WHP P10 REVISIT IN 2011 DATA BOOK

Field Activity of JAMSTEC towards International Repeat Hydrography and Carbon Program

WHP P10 REVISIT IN 2011 DATA BOOK

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

WHP P10 REVISIT
in 2011
Towards
Intl. Repeat Hydrography
and Carbon Program

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

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Preface

At 14:46 on 11 March 2011, Japan was attacked by the huge catastrophe earthquake with magnitude of 9.0. The epicenter of the earthquake widely distributed along the Japan trench off the east coasts of Tohoku district. Unprecedented tragedies were brought about by the Tsunami which attacked the Pacific coast of eastern Japan twenty minutes after the earthquake. More than 18,000 people were killed or lost by this Tsunami. Moreover, the Fukushima First Nuclear Power Plant was destroyed by the Tsunami and considerable amount of radio nuclides were discharged from the power plant into the atmosphere and the ocean.

Right after the earthquake, we, Research Institute for Global Change started to monitor and forecast the dispersion of the discharged radio nuclides off coast of Fukushima under the request from the Japanese government. It was very hard task for scientists in RIGC/JAMSTEC to conduct ocean monitoring and prediction, nevertheless, RIGC/JAMSTEC was expected to be deeply engaged in the task because RIGC is the only institute which has the ability to pursue the governmental requests.

Facing the Fukushima Disaster brought about by the earthquake, RIGC/JAMSTEC changed the cruise plan for GO-SHIP hydrographic observation. As the result, RIGC/JAMSTEC decided to re-occupy P10 in the western North Pacific Ocean instead of I08N/I05E in the Indian Ocean since we believed this change of our plan made it possible for the world GO-SHIP community to build a data network on radio nuclides in the western North Pacific within three years together with US cruise along P02 in 2013 and RIGC/JAMSTEC cruise along P01 in 2014. The preparation for the original plan to re-occupy the line in the Indian Ocean had been proceeded under collaboration with Sri Lanka and India. Thus, here, I would like to express my heartfelt thanks to all those concerned in both countries for their kind acceptance of our sudden changes of the cruise at that time.

The cruise along P10 was started on 20 December 2011 from Palau. Stations were set to reoccupy the stations which were observed in 2005 by IORGC, a predecessor of RIGC/JAMSTEC, namely 124 stations on the cruise track from Papua New Guinea to Hokkaido. We completed the cruise on 9 February 2012, however, bad weather and sea condition forced us to decrease the number of CTD/water sampling stations in the northern part of the cruise.

Of course, this cruise was carried out as Japanese activity within the framework of GO-SHIP. On the other hand, we had our specific objective for this cruise that was to prepare data network for radio nuclides in the western North Pacific Ocean after the Fukushima Disaster. It was the reason why we placed larger priority on the northern part of P10 in the cruise. Now, the data including results from chemical analysis can be used by anyone through this data book and websites of JAMSTEC, CCHDO and CDIAC.

Lastly, I would like to ask favors of all scientists to refer our data book as often as possible. Such reference from scientists proves the scientific importance of GO-SHIP and consequently helps RIGC/JAMSTEC to continue GO-SHIP activity.

On the memorial day after three years of the Tragic Earthquake and Tsunami

Masao Fukasawa
Research Director   RIGC/JAMSTEC

*Acronyum

RIGC	Research Institute for Global Change
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
GO-SHIP	Global Ocean Ship-Based Hydrographic Investigation Program
CCHDO	CLIVAR and Carbon Hydrographic Data Office
CDIAC	Carbon Dioxide Information Analysis Center

1 Cruise Narrative

Akihiko Murata (RIGC/JAMSTEC)

Yuichiro Kumamoto (RIGC/JAMSTEC)

1.1 Highlight

GHPO Section Designation: P10

Cruise code: MR11-08

Expedition Designation: 49NZ20111220
49NZ20120113

Chief Scientists and Affiliation:

Leg 2: *Akihiko Murata*
murataa@jamstec.go.jp
Leg 3: *Yuichiro Kumamoto*
kumamoto@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: +81-46-867-9835

Ship: R/V Mirai

Ports of Call: Leg 2: Koror, Palau – Guam, USA
Leg 3: Guam, USA – Sekinehama, Japan

Cruise Dates: Leg 2: December 20, 2011 – January 12, 2012
Leg 3: January 13, 2012 – February 9, 2012

Number of Stations: 102 stations for CTD/Carousel Water Sampler
(Leg 2: 59, Leg 3: 43)

Geographic Boundaries (for hydrographic stations):
10°S - 43°N
140°E - 151°E

Floats and Drifters Deployed:
2 Argo floats

Mooring Deployed or Recovered Mooring:
None

1.2 Cruise Summary

It is well known that climate changes of a timescale more than a decade are influenced by changes of oceanic conditions. Among various oceanic changes, we conducted shipboard observations focusing on storage and transport of anthropogenic CO_2, heat and freshwater in the ocean, which are important for global warming and relevant climate changes. Our observation line (Figs. 1.2.1 and 1.2.2) is a meridional line, which is set in the western Pacific, and traverses the main subtropical gyre in the ocean. By occupying the observation line, we intended to clarify: (1) storage of anthropogenic CO_2, distributions of dissolved oxygen, etc. in the subtropical gyre and the temporal changes, (2) temperature rise and transport of dissolved substances along the route of Circumpolar Deep Water, and (3) current degree of ocean acidification in the western Pacific. This study was conducted under the Global Ocean Ship-based Hydrographic Investigations Program (abbreviated as GO-SHIP, http://www.go-ship.org/).

In addition to the objectives listed above, we were also aimed at elucidating dispersion of radioactive substances, released into the sea unfortunately from the Fukushima Dai-ichi nuclear power plant.

During the 2nd leg, we could conduct hydrographic observations steadily. But during the 3rd leg, we had to give up some hydrographic casts due to big waves.

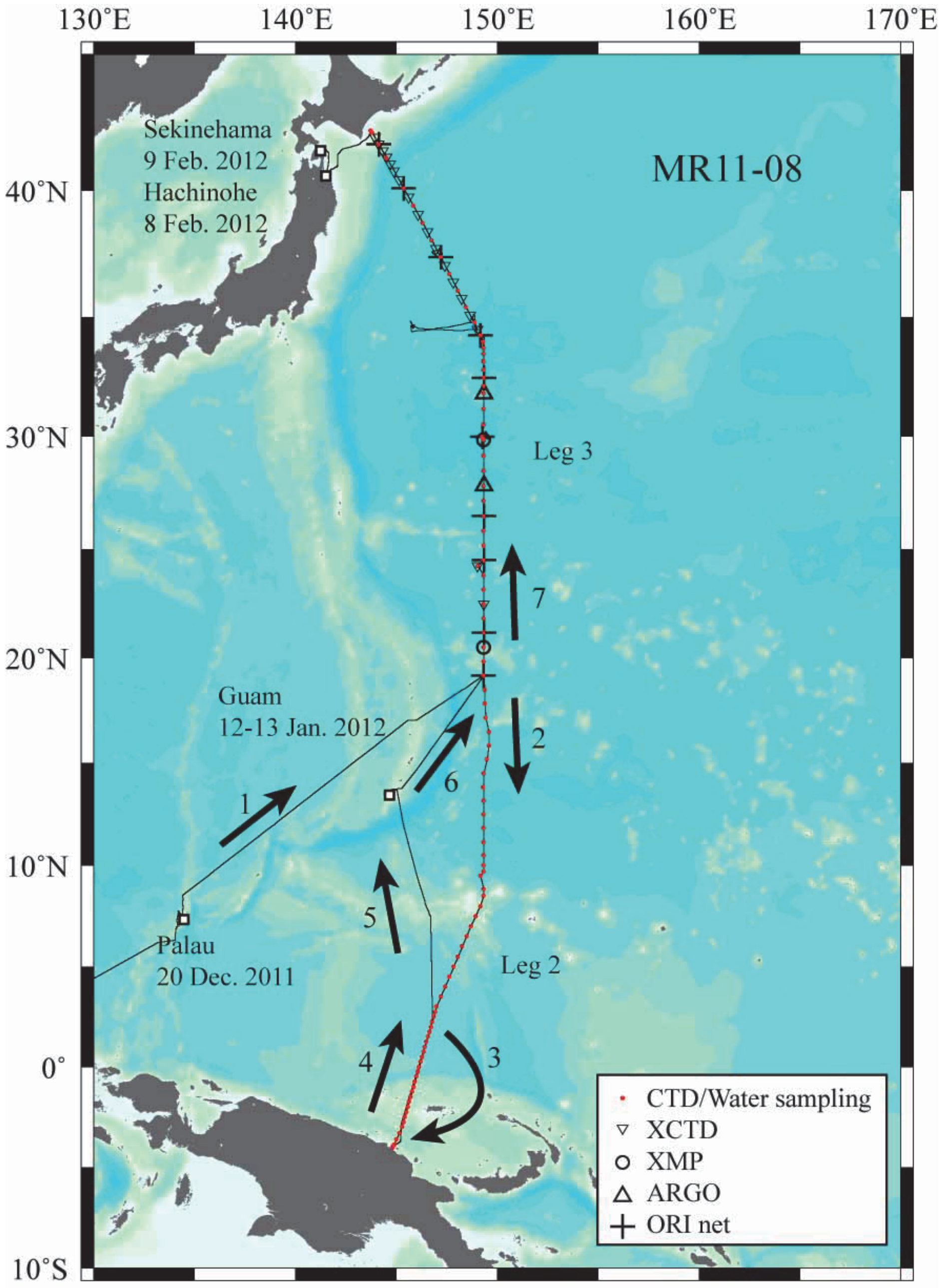

Figure 1.2.1. Cruise track and hydrographic stations.

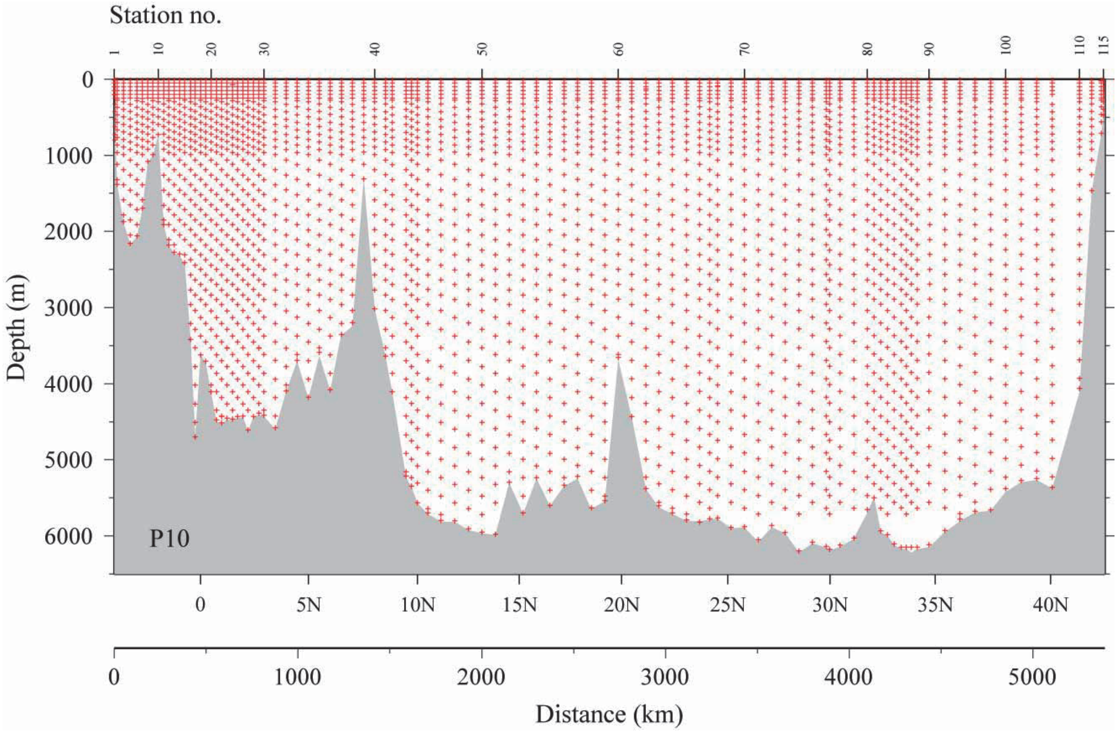

Figure 1.2.2. Bottle depth diagram.

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
Underway		
ADCP	Shinya Kouketsu (JAMSTEC) *skouketsu@jamstec.go.jp*	Kazuho Yoshida (GODI) (leg 2) Katsuhisa Maeno (GODI) (lge 3)
Bathymetry	Takeshi Matsumoto (Univ. of Ryukyus) *tak@sci.u-ryukyu.ac.jp* Naoto Hirano (Tohoku Univ.) *nhirano@cneas.tohoku.ac.jp*	Kazuho Yoshida (GODI) (leg 2) Katsuhisa Maeno (GODI) (leg 3)
Meteorology	Kunio Yoneyama (JAMSTEC) *yoneyamak@jamstec.go.jp*	Kazuho Yoshida (GODI) (leg 2) Katsuhisa Maeno (GODI) (leg 3)
T-S	Hiroshi Uchida (JAMSTEC) *huchida@jamtec.go.jp*	Miyo Ikeda (MWJ) (leg 2) Misato Kuwahara (MWJ) (leg 3)
pCO_2	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Yoshiko Ishikawa (MWJ)
Hydrography		
CTD/O_2	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Shinsuke Toyoda (MWJ) (leg 2) Kenichi Katayama (MWJ) (leg 3)
XCTD	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Katsuhisa Maeno (GODI)
LADCP	Shinya Kouketsu (JAMSTEC) *skouketsu@jamstec.go.jp*	Shinya Kouketsu (JAMSTEC) (leg 2) Katsuro Katsumata (JAMSTEC) (leg 3)

Salinity	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Fujio Kobayashi (MWJ) (leg 2) Tatsuya Tanaka (MWJ) (leg 3)
Density	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Hiroshi Uchida (JAMSTEC)
Oxygen	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Miyo Ikeda (MWJ) (leg 2) Misato Kuwahara (MWJ) (leg 3)
Nutrients	Michio Aoyama (MRI) *maoyama@mri-jma.go.jp*	Minoru Kamata (MWJ)
DIC	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Yoshiko Ishikawa (MWJ)
Alkalinity	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Tomonori Watai (MWJ)
pH	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Tomonori Watai (MWJ)
CFCs	Ken’ichi Sasaki (JAMSTEC) *ksasaki@jamstec.go.jp*	Ken’ichi Sasaki (JAMSTEC)
$\Delta^{14}C/\delta^{13}C$	Yuichiro Kumamoto (JAMSTEC) *kumamoto@jamstec.go.jp*	Yuichiro Kumamoto (JAMSTEC)
$^{134}Cs/^{137}Cs$	Yuichiro Kumamoto (JAMSTEC) *kumamoto@jamstec.go.jp*	Yuichiro Kumamoto (JAMSTEC)
Tritium	Tatsuo Aono (NIRS) *t_aono@nirs.go.jp*	
Iodine-129	Shigeyoshi Otosaka (JAEA) *otosaka.shigeyoshi@jaea.go.jp*	
Chlorophyll *a*	Osamu Yoshida (RGU) *yoshida@rakuno.ac.jp* Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Osamu Yoshida (RGU) (leg 2) Hiroshi Uchida (JAMSTEC) (leg 3)
N_2O/CH_4	Osamu Yoshida (RGU) *yoshida@rakuno.ac.jp*	Osamu Yoshida (RGU) (leg 2) Yuki Okazaki (RGU) (leg 3)
PFCs	Nobuyasu Yamashita (AIST) *nob.yamashita@aist.go.jp*	
Plankton	Minoru Kitamura (JAMSTEC) *kitamura@jamstec.go.jp*	Minoru Kitamura (JAMSTEC)
Floats		
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.
NIRS	National Institute of Radiological Sciences
JAEA	Japan Atomic Energy Agency
RGU	Rakuno Gakuen University
AIST	National Institute of Advanced Industrial Science and Technology

1.4 List of Cruise Participants

Table 1.4.1. List of cruise participants for leg 2.

Name	Responsibility	Affiliation
Akihiko Murata	Chief Scientist/CTD/water sampling	RIGC/JAMSTEC
Yuichiro Kumamoto	DO/radionuclides	RIGC/JAMSTEC
Hiroshi Uchida	CTD/density/water sampling	RIGC/JAMSTEC
Shinya Kouketsu	LADCP/ADCP/water sampling	RIGC/JAMSTEC
Kazuhiko Hayashi	Water sampling	RIGC/JAMSTEC
Ken'ichi Sasaki	CFCs	MIO/JAMSTEC
Moyap Kilepak	Observer	University of PNG
Benjamin Malai	Observer	NWS/PNG
Osamu Yoshida	CH_4 and N_2O/water sampling	RGU
Yuki Okazaki	CH_4 and N_2O/water sampling	RGU
Shinichi Oikawa	CH_4 and N_2O/water sampling	RGU
Hikari Shimizu	CH_4 and N_2O/water sampling	RGU
Satoshi Ozawa	Chief technologist/CTD/water sampling	MWJ
Hirokatsu Uno	CTD/water sampling	MWJ
Fujio Kobayashi	Salinity	MWJ
Kenichi Kato	CTD/water sampling	MWJ
Shinsuke Toyoda	CTD/water sampling	MWJ
Hiroki Ushiromura	Salinity	MWJ
Shungo Oshitani	CTD/water sampling	MWJ
Kenichiro Sato	Nutrients	MWJ
Minoru Kamata	Nutrients	MWJ
Masanori Enoki	Nutrients	MWJ
Tomonori Watai	pH/total alkalinity	MWJ
Yoshiko Ishikawa	DIC/pCO_2	MWJ
Miyo Ikeda	DO	MWJ
Ayaka Hatsuyama	pH/total alkalinity	MWJ
Hatsumi Aoyama	DIC/pCO_2	MWJ
Masahiro Orui	CFCs	MWJ
Makoto Takada	Water sampling/radionuclides	MWJ
Katsunori Sagishima	CFCs	MWJ
Shoko Tatamisashi	CFCs	MWJ
Kanako Yoshida	DO	MWJ
Yuki Miyajima	DO	MWJ
Elena Hayashi	Water sampling	MWJ
Tatsuya Ando	Water sampling	MWJ
Hitomi Takahashi	Water sampling	MWJ
Mizuho Yasui	Water sampling	MWJ
Daiki Hayashi	Water sampling	MWJ
Yusuke Ogiwara	Water sampling	MWJ
Satoshi Okumura	Chief technologist /meteorology/ geophysics/ADCP/XCTD	GODI
Kazuho Yoshida	Meteorology/geophysics/ADCP/XCTD	GODI
Ryo Kimura	Meteorology/geophysics/ADCP/XCTD	GODI

GODI	Global Ocean Development Inc.
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
RIGC	Research Institute for Global Change
MIO	Mutsu Institute of Oceanography
MWJ	Marine Works Japan, Ltd.
RGU	Rakuno Gakuen University
PNG	Papua New Guinea
NWS	National Weather Service

Table 1.4.2. List of cruise participants for leg 3.

Name	Responsibility	Affiliation
Yuichiro Kumamoto	Chief scientist/DO/radionuclides	RIGC/JAMSTEC
Hiroshi Uchida	CTD/density/water sampling	RIGC/JAMSTEC
Katsuro Katsumata	XMP/LADCP/water sampling	RIGC/JAMSTEC
Toshimasa Doi	LADCP/water sampling	RIGC/JAMSTEC
Kazuhiko Hayashi	Water sampling	RIGC/JAMSTEC
Ken’ichi Sasaki	CFCs	MIO/JAMSTEC
Minoru Kitamura	Plankton	BGS/JAMSTEC
Eric Cruz	Plankton net dragging/water sampling	NMFS/NOAA
Nobuyoshi Yamashita	PFCs	AIST
Yuki Okazaki	CH_4 and N_2O/water sampling	RGU
Shinichi Oikawa	CH_4 and N_2O/water sampling	RGU
Hikari Shimizu	CH_4 and N_2O/water sampling	RGU
Yoshiko Ishikawa	Chief technologist /DIC/pCO_2	MWJ
Hideki Yamamoto	Water sampling/radionuclides	MWJ
Toru Idai	CTD/water sampling	MWJ
Kenichi Katayama	CTD/water sampling	MWJ
Naoko Miyamoto	CTD/water sampling	MWJ
Tatsuya Tanaka	Salinity	MWJ
Tamami Ueno	Salinity	MWJ
Kenichiro Sato	Nutrients	MWJ
Minoru Kamata	Nutrients	MWJ
Tomonori Watai	pH/total alkalinity	MWJ
Yasuhiro Arii	Nutrients	MWJ

Misato Kuwahara	DO	MWJ
Hatsumi Aoyama	DIC/pCO_2	MWJ
Makoto Takada	DIC/pCO_2	MWJ
Shinichiro Yokokawa	DO	MWJ
Katsunori Sagishima	CFCs	MWJ
Shoko Tatamisashi	CFCs	MWJ
Hironori Sato	DO	MWJ
Kanako Yoshida	DO	MWJ
Takami Mori	CTD/water sampling	MWJ
Yasumi Yamada	pH/total alkalinity	MWJ
Elena Hayashi	Water sampling	MWJ
Tatsuya Ando	Water sampling	MWJ
Rie Muranaka	Water sampling	MWJ
Shihomi Saito	Water sampling	MWJ
Emi Deguchi	Water sampling	MWJ
Erina Matsumoto	Water sampling	MWJ
Katsuhisa Maeno	Chief technologist /meteorology/ geophysics/ADCP/XCTD	GODI
Asuka Doi	Meteorology/geophysics/ADCP/XCTD	GODI
Kazuho Yoshida	Meteorology/geophysics/ADCP/XCTD	GODI
Toshimitsu Goto	Meteorology/geophysics/ADCP/XCTD	GODI

BGS	Institute of Biogeosciences
NMFS/NOAA	National Marine Fisheries Service, National Oceanic and Atmospheric Administration

2 Underway Measurements

2.1 Navigation

February 5, 2014

(1) Personnel

Kazuho Yoshida	(GODI)	-leg1, leg2-
Ryo Kimura	(GODI)	-leg1, leg2-
Satoshi Okumura	(GODI)	-leg2-
Katsuhisa Maeno	(GODI)	-leg3-
Asuka Doi	(GODI)	-leg3-
Toshimitsu Goto	(GODI)	-leg3-
Ryo Ohyama	(MIRAI Crew)	-leg1, leg2, leg3-

(2) System description

Ship's position and velocity were provided by Radio Navigation System on R/V Mirai. This system integrates GPS position, log speed, gyro compass heading and other basic data for navigation, and calculated speed/course over ground on workstation. Radio navigation System also distributed ship's standard time synchronized to GPS time server via Network Time Protocol. These data were logged on the network server as "SOJ" data every 5 seconds.

Sensors for navigation data are listed below;

i) GPS system: MultiFix6 (software version 1.01), Differential GPS system.

Receiver: Trimble SPS751, with two GPS antennas located on navigation deck, starboard side and port side, manually switched as to GPS receiving state and offset to radar-mast position, datum point.

Decoder: Fugro STARFIX 4100LR

ii) Doppler log: Furuno DS-30, which use three acoustic beam for current measurement under the hull.

iii) Gyrocompass: Tokimec TG-6000, sperry type mechanical gyrocompass.

iv) GPS time server: SEIKO TS-2540 Time Server, synchronizing to GPS satellite every 1 second.

(3) Data period (Times in UTC)

Leg1: 04:50 4th Dec. 2011 to 00:00 20th Dec. 2011

Leg2: 06:00 20th Dec. 2011 to 02:00 12th Jan. 2012

Leg3: 23:00 12th Jan. 2012 to 00:00 9th Feb. 2012

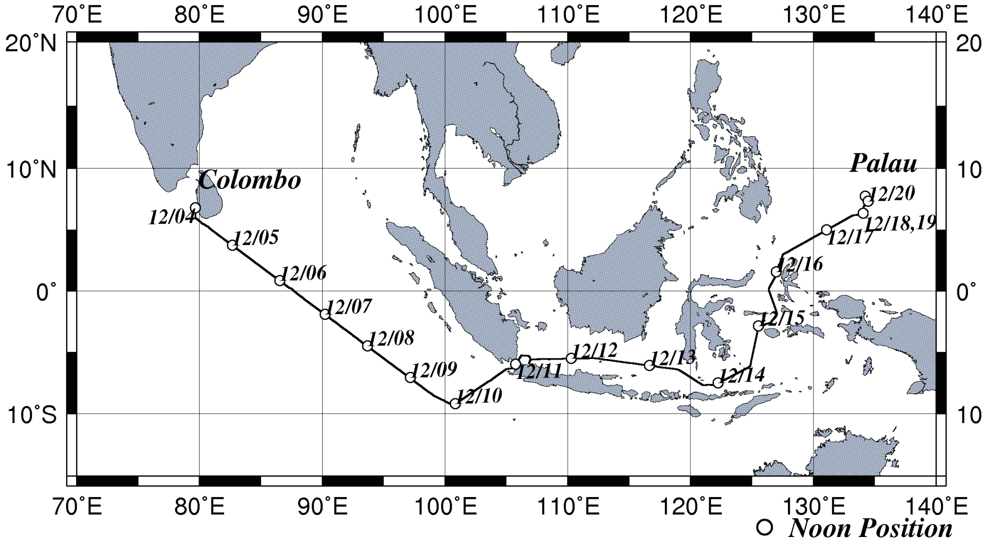

Figure 2.1.1. Cruise Track of MR11-08 Leg 1.

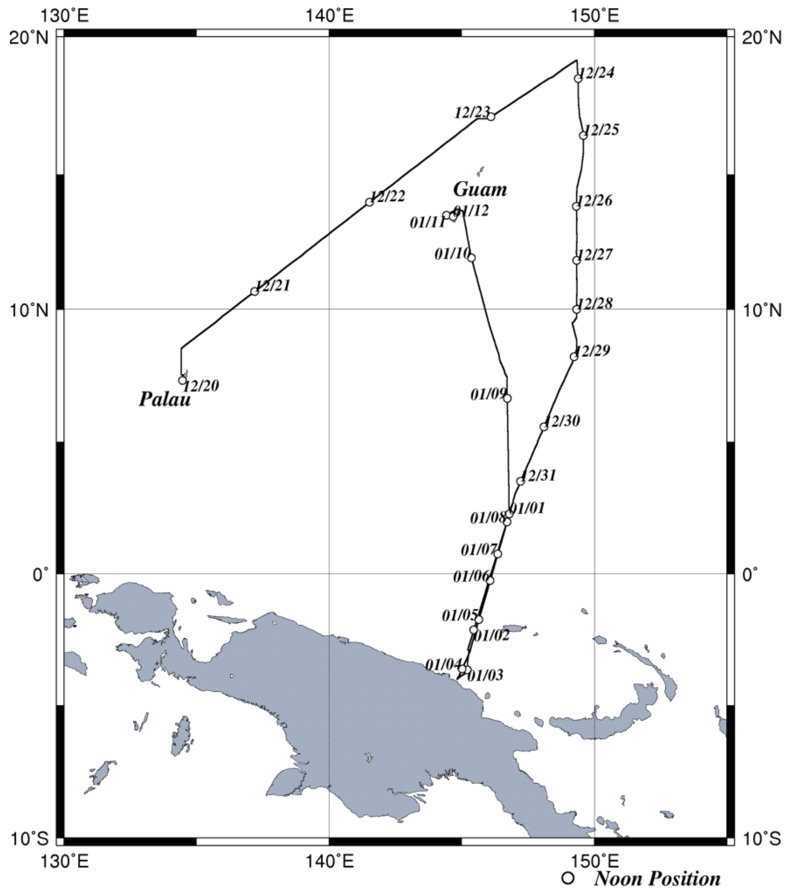

Figure 2.1.2. Cruise Track of MR11-08 Leg 2.

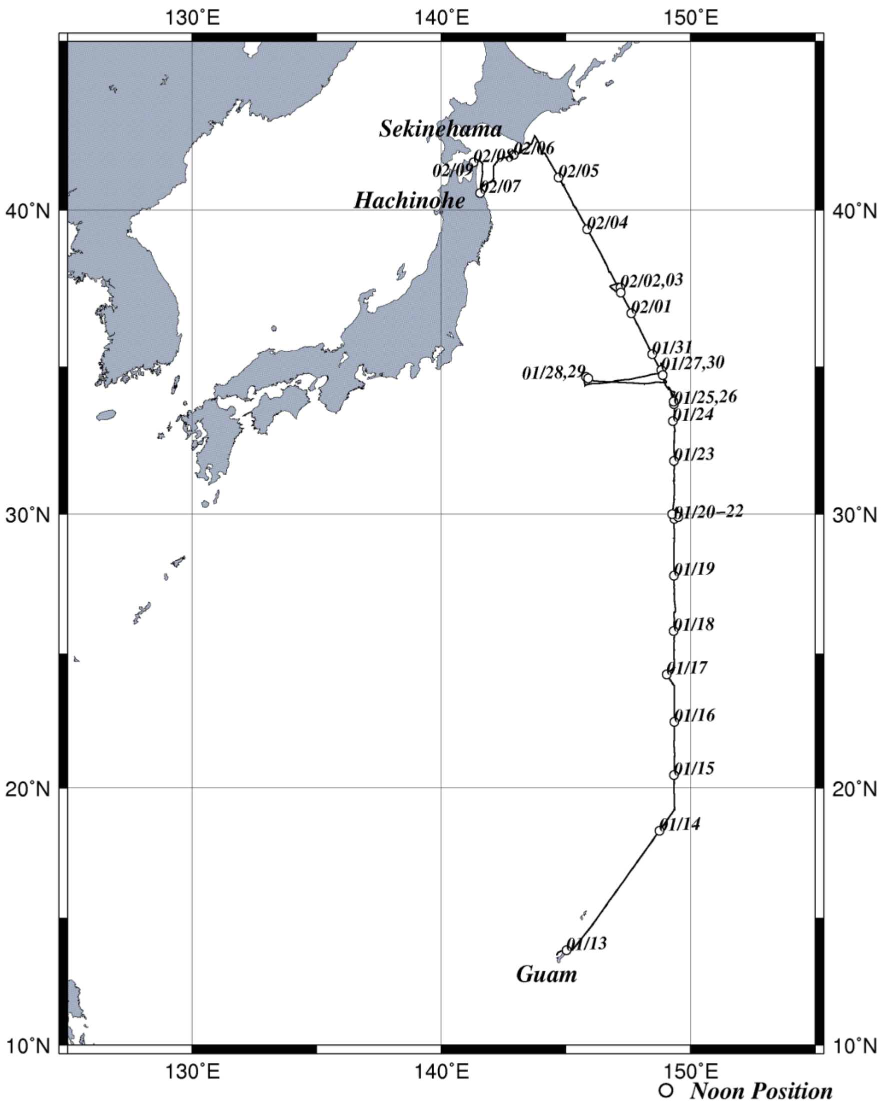

Figure 2.1.3. Cruise Track of MR11-08 Leg 3.

