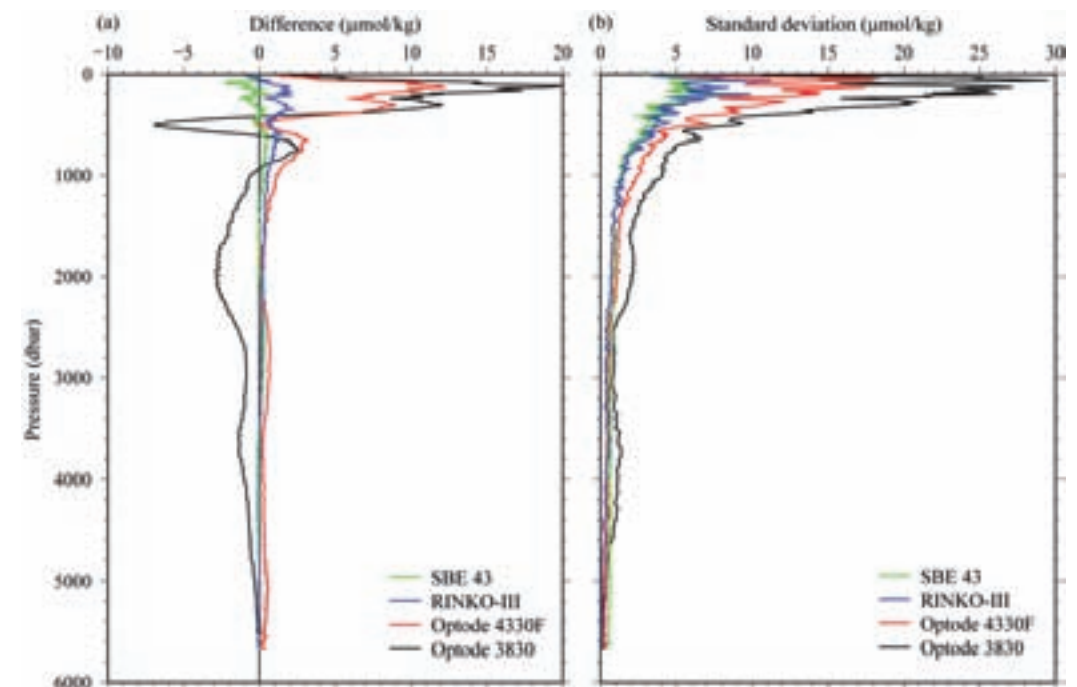


Figure 3.1.8. Difference between the up and down cast oxygen profiles from RINKO, SBE 43, Optode 4330F, and Optode 3830. (a) mean and (b) standard deviation calculated from all CTD data.

Table 3.1.7. Calibration coefficients for the RINKO oxygen sensor.

Group	C <sub>0</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>
<i>Leg 1</i>							
A	6.689376e-3	1.762279e-4	4.882030e-6	8.338279e-2	0.2267409	-4.196177e-3	3.326666e-3
B	6.782221e-3	1.365800e-4	6.972649e-6	7.467877e-2	0.2304436	-2.522455e-3	2.283958e-3
C	6.422881e-3	2.150534e-4	2.960990e-6	8.887120e-2	0.2285794	-7.967244e-5	8.759761e-4
D	6.707974e-3	2.692866e-4	1.586005e-6	7.623816e-2	0.2298613	-1.307925e-4	8.577014e-4
E	7.702781e-3	3.032778e-4	3.319508e-6	3.659057e-2	0.2395650	-3.795239e-4	5.390385e-4
F	8.815933e-3	3.357220e-4	4.934811e-6	2.385302e-2	0.2267504	-1.456302e-3	1.483800e-3
<i>Leg 2</i>							
G	8.751177e-3	3.336450e-4	4.553403e-6	-4.679584e-2	0.2673914	2.997944e-3	-9.971862e-4
H	8.835125e-3	3.345906e-4	5.044742e-6	1.583165e-2	0.2399865	-9.708137e-4	6.960351e-4

*Group of CTD stations*      A: 29\_1-33\_1, B: 14\_1-28\_1, C: 41\_1-68\_1, D: 69\_1-86\_1,  
 E: 87\_1-148\_1, F: 149\_1-156\_1, G: 164\_1-172\_1, H: 173\_1-288\_1

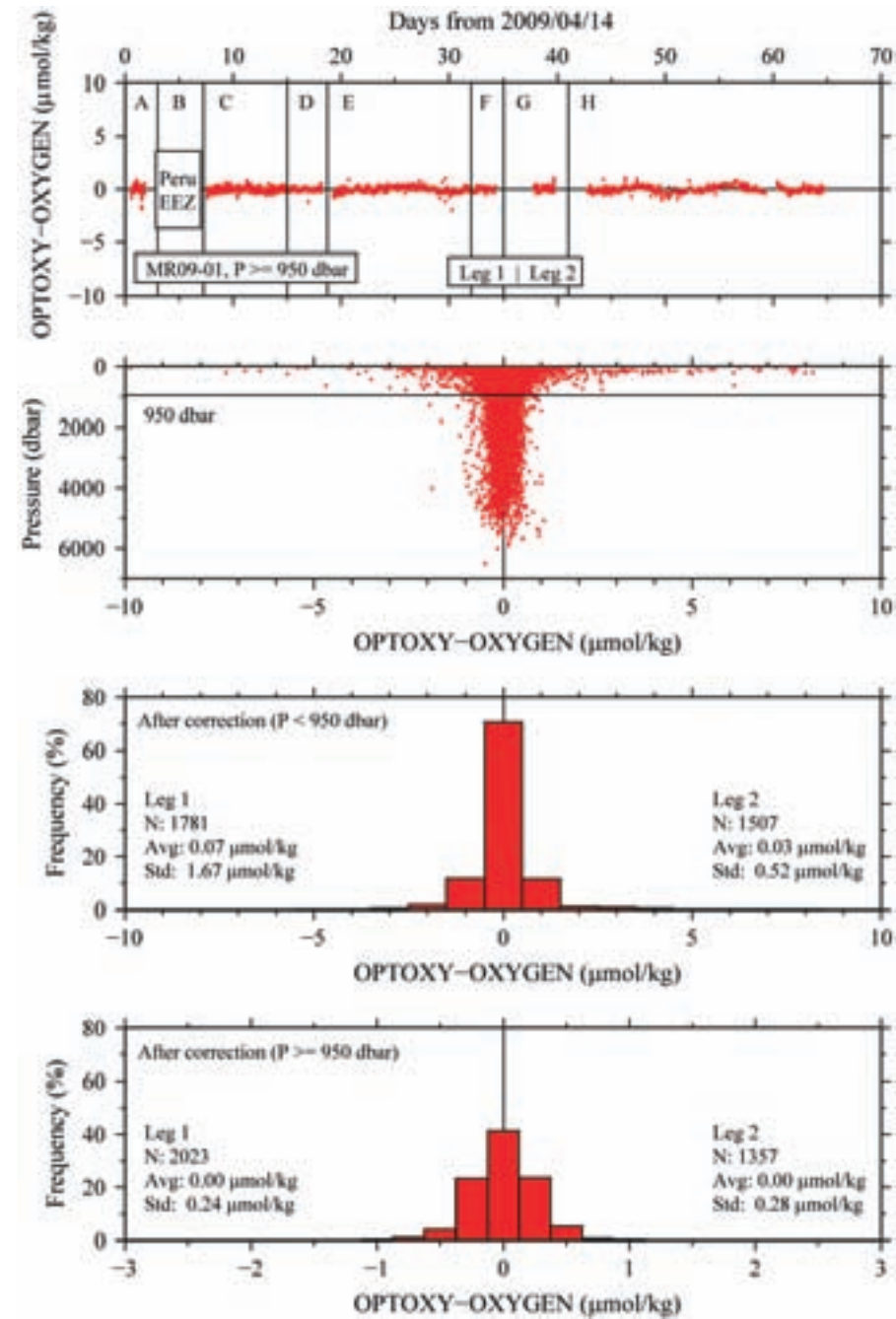


Figure 3.1.9. Difference between the RINKO oxygen and the bottle oxygen after the post-cruise calibration.

Lower two panels show histogram of the difference.



Table 3.1.8. Difference between the RINKO oxygen and the bottle oxygen after the post-cruise calibration. Mean and standard deviation (Sdev) are calculated for the data below and above 950 dbar. Number of data used is also shown.

Leg	Pressure ≥ 950 dbar			Pressure < 950 dbar		
	Number	Mean ( $\mu\text{mol/kg}$ )	Sdev ( $\mu\text{mol/kg}$ )	Number	Mean ( $\mu\text{mol/kg}$ )	Sdev ( $\mu\text{mol/kg}$ )
Leg 1	2023	0.00	0.24	1781	0.07	1.67
Leg 2	1357	0.01	0.28	1507	0.03	0.52

**(8) Estimation of tripped depth for the bottle #13 of stations P21\_33\_1 and P21\_18\_1**

True tripped depths for the following miss tripped bottles were estimated by using post-cruise calibrated CTD salinity and oxygen data compared to the bottle sampled salinity and oxygen data (Table 3.1.9).

Table 3.1.9. Estimated pressure of tripped depth for miss tripped bottles. The CTD temperature, salinity and oxygen data at the estimated pressure are also shown.

Bottle	Estimated pressure (dbar)			CTDTMP (ITS-90)	CTDSAL (PSS-78)	CTDOXY ( $\mu\text{mol/kg}$ )
	by CTDSAL	by CTDOXY	Average			
P21_33_1_#13	2403.0	2388.6	2395.8	1.9394	34.6628	134.45
P21_18_1_#13	762.2	763.2	762.7	5.6999	34.5179	28.86

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## 3.2 Bottle Salinity

September 9, 2009

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### (2) Objectives

Bottle salinities were measured to compare with CTD salinities for calibrating CTD salinities and for identifying leaking bottles.

### (3) Instrument and Method

#### i. Salinity Sample Collection

The bottles in which the salinity samples are collected and stored are 250 ml Phoenix brown glass bottles with screw caps. Each bottle was rinsed three times with sample water and was filled to the shoulder of the bottle. The caps were also thoroughly rinsed. Salinity samples were stored more than 12 hours in the same laboratory as the salinity measurement was made.

#### ii. Instruments and Method

The salinity analysis was carried out on Guildline Autosol salinometer model 8400B (S/N 62556), which was modified by adding an Ocean Scientific International Ltd. peristaltic-type sample intake pump and two Guildline platinum thermometers model 9450. One thermometer monitored an ambient temperature and the other monitored a bath temperature. The resolution of the thermometers was 0.001 °C. The measurement system was

almost same as Aoyama et al. (2002). The salinometer was operated in the air-conditioned laboratory of the ship at a bath temperature of 24 °C.

An ambient temperature varied from approximately 20 °C to 24 °C, while a bath temperature is very stable and varied within  $\pm 0.002$  °C on rare occasion. A measure of a double conductivity ratio of a sample is taken as a median of 31 readings. Data collection was started after 10 seconds and it took about 10 seconds to collect 31 readings by a personal computer. Data were sampled for the sixth and seventh filling of the cell. In case where the difference between the double conductivity ratio of this two fillings is smaller than 0.00002, the average value of the two double conductivity ratios is used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981). If the difference is greater than or equal to the 0.00003, we measure another additional filling of the cell. In case where the double conductivity ratio of the additional filling does not satisfy the criteria above, we measure other additional fillings of the cell within 10 fillings in total. In case where the number of fillings is 10 and those fillings do not satisfy the criteria above, the median of the double conductivity ratios of five fillings are used to calculate the bottle salinity.

The measurement was conducted about from 12 to 20 hours per day and the cell was cleaned with soap after the measurement of the day. We measured more than 8,500 samples in total.

### (4) Preliminary Result

#### i. Standard Seawater

##### Leg1 and Leg2a

Standardization control was set to 649 during Leg1 and Leg2a. The value of STANDBY was  $5491 \pm 0002$  and that of ZERO was  $0.00000 \pm 0.00001$ . We used IAPSO Standard Seawater batch P150 which conductivity ratio was 0.99978 (double conductivity ratio is 1.99956) as the standard for salinity. We measured 219 bottles of P150 during routine measurement. Fig.3.2.1 shows the history of double conductivity ratio of the Standard Seawater batch P150 during Leg1 and Leg2a.

Drifts were calculated by fitting data from P150 to the equation obtained by the least square method (solid lines). Correction for the double conductivity ratio of the sample was made to compensate for the drift. After

correction, the average of double conductivity ratio became 1.99956 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity.

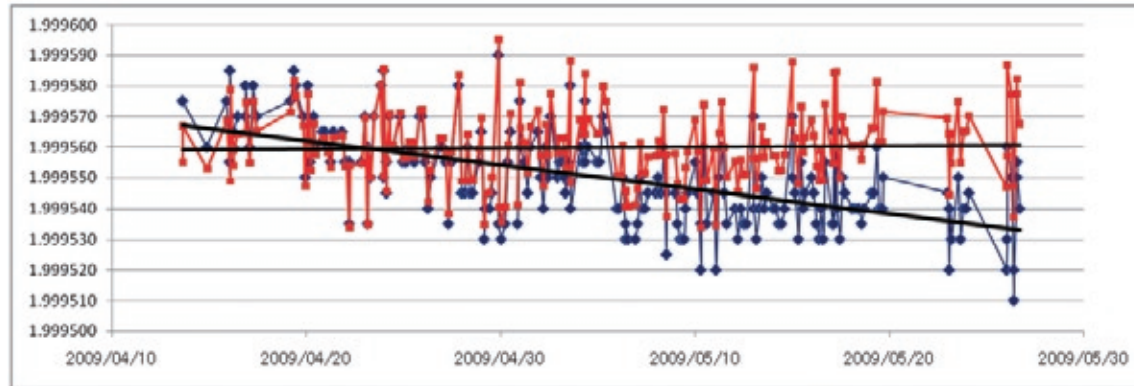


Figure 3.2.1. History of Double conductivity ratio of P150 during Leg1 and Leg2a. X and Y axes represents date and double conductivity ratio, respectively. Blue diamond is raw data and red rectangular is corrected data.

### Leg2b

As the drift of this salinometer had been significant, the re-standardization was done on 27 May, and standardization control was set to 652 during Leg2b. The value of STANDBY was  $5492 \pm 0001$  and that of ZERO was  $.00000 \pm 0.00001$ . We used IAPSO Standard Seawater batch P150 which conductivity ratio was 0.99978 (double conductivity ratio is 1.99956) as the standard for salinity. We measured 137 bottles of P150 during routine measurement. Fig.3.2.2 shows the history of double conductivity ratio of the Standard Seawater batch P150 during Leg2b.

Drifts were calculated by fitting data from P150 to the equation obtained by the least square method (solid lines). Correction for the double conductivity ration of the sample was made to compensate for the drift. After correction, the average of double conductivity ratio became 1.99956 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity.

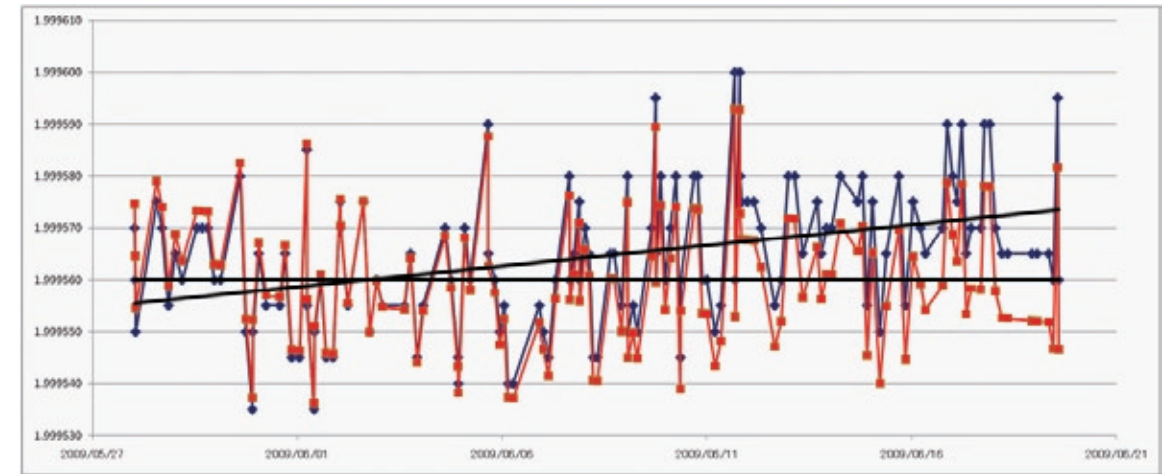


Figure 3.2.2. History of Double conductivity ratio of P150 during Leg2b. X and Y axes represents date and double conductivity ratio, respectively. Blue diamond is raw data and red rectangular is corrected data.

### ii. Sub-Standard Seawater

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

### iii. Replicate Samples

#### Leg1

We took 819 pairs of replicate during Leg1. Fig.3.2.3 shows the histogram of the absolute difference between replicate samples. There was 1 bad measurement of replicate samples. Excluding these bad measurements, the standard deviation of the absolute deference of 818 pairs of replicate samples was 0.00023 in salinity.

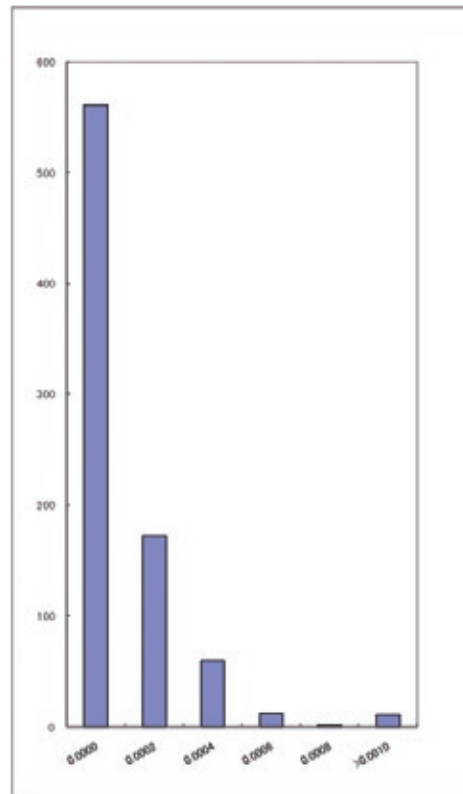


Figure 3.2.3. The histogram of the absolute difference between replicate samples in Leg1. X axis is absolute difference in salinity and Y axis is frequency.

### Leg2

We took 613 pairs of replicate during Leg2. Fig.3.2.4 shows the histogram of the absolute difference between replicate samples. There was 1 bad measurement of replicate samples. Excluding these bad measurements, the standard deviation of the absolute difference of 612 pairs of replicate samples was 0.00019 in salinity.

### (5) Further data quality check

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

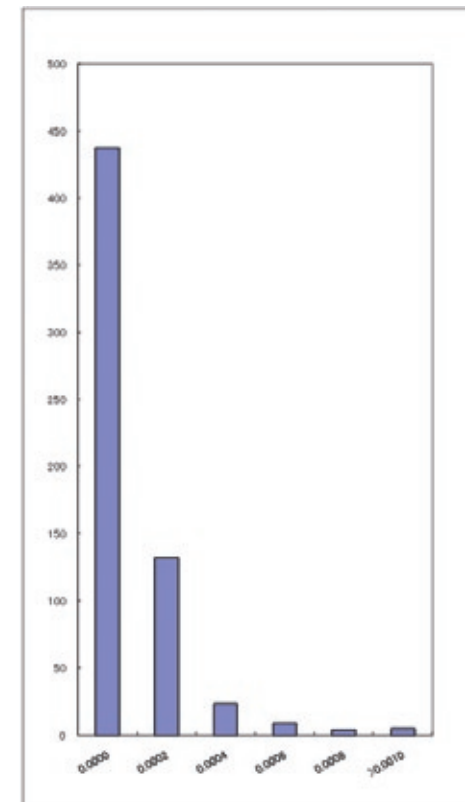


Figure 3.2.4. The histogram of the absolute difference between replicate samples in Leg2. X axis is absolute difference in salinity and Y axis is frequency.

### References

- Aoyama, M., T. Joyce, T. Kawano and Y. Takatsuki (2002): Standard seawater comparison up to P129. Deep-Sea Research, I, Vol. 49, 1103–1114.
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### 3.3 Oxygen

July 31, 2010

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#### (2) Objectives

Dissolved oxygen is one of good tracers for the ocean circulation. Recent studies indicated that the oxygen minimum layers in the tropical region have expanded (Stramma et al., 2008). Climate models predict a decline in oceanic dissolved oxygen concentration and a consequent expansion of the oxygen minimum layers under the global warming, which results mainly from decreased interior advection and ongoing oxygen consumption by remineralization. The mechanism of the decrease, however, is still unknown. During MR09-01, we measured dissolved oxygen concentration from surface to bottom layers at all the hydrocast stations along approximately 18°S in the tropical South Pacific. These stations reoccupied the WOCE Hydrographic Program (WHP) P21 stations in 1994. Our purpose is to evaluate temporal change in dissolved oxygen concentration in the tropical South Pacific between the 1994 and 2009.

#### (3) Reagents

Pickling Reagent I: Manganous chloride solution (3M)

Pickling Reagent II: Sodium hydroxide (8M) / sodium iodide solution (4M)

Sulfuric acid solution (5M)

Sodium thiosulfate (0.025M)

Potassium iodate (0.001667M)

CSK standard of potassium iodate: Lot TSK3592, Wako Pure Chemical Industries Ltd., 0.0100N

#### (4) Instruments

Burette for sodium thiosulfate and potassium iodate: APB-510 manufactured by Kyoto Electronic Co.

Ltd. / 10 cm<sup>3</sup> of titration vessel

Detector: Automatic photometric titrator, DOT-01 manufactured by Kimoto Electronic Co. Ltd.

#### (5) Seawater sampling

Following procedure is based on an analytical method, entitled by “Determination of dissolved oxygen in sea water by Winkler titration”, in the WHP Operations Manual (Dickson, 1996). Seawater samples were collected from 12-liters Niskin sampler bottles attached to the CTD-system. Seawater for bottle oxygen measurement was transferred from the Niskin sampler bottle to a volume calibrated glass flask (ca. 100 cm<sup>3</sup>). Three times volume of the flask of seawater was overflowed. Sample temperature was measured by a thermometer during the overflowing. Then two reagent solutions (Reagent I, II) of 0.5 cm<sup>3</sup> each were added immediately into the sample flask and the stopper was inserted carefully into the flask. The sample flask was then shaken vigorously to mix the contents and to disperse the precipitate finely throughout. After the precipitate has settled at least halfway down the flask, the flask was shaken again to disperse the precipitate. The sample flasks containing pickled samples were stored in a laboratory until they were titrated.

#### (6) Sample measurement

At least two hours after the re-shaking, the pickled samples were measured on board. A magnetic stirrer bar and 1 cm<sup>3</sup> sulfuric acid solution were added into the sample flask and stirring began. Samples were titrated automatically by sodium thiosulfate solution whose molarity was determined by standard solution of potassium iodate (see section 7). Temperature of sodium thiosulfate during titration was recorded by a thermometer. We measured dissolved oxygen concentration using two sets of the titration apparatus, named DOT-1 and DOT-2.

Dissolved oxygen concentration ( $\mu\text{mol kg}^{-1}$ ) was calculated by the sample temperature during the sampling, CTD salinity, flask volume, and the titrant concentration and volume corrected with burette-volume calibration. When we measured suboxic samples (oxygen concentration less than about  $40 \mu\text{mol kg}^{-1}$ ), titration procedure was adjusted manually. In case of anoxic sample measurements (oxygen concentration less than about  $6 \mu\text{mol kg}^{-1}$ ), titration volume of sodium thiosulfate titrant was not corrected with the burette-volume calibration.

### (7) Standardization

Concentration of sodium thiosulfate titrant (ca. 0.025M) was determined by potassium iodate solution. Pure potassium iodate (Lot TSK3592, Wako Pure Chemical Industries Ltd.,  $99.96 \pm 0.01\%$ ) was dried in an oven at  $130^\circ\text{C}$ . 1.7835 g potassium iodate weighed out accurately was dissolved in deionized water and diluted to final volume of  $5 \text{ dm}^3$  in a calibrated volumetric flask (0.001667M).  $10 \text{ cm}^3$  of the standard potassium iodate solution was added to a flask using a volume-calibrated dispenser. Then  $90 \text{ cm}^3$  of deionized water,  $1 \text{ cm}^3$  of sulfuric acid solution, and  $0.5 \text{ cm}^3$  of pickling reagent solution II and I were added into the flask in order. Amount of titrated volume of sodium thiosulfate (usually 5 times measurements average) gave the molarity of the sodium thiosulfate titrant (Table 3.3.1). Error (C.V.) of the standardization was  $0.02 \pm 0.01 \%$ , or c.a.  $0.05 \mu\text{mol kg}^{-1}$ .

### (8) Determination of the blank

The oxygen in the pickling reagents I ( $0.5 \text{ cm}^3$ ) and II ( $0.5 \text{ cm}^3$ ) was assumed to be  $3.8 \times 10^{-8} \text{ mol}$  (Murray *et al.*, 1968). The blank due to other than oxygen was determined as follows. 1 and  $2 \text{ cm}^3$  of the standard potassium iodate solution were added to two flasks respectively. Then  $100 \text{ cm}^3$  of deionized water,  $1 \text{ cm}^3$  of sulfuric acid solution, and  $0.5 \text{ cm}^3$  of pickling reagent solution II and I each were added into the two flasks in order. The blank was determined by difference between the two times of the first ( $1 \text{ cm}^3$  of  $\text{KIO}_3$ ) titrated volume of the sodium thiosulfate and the second ( $2 \text{ cm}^3$  of  $\text{KIO}_3$ ) one. The results of 3 times blank determinations were averaged (Table 3.3.1). The averaged blank values for DOT-1 and DOT-2 were  $-0.002 \pm 0.001$  (S.D.,  $n=27$ ) and  $-0.000 \pm 0.001$  (S.D.,  $n=27$ )  $\text{cm}^3$ , respectively. The blank determined here can cancel a sum of errors due to oxidants or reductants in the reagents, differences between the measured end-point and the equivalence point, and oxidation

of iodide to iodate with the atmospheric  $\text{O}_2$  during the titration. However, blank due to redox species other than oxygen in seawater sample, called “seawater blank”, still remains in the Winkler oxygen concentration.

Table 3.3.1. Results of the standardization and the blank determinations during MR09-01.

Date (UTC)	$\text{KIO}_3$ standard		$\text{Na}_2\text{S}_2\text{O}_3$	DOT-1		DOT-2		Stations	
	#	ID No.		E.P.	blank	E.P.	blank		
2009/4/13	11	20081203-11-02	20080704-2-1	3.957	-0.001	3.957	-0.001	029,030,031,032,040,033	
2009/4/18		20081203-11-03	20080704-2-1	3.958	0.001	3.959	0.003	-	
2009/4/18		20081203-11-04	20080704-2-2	3.958	-0.002	3.957	-0.002	-	
2009/4/21		20081203-11-05	20080704-2-2	3.956	-0.001	3.956	0.001	041,034,042,035	
2009/4/22		20081203-11-07	20080704-3-1	3.960	-0.002	3.960	-0.001	043,036,044,037,045,038,046,039	
2009/4/24		20081203-12-02	20080704-3-1	3.962	-0.002	3.962	-0.001	047,X19,049,050	
2009/4/25		20081203-12-03	20080704-3-2	3.961	-0.002	3.964	0.001	054,051,055,056,053,057,058,059,060,061,062,063,064,065	
2009/4/26		20081203-12-04	20080704-3-2	3.962	-0.002	3.961	0.000	052	
2009/4/28		12	20081203-12-06	20080704-4-1	3.963	-0.002	3.962	0.000	066,067,068,069,070,071,072,073,074,075,076,X18,077,078
2009/5/1		20081203-12-08	20080704-4-2	3.963	-0.002	3.964	-0.001	079,080,085,086,087,088,089,090,095,096,097-2,098,099,100	
2009/5/5		20081203-12-10	20080704-5-1	3.964	-0.002	3.964	0.000	101,102,103,104,105,106	
2009/5/6	13	20081203-13-01	20080704-5-1	3.962	-0.001	3.962	0.000	107,108,109,110,111,112,113,114	
2009/5/8		20081203-13-02	20080704-5-2	3.965	-0.002	3.964	-0.001	115,116,117,118,119,120,121,122,123,124,125,126,127	
2009/5/11		20081203-13-04	20080704-6-1	3.964	-0.001	3.964	0.000	128,129,130,X17,131,132,133,134,135,136,137	



Table 3.3.1. continued.

Date (UTC)	KIO <sub>3</sub> standard		Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	DOT-1		DOT-2		Stations
	#	ID No.		E.P.	blank	E.P.	blank	
2009/5/14	13	20081203-13-06	20080704-6-2	3.964	-0.002	3.964	-0.001	138,139,140,141,142,143,144,145,146,147,148,149,150,151,152
2009/5/16		20081203-13-08	20080704-7-1	3.963	-0.001	3.965	0.000	153,154,155,160,159,158,157,156
2009/5/21	14	20081203-14-01	20080704-7-2	3.963	-0.003	3.965	-0.003	164,165,X16,167,168,169,170,171,172
2009/5/26		20081203-14-03	20080704-8-1	3.968	-0.001	3.971	0.001	173,174,175,176,177,178,179,180,181,182,183
2009/5/29		20081203-14-05	20080704-8-2	3.968	-0.001	3.969	-0.001	184,185,186,187,188,189,190,191,192
2009/6/1		20081203-14-07	20080704-9-1	3.965	-0.001	3.965	-0.001	193,194,195,196,197,198,199,200,201,203,204,205
2009/6/3		20081203-14-09	20080704-9-2	3.965	-0.002	3.966	0.000	206,207,208,209,210,211,212,213
2009/6/5	15	20081203-15-01	20080704-9-2	3.963	-0.002	3.964	0.000	214,215,216,217,218,220,221,222
2009/6/6		20081203-15-03	20080704-10-1	3.975	-0.001	3.976	0.001	223,224,225,226,227,228,229,230,231,232,233
2009/6/9		20081203-15-05	20080704-10-2	3.977	-0.001	3.978	0.002	234,235,236,237,238,239,240,241,243,244,245,246
2009/6/10		20081203-15-07	20080704-11-1	3.965	-0.001	3.965	0.000	247,248,249,250,251,252,253,255,254
2009/6/13	16	20081204-16-01	20080704-11-2	3.967	-0.002	3.968	0.000	260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276
2009/6/16		20081204-16-03	20080704-12-1	3.966	-0.002	3.967	0.000	277,278,279,280,281,282,283,285,287,286,288

# Batch number of the KIO<sub>3</sub> standard solution

### (9) Replicate sample measurement

Replicate samples were taken from every CTD cast. Total amount of the replicate sample pairs of good measurement (flagged 2) was 656. The standard deviation of the replicate measurement was  $0.09 \mu\text{mol kg}^{-1}$  that was calculated by a procedure (SOP23) in DOE (1994). The replicate measurements depended on neither measurement date nor sampling depth (Fig.3.3.1). Each set of “good” data from replicate sample pairs were

averaged and then flagged 2 (see section 12).