2.2 Swath Bathymetry

February 5, 2014

(1) Personnel

Takeshi Matsumoto	(University of the Ryukyu):	Principal Investigator (Not on-board)
Naoto Hirano	(Tohoku University):	Principal Investigator (Not on-board)
Kazuho Yoshida	(GODI)	-leg1, leg2-
Ryo Kimura	(GODI)	-leg1, leg2-
Satoshi Okumura	(GODI)	-leg2-
Katsuhisa Maeno	(GODI)	-leg3-
Asuka Doi	(GODI)	-leg3-
Toshimitsu Goto	(GODI)	-leg3-
Ryo Ohyama	(MIRAI Crew)	-leg1, leg2, leg3-

(2) Introduction

R/V MIRAI is equipped with a Multi narrow Beam Echo Sounding system (MBES), SEABEAM 2112 (SeaBeam Instruments Inc.). The objective of MBES is collecting continuous bathymetric data along ship's track to make a contribution to geological and geophysical investigations and global datasets.

(3) Data acquisition

The "SEABEAM 2112" on R/V MIRAI was used for bathymetry mapping during the MR11-08 cruise from 4th December 2011 to 9th February 2012.

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 (6.2m) sound velocity, and the deeper depth sound velocity profiles were calculated by temperature and salinity profiles from CTD or XCTD or ARGO data by the equation in Del Grosso (1974) during the cruise.

Table 2.2.1 shows system configuration and performance of SEABEAM 2112.004 system.

Table 2.2.1. System configuration and performance.

SEABEAM 2112 (12 kHz system)	
Frequency:	12 kHz
Transmit beam width:	2 degree
Transmit power:	20 kW
Transmit pulse length:	3 to 20 msec.
Depth range:	100 to 11,000 m
Beam spacing:	1 degree athwart ship
Swath width:	150 degree (max) 120 degree to 4,500 m 100 degree to 6,000 m 90 degree to 11,000 m
Depth accuracy:	Within < 0.5% of depth or +/-1m, whichever is greater, over the entire swath. (Nadir beam has greater accuracy; typically within < 0.2% of depth or +/-1m, whichever is greater)

(4) Data processing

i. Sound velocity correction

The continuous bathymetry data were split into small areas around each CTD station. For each small area, the bathymetry data were corrected with a sound velocity profile calculated from the CTD data or XCTD data in the area. The equation of Del Grosso (1974) was used for calculating sound velocity. The data processing is carried out using "mbprocess" command of MBsystem.

ii. Editing and Gridding

Gridding for the bathymetry data were carried out using the HIPS software version 7.1 (CARIS, Canada). Firstly, the bathymetry data during Ship's turning was basically removed before "BASE surface" was made. A spike noise of each swath data was also removed using "swath editor" and "subset editor". Then the bathymetry data was gridded by "Interpolate" function of the software with the parameters shown as Table 2.2.2.

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

Table 2.2.2. Parameters for interpolate of bathymetry data.

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

(5) Data archives

Bathymetric data obtained during this cruise will be submitted to the Data Management Group (DMG) of JAMSTEC, and will be archived there.

(6) Remarks (Times in UTC)

1) The observation was carried out within following periods,

Leg1:	10:00 5th Dec. 2011 to 08:30 10th Dec.2011
Leg2:	22:10 21th Dec. 2011 to 00:00 22th Dec. 2011
	19:30 23th Dec. 2011 to 04:30 1st Jan. 2012
	14:00 3rd Jan 2012 to 14:09 12th Jan. 2012
Leg3:	02:48 13th Jan. 2012 to 05:13 06th Feb 2012.

2) The following period, data acquisition was suspended due to system trouble and network trouble.

15:27 to 18:22 8th Dec. 2011

21:00 to 21:37 20th Dec. 2011

08:10 to 08:34 10th Jan. 2012

21:35 to 22:03 22th Jan. 2012

15:48 to 16:15 31th Jan. 2012

3) The following period, GPS data acquisition was suspended due to GPS trouble.

03:39 to 03:52 3rd Feb. 2012

2.3 Surface Meteorological Observation

January 25, 2014

(1) Personnel

Kunio Yoneyama	(JAMSTEC)
Kasuo Yoshida	(GODI) (Legs 1, 2)
Ryo Kimura	(GODI) (Legs 1, 2)
Satoshi Okumura	(GODI) (Leg 2)
Katsuhisa Maeno	(GODI) (Leg 3)
Asuka Doi	(GODI) (Leg 3)
Toshimitsu Goto	(GODI) (Leg 3)
Ryo Ohyama	(Mirai Crew) (Legs 1, 2, 3)

(2) Objective

As basic information about general weather conditions during the cruise, surface meteorological observation had been continuously conducted.

(3) Methods

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

Instruments of SMET whose data are used here are listed in Table 2.3.1. All SMET data were collected 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 low starting threshold wind speed (1 m/sec) comparing to SMET's (2m/sec), and 3) SMET's radiometers has 10 W/m^2 resolution, while SOAR takes 1 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. 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), that has been developed by the U.S. National Oceanic and Atmospheric Administration (NOAA) for data collection, management, real-time monitoring, etc. Information on sensors used here is listed in Table 2.3.2.

Table 2.3.1. Instruments and locations of SMET.

Sensor	Parameter	Manufacturer / type	Location / height from sea level
Thermometer*1	air temperature relative humidity	Vaisala, Finland / HMP45A	compass deck*2 / 21 m
Thermometer	sea temperature	SBE, USA / SBE-3S	bow thruster room / -5 m
Barometer	pressure	Setra System, USA / Model-370	captain deck / 13 m

*1: Gill aspirated radiation shield 43408 made by R. M. Young, USA is attached.

*2: Thermometers are equipped at both starboard and port sides, and upwind-side data are used.

Table 2.3.2. 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 Long wave radiation	Eppley, USA / PSP Eppley, USA / PIR	Foremast / 25 m Foremast / 25 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). They are mean of 8 samples (10 samples minus maximum/minimum values) to exclude singular values. Liner interpolation onto missing values was applied only when their interval is less than 4 minutes. Since the thermometers are equipped on both starboard/port sides, we adopted air temperature/relative humidity data taken at upwind side. Dew point temperature was calculated from relative humidity and air temperature data. No adjustment to sea level values is applied except pressure data.

Data are stored as ASCII format and contain the 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), shortwave and 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. It is remarked, however, since there is a possibility that data may contain noises caused by turbulence, it is recommended to filter out such data by using smoothed data (e.g., 1-hour mean) from this 1-minute mean data sets depending on the scientific purpose.

T/RH sensor;

Temperature and humidity probes were calibrated before (Aug. 3, 2011) and after (Feb. 28, 2012) the cruise by the manufacturer. Certificated accuracy for T/RH sensors are better than ±0.2 °C and ±2 %, respectively. We also checked T/RH values using another calibrated portable T/RH sensor (Vaisala, HMP45A) before each cruise. The results are listed below.

Check date			Dec. 01, 2011	Feb. 10, 2012
Temperature (°C)	Port side	SMET	27.6	–5.7
		Portable	27.9	–5.6
	Starboard side	SMET	27.9	–5.1
		Portable	27.9	–5.0
Relative Humidity (%)	Port side	SMET	76.9	62.1
		Portable	74.0	61.7
	Starboard side	SMET	78.1	66.0
	Portable		76.2	62.1

Pressure sensor;

Using calibrated portable barometer (Vaisala, Finland / PTB220), pressure sensor was checked before/after the cruise. Accuracy is better than ±0.2 hPa.

Check date	Oct.26	Dec.01	Feb.10	Mar.30
SMET	1007.45	1008.06	1013.52	1016.51
Reference	1007.43	1008.00	1013.64	1016.40
Difference	+0.02	+0.06	–0.12	0.11

Precipitation;

Prior to the cruise, we put the water into the rain gauge to check their linearity between the indicated values and actual water amount input. Expected accuracy is better than ± 1mm which corresponds to sensor's original specification.

Calibration date	Dec. 2 (1)	Dec. 2 (2)	Dec. 2 (3)	Feb. 9 (1)	Feb. 9 (2)	Feb. 9 (3)
Min input water volume (cc)	0.00	0.00	0.00	0.00	0.00	0.00
Min measured value (mm)	0.13	0.11	0.12	0.47	0.47	0.53
Max input water volume (cc)	505.00	504.50	502.50	504.50	506.50	506.00
Max measured value (mm)	49.28	49.25	49.28	50.10	50.21	50.29

Radiation sensors ;

Short wave and long wave radiometers were calibrated by Remote Measurement & Research Company with the help of Department of Energy, Atmospheric Radiation Measurement Program prior to the cruise. Sensors used here were calibrated on June 3, 2011.

For PSP; $y = 3.691x + 4.2$

For PIR; $y = 1.252x - 23.3$,

where y = Insolation (W/m^2), and x = ADC value (mV).

$1 / (T+T_0) = P_1 a^3 + P_2 a^2 + P_3 a + P_4$, where $a = \ln(\text{ADC mV})$, and $T_0 = 273.15$ K

Case temperature fit; max error = 0.000 °C

$P_1 = 3.0273e{-6}$, $P_2 = -3.6335e{-5}$, $P_3 = 4.2203e{-4}$, $P_4 = 1.7194e{-3}$

Dome temperature fit; max error = 0.000 °C

$P_1 = 3.0297e{-6}$, $P_2 = -3.6490e{-5}$, $P_3 = 4.2347e{-4}$, $P_4 = 1.7153e{-3}$

(6) Data periods

Leg-1: December 05, 2011, 1001Z – December 10, 2011, 0829Z
Leg-2: December 20, 2011, 2101Z – December 22, 2011, 0000Z
December 23, 2011, 1931Z – January 01, 2012, 0429Z
January 03, 2012, 1401Z – January 10, 2012, 1400Z
Leg-3: January 13, 2012, 0246Z – February 09, 2012, 0900Z

(7) Preliminary results

Figures 2.3.1, 2.3.2 and 2.3.3 show the time series of surface meteorological observation for each cruise. One hour mean values (time stamp at the medium of the average) instead of 1 minute mean are used to depict these figures.

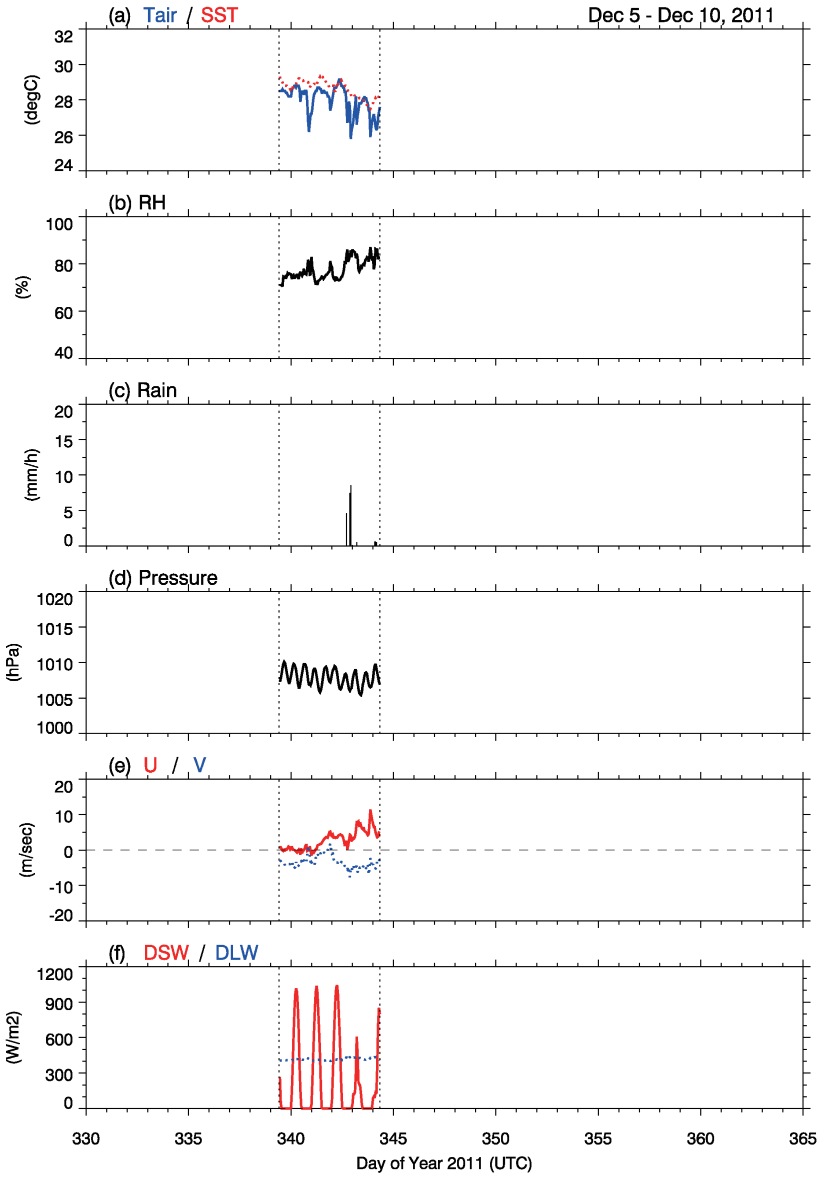

Figure 2.3.1. Time series of (a) air and sea surface temperature, (b) relative humidity, (c) precipitation, (d) pressure, (e) zonal and meridional wind components, and (e) short and long wave radiation for the Leg-1 cruise. Day-330 corresponds to Nov. 26, 2011.

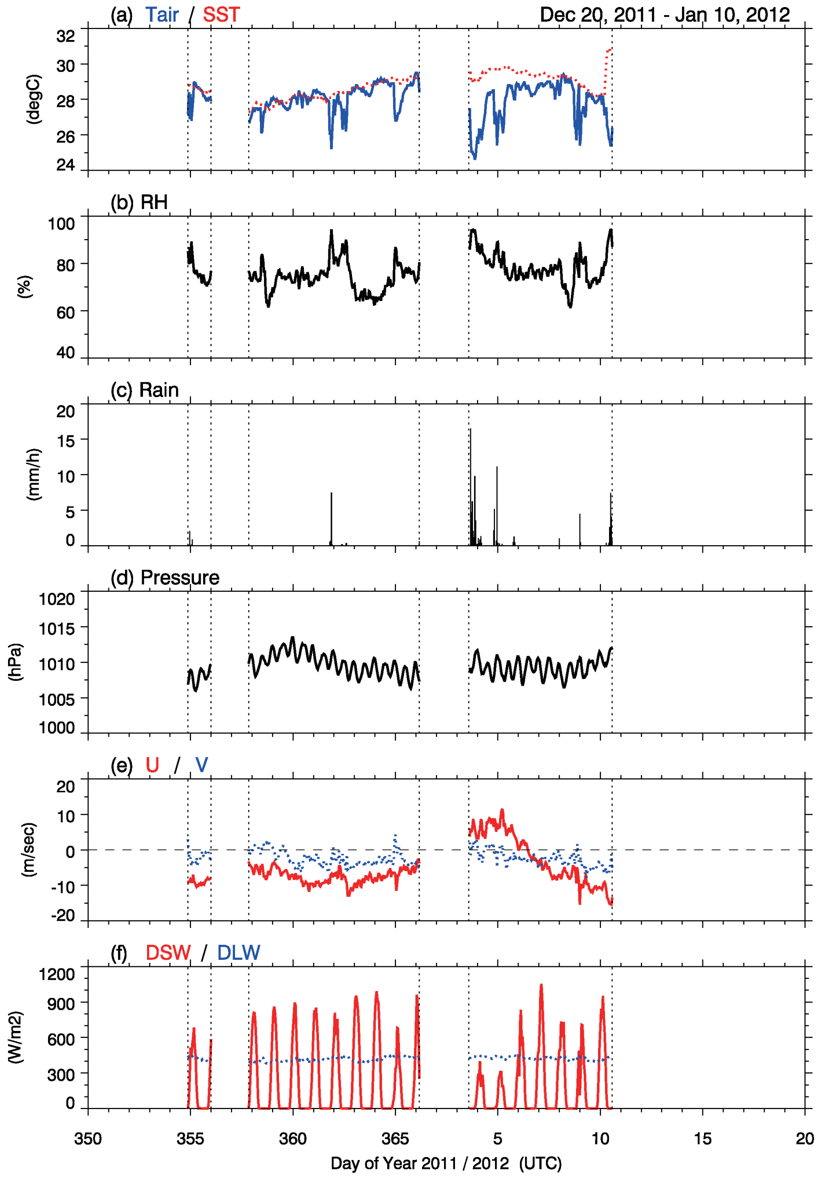

Figure 2.3.2. Same as Fig. 2.3.1, but for the Leg-2 cruise. Day-350 corresponds to Dec. 16, 2011.

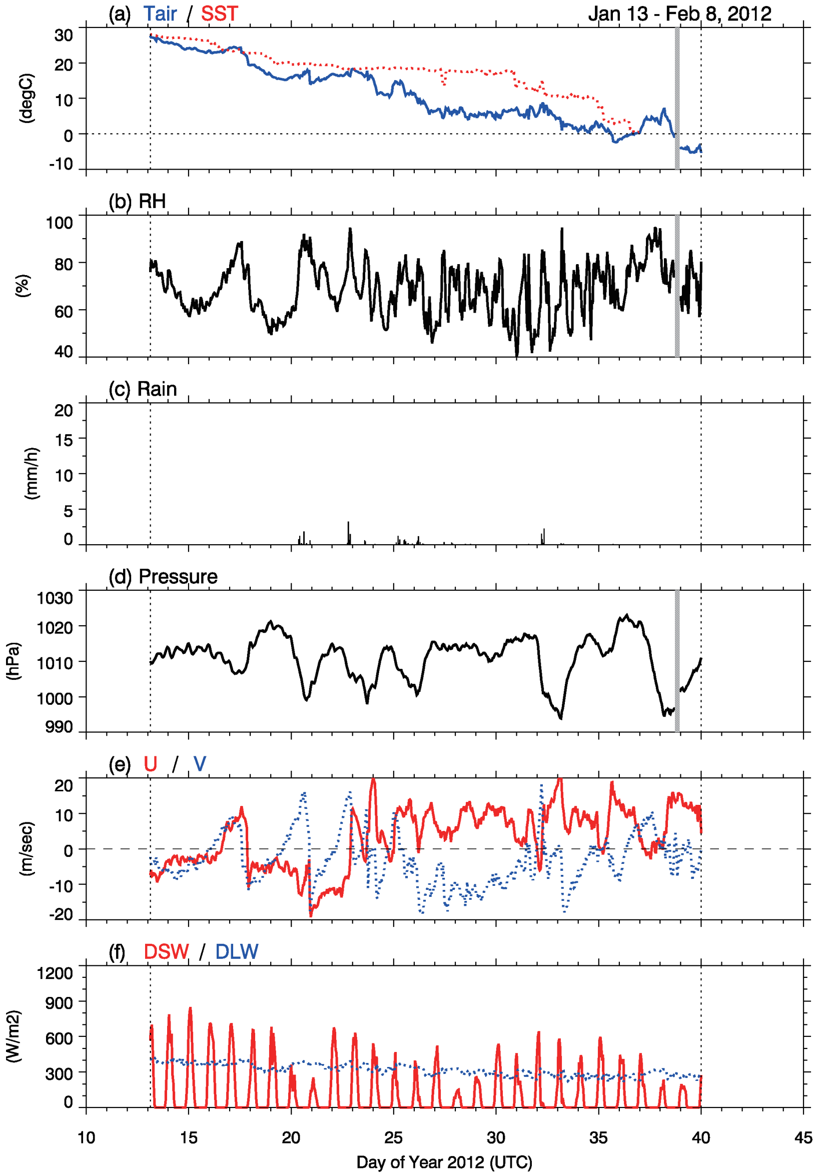

Figure 2.3.3. Same as Fig. 2.3.1, but for the Leg-3 cruise. Vertical scale for (a) and (d) are also different with Fig. 2.3.1. Day-10 corresponds to Jan. 10, 2012.

2.4 Thermo-Salinograph and Related Measurements

February 4, 2014

(1) Personnel

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Kanako Yoshida (MWJ) (Leg 2, 3)

Yuki Miyajima (MWJ) (Leg 2)

Misato Kuwahara (MWJ) (Leg 3)

Shinichiro Yokogawa (MWJ) (Leg 3)

(2) Objectives

The objective is to collect sea surface salinity, temperature, dissolved oxygen, and fluorescence data continuously along the cruise track.

(3) Materials and methods

The Continuous Sea Surface Water Monitoring System (Marine Works Japan Co, Ltd.) has six sensors and automatically measures salinity, temperature, dissolved oxygen, and fluorescence in sea surface water every one minute. This system is located in the sea surface monitoring laboratory and connected to shipboard LAN system. Measured data along with time and location of the ship were displayed on a monitor and stored in a desktop computer. The sea surface water was continuously pumped up to the laboratory from about 5 m water depth and flowed into the system through a vinyl-chloride pipe. The flow rate of the surface seawater was controlled to be 5 dm^3/min. Manufacturer's specifications of the each sensor in this system are listed below.

i. Software Seamoni-kun Ver.1.20

ii. Sensors

Temperature and conductivity sensor

Model: SBE-45, SEA-BIRD ELECTRONICS, INC.
Serial number: 4563325-0362 (leg 1)
4557820-0319 (legs 2, 3)
Measurement range: Temperature –5 to 35^{o}C
Conductivity 0 to 7 S m^{-1}
Initial accuracy: Temperature 0.002^{o}C
Conductivity 0.0003 S m^{-1}
Typical stability (per month): Temperature 0.0002^{o}C
Conductivity 0.0003 S m^{-1}
Resolution: Temperatures 0.0001^{o}C
Conductivity 0.00001 S m^{-1}

Bottom of ship thermometer

Model: SBE 38, SEA-BIRD ELECTRONICS, INC.
Serial number: 3857820-0540
Measurement range: –5 to +35^{o}C
Initial accuracy: ±0.001^{o}C
Typical stability (per 6 month): 0.001^{o}C
Resolution: 0.00025^{o}C

Dissolved oxygen sensor

Model: OPTODE 3835, AANDERAA Instruments.
Serial number: 1519
Measuring range: 0 - 500 μmol L^{-1}
Resolution: <1 μmol L^{-1}
Accuracy: <8 μmol L^{-1} or 5% whichever is greater
Settling time (63%): <25 s

Fluorometer

Model: C3, TURNER DESIGNS
Serial number: 2300123

(4) Data Processing and Quality Control

Data from the Continuous Sea Surface Water Monitoring System were processed as follows. Data gaps were linearly interpolated when the gap was ≤ 7 minutes. Spikes in the temperature and salinity data were removed using a median filter with a window of 3 scans (3 minutes) when difference between the original data and the median filtered data was larger than 0.1 ^{o}C for temperature and 0.5 for salinity. Fluorometer data were low-pass filtered using a median filter with a window of 3 scans (3 minutes) to remove spikes. Raw data from the OPTODE oxygen sensor and the fluorometer data were low-pass filtered using a Hamming filter with a window of 15 scans (15 minutes).

Salinity (S [PSU]), dissolved oxygen (O [μmol/kg]) and fluorescence (Fl [RFU]) data were corrected using the water sampled data. Details of the measurement methods are described in Sections 3.2, 3.4, and 3.8 for salinity, dissolved oxygen and chlorophyll-a, respectively. Corrected salinity (S_{cor}), dissolved oxygen (O_{cor}), and estimated chlorophyll *a* (Chl-a) were calculated from following equations

S_{cor} [PSU] $= c_0 + c_1 S + c_2 t$

O_{cor} [μmol/kg] $= c_0 + c_1 O + c_2 T + c_3 t$

Chl-a [μg/L] $= c_0 + c_1 Fl$

where t is days from a reference time, T is temperature in ^{o}C. The best fit sets of calibration coefficients ($c_0 \sim c_3$) were determined by a least square technique to minimize the deviation from the water sampled data. The reference times were listed in Table 2.4.1. The calibration coefficients were listed in Table 2.4.2. Comparisons between the Continuous Sea Surface Water Monitoring System data and water sampled data are shown in from

Figs. 2.4.1 to 2.4.6. For leg 3, sensitivity of the fluorometer to chlorophyll *a* was different between subtropical region and subarctic region. Therefore, slope (c_1) of the calibration coefficients was changed according to the temperature for each area (Table 2.4.2).

Table 2.4.1. Reference time used in the calibration equations for salinity and dissolved oxygen.

Leg	Date	Time (UTC)
2	2011/12/20	21:00
3	2012/01/13	02:47

Table 2.4.2. Calibration coefficients for the salinity, dissolved oxygen, and chlorophyll *a*.

	Leg	c0	c1	c2	c3
Salinity					
	2	1.012865e-02	0.9995585	7.254156e-04	
	3	-8.713569e-02	1.002669	5.683519e-04	
Dissolved oxygen					
	2	11.34542	1.102664	-0.6163531	-1.981512e-02
	3	36.55213	0.9906656	-0.738031	-0.1868786
Chlorophyll a					
	2	4.082381e-02	0.1021539		
	3	3.746690e-02	0.1262224 (for temperature < 17 °C)		
		3.746690e-02	8.794529e-02 (for temperature ≥ 17 °C)		

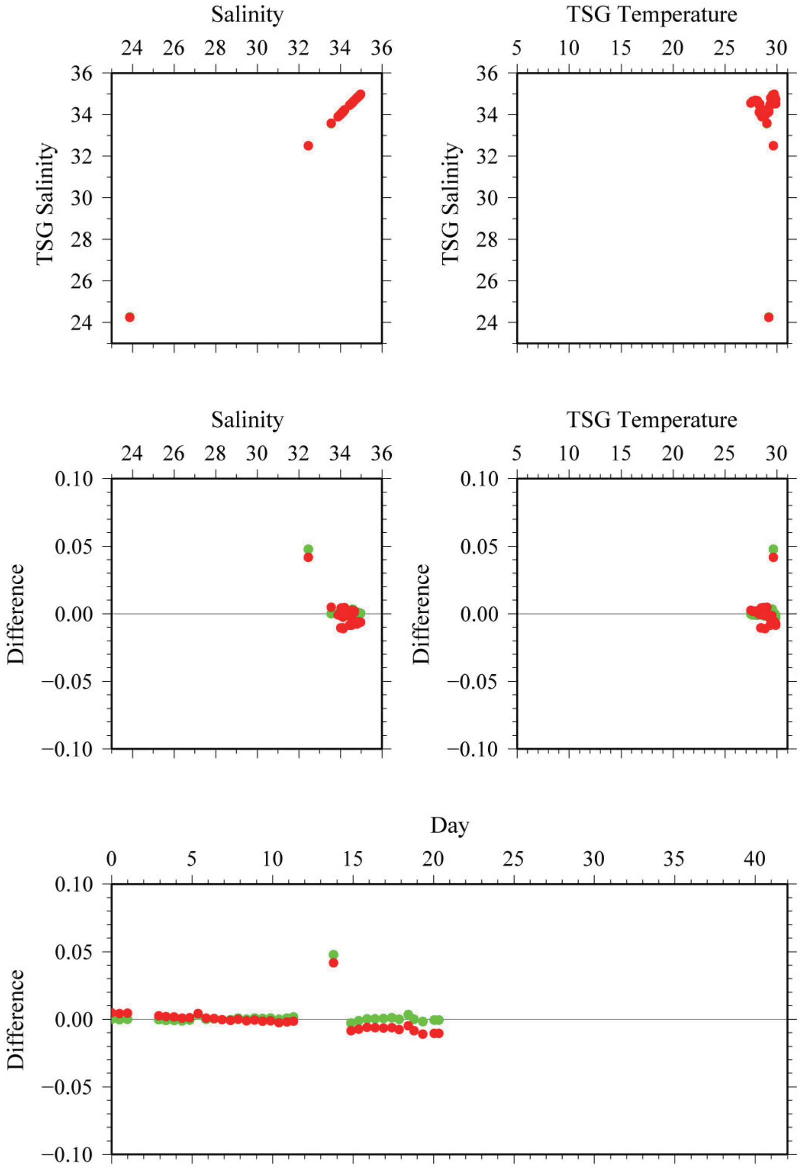

Figure 2.4.1. Comparison between TSG salinity (red: before correction, green: after correction) and sampled salinity for leg 2.

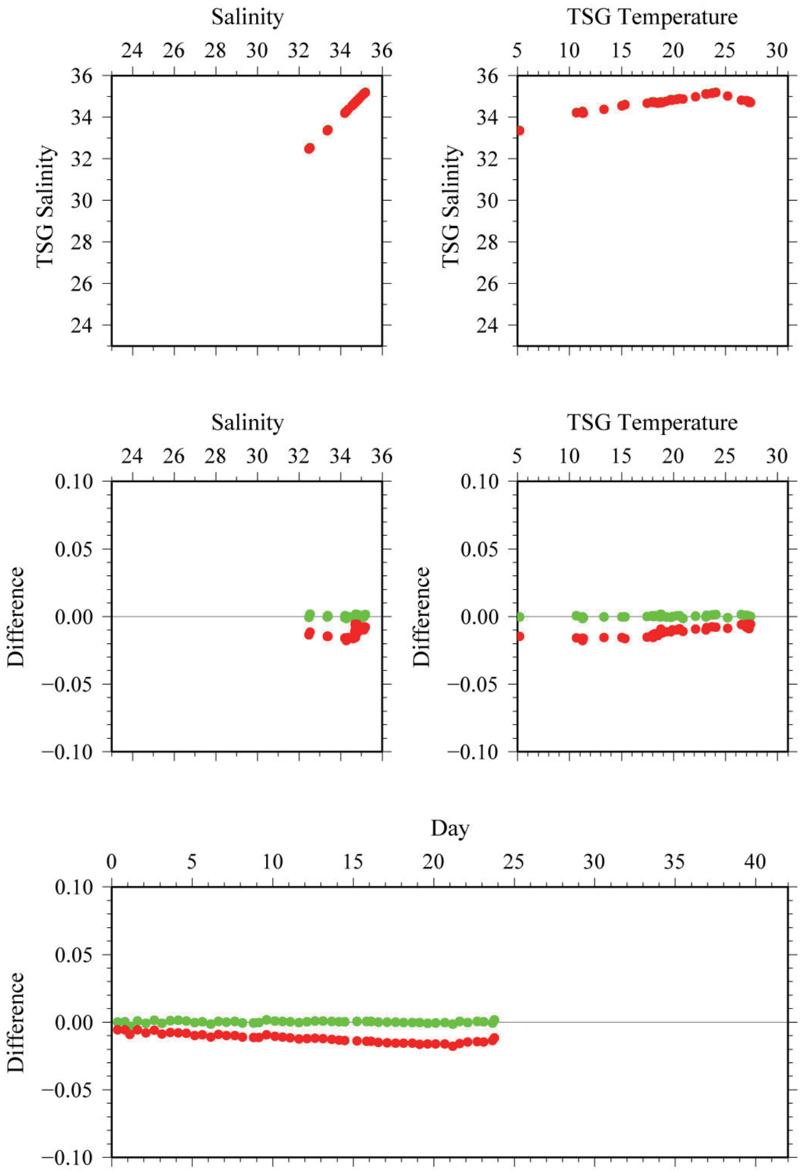

Figure 2.4.2. Same as Fig. 2.4.1, but for leg 3.

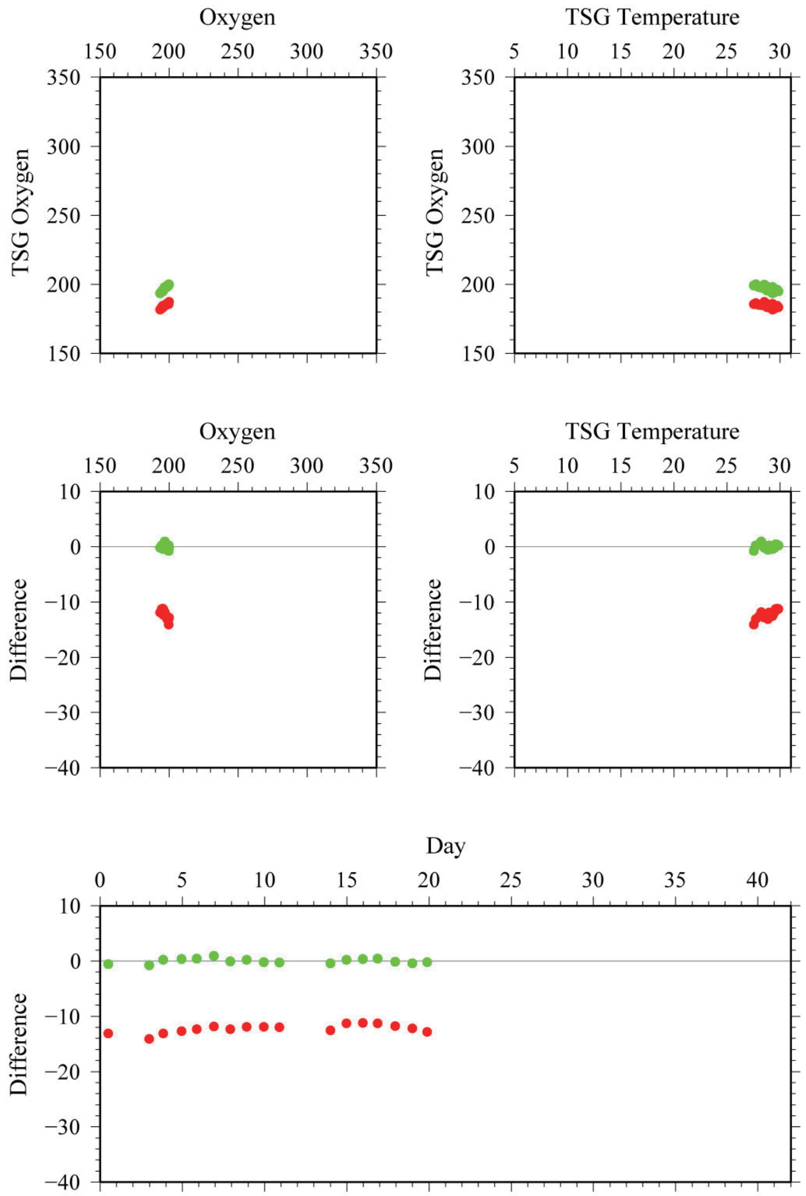

Figure 2.4.3. Comparison between TSG oxygen (red: before correction, green: after correction) and sampled oxygen for leg 2.

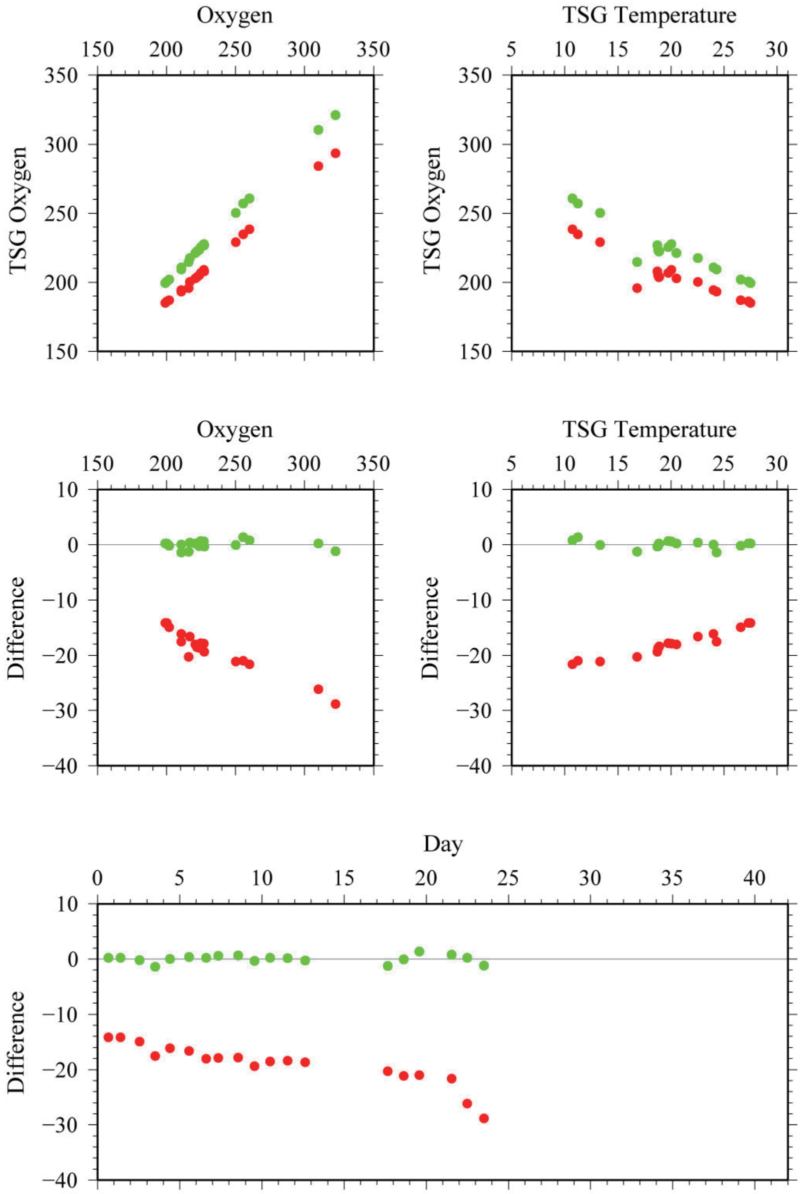

Figure 2.4.4. Same as Fig. 2.4.3, but for leg 3.

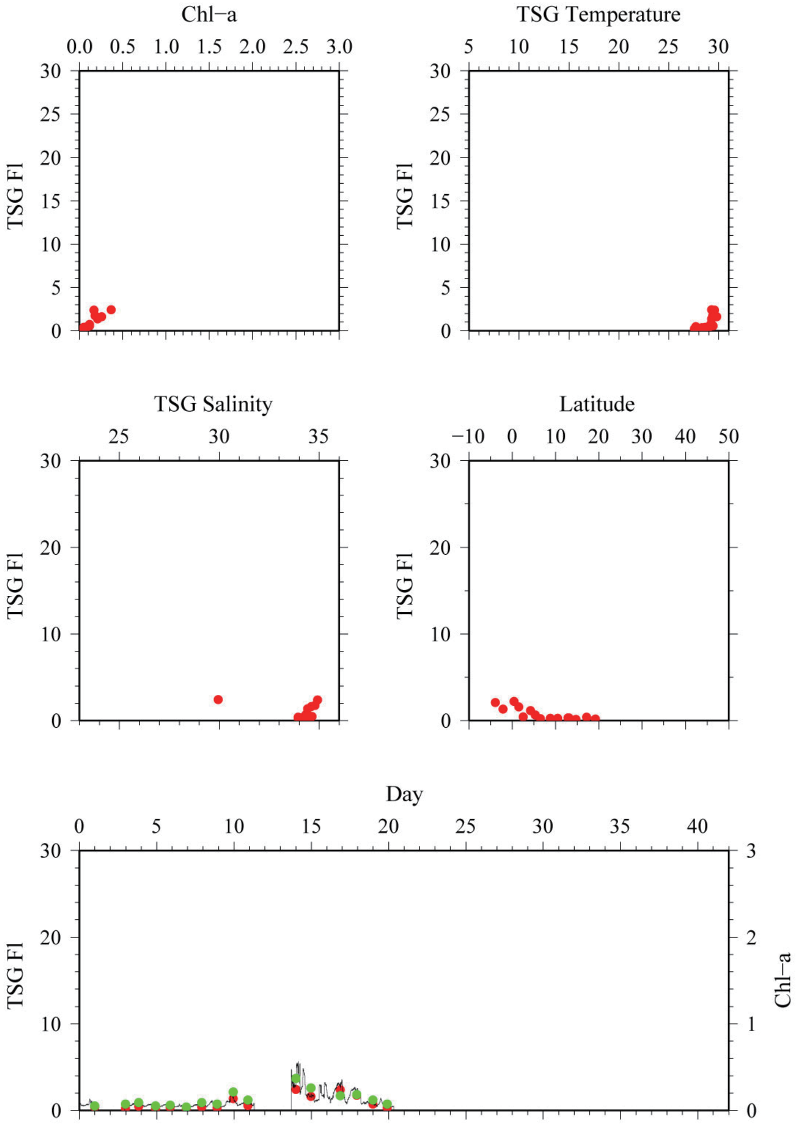

Figure 2.4.5. Comparison between TSG fluorescence and sampled chlorophyll a for leg 2. For bottom panel, red (temperature ≥ 17°C) and blue (temperature < 17°C) dots indicate fluorescence and green dots indicate water sampled chlorophyll a. Line indicates chlorophyll a estimated from fluoremeter.

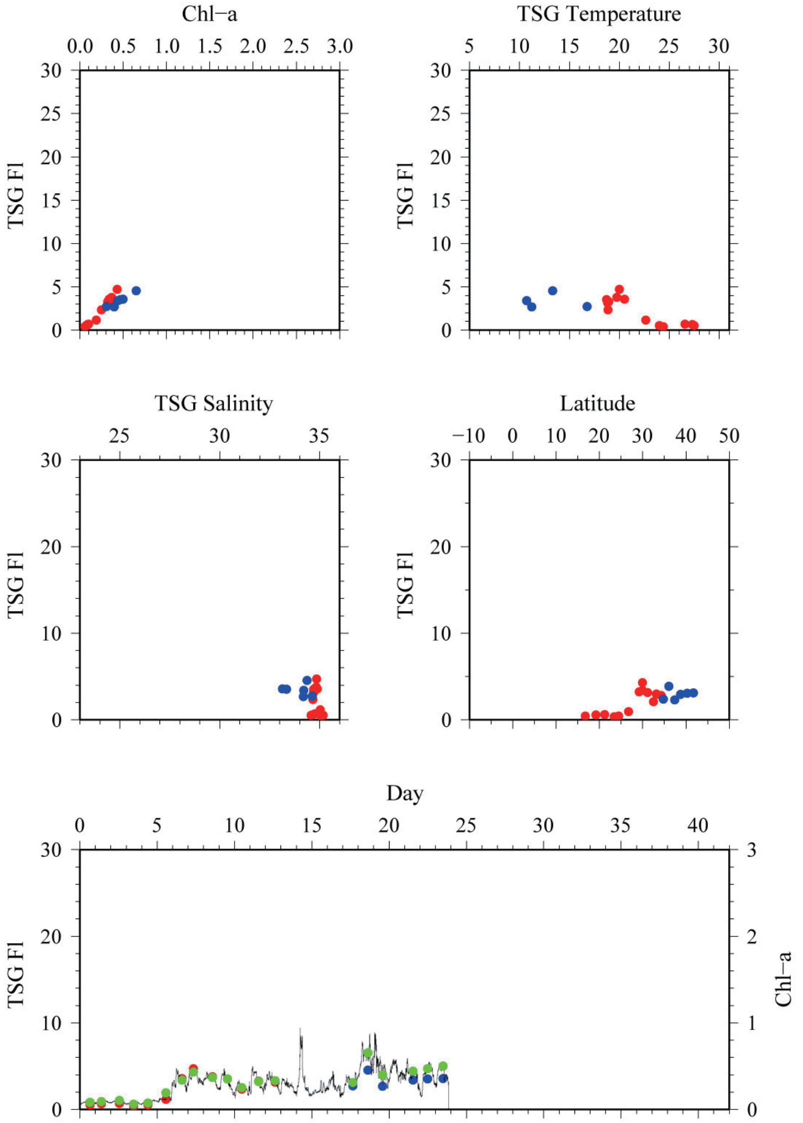

Figure 2.4.6. Same as Fig. 2.4.5, but for leg 3.

2.5 Underway pCO_2

24 September, 2013

(1) Personnel

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Yoshiko Ishikawa (MWJ)

Hatsumi Aoyama (MWJ)

Makoto Takada (MWJ)

(2) Introduction

Concentrations of CO_2 in the atmosphere are now increasing at a rate of 1.9 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 ocean 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 P10 revisit cruise, we were aimed at quantifying how much anthropogenic CO_2 is absorbed in the surface ocean in the western Pacific. For the purpose, we measured pCO_2 (partial pressures of CO_2) in the atmosphere and in the surface seawater.

(3) Apparatus and shipboard measurement

Continuous underway measurements of atmospheric and surface seawater pCO_2 were made with the CO_2 measuring system (Nippon ANS, Ltd) installed in the R/V *Mirai* of JAMSTEC. The system comprises of a non-dispersive infrared gas analyzer (Li-COR LI-7000), an air-circulation module and a showerhead-type equilibrator. To measure concentrations (mole fraction) of CO_2 in dry air (xCO_2a), air sampled from the bow of the ship (approx. 30 m above the sea level) 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 ($Mg(ClO_4)_2$). The flow rate of the air was 500 ml min^{-1}. To measure surface seawater concentrations of CO_2 in dry air (xCO_2s), the air equilibrated with seawater within the equilibrator was introduced into the NDIR through the same flow route as the dehydrated air used in measuring xCO_2a. The flow rate of the equilibrated air was 700 – 800 ml min^{-1}. 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 400 – 500 ml min^{-1}.

The CO_2 measuring system was set to repeat the measurement cycle such as 4 kinds of CO_2 standard gases (Table 2.5.1), xCO_2a (twice), xCO_2s (7 times). This measuring system was run automatically throughout the cruise by a PC control.

(4) Quality control

Concentrations of CO_2 of the standard gases are listed in Table 2.5.1, which were calibrated after cruise by the JAMSTEC primary standard gases. The CO_2 concentrations of the primary standard gases were calibrated by the Scripps Institution of Oceanography, La Jolla, CA, USA.

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_2s were adjusted based on Takahashi *et al*. (1993), although the temperature increases were slight, being ~0.3 °C.

We checked values of xCO_2a and xCO_2s by examining signals of the NDIR by plotting the xCO_2a and xCO_2s as a function of sequential day, longitude, sea surface temperature and sea surface salinity.

Reference

Takahashi, T., J. Olafsson, J. G. Goddard, D. W. Chipman, and S. C. Southerland (1993): Seasonal variation of CO_2 and nutrients in the high-latitude surface oceans: a comparative study, Global *Biogeochem. Cycles*, 7, 843 – 878.

Table 2.5.1. Concentrations of CO_2 standard gases used during MR11–08 cruise.

Cylinder no.	Concentrations (ppmv)
CRC00049	270.13
CRC00046	330.29
CRC00047	360.28
CRC00048	420.25

2.6 Shipboard ADCP

August 13, 2013

(1) Personnel

Shinya Kouketsu	(JAMSTEC): Principal Investigator	
Kazuho Yoshida	(Global Ocean Development Inc., GODI)	-leg1, leg2-
Ryo Kimura	(GODI)	-leg1, leg2-
Satoshi Okumura	(GODI)	-leg2-
Katsuhisa Maeno	(GODI)	-leg3-
Asuka Doi	(GODI)	-leg3-
Toshimitsu Goto	(GODI)	-leg3-
Ryo Ohyama	(MIRAI Crew)	-leg1, leg2, leg3-

(2) Objective

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

(3) Methods

Upper ocean current measurements were made in MR11-08 cruise, using the hull-mounted Acoustic Doppler Current Profiler (ADCP) system. For most of its operation the instrument was configured for water-tracking mode. Bottom-tracking mode, interleaved bottom-ping with water-ping, was made to get the calibration data for evaluating transducer misalignment angle in the shallow water. The system consists of following components;

1) R/V MIRAI has installed vessel-mount ADCP (75 kHz "Ocean Surveyor", Teledyne RD Instruments). It has a phased-array transducer with single assembly and creates 4 acoustic beams electronically.
2) For heading source, we use ship's gyro compass (Tokimec, Japan), continuously providing heading to the ADCP system directory. Also we have Inertial Navigation System (PHINS, iXSEA) which provide high-precision heading and attitude information are stored in ".N2R" data files.
3) DGPS system (Trimble SPS751 & StarFixXP) providing position fixes.
4) We used VmDas version 1.4.6 (TRDI) for data acquisition.
5) To synchronize time stamp of pinging 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).

Data was configured for 8-m intervals starting 19-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. Major parameters for the measurement (Direct Command) are shown in Table 2.6.1.

(4) Preliminary results

Figs.2.6.1, 2.6.2 and 2.6.3 shows surface current profile along the ship's track, averaged four depth cells from the top, 23 m to 55 m with 30 minutes average. In the layer upper 300m, the velocity estimation were good during this cruise, because the echo intensities for each beams were over 60 counts at such depths (Fig. 2.6.4).

(5) Data

The processed data were fixed the ADCP misalignment by comparison between bottom track and ship velocities (based on GPS data) and were averaged over 10 minutes.

All the data obtained in this cruise will be submitted to the Data Management Group (DMG) of JAMSTEC, and will be opened to the public via JAMSTEC home page.

(6) Remarks (Times in UTC)

The observation was carried out within following periods

Leg1: 10:00 5th Dec. 2011 to 08:30 10th Dec. 2011
Leg2: 21:00 20th Dec. 2011 to 00:00 22th Dec. 2011
19:30 23th Dec. 2011 to 04:30 1st Jan. 2012
14:00 3rd Jan. 2012 to 14:00 10th Jan. 2012
Leg3: 02:45 13th Jan. 2012 to 00:00 9th Feb. 2012

Table 2.6.1. Major parameters.

Environmental Sensor Commands	
EA = +04500	Heading Alignment (1/100 deg)
EB = +00000	Heading Bias (1/100 deg)
ED = 00065	Transducer Depth (0 - 65535 dm)
EF = +001	Pitch/Roll Divisor/Multiplier (pos/neg) [1/99 - 99]
EH = 00000	Heading (1/100 deg)
ES = 35	Salinity (0-40 pp thousand)
EX = 00000	Coord Transform (Xform:Type; Tilts; 3Bm; Map)
EZ = 10200010	Sensor Source (C; D; H; P; R; S; T; U) C (1): Sound velocity calculates using ED, ES, ET (temp.) D (0): Manual ED H (2): External synchro P (0), R (0): Manual EP, ER (0 degree) S (0): Manual ES T (1): Internal transducer sensor U (0): Manual EU
Timing Commands	
TE = 00:00:02.00	Time per Ensemble (hrs:min:sec.sec/100)
TP = 00:02.00	Time per Ping (min:sec.sec/100)
Water-Track Commands	
WA = 255	False Target Threshold (Max) (0-255 count)
WB = 1	Mode 1 Bandwidth Control (0=Wid, 1=Med, 2=Nar)
WC = 120	Low Correlation Threshold (0-255)
WD = 111 100 000	Data Out (V; C; A; PG; St; Vsum; Vsum ^ 2;#G;P0)
WE = 1000	Error Velocity Threshold (0-5000 mm/s)
WF = 0800	Blank After Transmit (cm)
WG = 001	Percent Good Minimum (0-100%)
WI = 0	Clip Data Past Bottom (0 = OFF, 1 = ON)
WJ = 1	Rcvr Gain Select (0 = Low, 1 = High)
WM = 1	Profiling Mode (1-8)
WN = 100	Number of depth cells (1-128)
WP = 00001	Pings per Ensemble (0-16384)
WS= 0800	Depth Cell Size (cm)
WT = 000	Transmit Length (cm) [0 = Bin Length]
WV = 0390	Mode 1 Ambiguity Velocity (cm/s radial)

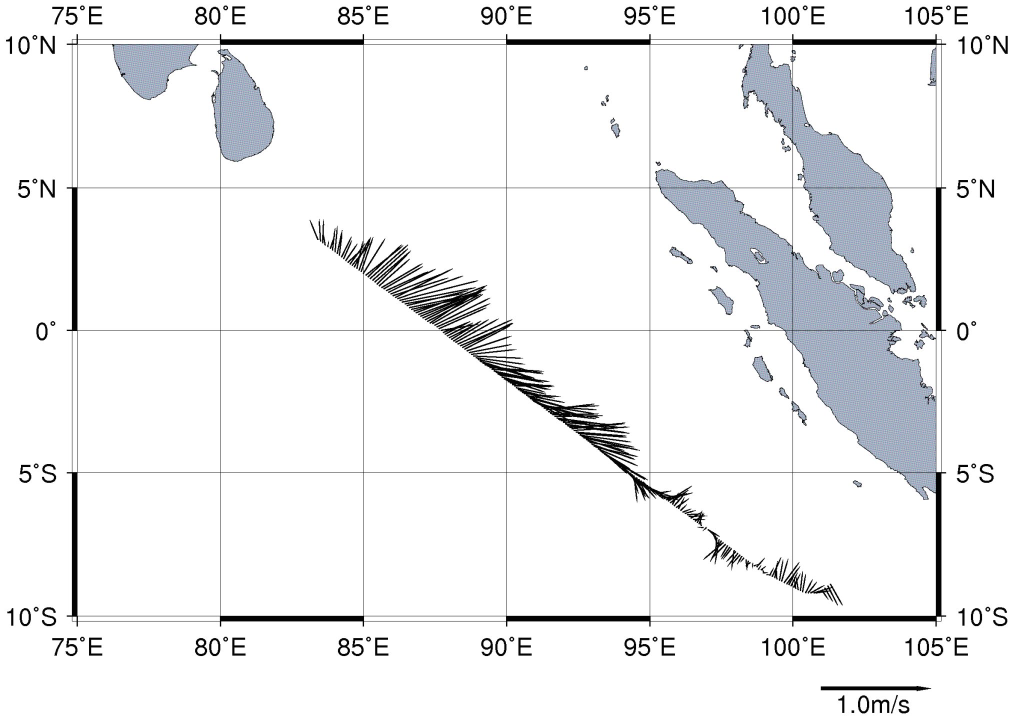

Figure 2.6.1. Current profile along the ship's track, from 23m to 55m, averaged every 30 minutes (Leg1).

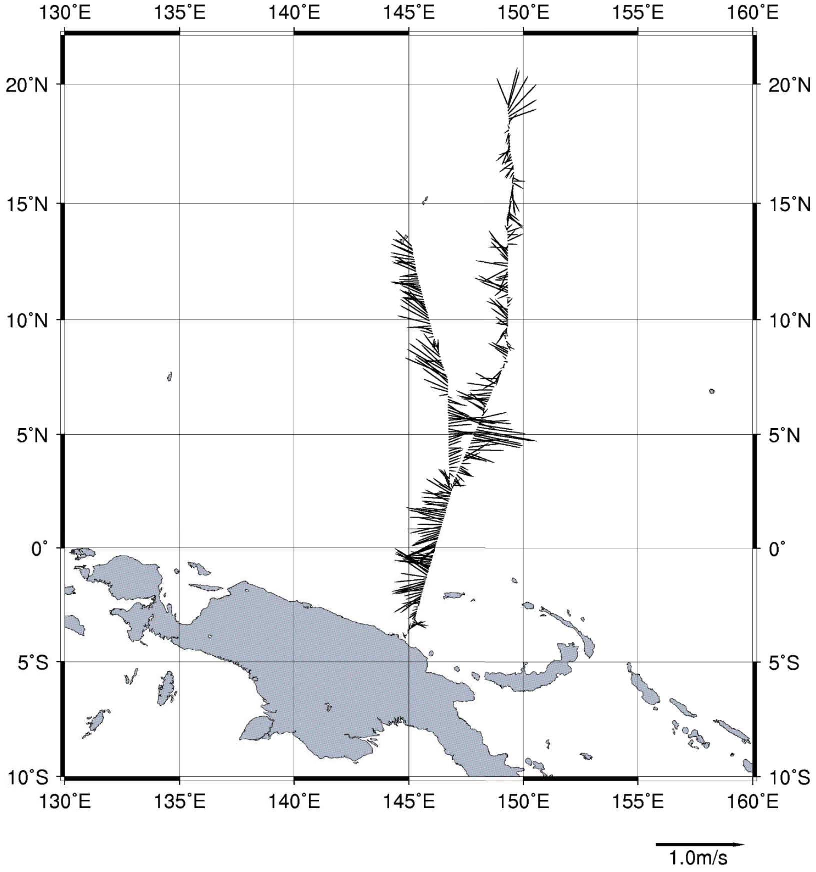

Figure 2.6.2. Current profile along the ship's track, from 23m to 55m, averaged every 30 minutes (Leg2).

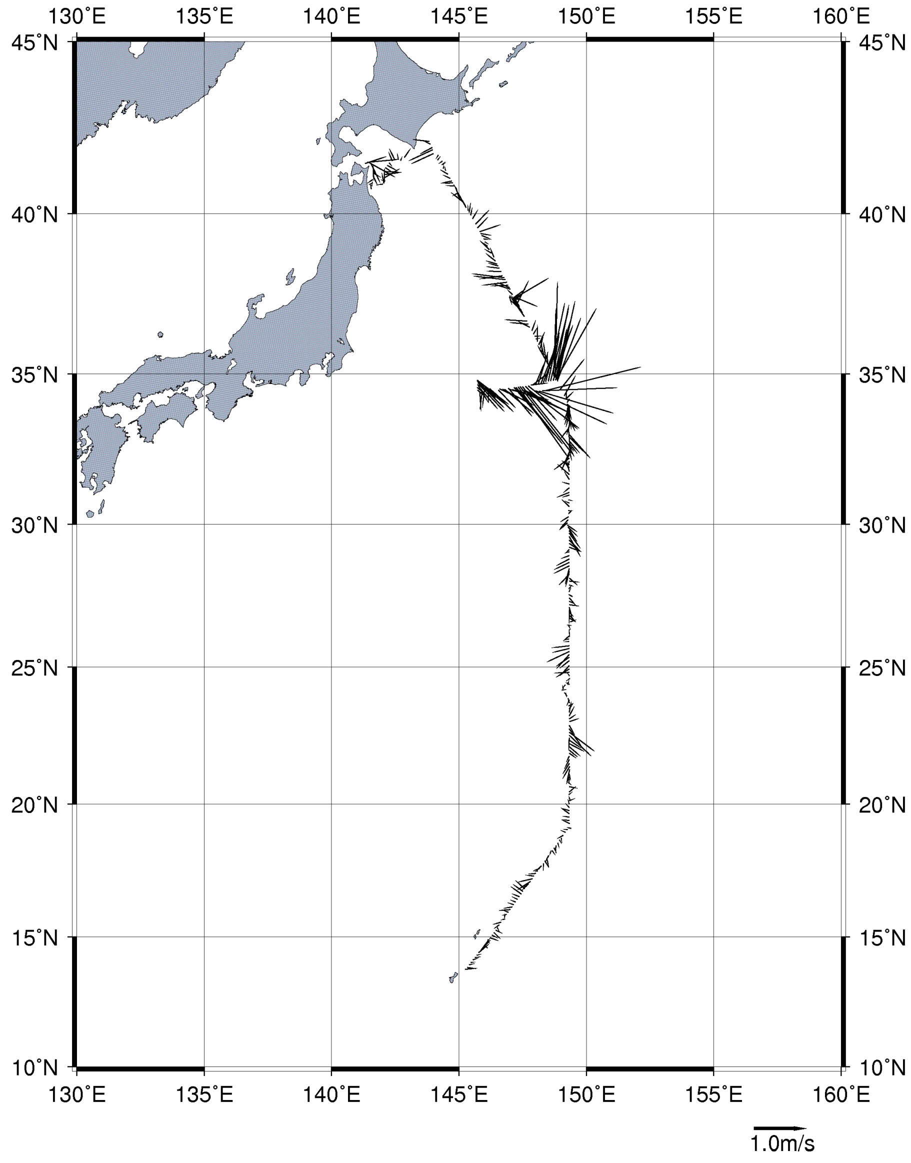

Figure 2.6.3. Current profile along the ship’s track, from 23m to 55m, averaged every 30 minutes (Leg3).