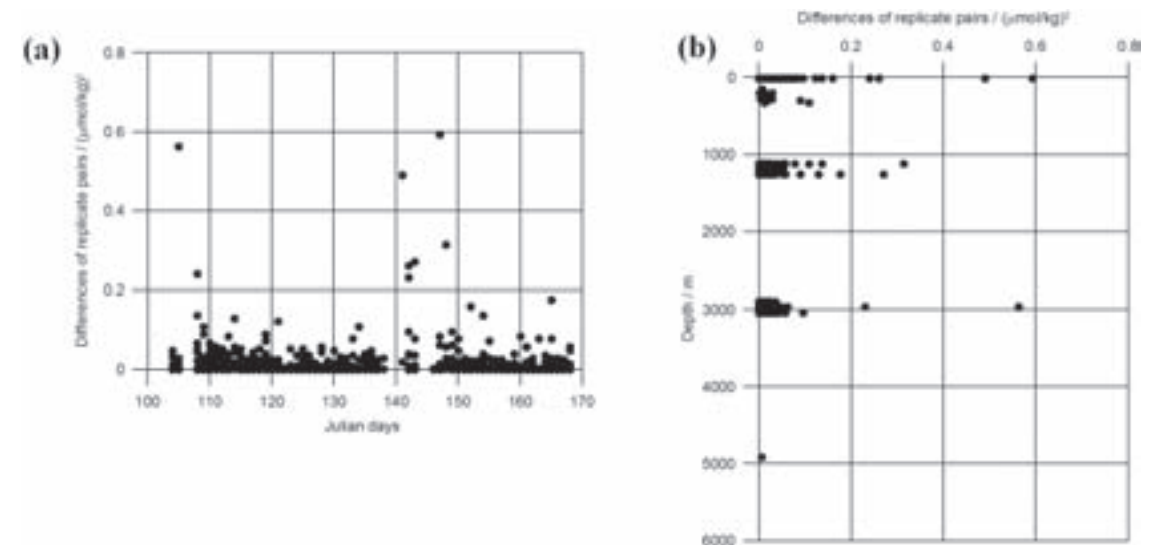


Figure 3.3.1. Differences ( $\mu\text{mol kg}^{-1}$ ) of replicate sample pairs against the Julian days (a) and sampling depth (b).

### (10) Duplicate sample measurement

Duplicate samples were taken from 27 CTD casts during this cruise. The standard deviation of the duplicate measurements was calculated to be  $0.07 \mu\text{mol kg}^{-1}$  which was equivalent with that of the replicate measurements ( $0.09 \mu\text{mol kg}^{-1}$ ). We concluded that the precision of our oxygen measurement through this cruise, including errors from the seawater sampling, pickling, and the Winkle titration, were about  $0.1 \mu\text{mol kg}^{-1}$ .

### (11) CSK standard measurements

The CSK standard is a commercial potassium iodate solution (0.0100 N) for analysis of dissolved oxygen. Before the cruise, we titrated the CSK standard solutions (Lot TSK3592) against all the six batch series (#11–#16) of our KIO<sub>3</sub> standard solution (see section 7) which had been prepared for this cruise. In addition, the CSK solution was also measured at the beginning, mid, and end of the cruise. The results of the CSK are shown in Table 3.3.2. A good agreement among them confirms that there was no systematic shift in our oxygen analyses

on board. We also confirmed that there was not difference in the results between the current (TSK3592) and former (EWL3818) batches of the CSK standard solutions which were applied to this cruise and previous ones in 2007 (MR07-04 and MR07-06), respectively. This agreement indicates comparability in the oxygen data between 2007 and 2009.

Table 3.3.2. Results of the CSK standard (Lot TSK3592) measurements.

Date (UTC)	KIO <sub>3</sub> ID No.	DOT-3		–		Remarks
		Conc. (N)	error (N)	–	–	
2008/12/08	20081203-11-12	0.010000	0.000002	–	–	before cruise
2008/12/08	20081203-12-12	0.010001	0.000002	–	–	before cruise
2008/12/08	20081203-13-12	0.010001	0.000002	–	–	before cruise
2008/12/08	20081203-14-12	0.009999	0.000002	–	–	before cruise
2008/12/08	20081203-15-12	0.009999	0.000002	–	–	before cruise
2008/12/09	20081203-16-12	0.010001	0.000003	–	–	before cruise
Date (UTC)	KIO <sub>3</sub> ID No.	DOT-1		DOT-2		Remarks
		Conc. (N)	error (N)	Conc. (N)	error (N)	
2009/04/10	20081203-11-01	0.010003	0.000002	0.010008	0.000001	MR09-01 Leg-1
2009/05/18	20081203-13-09	0.010008	0.000001	0.010003	0.000003	MR09-01 Leg-1
2009/06/18	20081204-16-04	0.010005	0.000007	0.010002	0.000002	MR09-01 Leg-2

## (12) Quality control flag assignment

Quality flag values were assigned to oxygen measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev.2 section 4.5.2 (Joyce *et al.*, 1994). Measurement flags of 2 (good), 3 (questionable), 4 (bad), and 5 (missing) have been assigned (Table 3.3.3). The replicate data were averaged and flagged 2 if both of them were flagged 2. If either of them was flagged 3 or 4, a datum with “younger” flag was selected. Thus we did not use flag of 6 (see section 9). For the choice between 2, 3, or 4, we basically followed a flagging procedure as listed below:

- a. Bottle oxygen concentration was plotted against sampling pressure. Any points not lying on a generally smooth trend were noted.
- b. Difference between the bottle oxygen and CTD oxygen was then plotted against sampling pressure. If a

datum deviated from a group of plots, it was flagged 3.

- c. Vertical transections against pressure and potential density were drawn. If a datum was anomalous on the section plots, datum flag was degraded from 2 to 3, or from 3 to 4.
- d. If there was problem in the measurement, the datum was flagged 4.
- e. If the bottle flag was 4 (did not trip correctly), a datum was flagged 4 (bad). In case of the bottle flag 3 (leaking) or 7 (unknown problem), a datum was flagged based on steps a, b, c, and d.

Table 3.3.3. Summary of assigned quality control flags.

Flag	Definition	
2	Good	6319
3	Questionable	30
4	Bad	29
5	Not report (missing)	0
Total		6378

## References

- Dickson, A. (1996): Determination of dissolved oxygen in sea water by Winkler titration, in WHPO Pub. 91-1 Rev. 1, November 1994, Woods Hole, Mass., USA.
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- Stramma, L., G.C. Johnson, J. Sprintall, and V. Mohrholz (2008): Expanding Oxygen-Minimum Zones in the Tropical Oceans, *Science*, 320, 655-668.

## 3.4 Nutrients

September 1, 2010

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*Kohei Miura (Marine Works Japan Ltd.)*

### (2) Objectives

The objectives of nutrients analyses during the R/V Mirai MR0901 cruise, WOCE P21 revisited cruise in 2009, in the North Pacific are as follows;

- Describe the present status of nutrients concentration with excellent comparability.
- The determinants are nitrate, nitrite, phosphate and silicate.
- Study the temporal and spatial variation of nutrients concentration based on the previous high quality experiments data of WOCE previous P21 cruises in 1994, GOSECS, IGY and so on.
- Study of temporal and spatial variation of nitrate: phosphate ratio, so called Redfield ratio.
- Obtain more accurate estimation of total amount of nitrate, phosphate and silicate in the interested area.
- Provide more accurate nutrients data for physical oceanographers to use as tracers of water mass movement.

### (3) Summary of nutrients analysis

We made 233 TRAACS800 runs for the samples at 243 stations in MR0901. The total amount of layers of the seawater sample reached up to 6369 for MR0901. We made duplicate measurement at all layers.

### (4) Instrument and Method

#### (4.1) Analytical detail using TRAACS 800 systems (BRAN+LUEBBE)

The phosphate analysis is a modification of the procedure of Murphy and Riley (1962). Molybdc acid is added to the seawater sample to form phosphomolybdc acid which is in turn reduced to phosphomolybdous acid using L-ascorbic acid as the reductant.

Nitrate + nitrite and nitrite are analyzed according to the modification method of Grasshoff (1970). The sample nitrate is reduced to nitrite in a cadmium tube inside of which is coated with metallic copper. The sample stream with its equivalent nitrite is treated with an acidic, sulfanilamide reagent and the nitrite forms nitrous acid which reacts with the sulfanilamide to produce a diazonium ion. N-1-Naphthylethylene-diamine added to the sample stream then couples with the diazonium ion to produce a red, azo dye. With reduction of the nitrate to nitrite, both nitrate and nitrite react and are measured; without reduction, only nitrite reacts. Thus, for the nitrite analysis, no reduction is performed and the alkaline buffer is not necessary. Nitrate is computed by difference.

The silicate method is analogous to that described for phosphate. The method used is essentially that of Grasshoff et al. (1983), wherein silicomolybdc acid is first formed from the silicate in the sample and added molybdc acid; then the silicomolybdc acid is reduced to silicomolybdous acid, or "molybdenum blue," using ascorbic acid as the reductant. The analytical methods of the nutrients during this cruise are same as the methods used in (Kawano et al. 2009). We, though, changed the rate of NED in channel 2 from WHT/WHT to RED/RED to increase stability of the analysis. We also made slight change in NED reagent that we add Triton(R) X-100 as shown in (4.3) Nitrite Regents. The flow diagrams and reagents for each parameter are shown in Figures 3.4.1 to 3.4.4.

#### (4.2) Nitrate Reagents

Imidazole (buffer), 0.06 M (0.4 % w/v)

Dissolve 4 g imidazole,  $C_3H_4N_2$ , in ca. 1000 ml DIW; add 2 ml concentrated HCl. After mixing, 1 ml Triton(R) X-100 (50 % solution in ethanol) is added.

Sulfanilamide, 0.06 M (1 % w/v) in 1.2M HCl

Dissolve 10 g sulfanilamide,  $4-NH_2C_6H_4SO_3H$ , in 900 ml of DIW, add 100 ml concentrated HCl. After mixing, 2 ml Triton(R)X-100 (50 % solution in ethanol) is added.

N-1-Naphthylethylene-diamine dihydrochloride, 0.004 M (0.1 % w/v)

Dissolve 1 g NEDA,  $C_{10}H_7NHCH_2CH_2NH_2 \cdot 2HCl$ , in 1000 ml of DIW and add 10 ml concentrated HCl. After mixing, 1 ml Triton(R)X-100 (50 % solution in ethanol) is added.

Stored in a dark bottle.

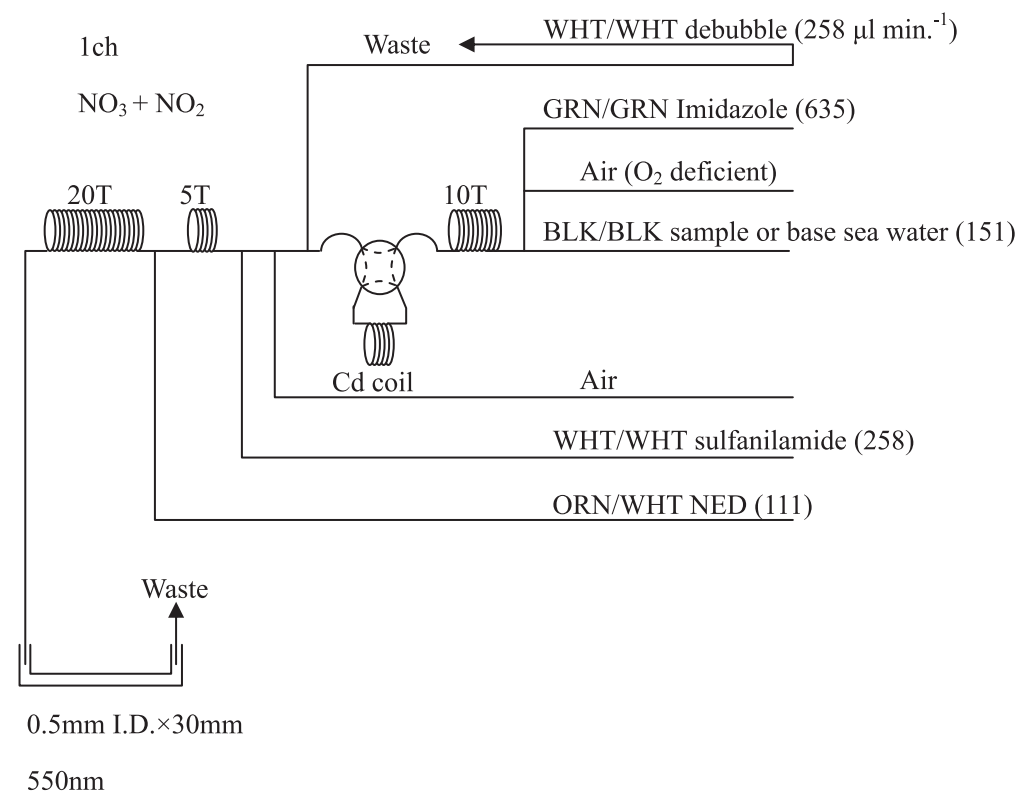


Figure 3.4.1. 1ch. ( $NO_3+NO_2$ ) Flow diagram

#### (4.3) Nitrite Reagents

Sulfanilamide, 0.06 M (1 % w/v) in 1.2 M HCl

Dissolve 10g sulfanilamide,  $4-NH_2C_6H_4SO_3H$ , in 900 ml of DIW, add 100 ml concentrated HCl. After mixing, 2 ml Triton(R)X-100 (50 % solution in ethanol) is added.

N-1-Naphthylethylene-diamine dihydrochloride, 0.004 M (0.1 % w/v)

Dissolve 1 g NEDA,  $C_{10}H_7NHCH_2CH_2NH_2 \cdot 2HCl$ , in 1000 ml of DIW and add 10 ml concentrated HCl.

After mixing, 1 ml Triton(R)X-100 (50 % solution in ethanol) is added.

Stored in a dark bottle.

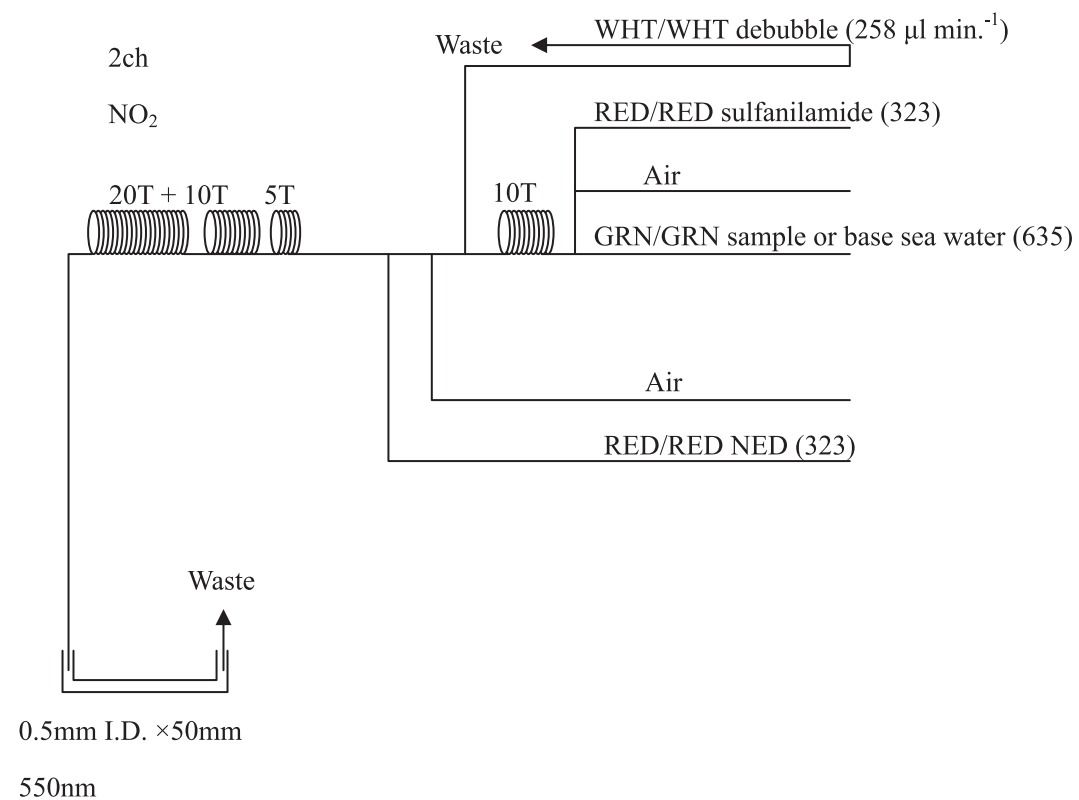


Figure 3.4.2. 2ch. (NO<sub>2</sub>) Flow diagram

#### (4.4) Silicate Reagents

Molybdic acid, 0.06 M (2 % w/v)

Dissolve 15 g Disodium Molybdate(VI) Dihydrate, Na<sub>2</sub>MoO<sub>4</sub> · 2H<sub>2</sub>O, in 980 ml DIW, add 8 ml concentrated H<sub>2</sub>SO<sub>4</sub>. After mixing, 20 ml sodium dodecyl sulphate (15 % solution in water) is added.

Oxalic acid, 0.6 M (5 % w/v)

Dissolve 50 g Oxalic Acid Anhydrous, HOOC: COOH, in 950 ml of DIW.

Ascorbic acid, 0.01 M (3 % w/v)

Dissolve 2.5 g L (+)-Ascorbic Acid, C<sub>6</sub>H<sub>8</sub>O<sub>6</sub>, in 100 ml of DIW. Stored in a dark bottle and freshly prepared before every measurement.

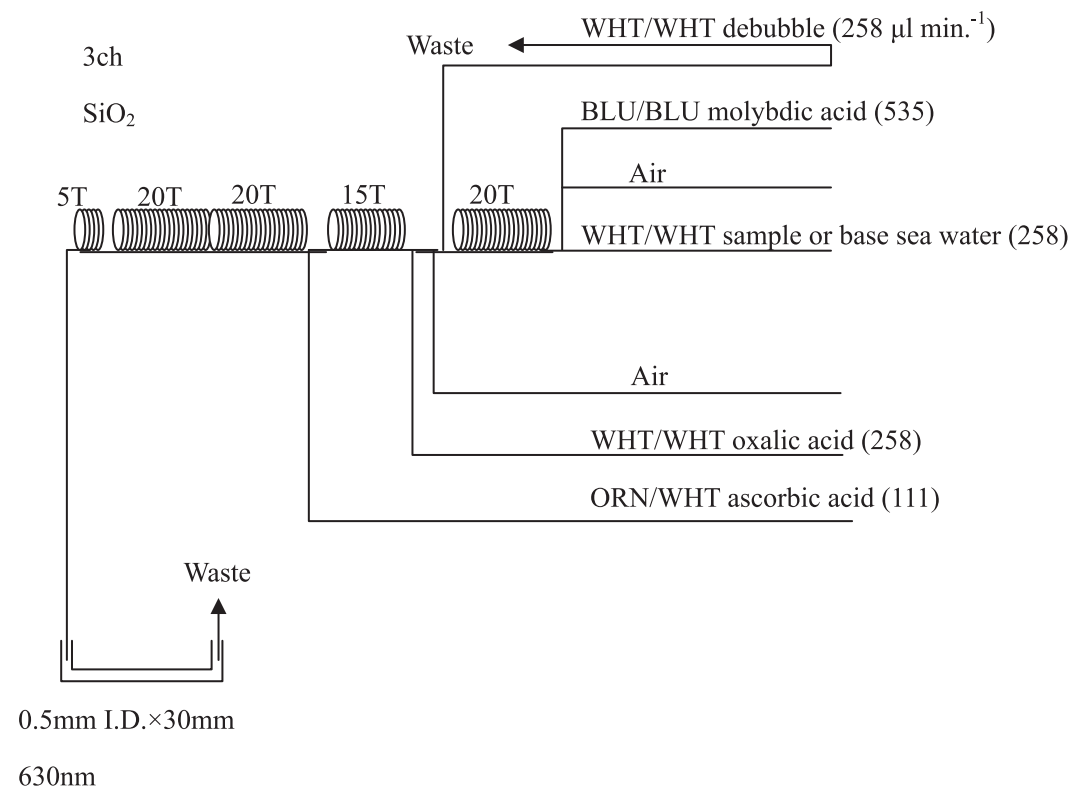


Figure 3.4.3. 3ch. (SiO<sub>2</sub>) Flow diagram.

#### (4.5) Phosphate Reagents

Stock molybdate solution, 0.03 M (0.8 % w/v)

Dissolve 8 g Disodium Molybdate(VI) Dihydrate, Na<sub>2</sub>MoO<sub>4</sub> · 2H<sub>2</sub>O, and 0.17 g Antimony Potassium Tartrate, C<sub>8</sub>H<sub>4</sub>K<sub>2</sub>O<sub>12</sub>Sb<sub>2</sub> · 3H<sub>2</sub>O, in 950 ml of DIW and add 50 ml concentrated H<sub>2</sub>SO<sub>4</sub>.

Mixed Reagent

Dissolve 0.8 g L (+)-Ascorbic Acid, C<sub>6</sub>H<sub>8</sub>O<sub>6</sub>, in 100 ml of stock molybdate solution. After mixing, 2 ml sodium

dodecyl sulphate (15 % solution in water) is added. Stored in a dark bottle and freshly prepared before every measurement.

Reagent for sample dilution

Dissolve Sodium Hydrate, NaCl, 10 g in ca. 950 ml of DIW, add 50 ml Acetone and 4 ml concentrated H<sub>2</sub>SO<sub>4</sub>.

After mixing, 5 ml sodium dodecyl sulphate (15 % solution in water) is added.

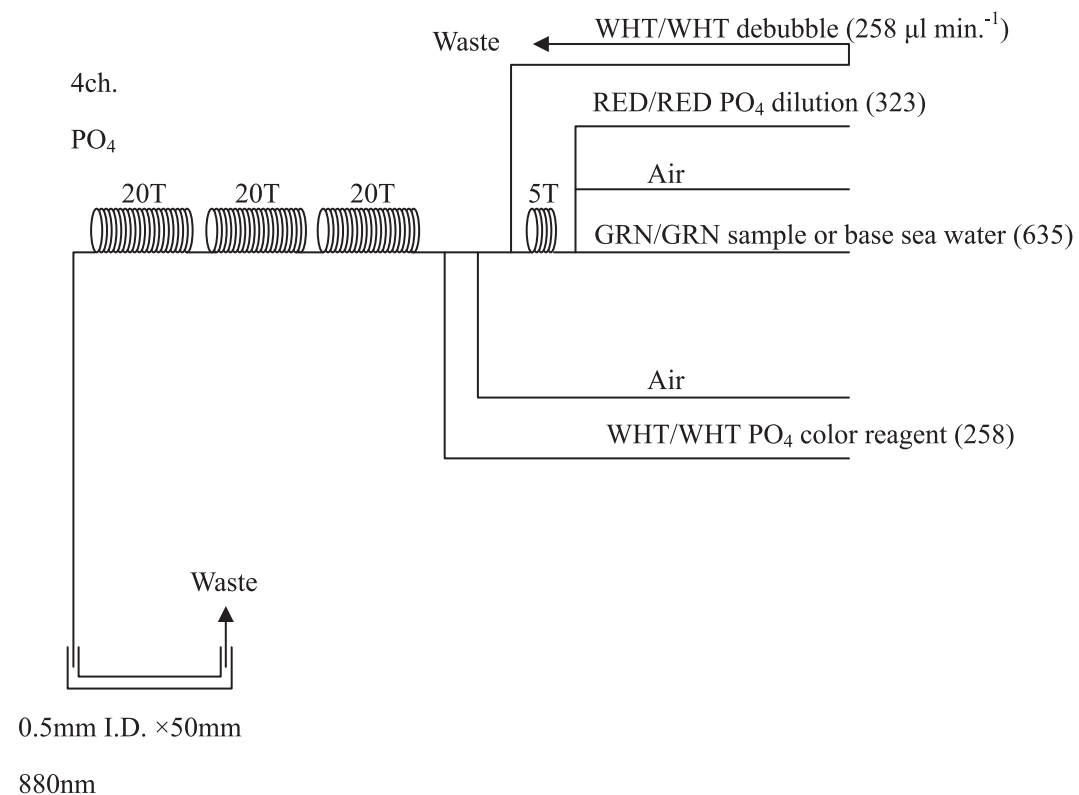


Figure 3.4.4. 4ch. (PO<sub>4</sub>) Flow diagram.

#### (4.6) Sampling procedures

Sampling of nutrients followed that oxygen, trace gases and salinity. Samples were drawn into two of virgin 10 ml polyacrylates vials without sample drawing tubes. These were rinsed three times before filling and vials

were capped immediately after the drawing. The vials are put into water bath adjusted to ambient temperature, 25 ± 1 °C, in 10 to 20 minutes before use to stabilize the temperature of samples in MR0901.

No transfer was made and the vials were set an auto sampler tray directly. Samples were analyzed after collection basically within 17 hours in MR0901.

#### (4.7) Data processing

Raw data from TRAACS800 were treated as follows;

- Check baseline shift.
- Check the shape of each peak and positions of peak values taken, and then change the positions of peak values taken if necessary.
- Carry-over correction and baseline drift correction were applied to peak heights of each samples followed by sensitivity correction.
- Baseline correction and sensitivity correction were done basically using liner regression.
- Load pressure and salinity from CTD data to calculate density of seawater.
- Calibration curves to get nutrients concentration were assumed second order equations.

#### (5) Nutrients standards

##### (5.1) Volumetric Laboratory Ware of in-house standards

All volumetric glass ware and polymethylpentene (PMP) ware used were gravimetrically calibrated. Plastic volumetric flasks were gravimetrically calibrated at the temperature of use within 0 to 4 K.

##### Volumetric flasks

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



within 0 to 4 K of the calibration temperature.

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

Because of their larger temperature coefficients of cubical expansion and lack of tables constructed for these materials, the plastic volumetric flasks were gravimetrically calibrated over the temperature range of intended use and used at the temperature of calibration within 0 to 4 K. The weights obtained in the calibration weightings were corrected for the density of water and air buoyancy.

#### Pipettes and pipettors

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

#### (5.2) Reagents, general considerations

##### Specifications

For nitrate standard, “potassium nitrate 99.995 suprapur” provided by Merck, CAS No. : 7757-91-1, was used.

For phosphate standard, “potassium dihydrogen phosphate anhydrous 99.995 suprapur” provided by Merck, CAS No. : 7778-77-0, was used.

For nitrite standard, “sodium nitrate” provided by Wako, CAS No. : 7632-00-0, was used. And assay of nitrite was determined according JIS K8019 and assays of nitrite salts were 98.04 %. We use that value to adjust the weights taken.

For the silicate standard, we use “Silicon standard solution SiO<sub>2</sub> in NaOH 0.5 mol/l CertiPUR” provided by Merck, CAS No. : 1310-73-2, of which lot number is HC751838 is used. The silicate concentration is certified by NIST-SRM3150 with the uncertainty of 0.5 %.

#### Ultra pure water

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

#### Low-Nutrient Seawater (LNSW)

Surface water having low nutrient concentration was taken and filtered using 0.45 μm pore size membrane filter. This water is stored in 20 liter cubitainer with paper box. The concentrations of nutrient of this water were measured carefully in Jul 2008.

#### (5.3) Concentrations of nutrients for A, B and C standards

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

The calibration curves for each run were obtained using 6 levels, C-1, C-2, C-3, C-4, C-5 and C-6. For the 10 stations from station 233 to station 245, we used only five levels, from C-1 to C-5 because silicate concentration of C-6 for these stations might be higher rather than target concentration. For the 19 runs, we used only five levels because nutrients concentration of one of the RMs was outlier.

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

	A	B	C-1	C-2	C-3	C-4	C-5	C-6
NO <sub>3</sub> (μM)	45000	900	AS	BJ	AX	BE	AZ	55
NO <sub>2</sub> (μM)	4000	20	AS	BJ	AX	BE	AZ	1.2
SiO <sub>2</sub> (μM)	36000	2880	AS	BJ	AX	BE	AZ	170
PO <sub>4</sub> (μM)	3000	60	AS	BJ	AX	BE	AZ	3.6

Table 3.4.2. Working calibration standard recipes.

C Std.	B-1 Std.	B-2 Std.
C-6	30 ml	30 ml

B-1 Std.: Mixture of nitrate, silicate and phosphate

B-2 Std.: Nitrite

**(5.4) Renewal of in-house standard solutions.**

In-house standard solutions as stated in (iii) were renewed as shown in Table 3.4.3(a) to (c).

Table 3.4.3(a). Timing of renewal of in-house standards.

NO <sub>3</sub> , NO <sub>2</sub> , SiO <sub>2</sub> , PO <sub>4</sub>	Renewal
A-1 Std. (NO <sub>3</sub> )	maximum 1 month
A-2 Std. (NO <sub>2</sub> )	maximum 1 month
A-3 Std. (SiO <sub>2</sub> )	commercial prepared solution
A-4 Std. (PO <sub>4</sub> )	maximum 1 month
B-1 Std. (mixture of NO <sub>3</sub> , SiO <sub>2</sub> , PO <sub>4</sub> )	8 days
B-2 Std. (NO <sub>2</sub> )	8 days

Table 3.4.3(b). Timing of renewal of in-house standards.

C Std.	Renewal
C-6 Std. (mixture of B-1 and B-2 Std.)	24 hours

Table 3.4.3(c). Timing of renewal of in-house standards.

Reduction estimation	Renewal
D-1 Std.(7200µM NO <sub>3</sub> )	when A-1 Std. renewed
43µM NO <sub>3</sub>	when C Std. renewed
47µM NO <sub>2</sub>	when C Std. renewed

**(6) Reference material of nutrients in seawater**

To get the more accurate and high quality nutrients data to achieve the objectives stated above, huge numbers of the bottles of the reference material of nutrients in seawater (hereafter RMNS) are prepared (Aoyama et al., 2006, 2007, 2008). In the previous world wide expeditions, such as WOCE cruises, the higher reproducibility and precision of nutrients measurements were required (Joyce and Corry, 1994). Since no standards were available for the measurement of nutrients in seawater at that time, the requirements were described in term of reproducibility. The required reproducibility was 1 %, 1 to 2 %, 1 to 3 % for nitrate, phosphate and silicate, respectively. Although nutrient data from the WOCE one-time survey was of unprecedented quality and coverage due to much care in sampling and measurements, the differences of nutrients concentration at crossover points are still found among the expeditions (Aoyama and Joyce, 1996, Mordy et al., 2000, Gouretski and Jancke, 2001). For instance, the mean offset of nitrate concentration at deep waters was 0.5 µmol kg<sup>-1</sup> for 345 crossovers at world oceans, though the maximum was 1.7 µmol kg<sup>-1</sup> (Gouretski and Jancke, 2001). At the 31 crossover points in the Pacific WHP one-time lines, the WOCE standard of reproducibility for nitrate of 1 % was fulfilled at about half of the crossover points and the maximum difference was 7 % at deeper layers below 1.6 °C in potential temperature (Aoyama and Joyce, 1996).

**(6.1) RMNSs for this cruise**

RMNS lots AS, BJ, AX, BE and AZ, which cover full range of nutrients concentrations in the western North Pacific Ocean are prepared. 160 sets of AS, BJ, AX, BE and AZ are prepared.

Three hundred ten bottles of RMNS lot BI and 200 bottles of RMNS lot AV are prepared for MR0901. Lot BI was used at 99 stations from 14 to 120 and lot AV was used at 158 stations from 121 to 288, respectively. These RMNS assignment were completely done based on random number. The RMNS bottles were stored at a room in the ship, REAGENT STORE, where the temperature was maintained around 24 °C.

### (6.2) Assigned concentration for RMNSs

We assigned nutrients concentrations for RMNS lots AS, BJ, AX, BE, AZ, BI and AV as shown in Table 3.4.4.

Table 3.4.4. Assigned concentration of RMNSs.

	unit: $\mu\text{mol kg}^{-1}$			
	Nitrate	Phosphate	Silicate	Nitrite
AS*	0.11	0.077	1.58	0.02
BJ*	7.74	0.628	31.04	0.02
AX**	21.42	1.619	58.06	0.35
BE*	36.70	2.662	99.20	0.03
AZ*	42.36	3.017	133.93	0.03
BI*	41.36	2.576	147.51	0.02
AV**	33.36	2.516	154.14	0.10

\* The value in the Table is result of measurement on 6 January, 2009.

\*\* The value in the Table is result of measurement on 7 October, 2007.

### (6.3) The homogeneity of RMNSs

The homogeneity of lot AV and AZ used in MR0901 cruise and analytical precisions are shown in Table 3.4.5. These are for the assessment of the magnitude of homogeneity of the RMNS bottles those are used during the cruise. As shown in Table 3.4.5 homogeneity of RMNS lot AV and AZ for nitrate, phosphate and silicate are the same magnitude of analytical precision derived from fresh raw seawater in January 2009.

Table 3.4.5. Homogeneity of lot AV and AZ derived from simultaneous 297 samples measurements and analytical precision onboard R/V Mirai in MR0901.

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
AV	0.09	0.12	0.08
AZ	0.13	0.15	0.08
Precision	0.08	0.10	0.07

AV: N=297 AZ: N=244

We can see history of homogeneity of several lots of RMNS as shown in Table 3.4.6. The homogeneity of phosphate in old lots such as lot AH and K were relatively larger than those of recent lots, BI and BC. The homogeneities of nitrate and silicate, we also see progress from lot K to recent lots.

Table 3.4.6. History of homogeneity of lot BI and previous lots derived from simultaneous 30 samples measurements and analytical precision onboard R/V Mirai in January 2009.

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
BI	0.19	0.21	0.08
BC*	0.22	0.32	0.19
AH*	0.39	0.83	0.13
K*	0.3	1.0	0.2
Precision	0.18	0.14	0.07

\* Table 3.4.5 in WHP P01, P14 REVISIT DATA BOOK (Kawano et al. 2009)

**(6.4) Comparability of RMNSs during the periods from 2003 to 2009**

Cruise-to-cruise comparability has examined based on the results of the previous results of RMNSs measurements obtained among cruises, and RMNS international comparison experiments in 2003 and 2009. The uncertainties for each value were obtained similar method described in 7.1 in this chapter at the measurement before each cruise and inter-comparison study, shown as precruise and intercomparison, and mean of uncertainties during each cruise, only shown cruise code, respectively. As shown in Table 3.4.7, the nutrients concentrations of RMNSs were in good agreement among the measurements during the period from 2003 to 2009. For the silicate measurements, we show lot numbers and chemical company names of each cruise/ measurement in the footnote. As shown in Table 3.4.7, there shows less comparability among the measurements due to less comparability among the standard solutions provided by chemical companies in the silicate measurements.

Table 3.4.7 (a). Comparability for nitrate.

unit:  $\mu\text{mol kg}^{-1}$

Cruise / Lab.	RM Lots													
	AH	unc.	AZ	unc.	BA	unc.	AX	unc.	AV	unc.	BC	unc.	BE	unc.
Nitrate														
2003														
2003intercomp_repeorted	35.23	0.06					21.39							
MR03-K04 Leg1	35.25													
MR03-K04 Leg2	35.37													
MR03-K04 Leg4	35.37													
MR03-K04 Leg5	35.34													
2005														
MR05-02			42.30		0.07	0.02	21.45	0.07	33.35	0.06	40.70	0.06		
MR05-05_1 precruise	35.65	0.05	42.30	0.10	0.07	0.00	21.41	0.01	33.41	0.02	40.76	0.03		
MR05-05_1			42.33		0.07	0.01	21.43	0.05	33.36	0.05	40.73	0.85		
MR05-05_2 precruise			42.33		0.08	0.00	21.39	0.02	33.36	0.05	40.72	0.03		
MR05-05_2			42.34		0.07	0.01	21.44	0.05	33.36	0.05	40.73	0.06		
MR05-05_3 precruise			42.35		0.06	0.00	21.49	0.01	33.39	0.01	40.79	0.01		
MR05-05_3			42.36		0.07	0.01	21.44	0.04	33.37	0.05	40.75	0.05		
2006														
2006intercomp			42.24	0.04	0.04	0.00	21.40	0.02	33.32	0.03	40.63	0.04		
2003intercomp_revisit	35.40	0.03												
2007														
MR07-04_1 precruise	35.74	0.03			0.07	0.00	21.59	0.02	33.49	0.03	40.83	0.03		
MR07-04_2 precruise	35.80	0.01			0.08	0.00	21.60	0.01	33.47	0.01	40.92	0.02		

Cruise / Lab.	RM Lots													
	AH	unc.	AZ	unc.	BA	unc.	AX	unc.	AV	unc.	BC	unc.	BE	unc.
	Nitrate													
MR07-04					0.08	0.01	21.41	0.06	33.38	0.05	40.77	0.05		
MR07-06_1 precruise	35.61	0.02			0.07	0.00	21.44	0.01	33.43	0.02	40.79	0.02		
MR07-06_2 precruise	35.61	0.04			0.06	0.00	21.43	0.02	33.54	0.04	40.79	0.05		
MR07-06_1					0.08	0.01	21.44	0.03	33.41	0.05	40.81	0.04		
MR07-06_2					0.09	0.01	21.44	0.03	33.39	0.06	40.81	0.04		
	2008													
2008intercomp_report					0.08	0.00	21.44	0.02						
2006intercomp_revisit			42.27	0.04	0.07	0.00	21.47	0.02	33.34	0.03				
2003intercomp_revisit	35.35	0.04												
	2009													
MR09-01_0 precruise			42.36	0.02	0.07	0.00	21.43	0.01	33.42	0.02	40.81	0.02	36.70	0.02
MR09-01_1			42.42	0.06	0.11	0.01	21.51	0.04	33.53	0.04	40.82	0.11	36.74	0.04
MR09-01_2			42.43	0.05			21.54	0.03	33.53	0.03			36.74	0.03
INSS stability test_1	35.76	0.22			0.08	0.01	21.49	0.02	33.45	0.03				

Table 3.4.7 (b). Comparability for nitrate.

unit:  $\mu\text{mol kg}^{-1}$

Cruise / Lab.	RM Lots													
	AH	unc.	AZ	unc.	BA	unc.	AX	unc.	AV	unc.	BC	unc.	BE	unc.
	Phosphate													
	2003													
2003intercomp	2.141	0.001												
MR03-K04 Leg1	2.110													
MR03-K04 Leg2	2.110													
MR03-K04 Leg4	2.110													
MR03-K04 Leg5	2.110													
	2005													
MR05-02			3.010		0.061	0.010	1.614	0.008	2.515	0.008	2.778	0.010		
MR05-05_1 precruise	2.148	0.006	3.020	0.010	0.045	0.000	1.620	0.001	2.517	0.002	2.781	0.002		
MR05-05_1			3.016		0.063	0.007	1.615	0.006	2.515	0.007	2.778	0.033		
MR05-05_2 precruise			3.015		0.066	0.000	1.608	0.001	2.510	0.001	2.784	0.002		
MR05-05_2			3.018		0.064	0.005	1.614	0.004	2.515	0.005	2.782	0.006		
MR05-05_3 precruise			3.020		0.060	0.000	1.620	0.001	2.517	0.002	2.788	0.002		
MR05-05_3			3.016		0.061	0.004	1.618	0.005	2.515	0.004	2.779	0.008		
	2006													
2006intercomp			3.018	0.002	0.071	0.000	1.623	0.001	2.515	0.001	2.791	0.001		
2003intercomp_revisit	2.141	0.001												
	2007													
MR07-04_1 precruise	2.140	0.002			0.062	0.000	1.620	0.001	2.512	0.002	2.782	0.002		
MR07-04_2 precruise	2.146	0.002			0.056	0.000	1.620	0.001	2.517	0.002	2.788	0.002		

Cruise / Lab.	RM Lots													
	AH	unc.	AZ	unc.	BA	unc.	AX	unc.	AV	unc.	BC	unc.	BE	unc.
	Phosphate													
MR07-04_2 precruise	2.146	0.002			0.056	0.000	1.620	0.001	2.517	0.002	2.788	0.002		
MR07-04					0.066	0.004	1.617	0.005	2.513	0.004	2.781	0.007		
MR07-06_1 precruise	2.144	0.001			0.066	0.000	1.617	0.001	2.517	0.001	2.790	0.001		
MR07-06_2 precruise	2.146	0.002			0.067	0.000	1.620	0.001	2.517	0.002	2.789	0.002		
MR07-06_1					0.064	0.004	1.620	0.003	2.515	0.003	2.783	0.005		
MR07-06_2					0.066	0.004	1.619	0.005	2.515	0.003	2.785	0.006		
2008														
2008intercomp_report					0.068	0.000	1.615	0.005						
2006intercomp_revisit			3.014	0.008	0.065	0.000	1.627	0.005	2.513	0.007				
2003intercomp_revisit	2.131	0.006												
2009														
MR09-01_0 precruise			3.017	0.001	0.074	0.000	1.619	0.001	2.520	0.001	2.790	0.001	2.662	0.001
MR09-01_1			3.019	0.005	0.072	0.002	1.623	0.004	2.528	0.003	2.783	0.004	2.668	0.005
MR09-01_2			3.018	0.004			1.625	0.003	2.527	0.003			2.668	0.003
INSS stability test_1	2.134	0.008			0.069	0.001	1.606	0.001	2.512	0.003				

Table 3.4.7 (C). Comparability for phosphate.

unit:  $\mu\text{mol kg}^{-1}$

Cruise	RM Lots													
	AH	unc.	AZ	unc.	BA	unc.	AX	unc.	AV	unc.	BC	unc.	BE	unc.
	Silicate													
2003														
2003intercomp *	130.51	0.20												
MR03-K04 Leg1 **	132.01													
MR03-K04 Leg2 **	132.26													
MR03-K04 Leg4 **	132.28													
MR03-K04 Leg5 **	132.19													
2005														
MR05-02 #			133.69		1.61	0.05	58.04	0.11	153.92	0.19	155.93	0.19		
MR05-05_1 precruise **	132.49	0.13	133.77	0.02	1.51	0.00	58.06	0.03	153.97	0.09	156.55	0.09		
MR05-05_1 **			133.79		1.59	0.07	58.01	0.12	154.01	0.26	156.08	0.36		
MR05-05_2 precruise **			133.78		1.58	0.00	57.97	0.04	154.07	0.09	156.21	0.10		
MR05-05_2 **			133.88		1.59	0.06	58.00	0.09	154.05	0.16	156.14	0.15		
MR05-05_3 precruise **			134.02		1.57	0.00	58.05	0.05	154.07	0.14	156.11	0.14		
MR05-05_3 **			133.79		1.60	0.05	57.98	0.09	153.98	0.18	156.08	0.13		
2006														
2006intercomp <sup>s</sup>			133.83	0.07	1.64	0.00	58.20	0.03	154.16	0.08	156.31	0.08		
2003intercomp_revisit <sup>s</sup>	132.55	0.07												
2007														
MR07-04_1 precruise <sup>ss</sup>	133.38	0.06			1.61	0.00	58.46	0.03	154.82	0.07	156.98	0.07		
MR07-04_2 precruise <sup>ss</sup>	133.15	0.12			1.69	0.00	58.44	0.05	154.87	0.14	156.86	0.14		



Cruise	RM Lots													
	AH	unc.	AZ	unc.	BA	unc.	AX	unc.	AV	unc.	BC	unc.	BE	unc.
	Silicate													
MR07-04 <sup>ss</sup>					1.62	0.07	58.11	0.11	154.45	0.21	156.62	0.48		
MR07-06_1 precruise <sup>ss</sup>	133.02	0.09			1.64	0.00	58.50	0.04	155.06	0.11	156.33	0.11		
MR07-06_2 precruise <sup>ss</sup>	132.70	0.07			1.56	0.00	58.25	0.03	154.39	0.08	156.57	0.08		
MR07-06_1 <sup>ss</sup>					1.61	0.04	58.13	0.08	154.48	0.13	156.64	0.08		
MR07-06_2 <sup>ss</sup>					1.58	0.07	58.04	0.10	154.38	0.16	156.61	0.13		
2008														
2008intercomp <sup>¥</sup>					1.64	0.00	58.17	0.05						
2006intercomp_re <sup>¥</sup>			134.11	0.11	1.65	0.00	58.26	0.05	154.36	0.12				
2003intercomp_re <sup>¥</sup>	132.11	0.11												
2009														
MR09-01_0 precruise <sup>¥</sup>			133.93	0.04	1.57	0.00	58.06	0.02	154.23	0.05	156.16	0.05	99.20	0.03
MR09-01_1 <sup>¥</sup>			133.97	0.11	1.34	0.11	58.15	0.08	154.48	0.09	155.89	0.13	99.24	0.08
MR09-01_2 <sup>¥</sup>			133.96	0.11			58.19	0.08	154.42	0.12			99.23	0.08
INSS stability test_1 <sup>¥¥</sup>	132.40	0.35			1.69	0.02	58.18	0.02	154.43	0.09				

List of lot numbers: \*: Kanto 306F9235; \*\*: Kanto 402F9041; #: Kanto 507F9205; ##: Kanto 609F9157; \$: Merck OC551722; \$\$: Merck HC623465; ¥: Merck HC751838; ¥¥: HC814662

## (7) Quality control

### (7.1) Precision of nutrients analyses during the cruise

Precision of nutrients analyses during the cruise was evaluated based on the 9 to 11 measurements, which are measured every 10 to 13 samples, during a run at the concentration of C-6 std. There is exception for the number of the measurements that are used to evaluate analytical precision of silicate at 10 runs from stations 233 to 245 where we evaluate analytical precision based on 6 to 8 measurements. Summary of precisions are

shown as shown in Table 3.4.8 and Figures 3.4.5 to 3.4.7, the precisions for each parameter are generally good considering the analytical precisions estimated from the simultaneous analyses of 14 samples in January 2009 as shown in Table 3.4.6. Analytical precisions previously evaluated were 0.18 % for nitrate, 0.14 % for phosphate and 0.08 % for silicate, respectively. During this cruise, analytical precisions were 0.08 % for nitrate, 0.10 % for phosphate and 0.07 % for silicate in terms of median of precision, respectively. Then we can conclude that the analytical precisions for nitrate, phosphate and silicate were maintained throughout this cruise. The time series of precision are shown in Figures 3.4.5 to 3.4.7.

Table 3.4.8. Summary of precision based on the replicate analyses.

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
Median	0.08	0.10	0.07
Mean	0.08	0.10	0.08
Maximum	0.18	0.17	0.14
Minimum	0.02	0.04	0.02
N	265	265	263

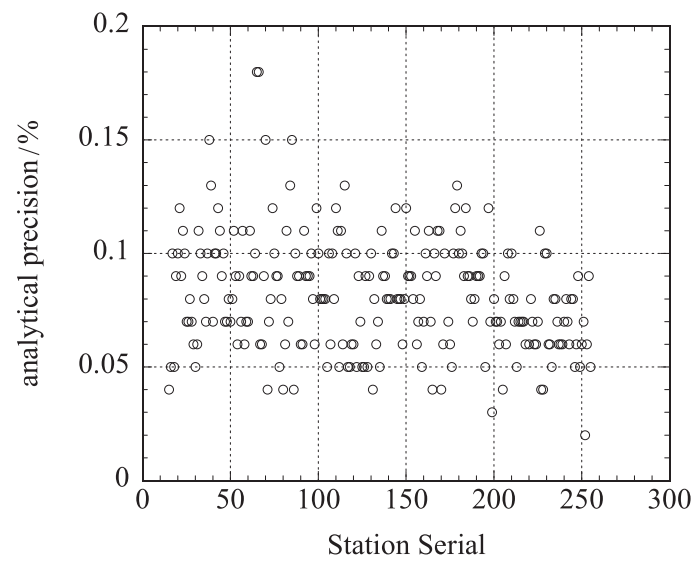


Figure 3.4.5. Time series of precision of nitrate for MR0901.

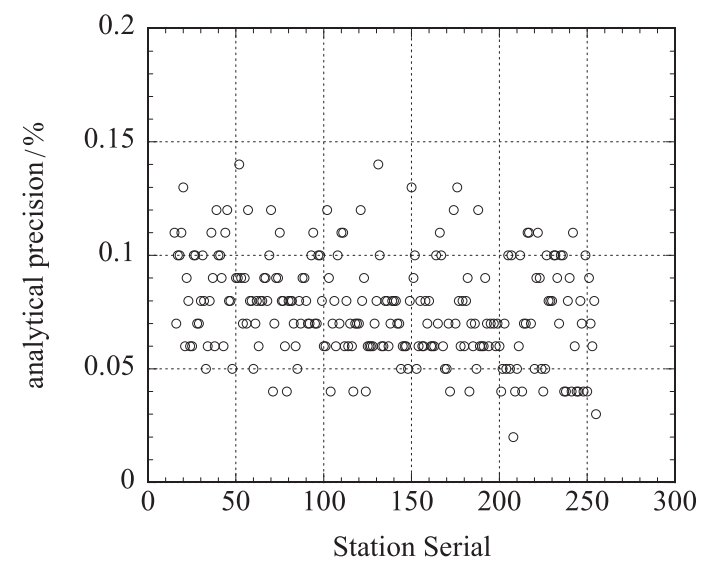


Figure 3.4.7. Time series of precision of silicate for MR0901.

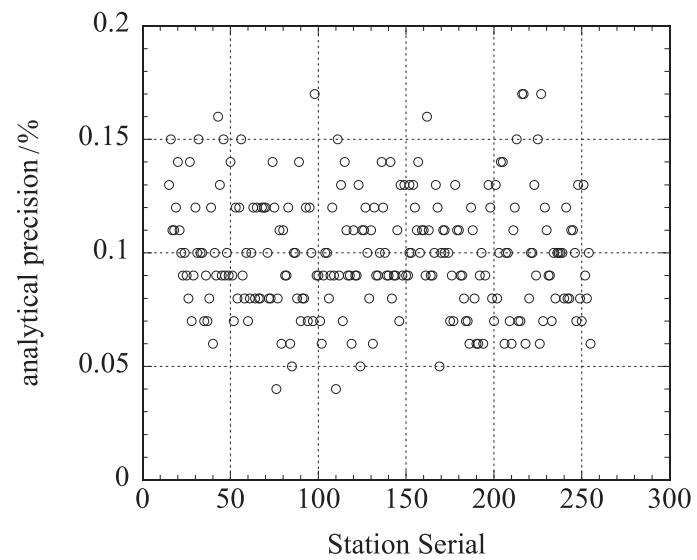


Figure 3.4.6. Time series of precision of phosphate for MR0901.

### (7.2) Carry over

We can also summarize the magnitudes of carry over throughout the cruise. These are small enough within acceptable levels as shown in Table 3.4.10.

Table 3.4.10. Summary of carry over through out MR0901 cruise.

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
Median	0.21	0.24	0.20
Mean	0.21	0.23	0.20
Maximum	0.38	0.53	0.33
Minimum	0.03	0.01	0.03
N	237	237	237

### (7.3) Dilution for shallower samples by lot AZ.

We decided to dilute 41 samples from shallower layers as shown Table 3.4.11 due to higher nitrite concentration which exceed  $2 \mu\text{mol kg}^{-1}$ . We add 5.060 ml of lot AZ to 0.504 ml of sample. Therefore, uncertainties of the nutrients concentration of diluted samples were larger compared with non-diluted samples.

Table 3.4.11. Summary of diluted samples.

Station	Pressure (dbar)
29	10, 50, 100, 150, 200, 250, 280
30	10, 50, 100, 150, 200, 250, 300
31	10, 50, 100, 150, 200, 250, 330
32	150, 200, 250, 280
35	280
40	150, 200, 250, 300
41	250, 280
43	250, 300
46	200, 250
51	100
67	100
68	100
143	150
144	150

### (7.4) Possible concentration change of lot AV

We found that nutrients concentrations of RM-AV were about 0.5% higher rather than those we assigned before cruise as shown in Table 3.4.4. The reasons of this increase are not clear yet, it might occur depend on the

storage history of this RM-AV.

### (8) Problems/improvements occurred and solutions.

No problem occurred during this cruise.

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### 3.5 Chlorofluorocarbons (CFCs)

July 31, 2010

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#### (2) Introduction

Chlorofluorocarbons (CFCs) are completely man-made compounds that are chemically and biologically stable gasses in the environment. The CFCs have accumulated in the atmosphere since 1930's (Walker et al., 2000) and the atmospheric CFCs can slightly dissolve in sea surface water by air-sea gas exchange. The dissolved CFCs concentrations in sea surface water should have changed year by year and then penetrate into the ocean interior by water circulation. Three chemical species of CFCs, namely CFC-11 ( $\text{CCl}_3\text{F}$ ), CFC-12 ( $\text{CCl}_2\text{F}_2$ ) and CFC-113 ( $\text{C}_2\text{Cl}_3\text{F}_3$ ), dissolved in seawater are useful as the transient tracers for the ocean circulation with times scale on the order of several decades. In these cruises, we determined concentrations of CFCs dissolved in seawater on board.

#### (3) Apparatus

Dissolved CFCs were measured by a typical method modified from the original design of Bullister and Weiss (1988). A developed purging and trapping system was attached to gas chromatograph (GC-14B: Shimadzu Ltd) having an electron capture detector (ECD-14: Shimadzu Ltd). Cold trap columns were "1/16 stainless steel tubing packed with 5 cm of 100/120 mesh Porapak T. A pre-column and a main columns were Silica Plot capillary column [i.d.: 0.53 mm, length: 8 m, film thickness: 6  $\mu\text{m}$ ] and a complex capillary column (Pola Bond-Q [i.d.:

0.53 mm, length: 7 m, film thickness: 10  $\mu\text{m}$ ] followed by Silica Plot [i. d.: 0.53 mm, length: 22 m, film thickness: 6  $\mu\text{m}$ ]), respectively.

#### (4) Shipboard measurement

##### (4.1) Sampling

Before every CTD cast, the water sampler was cleaned by diluted acetone to remove any oils which could cause contaminations of CFCs. Seawater sub-samples were collected from 12 litter Niskin bottles into 250 ml glass bottles. The bottles had been filled with pure nitrogen gas before the sampling. The two times bottle volumes of seawater sample were overflowed. The bottles filled with seawater were kept in water bathes roughly controlled on the sample temperature. The CFC concentrations were determined within 12 hrs.

In order to confirm CFC concentrations of standard gases and their stabilities and also to check CFC saturation levels in sea surface water with respect to overlying air, CFC mixing ratios in the background air were periodically analyzed. Air samples were continuously led into the Environmental Research Laboratory using 10 mm OD Dekaron® tubing. The end of the tubing was put on a head of the compass deck and another end was connected onto an air pump in the laboratory. The tubing was relayed by a T-type union which had a small stop cock. Air samples were collected from the flowing air into a 200 ml glass cylinder attached on the cock during running ship from a station to next station. Average mixing ratios of the atmospheric CFC-11, CFC-12 and CFC-113 are  $242.6 \pm 6.3$  ppt,  $530.4 \pm 7.6$  ppt, and  $76.2 \pm 5.4$  ppt, respectively.

##### (4.2) Analysis

Constant volume of sample water (50 ml) was taken into the purging & trapping system. Dissolved CFCs were extracted by nitrogen gas purge. The sample gases were dried by magnesium perchlorate desiccant and concentrated on a trap column cooled to  $< -45$  °C. Following 8 minutes extraction, the trap column was isolated by valve switching and heated electrically to 140 °C within 1.5 minutes to desorb CFCs. The trap column was connected to GC and CFCs led into the pre-column. The gasses were roughly separated on the pre-column. When required compounds were eluted, the pre-column was switched onto cleaning line and flushed back by

counter flow of pure nitrogen gas. The compounds which were sent onto main column were separated further and detected by an electron capture detector (ECD). Retention times of compounds were around 1.5, 4.5 and 11.5 minutes for CFC-12, -11 and -113, respectively. Temperature of an analytical column and a detector was 95 and 240 °C. Pure nitrogen gas (99.99995) was further purified by a molecular sieve 13X gas filter and was used for analyses. Mass flow rates of nitrogen gas were 10, 27, 20 and 120 ml/min for carrier, detector make up, back flush and sample purging gasses, respectively. Gas loops whose volumes were 1, 3 and 10 ml were used for introducing standard gases into the analytical system. Calibration curves were made every several days and standard gas analysis using large loop (10 ml) were performed more frequently to monitor change in the detector sensitivity. The standard gasses had been made by Japan Fine Products co. ltd. Standard gas cylinder numbers used in cruises were listed in Table 3.5.1. Cylinder of CPB30524 was used as reference gas. Precise mixing ratios of the standard gasses were calculated by gravimetric data. The standard gases used in this cruise have not been calibrated to SIO scale standard gases yet because SIO scale standard gasses is hard to obtain due to legal difficulties for CFCs import into Japan. The data will be corrected as soon as possible when we obtain the standard gasses.

## (5) Quality control

### (5.1) Main problems on the shipboard analysis

A large and broad peak was interfered determining CFC-113 peak area for samples collected from surface layer (several hundred meters depth). Retention time of the interfering peak was around 3 % shorter than that of CFC-113. The peak of compound interfering CFC-113 determination could not be completely separated from the peak of CFC-113 by our analytical condition. We tried to split these peaks on chromatogram analysis and give flag “4”. In the case of the interfering peak completely covering the CFC-113 peak, we could not determine CFC-113 peak area and give flag “5”.

### (5.2) Blanks

CFCs concentrations in deep water which was one of oldest water masses in the ocean were low but

not zero for CFC-11 and -12. Average concentrations of CFC-11, 12 in the deep water were  $0.003 \pm 0.001$ ,  $0.008 \pm 0.001$  pmol kg<sup>-1</sup> (n= ~1500), respectively. These values were assumed as sampling blanks which was contaminations from Niskin bottle and/or during sub-sampling and were subtracted from all data. Significant blank was not found in CFC-113 measurements.

### (5.3) Precisions

The analytical precisions were estimated from replicate sample analyses (610 pairs for CFC-12, 609 pairs for CFC-11 and 401 pairs for CFC-113). The replicate samples were basically collected from two or three sampling depths which is around 100, 400 and 600 m depths in every stations. Precisions of CFCs are less than  $\pm 0.010$  pmol kg<sup>-1</sup> or 0.6 % for CFC-11 (whichever is greater),  $\pm 0.006$  pmol kg<sup>-1</sup> or 0.8 % for CFC-12 (whichever is greater), and  $\pm 0.010$  pmol kg<sup>-1</sup> for CFC-113, respectively.

## (6) References

Bullister, J.L and R. F. Weiss (1998): Determination of CCl<sub>3</sub>F and CCl<sub>2</sub>F<sub>2</sub> in seawater and air. *Deep Sea Research*, **35**, 839-853.

Table 3.5.1. Standard gas cylinder list.

Cylinder No.	CFC Concentrations (pptv).		
	CFC-11	CFC-12	CFC-113
CPB03013	300	159	30.1
CPB19294	299	159	30.1
CPB28545	293	163	29.9
CPB30524	300	159	30.2



### 3.6 Dissolved Inorganic Carbon ( $C_T$ )

December 4, 2010

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#### (2) Objectives

Concentrations of  $CO_2$  in the atmosphere are now increasing at a rate of  $1.9 \text{ ppmv y}^{-1}$  due to human activities such as burning of fossil fuels, deforestation, cement production, etc. It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric  $CO_2$ , and to clarify the mechanism of the  $CO_2$  absorption, because the magnitude of the predicted global warming depends on the levels of  $CO_2$  in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In the cruise (MR09-01, revisit of WOCE P21 line) using the R/V Mirai, we were aimed at quantifying how much anthropogenic  $CO_2$  is absorbed in the Pacific Ocean. For the purpose, we measured  $CO_2$ -system properties such as dissolved inorganic carbon ( $C_T$ ), total alkalinity ( $A_T$ ), pH and underway  $pCO_2$ .

In this section, we describe data on  $C_T$  obtained in the cruise in detail.

#### (3) Apparatus

Measurements of  $C_T$  were made with two total  $CO_2$  measuring systems (systems-A and -B; Nippon ANS, Inc.), which are slightly different from each other. The systems comprise of a seawater dispensing system, a  $CO_2$  extraction system and a coulometer (Model 5012, UIC Inc.).

The seawater dispensing system has an auto-sampler (6 ports), which takes seawater from a 300 ml

borosilicate glass bottle and dispenses the seawater to a pipette of nominal 21 ml volume by a PC control. The pipette is kept at  $20^\circ C$  by a water jacket, where water from a water bath set at  $20^\circ C$  is circulated.

$CO_2$  dissolved in a seawater sample is extracted in a stripping chamber of a  $CO_2$  extraction system by adding phosphoric acid (10% v/v). The stripping chamber is approx. 25 cm long and has a fine frit at the bottom. The acid is added to the stripping chamber from the bottom of the chamber by pressurizing an acid bottle for a given time to push out a right amount of acid. The pressurizing is made with nitrogen gas (99.9999 %). After the acid is transferred to the stripping chamber, a seawater sample kept in a pipette is introduced to the stripping chamber by the same method as in adding an acid. The seawater reacted with phosphoric acid is stripped of  $CO_2$  by bubbling the nitrogen gas through a fine frit at the bottom of the stripping chamber. The  $CO_2$  stripped in the stripping chamber is carried by the nitrogen gas ( $140 \text{ ml min}^{-1}$  for the systems A and B) to the coulometer through a dehydrating module. For the system A, the module consists of two electric dehumidifiers (kept at  $1 - 2^\circ C$ ) and a chemical desiccant ( $Mg(ClO_4)_2$ ). For the system B, it consists of three electric dehumidifiers with a chemical desiccant.