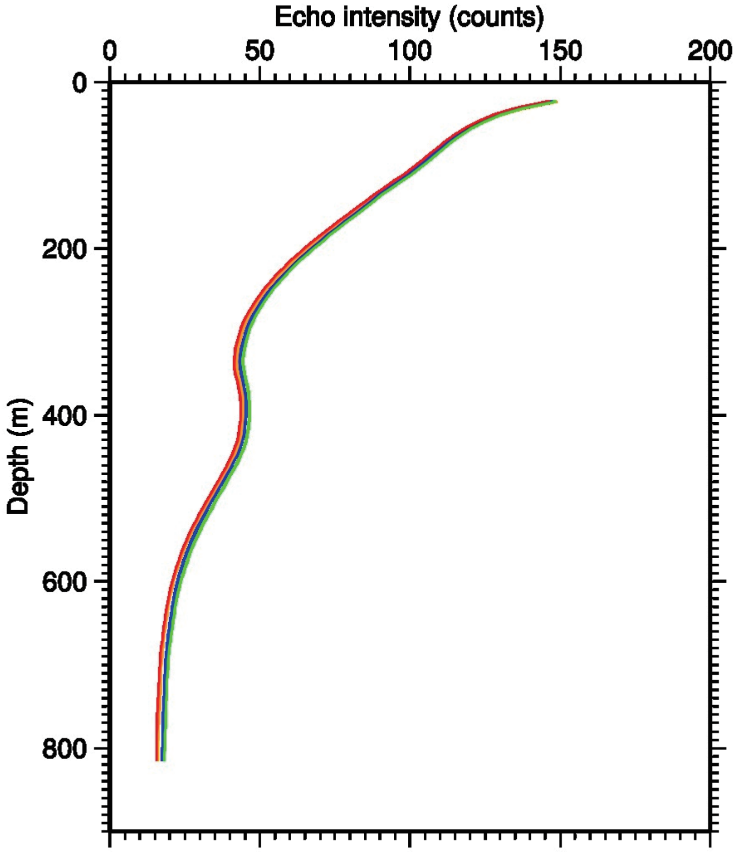

Figure 2.6.4. Echo intensity.

2.7 XCTD

February 5, 2014

(1) Personnel

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Ryo Ohyama (GODI)
Asuka Doi (GODI)
Toshimitsu Goto (GODI)

(2) Objectives

In this cruise, XCTD (eXpendable Conductivity, Temperature and Depth profiler) measurements were carried out to evaluate the fall rate equation and temperature by comparing with CTD (Conductivity, Temperature and Depth profiler) measurements, and to substitute for CTD measurements.

(3) Instrument and Method

The XCTDs used were XCTD-2 (Tsurumi-Seiki Co., Ltd., Yokohama, Kanagawa, Japan) with an MK-150N deck unit (Tsurumi-Seiki Co., Ltd.). The manufacturer's specifications are listed in Table 2.7.1. In this cruise, the XCTD probes were deployed by using 8-loading automatic launcher (stations 64, 67, 89_1, 89_2, 91, 93, 95, 103 and 105) or hand launcher (Tsurumi-Seiki Co., Ltd.). For comparison with CTD, XCTD was deployed at about 10 minutes after the beginning of the down cast of the CTD (stations 64, 67, 110, 112).

(4) Data Processing and Quality Control

The XCTD data were processed and quality controlled based on a method by Uchida et al. (2011). Depth error of the XCTD data was corrected by using the estimated terminal velocity error (-0.0362 m s^{-1}) (Fig. 2.7.1). Mean thermal bias (+0.014 °C) of the XCTD data was estimated by comparing with the CTD data and corrected (Fig. 2.7.2). 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 2.7.2). For the XCTD data of the station P10N_89_1~4 and P10N_113_1, salinity bias could not be estimated because the maximum depth was too shallow to estimate the salinity bias.

The temperature and salinity relationships in the deep ocean obtained from the post-cruise calibrated CTD and XCTD data were shown in Fig. 2.7.3.

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 2.7.1. Manufacturer's specifications of XCTD-2.

Parameter	Range	Accuracy
Conductivity	0 ~ 60 mS cm^{-1}	±0.03 mS cm^{-1}
Temperature	–2 ~ 35 °C	±0.02 °C
Depth	0 ~ 1850 m (for XCTD-2)	5 m or 2%, whichever is greater *

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

Table 2.7.2. Serial number 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	Depth [m]	SST [°C]	SSS [PSU]	Max pressure [dbar]	Salinity offset [PSU]	Reference salinity [PSU]
64_1	11022006	5714	25.045	35.045	2018	0.025	34.6081 @ 2.1°C
67_3	11022005	5786	23.895	35.178	2018	0.022	34.6017 @ 2.0°C
89_1	11022004	6145	17.866	34.717	889	–	NA
89_2	11022001	6078	17.788	34.715	655	–	NA
89_3	11021998	6130	17.797	34.717	823	–	NA
89_4	11022002	6134	17.857	34.717	846	–	NA
91_1	11021999	6067	12.769	34.303	2021	-0.002	34.5834 @ 2.0°C
93_1	11021995	5778	14.356	34.513	2021	0.008	34.5834 @ 2.0°C
95_1	11021996	5711	12.258	34.315	2021	0.008	34.5834 @ 2.0°C
97_1	11021849	5622	15.091	34.592	1999	0.004	34.5834 @ 2.0°C
99_1	11021850	5555	10.229	34.184	2021	-0.009	34.5834 @ 2.0°C
101_1	11021851	5450	10.151	34.189	2011	0.005	34.5834 @ 2.0°C
103_1	11022000	5300	9.662	34.128	2021	0.005	34.5834 @ 2.0°C
105_1	11021846	5276	4.441	33.353	2022	0.025	34.5834 @ 2.0°C
107_1	11021848	5817	4.642	33.409	2022	0.005	34.5834 @ 2.0°C
108_1	11021847	6224	3.454	33.329	2016	0.019	34.5834 @ 2.0°C
109_1	11021844	6321	3.415	33.325	2020	0.015	34.5834 @ 2.0°C
110_2	11021843	4057	4.001	33.409	2022	0.018	34.5834 @ 2.0°C
111_1	11021840	2695	3.810	33.370	2022	0.034	34.5834 @ 2.0°C
112_1	11021841	1481	1.748	33.157	1475	0.010	34.4829 @ 2.4°C
113_1	11021842	1047	0.501	32.511	1051	–	NA

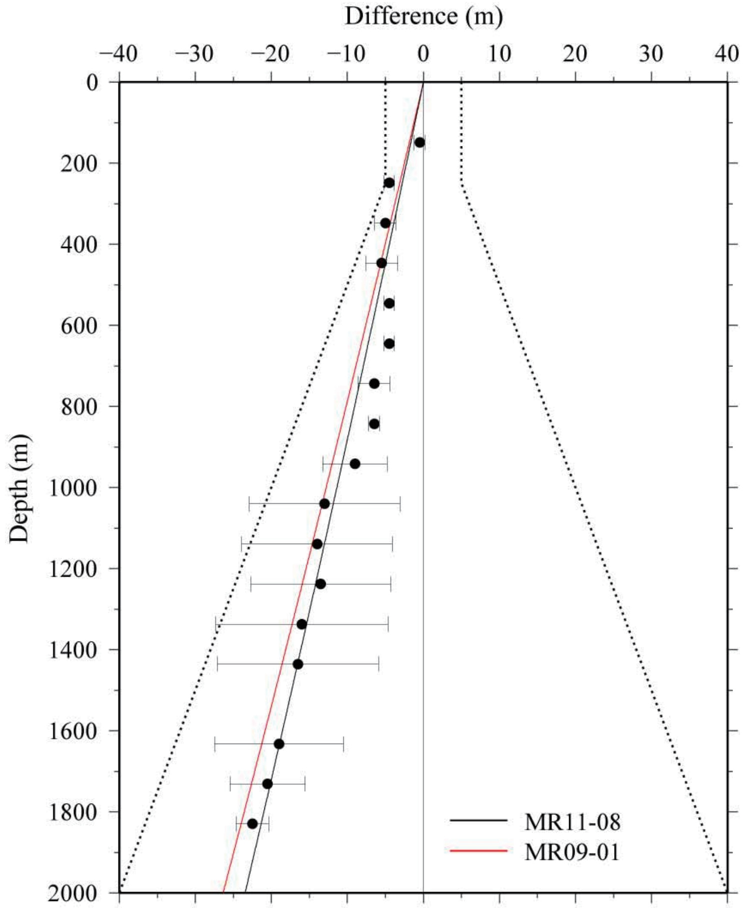

Figure 2.7.1. Differences between XCTD and CTD depths for stations 64, 67, 110 and 112. Differences were estimated with the same method as Uchida et al. (2011). Standard deviation of the estimates (horizontal bars) and the manufacturer’s specification for XCTD depth error (dotted lines) are shown. The regression for the XCTD-2 data obtained in this cruise (black line) and for the XCTD-2 data obtained in the MR09-01 cruise (red line) are shown.

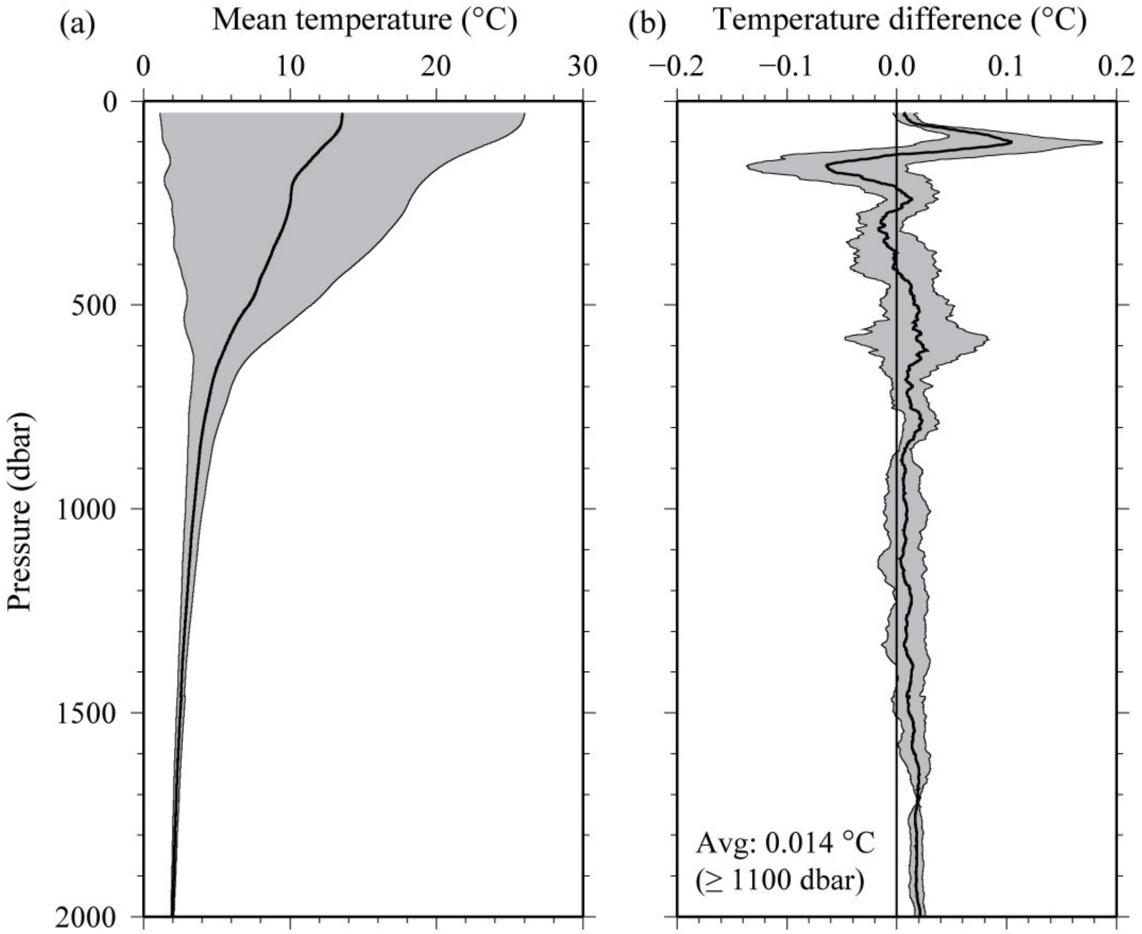

Figure 2.7.2. Comparison between XCTD and CTD temperature profiles. (a) Mean temperature profile of CTD profiles (thick line) with standard deviation (shade). (b) Mean temperature difference (thick line) with standard deviation (shade) between the XCTD and CTD.

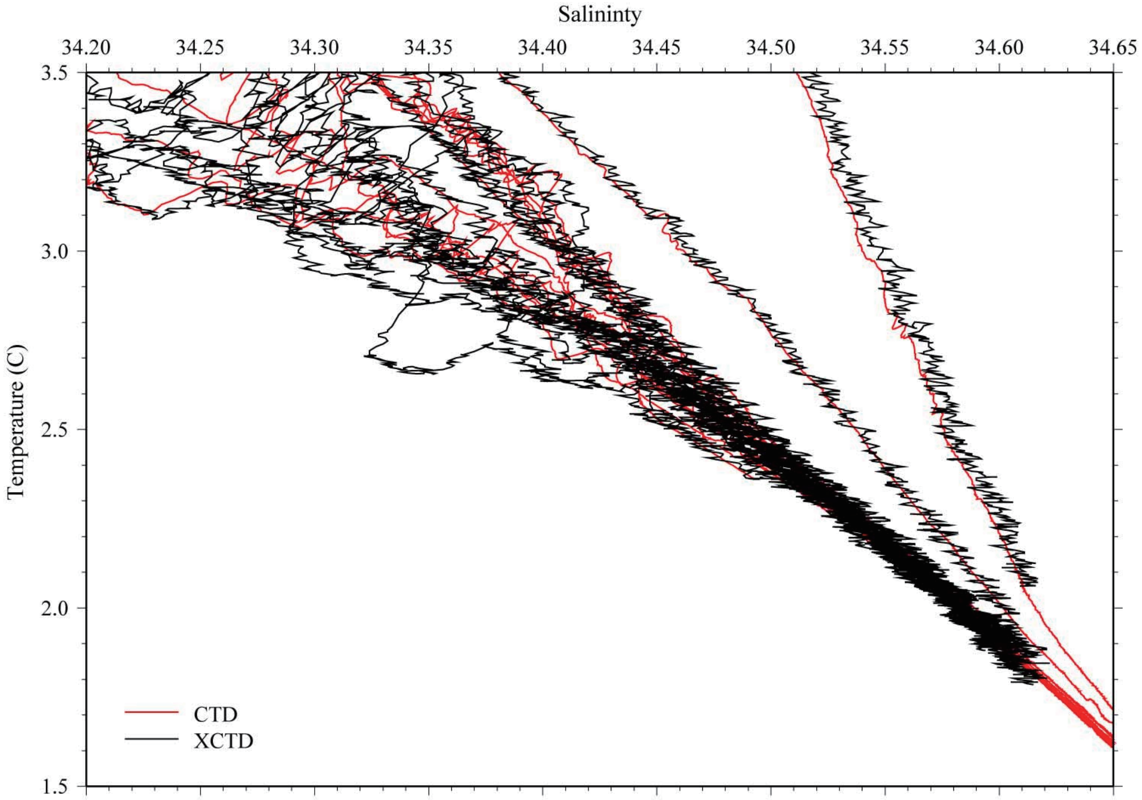

Figure 2.7.3. Comparison of temperature-salinity profiles of post-cruise calibrated CTD (red lines) and XCTD (black lines).

3 Hydrographic Measurement Techniques and Calibrations

3.1 CTDO$_2$ Measurements

February 10, 2014

(1) Personnel

Hiroshi Uchida (JAMSTEC)
Shinsuke Toyoda (MWJ) (Leg 2)
Hirokatsu Uno (MWJ) (Leg 2)
Shungo Oshitani (MWJ) (Leg 2)
Kenichi Kato (MWJ) (Leg 2)
Satoshi Ozawa (MWJ) (Leg 2)
Kenichi Katayama (MWJ) (Leg 3)
Toru Idai (MWJ) (Leg 3)
Naoko Miyamoto (MWJ) (Leg 3)
Takami Mori (MWJ) (Leg 3)

(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 Falmous, Massachusetts, USA), two oxygen optodes (RINKO-III; JFE Alec Co., Ltd, Kobe Hyogo, Japan), a fluorometer (Seapoint sensors, Inc., Kingston, New Hampshire, USA), a transmissometer (C-Star Transmissometer; WET Labs, Inc., Philomath, Oregon, USA), and a Photosynthetically Active Radiation (PAR) sensor (Satlantic, LP, Halifax, Nova Scotia, Canada) 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).

An additional set of SBE 911plus CTD system with 12-position SBE 32 was also used for three deep casts (P10N 90_2, 92_1, and 94_1) in leg 3, because tension of the winch exceeded the load capacity (3 ton) of the winch system at the CTD depths deeper than 5700 dbar, although tension of the winch had not exceeded the load capacity for the maximum depth of the CTD (6500 dbar) before the calibration of the tension meter performed in April 2011. The SBE 9plus was mounted horizontally in a 12-position carousel frame.

Summary of the system used in this cruise

36-position CWS system (Set 1)

Deck unit:

SBE 11plus, S/N 0272

Under water unit:

SBE 9plus, S/N 117457 (Pressure sensor: S/N 1027)

Temperature sensor:

SBE 3plus, S/N 4815 (primary)

SBE 3plus, S/N 5329 (secondary, leg 2)

SBE 3plus, S/N 4811 (secondary, leg 3)

Conductivity sensor:

SBE 4, S/N 2854 (primary)

SBE 4, S/N 3036 (secondary)

Oxygen sensor:

SBE 43, S/N 0394

JFE Advantech RINKO-III, S/N 0024 (foil batch no. 144002A)

JFE Advantech RINKO-III, S/N 0079 (foil batch no. 160002A)

Pump:

SBE 5T, S/N 4598 (primary)

SBE 5T, S/N 4595 (secondary)

Altimeter:

PSA-916T, S/N 1100 (leg 2)

PSA-916T, S/N 1157 (leg 3)

Deep Ocean Standards Thermometer:

SBE 35, S/N 0045

Fluorometer:

Seapoint Sensors, Inc., S/N 3054

Transmissometer:

C-Star, S/N CST-1363DR

PAR:

Satlantic LP, S/N 0049

Carousel Water Sampler:

SBE 32, S/N 0391 (36-position)

SBE 32, S/N 0389 (12-position)

Water sample bottle:

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

12-position CWS system (Set 2)

Deck unit:

SBE 11plus, S/N 0272

Under water unit:

SBE 9plus, S/N 94766 (Pressure sensor: S/N 0786)

Temperature sensor:

SBE 3plus, S/N 1359 (primary)

SBE 3plus, S/N 1525 (secondary)

Conductivity sensor:

SBE 4, S/N 1203 (primary)

SBE 4, S/N 2435 (secondary)

Oxygen sensor:

SBE 43, S/N 0205

JFE Advantech RINKO-III, S/N 0037 (foil batch no. 144005A)

Pump:

SBE 5T, S/N 3118 (primary)

SBE 5T, S/N 3293 (secondary)

Altimeter:

PSA-916T, S/N 1100

Deep Ocean Standards Thermometer:

SBE 35, S/N 0022

Carousel Water Sampler:

SBE 32, S/N 0389

Water sample bottle:

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

(4) Pre-cruise calibration

i. Pressure

The Paroscientific series 4000 Digiquartz high pressure transducer (Model 415K: 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 1027, 4 February 2011

S/N 0786, 17 November 2009

The time drift of the pressure sensor is adjusted by periodic recertification corrections against a dead-weight piston gauge (Model 480DA, S/N 23906; Piston unit, S/N 079K; Weight set, S/N 3070; 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 1027, 19 May 2011

slope = 1.00017335

offset = 0.16281

S/N 0786, 27 May 2011

slope = 0.99988759

offset = 0.05087

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, 25 January 2011

S/N 5329, 11 February 2011

S/N 4811, 9 February 2011

S/N 1359, 18 May 2011

S/N 1525, 10 June 2011

Pressure sensitivities of SBE 3s were corrected according to a method by Uchida et al. (2007), for the following sensors.

S/N 4815, –3.45974716e–7 [°C/dbar]

S/N 4811, –2.7192e–7 [°C/dbar]

S/N 1359, –1.8386e–7 [°C/dbar]

Pressure sensitivities were not yet determined for S/N 5329 and 1525.

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. The conductivity cells have been replaced to newer style cells for deep ocean measurements.

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

S/N 2854, 1 June 2011

S/N 3036, 1 June 2011

S/N 1203, 25 May 2011

S/N 2435, 2 March 2011

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 calibration was performed at SBE, Inc.

S/N 0394, 25 October 2011

S/N 0205, 27 May 2011

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 September 2002

S/N 0022, 4 March 2009

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, 10 February 2011 (slope and offset correction)

S/N 0022, 23 January 2011 (slope and offset correction)

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

From the end of 2011, the SBE has been applying a NIST correction to the fixed-point cells used for the calibration. The offset values were estimated for the above fixed-point cells as 140 μK (TPW) and 89 μK (GaMP) for the S/N 0045 and 120 μK (TPW) and 89 μK (GaMP) for the S/N 0022, and the following NIST corrected coefficients were used in this cruise.

S/N 0045: Slope = 1.000030, Offset = –0.001513

S/N 0022: Slope = 1.000010, Offset = –0.000116

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 (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 RINKO are the raw phase shift data. The RINKO can be calibrated by the Stern-Volmer equation, according to a method by Uchida et al. (2010):

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

where V is voltage, V_0 is voltage in the absence of oxygen and K_{sv} is Stern-Volmer constant. The V_0 and the K_{sv} 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 (°C) and V_b is raw output (volts). V_0 and V are normalized by the output in the absence of oxygen at 0°C. The oxygen concentration is calculated using accurate temperature data from the CTD temperature sensor instead of temperature data from the RINKO. The pressure-compensated oxygen concentration O_{2c} can be calculated as follows.

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

where p is CTD pressure (dbar) and C_p 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.

Pre-cruise sensor calibrations were performed at RIGC/JAMSTEC.

S/N 0024, 20 June 2011

S/N 0079, 6 December 2011

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 know 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.

Transmittance (T_r) is related to the beam attenuation coefficient c by the relationship:

$$T_r = e^{-cx}$$

$$x = 0.25 \text{ m (S/N CST-136DR)}$$

where x is the pathlength through the water volume.

x. PAR

Satlantic's Photosynthetically Active Radiation (PAR) sensors provide highly accurate measurements of PAR (400 – 700 nm) for a wide range of aquatic and terrestrial applications. The ideal spectral response for a PAR sensor is one that gives equal emphasis to all photons between 400 – 700 nm. Satlantic PAR sensors use a high quality filtered silicon photodiode to provide a near equal spectral response across the entire wavelength range of the measurement.

Pre-cruise sensor calibration was performed at Satlantic, LP.

22 January 2009

(5) Data collection and processing

i. Data collection

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

The pressure windows of the transmissometer were wiped with Kimwipes wetted with ethanol before each CTD cast to clean the windows.

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 stops, the bottle was fired after waiting from the stop for 30 seconds (or 20 seconds from station P10_78_1 to save time) 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 (or 12-bottles) SBE 32 Carousel Water Sampler with 12-litre Niskin-X bottles. Before a cast taken water for CFCs, the bottle frame and Niskin-X bottles were wiped with acetone.

Data acquisition software

SEASAVE-Win32, version 7.18c

ii. Data collection problems

(a) Miss trip and miss fire

Niskin bottles did not trip correctly at the following stations.

Miss trip	Miss fire
P10_46_1, #11	P10N_106_2, #31

(b) Detaching the fluorometer, transmissometer and LADCP

At station P10_74_2 and P10N_77_2, the fluorometer, transmissometer and LADCP were detached from the CTD system, because the maximum depth of the CTD cast exceeded the pressure capacity of the sensors.

(c) Cancellation of CTD casts

At station P10_67_1, the CTD cast was cancelled at 236 dbar of down cast, because the ship maneuvering equipment was on the blink. At station P10N_84_1, the CTD cast was cancelled at 5073 dbar of down cast because of rough weather.

(d) Bottle firing without stops

At following stations, the Niskin bottles were fired without stop of the CTD package because of rough weather.

P10N_83_1: bottles #24~36

P10N_87_1: bottles #14~27, #29~36

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

SBEDataProcessing-Win32, version 7.21d

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. When the bottle was fired without bottle firing stop, the duration was set to 1.0 second and the offset was set to 0.0 second, and a quality flag of 4 (bad) was set to the SBE 35 data. 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 (or 1 second for the bottle fired without stop).

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 6 seconds advancing the SBE 43 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. Delay of the transmissometer data was also compensated by 2 seconds 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, 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.

DERIVE was re-used to compute salinity, potential temperature, and density (σ_θ).

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 to check the pressure sensor time drift. 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. 3.1.1. The CTD pressure sensor offset was estimated from the deck pressure. Mean of the pre- and the post-casts data over the whole period gave an estimation of the pressure sensor offset (0.25 dbar for S/N 1027 and –0.47 dbar for S/N 0786) from the pre-cruise calibration. The post-cruise correction of the pressure data is not deemed necessary for the pressure sensor.

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 in August 2013.

S/N 0045, 15 April 2012 (2nd step: fixed point calibration)

Slope = 1.000029

Offset = –0.001423

S/N 0022, 12 March 2012 (2nd step: fixed point calibration)

Slope = 1.000012

Offset = –0.000023

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

The CTD temperature was 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 950 dbar.

The primary temperature data were used for the post-cruise calibration. The calibration coefficients are listed in Table 3.1.1. The results of the post-cruise calibration for the CTD temperature are summarized in Table 3.1.2 and shown in Fig. 3.1.2.

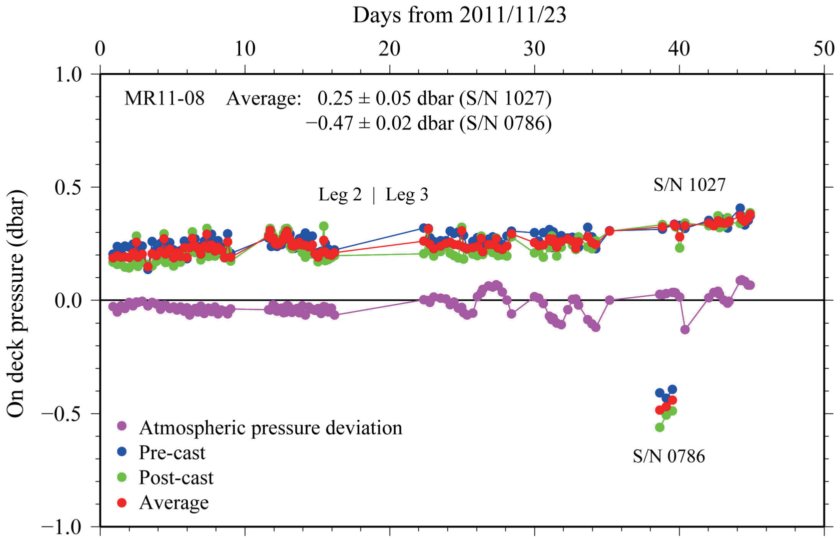

Fig. 3.1.1. Time series of the CTD deck pressure. Atmospheric pressure deviation (magenta dots) from a standard atmospheric pressure was subtracted from the CTD deck pressure. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dots indicate averages of the pre- and the post-cast deck pressures.

Table 3.1.1. Calibration coefficients for the CTD temperature sensors.

Leg	Serial number	c_0 (°C/dbar)	c_1 (°C/day)	c_2 (°C)
2	4815	–2.68889e–8	2.87072e–5	–0.0071
3	4815	–4.08124e–8	9.57543e–6	–0.0025
3	1359	1.13346e–7		0.0004

Table 3.1.2. Difference between the CTD temperature and the SBE 35 after the post-cruise calibration. Mean and standard deviation (Sdev) are calculated for the data below and above 950 dbar. Number of data used is also shown.