#### (4) Shipboard measurement

##### (4.1) Sampling

All seawater samples were collected from depth with 12 liter Niskin bottles basically at every other stations. The seawater samples for  $C_T$  were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into a 300 ml borosilicate glass bottle. The glass bottle was filled with seawater smoothly from the bottom following a rinse with a seawater of 2 full, bottle volumes. The glass bottle was closed by a stopper, which was fitted to the bottle mouth gravimetrically without additional force.

At a chemical laboratory on the ship, a headspace of approx. 1 % of the bottle volume was made by removing seawater with a plastic pipette. A saturated mercuric chloride of  $100 \mu\text{l}$  was added to poison seawater samples. The glass bottles were sealed with a greased (Apiezon M, M&I Materials Ltd) ground glass stopper and the clips were secured. The seawater samples were kept at  $4^\circ C$  in a refrigerator until analysis. A few hours just before analysis, the seawater samples were kept at  $20^\circ C$  in a water bath.

#### (4.2) Analysis

At the start of each leg, we calibrated the measuring systems by blank and 5 kinds of Na<sub>2</sub>CO<sub>3</sub> solutions (nominally 500, 1000, 1500, 2000, 2500 μmol/L). As it was empirically known that coulometers do not show a stable signal (low repeatability) with fresh (low absorption of carbon) coulometer solutions. Therefore we measured 2% CO<sub>2</sub> gas repeatedly until the measurements became stable. Then we started the calibration.

The measurement sequence such as system blank (phosphoric acid blank), 2 % CO<sub>2</sub> gas in a nitrogen base, seawater samples (6) was programmed to repeat. The measurement of 2 % CO<sub>2</sub> gas was made to monitor response of coulometer solutions (from UIC, Inc.). For every renewal of coulometer solutions, certified reference materials (CRMs, batch 92 and a small number of batch 79) provided by Prof. A. G. Dickson of Scripps Institution of Oceanography were analyzed. In addition, in-house reference materials (RM) (batch QRM Q20 and Q19 for systems A and B, respectively) were measured at the initial, intermediate and end times of a coulometer solution's lifetime.

The preliminary values were reported in a data sheet on the ship. Repeatability and vertical profiles of C<sub>T</sub> based on raw data for each station helped us check performances of the measuring systems.

In the cruise, we finished all the analyses for C<sub>T</sub> on board the ship. As we used two systems, we had not encountered such a situation as we had to abandon the measurement due to time limitation.

#### (5) Quality control

We conducted quality control of the data after return to a laboratory on land. With calibration factors, which had been determined on board a ship based on blank and 5 kinds of Na<sub>2</sub>CO<sub>3</sub> solutions, we calculated C<sub>T</sub> of CRM (batches 92 and 79), and plotted the values as a function of sequential day, separating legs and the systems used. There were no statistically-significant trends of CRM measurements.

Based on the averages of C<sub>T</sub> of CRM, we re-calculated the calibration factors so that measurements of seawater samples become traceable to the certified value of batches 92. We did use the measured results of batch 79 because of a small number of measurements.

Temporal variations of RM measurements for one coulometer solution are shown in Fig. 3.6.1. From

this figure, it is evident that RM measurements had a linear trend of ~3 to ~7 μmol kg<sup>-1</sup>, implying that measurements of seawater samples also have the trend. The trend was also found in temporal changes of 2 % CO<sub>2</sub> gas measurements. The trend seems to be due to “cell age” change (Johnson *et al.*, 1998) of a coulometer solution.

Considering the trends, we adjusted measurements of seawater samples so as to be traceable to the certified value of batch 92.

Finally we surveyed vertical profiles of C<sub>T</sub>. In particular, we examined whether systematic differences between measurements of the systems A and B existed or not. Then taking other information of analyses into account, we determined a flag of each value of C<sub>T</sub>.

The average and standard deviation of absolute values of differences of C<sub>T</sub> analyzed consecutively were 0.8 and 0.7 μmol kg<sup>-1</sup> (n=211), and 0.6 and 0.6 μmol kg<sup>-1</sup> (n=165), for legs 1 and 2, respectively. The combined values were 0.7 and 0.7 μmol kg<sup>-1</sup> (n=376).

#### Reference

Johnson, K. M., A. G. Dickson, G. Eiseid, C. Goyet, P. Guenther, R. M. Key, F. J. Millero, D. Purkerson, C. L. Sabine, R. G. Schottle, D. W. R. Wallace, R. J. Wilke and C. D. Winn (1998): Coulometric total carbon dioxide analysis for marine studies: assessment of the quality of total inorganic carbon measurements made during the US Indian Ocean CO<sub>2</sub> survey 1994-1996, *Mar. Chem.*, 63, 21-37.

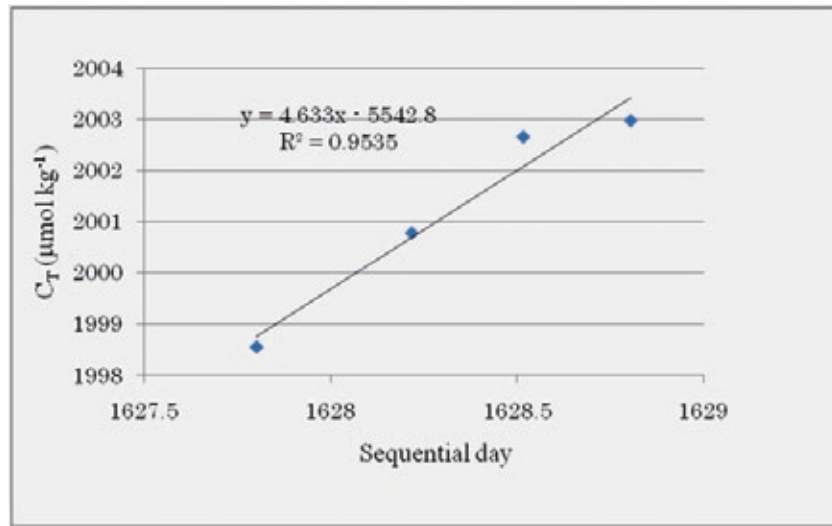


Figure 3.6.1. Distributions of RM measurements as a function of sequential day for Stns. 279 and 282 during MR09-01.

### 3.7 Total Alkalinity ( $A_T$ )

December 4, 2010

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#### (2) Objectives

Concentrations of  $CO_2$  in the atmosphere are now increasing at a rate of  $1.9 \text{ ppmv y}^{-1}$  due to human activities such as burning of fossil fuels, deforestation, cement production, etc. It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric  $CO_2$ , and to clarify the mechanism of the  $CO_2$  absorption, because the magnitude of the predicted global warming depends on the levels of  $CO_2$  in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In the cruise (MR09-01, revisit of WOCE P21 line) using the R/V Mirai, we were aimed at quantifying how much anthropogenic  $CO_2$  is absorbed in the Pacific Ocean. For the purpose, we measured  $CO_2$ -system properties such as dissolved inorganic carbon ( $C_T$ ), total alkalinity ( $A_T$ ), pH and underway  $pCO_2$ .

In this section, we describe data on  $A_T$  obtained in the cruise in detail.

#### (3) Apparatus

Measurement of  $A_T$  was made based on spectrophotometry using a custom-made system (Nippon ANS, Inc.). The system comprises of a water dispensing unit, an auto-burette (765 Dosimat, Metrohm), and a spectrophotometer (Carry 50 Bio, Varian), which are automatically controlled by a PC. The water dispensing unit has a water-jacketed pipette and a water-jacketed titration cell. The spectrophotometer has a water-jacketed

quartz cell, length and volume of which are 8 cm and 13 ml, respectively. To circulate sample seawater between the titration and the quartz cells, PFA tubes are connected to the cells.

A seawater of approx. 42 ml is transferred from a sample bottle (borosilicate glass bottle; 130 ml) into the water-jacketed (25 °C) pipette by pressurizing the sample bottle (nitrogen gas), and is introduced into the water-jacketed (25 °C) titration cell. The seawater is circulated between the titration and the quartz cells by a peristaltic pump to rinse the route. Then, Milli-Q water is introduced into the titration cell, and is circulated in the same route twice to rinse the route. Next, a seawater of approx. 42 ml is weighted again by the pipette, and is transferred into the titration cell. The weighted seawater is introduced into the quartz cell. Then, for seawater blank, absorbances are measured at three wavelengths (750, 616 and 444 nm). After the measurement, an acid titrant, which is a mixture of approx. 0.05 M HCl in 0.65 M NaCl and bromocresol green (BCG) is added (approx. 2.1 ml) into the titration cell. The seawater + acid titrant solution is circulated for 6 minutes between the titration and the quartz cells, with stirring by a stirring tip and bubbling by wet nitrogen gas in the titration cell. Then, absorbances at the three wavelengths are measured again.

Calculation of AT was made by the following equation:

$$A_T = (-[H^+]_T V_{SA} + M_A V_A) / V_S,$$

where  $M_A$  is the molarity of the acid titrant added to the seawater sample,  $[H^+]_T$  is the total excess hydrogen ion concentration in the seawater, and  $V_S$ ,  $V_A$  and  $V_{SA}$  are the initial seawater volume, the added acid titrant volume, and the combined seawater plus acid titrant volume, respectively.  $[H^+]_T$  is calculated from the measured absorbances based on the following equation (Yao and Byrne, 1998):

$$pH_T = -\log[H^+]_T = 4.2699 + 0.002578(35-S) + \log((R-0.00131)/(2.3148-0.1299R)) - \log(1-0.001005S),$$

where S is the sample salinity, and R is the absorbance ratio calculated as:

$$R = (A_{616} - A_{750}) / (A_{444} - A_{750}),$$

where  $A_i$  is the absorbance at wavelength  $i$  nm.

The HCl in the acid titrant was standardized (0.049983 M, 0.049982 M) on land.

#### (4) Shipboard measurement

##### (4.1) Sampling

All seawater samples were collected from depth using 12 liter Niskin bottles basically at every other stations. The seawater samples for  $A_T$  were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into borosilicate glass bottles of 130 ml. The glass bottle was filled with seawater smoothly from the bottom after rinsing it with a seawater of half a or a full bottle volume. A few hours before analysis, the seawater samples were kept at 25 °C in a water bath.

##### (4.2) Analysis

We analyzed reference materials (RM), which were produced for  $C_T$  measurement by JAMSTEC, but were efficient also for the monitor of  $A_T$  measurement. In addition, certified reference materials (CRM, batches 92, certified value = 2201.91  $\mu\text{mol kg}^{-1}$ , respectively) were also analyzed periodically to monitor systematic differences of measured  $A_T$ . The reported values of  $A_T$  were set to be traceable to the certified value of the batch 92.

The preliminary values were reported in a data sheet on the ship. Repeatability calculated from replicate samples and vertical profiles of  $A_T$  based on raw data for each station helped us check performance of the measuring system.

In the cruise, we finished all the analyses for  $A_T$  on board the ship. We did not encounter so serious problems as we had to give up the analyses. However, we experienced some malfunctions of the system during the cruise, which are listed in the followings:

At the early stage of the 1st leg, we found malfunction of the instrument such as showing different  $A_T$  values by different quantities of acid titrant added. The malfunction was attributed to the light source of spectrophotometer. After the light source was changed to a new one, the malfunction was resolved.

##### (5) Quality control

Temporal changes of  $A_T$ , which originate from analytical problems, were monitored by measuring  $A_T$  of CRM.

We found no abnormal measurements during the cruises.

After making the measured values of  $A_T$  comparable to CRM, we examined vertical profiles of  $A_T$ . Then taking other information of analyses into account, we determined a flag of each value of  $A_T$ .

The average and standard deviation of absolute values of differences of  $A_T$  analyzed consecutively were 0.5 and 0.5  $\mu\text{mol kg}^{-1}$  ( $n = 200$ ), and 0.6 and 0.5  $\mu\text{mol kg}^{-1}$  ( $n = 165$ ) for legs 1 and 2, respectively. The combined values were calculated to be 0.5 and 0.5  $\mu\text{mol kg}^{-1}$  ( $n = 365$ ).

#### Reference

Yao, W. and R. H. Byrne (1998): Simplified seawater alkalinity analysis: Use of linear array spectrometers. Deep-Sea Research I 45, 1383-1392.

### 3.8 pH (pH<sub>T</sub>)

December 10, 2010

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#### (2) Objectives

Concentrations of CO<sub>2</sub> in the atmosphere are now increasing at a rate of 1.9 ppmv y<sup>-1</sup> due to human activities such as burning of fossil fuels, deforestation, cement production, etc. It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric CO<sub>2</sub>, and to clarify the mechanism of the CO<sub>2</sub> absorption, because the magnitude of the anticipated global warming depends on the levels of CO<sub>2</sub> in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In the cruises (MR09-01, revisit of WOCE P21 line) using the R/V Mirai, we were aimed at quantifying how much anthropogenic CO<sub>2</sub> is absorbed in the Pacific Ocean. For the purpose, we measured CO<sub>2</sub>-system properties such as dissolved inorganic carbon (C<sub>T</sub>), total alkalinity (A<sub>T</sub>), pH and underway pCO<sub>2</sub>.

In this section, we describe data on pH obtained in the cruise in detail.

#### (3) Apparatus

Measurement of pH was made by a pH measuring system (Nippon ANS, Inc.), which adopts spectrophotometry. The system comprises of a water dispensing unit and a spectrophotometer (Carry 50 Scan, Varian).

Seawater is transferred from borosilicate glass bottle (300 ml) to a sample cell in the spectrophotometer.

The length and volume of the cell are 8 cm and 13 ml, respectively, and the sample cell was kept at 25.00 ± 0.05 °C in a thermostated compartment. First, absorbances of seawater only are measured at three wavelengths (730, 578 and 434 nm). Then an indicator is injected and circulated for about 4 minutes, to mix the indicator and seawater sufficiently. After the pump is stopped, the absorbances of seawater + indicator are measured at the same wavelengths.

The pH is calculated based on the following equation (Clayton and Byrne, 1993):

$$pH = pK_2 + \log \left( \frac{A_1/A_2 - 0.00691}{2.2220 - 0.1331(A_1/A_2)} \right) \quad (1),$$

where A<sub>1</sub> and A<sub>2</sub> indicate absorbances at 578 and 434 nm, respectively, and pK<sub>2</sub> is calculated as a function of water temperature and salinity.

#### (4) Shipboard measurement

##### (4.1) Sampling

All seawater samples were collected from depth with 12 liter Niskin bottles basically at every other stations. The seawater samples for pH were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into a 300 ml borosilicate glass bottle, which was the same as used for C<sub>T</sub> sampling. The glass bottle was filled with seawater smoothly from the bottom following a rinse with a sea water of 2 full, bottle volumes. The glass bottle was closed by a stopper, which was fitted to the bottle mouth gravimetrically without additional force.

A few hours just before analysis, the seawater samples were kept at 25 °C in a water bath.

##### (4.2) Analysis

For an indicator solution, *m*-cresol purple (2 mM) was used. The indicator solution was produced on board a ship, and retained in a 1000 ml DURAN® laboratory bottle. We renewed an indicator solution 3 times when the headspace of the bottle became large, and monitored pH or absorbance ratio of the indicator solution by another



spectrophotometer (Carry 50 Scan, Varian) using a cell with a short path length of 0.5 mm. In most indicator solutions, the absorbance ratios of the indicator solution were kept mostly between 1.4 and 1.6 by adding acid or alkali solution appropriately.

It is difficult to mix seawater with an indicator solution sufficiently under no headspace condition. However, by circulating the mixed solution with a peristaltic pump, a well-mixed condition came to be attained rather shortly, leading to a rapid stabilization of absorbance. We renewed a TYGON<sup>®</sup> tube of a peristaltic pump periodically, when a tube deteriorated.

Absorbances of seawater only and seawater + indicator solutions were measured 11 times each, and the last value was used for the calculation of pH (Eq. 1).

The preliminary values of pH were reported in a data sheet on the ship. Repeatability calculated from replicate samples and vertical profiles of pH based on raw data for each station helped us check performance of the measuring system.

We finished all the analyses for pH on board the ship. We did not encounter so serious a problem as we had to give up the analyses. However, we sometimes experienced malfunctions of the system during the cruise.

##### **(5) Quality control**

It is recommended that correction for pH change resulting from addition of indicator solutions is made (DOE, 1994). To check the perturbation of pH due to the addition, we measured absorbance ratios by doubling the volume of indicator solutions added to a same seawater sample. We corrected absorbance ratios based on an empirical method (DOE, 1994), although the perturbations were small. Figure 3.8.1 illustrates an example of perturbation of absorbance ratios by adding indicator solutions.

We surveyed vertical profiles of pH. In particular, we examined whether systematic differences between before and after the renewal of indicator solutions existed or not. Then taking other information of analyses into account, we determined a flag of each value of pH. The reported values, which are the total scale, were set to the values at 25°C by the CO<sub>2</sub> system calculation using data for pH and C<sub>T</sub> with K<sub>1</sub>, K<sub>2</sub> from Mehrbach et al. (1973) refit by Dickson and Millero (1987).

The average and standard deviation of absolute values of differences of pH analyzed consecutively were 0.0005 and 0.0004 pH unit (n = 266), and 0.0004 and 0.0004 pH unit (n = 205) for legs 1 and 2, respectively. The combined values were 0.0004 and 0.0004 pH unit (n = 471).

##### **References**

- Clayton T. D. and R. H. Byrne (1993): Spectrophotometric seawater pH measurements: total hydrogen ion concentration scale calibration of m-cresol purple and at-sea results. *Deep-Sea Research*, 40, 2115-2129.
- Dickson A. G. and F. J. Millero (1987): A Comparison of the equilibrium constants for the dissociation of carbonic acid in seawater media. *Deep-Sea Research*, 34, 1733-1743.
- 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. (unpublished manuscript).
- Mehrbach, C., C. H. Culberson, J. E. Hawley, and R. M. Pytkowicz (1973): Measurement of the apparent dissociation constants of carbonic acid in seawater at atmospheric pressure. *Limnology and Oceanography*, 18, 897-907.

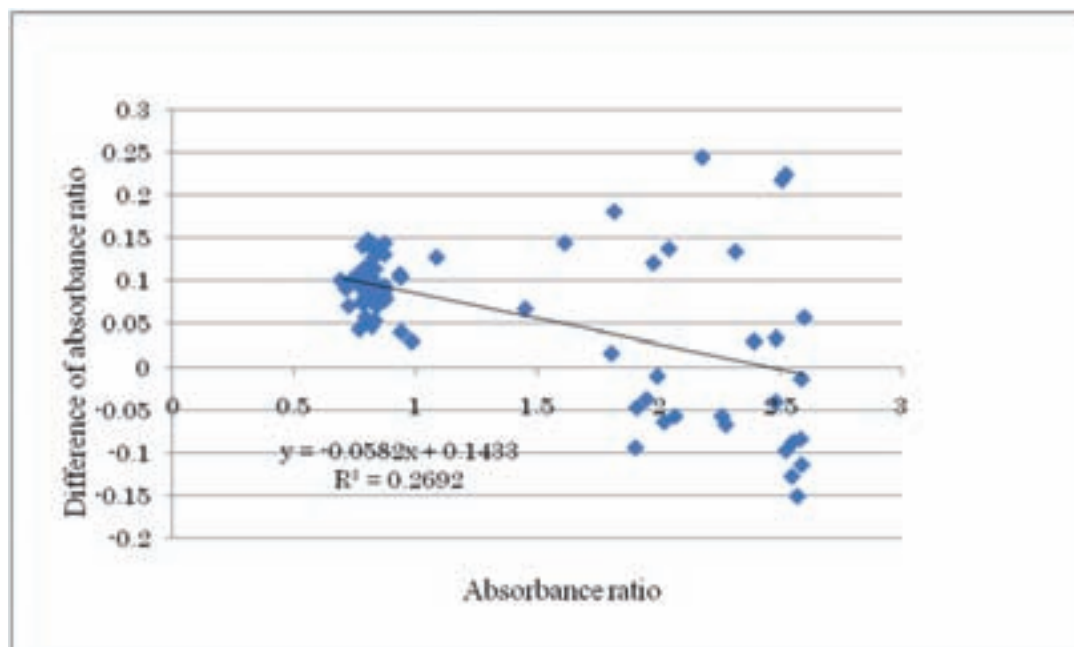


Figure 3.8.1. Perturbation of absorbance ratios by adding indicator solutions. The line was determined by the method of least squares.

### 3.9 LADCP

November 1, 2010

#### (1) Personnel

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#### (2) Overview of the equipment

An acoustic Doppler current profiler (ADCP) was integrated with the CTD/RMS package. The lowered ADCP (LADCP), Workhorse Monitor WHM300 (Teledyne RD Instruments, San Diego, California, USA), which has 4 downward facing transducers with 20-degree beam angles, rated to 6000 m. The LADCP makes direct current measurements at the depth of the CTD, thus providing a full profile of velocity. The LADCP was powered during the CTD casts by a 50.4 volts rechargeable Ni-Cd battery pack. The LADCP unit was set for recording internally prior to each cast. After each cast the internally stored observed data was uploaded to the computer on-board. By combining the measured velocity of the sea water and bottom with respect to the instrument, and shipboard navigation data during the CTD cast, the absolute velocity profile can be obtained (e.g., Visbeck, 2002).

The instrument used in this cruise was as follows.

Teledyne RD Instruments, WHM300

S/N 11853 (CPU firmware ver. 50.32, ver. 50.35, with pressure sensor)

S/N 8484 (CPU firmware ver. 50.32, ver. 50.35)

S/N 1512 (CPU firmware ver. 50.35)

#### (3) Data collection

In this cruise, data were collected with the following configuration.

Bin size: 8 m

Number of bins: 14

Pings per ensemble: 1

Ping interval: 1 sec

At the following stations, the CTD cast was carried out without the LADCP, because maximum pressure was beyond the pressure-proof of the LADCP (6000 m).

Station P21-200

#### (4) Data collection problems

We changed the instruments many times due to various troubles. The log of changing instruments is as follows.

Station P21-120: from S/N 11853 (firmware ver. 50.32) to S/N 8484 (firmware ver. 50.32)

Station P21-132: from S/N 8484 (firmware ver. 50.32) to S/N 8484 (firmware ver. 50.35)

Station P21-141: from S/N 8484 (firmware ver. 50.35) to S/N 11853 (firmware ver. 50.35)

Station P21-174: from S/N 11853 (firmware ver. 50.35) to S/N 1512 (firmware ver. 50.35)

Station P21-181: from S/N 1512 (firmware ver. 50.35) to S/N 11853 (firmware ver. 50.35)

Station P21-182: from S/N 11853 (firmware ver. 50.35) to S/N 1512 (firmware ver. 50.35)

Until the Station 120, data recording was intermittently stopped during a cast due to the firmware (ver. 50.32) bug. Because the beam 2 of S/N 8484 became weak at the Station 139, we changed instruments from S/N 8484 to S/N 11853. The beam 2 of the instrument (S/N 11853) also didn't work well at the Station 173 and the instrument was changed to S/N 1512. Since the beam 3 of the instrument (S/N 1512) became weak at the Station 180, we tried the S/N 11853 again at the Station 181 to compare the echo intensities. Since the instrument of S/N 1512 worked better than S/N 11853, the S/N 1512 was used after the Station 182 (see Fig. 3.9.1).

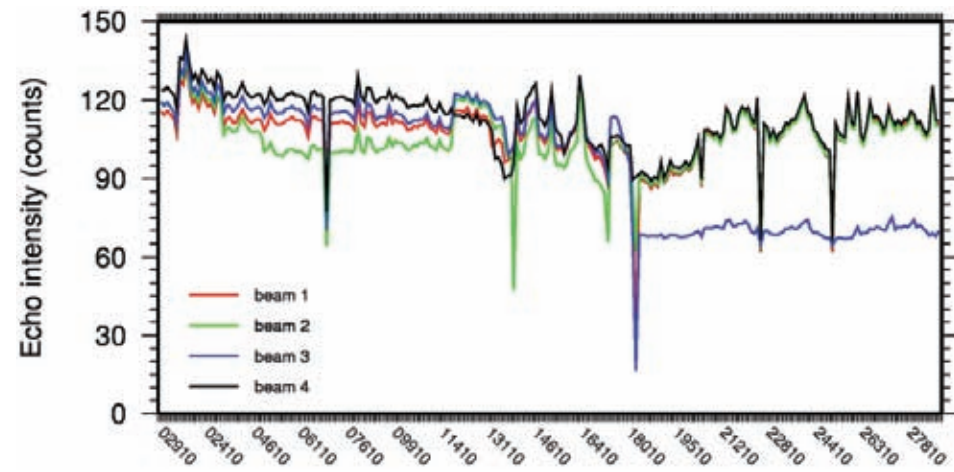


Figure 3.9.1. Cast-averaged echo intensities at 3<sup>rd</sup> bin.

#### (4) Data process

Vertical profiles of velocity are obtained by the inversion method (Visbeck, 2002). Since the first bin from LADCP is influenced by the turbulence generated by CTD frame, the weight for the inversion is set to 0.1. GPS navigation data and the bottom-track data are used in the calculation of the reference velocities. Shipboard ADCP data averaged for 1 minutes are also included in the calculation. The CTD data are used for the sound speed and depth calculation. The directions of velocity are corrected using the magnetic deviation estimated with International Geomagnetic reference field data.

However, the inversion method doesn't work well due to no-good velocity data due to the instrument problems as well as weak echo intensity at deep layers. So we added a cast flag for each profile. The flag of 5 means that data files for one cast were divided into small files due to firmware bugs provided from RDI. The flag of 6 means that 3 beam solutions were included in the cast.

#### Reference

Visbeck, M. (2002): Deep velocity profiling using Lowered Acoustic Doppler Current Profilers: Bottom track and inverse solutions. *J. Atmos. Oceanic Technol.*, 19, 794-807.

# Station Summary

P21 REV R/V MIRAI CRUISE MR0901 LEG1

SHIP/CRS	WOCE	CAST		UTC EVENT		POSITION			UNC	COR HT ABOVE	WIRE	MAX NO. OF		COMMENTS				
EXPCODE	SECT	STNNBR	CASTNO	TYPE	DATE	TIME	CODE	LATITUDE	LONGITUDE	NAV	DEPTH	DEPTH	BOTTOM	OUT	PRESS	BOTTLES	PARAMETERS	
49NZ20090410		1001	1	UNK	041309	0614	BE 16	56.20 S	074 33.84 W	GPS	6403	6403						RELEASED EXCESS TWIST OF CTD CABLE
49NZ20090410		1001	1	UNK	041309	1110	EN 16	56.10 S	074 33.95 W	GPS	6387	6387						WOUT 6000M, WEIGHT OF 350KG WITH A COMPASS/TILT METER
49NZ20090410	P21	29	1	ROS	041409	1308	BE 16	45.07 S	078 42.56 W	GPS	3847	3844						
49NZ20090410	P21	29	1	BUC	041409	1316	UN 16	45.06 S	078 42.53 W	GPS	3846	3843					1,4-6,30,34,41,48,86,88	23.9C, PLANKTON NET
49NZ20090410	P21	29	1	ROS	041409	1410	BO 16	44.90 S	078 42.36 W	GPS	3849	3849	9	3859	3882	28	1-8,27	
49NZ20090410	P21	29	1	ROS	041409	1555	EN 16	44.42 S	078 41.68 W	GPS	3830	3830						
49NZ20090410		1002	1	UNK	041409	1701	UN 16	44.75 S	078 56.03 W	GPS	4162	4162						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-1
49NZ20090410	P21	30	1	ROS	041409	1842	BE 16	45.18 S	079 20.12 W	GPS	4456	4453						
49NZ20090410	P21	30	1	BUC	041409	1849	UN 16	45.19 S	079 20.15 W	GPS	4468	4468					1,20	24.2C
49NZ20090410	P21	30	1	ROS	041409	1951	BO 16	45.19 S	079 20.15 W	GPS	4464	4462	9	4457	4504	30	1-8,23,24,26,27	
49NZ20090410	P21	30	1	ROS	041409	2149	EN 16	45.05 S	079 19.88 W	GPS	4473	4471						
49NZ20090410	P21	31	1	ROS	041509	0046	BE 16	44.97 S	079 59.94 W	GPS	4439	4437						
49NZ20090410	P21	31	1	BUC	041509	0054	UN 16	44.96 S	079 59.91 W	GPS	4445	4443					1	24.8C
49NZ20090410	P21	31	1	ROS	041509	0157	BO 16	44.71 S	079 59.78 W	GPS	4446	4444	9	4450	4486	31	1-8,27	#1=#2 DUPL BTLs
49NZ20090410	P21	31	1	ROS	041509	0357	EN 16	44.23 S	079 59.50 W	GPS	4447	4447						
49NZ20090410	P21	32	1	ROS	041509	0654	BE 16	44.85 S	080 39.71 W	GPS	4720	4721						
49NZ20090410	P21	32	1	BUC	041509	0702	UN 16	44.81 S	080 39.73 W	GPS	4722	4722					1	23.7C
49NZ20090410	P21	32	1	ROS	041509	0807	BO 16	44.64 S	080 39.70 W	GPS	4726	4727	10	4724	4774	32	1-8,12,13,23,24,26,27	
49NZ20090410	P21	32	1	ROS	041509	1014	EN 16	43.99 S	080 39.63 W	GPS	4729	4729						
49NZ20090410	P21	40	1	ROS	041509	1218	BE 16	44.86 S	081 0.32 W	GPS	4587	4588						
49NZ20090410	P21	40	1	BUC	041509	1225	UN 16	44.85 S	081 0.34 W	GPS	4590	4591					1,4-6,30,34,41,48,86,88	24.1C, PLANKTON NET
49NZ20090410		1003	1	UNK	041509	1234	UN 16	44.84 S	081 0.35 W	GPS	4590	4591						AIR BVOC SMPL #1153
49NZ20090410	P21	40	1	ROS	041509	1330	BO 16	44.65 S	081 0.45 W	GPS	4608	4608	9	4611	4653	36	1-8,24,27,30,34,41,86,88	
49NZ20090410	P21	40	1	ROS	041509	1527	EN 16	44.39 S	081 0.57 W	GPS	4615	4615						
49NZ20090410		1004	1	UNK	041509	1700	UN 16	44.89 S	081 17.20 W	GPS	4508	4508						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-2
49NZ20090410	P21	33	1	ROS	041509	1727	BE 16	44.91 S	081 20.00 W	GPS	4448	4448						
49NZ20090410	P21	33	1	BUC	041509	1734	UN 16	44.87 S	081 20.02 W	GPS	4448	4448					1,20,31,33,82	23.7C
49NZ20090410	P21	33	1	ROS	041509	1837	BO 16	44.64 S	081 20.15 W	GPS	4436	4435	11	4440	4484	30	1-8,23,24,26,27,31,33,82	#13 MISS TRIP
49NZ20090410	P21	33	1	ROS	041509	2031	EN 16	44.53 S	081 20.21 W	GPS	4431	4431						
49NZ20090410	P21	29	1	XCT	042109	0024	DE 16	45.03 S	078 39.97 W	GPS	3798	3798						TSK XCTD-2(MK-130) #08112315, FAILED DUE TO NOISE
49NZ20090410	P21	29	2	XCT	042109	0037	DE 16	45.27 S	078 40.59 W	GPS	3816	3816						TSK XCTD-2(MK-130) #08112312
49NZ20090410	P21	30	1	XCT	042109	0331	DE 16	45.22 S	079 20.25 W	GPS	4461	4462						TSK XCTD-2(MK-130) #08112308
49NZ20090410	P21	31	1	XCT	042109	0626	DE 16	45.05 S	080 0.08 W	GPS	4443	4441						TSK XCTD-2(MK-130) #08112304
49NZ20090410	P21	32	1	XCT	042109	0919	DE 16	44.77 S	080 39.85 W	GPS	4714	4713						TSK XCTD-2(MK-130) #08112309
49NZ20090410	P21	33	1	XCT	042109	1211	DE 16	44.95 S	081 20.03 W	GPS	4442	4442						TSK XCTD-2(MK-130) #08112306
49NZ20090410	P21	41	1	ROS	042109	1350	BE 16	45.07 S	081 40.23 W	GPS	4661	4661						
49NZ20090410	P21	41	1	XCT	042109	1354	DE 16	45.05 S	081 40.25 W	GPS	4659	4659						TSK XCTD-1(MK-130) #03022164
49NZ20090410	P21	41	1	BUC	042109	1400	UN 16	45.03 S	081 40.24 W	GPS	4657	4657					1,41,86,88	23.9C
49NZ20090410	P21	41	2	XCT	042109	1401	DE 16	45.04 S	081 40.24 W	GPS	4660	4659						TSK XCTD-2(MK-130) #08112305
49NZ20090410	P21	41	1	ROS	042109	1504	BO 16	44.84 S	081 40.13 W	GPS	4650	4651	9	4664	4710	32	1-8,27	





49NZ20090410	P21	46	1	ROS 042309 1727	BO 16 44.71 S 084 59.96 W GPS	4761	4760	10	4801	4851	32	1-8,23,24,26,27	
49NZ20090410	P21	46	1	ROS 042309 1919	EN 16 44.20 S 084 59.82 W GPS	4713	4712						
49NZ20090410	P21	39	1	ROS 042309 2115	BE 16 45.12 S 085 19.64 W GPS	4582	4581						
49NZ20090410	P21	39	1	BUC 042309 2124	UN 16 45.12 S 085 19.59 W GPS	4580	4580					1	23.1C
49NZ20090410	P21	39	1	ROS 042309 2228	BO 16 44.92 S 085 19.43 W GPS	4581	4582	8	4597	4639	32	1-8,27	#2=#12 DUPL BTLS
49NZ20090410	P21	39	1	ROS 042409 0023	EN 16 44.40 S 085 18.98 W GPS	4570	4570						
49NZ20090410	P21	47	1	ROS 042409 0224	BE 16 44.97 S 085 40.10 W GPS	4542	4541						
49NZ20090410	P21	47	1	BUC 042409 0234	UN 16 44.94 S 085 40.05 W GPS	4537	4537					1	23.2C
49NZ20090410	P21	47	1	ROS 042409 0336	BO 16 44.64 S 085 39.82 W GPS	4521	4521	9	4562	4590	32	1-8,27	#2=#13 DUPL BTLS
49NZ20090410	P21	47	1	ROS 042409 0524	EN 16 44.09 S 085 39.73 W GPS	4543	4543						
49NZ20090410	P21	X19	1	ROS 042409 0837	BE 16 50.53 S 086 23.49 W GPS	4508	4508						
49NZ20090410	P21	X19	1	BUC 042409 0847	UN 16 50.44 S 086 23.45 W GPS	4507	4508					1,31,33,34,82	22.8C
49NZ20090410	P21	X19	1	ROS 042409 0949	BO 16 50.00 S 086 23.17 W GPS	4503	4503	9	4552	4555	30	1-8,12,13,23,24,26,27,31,33,34,82	
49NZ20090410	P21	X19	1	ROS 042409 1139	EN 16 49.41 S 086 22.90 W GPS	4501	4501						
49NZ20090410	P21	X19	1	UNK 042409 1147	UN 16 49.40 S 086 23.22 W GPS	4518	4517						AIR 13CH4/CH3D/15N2O SMPL
49NZ20090410	P21	49	1	ROS 042409 1418	BE 16 44.91 S 086 59.83 W GPS	4469	4470						
49NZ20090410	P21	49	1	BUC 042409 1426	UN 16 44.83 S 086 59.86 W GPS	4482	4482					1,20	23.1C, PLANKTON NET
49NZ20090410		1014	1	UNK 042409 1443	UN 16 44.70 S 086 59.83 W GPS	4480	4481						AIR BVOC SMPL #2219
49NZ20090410	P21	49	1	ROS 042409 1529	BO 16 44.35 S 086 59.69 W GPS	4485	4484	8	4527	4538	31	1-8,27	
49NZ20090410		1015	1	UNK 042409 1658	UN 16 43.74 S 086 59.50 W GPS	4492	4492						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-9
49NZ20090410	P21	49	1	ROS 042409 1710	EN 16 43.65 S 086 59.49 W GPS	4488	4489						
49NZ20090410	P21	50	1	ROS 042409 2000	BE 16 44.97 S 087 40.29 W GPS	4381	4381						
49NZ20090410	P21	50	1	BUC 042409 2009	UN 16 44.96 S 087 40.32 W GPS	4380	4380					1,4-6,30,34,41,48,86,88	23.0C
49NZ20090410	P21	50	1	ROS 042409 2111	BO 16 44.71 S 087 40.33 W GPS	4397	4397	10	4393	4428	36	1-8,27,30,34,41,86,88	
49NZ20090410	P21	50	1	ROS 042409 2300	EN 16 44.46 S 087 40.27 W GPS	4399	4397						
49NZ20090410	P21	54	1	ROS 042509 0051	BE 16 45.03 S 088 0.02 W GPS	4528	4528						
49NZ20090410	P21	54	1	BUC 042509 0100	UN 16 45.00 S 088 0.04 W GPS	4520	4519					1	23.2C
49NZ20090410	P21	54	1	ROS 042509 0203	BO 16 44.89 S 087 59.94 W GPS	4544	4544	9	4541	4586	31	1-8,23,24,26,27	
49NZ20090410	P21	54	1	ROS 042509 0352	EN 16 44.71 S 087 59.59 W GPS	4534	4535						
49NZ20090410	P21	51	1	ROS 042509 0549	BE 16 45.01 S 088 20.09 W GPS	4298	4297						
49NZ20090410	P21	51	1	BUC 042509 0558	UN 16 44.98 S 088 20.06 W GPS	4296	4295					1	23.1C
49NZ20090410	P21	51	1	ROS 042509 0658	BO 16 44.81 S 088 19.90 W GPS	4280	4279	10	4286	4326	30	1-8,27	
49NZ20090410	P21	51	1	ROS 042509 0842	EN 16 44.67 S 088 19.70 W GPS	4271	4270						
49NZ20090410	P21	55	1	ROS 042509 1042	BE 16 45.01 S 088 39.87 W GPS	4336	4336						
49NZ20090410	P21	55	1	BUC 042509 1051	UN 16 44.98 S 088 39.86 W GPS	4349	4350					1	23.1C
49NZ20090410	P21	55	1	ROS 042509 1151	BO 16 44.71 S 088 39.60 W GPS	4364	4363	9	4377	4397	30	1-8,23,24,26,27	
49NZ20090410	P21	55	1	ROS 042509 1334	EN 16 44.31 S 088 39.14 W GPS	4397	4396						
49NZ20090410	P21	52	1	ROS 042509 1533	BE 16 45.03 S 089 0.24 W GPS	4323	4324						
49NZ20090410	P21	52	1	BUC 042509 1541	UN 16 45.00 S 089 0.24 W GPS	4322	4324					1	23.2C, PLANKTON NET
49NZ20090410	P21	52	1	ROS 042509 1644	BO 16 44.44 S 089 0.02 W GPS	4348	4347	9	4404	4403	31	1-8,27	
49NZ20090410		1016	1	UNK 042509 1700	UN 16 44.40 S 089 0.02 W GPS	4344	4344						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-10
49NZ20090410	P21	52	1	ROS 042509 1827	EN 16 43.89 S 089 0.00 W GPS	4374	4374						
49NZ20090410	P21	56	1	ROS 042509 2028	BE 16 45.00 S 089 20.11 W GPS	4573	4573						
49NZ20090410	P21	56	1	BUC 042509 2039	UN 16 44.91 S 089 20.09 W GPS	4574	4575					1	23.5C
49NZ20090410	P21	56	1	ROS 042509 2142	BO 16 44.46 S 089 19.79 W GPS	4566	4565	9	4613	4626	31	1-8,23,24,26,27	
49NZ20090410	P21	56	1	ROS 042509 2334	EN 16 43.78 S 089 19.51 W GPS	4565	4565						
49NZ20090410	P21	53	1	ROS 042609 0127	BE 16 45.14 S 089 40.06 W GPS	4483	4483						
49NZ20090410	P21	53	1	BUC 042609 0137	UN 16 45.07 S 089 40.05 W GPS	4486	4486					1	23.6C
49NZ20090410	P21	53	1	ROS 042609 0240	BO 16 44.78 S 089 39.96 W GPS	4490	4491	9	4512	4550	32	1-8,27	#2=#17 DUPL BTLS

49NZ20090410	P21	53	1	ROS 042609 0430	EN 16 44.27 S 089 39.84 W GPS	4482	4482												
49NZ20090410	P21	57	1	ROS 042609 0628	BE 16 45.16 S 090 0.05 W GPS	4307	4307												
49NZ20090410	P21	57	1	BUC 042609 0639	UN 16 45.07 S 090 0.01 W GPS	4321	4321												23.4C
49NZ20090410		1017	1	UNK 042609 0645	UN 16 45.04 S 090 0.01 W GPS	4327	4328												AIR BVOC SMPL #5391
49NZ20090410	P21	57	1	ROS 042609 0739	BO 16 44.84 S 089 59.87 W GPS	4335	4334	9	4341	4378	30	1-8,23,24,26,27							
49NZ20090410	P21	57	1	ROS 042609 0927	EN 16 44.43 S 089 59.73 W GPS	4357	4357												
49NZ20090410	P21	58	1	ROS 042609 1218	BE 16 45.02 S 090 40.05 W GPS	4428	4429												
49NZ20090410	P21	58	1	BUC 042609 1226	UN 16 44.98 S 090 40.06 W GPS	4422	4421						1,4-6,30,34,41,48,86,88						23.7C
49NZ20090410	P21	58	1	ROS 042609 1328	BO 16 44.70 S 090 39.96 W GPS	4437	4438	10	4448	4475	36	1-8,27,30,34,41,86,88							
49NZ20090410	P21	58	1	ROS 042609 1511	EN 16 44.26 S 090 39.87 W GPS	4430	4431												
49NZ20090410		1018	1	UNK 042609 1759	UN 16 45.11 S 091 20.05 W GPS	-9	-9												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-11
49NZ20090410	P21	59	1	ROS 042609 1801	BE 16 45.11 S 091 20.07 W GPS	4378	4376												
49NZ20090410	P21	59	1	BUC 042609 1811	UN 16 45.06 S 091 20.12 W GPS	4395	4394						1,20,31,33,82						23.7C, PLANKTON NET
49NZ20090410	P21	59	1	ROS 042609 1912	BO 16 44.79 S 091 20.03 W GPS	4409	4409	11	4424	4456	30	1-8,12,13,23,24,26,27,31,33,82							
49NZ20090410	P21	59	1	ROS 042609 2101	EN 16 44.51 S 091 20.04 W GPS	4372	4372												
49NZ20090410	P21	60	1	ROS 042609 2347	BE 16 45.01 S 092 0.01 W GPS	4384	4384												
49NZ20090410	P21	60	1	BUC 042609 2355	UN 16 45.00 S 092 0.06 W GPS	4384	4384						1						23.1C
49NZ20090410	P21	60	1	ROS 042709 0057	BO 16 44.82 S 092 0.03 W GPS	4388	4389	10	4404	4436	31	1-8,27							#2=#18 DUPL BTLS
49NZ20090410	P21	60	1	ROS 042709 0244	EN 16 44.49 S 092 0.05 W GPS	4368	4368												
49NZ20090410	P21	61	1	ROS 042709 0539	BE 16 45.02 S 092 40.27 W GPS	4258	4257												
49NZ20090410	P21	61	1	BUC 042709 0548	UN 16 45.00 S 092 40.27 W GPS	4244	4248						1						23.4C
49NZ20090410	P21	61	1	ROS 042709 0648	BO 16 44.80 S 092 40.20 W GPS	4232	4232	10	4242	4292	28	1-8,23,24,26,27							#14 MISS FIRE
49NZ20090410	P21	61	1	ROS 042709 0835	EN 16 44.53 S 092 40.25 W GPS	4227	4226												
49NZ20090410		1019	1	UNK 042709 1034	UN 16 44.73 S 093 9.02 W GPS	4205	4206												AIR BVOC SMPL #5490
49NZ20090410	P21	62	1	ROS 042709 1125	BE 16 45.00 S 093 20.00 W GPS	4262	4263												
49NZ20090410	P21	62	1	BUC 042709 1133	UN 16 44.94 S 093 19.99 W GPS	4270	4270						1,41,86,88						23.7C
49NZ20090410	P21	62	1	ROS 042709 1234	BO 16 44.60 S 093 19.88 W GPS	4297	4296	9	4307	4337	30	1-8,27							
49NZ20090410	P21	62	1	ROS 042709 1419	EN 16 44.05 S 093 19.73 W GPS	4266	4266												
49NZ20090410	P21	63	1	ROS 042709 1712	BE 16 45.20 S 094 0.00 W GPS	4379	4379												
49NZ20090410	P21	63	1	BUC 042709 1719	UN 16 45.13 S 093 59.98 W GPS	4379	4379						1,20						23.8C, PLANKTON NET
49NZ20090410		1020	1	UNK 042709 1811	UN 16 44.73 S 093 59.86 W GPS	4344	4344												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-12
49NZ20090410	P21	63	1	ROS 042709 1821	BO 16 44.63 S 093 59.86 W GPS	4352	4351	10	4374	4399	30	1-8,23,24,26,27							
49NZ20090410	P21	63	1	ROS 042709 2005	EN 16 43.78 S 093 59.62 W GPS	4319	4319												
49NZ20090410	P21	64	1	ROS 042709 2258	BE 16 45.06 S 094 40.20 W GPS	4032	4031												
49NZ20090410	P21	64	1	BUC 042709 2306	UN 16 45.00 S 094 40.24 W GPS	4024	4025						1						23.8C
49NZ20090410	P21	64	1	ROS 042809 0004	BO 16 44.76 S 094 40.21 W GPS	4038	4037	9	4044	4078	28	1-8,27							
49NZ20090410	P21	64	1	ROS 042809 0148	EN 16 44.06 S 094 40.17 W GPS	4137	4137												
49NZ20090410	P21	65	1	ROS 042809 0437	BE 16 45.02 S 095 20.06 W GPS	4107	4108												
49NZ20090410	P21	65	1	BUC 042809 0446	UN 16 45.01 S 095 20.04 W GPS	4115	4114						1						24.3C
49NZ20090410	P21	65	1	ROS 042809 0544	BO 16 44.81 S 095 20.14 W GPS	4075	4074	11	4096	4127	30	1-8,27							
49NZ20090410	P21	65	1	ROS 042809 0727	EN 16 44.53 S 095 20.14 W GPS	4072	4071												
49NZ20090410	P21	66	1	ROS 042809 1018	BE 16 45.37 S 096 0.20 W GPS	4114	4113												
49NZ20090410	P21	66	1	BUC 042809 1026	UN 16 45.31 S 096 0.22 W GPS	4145	4144						1,31,33,34,82						23.9C
49NZ20090410		1021	1	UNK 042809 1039	UN 16 45.27 S 096 0.26 W GPS	4178	4176												AIR BVOC SMPL #7932
49NZ20090410	P21	66	1	ROS 042809 1126	BO 16 45.13 S 096 0.30 W GPS	4207	4206	10	4203	4236	29	1-8,23,24,26,27,31,33,34,82							
49NZ20090410	P21	66	1	ROS 042809 1309	EN 16 44.81 S 096 0.38 W GPS	4267	4266												
49NZ20090410	P21	66	1	UNK 042809 1316	UN 16 44.74 S 096 0.37 W GPS	4261	4260												AIR 13CH4/CH3D/15N2O SMPL
49NZ20090410	P21	67	1	ROS 042809 1557	BE 16 44.94 S 096 39.86 W GPS	3882	3881												
49NZ20090410	P21	67	1	BUC 042809 1605	UN 16 44.89 S 096 39.90 W GPS	3888	3887						1,20						23.8C, PLANKTON NET

49NZ20090410	P21	67	1	ROS 042809 1659	BO 16 44.56 S 096 39.99 W GPS	3881	3881	9	3918	3904	28	1-8,27	
49NZ20090410		1022	1	UNK 042809 1800	UN 16 44.24 S 096 39.98 W GPS	3907	3906						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-13
49NZ20090410	P21	67	1	ROS 042809 1831	EN 16 44.03 S 096 40.09 W GPS	3908	3907						
49NZ20090410	P21	68	1	ROS 042809 2123	BE 16 44.98 S 097 20.19 W GPS	4144	4144						
49NZ20090410	P21	68	1	BUC 042809 2131	UN 16 44.91 S 097 20.23 W GPS	4150	4149					1,4-6,30,34,41,48,86,88	23.9C
49NZ20090410	P21	68	1	ROS 042809 2230	BO 16 44.46 S 097 20.46 W GPS	4102	4102	8	4175	4178	35	1-8,23,24,26,27,30,34,41,82,86,88	
49NZ20090410	P21	68	1	ROS 042909 0015	EN 16 43.78 S 097 20.41 W GPS	4078	4078						
49NZ20090410	P21	69	1	ROS 042909 0306	BE 16 45.06 S 098 0.00 W GPS	4198	4197						
49NZ20090410	P21	69	1	BUC 042909 0315	UN 16 45.02 S 098 0.00 W GPS	4199	4199					1	24.4C
49NZ20090410	P21	69	1	ROS 042909 0413	BO 16 44.87 S 098 0.06 W GPS	4194	4193	10	4212	4251	28	1-8,27	#15 MISS FIRE
49NZ20090410	P21	69	1	ROS 042909 0555	EN 16 44.58 S 097 59.95 W GPS	4188	4187						
49NZ20090410	P21	70	1	ROS 042909 0847	BE 16 45.01 S 098 40.07 W GPS	3997	3997						
49NZ20090410	P21	70	1	BUC 042909 0855	UN 16 44.97 S 098 40.07 W GPS	3992	3993					1	24.3C
49NZ20090410	P21	70	1	ROS 042909 0950	BO 16 44.76 S 098 40.12 W GPS	3975	3975	9	3991	4022	28	1-8,27	
49NZ20090410	P21	70	1	ROS 042909 1131	EN 16 44.39 S 098 40.23 W GPS	3989	3988						
49NZ20090410		1023	1	UNK 042909 1253	UN 16 44.53 S 098 59.97 W GPS	4099	4098						AIR BVOC SMPL #1143
49NZ20090410	P21	71	1	ROS 042909 1416	BE 16 45.05 S 099 19.98 W GPS	3711	3712						
49NZ20090410	P21	71	1	BUC 042909 1424	UN 16 44.96 S 099 20.01 W GPS	3714	3715					1	23.8C
49NZ20090410	P21	71	1	ROS 042909 1517	BO 16 44.51 S 099 20.18 W GPS	3819	3820	9	3770	3762	30	1-8,23,24,26,27	
49NZ20090410	P21	71	1	ROS 042909 1645	EN 16 43.94 S 099 20.33 W GPS	3848	3848						
49NZ20090410		1024	1	UNK 042909 1800	UN 16 44.63 S 099 37.89 W GPS	4030	4030						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-14
49NZ20090410	P21	72	1	ROS 042909 1934	BE 16 45.01 S 100 0.00 W GPS	3847	3847						
49NZ20090410	P21	72	1	BUC 042909 1941	UN 16 44.99 S 100 0.05 W GPS	3859	3859					1,20	24.6C, PLANKTON NET
49NZ20090410	P21	72	1	ROS 042909 2038	BO 16 44.75 S 100 0.09 W GPS	3991	3991	9	3959	3986	28	1-8,27	
49NZ20090410	P21	72	1	ROS 042909 2219	EN 16 43.90 S 100 0.30 W GPS	4019	4020						
49NZ20090410	P21	73	1	ROS 043009 0110	BE 16 44.99 S 100 40.00 W GPS	3931	3932						
49NZ20090410	P21	73	1	BUC 043009 0119	UN 16 44.97 S 100 40.04 W GPS	3944	3944					1,31,33,82	24.3C
49NZ20090410	P21	73	1	ROS 043009 0215	BO 16 44.72 S 100 40.14 W GPS	3993	3993	10	4013	4040	28	1-8,23,24,26,27,31,33,82	
49NZ20090410	P21	73	1	ROS 043009 0353	EN 16 44.37 S 100 40.18 W GPS	3995	3994						
49NZ20090410	P21	74	1	ROS 043009 0646	BE 16 45.03 S 101 20.03 W GPS	3666	3667						
49NZ20090410	P21	74	1	BUC 043009 0654	UN 16 44.99 S 101 20.04 W GPS	3672	3673					1	24.7C
49NZ20090410	P21	74	1	ROS 043009 0748	BO 16 44.84 S 101 20.00 W GPS	3667	3667	10	3682	3710	28	1-8,27	
49NZ20090410	P21	74	1	ROS 043009 0924	EN 16 44.54 S 101 19.99 W GPS	3634	3634						
49NZ20090410	P21	75	1	ROS 043009 1215	BE 16 44.99 S 101 59.79 W GPS	3827	3827						
49NZ20090410	P21	75	1	BUC 043009 1223	UN 16 44.95 S 101 59.84 W GPS	3832	3832					1,4-6,30,34,41,48,86,88	24.6C
49NZ20090410		1025	1	UNK 043009 1240	UN 16 44.91 S 101 59.97 W GPS	3857	3856						AIR BVOC SMPL #5264
49NZ20090410	P21	75	1	ROS 043009 1317	BO 16 44.84 S 102 0.28 W GPS	3860	3860	10	3895	3885	34	1-8,23,24,26,27,30,34,41,86,88	
49NZ20090410	P21	75	1	ROS 043009 1449	EN 16 44.44 S 102 1.07 W GPS	3869	3868						
49NZ20090410	P21	76	1	ROS 043009 1735	BE 16 44.97 S 102 39.93 W GPS	3713	3712						
49NZ20090410	P21	76	1	BUC 043009 1743	UN 16 44.97 S 102 40.02 W GPS	3715	3713					1,20	PLANKTON NET, TEMP MEASUREMENT FAILED
49NZ20090410		1026	1	UNK 043009 1758	UN 16 44.99 S 102 40.18 W GPS	3664	3665						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-15
49NZ20090410	P21	76	1	ROS 043009 1834	BO 16 44.85 S 102 40.46 W GPS	3695	3694	9	3684	3675	27	1-8,27	
49NZ20090410	P21	76	2	BUC 043009 1852	UN 16 44.89 S 102 40.60 W GPS	3709	3709						24.9C, ONLY TEMP MEASUREMENT
49NZ20090410	P21	76	1	ROS 043009 2004	EN 16 45.00 S 102 41.06 W GPS	3766	3766						
49NZ20090410	P21	X18	1	ROS 043009 2212	BE 16 59.92 S 102 59.79 W GPS	3924	3924						REPLACED SBE43 SENSOR FROM #0394 TO #0330
49NZ20090410	P21	X18	1	BUC 043009 2220	UN 16 59.98 S 102 59.80 W GPS	3924	3925					1	24.9C
49NZ20090410	P21	X18	1	ROS 043009 2317	BO 17 0.27 S 103 0.02 W GPS	3895	3895	8	3955	3970	29	1-8,23,24,26,27	

49NZ20090410	P21	X18	1	ROS 050109 0100	EN 17 0.61 S 103 0.35 W GPS	3851	3852										JELLYFISH ON THE RMS FRAME
49NZ20090410	P21	77	1	ROS 050109 0316	BE 16 44.82 S 103 20.07 W GPS	3715	3714										
49NZ20090410	P21	77	1	BUC 050109 0324	UN 16 44.87 S 103 20.10 W GPS	3708	3707										
49NZ20090410	P21	77	1	ROS 050109 0417	BO 16 45.01 S 103 20.29 W GPS	3689	3688	9	3715	3742			27	1-8,27			24.9C
49NZ20090410	P21	77	1	ROS 050109 0547	EN 16 45.26 S 103 20.47 W GPS	3640	3638										
49NZ20090410	P21	78	1	ROS 050109 0837	BE 16 45.00 S 104 0.07 W GPS	3856	3856										
49NZ20090410	P21	78	1	BUC 050109 0846	UN 16 45.01 S 104 0.10 W GPS	3864	3864										
49NZ20090410	P21	78	1	ROS 050109 0941	BO 16 45.18 S 104 0.07 W GPS	3861	3860	10	3877	3906			28	1-8,23,24,26,27			24.7C
49NZ20090410	P21	78	1	ROS 050109 1115	EN 16 45.50 S 104 0.08 W GPS	3784	3784										
49NZ20090410	P21	79	1	ROS 050109 1403	BE 16 44.96 S 104 40.01 W GPS	1219	1220										
49NZ20090410	P21	79	1	BUC 050109 1411	UN 16 44.98 S 104 40.03 W GPS	1233	1233										
49NZ20090410	P21	79	1	ROS 050109 1428	BO 16 45.00 S 104 40.09 W GPS	1201	1201	7	1213	1210			16	1-8,23,24,26,27			24.9C
49NZ20090410	P21	79	1	ROS 050109 1508	EN 16 45.11 S 104 40.22 W GPS	1211	1210										
49NZ20090410		1027	1	UNK 050109 1642	UN 16 45.09 S 105 2.89 W GPS	1905	1904										AIR BVOC SMPL #5481
49NZ20090410	P21	80	1	ROS 050109 1754	BE 16 45.06 S 105 20.04 W GPS	2891	2892										
49NZ20090410	P21	80	1	BUC 050109 1802	UN 16 45.04 S 105 20.04 W GPS	2933	2932										
49NZ20090410	P21	80	1	ROS 050109 1843	BO 16 45.21 S 105 20.07 W GPS	2797	2797	5	2902	2914			24	1-8,23,24,26,27			24.7C, PLANKTON NET
49NZ20090410		1028	1	UNK 050109 1900	UN 16 45.26 S 105 20.17 W GPS	2785	2785										INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-16
49NZ20090410	P21	80	1	ROS 050109 1953	EN 16 45.21 S 105 20.29 W GPS	2812	2812										
49NZ20090410	P21	80	1	FLT 050109 2003	DE 16 45.21 S 105 20.41 W GPS	2814	2812										ARGO #4099/ID86536
49NZ20090410	P21	85	1	ROS 050109 2247	BE 16 45.00 S 106 0.16 W GPS	3827	3827										
49NZ20090410	P21	85	1	BUC 050109 2255	UN 16 45.01 S 106 0.16 W GPS	3826	3826										
49NZ20090410	P21	85	1	ROS 050109 2350	BO 16 45.03 S 106 0.03 W GPS	3837	3837	9	3876	3909			28	1-8,23,24,26,27,31,33,34,82			25.0C
49NZ20090410	P21	85	1	ROS 050209 0123	EN 16 45.08 S 106 0.09 W GPS	3802	3803										
49NZ20090410	P21	85	1	UNK 050209 0134	UN 16 45.10 S 106 0.94 W GPS	3625	3625										AIR 13CH4/CH3D/15N2O SMPL
49NZ20090410	P21	86	1	ROS 050209 0412	BE 16 44.98 S 106 40.03 W GPS	2935	2934										
49NZ20090410	P21	86	1	BUC 050209 0420	UN 16 44.96 S 106 40.00 W GPS	2914	2914										
49NZ20090410	P21	86	1	ROS 050209 0504	BO 16 44.92 S 106 39.91 W GPS	2908	2907	9	2949	2967			24	1-8,23,24,26,27			25.2C
49NZ20090410	P21	86	1	ROS 050209 0620	EN 16 44.85 S 106 39.80 W GPS	2873	2872										
49NZ20090410		1029	1	UNK 050209 1719	BE 16 44.87 S 107 4.87 W GPS	3638	3637										3-AXIS MAGNETOMETER CALIBRATION
49NZ20090410		1029	1	UNK 050209 1752	EN 16 44.24 S 107 4.76 W GPS	3709	3709										
49NZ20090410		1030	1	UNK 050209 1900	UN 16 44.85 S 107 9.38 W GPS	3807	3806										INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-17
49NZ20090410	P21	87	1	ROS 050309 0658	BE 16 44.83 S 107 20.07 W GPS	2972	2972										REPLACED SEC COND SENSOR FROM #1203 TO #3261
49NZ20090410	P21	87	1	BUC 050309 0708	UN 16 44.77 S 107 20.06 W GPS	2945	2945										
49NZ20090410	P21	87	1	ROS 050309 0750	BO 16 44.63 S 107 20.04 W GPS	2843	2843	10	2903	2920			24	1-8,27			25.3C
49NZ20090410	P21	87	1	ROS 050309 0907	EN 16 44.42 S 107 19.90 W GPS	2559	2559										
49NZ20090410	P21	88	1	FLT 050309 0915	DE 16 44.51 S 107 19.90 W GPS	2666	2666										ARGO #4042/ID86510
49NZ20090410	P21	88	1	ROS 050309 1205	BE 16 45.09 S 108 0.25 W GPS	3652	3650										
49NZ20090410	P21	88	1	BUC 050309 1212	UN 16 45.02 S 108 0.33 W GPS	3662	3662										
49NZ20090410		1031	1	UNK 050309 1223	UN 16 44.93 S 108 0.39 W GPS	3661	3662										
49NZ20090410	P21	88	1	ROS 050309 1303	BO 16 44.57 S 108 0.43 W GPS	3670	3670	9	3697	3682			33	1-8,23,24,26,27,30,34,41,86,88			AIR BVOC SMPL #1117
49NZ20090410	P21	88	1	ROS 050309 1427	EN 16 44.09 S 108 0.56 W GPS	3665	3666										
49NZ20090410	P21	89	1	ROS 050309 1714	BE 16 45.10 S 108 40.05 W GPS	3634	3634										
49NZ20090410	P21	89	1	BUC 050309 1722	UN 16 45.17 S 108 40.12 W GPS	3645	3645										
49NZ20090410	P21	89	1	ROS 050309 1813	BO 16 45.25 S 108 40.53 W GPS	3636	3636	10	3680	3688			27	1-8,27			25.7C, PLANKTON NET
49NZ20090410		1032	1	UNK 050309 1900	UN 16 45.40 S 108 40.82 W GPS	3699	3699										INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-18