Leg	Serial number	Pressure ≥ 950 dbar			Pressure < 950 dbar		
		Number	Mean (mK)	Sdev (mK)	Number	Mean (mK)	Sdev (mK)
2	4815	647	0.0	0.2	1286	–0.6	7.0
3	4815	631	–0.0	0.2	1060	0.1	7.6
3	1359	36	–0.0	0.1			

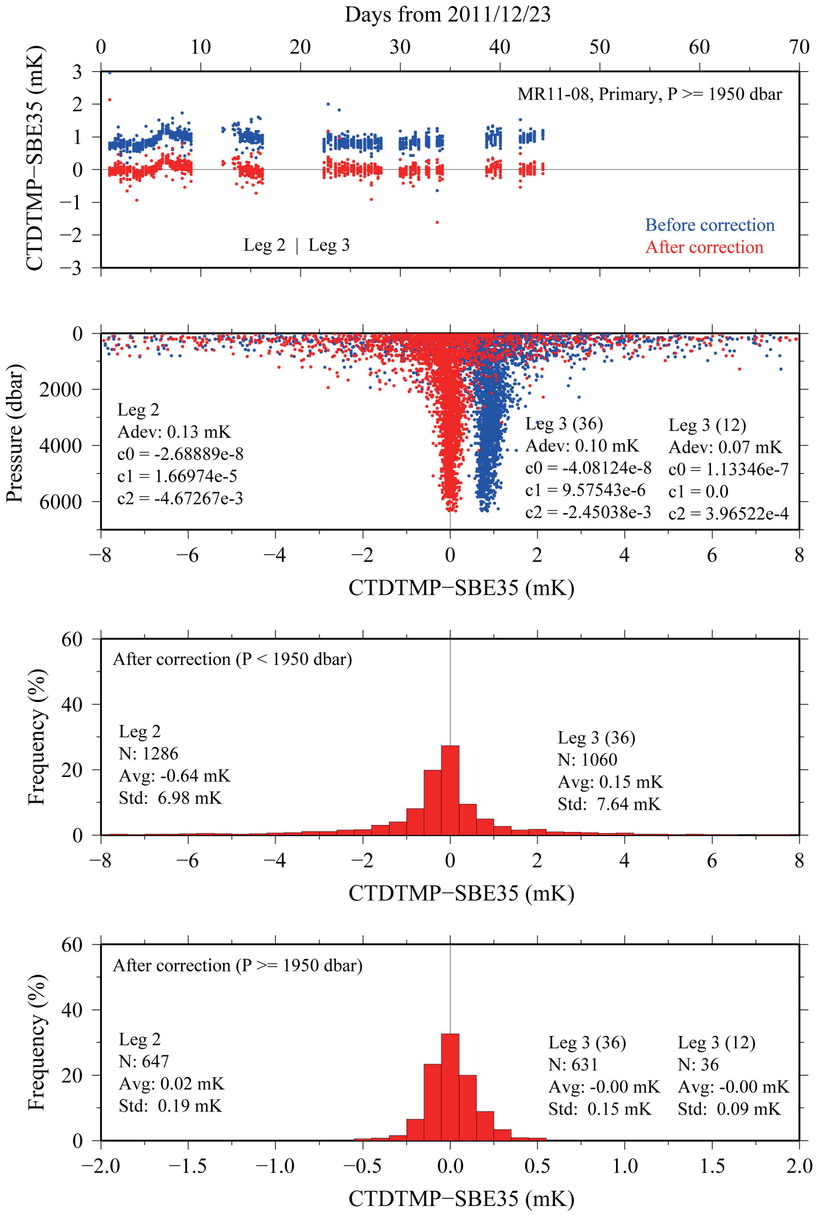

Fig. 3.1.2. Difference between the CTD temperature (primary) and the SBE 35. Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Lower two panels show histogram of the difference after the calibration.

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 23 December 2011 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 least square technique to minimize the deviation from the conductivity calculated from the bottle salinity data.

The primary conductivity data created by the software module ROSSUM were basically used after the post-cruise calibration for the temperature data. The secondary conductivity sensor was also calibrated and used instead of the primary conductivity data when the data quality of the primary temperature or conductivity data was bad. The coefficients were determined for each leg. The calibration coefficients are listed in Table 3.1.3. The results of the post-cruise calibration for the CTD salinity are summarized in Table 3.1.4 and shown in Fig. 3.1.3.

Table 3.1.3. Calibration coefficients for the CTD conductivity sensors.

Leg	Serial Number	c_0	c_1 [S/(m dbar)]	c_2 (1/dbar)	c_3 [S/(m day)]	c_4 (S/m)
2	2854	0.999999	1.52141e−7	−5.00025e−8	3.69363e−6	2.68130e−4
3	2854	0.999969	−1.92594e−7	5.97695e−8	−1.20584e−6	4.13868e−4
3	120	1.00070	−1.03014e−6	2.97097e−7		−1.93434e−3

Table 3.1.4. 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 number	Pressure ≥ 950 dbar			Pressure < 950 dbar		
		Number	Mean	Sdev	Number	Mean	Sdev
2	2854	939	–0.0	0.6	748	0.0	4.7
3	2854	845	0.0	0.4	549	–0.0	2.8
3	1203	39	0.0	0.3			

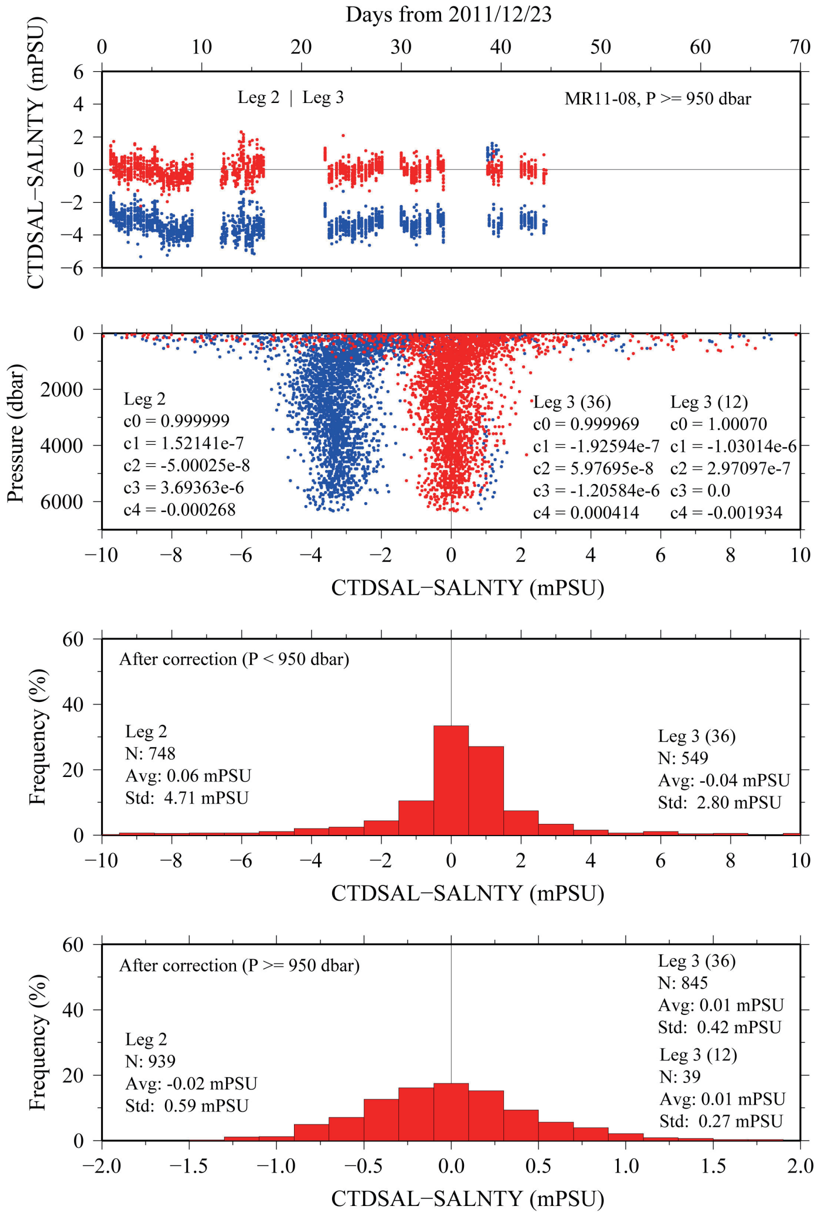

Fig. 3.1.3. Difference between the CTD salinity (primary) and the bottle salinity. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration.

iv. Oxygen

The RINKO oxygen optodes (S/N 0024 and S/N 0037) were calibrated and used as the CTD oxygen data, since the RINKO has a fast time response. The pressure-hysteresis corrected RINKO data was calibrated by the Stern-Volmer equation, basically according to a method by Uchida et al. (2010):

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

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 °C, and t is working time (in days) of the RINKO sensor integrated from the first CTD cast for each leg. Time drift of the RINKO output was corrected. The pressure-compensated oxygen concentration O_{2c} was calculated as follows.

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

where p is CTD pressure (dbar) and Cp is the compensation coefficient. The calibration coefficients 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 post-cruise calibrated temperature and salinity data were used for the calibration. The calibration coefficients are listed in Table 3.1.5. The results of the post-cruise calibration for the RINKO oxygen are summarized in Table 3.1.6 and shown in Fig. 3.1.4.

Table 3.1.5. Calibration coefficients for the RINKO oxygen sensors.

Leg	Serial number	c_0	c_1	c_2	c_3	c_4
2	0024	3.89290e–3	1.52171e–4	1.93156e–6	–5.08841e–4	–0.117182
3	0024	4.11419e–3	1.64439e–4	2.93308e–6	4.45790e–4	–0.140317
3	0037	3.04531e–3	1.09824e–3	–3.46770e–4	7.63642e–3	–0.146284

Table 3.1.5. Continue.

Leg	Serial number	c_5	c_6	c_7	C_p
2	0024	0.336087	5.16436e–5	2.38398e–4	0.05
3	0024	0.342439	–2.97398e–4	1.80689e–4	0.05
3	0037	0.325744			0.05

Table 3.1.6. Difference between the RINKO oxygen and the bottle ooxygen 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	Serial number	Pressure ≥ 950 dbar			Pressure < 950 dbar		
		Number	Mean	Sdev	Number	Mean	Sdev
			[μmol/kg]			[μmol/kg]	
2	0024	890	0.00	0.23	753	0.03	0.47
3	0024	851	0.01	0.28	550	–0.09	0.81
3	0037	39	–0.03	0.27			

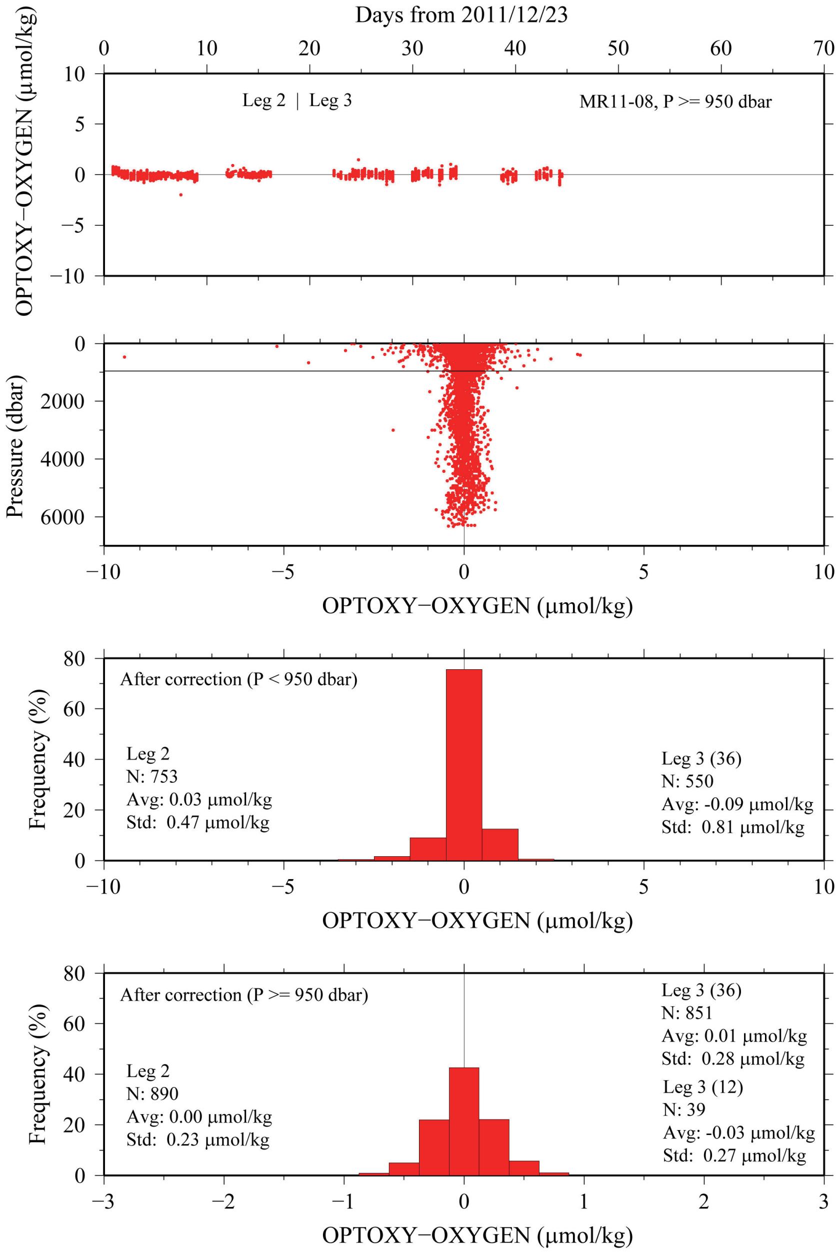

Fig. 3.1.4. Difference between the calibrated CTD oxygen and the bottle oxygen. Lower two panels show histogram of the difference.

v. Fluorometer

The CTD fluorometer (Fl in μg/L) was calibrated with the bottle sampled chlorophyll-a (Chla) as

$$F_l = c_0 + c_1 \times \mathrm{Chla}$$

where c_0 and c_1 are calibration coefficients. The CTD fluorometer data is slightly noisy so that the up cast profile data which was averaged over one decibar agree with the bottle sampled data better than the discrete CTD fluorometer data obtained at bottle-firing stop. Therefore, the CTD fluorometer data at water sampling depths extracted from the up cast profile data were compared with the bottle sampled chlorophyll-a data (Fig. 3.1.5) and the calibration coefficients are listed in Table 3.1.7.

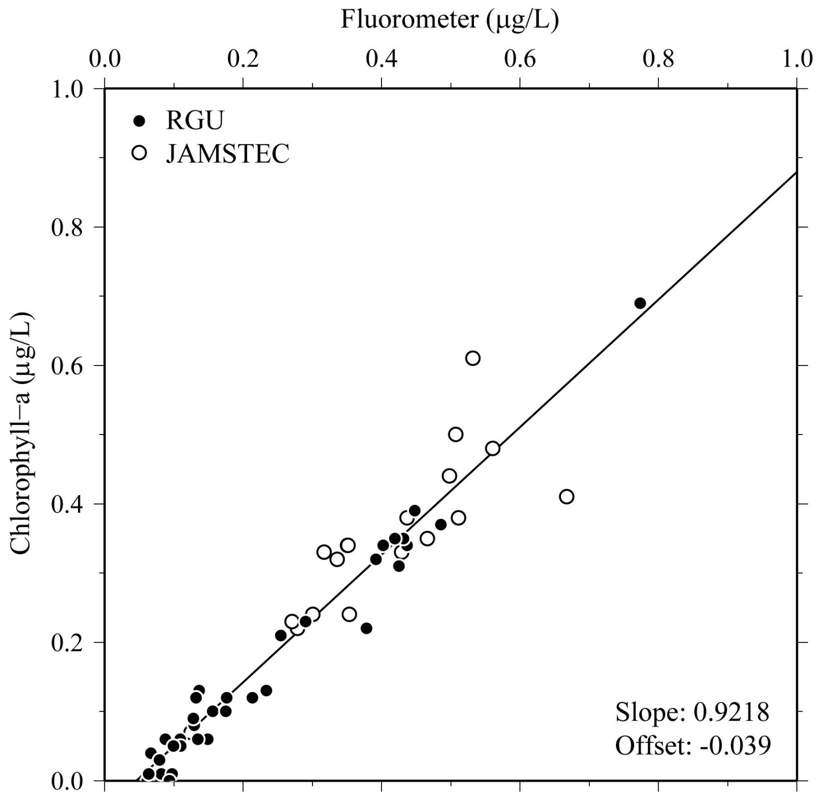

Fig. 3.1.5. Comparison of the CTD fluorometer and the bottle sampled chlorophyll-a. The solid line is the regression line.

Table 3.1.7. Calibration coefficients for the CTD fluorometer.

c_0	c_1	Standard deviation from the regression line
–0.039	0.9218	0.05 μg/L

vi. Transmissometer

The transmissometer is calibrated as

$$T_r = (V–V_d) / (V_r–V_d)$$

wehre V is the measured signal (voltage), V_d is the dark offset for the instrument, and V_r is the signal for clear water. V_d can be obtained by blocking the light path. V_d was measured on deck before each cast and estimated to be 0.0012 during the cruise. V_r is estimated from the measured signal in the deep ocean, although the transmittance tended to decrease when the water depth was shallow (Fig. 3.1.6). Since the transmissometer drifted in time, V_r is expressed as

$$V_r = 4.84280 – 6.73551e–3\times t + 1.78673e–4\times t^2$$

where t is working time (in days) of the transmissometer.

vii. PAR

The PAR sensor was calibrated with an offset correction. The offset was estimated from the data measured in the deep ocean during the cruise. The corrected data (PARc) is calculated from the raw data (PAR) as follows:

$$PARc\ [\mu E\ m^{-2}\ s^{-1}] = PAR – 0.046.$$

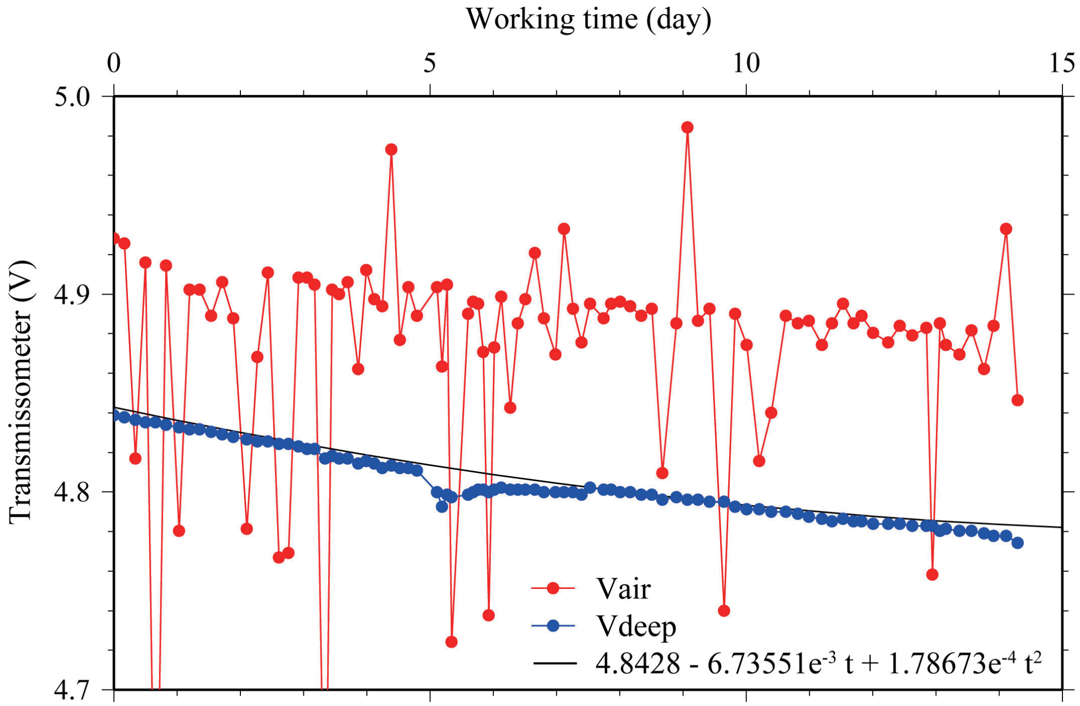

Fig. 3.1.6. Time series of an output signal (voltage) from transmissometer at on deck before CTD casts (Vair) and deep ocean (Vdeep). The solid line indicates the modeled signal in the deep clear ocean.

(7) Combining of CTD profiles

Two sets of SBE 911plus CTD system with 36 and 12-position SBE 32 were used at three CTD stations (Table 3.1.8). The 12-position CWS CTD system (set 2) can be accurately calibrated with water sampled data for the depths deeper than about 3000 dbar. Therefore, the CTD profiles obtained at these casts were combined to obtain a calibrated CTD profile from surface to bottom. The data between the shallow and deep profiles were linearly interpolated for 100 dbar from the maximum depth of the shallow profile to the top of the deep profile used to combine (Fig. 3.1.7).

Table 3.1.8. List of deep double casts of CTD in leg 3. Set 1 is 36-position CWS system and set 2 is 12-position CWS system.

Station no.	Cast no.	Set of CTD system	Water sampling depth
P10N 90	2	2	3170 dbar – bottom
	3	1	Surface – 2930 dbar
P10N 92	1	2	3250 dbar – bottom
	3	1	Surface – 2999 dbar
P10N 94	1	2	3332 dbar – bottom
	3	1	Surface – 3082 dbar

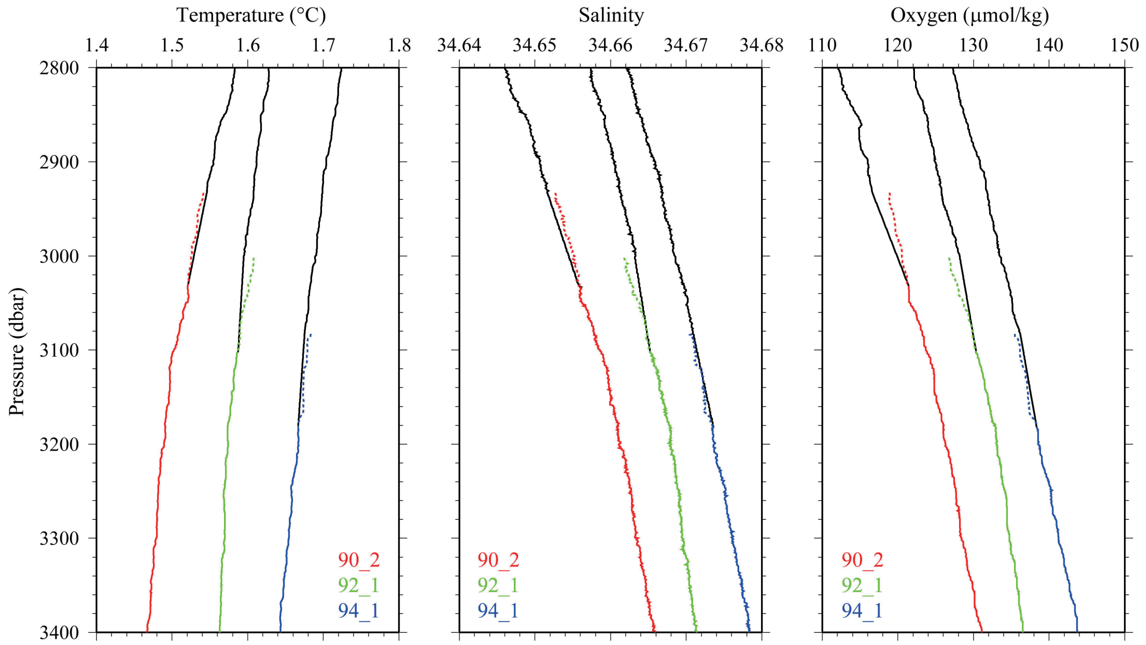

Fig. 3.1.7. Combined CTD profiles of stations P10N 90_3, 92_3, and 94_3.

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3.2 Bottle Salinity

May 10, 2012

(1) Personnel

Hiroshi Uchida (JAMSTEC)
Fujio Kobayashi (MWJ) (Leg 2)
Tatsuya Tanaka (MWJ) (Leg 3)
Hiroki Ushiromura (MWJ) (Leg 2)
Tamami Ueno (MWJ) (Leg 3)

(2) Objectives

Bottle salinities were measured to calibrate CTD salinity data.

(3) Instrument and Method

Salinity measurement was conducted basically based on a method by Kawano (2010).

i. Salinity Sample Collection

Samples for salinity measurement were collected and stored in 250-mL brown borosilicate glass bottles with GL32 screw caps with PTFE liners (without cones). Each bottle and cap was rinsed three times with sample water, and the water was allowed to overflow the bottle. Excess water was poured out until the water was level with the shoulder of the bottle. The bottles were stored at least 12 hours in a laboratory where the salinity was to be measured for temperature equilibration with upside down in a carrying case.

ii. Instruments and Method

Salinity of water samples was measured with two salinometers (Autosal model 8400B; Guildline Instruments Ltd., Ontario, Canada; serial no. 62556 for leg 2 and serial no. 62827 for leg 3), which was modified by adding an peristaltic-type intake pump (Ocean Scientific International Ltd., Hampshire, UK) and two platinum thermometers (Guildline Instruments Ltd., model 9450). One thermometer monitored an ambient temperature and the other monitored a salinometer's 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. The ambient temperature varied from approximately 20 to 24 °C, while the bath temperature was stable and varied within ±0.002 °C.

A measure of a double conductivity ratio of a sample was 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 was smaller than 0.00002, the average value of the two double conductivity ratios was used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981). When the difference was grater than or equal to the 0.00003, we measured another additional filling of the cell. In case where the double conductivity ratio of the additional filling did not satisfy the criteria above, we measured other additional fillings of the cell within 10 fillings in total. In case where the number of fillings was 10 and those fillings did not satisfy the criteria above, the median of the double conductivity ratios of five fillings were used to calculate the bottle salinity.

The measurement was conducted about from 6 to 23 hours per day and the cell was cleaned with soap after the measurement for each day. A total of about 4,000 sea water samples were measured during the cruise.

(4) Results

i. Standard Seawater

Standardization control was set to 796 (leg 2) and 482 (leg 3). The value of STANDBY was 5602 ± 0002 (leg 2) and 5408 ± 0.002 (leg 3), and that of ZERO was 0.00000 ± 0.00001 for both legs. We used IAPSO Standard Seawater (Ocean Scientific International Ltd., Havant, UK) batch P153 whose conductivity ratio was 0.99979 (double conductivity ratio is 1.99958) as the standard for salinity measurement. We measured 90 (leg 2) and 85 (leg 3) bottles of the Standard Seawater during routine measurement. Figs. 3.2.1 and 3.2.2 show the history of the measured double conductivity ratio of the Standard Seawater during legs 2 and 3.

For leg 2, the salinometer was not stable. Therefore, an offset of the measurements was estimated by averaging the measured double conductivity ratio of the Standard Seawater for each day. The estimated offset was subtracted from the measured double conductivity ratio of the sample. After the offset correction, the average of the double conductivity ratio of the Standard Seawater became 1.99958 and the standard deviation was 0.00002, which is equivalent to 0.0003 in salinity.

For leg 3, the salinometer was slightly drifted in time. Therefore, a linear trend of the measurements was estimated by fitting the measured double conductivity ratio of the Standard Seawater for whole period. The estimated linear trend was subtracted from the measured double conductivity ratio of the sample. After the correction, the average of the double conductivity ratio of the Standard Seawater became 1.99958 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity.

ii. Sub-Standard Seawater

We also used sub-standard seawater which was deep-sea water filtered by pore size of 0.45 μm and stored in a 20 liter cubitainer made of polyethylene and stirred for at least 24 hours before measurement. It was measured every 6 water samples in order to check the possible sudden drift of the salinometer. In this cruise, no remarkable sudden drift was detected for the salinometers.

iii. Replicate Samples

We took 323 (leg 2) and 245 (leg 3) pairs of replicate samples during the cruise. Histograms of the absolute difference between replicate samples are shown in Figs. 3.2.3 and 3.2.4. The root-mean squares of the absolute difference of replicate samples were 0.00035 (leg 2) and 0.00017 (leg 3).

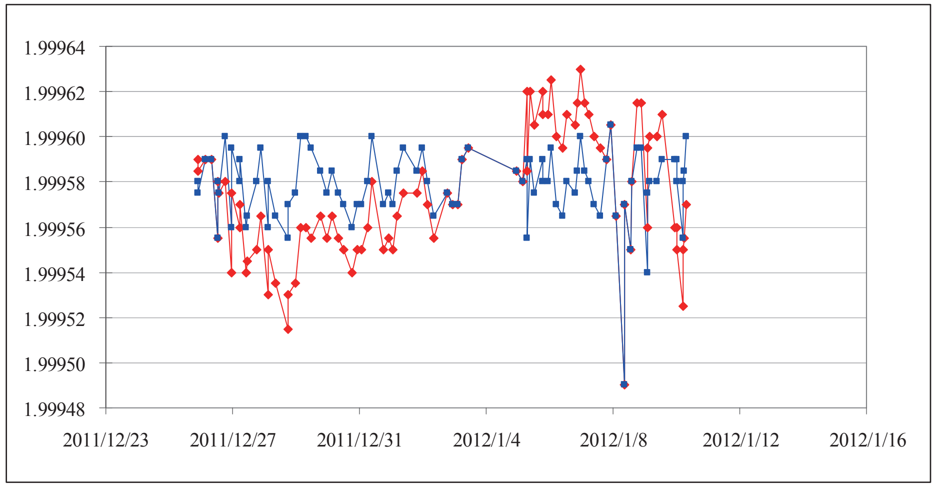

Figure 3.2.1. History of measured double conductivity ratio of the Standard Seawater (P153) during leg 2. Horizontal and vertical axes represents date and double conductivity ratio, respectively. Red dots are raw data and blue dots are corrected data.

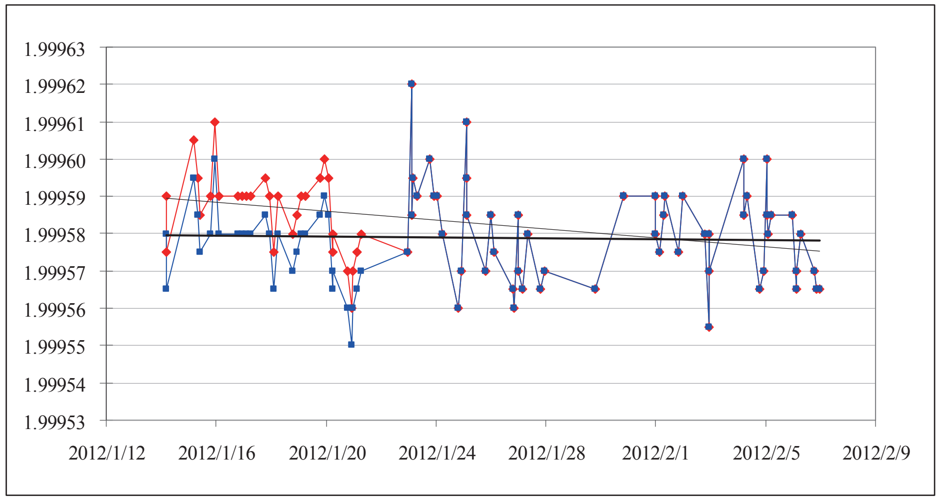

Figure 3.2.2. Same as Fig. 3.2.1, but for leg 3.

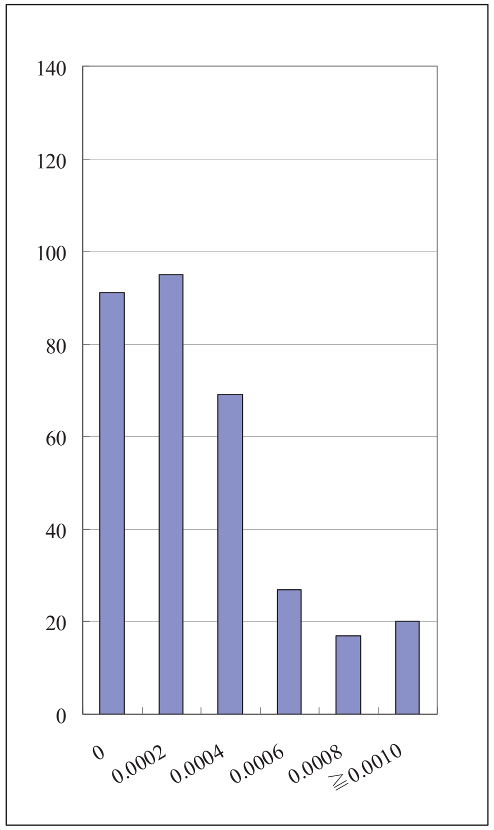

Figure 3.2.3. Histogram of the absolute difference between replicate samples for leg 2. Horizontal axis is absolute difference in salinity and vertical axis is frequency.

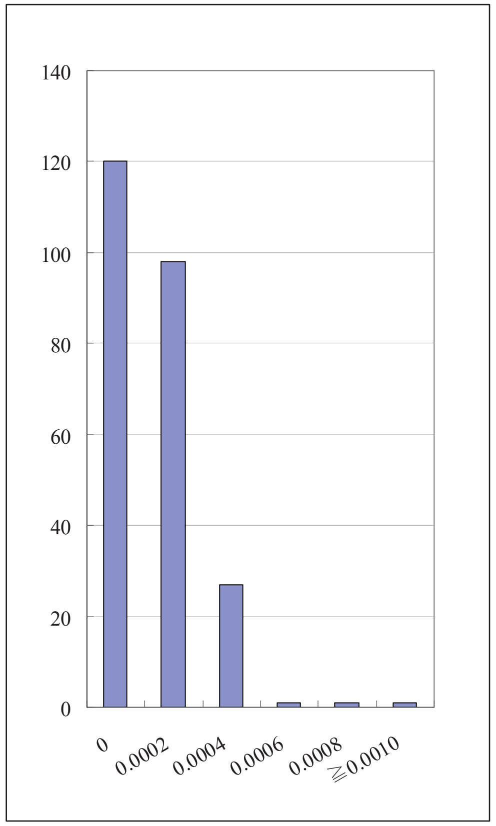

Figure 3.2.4. Same as Fig. 3.2.3, but for leg 3.

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3.3 Density

February 13, 2014

(1) Personnel

Hiroshi Uchida (JAMSTEC)

(2) Objectives

The objective of this study is to collect absolute salinity (also called "density salinity") data, and to evaluate an algorithm to estimate absolute salinity provided along with TEOS-10 (the International Thermodynamic Equation of Seawater 2010) (IOC et al., 2010).

(3) Materials and methods

Seawater densities were measured during the cruise and a part of the seawater samples were measured in a laboratory in the Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan, after the cruise with an oscillation-type density meter (DMA 5000M, serial no. 80570578, Anton-Paar GmbH, Graz, Austria) with a sample changer (Xsample 122, serial no. 80548492, Anton-Paar GmbH). The sample changer was used to load samples automatically from up to ninety-six 12-mL glass vials. AC power was supplied to the density meter through a frequency conversion AC power supply unit (AA500F, Takasago, Ltd., Japan).

The water samples were collected in 100-mL PFA bottles (Sanplatec Co., Japan), 100-mL or 50-mL I-BOY polypropylene bottles (AS ONE, Co., Japan), and vacuum sealed with an aluminum bag (HRS, MAL or ALH, Meiwa Sanshou Co., Ltd, Japan). Densities of the samples were measured at 20 $^{\circ}$C by the density meter from two to six times for each bottle. The glass vial was sealed with Parafilm M (Pechiney Plastic Packaging, Inc., Menasha, Wisconsin, USA) until the density was measured.

Time drift of the density meter was monitored by periodically measuring the density of ultra-pure water (Milli-Q water, Millipore, Billerica, Massachusetts, USA) prepared from Yokosuka (Japan) tap water in July 2010. The true density (ρ_{PW}) at 20 $^{\circ}$C of the Milli-Q water was estimated to be 998.2041 kg/m^3 from the isotopic composition ($\delta D = -9.08$ ‰, $\delta^{18}O = -58.8$ ‰) and International Association for the Properties of Water and Steam (IAPWS)-95 standard. An offset correction was applied to the measured density by using the Milli-Q water measurements ($\rho_{\text{Milli-Q}}$) with a slight modification of the density dependency (Uchida et al., 2011). The offset (ρ_{offset}) of the measured density (ρ) was estimated from the following equation:

$$\rho_{\text{offset}} = (\rho_{\text{Milli-Q}} - \rho_{\text{PW}}) - (\rho - \rho_{\text{PW}}) \times 0.000241 \text{ [kg/m}^3\text{]}.$$

The offset correction was verified by measuring Reference Material for Nutrients in Seawater (RMNS) lot BF (Kanso Technos Co., Ltd., Osaka, Japan) along with the Milli-Q water. Reference Material for Density in Seawater (prototype Dn-RM1) developed with Marine Works Japan, Ltd., Kanagawa, Japan, and produced by Kanso Technos Co., Ltd., Osaka, Japan, was also measured at post-cruise measurements. The Dn-RM1 was similarly produced with the RMNS. Material of the bottle is not polypropylene but PFA, and vacuumed sealed aluminum bag (MAL) is not single but double.

Density salinity can be back calculated from measured density and temperature (20 °C) with TEOS-10.

The water samples collected at stations 56, 53, 49, 45, 41, 37, 34, 31, 27, 1, 5, and 10 were vacuum sealed with the HRS aluminum bag and measured within a few days after the collection. The rest of water samples were vacuum sealed with the HRS or ALH aluminum bag and stored in a refrigerator to measure in the laboratory after the cruise since the density meter was broken during the cruise.

(4) Results

List of the series of density measurement was shown in Table 3.3.1. The water samples for station 68 (#2, 5, 8, 15, 16, 22, 24, 25, and 30), 71 (#6, 10, 16, and 29), 90 (#2, 5-12, 23, 24, 27, 29, 31, 32, and 36), 92 (#8-12), and 110 (#10, 12, 13, 16, 17_2, 19, 23, and 28-32) were not measured because the aluminum bags were torn during their storage.

For the series of measurement at April 5, 2012, the density meter was largely drifted in time between the first and the last measurement of Milli-Q water (about 16 hours). In addition, magnitude of the drift was different for the Milli-Q water (+0.008 kg/m^3) and the RMNS (+0.018 kg/m^3). Therefore, linear time drift and offset for the sea water measurement was estimated from the result of the RMNS measurement. Density of the RMNS was adjusted to 1024.4826 kg/m^3 to match with the overall mean density of the RMNS (Table 3.3.1).

The measured density of the RMNS was smaller than twice the standard deviation from the mean for the series of measurement at January 5 and April 6, 2012. Therefore, offset for the sea water measurement was estimated from the RMNS measurement. Mean density of the RMNS at the series of measurement was adjusted to 1024.4826 kg/m^3 to match with the overall mean density of the RMNS (Table 3.3.1). The estimated offsets were +0.0041 and +0.0043 kg/m^3 for the series of measurements at January 5 and April 6, respectively.

To check those time drift and offset corrections by using the RMNS measurements, measured densities of the Dn-RM1 were compared (Table 3.3.2). The measured densities agreed well with each other.

A total of 26 pairs of replicate samples were measured. The root-mean square of the absolute difference of replicate samples was 0.0011 g/kg.

The measured density salinity anomalies (δS_A) are shown in Fig. 3.3.1. The measured δS_A well agree with calculated δS_A from Pawlowicz et al. (2011) which exploits the correlation between δS_A and nutrient concentrations and carbonate system parameters based on mathematical investigation using a model relating composition, conductivity and density of arbitrary seawaters.

Table 3.3.1. List of the series of density measurement.

Date	Stations (samples no.)	Mean density of RMNS Lot BF (kg/m^3)	Note
2011/12/25	56	1024.4847	relatively large variation #15: bad (flag 4)
2011/12/26	53	1024.4849	
2011/12/27	49	1024.4821	
2011/12/29	45	1024.4814	#12: questionable (flag 3)
2011/12/30	41	1024.4841	
2011/12/31 (1)	37	1024.4838	
2011/12/31 (2)	34	1024.4840	
2012/01/01	31	1024.4816	
2012/01/02	27	1024.4820	relatively large variation
2012/01/04	1	1024.4799	
2012/01/05	5, 10	1024.4831	frequent errors, large variation, bias correction using RMNS
2012/04/04	74, 77 (except for #6,9,10,16,27,30,36)	1024.4838	
2012/04/05	15, 21, 71 (#1,3-5,11,13,20-25,28, 31, 32,35,36), 77 (#6,9,10,16,27,30,36)	1024.4827	time drift correction using RMNS
2012/04/06	60 (#1,11,12,16-18,26), 110, 114	1024.4829	bias correction using RMNS
2012/04/09	90	1024.4810	
2012/10/15	60 (except for #1,11,12,16-18,26), 64 (except for #30-33,35)	1024.4823	
2012/10/18	102, 106	1024.4833	
2012/10/25 (1)	64 (#30-33,35), 68	1024.4836	
2012/10/25 (2)	71, 79 (#1-16)	1024.4815	
2012/10/26 (1)	79 (except for #1-16), 83 (except for #23,25)	1024.4825	
2012/10/26 (2)	83 (#23,25), 86, 92	1024.4817	
2012/10/28	94	1024.4837	
2012/10/30	98	1024.4831	
	Average:	1024.4827 ± 0.0016	

Table 3.3.2. Comparison of density measurement for the Reference Material for Density in Seawater (prototype Dn-RM1).

Date	Serial no.	Density [kg/m^3]	Note
2012/04/04	050	1024.2616	
2012/04/05	051	1024.2612	drift correction
2012/04/06	052	1024.2624	offset correction
2012/04/09	053	1024.2590	
	Average:	1024.2611 ± 0.0015	

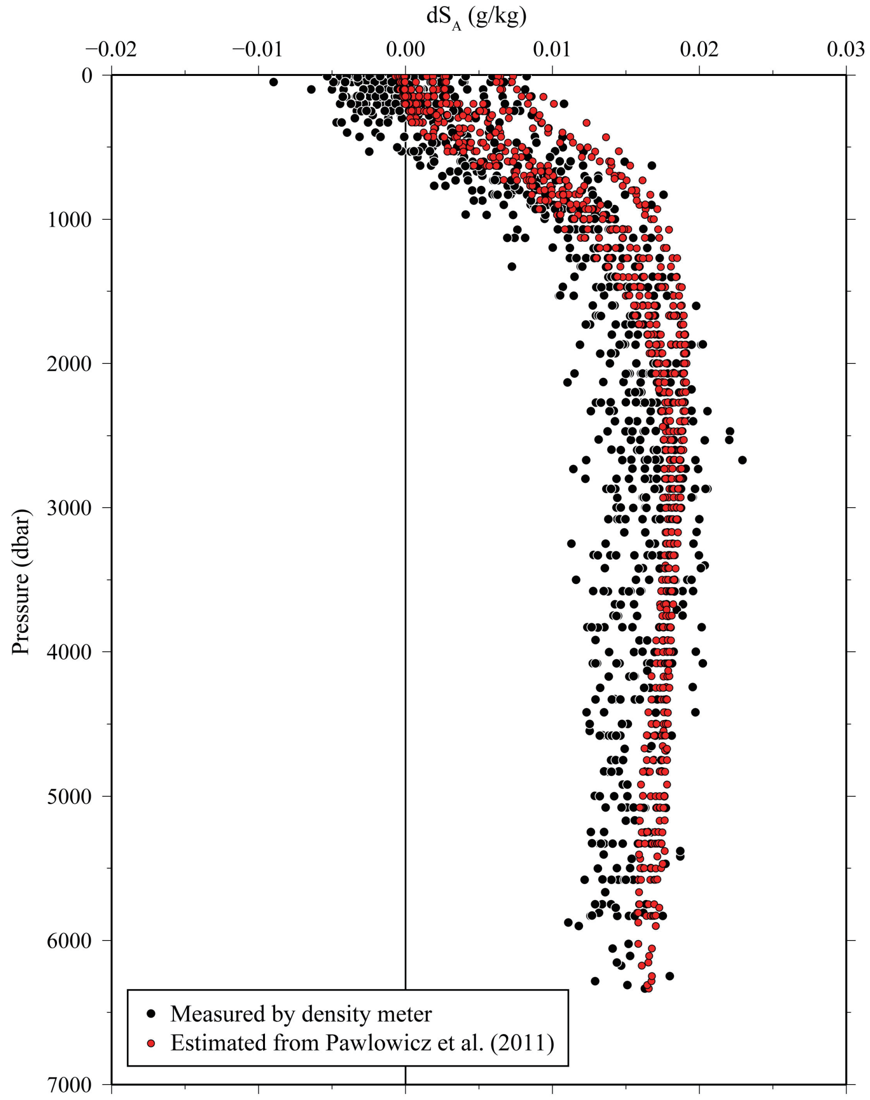

Figure 3.3.1. Vertical distribution of density salinity anomaly measured by the density meter. Absolute Salinity anomaly estimated from nutrients and carbonate parameters (Pawlowicz et al., 2011) are also shown for comparison.

Acknowledgment

The author thank Tamami Ueno (MWJ) for helping density measurement of station 83 (#23,25) and 86.

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3.4 Oxygen

September 27, 2013

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(2) Objectives

Dissolved oxygen is one of good tracers for the ocean circulation. Recent studies indicated that 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 MR11-08 cruise, we measured dissolved oxygen concentration from surface to bottom layers at all the hydrocast stations along approximately 149^{o}E in the western Pacific. These stations reoccupied the WOCE Hydrographic Program P10 and P10N stations in 1993 and 2005. Our purpose is to evaluate temporal change in dissolved oxygen concentration in the western Pacific between the 1993/2005 and 2011/12.

(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): Wako Pure Chemical Industries, Ltd., volumetric standard, reference material for iodometry, Lot No.EPR3227, Purity: 99.96 ± 0.01%

CSK standard of potassium iodate: Lot EPJ3885, Wako Pure Chemical Industries Ltd., 0.0100N

(4) Instruments

Burette for sodium thiosulfate and potassium iodate;

APB-620 and APB-510 manufactured by Kyoto Electronic Co. Ltd. / 10 cm^3 of titration vessel

Detector;

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

(5) Seawater sampling

Following procedure is based on a determination method in the WHP Operations Manual (Dickson, 1996). Seawater samples were collected from 12-liters Niskin sampler bottles attached to a CTD-system. Seawater for bottle oxygen measurement was transferred from the Niskin sampler bottle to a volume calibrated glass flask (ca. 100 cm^3). 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^3 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^3 sulfuric acid solution were added into the sample flask and stirring began. Samples were titrated by sodium thiosulfate solution whose molarity was determined by potassium iodate solution. Temperature of sodium thiosulfate during titration was recorded by a thermometer. We measured dissolved oxygen concentration using two sets of the titration apparatus, named DOT-7 and DOT-8. Dissolved oxygen concentration (μmol kg^{-1}) was calculated by the sample temperature during the sampling, a value of bottle salinity, the flask volume, and the titrated volume of the sodium thiosulfate solution. When the bottle salinity datum is flagged to be 3 (questionable), 4 (bad), or 5 (missing), CTD salinity (primary) datum is referred in the calculation alternatively.

(7) Standardization

Concentration of sodium thiosulfate titrant (ca. 0.025M) was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130°C. 1.7835 g potassium iodate weighed out accurately was dissolved in deionized water and diluted to final volume of 5 dm^3 in a calibrated volumetric flask (0.001667M). 10 cm^3 of the standard potassium iodate solution was added to a flask using the volume-calibrated dispenser. Then 90 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were added into the flask in order. Amount of titrated volume of sodium thiosulfate (usually 5 times measurements average) gave the molarity of the sodium thiosulfate titrant. Table 3.4.1 shows result of the standardization during this cruise. Error (coefficient of variation) of the standardization was 0.02 %, or c.a. 0.05 μmol kg^{-1}.

(8) Determination of the blank

The oxygen in the pickling reagents I (0.5 cm^3) and II (0.5 cm^3) was assumed to be 3.8 x 10^{-8} mol (Murray *et al*., 1968). The blank from the presence of redox species apart from oxygen in the reagents (the pickling reagents I, II, and the sulfuric acid solution) was determined as follows. 1 and 2 cm^3 of the standard potassium iodate solution were added to the flask each. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I each were added into the two flasks in order. The blank was determined by difference between the two times of the first (1 cm3 of KIO_3) titrated volume of the sodium thiosulfate and the second (2 cm^3 of KIO_3) one. The results of 3 times blank determinations were averaged (Table 3.4.1). The averaged blank values for DOT-7 and DOT-8 were –0.001 ± 0.002 (standard deviation, n=21) and 0.001 ± 0.001 (standard deviation, n=21) cm^3, respectively.

(9) Replicate sample measurement

From a single routine CTD cast, a pair of replicate samples was collected at three layers of 10, 1800, and 3750 dbar. In order to estimate uncertainty including instrumental error, one and the other of a replicate pair were measured using DOT-7 and DOT-8, respectively. The total amount of the replicate sample pairs in good measurement (flagged 2) was 331. The standard deviation of the replicate measurement was 0.13 μmol kg^{-1} that was calculated by a procedure (SOP23) in DOE (1994). A difference between measurements of a replicate pair is slightly large in samples from low-oxygen layers (Fig. 3.4.1), which is probably due to sampling error on the deck. In the hydrographic data sheet, the first of the two results from a replicate pair was presented with the flag 2 (see section 12).

(10) Duplicate sample measurement

A duplicate sampling, water samplings from two Niskin bottles that collected seawater at a same depth (deeper than 1000 dbar), were conducted at 35 stations during this cruise. Niskin numbers and sampling pressure of the duplicate pairs are shown in Table 3.4.2. One and the other of a duplicate pair were measured using DOT-7 and DOT-8 respectively in the same way of the replicate sample measurements. The standard deviation of the duplicate measurements was calculated to be 0.14 μmol kg^{-1} that was equivalent with that of the replicate measurements (0.13 μmol kg^{-1}, see section 9), suggesting that there was no problem in a water sampling system during our CTD casts.

(11) CSK standard measurements

The CSK standard is a commercial potassium iodate solution (0.0100 N) for analysis of dissolved oxygen. We titrated the CSK standard solutions (Lot EPJ3885) against our KIO_3 standards prepared in our laboratory in 2010 and 2011 (Table 3.4.3). A good agreement among them confirms that there was no systematic shift in our oxygen analyses using our KIO_3 standards during 2010 and 2011.

(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 3.4.4). 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 (replicate measurements). For the choice between 2, 3, or 4, we basically followed a flagging procedure as listed below:

a. Bottle oxygen concentration at the sampling layer was plotted against sampling pressure. Any points not lying on a generally smooth trend were noted.

b. A difference between bottle oxygen and CTD oxygen (OPTODE sensor) was then plotted against sampling pressure. If a datum deviated from a group of plots, it was flagged 3.

c. Vertical sections 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 5 (unknown problem), a datum was flagged according to the steps a, b, c, and d.

Table 3.4.1. Results of the standardization and the blank determinations during MR11-08.

	KIO_3 No.		$Na_2S_2O_3$ No.	DOT-7		DOT-8		Stations
(UTC)	#	ID No.		E.P.	blank	E.P.	blank	
2011/12/22	05	20110523-05-02	20110602-01	3.953	-0.002	3.957	-0.001	P10-059,058,057,056,055,054,053,052,051,050,049,048,047,046,045
2011/12/28		20110523-05-01	20110602-01	3.952	-0.001	3.956	0.001	P10-044,043,042,041,040, 039
2011/12/29		20110523-05-07	20110602-02	3.956	-0.003	3.961	-0.001	P10-038,037,036,035,034,033,032,031,030,029,028,027
2012/01/03		20110523-05-08	20110602-02	3.963	0.000	3.964	0.003	P10-001,002,003,004,005,006,007,008,009,010,011,012,013,014,015,016,017,018,019,020,021,022
2012/1/7		20110523-05-05	20110602-03	3.959	-0.001	3.961	0.001	P10-023,024,025,026
2012/1/14	06	20110524-06-03	20110602-03	3.963	-0.001	3.964	0.001	P10-059,060,061,062,063,064,065,066,067,068,069,070,071,072,073
2012/1/19		20110524-06-05	20110602-04	4.075	-0.004	4.076	0.000	P10-074,P10N-075,076,077,078,079,080,081,082,083,084,085,088,086,087,090,092,094,096
2012/2/1		20110524-06-01	20110602-05	3.957	-0.002	3.959	0.001	P10N-098,100,102,104,106,110,112,114,115

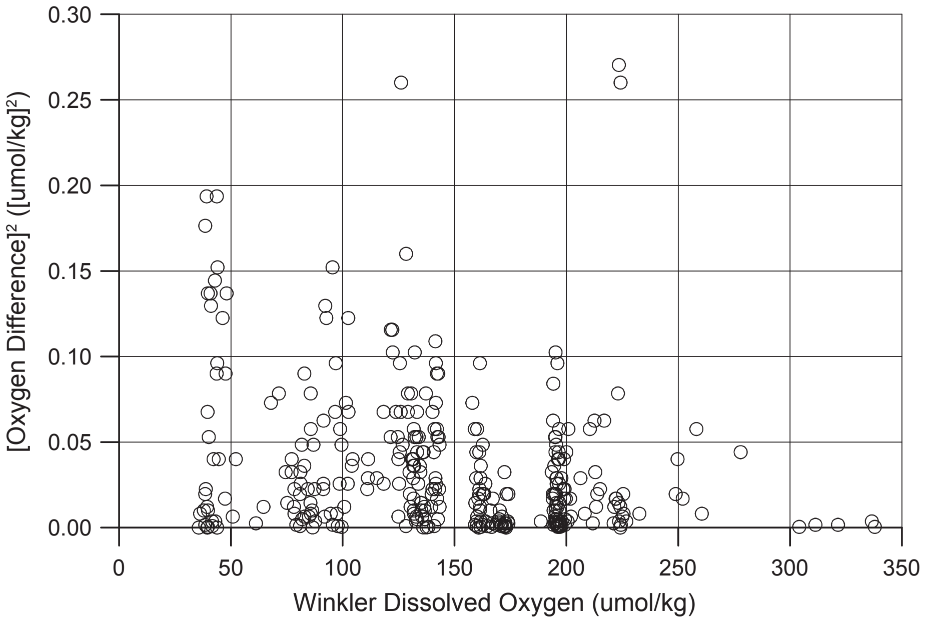

Figure 3.4.1. Oxygen difference between measurements of a replicate pair against oxygen concentration.

Table 3.4.2. Results of the duplicate sample measurements during MR11-08.

	Leg	Stations	Pres. (db)	#1 Niskin		#1 Oxygen [μmol/kg]	#2 Niskin		#2 Oxygen [μmol/kg]	Difference [(μmol/kg)^2]
1	2	P10-59	5656	1	X12J01	176.21	2	X12J02	176.25	0.002
2	2	P10-58	5500	2	X12J02	174.49	3	X12J03	174.42	0.005
3	2	P10-57	5170	2	X12J02	173.25	4	X12J04	173.33	0.006
4	2	P10-56	5080	2	X12J02	172.65	5	X12J05	172.50	0.023
5	2	P10-55	4750	2	X12J02	164.09	6	X12J06	164.11	0.000
6	2	P10-54	4420	2	X12J02	164.89	7	X12J07	164.94	0.003
7	2	P10-53	4330	2	X12J02	163.54	8	X12J08	163.61	0.005
8	2	P10-52	4000	2	X12J02	155.00	9	X12J09	154.90	0.010
9	2	P10-44	3830	2	X12J02	155.70	10	X12J10	155.56	0.020
10	2	P10-43	3500	2	X12J02	149.74	11	X12J11	149.56	0.032
11	2	P10-42	3170	5	X12102	143.09	12	X12J12	143.07	0.000
12	2	P10-41	3080	2	X12103	139.96	13	X12101	140.13	0.029
13	2	P10-38	2870	4	X12104	138.17	14	X12J14	138.00	0.029
14	2	P10-37	2600	2	X12103	129.87	15	X12J15	129.92	0.002
15	2	P10-36	2330	2	X12103	119.45	16	X12J16	119.35	0.010
16	2	P10-35	2270	2	X12103	117.47	17	X12J17	116.93	0.292
17	2	P10-34	2000	2	X12103	113.64	18	X12J18	113.39	0.063
18	2	P10-33	1730	2	X12103	103.02	19	X12J19	102.90	0.014
19	2	P10-32	1670	2	X12103	101.57	20	X12001	101.45	0.014
20	2	P10-31	1400	2	X12103	96.37	21	X12J21	96.64	0.073
21	2	P10-30	1130	2	X12103	92.36	22	X12J22	92.70	0.116
22	2	P10-4	1400	2	X12103	109.34	21	X12J36	109.40	0.004
23	2	P10-5	1670	2	X12103	110.04	20	X12J35	109.89	0.023
24	2	P10-6	1730	2	X12103	109.66	19	X12J34	109.45	0.044
25	2	P10-12	1930	2	X12103	116.36	18	X12J33	116.08	0.078
26	2	P10-13	2200	2	X12103	125.37	17	X12J32	125.40	0.001
27	2	P10-15	2330	2	X12103	128.02	16	X12046	128.23	0.044
28	2	P10-16	2600	2	X12103	135.43	15	X12J30	135.42	0.000
29	2	P10-17	2870	2	X12103	139.94	14	X12J29	139.56	0.144
30	2	P10-18	2930	2	X12103	140.07	13	X12J28	139.79	0.078
31	2	P10-19	3250	2	X12103	144.23	12	X12J27	143.98	0.063
32	2	P10-21	3920	2	X12103	152.71	9	X12J25	152.57	0.020
33	2	P10-22	4500	2	X12103	156.23	7	X12J23	156.01	0.048
34	2	P10-23	4330	2	X12103	155.42	8	X12J24	155.31	0.012
35	2	P10-24	3670	2	X12103	148.59	10	X12J26	148.72	0.017

Table 3.4.3. Results of the CSK standard (Lot EPJ3885) measurements on board.

Date (UTC)	KIO$_3$ ID No.	DOT-7		DOT-8		Remarks
		Conc. (N)	error (N)	Conc. (N)	error (N)	
2011/12/22	20110523-05-02	0.010008	0.000003	0.010008	0.000007	MR11-08 Leg-2
2012/01/14	20110524-06-07	0.010009	0.000002	0.010005	0.000009	MR11-08 Leg-3

Date (UTC)	KIO$_3$ ID No.	DOT-1		–		Remarks
		Conc. (N)	error (N)	–	–	
2011/5/27	20100630-01-11	0.010008	0.000005	–	–	before cruise
2011/5/30	20110524-07-12	0.010007	0.000004	–	–	before cruise
2011/5/31	20110523-05-12	0.010006	0.000007	–	–	before cruise
2011/6/1	20110523-01-12	0.010006	0.000010			before cruise

Table 3.4.4. Summary of assigned quality control flags.

Flag	Definition	
2	Good	3080
3	Questionable	4
4	Bad	4
5	Not report (missing)	0
	Total	3088

(13) Preliminary Results

i. Comparison of oxygen measurements at a cross point

We compared a vertical profile of oxygen concentration at a cross point (24°N/149°E) from this cruise with that from our past cruise (MR05-05). The first and second measurements were conducted on 30-Dec.-2005 (MR05-05_P03-X10, 24.486°N/149.356°E) and 17-January-2012 (MR11-08_P10-067, 24.241°N/149.033°E), respectively. Below layers below about 2000 dbar, the vertical profiles in 2005 and 2011 agree well within the analytical error (Fig. 3.4.2).

ii. Distribution of dissolved oxygen along WHP-P10/P10N in 2011/12

Figure 3.4.3 shows that a tongue-shaped oxygen minima is lying around 500 – 1500 m depth. The highest concentration was measured in surface waters of the northernmost stations off Hokkaido. Another high-oxygen water was found in bottom waters of the north of 10°N, which corresponds to the Circumpolar Deep Water (CDW). The basin-scale distribution of dissolved oxygen in 2011/12 well agrees with those obtained in 1993 and 2005.

iii. Decadal changes in dissolved oxygen along the WHP-P10/P10N line from 2005 and 2011/12

Along the P10/P10N line, difference in dissolved oxygen concentration between 2005 and 2011/12 was large (< about 10 μmol/kg) above 1000 m depth, where the vertical gradient of dissolved oxygen is sharp. In deeper layers dissolved oxygen change less than 10 μmol/kg were also observed in some regions, implying influence of heaving and internal waves. In addition, we found 1~2 μmol/kg of oxygen decrease in near bottom waters between 10°N and 30°N.