49NZ20090410	P21	89	1	ROS 050309 1941	EN 16 45.63 S 108 41.06 W GPS	3697	3697												
49NZ20090410	P21	90	1	ROS 050309 2235	BE 16 45.04 S 109 20.01 W GPS	3631	3630												
49NZ20090410	P21	90	1	BUC 050309 2243	UN 16 45.10 S 109 19.98 W GPS	3629	3628												
49NZ20090410	P21	90	1	ROS 050309 2333	BO 16 45.19 S 109 19.97 W GPS	3624	3623												
49NZ20090410	P21	90	1	ROS 050409 0102	EN 16 45.35 S 109 19.96 W GPS	3638	3638												
49NZ20090410	P21	95	1	ROS 050409 0400	BE 16 45.01 S 109 59.74 W GPS	3601	3601												
49NZ20090410	P21	95	1	BUC 050409 0408	UN 16 44.99 S 109 59.68 W GPS	3601	3600												
49NZ20090410	P21	95	1	ROS 050409 0459	BO 16 44.98 S 109 59.47 W GPS	3589	3589												
49NZ20090410	P21	95	1	ROS 050409 0628	EN 16 44.97 S 109 59.32 W GPS	3624	3624												
49NZ20090410	P21	95	1	FLT 050409 0635	DE 16 45.05 S 109 59.34 W GPS	3627	3626												
49NZ20090410	P21	96	1	ROS 050409 0929	BE 16 44.97 S 110 40.18 W GPS	3727	3727												
49NZ20090410	P21	96	1	XCT 050409 0933	DE 16 44.99 S 110 40.19 W GPS	3733	3732												
49NZ20090410	P21	96	1	BUC 050409 0937	UN 16 44.99 S 110 40.22 W GPS	3745	3745												
49NZ20090410	P21	96	2	XCT 050409 0942	DE 16 44.99 S 110 40.24 W GPS	3750	3751												
49NZ20090410	P21	96	1	ROS 050409 1032	BO 16 45.04 S 110 40.35 W GPS	3708	3707												
49NZ20090410	P21	96	1	ROS 050409 1200	EN 16 45.21 S 110 40.36 W GPS	3695	3694												
49NZ20090410		1033	1	UNK 050409 1330	UN 16 45.32 S 111 1.32 W GPS	3443	3443												
49NZ20090410	P21	97	1	ROS 050409 1451	BE 16 44.95 S 111 20.04 W GPS	3465	3466												
49NZ20090410	P21	97	1	XCT 050409 1454	DE 16 44.96 S 111 20.04 W GPS	3461	3462												
49NZ20090410	P21	97	1	BUC 050409 1459	UN 16 44.92 S 111 20.08 W GPS	3454	3452												
49NZ20090410	P21	97	2	XCT 050409 1502	DE 16 44.92 S 111 20.10 W GPS	3453	3453												
49NZ20090410	P21	97	1	ROS 050409 1513	UN 16 44.89 S 111 20.19 W GPS	3455	3455												
49NZ20090410	P21	97	1	ROS 050409 1518	EN 16 44.87 S 111 20.22 W GPS	3460	3461												
49NZ20090410	P21	97	2	ROS 050409 1619	BE 16 44.98 S 111 20.03 W GPS	3460	3462												
49NZ20090410	P21	97	2	ROS 050409 1715	BO 16 44.99 S 111 20.14 W GPS	3444	3445												
49NZ20090410	P21	97	2	ROS 050409 1837	EN 16 44.97 S 111 20.35 W GPS	3437	3438												
49NZ20090410		1034	1	UNK 050409 1900	UN 16 44.99 S 111 23.49 W GPS	3326	3327												
49NZ20090410	P21	98	1	ROS 050409 2133	BE 16 45.14 S 112 0.07 W GPS	3304	3303												
49NZ20090410	P21	98	1	XCT 050409 2137	DE 16 45.14 S 112 0.07 W GPS	3287	3287												
49NZ20090410	P21	98	1	BUC 050409 2144	UN 16 45.13 S 112 0.05 W GPS	3297	3297												
49NZ20090410	P21	98	2	XCT 050409 2146	DE 16 45.14 S 112 0.05 W GPS	3295	3297												
49NZ20090410	P21	98	1	ROS 050409 2228	BO 16 45.16 S 112 0.09 W GPS	3296	3296												
49NZ20090410	P21	98	1	ROS 050409 2349	EN 16 45.34 S 112 0.14 W GPS	3337	3337												
49NZ20090410	P21	99	1	ROS 050509 0234	BE 16 44.94 S 112 40.05 W GPS	3141	3140												
49NZ20090410	P21	99	1	BUC 050509 0242	UN 16 44.93 S 112 40.12 W GPS	3156	3156												
49NZ20090410	P21	99	1	ROS 050509 0326	BO 16 44.99 S 112 40.33 W GPS	3161	3166												
49NZ20090410	P21	99	1	ROS 050509 0444	EN 16 45.16 S 112 40.92 W GPS	3090	3089												
49NZ20090410	P21	99	1	FLT 050509 0452	DE 16 44.99 S 112 41.19 W GPS	3108	3107												
49NZ20090410	P21	100	1	ROS 050509 0730	BE 16 45.01 S 113 20.06 W GPS	2977	2977												
49NZ20090410	P21	100	1	BUC 050509 0739	UN 16 45.06 S 113 20.16 W GPS	2983	2983												
49NZ20090410	P21	100	1	ROS 050509 0821	BO 16 45.14 S 113 20.42 W GPS	3004	3004												
49NZ20090410	P21	100	1	ROS 050509 0936	EN 16 45.33 S 113 20.84 W GPS	2997	2998												
49NZ20090410	P21	101	1	ROS 050509 1221	BE 16 45.00 S 114 0.03 W GPS	3033	3033												
49NZ20090410	P21	101	1	BUC 050509 1228	UN 16 45.05 S 114 0.06 W GPS	3052	3055												
49NZ20090410		1035	1	UNK 050509 1230	UN 16 45.06 S 114 0.08 W GPS	3043	3042												
49NZ20090410	P21	101	1	ROS 050509 1310	BO 16 45.11 S 114 0.34 W GPS	3076	3076												
49NZ20090410	P21	101	1	ROS 050509 1423	EN 16 45.25 S 114 0.60 W GPS	3012	3013												
49NZ20090410	P21	102	1	ROS 050509 1714	BE 16 45.01 S 114 40.02 W GPS	3256	3255												
49NZ20090410	P21	102	1	BUC 050509 1721	UN 16 45.05 S 114 40.01 W GPS	3256	3255												
49NZ20090410	P21	102	1	ROS 050509 1807	BO 16 45.25 S 114 40.11 W GPS	3258	3258												

49NZ20090410		1036	1	UNK 050509 1859	UN 16 45.35 S 114 40.14 W GPS	3259	3258												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-20
49NZ20090410	P21	102	1	ROS 050509 1925	EN 16 45.34 S 114 40.16 W GPS	3258	3257												
49NZ20090410	P21	102	1	FLT 050509 1937	DE 16 45.33 S 114 40.55 W GPS	3247	3246												ARGO #4102/ID86538
49NZ20090410	P21	103	1	ROS 050509 2227	BE 16 45.17 S 115 20.17 W GPS	3341	3340												
49NZ20090410	P21	103	1	BUC 050509 2236	UN 16 45.18 S 115 20.19 W GPS	3337	3336												26.0C
49NZ20090410	P21	103	1	ROS 050509 2323	BO 16 45.20 S 115 20.26 W GPS	3310	3308	9	3353	3379				26	1-8,27				
49NZ20090410	P21	103	1	ROS 050609 0047	EN 16 45.19 S 115 20.42 W GPS	3306	3306												
49NZ20090410	P21	103	1	UNK 050609 0103	UN 16 45.18 S 115 22.36 W GPS	3257	3256												AIR COS SMPL
49NZ20090410	P21	104	1	ROS 050609 0340	BE 16 44.99 S 116 0.01 W GPS	3404	3403												
49NZ20090410	P21	104	1	BUC 050609 0348	UN 16 45.02 S 116 0.04 W GPS	3404	3402												25.8C
49NZ20090410	P21	104	1	ROS 050609 0435	BO 16 45.01 S 116 0.29 W GPS	3400	3400	10	3414	3436				26	1-8,23,24,26,27,31,33,34,82				
49NZ20090410	P21	104	1	ROS 050609 0600	EN 16 45.11 S 116 0.65 W GPS	3374	3374												
49NZ20090410	P21	104	1	UNK 050609 0609	UN 16 45.00 S 116 0.92 W GPS	3369	3368												AIR 13CH4/CH3D/15N2O SMPL
49NZ20090410	P21	105	1	ROS 050609 0853	BE 16 44.99 S 116 40.12 W GPS	3315	3316												
49NZ20090410	P21	105	1	BUC 050609 0903	UN 16 44.98 S 116 40.14 W GPS	3307	3307												25.8C
49NZ20090410	P21	105	1	ROS 050609 0948	BO 16 44.96 S 116 40.18 W GPS	3308	3308	10	3320	3346				26	1-8,27				
49NZ20090410	P21	105	1	ROS 050609 1109	EN 16 45.08 S 116 40.55 W GPS	3342	3342												
49NZ20090410		1037	1	UNK 050609 1235	UN 16 45.05 S 117 0.11 W GPS	3339	3338												AIR BVOC SMPL #1141
49NZ20090410	P21	106	1	ROS 050609 1400	BE 16 44.97 S 117 20.06 W GPS	3375	3379												
49NZ20090410	P21	106	1	BUC 050609 1407	UN 16 44.98 S 117 20.11 W GPS	3412	3411												25.9C
49NZ20090410	P21	106	1	ROS 050609 1455	BO 16 44.91 S 117 20.20 W GPS	3416	3415	10	3419	3443				26	1-8,23,24,26,27				
49NZ20090410	P21	106	1	ROS 050609 1615	EN 16 44.82 S 117 20.60 W GPS	3471	3471												
49NZ20090410		1038	1	UNK 050609 1900	UN 16 44.97 S 118 0.06 W GPS	3543	3543												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-21
49NZ20090410	P21	107	1	ROS 050609 1901	BE 16 44.95 S 118 0.07 W GPS	3544	3545												
49NZ20090410	P21	107	1	BUC 050609 1910	UN 16 44.92 S 118 0.13 W GPS	3551	3550												26.2C, PLANKTON NET
49NZ20090410	P21	107	1	ROS 050609 1959	BO 16 45.02 S 118 0.43 W GPS	3541	3541	10	3572	3581				26	1-8,27				
49NZ20090410	P21	107	1	ROS 050609 2124	EN 16 45.12 S 118 0.96 W GPS	3580	3580												
49NZ20090410	P21	108	1	ROS 050709 0012	BE 16 45.00 S 118 40.02 W GPS	3545	3545												
49NZ20090410	P21	108	1	BUC 050709 0019	UN 16 45.03 S 118 40.04 W GPS	3547	3546												26.4C
49NZ20090410	P21	108	1	ROS 050709 0109	BO 16 45.24 S 118 40.37 W GPS	3540	3540	9	3583	3584				27	1-8,12,13,23,24,26,27				
49NZ20090410	P21	108	1	ROS 050709 0237	EN 16 45.74 S 118 40.89 W GPS	3531	3531												
49NZ20090410	P21	109	1	ROS 050709 0525	BE 16 45.00 S 119 20.04 W GPS	3538	3538												
49NZ20090410	P21	109	1	BUC 050709 0533	UN 16 45.01 S 119 20.07 W GPS	3537	3537												26.6C
49NZ20090410	P21	109	1	ROS 050709 0623	BO 16 45.05 S 119 20.15 W GPS	3547	3547	10	3552	3579				27	1-8,27				
49NZ20090410	P21	109	1	ROS 050709 0751	EN 16 45.23 S 119 20.29 W GPS	3550	3550												
49NZ20090410	P21	110	1	ROS 050709 1040	BE 16 45.08 S 120 0.00 W GPS	3748	3747												
49NZ20090410	P21	110	1	BUC 050709 1049	UN 16 45.10 S 120 0.04 W GPS	3748	3747												26.4C
49NZ20090410		1039	1	UNK 050709 1101	UN 16 45.08 S 120 0.08 W GPS	3748	3746												AIR BVOC SMPL #H1260
49NZ20090410	P21	110	1	ROS 050709 1140	BO 16 45.10 S 120 0.17 W GPS	3748	3747	10	3756	3785				33	1-8,23,24,26,27,30,34,41,86,88				
49NZ20090410	P21	110	1	ROS 050709 1308	EN 16 45.19 S 120 0.25 W GPS	3750	3749												
49NZ20090410	P21	111	1	ROS 050709 1558	BE 16 45.01 S 120 40.02 W GPS	3494	3495												
49NZ20090410	P21	111	1	BUC 050709 1606	UN 16 45.06 S 120 40.03 W GPS	3495	3495												26.8C, PLANKTON NET
49NZ20090410	P21	111	1	ROS 050709 1655	BO 16 45.11 S 120 40.14 W GPS	3502	3502	10	3503	3530				27	1-8,27				
49NZ20090410	P21	111	1	ROS 050709 1816	EN 16 45.27 S 120 40.37 W GPS	3436	3436												
49NZ20090410		1040	1	UNK 050709 2000	UN 16 45.03 S 121 5.09 W GPS	3019	3018												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-22
49NZ20090410	P21	112	1	ROS 050709 2107	BE 16 44.97 S 121 20.06 W GPS	3615	3614												
49NZ20090410	P21	112	1	BUC 050709 2117	UN 16 44.97 S 121 20.08 W GPS	3616	3615												26.5C
49NZ20090410	P21	112	1	ROS 050709 2206	BO 16 44.94 S 121 20.22 W GPS	3614	3613	12	3625	3651				27	1-8,23,24,26,27,31,33				



49NZ20090410	P21	112	1	ROS 050709 2338	EN 16 44.76 S 121 20.46 W GPS	3606	3605												
49NZ20090410	P21	113	1	ROS 050809 0226	BE 16 44.98 S 122 0.02 W GPS	3158	3158												
49NZ20090410	P21	113	1	BUC 050809 0233	UN 16 44.96 S 122 0.05 W GPS	3176	3177												1
49NZ20090410	P21	113	1	ROS 050809 0320	BO 16 45.08 S 122 0.17 W GPS	3258	3257	10	3267	3285			25	1-8,27					26.6C
49NZ20090410	P21	113	1	ROS 050809 0440	EN 16 45.11 S 122 0.17 W GPS	3282	3282												
49NZ20090410	P21	114	1	ROS 050809 0729	BE 16 45.00 S 122 40.00 W GPS	3653	3654												
49NZ20090410	P21	114	1	BUC 050809 0737	UN 16 44.99 S 122 40.03 W GPS	3653	3653												1
49NZ20090410	P21	114	1	ROS 050809 0829	BO 16 45.02 S 122 40.09 W GPS	3654	3653	10	3662	3692			27	1-8,23,24,26,27					26.7C
49NZ20090410	P21	114	1	ROS 050809 1002	EN 16 44.96 S 122 40.23 W GPS	3653	3653												
49NZ20090410		1041	1	UNK 050809 1129	UN 16 44.89 S 123 0.12 W GPS	3646	3645												AIR BVOC SMPL #1312
49NZ20090410	P21	115	1	ROS 050809 1254	BE 16 45.04 S 123 20.19 W GPS	3681	3682												
49NZ20090410	P21	115	1	BUC 050809 1301	UN 16 45.09 S 123 20.22 W GPS	3695	3695												1,4-6,30,34,41,86,88
49NZ20090410	P21	115	1	ROS 050809 1353	BO 16 45.13 S 123 20.41 W GPS	3693	3693	9	3692	3719			27	1-8,27					26.8C
49NZ20090410	P21	115	1	ROS 050809 1516	EN 16 45.00 S 123 20.97 W GPS	3713	3715												
49NZ20090410	P21	116	1	ROS 050809 1807	BE 16 44.99 S 123 59.95 W GPS	3651	3650												
49NZ20090410	P21	116	1	BUC 050809 1815	UN 16 45.03 S 123 59.98 W GPS	3651	3650												1,20
49NZ20090410	P21	116	1	ROS 050809 1906	BO 16 45.07 S 124 0.10 W GPS	3648	3647	9	3657	3686			27	1-8,23,24,26,27					26.9C, PLANKTON NET
49NZ20090410		1042	1	UNK 050809 1958	UN 16 45.08 S 124 0.22 W GPS	3652	3651												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-23
49NZ20090410	P21	116	1	ROS 050809 2032	EN 16 45.17 S 124 0.32 W GPS	3652	3651												
49NZ20090410	P21	117	1	ROS 050809 2326	BE 16 45.00 S 124 40.00 W GPS	3785	3785												
49NZ20090410	P21	117	1	BUC 050809 2334	UN 16 44.98 S 124 40.01 W GPS	3784	3783												1
49NZ20090410	P21	117	1	ROS 050909 0027	BO 16 45.02 S 124 40.07 W GPS	3780	3780	9	3791	3821			30	1-8,27					26.9C
49NZ20090410	P21	117	1	ROS 050909 0157	EN 16 45.06 S 124 40.08 W GPS	3772	3772												
49NZ20090410	P21	118	1	ROS 050909 0452	BE 16 44.97 S 125 19.97 W GPS	3794	3793												
49NZ20090410	P21	118	1	ROS 050909 0459	EN 16 44.96 S 125 19.98 W GPS	3797	3796												
49NZ20090410	P21	118	2	ROS 050909 0510	BE 16 44.97 S 125 19.99 W GPS	3797	3796												
49NZ20090410	P21	118	1	BUC 050909 0518	UN 16 45.00 S 125 20.00 W GPS	3797	3798												1
49NZ20090410	P21	118	2	ROS 050909 0612	BO 16 44.98 S 125 20.07 W GPS	3813	3813	10	3806	3839			28	1-8,23,24,26,27					27.0C
49NZ20090410	P21	118	2	ROS 050909 0744	EN 16 45.10 S 125 20.19 W GPS	3822	3821												
49NZ20090410	P21	119	1	ROS 050909 1038	BE 16 45.05 S 126 0.16 W GPS	3753	3754												
49NZ20090410	P21	119	1	BUC 050909 1046	UN 16 45.04 S 126 0.18 W GPS	3774	3775												1
49NZ20090410		1043	1	UNK 050909 1055	UN 16 45.02 S 126 0.20 W GPS	3770	3770												27.2C
49NZ20090410	P21	119	1	ROS 050909 1139	BO 16 45.00 S 126 0.31 W GPS	3786	3786	10	3785	3814			27	1-8,27					AIR BVOC SMPL #7915
49NZ20090410	P21	119	1	ROS 050909 1306	EN 16 45.00 S 126 0.41 W GPS	3795	3795												
49NZ20090410	P21	120	1	ROS 050909 1555	BE 16 44.99 S 126 40.03 W GPS	3804	3803												
49NZ20090410	P21	120	1	BUC 050909 1602	UN 16 45.00 S 126 40.08 W GPS	3806	3805												1,4-6,30,34,41,48,86,88
49NZ20090410	P21	120	1	ROS 050909 1655	BO 16 45.01 S 126 40.51 W GPS	3793	3792	10	3845	3849			34	1-8,27,30,34,41,82,86,88					27.0C
49NZ20090410	P21	120	1	ROS 050909 1820	EN 16 45.16 S 126 41.07 W GPS	3810	3809												
49NZ20090410		1044	1	UNK 050909 2000	UN 16 45.24 S 127 4.31 W GPS	3633	3633												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-24
49NZ20090410	P21	121	1	ROS 050909 2111	BE 16 45.02 S 127 20.18 W GPS	4007	4007												
49NZ20090410	P21	121	1	BUC 050909 2119	UN 16 45.08 S 127 20.21 W GPS	4013	4013												1,20,31,33,34,82
49NZ20090410	P21	121	1	ROS 050909 2215	BO 16 45.22 S 127 20.38 W GPS	4000	4001	9	4015	4044			29	1-8,23,24,26,27,31,33,34,64,82					27.4C, PLANKTON NET
49NZ20090410	P21	121	1	ROS 050909 2354	EN 16 45.37 S 127 20.54 W GPS	4003	4002												
49NZ20090410	P21	121	1	UNK 051009 0001	UN 16 45.40 S 127 20.77 W GPS	4003	4003												AIR 13CH4/CH3D/15N2O SMPL
49NZ20090410	P21	122	1	ROS 051009 0245	BE 16 44.99 S 128 0.02 W GPS	3833	3833												
49NZ20090410	P21	122	1	BUC 051009 0253	UN 16 45.03 S 128 0.07 W GPS	3840	3838												1
49NZ20090410	P21	122	1	ROS 051009 0347	BO 16 45.21 S 128 0.36 W GPS	3878	3876	10	3892	3913			28	1-8,27					27.3C
49NZ20090410	P21	122	1	ROS 051009 0520	EN 16 45.30 S 128 0.80 W GPS	3865	3865												
49NZ20090410	P21	123	1	ROS 051009 0808	BE 16 45.03 S 128 40.05 W GPS	3952	3953												









P21 REV R/V MIRAI CRUISE MR0901 LEG2

SHIP/CRS	WOCE	CAST		UTC EVENT		POSITION			UNC	COR	HT ABOVE	WIRE	MAX	NO. OF	COMMENTS		
EXPCODE	SECT	STNNBR	CASTNO	TYPE	DATE	TIME	CODE	LATITUDE	LONGITUDE	NAV	DEPTH	DEPTH	BOTTOM	OUT		PRESS	BOTTLES
49NZ20090521	P21	164	1	ROS	052109	2056	BE	17 30.14 S	149 57.28 W	GPS	1419	1419					
49NZ20090521	P21	164	1	BUC	052109	2104	UN	17 30.15 S	149 57.31 W	GPS	1444	1443					1,4-6,20,30,34,41,48,86,88
49NZ20090521	P21	164	1	ROS	052109	2127	BO	17 30.10 S	149 57.36 W	GPS	1466	1467	11	1459	1467	25	1-8,23,24,26,27,30,34,41,82,86,88
49NZ20090521		1061	1	UNK	052109	2200	UN	17 30.07 S	149 57.43 W	GPS	1507	1505					INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-33
49NZ20090521	P21	164	1	ROS	052109	2213	EN	17 30.04 S	149 57.43 W	GPS	1513	1515					
49NZ20090521	P21	165	1	ROS	052209	0030	BE	17 29.86 S	150 5.20 W	GPS	3092	3091					
49NZ20090521	P21	165	1	BUC	052209	0038	UN	17 29.87 S	150 5.25 W	GPS	3092	3091				1	28.2C, PLANKTON NET
49NZ20090521	P21	165	1	ROS	052209	0122	BO	17 29.75 S	150 5.41 W	GPS	3087	3085	9	3103	3118	25	1-8,27
49NZ20090521	P21	165	1	ROS	052209	0249	EN	17 29.43 S	150 5.66 W	GPS	3025	3024					
49NZ20090521	P21	X16	1	ROS	052209	0453	BE	17 30.61 S	150 28.91 W	GPS	3602	3602					
49NZ20090521	P21	X16	1	BUC	052209	0501	UN	17 30.63 S	150 28.92 W	GPS	3602	3602					1,31,33
49NZ20090521	P21	X16	1	ROS	052209	0552	BO	17 30.60 S	150 28.96 W	GPS	3594	3595	9	3613	3643	27	1-8,12,13,23,24,26,27,31,33
49NZ20090521	P21	X16	1	ROS	052209	0720	EN	17 30.30 S	150 29.12 W	GPS	3519	3519					
49NZ20090521	P21	167	1	ROS	052209	0941	BE	17 29.93 S	151 0.05 W	GPS	3612	3613					
49NZ20090521	P21	167	1	BUC	052209	0948	UN	17 29.93 S	151 0.07 W	GPS	3613	3614				1	27.9C
49NZ20090521	P21	167	1	ROS	052209	1039	BO	17 29.93 S	151 0.21 W	GPS	3666	3666	10	3646	3675	27	1-8,27
49NZ20090521	P21	167	1	ROS	052209	1211	EN	17 29.89 S	151 0.44 W	GPS	3663	3664					
49NZ20090521	P21	168	1	ROS	052209	1505	BE	17 29.99 S	151 40.23 W	GPS	4066	4065					
49NZ20090521	P21	168	1	BUC	052209	1512	UN	17 30.00 S	151 40.26 W	GPS	4065	4066					1,4-6,30,34,41,48,86,88
49NZ20090521	P21	168	1	ROS	052209	1610	BO	17 30.05 S	151 40.38 W	GPS	4067	4064	9	4071	4108	29	1-8,23,24,26,27
49NZ20090521	P21	168	1	ROS	052209	1753	EN	17 30.06 S	151 40.49 W	GPS	4066	4064					
49NZ20090521	P21	169	1	ROS	052209	2041	BE	17 29.99 S	152 20.02 W	GPS	4517	4515					
49NZ20090521	P21	169	1	BUC	052209	2049	UN	17 30.00 S	152 20.05 W	GPS	4516	4517					1,20,88
49NZ20090521	P21	169	1	ROS	052209	2151	BO	17 30.08 S	152 20.16 W	GPS	4515	4516	9	4525	4572	30	1-8,27
49NZ20090521		1062	1	UNK	052209	2200	UN	17 30.09 S	152 20.17 W	GPS	4515	4516					INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-34
49NZ20090521	P21	169	1	ROS	052209	2335	EN	17 30.07 S	152 20.28 W	GPS	4515	4514					
49NZ20090521	P21	170	1	ROS	052309	0228	BE	17 30.01 S	152 59.97 W	GPS	4494	4496					
49NZ20090521	P21	170	1	BUC	052309	0235	UN	17 30.01 S	152 59.95 W	GPS	4496	4494					1,88
49NZ20090521		1063	1	UNK	052309	0250	UN	17 30.00 S	152 59.84 W	GPS	4494	4494					AIR BVOC SMPL #5391
49NZ20090521	P21	170	1	ROS	052309	0339	BO	17 30.24 S	152 59.63 W	GPS	4401	4402	10	4521	4550	32	1-8,23,24,26,27
49NZ20090521	P21	170	1	ROS	052309	0536	EN	17 30.54 S	152 59.11 W	GPS	4394	4396					HEAVY RAIN
49NZ20090521	P21	171	1	ROS	052309	0831	BE	17 29.98 S	153 40.14 W	GPS	4701	4702					
49NZ20090521	P21	171	1	BUC	052309	0838	UN	17 29.96 S	153 40.06 W	GPS	4701	4702					1,88
49NZ20090521	P21	171	1	ROS	052309	0944	BO	17 30.16 S	153 39.74 W	GPS	4673	4675	8	4708	4749	32	1-8,27
49NZ20090521	P21	171	1	ROS	052309	1135	EN	17 30.32 S	153 39.45 W	GPS	4672	4674					
49NZ20090521	P21	172	1	ROS	052309	1430	BE	17 30.20 S	154 20.03 W	GPS	4720	4718					
49NZ20090521	P21	172	1	BUC	052309	1438	UN	17 30.19 S	154 20.00 W	GPS	4720	4721					1,4-6,30,34,41,48,86,88
49NZ20090521	P21	172	1	ROS	052309	1544	BO	17 30.27 S	154 19.89 W	GPS	4726	4724	10	4735	4784	36	1-8,23,24,26,27,30,34,41,82,86,88
49NZ20090521	P21	172	1	ROS	052309	1740	EN	17 30.44 S	154 19.77 W	GPS	4724	4724					
49NZ20090521	P21	172	1	XMP	052309	1752	DE	17 30.43 S	154 19.72 W	GPS	4724	4723					XMP #8
49NZ20090521	P21	172	2	XMP	052309	1839	DE	17 30.65 S	154 19.39 W	GPS	4726	4726					XMP #9