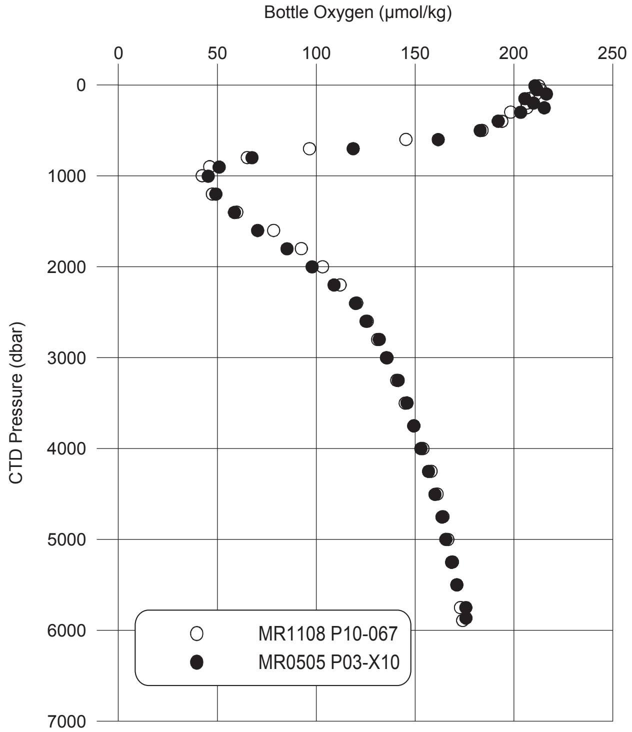

Figure 3.4.2. Vertical profiles of bottle oxygen concentration at a cross point (24ºN/149ºE) from MR05-05 (black circles) and MR11-08 cruises (white circles).

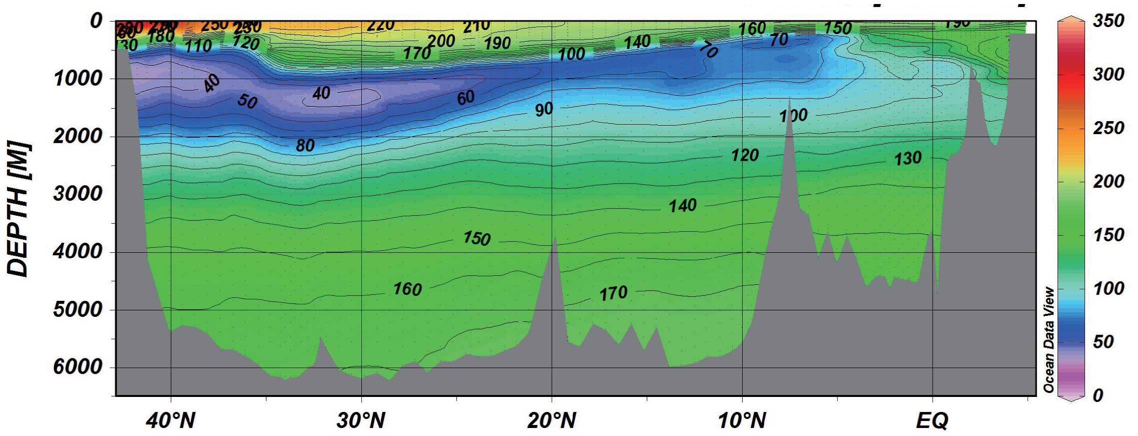

Figure 3.4.3. Transect of bottle oxygen concentration (μmol/kg) along the cruse track of MR11-08 in the winter of 2011-2012.

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3.5 Nutrients

June 13, 2012 (ver. 2.0)

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(2) Objectives

The objectives of nutrients analyses during the R/V Mirai MR11–08 cruise, WOCE P10 revisited cruise in 2011/2012, in the western Pacific Ocean are as follows;

- Describe the present status of nutrients concentration with excellent comparability.
- The determinants are nitrate, nitrite, silicate and phosphate.
- Study the temporal and spatial variation of nutrients concentration based on the previous high quality experiments data of WOCE previous P10 cruises in 1993 and 2005, GOESECS, 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, silicate and phosphate 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 95 QuAAtro 2-HR runs for the samples at 101 stations in MR11–08. The total amount of layers of the seawater sample reached up to 3091 for MR11–08. We made duplicate measurement at all layers.

(4) Instrument and Method

(4.1) Analytical detail using QuAAtro 2-HR systems (BL-Tech)

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

The silicate method was analogous to that described for phosphate. The method used was essentially that of Grasshoff et al. (1983), wherein silicomolybdic acid was first formed from the silicate in the sample and added molybdic acid; then the silicomolybdic acid was reduced to silicomolybdous acid, or “molybdenum blue” using ascorbic acid as the reductant. The analytical methods of the nutrients, nitrate, nitrite, silicate and phosphate, during this cruise were same as the methods used in (Kawano et al. 2009).

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

The details of modification of analytical methods used in this cruise are also compatible with the methods described in nutrients section in GO-SHIP repeat hydrography manual (Hydes et al., 2010). The flow diagrams and reagents for each parameter are shown in Figures 3.5.1 to 3.5.4.

(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 %f solution in ethanol) is added.

N-1-Napthylethylene-diamine dihydrochloride, 0.004 M (0.1 %f 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 %f solution in ethanol) is added.

Stored in a dark bottle.

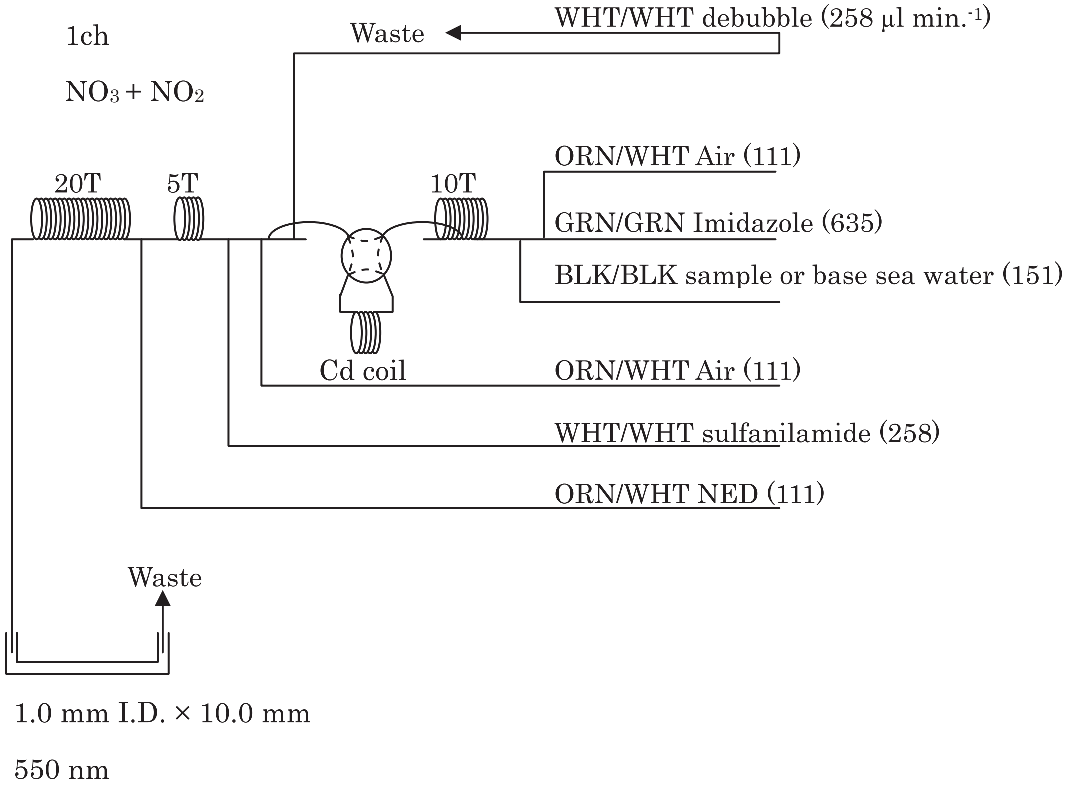

Figure 3.5.1. NO_3+NO_2 (1ch.) Flow diagram.

(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-Napthylethylene-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 %f solution in ethanol) is added. This reagent was stored in a dark bottle.

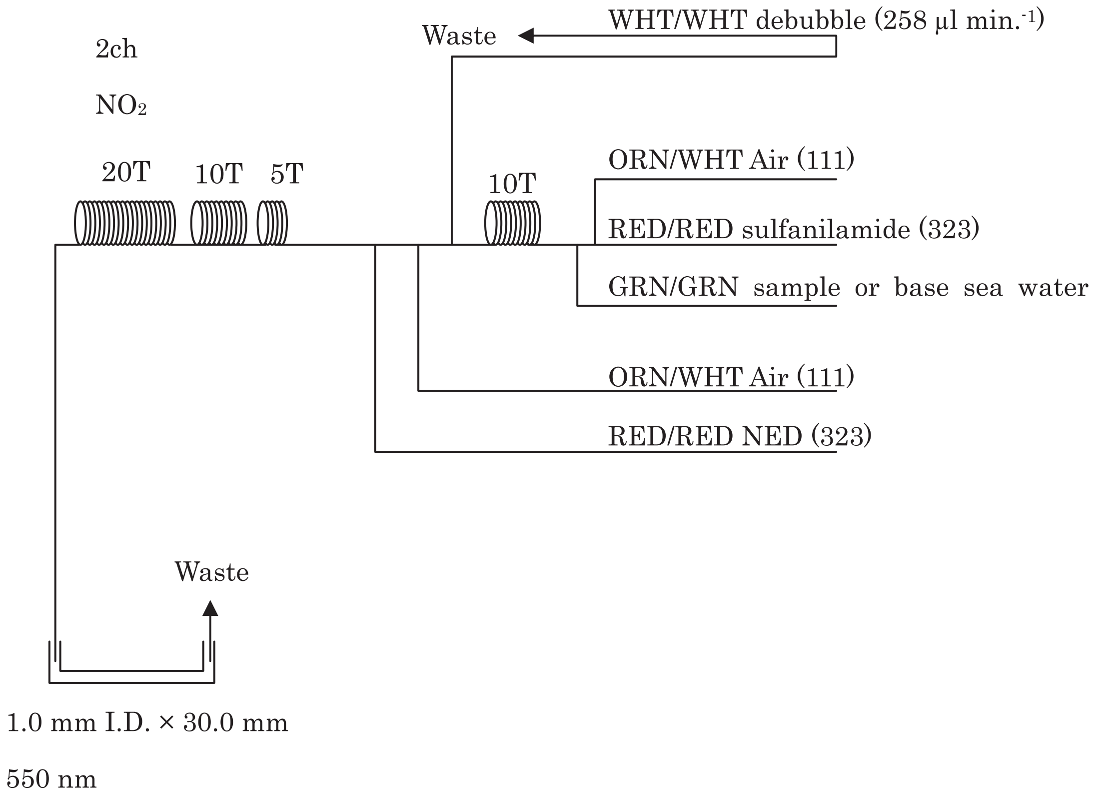

Figure 3.5.2. NO_2 (2ch.) Flow diagram.

(4.4) Silicate Reagents

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

Dissolve 15 g disodium Molybdate(VI) dihydrate, $Na_2M_oO_4 \cdot 2H_2O$, in 980 ml DIW, add 8 ml concentrated H_2SO_4. After mixing, 20 ml sodium dodecyl sulphate (15 % solution in water) is added.

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

Dissolved 50 g oxalic acid anhydrous, HOOC:COOH, in 950 ml of DIW.

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

Dissolved 2.5g L (+)-ascorbic acid, $C_6H_8O_6$, in 100 ml of DIW. This reagent was freshly prepared before every measurement.

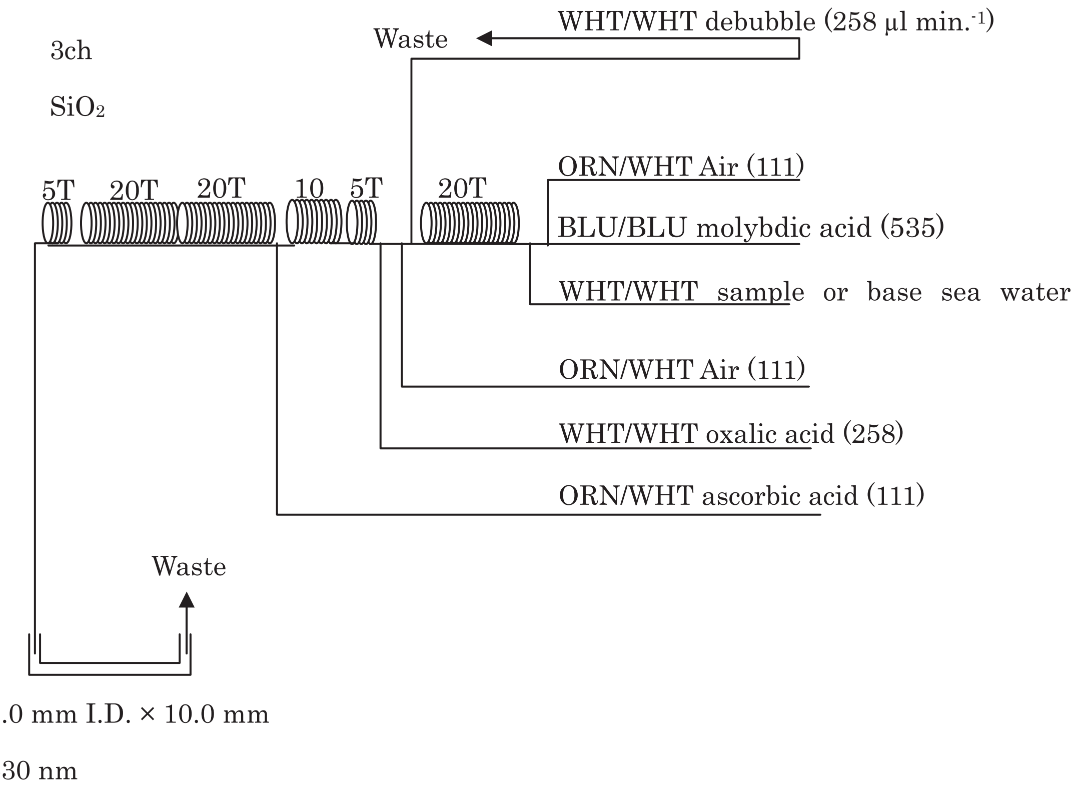

Figure 3.5.3. SiO_2 (3ch.) Flow diagram.

(4.5) Phosphate Reagents

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

Dissolved 8 g disodium molybdate (VI) dihydrate, $Na_2MoO_4 \cdot 2H_2O$, and 0.17 g antimony potassium tartrate, $C_8H_4K_2O_{12}Sb_2 \cdot 3H_2O$, in 950 ml of DIW and added 50 ml concentrated H_2SO_4.

Mixed Reagent

Dissolved 1.2 g L (+)-ascorbic acid, $C_6H_8O_6$, in 150 ml of stock molybdate solution. After mixing, 3 ml sodium dodecyl sulphate (15 % solution in water) was added in leg3 of this cruise, 4mL sodium dodecyl sulphate (15 % solution in water) was added in leg2 because to reduce relatively noisy signals. This reagent was freshly prepared before every measurement.

Reagent for sample dilution

Dissolved sodium chloride, NaCl, 10 g in ca. 950 ml of DIW, added 50 ml acetone and 4 ml concentrated H_2SO_4. After mixing, 5 ml sodium dodecyl sulphate (15 % solution in water) was added.

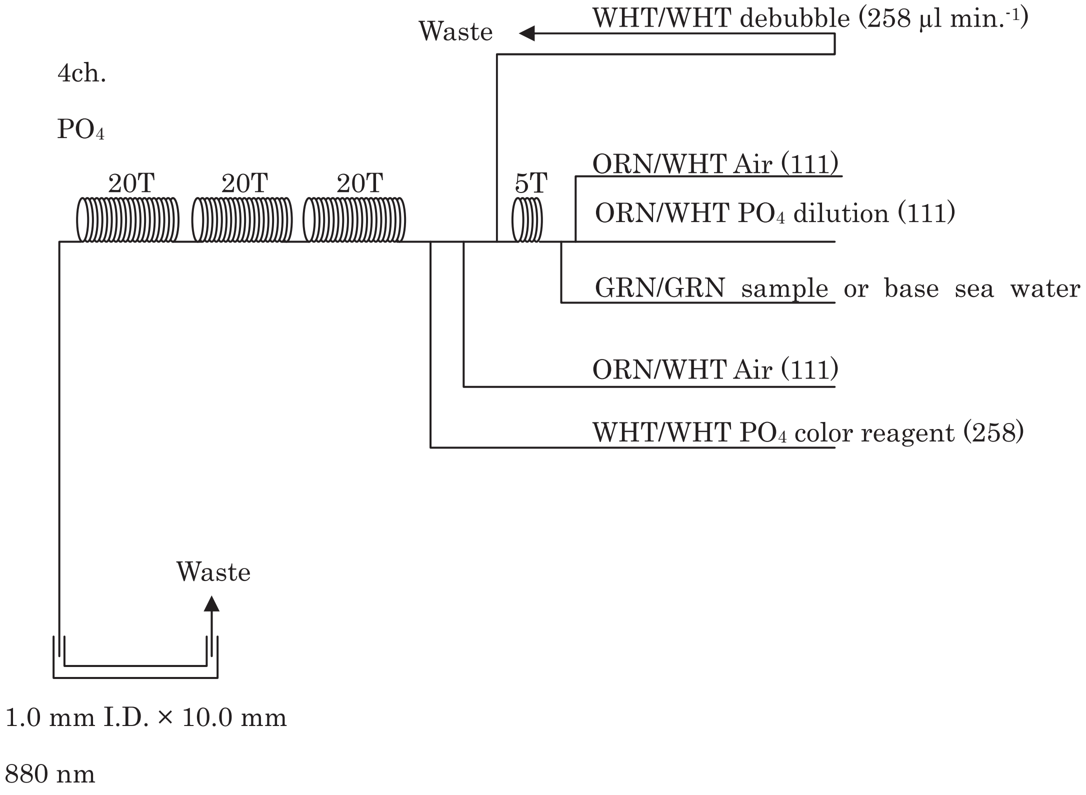

Figure 3.5.4. PO_4 (4ch.) Flow diagram.

(4.6) Sampling procedures

Sampling of nutrients followed that oxygen, salinity and trace gases. 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 were put into water bath adjusted to ambient temperature, 24 ± 2 deg. C, in about 30 minutes before use to stabilize the temperature of samples in MR11–08.

No transfer was made and the vials were set an auto sampler tray directly. Samples were analyzed after collection basically within 24 hours in MR11–08.

(4.7) Data processing

Raw data from QuAAtro 2-HR was treated as follows:

- Checked baseline shift.
- Checked the shape of each peak and positions of peak values taken, and then changed 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.
- Loaded 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 nitrite standard, “sodium nitrate” provided by Wako, CAS No. : 7632-00-0, was used. The assay of nitrite salts was determined according JIS K8019 were 98.31%. We use that value to adjust the weights taken.

For the silicate standard, we use “Silicon standard solution SiO_2 in NaOH 0.5 mol/l CertiPUR®” provided by Merck, CAS No. : 1310-73-2, of which lot number is HC097572 is used. The silicate concentration is certified by NIST-SRM3150 with the uncertainty of 0.5 %. Factor of HC097572 was signed 1.000, however we reassigned the factor as 0.976 from the result of comparison among RMNS in MR11-E02 cruise.

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

Ultra pure water

Ultra pure water (MilliQ water) freshly drawn was used for preparation of reagents, standard solutions 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 Jan 2011.

Treatment of silicate standard due to high alkalinity

Since the silicon standard solution Merck CertiPUR® is in NaOH 0.5 mol/l, we need to dilute and neutralize to avoid make precipitation of $MgOH_2$ etc. When we make B standard, silicon standard solution is diluted by factor 12 with pure water and neutralized by HCl 1.0 mol/l to be about 7. After that B standard solution is used to prepare C standards.

(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 3.5.1. The C standard is prepared according recipes as shown in Table 3.5.2. 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.

Table 3.5.1. 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_3(μM)	45000	900	BS	BU	BT	BD	BF	55
NO_2(μM)	4000	20	BS	BU	BT	BD	BF	1.2
SiO_2(μM)	36000	2880	BS	BU	BT	BD	BF	167
PO_4(μM)	3000	60	BS	BU	BT	BD	BF	3.6

Table 3.5.2. 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 3.5.3(a) to (c).

Table 3.5.3(a). Timing of renewal of in-house standards.

NO_3, NO_2, SiO_2, PO_4	Renewal
A-1 Std. (NO_3)	maximum 1 month
A-2 Std. (NO_2)	maximum 1 month
A-3 Std. (SiO_2)	commercial prepared solution
A-4 Std. (PO_4)	maximum 1 month
B-1 Std.	
(mixture of NO_3, SiO_2, PO_4)	8 days
B-2 Std. (NO_2)	8 days

Table 3.5.3(b). Timing of renewal of in-house standards.

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

Table 3.5.3(c). Timing of renewal of in-house standards for reduction estimation.

Reduction estimation	Renewal
D-1 Std. (3600μM NO_3)	8 days
43μM NO_3	when C Std. renewed
47μM NO_2	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, 2009). In the previous worldwide 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^{-1} for 345 crossovers at world oceans, though the maximum was 1.7 μmol kg^{-1} (Gouretski and Jancke, 2001). At the 31 crossover points in the Pacific WHP one-time lines, the WOCE standard of reproducibility for nitrate of 1 % was fulfilled at about half of the crossover points and the maximum difference was 7 % at deeper layers below 1.6 deg. C in potential temperature (Aoyama and Joyce, 1996).

During the period from 2003 to 2010, RMNS were used to keep comparability of nutrients measurement among the 8 cruises of CLIVAR project (Sato et al., 2010) , MR10–05 cruise for Arctic research (Aoyama et al., 2010) and MR10–06 cruise for “Change in material cycles and ecosystem by the climate change and its feedback” (Aoyama et al., 2011).

(6.1) RMNSs for this cruise

RMNS lots BS, BU, BT, BD and BF, which cover full range of nutrients concentrations in the western Pacific Ocean are prepared. 80 sets of BS, BU, BT, BD and BF are prepared.

One hundred forty bottles of RMNS lot BE are prepared for MR11–08. Lot BE was used all stations. 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 13-24 deg. C.

(6.2) Assigned concentration for RMNSs

We assigned nutrients concentrations for RMNS lots BS, BU, BT, BD, BE, and BF as shown in Table 3.5.4.

Table 3.5.4. Assigned concentration of RMNSs (in μmol kg^{-1}).

	Nitrate	Phosphate	Silicate	Nitrite
BS*	0.07	0.064	1.61	0.02
BU*	3.97	0.379	20.30	0.07
BT*	18.21	1.320	41.00	0.47
BD*	29.86	2.194	64.39	0.05
BE**	36.70	2.662	99.20	0.03
BF***	41.39	2.809	150.23†	0.02

* The values are assigned for this cruise on 27 July 2011.
** The values are assigned for this cruise on 4 April 2009
(Table 3.4.4 in WHP P21 REVISIT DATA BOOK).
*** The values are assigned for this cruise on 10 October 2007
(Table 3.4.4 in WHP P1, P14 REVISIT DATA BOOK).
† This value is changed in MR11–03 cruise.

(6.3) The homogeneity of RMNSs

The homogeneity of lot BE used in MR11–08 cruise and analytical precisions are shown in Table 3.5.5. These are for the assessment of the magnitude of homogeneity of the RMNS bottles those are used during the cruise. As shown in Table 3.5.5 homogeneity of RMNS lot BE for nitrate, phosphate and silicate are the same magnitude of analytical precision derived from fresh raw seawater in January 2009.

Table 3.5.5. Homogeneity of lot BE derived from simultaneous 209 samples measurements and analytical precision onboard R/V Mirai in MR11–08.

	Nitrate CV %	Phosphate CV %	Silicate CV %
BE	0.17	0.28	0.17
Precision	0.12	0.20	0.14

BE: N=209

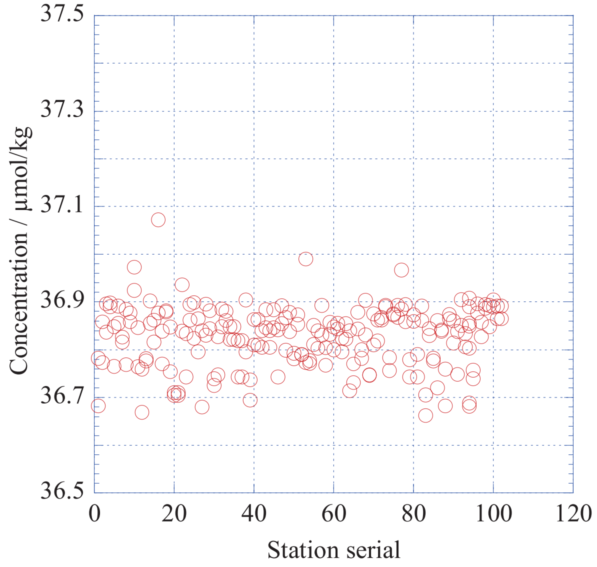

Figure 3.5.5. Time series of RMNS-BE of nitrate for MR11–08.

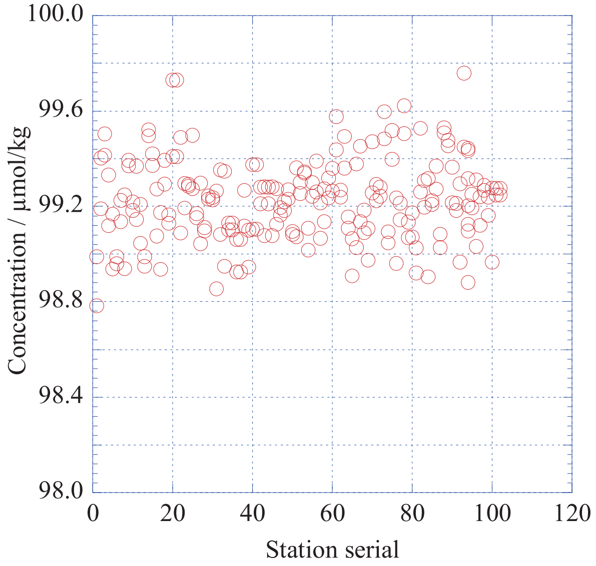

Figure 3.5.6. Time series of RMNS-BE of silicate for MR11–08.

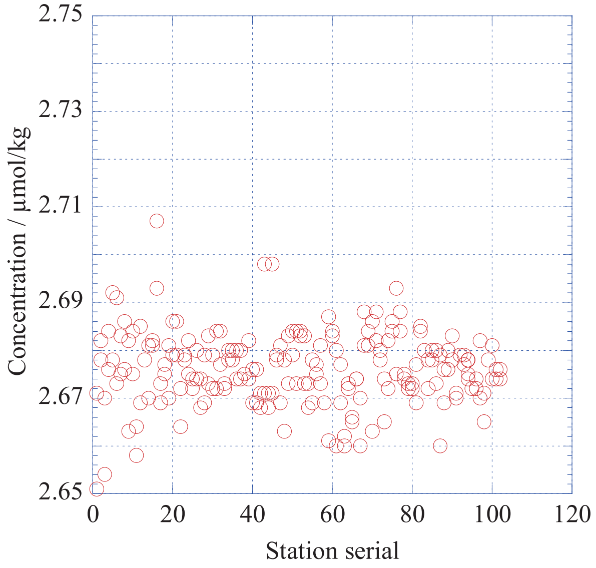

Figure 3.5.7. Time series of RMNS-BE of phosphate for MR11–08.

(6.4) Comparability of RMNSs during the periods from 2003 to 2011

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 3.5.6, the nutrients concentrations of RMNSs were in good agreement among the measurements during the period from 2003 to 2011. For the silicate measurements, we show lot numbers and chemical company names of each cruise/ measurement in the footnote. As shown in Table 3.5.6, there shows less comparability among the measurements due to less comparability among the standard solutions provided by chemical companies in the silicate measurements.

Table 3.5.6 (a). Comparability for nitrate (in μmol 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		
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				
2010														
SGONS stability test_2			42.46	0.05	0.10	0.00	21.51	0.02	33.52				36.76	0.02
SGONS stability test_3			42.48		0.09		21.52		33.63				36.77	
2011														
SGONS stability test_4			42.56	0.07	0.08	0.01	21.62	0.01	33.65	0.07			36.83	0.03
SGONS stability test_5			42.49	0.05	0.06	0.00							36.87	0.06
MR11-08_2													36.83	0.07
SGONS stability test_6														
MR11-08_3													36.83	0.06

Table 3.5.6 (b). Comparability for Phosphate (in μmol 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		
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				
2010														
SGONS stability test_2			3.012	0.008	0.059	0.001	1.618	0.004	2.520	0.008			2.663	0.006
SGONS stability test_3			3.024		0.055		1.617		2.528				2.666	
2011														
SGONS stability test_4			3.017	0.006	0.066	0.004	1.624	0.005	2.533	0.030			2.668	0.006
SGONS stability test_5			3.011	0.004	0.003								2.665	0.002
MR11-08_2													2.676	0.008
SGONS stability test_6														
MR11-08_3													2.676	0.007

Table 3.5.6 (C). Comparability for Silicate (in μmol 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	15.65	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		

Cruise	RM Lots													
	AH	unc.	AZ	unc.	BA	unc.	AX	unc.	AV	unc.	BC	unc.	BE	unc.
							Silicate							
2006														
2006intercomp [$]			133.83	0.07	1.64	0.00	58.20	0.03	154.16	0.08	156.31	0.08		
2003intercomp_revisit [$]	132.55	0.07												
2007														
MR07-04_1 precruise [$$]	133.38	0.06			1.61	0.00	58.46	0.03	154.82	0.07	156.98	0.07		
MR07-04_2 precruise [$$]	133.15	0.12			1.69	0.00	58.44	0.05	154.87	0.14	156.86	0.14		
MR07-04 [$$]					1.62	0.07	58.11	0.11	154.45	0.21	156.62	0.48		
MR07-06_1 precruise [$$]	133.02	0.09			1.64	0.00	58.50	0.04	155.06	0.11	156.33	0.11		
MR07-06_2 precruise [$$]	132.70	0.07			1.56	0.00	58.25	0.03	154.39	0.08	156.57	0.08		
MR07-06_1 [$$]					1.61	0.04	58.13	0.08	154.48	0.13	156.64	0.08		
MR07-06_2 [$$]					1.58	0.07	58.04	0.10	154.38	0.16	156.61	0.13		
2008														
2008intercomp [¥]					1.64	0.00	58.17	0.05						
2006intercomp_re [¥]			134.11	0.11	1.65	0.00	58.26	0.05	154.36	0.12				
2003intercomp_re [¥]	132.11	0.11												
2009														
MR09-01_0 precruise [¥]			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 [¥]			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 [¥]			133.96	0.11			58.19	0.08	154.42	0.12			99.23	0.08
INSS stability test_1 [¥¥]	132.40	0.35			1.69	0.02	58.18	0.02	154.43	0.09				
2010														
SGONS stability test_2 [¥¥]			133.89	0.12	1.58	0.02	58.15	0.04	154.43	0.21			99.20	0.07
SGONS stability test_3 [¥¥]			134.20		1.58		58.10		154.90				99.18	
2011														
SGONS stability test_4 [+]			134.16	0.09	1.68	0.04	58.26	0.05	154.56	0.05			99.30	0.07
SGONS stability test_5 [+]			133.27	0.21	1.49	0.02							98.82	0.18
MR11-08_2 [++]													99.21	0.17
SGONSstability test_6 [++]														
MR11-08_3 [++]													99.25	0.18

List of lot numbers: *: Kanto 306F9235; **: Kanto 402F9041; #: Kanto 507F9205; ##: Kanto 609F9157; $: Merck OC551722;
$$: Merck HC623465; ¥: Merck HC751838; ¥¥: HC814662; +: HC074650; ++: HC097572

(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. Summary of precisions are shown as shown in Table 3.5.7 and Figures 3.5.8 to 3.5.10, 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 3.5.6. 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 0.12 % for nitrate, 0.20 % for phosphate and 0.14 % for silicate in terms of median of precision, respectively. Then we can conclude that the analytical precisions for nitrate, phosphate and silicate throughout this cruise became relatively bad. The reasons of the phenomenon is discussed in chapter (8).