49NZ20090521	P21	193	1	BUC 053109 2039	UN 17 30.08 S 168 20.07 W GPS	4759	4759					1,20	28.0C
49NZ20090521	P21	193	1	ROS 053109 2147	BO 17 30.24 S 168 20.43 W GPS	4803	4802	10	4815	4847	31	1-8,23,24,26,27	
49NZ20090521		1074	1	UNK 053109 2305	UN 17 30.58 S 168 21.00 W GPS	4687	4688						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-42
49NZ20090521	P21	193	1	ROS 053109 2341	EN 17 30.79 S 168 21.16 W GPS	4619	4617						
49NZ20090521	P21	194	1	ROS 060109 0225	BE 17 30.03 S 169 0.03 W GPS	5357	5357						
49NZ20090521	P21	194	1	BUC 060109 0234	UN 17 30.10 S 169 0.03 W GPS	5329	5330					1	28.0C
49NZ20090521	P21	194	1	ROS 060109 0350	BO 17 30.54 S 169 0.40 W GPS	5321	5321	9	5383	5391	35	1-8,27	#2=#13 DUPL BTLS
49NZ20090521		1075	1	UNK 060109 0458	UN 17 30.86 S 169 0.44 W GPS	5328	5327						AIR BVOC SMPL #H1041
49NZ20090521	P21	194	1	ROS 060109 0559	EN 17 30.98 S 169 0.80 W GPS	5301	5304						
49NZ20090521	P21	195	1	ROS 060109 0848	BE 17 29.97 S 169 40.04 W GPS	4975	4974						
49NZ20090521	P21	195	1	BUC 060109 0855	UN 17 29.98 S 169 40.09 W GPS	4974	4974					1	27.8C
49NZ20090521	P21	195	1	ROS 060109 1004	BO 17 30.14 S 169 40.40 W GPS	4978	4977	10	4997	5043	32	1-8,12,13,23,24,26,27	
49NZ20090521	P21	195	1	ROS 060109 1205	EN 17 30.48 S 169 40.87 W GPS	4971	4970						
49NZ20090521	P21	196	1	ROS 060109 1454	BE 17 30.03 S 170 20.08 W GPS	5257	5259						
49NZ20090521	P21	196	1	BUC 060109 1503	UN 17 30.03 S 170 20.08 W GPS	5255	5258					1,4-6,30,34,41,48,86,88	28.1C, PLANKTON NET
49NZ20090521	P21	196	1	ROS 060109 1617	BO 17 29.98 S 170 19.94 W GPS	5258	5258	10	5271	5335	36	1-8,24,27,30,34,41,82,86,88	
49NZ20090521	P21	196	1	ROS 060109 1823	EN 17 29.62 S 170 19.27 W GPS	5257	5259						
49NZ20090521	P21	197	1	ROS 060109 2119	BE 17 30.02 S 171 0.01 W GPS	5110	5110						
49NZ20090521	P21	197	1	BUC 060109 2127	UN 17 29.97 S 170 59.96 W GPS	5109	5110					1,20	28.1C
49NZ20090521	P21	197	1	ROS 060109 2238	BO 17 29.85 S 170 59.63 W GPS	5118	5118	11	5147	5185	34	1-8,27	#2=#14 DUPL BTLS
49NZ20090521		1076	1	UNK 060109 2301	UN 17 29.88 S 170 59.62 W GPS	5117	5116						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-43
49NZ20090521	P21	197	1	ROS 060209 0040	EN 17 29.75 S 170 59.31 W GPS	5132	5132						
49NZ20090521	P21	198	1	ROS 060209 0333	BE 17 29.99 S 171 40.00 W GPS	4975	4978						
49NZ20090521	P21	198	1	BUC 060209 0342	UN 17 29.93 S 171 39.97 W GPS	4972	4974					1,31,33	27.8C
49NZ20090521	P21	198	1	ROS 060209 0452	BO 17 29.57 S 171 39.96 W GPS	4967	4969	10	4989	5036	32	1-8,23,24,26,27,31,33	
49NZ20090521	P21	198	1	ROS 060209 0657	EN 17 29.00 S 171 39.93 W GPS	4963	4963						
49NZ20090521	P21	199	1	ROS 060209 0901	BE 17 29.97 S 172 0.03 W GPS	5732	5732						
49NZ20090521	P21	199	1	BUC 060209 0909	UN 17 29.91 S 172 0.05 W GPS	5706	5704					1	27.7C
49NZ20090521	P21	199	1	ROS 060209 1030	BO 17 29.59 S 171 59.83 W GPS	5811	5810	10	5817	5893	36	1-8,27	
49NZ20090521	P21	199	1	ROS 060209 1252	EN 17 28.98 S 171 59.50 W GPS	5852	5853						
49NZ20090521	P21	200	1	ROS 060209 1502	BE 17 29.99 S 172 20.13 W GPS	7872	7873						
49NZ20090521	P21	200	1	BUC 060209 1513	UN 17 29.95 S 172 20.19 W GPS	7891	7890					1,4-6,20,30,34,41,48,86,88	27.7C, PLANKTON NET
49NZ20090521	P21	200	1	ROS 060209 1641	BO 17 29.82 S 172 20.15 W GPS	7930	7932	-9	6408	6501	36	1-8,23,24,26,27,41,86	WITHOUT LADCP/FLUOROMETER/ TRANSMISSOMETER/OPTODE4330F
49NZ20090521	P21	200	1	ROS 060209 1936	EN 17 29.35 S 172 20.05 W GPS	7943	7944						
49NZ20090521		1077	1	UNK 060209 1959	BE 17 29.22 S 172 20.00 W GPS	7951	7951						RELEASED EXCESS TWIST OF CTD CABLE
49NZ20090521		1078	1	UNK 060209 2306	UN 17 28.65 S 172 19.53 W GPS	7841	7839						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-44
49NZ20090521		1077	1	UNK 060309 0008	EN 17 28.65 S 172 19.48 W GPS	7846	7847						WOUT 7000M, WEIGHT OF 350KG WITH A COMPASS/TILT METER
49NZ20090521	P21	201	1	ROS 060309 0144	BE 17 30.03 S 172 40.04 W GPS	5130	5130						
49NZ20090521	P21	201	1	BUC 060309 0156	UN 17 29.96 S 172 40.01 W GPS	5120	5120					1	27.7C
49NZ20090521	P21	201	1	ROS 060309 0308	BO 17 29.74 S 172 39.72 W GPS	5167	5168	10	5205	5203	34	1-8,27	#2=#15 DUPL BTLS
49NZ20090521	P21	201	1	ROS 060309 0517	EN 17 29.62 S 172 39.55 W GPS	5222	5223						
49NZ20090521	P21	203	1	ROS 060309 0720	BE 17 30.06 S 172 50.06 W GPS	4318	4318						
49NZ20090521	P21	203	1	BUC 060309 0731	UN 17 30.01 S 172 50.06 W GPS	4326	4327					1	27.6C
49NZ20090521	P21	203	1	ROS 060309 0830	BO 17 29.81 S 172 49.90 W GPS	4343	4342	10	4351	4377	29	1-8,23,24,26,27	
49NZ20090521	P21	203	1	ROS 060309 1011	EN 17 29.58 S 172 49.83 W GPS	4316	4317						
49NZ20090521	P21	204	1	ROS 060309 1215	BE 17 30.03 S 172 59.99 W GPS	2553	2553						

49NZ20090521	P21	204	1	BUC 060309 1227	UN 17 29.97 S 173 0.00 W GPS	2552	2552					1						28.1C
49NZ20090521	P21	204	1	ROS 060309 1302	BO 17 29.86 S 172 59.98 W GPS	2557	2555	10	2560	2567	23	1-8,27					#2=#16 DUPL BTLS	
49NZ20090521		1079	1	UNK 060309 1314	UN 17 29.87 S 172 59.96 W GPS	2559	2558										AIR BVOC SMPL #8048	
49NZ20090521	P21	204	1	ROS 060309 1416	EN 17 29.66 S 172 59.86 W GPS	2545	2544											
49NZ20090521	P21	205	1	ROS 060309 1712	BE 17 30.03 S 173 40.00 W GPS	1363	1363											
49NZ20090521	P21	205	1	BUC 060309 1722	UN 17 30.02 S 173 40.07 W GPS	1362	1364						1,4-6,30,34,41,48,86,88				28.0C, PLANKTON NET	
49NZ20090521	P21	205	1	XCT 060309 1723	DE 17 30.03 S 173 40.08 W GPS	1363	1365										TSK XCTD-2(MK-130) #08112325	
49NZ20090521	P21	205	1	ROS 060309 1740	BO 17 29.95 S 173 40.14 W GPS	1363	1364	11	1360	1361	22	1-8,23,24,26,27,30,34,41,82,86,88						
49NZ20090521	P21	205	1	ROS 060309 1827	EN 17 29.83 S 173 40.36 W GPS	1364	1365											
49NZ20090521	P21	205	1	XMP 060309 1835	DE 17 29.81 S 173 40.32 W GPS	1364	1364										XMP #7	
49NZ20090521	P21	205	2	XMP 060309 1907	DE 17 30.08 S 173 39.88 W GPS	1363	1362										XMP #10	
49NZ20090521	P21	206	1	ROS 060309 2222	BE 17 25.08 S 174 20.04 W GPS	1485	1485											
49NZ20090521	P21	206	1	BUC 060309 2229	UN 17 25.06 S 174 20.04 W GPS	1487	1484						1,20				27.9C	
49NZ20090521	P21	206	1	XCT 060309 2232	DE 17 25.06 S 174 20.04 W GPS	1484	1484										TSK XCTD-2(MK-130) #08112317	
49NZ20090521	P21	206	1	ROS 060309 2249	BO 17 24.97 S 174 20.01 W GPS	1485	1486	9	1479	1483	16	1-8,27						
49NZ20090521		1080	1	UNK 060309 2304	UN 17 24.98 S 174 20.02 W GPS	1485	1484										INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-45	
49NZ20090521	P21	206	1	ROS 060309 2340	EN 17 24.89 S 174 20.01 W GPS	1486	1483											
49NZ20090521	P21	207	1	ROS 060409 0233	BE 17 30.07 S 175 0.09 W GPS	2380	2378											
49NZ20090521	P21	207	1	BUC 060409 0243	UN 17 30.04 S 175 0.11 W GPS	2379	2378											
49NZ20090521	P21	207	1	ROS 060409 0316	BO 17 29.96 S 175 0.13 W GPS	2379	2379	10	2376	2388	22	1-8,23,24,26,27					26.7C	
49NZ20090521	P21	207	1	ROS 060409 0426	EN 17 29.82 S 175 0.25 W GPS	2377	2377											
49NZ20090521	P21	208	1	ROS 060409 0712	BE 17 29.96 S 175 40.01 W GPS	2172	2174											
49NZ20090521	P21	208	1	BUC 060409 0719	UN 17 29.94 S 175 40.02 W GPS	2169	2168											
49NZ20090521	P21	208	1	ROS 060409 0749	BO 17 29.77 S 175 40.04 W GPS	2194	2195	9	2172	2177	20	1-8,27					26.8C	
49NZ20090521	P21	208	1	ROS 060409 0848	EN 17 29.35 S 175 39.91 W GPS	2220	2221											
49NZ20090521	P21	209	1	ROS 060409 1143	BE 17 30.06 S 176 20.00 W GPS	1858	1856											
49NZ20090521	P21	209	1	BUC 060409 1153	UN 17 30.06 S 176 19.93 W GPS	1905	1905						1,31,33,34,82				26.9C	
49NZ20090521	P21	209	1	XCT 060409 1155	DE 17 30.06 S 176 19.92 W GPS	1926	1924										TSK XCTD-2(MK-130) #08112318	
49NZ20090521	P21	209	1	ROS 060409 1221	BO 17 29.87 S 176 19.87 W GPS	1856	1855	11	1920	1919	19	1-8,23,24,26,27,31,33,34,82						
49NZ20090521	P21	209	1	ROS 060409 1319	EN 17 29.50 S 176 19.76 W GPS	1793	1792											
49NZ20090521	P21	209	1	UNK 060409 1328	UN 17 29.58 S 176 19.87 W GPS	1791	1791										AIR 13CH4/CH3D/15N2O SMPL	
49NZ20090521	P21	210	1	ROS 060409 1612	BE 17 29.95 S 177 0.03 W GPS	2418	2416											
49NZ20090521	P21	210	1	BUC 060409 1622	UN 17 29.84 S 177 0.05 W GPS	2419	2417											
49NZ20090521		1081	1	UNK 060409 1628	UN 17 29.81 S 177 0.07 W GPS	2424	2424											
49NZ20090521	P21	210	1	ROS 060409 1655	BO 17 29.67 S 177 0.08 W GPS	2440	2440	10	2436	2438	24	1-8,12,13,23,24,26,27,41,86,88						
49NZ20090521	P21	210	2	BUC 060409 1726	UN 17 29.49 S 177 0.09 W GPS	2457	2454						4-6,30,34,41,48,86,88				UT GROUP SAMPLING ONLY	
49NZ20090521	P21	210	1	ROS 060409 1808	EN 17 29.23 S 177 0.14 W GPS	2424	2424											
49NZ20090521	P21	211	1	ROS 060409 2102	BE 17 30.02 S 177 40.10 W GPS	2244	2245											
49NZ20090521	P21	211	1	BUC 060409 2109	UN 17 30.00 S 177 40.14 W GPS	2244	2241											
49NZ20090521	P21	211	1	ROS 060409 2140	BO 17 29.91 S 177 40.18 W GPS	2271	2271	12	2265	2276	21	1-8,27					27.5C	
49NZ20090521	P21	211	1	ROS 060409 2239	EN 17 29.68 S 177 40.17 W GPS	2255	2254											
49NZ20090521		1082	1	UNK 060409 2303	UN 17 31.48 S 177 43.53 W GPS	2505	2504										INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-46	
49NZ20090521	P21	212	1	ROS 060509 0126	BE 17 45.02 S 178 15.01 W GPS	1947	1947											
49NZ20090521	P21	212	1	BUC 060509 0134	UN 17 45.05 S 178 14.99 W GPS	1944	1944											
49NZ20090521	P21	212	1	ROS 060509 0202	BO 17 45.08 S 178 15.01 W GPS	1943	1942	10	1945	1955	19	1-8,23,24,26,27					27.6C	
49NZ20090521	P21	212	1	ROS 060509 0301	EN 17 45.03 S 178 14.97 W GPS	1957	1958											
49NZ20090521	P21	213	1	ROS 060509 0502	BE 17 54.03 S 178 32.96 W GPS	991	991											
49NZ20090521	P21	213	1	BUC 060509 0509	UN 17 54.01 S 178 32.97 W GPS	990	991											
49NZ20090521	P21	213	1	XCT 060509 0512	DE 17 54.01 S 178 32.96 W GPS	992	991										26.9C	
																	TSK XCTD-2(MK-130) #08112327	

49NZ20090521	P21	213	1	ROS	060509	0523	BO	17	53.96	S	178	33.00	W	GPS	991	991	11	986	983	14	1-8,23,24,26,27	
49NZ20090521	P21	213	1	ROS	060509	0602	EN	17	53.95	S	178	33.09	W	GPS	986	986						
49NZ20090521	P21	214	1	ROS	060509	0852	BE	18	10.04	S	179	9.97	W	GPS	965	966						
49NZ20090521	P21	214	1	BUC	060509	0900	UN	18	10.04	S	179	9.92	W	GPS	964	965					1	
49NZ20090521	P21	214	1	ROS	060509	0914	BO	18	10.00	S	179	9.86	W	GPS	961	962	10	957	960	14	1-8,27	26.8C
49NZ20090521	P21	214	1	ROS	060509	0950	EN	18	9.86	S	179	9.71	W	GPS	956	957						
49NZ20090521	P21	215	1	ROS	060509	1220	BE	18	24.97	S	179	40.00	W	GPS	2946	2946						
49NZ20090521	P21	215	1	BUC	060509	1227	UN	18	24.93	S	179	39.99	W	GPS	2948	2948					1	26.7C
49NZ20090521	P21	215	1	ROS	060509	1308	BO	18	24.90	S	179	39.82	W	GPS	2949	2951	10	2957	2969	25	1-8,27	#2=#16 DUPL BTLs
49NZ20090521	P21	215	1	ROS	060509	1429	EN	18	24.83	S	179	39.32	W	GPS	2948	2949						
49NZ20090521	P21	216	1	ROS	060509	1721	BE	18	24.99	S	179	39.97	E	GPS	3205	3204						
49NZ20090521	P21	216	1	BUC	060509	1729	UN	18	24.96	S	179	39.97	E	GPS	3203	3204					1,4-6,30,31,33,34,41,48,86,88	26.5C, PLANKTON NET
49NZ20090521	P21	216	1	ROS	060509	1814	BO	18	24.87	S	179	40.11	E	GPS	3195	3193	10	3211	3229	32	1-8,23,24,26,27,30,31,33,34,41,82,86,88	
49NZ20090521	P21	216	1	ROS	060509	1940	EN	18	24.79	S	179	40.31	E	GPS	3184	3182						
49NZ20090521	P21	217	1	ROS	060509	2227	BE	18	25.01	S	179	0.01	E	GPS	2247	2246						
49NZ20090521	P21	217	1	BUC	060509	2234	UN	18	25.00	S	179	0.03	E	GPS	2248	2246					1,20	26.0C
49NZ20090521		1083	1	UNK	060509	2250	UN	18	24.95	S	179	0.11	E	GPS	2245	2243						AIR BVOC SMPL #7774
49NZ20090521	P21	217	1	ROS	060509	2304	BO	18	24.90	S	179	0.17	E	GPS	2241	2240	10	2246	2251	22	1-8,27	#2=#17 DUPL BTLs
49NZ20090521	P21	217	1	ROS	060609	0005	EN	18	24.70	S	179	0.39	E	GPS	2235	2236						
49NZ20090521		1084	1	UNK	060609	0016	UN	18	24.77	S	178	59.54	E	GPS	2247	2249						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-47
49NZ20090521	P21	218	1	ROS	060609	0254	BE	18	24.99	S	178	19.93	E	GPS	2015	2015						
49NZ20090521	P21	218	1	BUC	060609	0301	UN	18	24.98	S	178	19.90	E	GPS	2016	2016					1	26.3C
49NZ20090521	P21	218	1	ROS	060609	0330	BO	18	24.93	S	178	19.96	E	GPS	2017	2017	10	2015	2022	19	1-8,23,24,26,27	
49NZ20090521	P21	218	1	ROS	060609	0428	EN	18	24.80	S	178	20.00	E	GPS	2026	2026						
49NZ20090521	P21	220	1	ROS	060609	0623	BE	18	45.03	S	178	3.88	E	GPS	2149	2150						
49NZ20090521	P21	220	1	BUC	060609	0630	UN	18	45.02	S	178	3.79	E	GPS	2149	2148					1,88	26.2C
49NZ20090521	P21	220	1	ROS	060609	0701	BO	18	44.94	S	178	3.81	E	GPS	2150	2150	10	2149	2157	20	1-8,12,13,23,24,26,27	
49NZ20090521	P21	220	1	ROS	060609	0802	EN	18	44.94	S	178	3.79	E	GPS	2150	2150						
49NZ20090521	P21	221	1	ROS	060609	0946	BE	18	45.05	S	177	50.01	E	GPS	1883	1882						
49NZ20090521	P21	221	1	BUC	060609	0952	UN	18	45.02	S	177	50.02	E	GPS	1881	1880					1,4-6,30,41,48,86,88	26.3C
49NZ20090521	P21	221	1	XCT	060609	0955	DE	18	45.02	S	177	50.03	E	GPS	1882	1883						TSK XCTD-2(MK-130) #08112320
49NZ20090521	P21	221	1	ROS	060609	1018	BO	18	44.92	S	177	49.97	E	GPS	1953	1953	11	1910	1912	19	1-8,27	
49NZ20090521	P21	221	1	ROS	060609	1110	EN	18	44.61	S	177	49.91	E	GPS	1936	1936						
49NZ20090521	P21	222	1	ROS	060609	1345	BE	18	35.00	S	177	15.02	E	GPS	2419	2419						
49NZ20090521	P21	222	1	BUC	060609	1353	UN	18	34.93	S	177	14.99	E	GPS	2438	2438					1,88	26.7C
49NZ20090521	P21	222	1	ROS	060609	1428	BO	18	34.68	S	177	14.97	E	GPS	2426	2426	10	2463	2463	21	1-8,23,24,26,27	
49NZ20090521	P21	222	1	ROS	060609	1536	EN	18	34.26	S	177	15.04	E	GPS	2108	2109						
49NZ20090521	P21	223	1	ROS	060609	1816	BE	18	2.04	S	177	0.00	E	GPS	2217	2216						
49NZ20090521	P21	223	1	BUC	060609	1823	UN	18	1.98	S	176	59.99	E	GPS	2215	2216					1,4-6,30,34,41,48,88	26.8C, PLANKTON NET
49NZ20090521	P21	223	1	ROS	060609	1854	BO	18	1.84	S	177	0.06	E	GPS	2213	2213	10	2227	2226	27	1-8,27,41	
49NZ20090521	P21	223	1	ROS	060609	1958	EN	18	1.55	S	177	0.26	E	GPS	2206	2205						
49NZ20090521	P21	224	1	ROS	060609	2154	BE	17	49.92	S	176	59.95	E	GPS	1339	1339						
49NZ20090521	P21	224	1	BUC	060609	2201	UN	17	49.93	S	176	59.94	E	GPS	1338	1336					1,20,88	27.2C
49NZ20090521	P21	224	1	ROS	060609	2220	BO	17	49.95	S	176	59.89	E	GPS	1348	1349	10	1350	1353	16	1-8,23,24,26,27	
49NZ20090521	P21	224	1	ROS	060609	2259	EN	17	49.98	S	176	59.89	E	GPS	1367	1368						
49NZ20090521		1085	1	UNK	060709	0000	UN	17	50.06	S	176	46.20	E	GPS	3095	3096						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-48
49NZ20090521	P21	225	1	ROS	060709	0146	BE	17	50.07	S	176	20.02	E	GPS	3098	3099						
49NZ20090521	P21	225	1	BUC	060709	0153	UN	17	50.06	S	176	20.01	E	GPS	3104	3105					1,88	27.1C
49NZ20090521	P21	225	1	ROS	060709	0237	BO	17	49.87	S	176	20.01	E	GPS	3121	3121	10	3126	3142	25	1-8,23,24,26,27	

49NZ20090521	P21	225	1	ROS 060709 0400	EN 17 49.66 S 176 20.22 E GPS	3072	3073												
49NZ20090521	P21	226	1	ROS 060709 0650	BE 17 50.02 S 175 39.99 E GPS	1951	1951												
49NZ20090521	P21	226	1	BUC 060709 0657	UN 17 50.00 S 175 39.99 E GPS	1936	1936												
49NZ20090521	P21	226	1	ROS 060709 0725	BO 17 49.78 S 175 39.99 E GPS	1981	1981	10	1973	1963		21	1-8,27						26.3C #2=#18 DUPL BTLS
49NZ20090521	P21	226	1	ROS 060709 0822	EN 17 49.58 S 175 40.25 E GPS	1890	1890												
49NZ20090521	P21	227	1	ROS 060709 1113	BE 17 49.99 S 174 59.99 E GPS	2089	2089												
49NZ20090521	P21	227	1	BUC 060709 1120	UN 17 49.93 S 174 59.98 E GPS	2092	2093												
49NZ20090521	P21	227	1	ROS 060709 1148	BO 17 49.74 S 175 0.00 E GPS	2056	2056	9	2057	2064		20	1-8,23,24,26,27						26.0C
49NZ20090521		1086	1	UNK 060709 1200	UN 17 49.69 S 175 0.03 E GPS	2032	2031												AIR BVOC SMPL #7068
49NZ20090521	P21	227	1	ROS 060709 1249	EN 17 49.33 S 175 0.01 E GPS	1973	1973												
49NZ20090521	P21	228	1	ROS 060709 1537	BE 17 49.99 S 174 19.97 E GPS	2845	2845												
49NZ20090521	P21	228	1	BUC 060709 1545	UN 17 49.93 S 174 19.92 E GPS	2849	2848												
49NZ20090521	P21	228	1	ROS 060709 1625	BO 17 49.89 S 174 19.97 E GPS	2849	2848	8	2861	2876		29	1-8,27,30,34,41,82,86,88						26.3C, PLANKTON NET
49NZ20090521	P21	228	1	ROS 060709 1743	EN 17 49.78 S 174 20.01 E GPS	2816	2817												
49NZ20090521	P21	229	1	ROS 060709 2031	BE 17 50.01 S 173 39.96 E GPS	2688	2689												
49NZ20090521	P21	229	1	BUC 060709 2039	UN 17 49.95 S 173 39.91 E GPS	2674	2673												
49NZ20090521	P21	229	1	ROS 060709 2116	BO 17 49.83 S 173 39.91 E GPS	2661	2661	11	2686	2700		23	1,31,33,34,82						26.7C
49NZ20090521	P21	229	1	ROS 060709 2222	EN 17 49.53 S 173 39.90 E GPS	2632	2631												
49NZ20090521	P21	229	1	UNK 060709 2228	UN 17 49.68 S 173 39.87 E GPS	2680	2679												
49NZ20090521		1087	1	UNK 060809 0005	UN 17 50.06 S 173 15.14 E GPS	2568	2568												AIR 13CH4/CH3D/15N2O SMPL INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-49
49NZ20090521	P21	230	1	ROS 060809 0111	BE 17 49.99 S 172 59.90 E GPS	2925	2924												
49NZ20090521	P21	230	1	BUC 060809 0118	UN 17 50.03 S 172 59.84 E GPS	2971	2971												
49NZ20090521	P21	230	1	ROS 060809 0200	BO 17 50.04 S 172 59.56 E GPS	3145	3145	10	2986	2992		24	1-8,27						26.6C
49NZ20090521	P21	230	1	ROS 060809 0318	EN 17 50.19 S 172 58.91 E GPS	3173	3174												
49NZ20090521	P21	231	1	ROS 060809 0611	BE 17 50.00 S 172 20.00 E GPS	2943	2944												
49NZ20090521	P21	231	1	BUC 060809 0619	UN 17 50.01 S 172 19.97 E GPS	2938	2940												
49NZ20090521	P21	231	1	ROS 060809 0700	BO 17 50.09 S 172 19.82 E GPS	2926	2928	11	2941	2954		24	1-8,12,13,23,24,26,27						26.4C
49NZ20090521	P21	231	1	ROS 060809 0816	EN 17 50.34 S 172 19.29 E GPS	2961	2961												
49NZ20090521	P21	232	1	ROS 060809 1104	BE 17 49.99 S 171 39.96 E GPS	2753	2752												
49NZ20090521	P21	232	1	BUC 060809 1111	UN 17 49.96 S 171 39.95 E GPS	2754	2756												
49NZ20090521	P21	232	1	ROS 060809 1149	BO 17 49.96 S 171 39.83 E GPS	2758	2757	9	2760	2771		23	1-8,27						26.5C
49NZ20090521	P21	232	1	ROS 060809 1305	EN 17 49.43 S 171 39.59 E GPS	2760	2762												
49NZ20090521	P21	233	1	ROS 060809 1555	BE 17 50.05 S 170 59.99 E GPS	2813	2814												
49NZ20090521	P21	233	1	BUC 060809 1603	UN 17 50.05 S 171 0.01 E GPS	2813	2813												
49NZ20090521	P21	233	1	ROS 060809 1642	BO 17 50.10 S 171 0.05 E GPS	2818	2819	11	2813	2829		31	1-8,23,24,26,27,30,41,86,88						26.6C, PLANKTON NET
49NZ20090521		1088	1	UNK 060809 1654	UN 17 50.12 S 171 0.05 E GPS	2814	2815												
49NZ20090521	P21	233	2	BUC 060809 1720	UN 17 50.05 S 171 0.10 E GPS	2821	2822												AIR BVOC SMPL #7922 UT GROUP SAMPLING ONLY
49NZ20090521	P21	233	1	ROS 060809 1759	EN 17 50.09 S 171 0.14 E GPS	2830	2831												
49NZ20090521	P21	234	1	ROS 060809 2053	BE 17 50.01 S 170 19.92 E GPS	2594	2593												
49NZ20090521	P21	234	1	BUC 060809 2100	UN 17 50.02 S 170 19.89 E GPS	2592	2592												
49NZ20090521	P21	234	1	ROS 060809 2136	BO 17 49.88 S 170 19.86 E GPS	2587	2588	10	2600	2606		22	1-8,27						27.2C
49NZ20090521	P21	234	1	ROS 060809 2241	EN 17 49.61 S 170 19.77 E GPS	2584	2584												
49NZ20090521		1089	1	UNK 060909 0001	UN 17 49.80 S 170 0.75 E GPS	2434	2432												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-50
49NZ20090521	P21	235	1	ROS 060909 0050	BE 17 49.95 S 169 49.95 E GPS	2101	2102												
49NZ20090521	P21	235	1	BUC 060909 0057	UN 17 49.93 S 169 49.91 E GPS	2078	2077												
49NZ20090521	P21	235	1	ROS 060909 0126	BO 17 49.94 S 169 49.82 E GPS	2057	2057	10	2064	2071		20	1-8,23,24,26,27						26.5C
49NZ20090521	P21	235	1	ROS 060909 0224	EN 17 49.87 S 169 49.78 E GPS	2056	2056												
49NZ20090521	P21	236	1	ROS 060909 0437	BE 17 49.99 S 169 20.02 E GPS	2665	2667												
49NZ20090521	P21	236	1	BUC 060909 0445	UN 17 49.97 S 169 19.97 E GPS	2664	2666												1,31,33,82 26.7C



49NZ20090521	P21	236	1	ROS	060909	0522	BO	17	49.88	S	169	19.80	E	GPS	2642	2644	10	2657	2665	23	1-8,23,24,26,27,31,33,82	
49NZ20090521	P21	236	1	ROS	060909	0635	EN	17	49.61	S	169	19.63	E	GPS	2621	2621						
49NZ20090521	P21	237	1	ROS	060909	0830	BE	17	56.93	S	169	5.04	E	GPS	2041	2042						
49NZ20090521	P21	237	1	BUC	060909	0837	UN	17	56.90	S	169	5.01	E	GPS	2019	2018					1	26.8C
49NZ20090521	P21	237	1	ROS	060909	0905	BO	17	56.88	S	169	4.82	E	GPS	1980	1979	10	2003	2000	19	1-8,27	
49NZ20090521	P21	237	1	ROS	060909	0959	EN	17	56.73	S	169	4.41	E	GPS	1939	1937						
49NZ20090521	P21	238	1	ROS	060909	1132	BE	18	2.97	S	168	49.92	E	GPS	990	992						
49NZ20090521	P21	238	1	BUC	060909	1140	UN	18	2.91	S	168	49.82	E	GPS	989	989					1	26.4C
49NZ20090521	P21	238	1	ROS	060909	1155	BO	18	2.82	S	168	49.82	E	GPS	988	988	11	983	983	14	1-8,23,24,26,27	
49NZ20090521	P21	238	1	ROS	060909	1231	EN	18	2.59	S	168	49.82	E	GPS	987	987						
49NZ20090521	P21	239	1	ROS	060909	1401	BE	18	9.02	S	168	36.09	E	GPS	861	861						
49NZ20090521	P21	239	1	BUC	060909	1409	UN	18	8.97	S	168	36.09	E	GPS	862	863					1	26.5C
49NZ20090521	P21	239	1	ROS	060909	1421	BO	18	8.89	S	168	36.06	E	GPS	866	867	10	859	859	13	1-8,23,24,26,27	
49NZ20090521	P21	239	1	ROS	060909	1455	EN	18	8.71	S	168	35.86	E	GPS	872	873						
49NZ20090521	P21	240	1	ROS	060909	1645	BE	18	14.97	S	168	21.92	E	GPS	999	999						
49NZ20090521	P21	240	1	BUC	060909	1652	UN	18	14.95	S	168	21.88	E	GPS	997	997					1,4-6,30,34,41,48,86,88	26.4C, PLANKTON NET
49NZ20090521	P21	240	1	ROS	060909	1706	BO	18	14.96	S	168	21.83	E	GPS	1002	1000	10	994	996	20	1-8,23,24,26,27,30,34,41,82,86,88	
49NZ20090521	P21	240	1	ROS	060909	1744	EN	18	14.87	S	168	21.68	E	GPS	980	978						
49NZ20090521	P21	241	1	ROS	060909	1950	BE	18	17.84	S	168	12.91	E	GPS	2213	2214						
49NZ20090521	P21	241	1	BUC	060909	1957	UN	18	17.85	S	168	12.84	E	GPS	2226	2225					1	26.4C
49NZ20090521	P21	241	1	ROS	060909	2030	BO	18	17.90	S	168	12.56	E	GPS	2353	2352	11	2300	2301	21	1-8,27	
49NZ20090521	P21	241	1	ROS	060909	2127	EN	18	18.15	S	168	12.30	E	GPS	2436	2435						
49NZ20090521	P21	243	1	ROS	060909	2258	BE	18	22.15	S	168	3.09	E	GPS	4151	4144						
49NZ20090521	P21	243	1	BUC	060909	2305	UN	18	22.16	S	168	3.05	E	GPS	4152	4148					1,20	26.2C
49NZ20090521		1090	1	UNK	061009	0000	UN	18	22.16	S	168	2.80	E	GPS	4191	4148						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-51
49NZ20090521	P21	243	1	ROS	061009	0002	BO	18	22.14	S	168	2.77	E	GPS	4196	4191	10	4201	4215	29	1-8,23,24,26,27	
49NZ20090521	P21	243	1	ROS	061009	0145	EN	18	22.27	S	168	2.00	E	GPS	4414	4408						
49NZ20090521	P21	244	1	ROS	061009	0353	BE	18	29.52	S	167	47.97	E	GPS	5013	5014						
49NZ20090521	P21	244	1	BUC	061009	0400	UN	18	29.57	S	167	47.92	E	GPS	5003	5002					1	26.5C, PLANKTON NET
49NZ20090521	P21	244	1	ROS	061009	0511	BO	18	29.67	S	167	47.53	E	GPS	4997	4997	10	5048	5085	32	1-8,27	
49NZ20090521	P21	244	1	ROS	061009	0709	EN	18	28.86	S	167	47.40	E	GPS	4928	4929						
49NZ20090521	P21	245	1	ROS	061009	0901	BE	18	34.80	S	167	34.85	E	GPS	5602	5602						
49NZ20090521	P21	245	1	BUC	061009	0907	UN	18	34.75	S	167	34.89	E	GPS	5601	5603					1	26.5C
49NZ20090521	P21	245	1	ROS	061009	1026	BO	18	34.16	S	167	35.01	E	GPS	5601	5603	9	5680	5698	35	1-8,12,13,23,24,26,27	
49NZ20090521	P21	245	1	ROS	061009	1235	EN	18	33.67	S	167	35.10	E	GPS	5621	5623						
49NZ20090521	P21	246	1	ROS	061009	1433	BE	18	42.01	S	167	19.04	E	GPS	4833	4834						
49NZ20090521	P21	246	1	BUC	061009	1440	UN	18	41.98	S	167	19.05	E	GPS	4839	4838					1	26.8C
49NZ20090521	P21	246	1	ROS	061009	1548	BO	18	41.70	S	167	19.04	E	GPS	4836	4835	10	4854	4898	32	1-8,27	
49NZ20090521	P21	246	1	ROS	061009	1744	EN	18	41.68	S	167	18.83	E	GPS	4812	4812						
49NZ20090521		1091	1	UNK	061009	1912	UN	18	50.13	S	166	59.47	E	GPS	4407	4408						AIR BVOC SMPL #5398
49NZ20090521	P21	247	1	ROS	061009	2013	BE	18	54.95	S	166	48.16	E	GPS	4494	4493						
49NZ20090521	P21	247	1	BUC	061009	2020	UN	18	54.96	S	166	48.15	E	GPS	4493	4493					1,4,5,6,30,31,33,34,41,48,82,86,88	26.5C, PLANKTON NET
49NZ20090521	P21	247	1	ROS	061009	2123	BO	18	54.72	S	166	47.99	E	GPS	4516	4516	10	4531	4567	36	1-8,23,24,26,27,31,33,41,82,86	
49NZ20090521	P21	247	1	ROS	061009	2301	EN	18	54.29	S	166	47.39	E	GPS	4495	4496						
49NZ20090521		1092	1	UNK	061109	0101	UN	19	6.82	S	166	20.71	E	GPS	4021	4021						INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-52
49NZ20090521	P21	248	1	ROS	061109	0133	BE	19	7.92	S	166	18.01	E	GPS	3961	3961						
49NZ20090521	P21	248	1	BUC	061109	0139	UN	19	7.91	S	166	18.00	E	GPS	3981	3982					1,20	26.7C
49NZ20090521	P21	248	1	ROS	061109	0235	BO	19	7.92	S	166	17.93	E	GPS	4034	4034	10	3999	4036	30	1-8,27	
49NZ20090521	P21	248	1	ROS	061109	0413	EN	19	8.20	S	166	17.72	E	GPS	4051	4052						

49NZ20090521	P21	249	1	ROS 061109 0656	BE 19 23.07 S 165 41.91 E GPS	2431	2429												
49NZ20090521	P21	249	1	BUC 061109 0703	UN 19 23.07 S 165 41.87 E GPS	2435	2436							1					25.1C
49NZ20090521	P21	249	1	ROS 061109 0737	BO 19 22.91 S 165 41.82 E GPS	2422	2420	11	2427	2433				22	1-8,23,24,26,27				
49NZ20090521	P21	249	1	ROS 061109 0843	EN 19 22.41 S 165 41.63 E GPS	2330	2330												
49NZ20090521	P21	250	1	ROS 061109 1035	BE 19 29.06 S 165 28.94 E GPS	1717	1718												
49NZ20090521	P21	250	1	BUC 061109 1042	UN 19 29.06 S 165 28.95 E GPS	1720	1720												24.9C
49NZ20090521	P21	250	1	XCT 061109 1045	DE 19 29.05 S 165 28.97 E GPS	1716	1716												TSK XCTD-2(MK-130) #08112321
49NZ20090521	P21	250	1	ROS 061109 1106	BO 19 29.02 S 165 29.09 E GPS	1731	1732	10	1728	1726				17	1-8,23,24,26,27				
49NZ20090521	P21	250	1	ROS 061109 1153	EN 19 28.91 S 165 29.19 E GPS	1729	1728												
49NZ20090521	P21	251	1	ROS 061109 1337	BE 19 34.95 S 165 14.66 E GPS	2431	2432												
49NZ20090521	P21	251	1	BUC 061109 1344	UN 19 34.89 S 165 14.61 E GPS	2481	2482												25.2C
49NZ20090521	P21	251	1	ROS 061109 1425	BO 19 34.78 S 165 14.69 E GPS	2451	2452	10	2533	2546				22	1-8,27				
49NZ20090521	P21	251	1	ROS 061109 1535	EN 19 34.69 S 165 14.76 E GPS	2553	2554												
49NZ20090521	P21	252	1	ROS 061109 1727	BE 19 43.05 S 164 55.93 E GPS	3254	3255												
49NZ20090521	P21	252	1	BUC 061109 1735	UN 19 43.00 S 164 55.85 E GPS	3254	3255								1,4,5,6,30,34,41,48,86,88				25.2C, PLANKTON NET
49NZ20090521	P21	252	1	ROS 061109 1821	BO 19 42.76 S 164 55.74 E GPS	3262	3261	10	3286	3290				31	1-8,23,24,26,27,30,34,41,82,86,88				
49NZ20090521	P21	252	1	ROS 061109 1942	EN 19 42.51 S 164 55.55 E GPS	3263	3262												
49NZ20090521	P21	253	1	ROS 061109 2150	BE 19 49.99 S 164 39.79 E GPS	3156	3156												
49NZ20090521	P21	253	1	BUC 061109 2157	UN 19 49.94 S 164 39.74 E GPS	3156	3158												25.1C
49NZ20090521	P21	253	1	ROS 061109 2240	BO 19 49.76 S 164 39.68 E GPS	3169	3170	10	3169	3185				25	1-8,27				
49NZ20090521	P21	253	1	ROS 061109 2353	EN 19 49.51 S 164 39.54 E GPS	3168	3166												
49NZ20090521		1093	1	UNK 061209 0101	UN 19 53.66 S 164 29.21 E GPS	2729	2729												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-53
49NZ20090521	P21	255	1	ROS 061209 0159	BE 19 56.70 S 164 21.08 E GPS	911	910												
49NZ20090521	P21	255	1	BUC 061209 0205	UN 19 56.74 S 164 21.09 E GPS	890	891								1,20,31,33,34,82				25.3C
49NZ20090521	P21	255	1	ROS 061209 0218	BO 19 56.78 S 164 21.08 E GPS	874	873	10	872	874				14	1-8,23,24,26,27,31,33,34,82				#33 MISS FIRE
49NZ20090521	P21	255	1	ROS 061209 0253	EN 19 56.84 S 164 21.07 E GPS	844	845												
49NZ20090521	P21	255	1	UNK 061209 0303	UN 19 56.63 S 164 21.20 E GPS	938	941												AIR 13CH4/CH3D/15N2O SMPL
49NZ20090521	P21	254	1	ROS 061209 0445	BE 19 54.81 S 164 27.98 E GPS	2521	2519												
49NZ20090521	P21	254	1	BUC 061209 0452	UN 19 54.80 S 164 27.98 E GPS	2524	2524												25.2C
49NZ20090521	P21	254	1	ROS 061209 0526	BO 19 54.70 S 164 27.93 E GPS	2435	2433	8	2460	2470				22	1-8,27				
49NZ20090521	P21	254	1	ROS 061209 0631	EN 19 54.60 S 164 27.64 E GPS	2433	2432												
49NZ20090521		1094	1	UNK 061309 0101	UN 20 11.69 S 163 33.24 E GPS	3345	3348												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-54
49NZ20090521	P21	260	1	ROS 061309 0902	BE 20 56.05 S 164 11.06 E GPS	3427	3429												
49NZ20090521	P21	260	1	BUC 061309 0911	UN 20 56.04 S 164 11.05 E GPS	3426	3428												24.2C
49NZ20090521	P21	260	1	ROS 061309 0959	BO 20 56.05 S 164 10.98 E GPS	3414	3414	8	3420	3446				26	1-8,27				
49NZ20090521	P21	260	1	ROS 061309 1120	EN 20 56.05 S 164 10.62 E GPS	3370	3371												
49NZ20090521	P21	261	1	ROS 061309 1307	BE 20 53.58 S 164 17.08 E GPS	1973	1973												
49NZ20090521	P21	261	1	BUC 061309 1314	UN 20 53.61 S 164 17.10 E GPS	2014	2014												24.2C
49NZ20090521	P21	261	1	ROS 061309 1344	BO 20 53.58 S 164 17.06 E GPS	2083	2083	10	2008	2019				19	1-8,23,24,26,27				
49NZ20090521	P21	261	1	ROS 061309 1443	EN 20 53.65 S 164 17.14 E GPS	2064	2065												
49NZ20090521	P21	262	1	ROS 061309 1724	BE 21 6.98 S 163 43.04 E GPS	3580	3581												
49NZ20090521	P21	262	1	BUC 061309 1735	UN 21 6.88 S 163 43.08 E GPS	3580	3581												23.4C, PLANKTON NET
49NZ20090521	P21	262	1	ROS 061309 1824	BO 21 6.72 S 163 43.30 E GPS	3578	3580	10	3595	3609				34	1-8,12,13,23,24,26,27,41,86,88				
49NZ20090521	P21	262	2	BUC 061309 1918	UN 21 6.63 S 163 43.39 E GPS	3578	3580								4,5,6,30,34,41,48,86,88				
49NZ20090521	P21	262	1	ROS 061309 1955	EN 21 6.52 S 163 43.53 E GPS	3580	3580												
49NZ20090521	P21	263	1	ROS 061309 2214	BE 21 18.08 S 163 14.83 E GPS	3579	3578												
49NZ20090521	P21	263	1	BUC 061309 2222	UN 21 18.03 S 163 14.85 E GPS	3580	3578												24.3C
49NZ20090521	P21	263	1	ROS 061309 2312	BO 21 17.85 S 163 15.06 E GPS	3581	3580	10	3599	3610				26	1-8,27				
49NZ20090521	P21	263	1	ROS 061409 0033	EN 21 17.63 S 163 15.47 E GPS	3579	3579												

49NZ20090521		1095	1	UNK 061409 0101	UN 21 19.77 S 163 10.45 E GPS	3577	3578												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-55 AIR BVOC SMPL #8047
49NZ20090521		1096	1	UNK 061409 0145	UN 21 23.93 S 162 59.43 E GPS	3037	3036												
49NZ20090521	P21	264	1	ROS 061409 0247	BE 21 29.13 S 162 45.97 E GPS	1547	1544												
49NZ20090521	P21	264	1	BUC 061409 0254	UN 21 29.13 S 162 45.95 E GPS	1544	1544							1,20					24.0C
49NZ20090521	P21	264	1	ROS 061409 0316	BO 21 29.05 S 162 45.85 E GPS	1540	1540	10	1534	1533				17	1-8,27				
49NZ20090521	P21	264	1	ROS 061409 0403	EN 21 28.85 S 162 45.85 E GPS	1549	1540												
49NZ20090521	P21	264	1	XMP 061409 0414	DE 21 29.05 S 162 46.03 E GPS	1555	1556												XMP #11
49NZ20090521	P21	265	1	ROS 061409 0547	BE 21 36.01 S 162 30.01 E GPS	767	768												
49NZ20090521	P21	265	1	BUC 061409 0554	UN 21 36.04 S 162 30.02 E GPS	768	768												24.3C
49NZ20090521	P21	265	1	ROS 061409 0606	BO 21 36.03 S 162 30.01 E GPS	768	768	10	758	761				12	1-8,23,24,26,27				
49NZ20090521	P21	265	1	ROS 061409 0635	EN 21 36.06 S 162 30.08 E GPS	768	767												
49NZ20090521	P21	266	1	ROS 061409 0822	BE 21 43.09 S 162 11.02 E GPS	1652	1651												
49NZ20090521	P21	266	1	BUC 061409 0829	UN 21 43.16 S 162 11.10 E GPS	1658	1658												23.9C
49NZ20090521	P21	266	1	XCT 061409 0833	DE 21 43.19 S 162 11.13 E GPS	1639	1638												TSK XCTD-2(MK-130) #08112324
49NZ20090521	P21	266	1	ROS 061409 0853	BO 21 43.26 S 162 11.25 E GPS	1637	1638	9	1637	1643				17	1-8,23,24,26,27				
49NZ20090521	P21	266	1	ROS 061409 0939	EN 21 43.19 S 162 11.61 E GPS	1619	1620												
49NZ20090521	P21	267	1	ROS 061409 1240	BE 21 58.01 S 161 33.02 E GPS	1624	1622												
49NZ20090521	P21	267	1	BUC 061409 1248	UN 21 58.01 S 161 33.06 E GPS	1625	1624												22.6C
49NZ20090521	P21	267	1	ROS 061409 1311	BO 21 57.97 S 161 33.16 E GPS	1628	1628	10	1624	1627				18	1-8,27				
49NZ20090521	P21	267	1	ROS 061409 1402	EN 21 57.75 S 161 33.30 E GPS	1639	1638												
49NZ20090521	P21	268	1	ROS 061409 1705	BE 22 13.01 S 160 55.01 E GPS	1562	1562												
49NZ20090521	P21	268	1	BUC 061409 1713	UN 22 12.99 S 160 55.04 E GPS	1563	1562												23.2C
49NZ20090521	P21	268	1	XCT 061409 1716	DE 22 12.99 S 160 55.07 E GPS	1563	1562												TSK XCTD-2(MK-130) #08112323
49NZ20090521	P21	268	1	ROS 061409 1736	BO 22 12.90 S 160 55.18 E GPS	1559	1561	10	1558	1560				18	1-8,23,24,26,27				
49NZ20090521	P21	268	1	ROS 061409 1830	EN 22 12.72 S 160 55.50 E GPS	1556	1557												
49NZ20090521	P21	269	1	ROS 061409 2122	BE 22 27.98 S 160 16.94 E GPS	2178	2180												
49NZ20090521	P21	269	1	BUC 061409 2130	UN 22 28.01 S 160 16.89 E GPS	2182	2185												23.7C, PLANKTON NET
49NZ20090521	P21	269	1	ROS 061409 2201	BO 22 27.99 S 160 16.76 E GPS	2180	2183	11	2186	2192				26	1-8,27,30,34,41,82,86,88				
49NZ20090521	P21	269	1	ROS 061409 2259	EN 22 28.07 S 160 16.57 E GPS	2189	2191												
49NZ20090521	P21	270	1	ROS 061509 0034	BE 22 35.91 S 159 56.96 E GPS	2231	2231												
49NZ20090521	P21	270	1	BUC 061509 0043	UN 22 35.89 S 159 56.92 E GPS	2231	2232												23.5C
49NZ20090521		1097	1	UNK 061509 0102	UN 22 35.91 S 159 56.90 E GPS	2231	2233												INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-56
49NZ20090521	P21	270	1	ROS 061509 0114	BO 22 35.99 S 159 56.89 E GPS	2232	2232	9	2236	2244				21	1-8,23,24,26,27				
49NZ20090521	P21	270	1	ROS 061509 0217	EN 22 36.06 S 159 56.47 E GPS	2228	2229												
49NZ20090521	P21	271	1	ROS 061509 0346	BE 22 43.02 S 159 39.05 E GPS	1455	1455												
49NZ20090521	P21	271	1	BUC 061509 0353	UN 22 42.96 S 159 39.12 E GPS	1409	1408												23.7C
49NZ20090521	P21	271	1	ROS 061509 0412	BO 22 43.01 S 159 39.08 E GPS	1448	1447	11	1408	1413				16	1-8,27				
49NZ20090521	P21	271	1	ROS 061509 0458	EN 22 43.07 S 159 39.05 E GPS	1450	1450												
49NZ20090521	P21	272	1	ROS 061509 0631	BE 22 50.17 S 159 20.95 E GPS	307	307												
49NZ20090521	P21	272	1	BUC 061509 0633	UN 22 50.18 S 159 20.96 E GPS	306	307												23.6C
49NZ20090521	P21	272	1	ROS 061509 0641	BO 22 50.20 S 159 20.95 E GPS	307	307	12	290	292				7	1-8,23,24,26,27				
49NZ20090521	P21	272	1	ROS 061509 0657	EN 22 50.22 S 159 20.96 E GPS	307	307												
49NZ20090521	P21	273	1	ROS 061509 0827	BE 22 57.25 S 159 2.92 E GPS	2516	2517												
49NZ20090521	P21	273	1	BUC 061509 0834	UN 22 57.23 S 159 2.93 E GPS	2517	2517												23.6C
49NZ20090521	P21	273	1	ROS 061509 0909	BO 22 57.37 S 159 2.89 E GPS	2520	2520	10	2522	2532				22	1-8,12,13,23,24,26,27,31,33,82				
49NZ20090521	P21	273	1	ROS 061509 1010	EN 22 57.48 S 159 2.96 E GPS	2520	2520												
49NZ20090521		1098	1	UNK 061509 1032	UN 22 58.85 S 158 59.72 E GPS	2523	2523												AIR BVOC SMPL #1156
49NZ20090521	P21	274	1	ROS 061509 1218	BE 23 8.01 S 158 34.98 E GPS	2534	2535												
49NZ20090521	P21	274	1	BUC 061509 1228	UN 23 8.06 S 158 34.97 E GPS	2535	2534												23.6C

49NZ20090521	P21	274	1	ROS	061509	1303	BO	23	8.22	S	158	34.91	E	GPS	2535	2535	10	2543	2551	22	1-8,27		
49NZ20090521	P21	274	1	ROS	061509	1413	EN	23	8.55	S	158	35.17	E	GPS	2536	2538							
49NZ20090521	P21	275	1	ROS	061509	1625	BE	23	19.04	S	158	6.99	E	GPS	2449	2449							
49NZ20090521	P21	275	1	BUC	061509	1632	UN	23	19.02	S	158	7.02	E	GPS	2448	2449					1		23.5C
49NZ20090521	P21	275	1	ROS	061509	1707	BO	23	19.02	S	158	7.12	E	GPS	2449	2448	10	2452	2463	21	1-8,23,24,26,27		
49NZ20090521	P21	275	1	ROS	061509	1813	EN	23	18.95	S	158	7.23	E	GPS	2449	2450							
49NZ20090521	P21	276	1	ROS	061509	2026	BE	23	30.01	S	157	39.00	E	GPS	2145	2145							
49NZ20090521	P21	276	1	BUC	061509	2034	UN	23	30.05	S	157	38.99	E	GPS	2146	2146					1,4,5,6,30,34,41,48,86,88		23.9C, PLANKTON NET
49NZ20090521	P21	276	1	ROS	061509	2103	BO	23	30.19	S	157	38.98	E	GPS	2140	2140	9	2144	2151	26	1-8,23,24,26,27,41		
49NZ20090521	P21	276	1	ROS	061509	2157	EN	23	30.41	S	157	38.88	E	GPS	2147	2145							
49NZ20090521	P21	277	1	ROS	061609	0004	BE	23	40.98	S	157	10.90	E	GPS	2188	2189					1,20		23.3C
49NZ20090521	P21	277	1	BUC	061609	0011	UN	23	40.92	S	157	10.83	E	GPS	2188	2189							
49NZ20090521	P21	277	1	ROS	061609	0041	BO	23	40.78	S	157	10.86	E	GPS	2191	2189	10	2195	2197	20	1-8,27		
49NZ20090521		1099	1	UNK	061609	0101	UN	23	40.67	S	157	10.85	E	GPS	2191	2192							INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-57
49NZ20090521	P21	277	1	ROS	061609	0142	EN	23	40.62	S	157	10.79	E	GPS	2191	2192							
49NZ20090521	P21	278	1	ROS	061609	0350	BE	23	51.98	S	156	43.00	E	GPS	2203	2205							
49NZ20090521	P21	278	1	BUC	061609	0357	UN	23	52.01	S	156	43.02	E	GPS	2202	2203					1		23.0C
49NZ20090521	P21	278	1	ROS	061609	0428	BO	23	52.11	S	156	43.12	E	GPS	2204	2204	10	2210	2216	20	1-8,23,24,26,27		
49NZ20090521	P21	278	1	ROS	061609	0530	EN	23	51.94	S	156	43.34	E	GPS	2217	2215							
49NZ20090521	P21	279	1	ROS	061609	0743	BE	24	2.72	S	156	15.01	E	GPS	2012	2013							
49NZ20090521	P21	279	1	BUC	061609	0751	UN	24	2.66	S	156	15.08	E	GPS	2015	2017					1		23.5C
49NZ20090521	P21	279	1	ROS	061609	0820	BO	24	2.57	S	156	15.16	E	GPS	2019	2021	10	2021	2028	20	1-8,23,24,26,27		
49NZ20090521	P21	279	1	ROS	061609	0916	EN	24	2.52	S	156	15.22	E	GPS	2021	2022							
49NZ20090521	P21	280	1	ROS	061609	1127	BE	24	14.05	S	155	47.63	E	GPS	3897	3894							
49NZ20090521	P21	280	1	BUC	061609	1135	UN	24	14.10	S	155	47.65	E	GPS	3897	3894					1		24.1C
49NZ20090521	P21	280	1	ROS	061609	1229	BO	24	14.19	S	155	47.63	E	GPS	3901	3897	10	3911	3944	28	1-8,27		
49NZ20090521	P21	280	1	ROS	061609	1407	EN	24	14.19	S	155	47.26	E	GPS	3914	3911							
49NZ20090521	P21	281	1	ROS	061609	1552	BE	24	21.01	S	155	30.04	E	GPS	4063	4062							
49NZ20090521	P21	281	1	BUC	061609	1559	UN	24	20.96	S	155	30.06	E	GPS	4068	4067					1,4,5,6,30,34,41,48,86,88		23.3C, PLANKTON NET
49NZ20090521	P21	281	1	ROS	061609	1657	BO	24	21.01	S	155	29.96	E	GPS	4078	4079	11	4083	4120	34	1-8,27,30,34,41,82,86,88		
49NZ20090521	P21	281	1	ROS	061609	1839	EN	24	21.01	S	155	29.81	E	GPS	4082	4082							
49NZ20090521		1100	1	UNK	061609	2047	UN	24	31.87	S	154	59.46	E	GPS	4460	4458							AIR BVOC SMPL #5475
49NZ20090521	P21	282	1	ROS	061609	2103	BE	24	32.58	S	154	57.59	E	GPS	4390	4386							
49NZ20090521	P21	282	1	BUC	061609	2111	UN	24	32.67	S	154	57.57	E	GPS	4387	4383					1		22.9C
49NZ20090521	P21	282	1	ROS	061609	2211	BO	24	32.82	S	154	57.50	E	GPS	4379	4376	10	4400	4435	30	1-8,12,13,23,24,26,27		
49NZ20090521	P21	282	1	ROS	061609	2347	EN	24	33.13	S	154	57.06	E	GPS	4372	4371							
49NZ20090521		1101	1	UNK	061709	0104	UN	24	39.63	S	154	39.60	E	GPS	4292	4292							INTAKE WATER SMPL FOR STABLE WATER ISOTOPE #O-58
49NZ20090521	P21	283	1	ROS	061709	0217	BE	24	46.05	S	154	22.97	E	GPS	4155	4154							
49NZ20090521	P21	283	1	BUC	061709	0224	UN	24	46.01	S	154	22.96	E	GPS	4154	4155					1,20		22.6C
49NZ20090521	P21	283	1	ROS	061709	0322	BO	24	45.93	S	154	23.01	E	GPS	4155	4154	10	4162	4201	29	1-8,27		
49NZ20090521	P21	283	1	ROS	061709	0501	EN	24	45.52	S	154	22.95	E	GPS	4153	4152							
49NZ20090521	P21	285	1	ROS	061709	0653	BE	24	52.70	S	154	2.99	E	GPS	3860	3862							
49NZ20090521	P21	285	1	BUC	061709	0701	UN	24	52.64	S	154	3.02	E	GPS	3865	3868					1,31,33,34,82		22.8C
49NZ20090521	P21	285	1	ROS	061709	0754	BO	24	52.32	S	154	3.16	E	GPS	3869	3870	10	3884	3905	28	1-8,23,24,26,27,31,33,34,82		
49NZ20090521	P21	285	1	ROS	061709	0927	EN	24	51.67	S	154	3.27	E	GPS	3889	3889							
49NZ20090521	P21	285	1	UNK	061709	0938	UN	24	51.86	S	154	2.39	E	GPS	3872	3874							AIR 13CH4/CH3D/15N2O SMPL & COS SMPL
49NZ20090521	P21	287	1	ROS	061709	1143	BE	24	59.81	S	153	44.52	E	GPS	1022	1024							
49NZ20090521	P21	287	1	BUC	061709	1150	UN	24	59.76	S	153	44.52	E	GPS	1022	1023					1		22.3C
49NZ20090521	P21	287	1	ROS	061709	1205	BO	24	59.66	S	153	44.54	E	GPS	1051	1050	11	1022	1025	14	1-8,23,24,26,27		



## Figure captions

- Figure 1 Station locations for WHP P21 revisit cruise with bottom topography based on Smith and Sandwell (1997).
- Figure 2 Bathymetry measured by Multi Narrow Beam Echo Sounding system.
- Figure 3 Surface wind measured at 25 m above sea level. Wind data is averaged over 1-hour and plotted every 1 degree in latitude or longitude.
- Figure 4 Sea surface temperature (SST). Temperature data is averaged over 1-hour.
- Figure 5 Sea surface salinity (SSS). Salinity data is averaged over 1-hour.
- Figure 6 Difference in the partial pressure of CO<sub>2</sub> between the ocean and the atmosphere,  $\Delta p\text{CO}_2$ .
- Figure 7 Surface current at 100 m depth measured by ship board acoustic Doppler current profiler (ADCP).
- Figure 8 Potential temperature (°C) cross section calculated by using CTD temperature and salinity data calibrated by bottle salinity measurements. Vertical exaggeration of the 0-6500 m section is 1000:1. Expanded section of the upper 1000 m is made with a vertical exaggeration of 2500:1.
- Figure 9 CTD salinity (psu) cross section calibrated by bottle salinity measurements. Vertical exaggeration is same as Figure 8.
- Figure 10 Absolute salinity (g/kg) cross section calculated by using CTD salinity data. Vertical exaggeration is same as Figure 8.
- Figure 11 Density ( $\sigma_0$ ) (kg/m<sup>3</sup>) cross section calculated by using CTD temperature and salinity data. Vertical exaggeration is same as Figure 8.
- Figure 12 Same as Figure 11 but for  $\sigma_t$  (kg/m<sup>3</sup>).
- Figure 13 Neutral density ( $\gamma^n$ ) (kg/m<sup>3</sup>) cross section calculated by using CTD temperature and salinity data. Vertical exaggeration is same as Figure 8.
- Figure 14 Cross section of CTD oxygen ( $\mu\text{mol/kg}$ ). Vertical exaggeration is same as Figure 8.
- Figure 15 Cross section of bottle sampled dissolved oxygen ( $\mu\text{mol/kg}$ ). Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 16 Silicate ( $\mu\text{mol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 17 Nitrate ( $\mu\text{mol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 18 Nitrite ( $\mu\text{mol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration of the upper 1000 m section is same as Figure 8.
- Figure 19 Phosphate ( $\mu\text{mol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 3.
- Figure 20 Dissolved inorganic carbon ( $\mu\text{mol/kg}$ ) cross section. Data with quality flags of 2 were plotted.



Vertical exaggeration is same as Figure 8.

Figure 21 Total alkalinity ( $\mu\text{mol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.

Figure 22 pH cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.

Figure 23 CFC-11 ( $\text{pmol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.

Figure 24 CFC-12 ( $\text{pmol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.

Figure 25 CFC-113 ( $\text{pmol/kg}$ ) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.

Figure 26 Cross section of current velocity ( $\text{cm/s}$ ) normal to the cruise track measured by LADCP (northward is positive).

Figure 27 Difference in potential temperature ( $^{\circ}\text{C}$ ) between results from WOCE (from March to June 1994) and the revisit cruise (from April to June 2009). Red and blue areas show areas where potential temperature increased and decreased in the revisit cruise, respectively. On white areas differences in temperature do not exceed the detection limit of  $0.002^{\circ}\text{C}$ . Vertical exaggeration is same as Figure 8.

Figure 28 Difference in salinity (psu) between results from WOCE and the revisit cruise. Red and blue areas show areas where salinity increased and decreased in the revisit cruise, respectively. CTD salinity data with SSW batch correction<sup>1</sup> were used. On white areas differences in salinity do not exceed the detection limit of  $0.002$  psu. Vertical exaggeration is same as Figure 8.

Figure 29 Difference in dissolved oxygen ( $\mu\text{mol/kg}$ ) between results from WOCE and the revisit cruise. Red and blue areas show areas where salinity increased and decreased in the revisit cruise, respectively. CTD oxygen data were used. On white areas differences in dissolved oxygen do not exceed the detection limit of  $2$   $\mu\text{mol/kg}$ . Vertical exaggeration is same as Figure 8.

#### Note

1. As for the traceability of SSW to Mantyla's value, the offset for the batches P123 (WOCE P21) and P150 (the revisit cruise) are  $-0.0006$  and  $-0.0005$ , respectively (Kawano et al, 2006; T. Kawano, personal communication, 2009).

#### References

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- Smith, W. H. F. and D. T. Sandwell (1997): Global seafloor topography from satellite altimetry and ship depth soundings, *Science*, 277, 1956–1962.