Table 3.5.7. Summary of precision based on the replicate analyses.

	Nitrate **CV %**	**Phosphate** **CV %**	**Silicate** **CV %**
Median	0.12	0.20	0.14
Mean	0.13	0.21	0.13
Maximum	0.4	0.4	0.25
Minimum	0.04	0.05	0.05
N	102	102	102

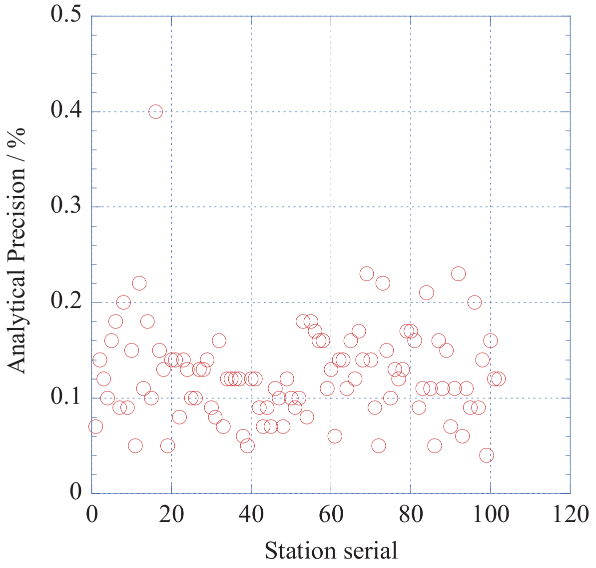

Figure 3.5.8. Time series of precision of nitrate for MR11–08.

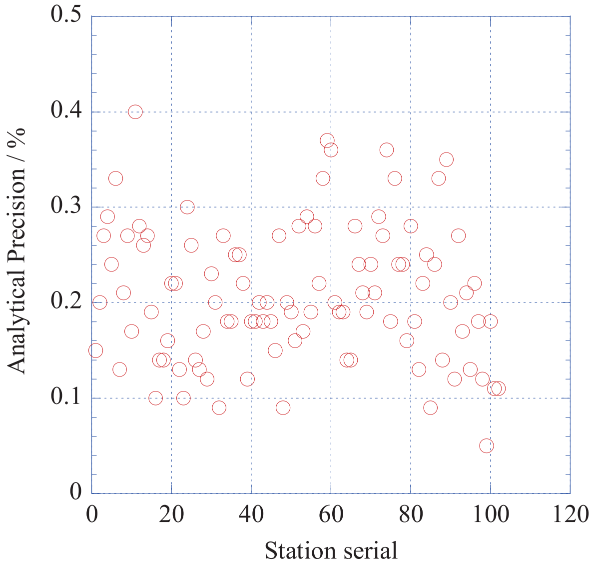

Figure 3.5.9. Time series of precision of phosphate for MR11–08.

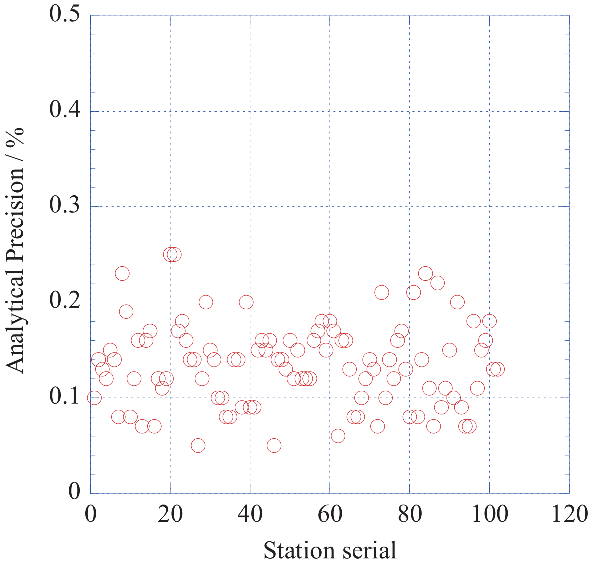

Figure 3.5.10. Time series of precision of silicate for MR11–08.

(7.2) Carry over

We also summarize the magnitudes of carry over throughout the cruise. These are small enough within acceptable levels as shown in Table 3.5.8 and Figures 3.5.11 – 3.5.13.

Table 3.5.8. Summary of carry over through out MR11–08 cruise.

	Nitrate CV %	Phosphate CV %	Silicate CV %
Median	0.11	0.19	0.10
Mean	0.12	0.21	0.10
Maximum	0.33	0.8	0.28
Minimum	0.00	0.00	0.00
N	102	102	102

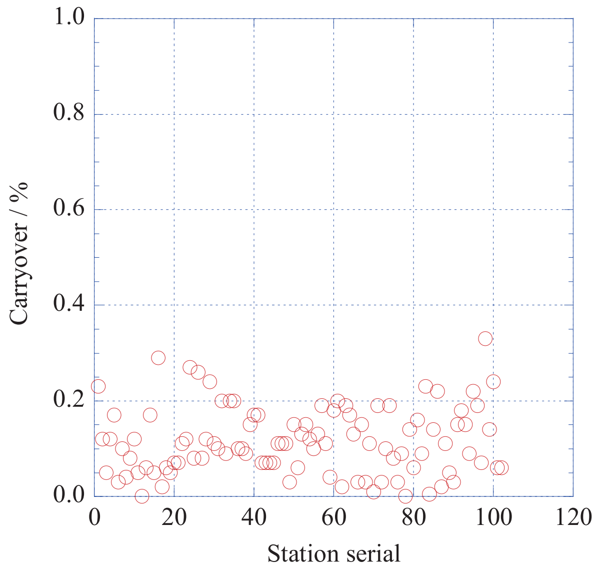

Figure 3.5.11. Time series of carryover of nitrate for MR11–08.

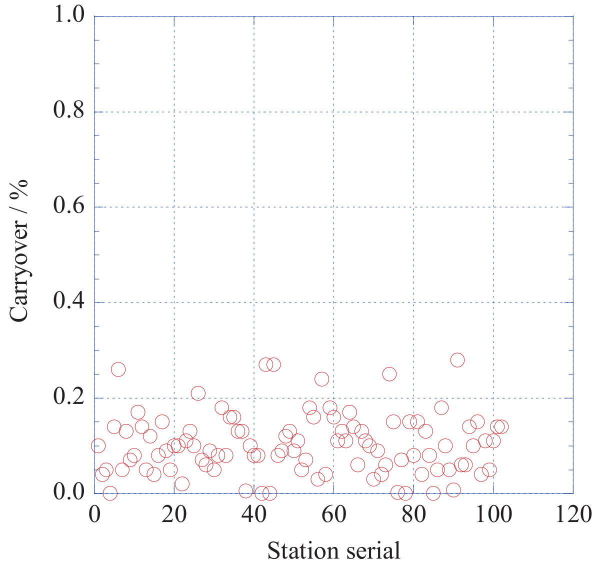

Figure 3.5.12. Time series of carryover of silicate for MR11–08.

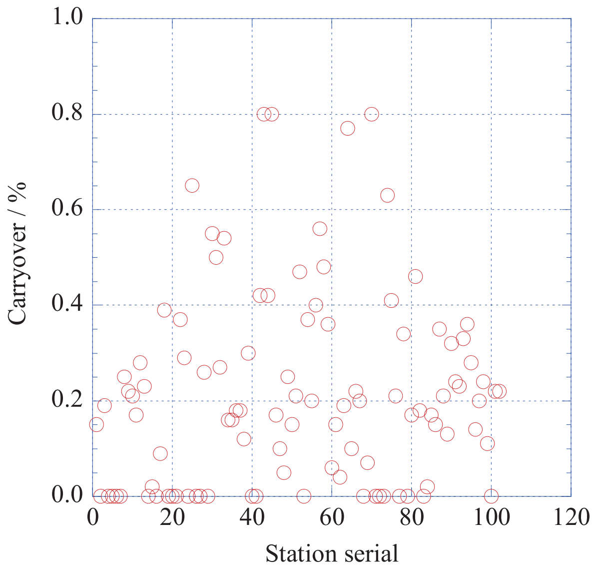

Figure 3.5.13. Time series of carryover of phosphate for MR11–08.

(7.3) Estimation of uncertainty of phosphate, nitrate and silicate concentrations

Empirical equations, eq. (1), (2) and (3) to estimate uncertainty of measurement of phosphate, nitrate and silicate are used based on measurements of 140 sets of RMNSs during the this cruise. These empirical equations are as follows, respectively.

Phosphate Concentration Cp in μmol kg^{-1}:

Uncertainty of measurement of phosphate (%) =

$$0.14871 + 0.61128 \times (1/Cp) + 0.02228 \times (1/Cp) \times (1/Cp) \qquad \text{--- (1)}$$

where Cp is phosphate concentration of sample.

Nitrate Concentration Cn in μmol kg^{-1}:

Uncertainty of measurement of nitrate (%) =

$$0.14629 + 2.5141 \times (1/Cn) + 0.056725 \times (1/Cn) \times (1/Cn) \qquad \text{--- (2)}$$

where Cn is nitrate concentration of sample.

Silicate Concentration Cs in μmol kg^{-1}:

Uncertainty of measurement of silicate (%) =

$$0.12394 + 9.9377 \times (1/Cs) + 7.6725 \times (1/Cs) \times (1/Cs) \quad \text{--- (3)}$$

where Cs is silicate concentration of sample.

(8) Problems/improvements occurred and solutions

During this cruse, we observed noisy signals in output of QuAAtro 2-HR systems. After this cruise we investigated on this and confirmed that noisy signals were originated from Kr-lamps of the colorimeters. We did fix this problem by using LED lamps instead of Kr-lamps.

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3.6 Chlorofluorocarbons and Sulfur Hexafluoride

September 5, 2013

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(2) Objectives

Chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF6) are man – made stable gases. These gases can slightly dissolve in sea surface water by air-sea gas exchange and then are spread into the ocean interior. These dissolved gases could be used as transient chemical tracers for the ocean circulation. We measured concentrations of three chemical species of CFCs, CFC-11 (CCl_3F), CFC-12 (CCl_2F_2) and CFC-113 ($C_2Cl_3F_3$), and SF_6 in seawater on board.

(3) Apparatuses

Measurement of CFCs and SF_6 were made with three gas chromatographs attached with purging and trapping systems (modified from the original design of Bullister and Weiss (1988)). One was SF_6/CFCs simultaneous analyzing system (System A). Other two were CFCs analyzing systems (System D and E). These purging and trapping systems were developed in JAMSTEC.

(3.1) SF_6/CFCs simultaneous analyzing system (System A)

Cold trap columns are 30 cm length stainless steel tubing packed the section of 5cm with 100/120 mesh Porapak T and followed by the section of 5cm of 100/120 mesh Carboxen 1000. Outer diameters of the main and focus trap columns are 1/8" and 1/16", respectively.

A gas chromatograph (GC-14B: Shimadzu LTD) has two electron capture detectors, ECD1 and ECD2 (ECD-14: Shimadzu LTD). A pre-column is Silica Plot capillary column [i.d.: 0.32 mm, length: 10 m, film thickness: 4 μm]. There are two main analytical columns in GC. Main column 1 (MC1) connected up to ECD1 is MS 5A packed column [1/16" OD, 10 cm length stainless steel tubing packed the section of 7 cm with 80/100 mesh Molecular Sieve 5A] followed by Gas Pro capillary column [i.d.: 0.32 mm, length: 35 m] for SF_6 and CFC-12 analyses. Main column 2 (MC2) connected up to ECD2 is Silica Plot capillary column [i.d.: 0.32mm, length: 30 m, film thickness: 4 μm] for CFC-11 and CFC-113 analyses.

(3.2) CFCs Systems (System D and E)

Cold trap column of the system is 1/16" stainless steel tubing packed with 5cm of 100/120 mesh Porapak T.

The GCs (GC-14B) in these systems had single ECD (ECD-14), respectively. A pre column was Silica Plot capillary column [i.d.: 0.53mm, length: 8 m, film thickness: 6μm]. A main column was Pola Bond-Q capillary column [i.d.: 0.53mm, length: 9 m, film thickness: 10μm] followed by Silica Plot capillary column [i. d.: 0.53mm, length: 14 m, film thickness: 6μm]

(4) Shipboard measurements

(4.1) Sampling

The marine water sampler was cleaned by diluted acetone before every CTD cast in order to remove any oils which could cause contaminations of CFCs. Seawater sub-samples were collected from 12 litter Niskin bottles to 250 ml and 400 ml of glass bottles for CFC and SF_6 measurements, respectively. CFCs sampling was made in every station and SF_6 sampling was done in every other station. The sub-sampling bottles were filled by nitrogen gas before sub-sampling. Two times of the bottle volumes of seawater sample were overflowed. The bottles filled by seawater samples were kept in thermostatic water bath (7^{o}C). The CFC and SF_6 concentrations were determined within 24 hours.

In order to confirm stabilities of standard gases and to check saturation levels of CFCs and SF_6 in sea surface water, mixing ratios of CFCs and SF_6 in background air were periodically analyzed. Air samples were continuously led into the Environmental Research Laboratory of R/V MIRAI by 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 sample was collected from the flowing air into a 200 ml glass cylinder attached on the cock. Average mixing ratios of the atmospheric CFC-11, CFC-12, CFC-113, and SF_6 were 237.7 ± 8.4 ppt, 522.8 ± 7.4 ppt, 71.4 ± 4.4 (n = 100) and 7.36 ± 0.25 ppt, respectively.

(4.2) Analyses

(4.2.1) SF_6/CFCs simultaneous analyses (System A)

Constant volume of sample water (200 ml) was taken into a sample loop. The sample was send into stripping chamber and dissolved gases were extracted by pure nitrogen gas purging for 9 minutes. The gas sample was dried by magnesium perchlorate desiccant and concentrated on a main trap column cooled to –80 ^{o}C. Stripping efficiencies were frequently confirmed by re-stripping of surface layer samples and more than 99 % of dissolved SF_6 and CFCs were extracted on the first purge. Following purging & trapping, the main trap column was isolated and heated to 170 ^{o}C for 1 minute. The desorbed gases were sent onto focusing trap cooled to –80 ^{o}C. Gaseous sample on the focusing trap were desorbed by heating to 170 ^{o}C for 1 minute and led into the pre-column. Sample gases were roughly separated in the pre-column. SF_6 and CFC-12 were sent onto MC1 and CFC-11 and CFC-113 still remain on the pre-column. Main column connected up to pre-column was switched to MC2 and another carrier gas line was connected up to MC1. SF_6 and CFC-12 were further separated and detected by the ECD1. CFC-11 and CFC-113 led onto MC 2 were detected by ECD2. When CFC-113 eluted from pre-column onto MC 2, the pre-column was switched onto another line and remaining compounds on the pre-column were backflushed. Temperature of the analytical column and ECD was 95 and 300 °C. Mass flow rates of nitrogen gas were 5, 32, 6 and 220 ml/min for carrier gases, detector make up gases, back flush gas and sample purging gas, respectively. Gas loops whose volumes were 0.05, 0.15, 0.3, 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 analyses using largest loop (10 ml) were performed more frequently to monitor change in the detector sensitivity.

(4.2.2) CFCs analyses (System D and E)

These systems were somewhat simple compared with the system A. Volume of water sample loop was 50 ml. Gas extraction time was for 8 minutes. Cooling and heating temperatures of trap column were –50 and 140 °C, respectively. There were not focusing trap in the systems. Stripping efficiencies were more than 99.5 % of dissolved CFCs on the first purge. Temperatures of the analytical column and ECD were 95 and 240 °C. Mass flow rates of nitrogen gas were 10, 27, 20 and 120 ml/min for carrier, detector make up, back flush and sample purging gases, respectively. There were three gas loops whose volumes were 1, 3 and 10 ml, respectively.

(4.2.3) Standard gases

The standard gasses had been made by Japan Fine Products co. ltd. Standard gas cylinder numbers used in this cruise were listed in Table 3.6.1. Cylinder of CPB15651 was used as reference gas. Precise mixing ratios of CFCs/SF_6 in the standard gases were calculated by gravimetric data. The standard gases have not been calibrated to SIO scale standard gases yet because SIO scale standard gasses were hard to obtain due to legal difficulties for CFCs import into Japan. The data would be corrected as soon as possible when we obtained the SIO scale standard gases.

(5) Quality control

(5.1) Interference peak for CFC-113

Analyzing surface layer samples (several hundred meters depth) of tropical and sub-tropical region, a large and broad peak was interfered determining CFC-113 peak area in chromatograms obtained from system D and E. Retention time of the interfering peak was slightly different from that of CFC-113. In this case, quality flag “5” was given (no data). The system A completely separated the unknown compound from CFC-113 peak. At the SF_6 stations, measurements of CFC-113 by the system A were adopted.

(5.2) Blanks

Deep water in the North Pacific which would be one of the oldest water masses in the world ocean. CFC concentrations in these water masses could be considered as overall blanks (from Niskin bottles, sub-sampling, and analytical systems). Average concentrations of CFC-11 and CFC-12 in the deep water masses (sigma theta > 27.7) were 0.011 ± 0.003, 0.005 ± 0.002 pmol kg^{-1} ($n = \sim 700$), respectively. These values were assumed as blanks and were subtracted from all data. Significant blanks were not found in CFC-113 and SF_6 measurements.

(5.3) Precisions

The analytical precisions were estimated from replicate sample analyses ($N = 201$ pairs for CFC-12 and CFC-11, 166 pairs for CFC-113, and 103 pairs for SF6 measurements). The replicate samples were collected from two or three sampling depths which were around 100, 400 and 600 m depths in every station. Precisions were estimated as less than ± 0.007 pmol kg^{-1} or 0.6 % for CFC-11, ± 0.004 pmol kg^{-1} or 0.5 % for CFC-12, ± 0.003 pmol kg^{-1} or 2 % for CFC-113 (whichever is greater), and ± 0.05 fmol kg^{-1} for SF_6, respectively. Although measurements of CFC-11 and CFC-12 were also obtained from the system A, the precisions were somewhat poor ± 0.016 pmol kg^{-1} for CFC-11 and ± 0.006 pmol kg^{-1} for CFC-12) compared with those of measurement by system D and E. Measurements of CFC-11 and CFC-12 from system A were rejected except the stations of P10-004 and P10-006 (because there was not measurements from the system D or E).

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Table 3.6.1. Standard gas cylinder list (Japan Fine Products co. ltd.).

Cylinder No.	Base gas	CFC-11 [ppt]	CFC-12 [ppt]	CFC113 [ppt]	SF_6 [ppt]	N_2O [ppb]
CPB23379	Air	501	251	40.3	5.02	198
CPB17172	Air	998	519	90.0	10.0	300
CPB17174	Air	1499	750	130	10.0	502
CPB26826	N2	299	160	30.1	0.0	0
CPB15674	N2	299	160	30.0	0.0	0
CPB15651	N2	299	159	30.2	0.0	0

3.7 Dissolved Inorganic Carbon (C_T)

October 4, 2013

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(2) Objectives

Concentrations of CO_2 in the atmosphere are now increasing at a rate of 1.9 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 (MR11-08, revisit of WOCE P10 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-C and -D; 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 3000, Nippon ANS, Inc.).

The seawater dispensing system has an auto-sampler (6 ports), which takes seawater from a 250 ml borosilicate glass bottle (DURAN®) and dispenses the seawater to a pipette of nominal 20 ml volume by a PC control. The pipette is kept at 20 °C by a water jacket, where water from a water bath set at 20 °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 ml min^{-1} for the systems C and D) to the coulometer through a dehydrating module. Both the systems have a module with two electric dehumidifiers (kept at 1−2 °C) and a chemical desiccant ($Mg(ClO_4)_2$).

(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 CT 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 tightly by a polyethylene inner cap.

At a chemical laboratory on the ship, a headspace of approx. 3 ml was made by removing seawater with a plastic pipette. A saturated mercuric chloride of 100 μl 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 5 °C in a refrigerator until analysis. A few hours just before analysis, the seawater samples were kept at 20 °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_2CO_3 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_2 gas repeatedly until the measurements became stable. Then we started the calibration.

The measurement sequence such as system blank (phosphoric acid blank), 1.865% CO_2 gas in a nitrogen base, seawater samples (6) was programmed to repeat. The measurement of 1.865% CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc.). For every renewal of coulometer solutions, certified reference materials (CRMs, batch 112) provided by Prof. A. G. Dickson of Scripps Institution of Oceanography were analyzed. In addition, in-house reference materials (RM) (batch Q24 and Q25 for systems C and D, 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_T 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_T 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_2CO_3 solutions, we calculated C_T of CRM (batch 112), 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_T of CRM, we re-calculated the calibration factors so that measurements of seawater samples become traceable to the certified value of batch 112.

Temporal variations of RM measurements for one coulometer solution are shown in Fig. 3.7.1. From this figure, it is evident that RM measurements had a linear trend of ~6 μmol kg^{-1}, implying that measurements of seawater samples also have the trend. The trend was also found in temporal changes of 1.865% CO_2 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 112.

The average and standard deviation of absolute values of differences of C_T analyzed consecutively were 0.7 and 0.5 μmol kg^{-1} (n=96), and 0.7 and 0.6 μmol kg^{-1} (n=85) for legs 1 and 2, respectively. The values for the entire cruises were 0.7 and 0.6 μmol kg^{-1} (n=181).

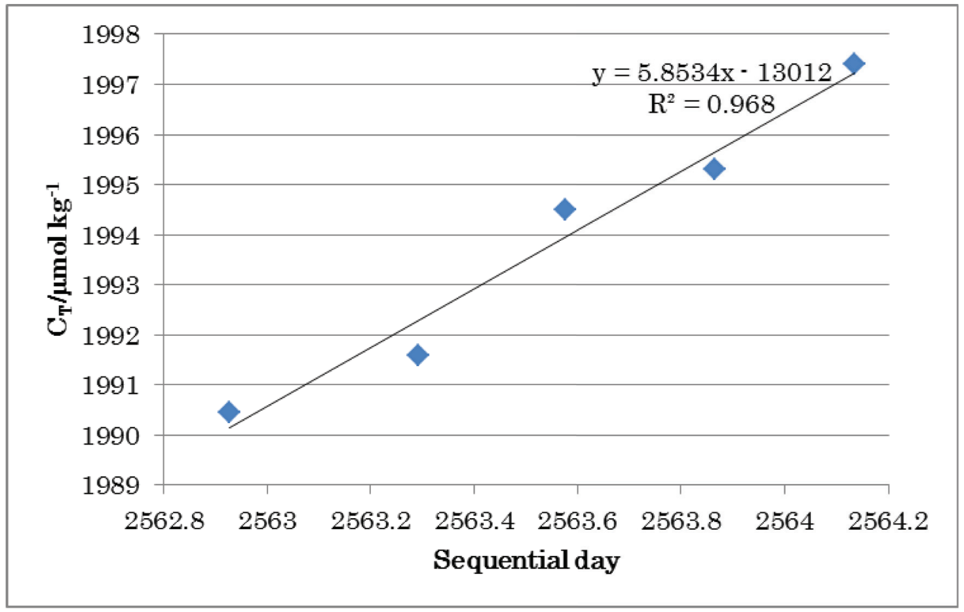

Figure 3.7.1. Distributions of RM measurements as a function of sequential day for Stns. 21 and 25 during MR11–08.

Reference

Johnson, K. M., A. G. Dickson, G. Eischeid, 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_2 survey 1994-1996, Mar. Chem., 63, 21-37.

3.8 Total Alkalinity (A_T)

October 4, 2013

(1) Personnel

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Tomonori Watai (MWJ)
Ayaka Hatsuyama (MWJ)
Yasumi Yamada (MWJ)

(2) Objectives

Concentrations of CO_2 in the atmosphere are now increasing at a rate of 1.9 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 (MR11-08, revisit of WOCE P10 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 (AT), 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 Scan, 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 (brosilicate glass bottle; 130 ml) into the water-jacketed (25 ^{o}C) pipette by pressurizing the sample bottle (nitrogen gas), and is introduced into the water-jacketed (25 ^{o}C) titration cell. The seawater is circulated between the titration and the quartz cells by a peristaric 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 wavelenghts (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 A_T was made by the following equation:

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

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 VS_A 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):

$$\begin{aligned} pH_T &= -\log[H^+]_T = 4.2699 + 0.002578(35 - S) + \log((R - 0.00131)/(2.3148 - 0.1299R)) \\ &\quad - \log(1 - 0.001005S), \end{aligned}$$

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

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

where A_i is the absorbance at wavelength i nm.

The HCl in the acid titrant was standardized (0.050002M, 0.50002 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 112, certified value = 2223.26 μmol 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 112.

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:

(5) Quality control

During the cruise, 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.

On land, after making the measured values of A_T comparable to CRM, we examined vertical profiles of A_T. In doing so, we found systematic differences in A_T between 2005 and 2011. To quantify the systematic differences, we conducted following analyses; first, we took A_T observed below 2000 dbar from both 2005 and 2011 datasets. The A_T data for 2005 were obtained by our cruise by the R/V *Mirai* (MR11-08). Then we selected A_T data collected in same or close stations for the two cruises, and found 40 pairs in total. For the selected data of each cruise, after normalizing to a salinity of 35 (nA_T), we applied a Piecewise Hermite Interpolating scheme to fixed depths to bottom with an interval of 250 dbar : 2250, 2500, 2750 … . Next, we compared nA_T differences of each depth in respective pairs (Fig. 3.8.1). The average of the differences was 6.0 ± 2.6 μmol kg^{-1}. Therefore we applied a value of 6.0 μmol kg^{-1} to each A_T in 2011.

The average and standard deviation of absolute values of differences of A_T analyzed consecutively were 0.5 and 0.4 μmol kg^{-1} (n = 96), and 0.5 and 0.4 μmol kg^{-1} (n = 88) for legs 2 and 3, respectively. The combined values were calculated to be 0.5 and 0.4 μmol kg^{-1} (n = 184).

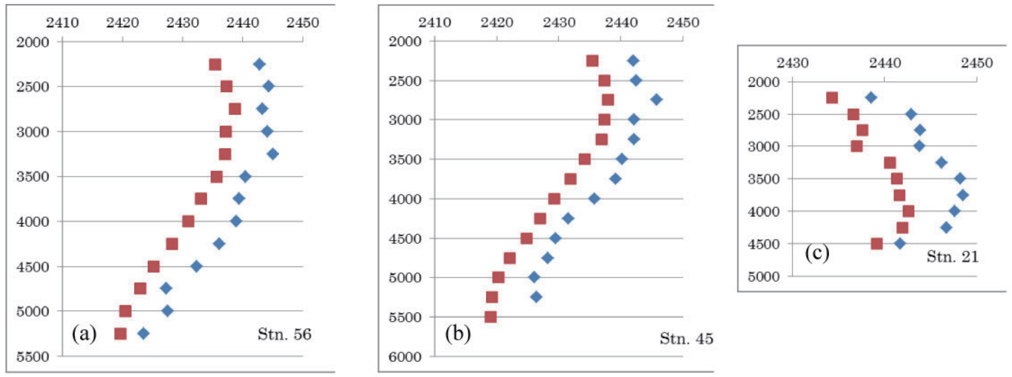

Fig. 3.8.1. Differences of nA_T between 1994 (red) and 2009 (blue) at selected stations.

Reference

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

3.9 pH

October 12, 2013

(1) Personnel

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(2) Objectives

Concentrations of CO_2 in the atmosphere are now increasing at a rate of 1.9 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 anticipated global warming depends on the levels of CO_2 in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In the cruise (MR11-08, revisit of WOCE P10 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 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 respective 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_1 and A_2 indicate absorbances at 578 and 434 nm, respectively, and pK_2 is calculated as a function of water temperature and salinity.

(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. 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® 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 3.9.1 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_2 system calculation using data for pH and C_T with K_1, K_2 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 0.0006 and 0.0006 pH unit (n = 116), and 0.0008 and 0.0010 pH unit (n = 109) for legs 1 and 2, respectively. The combined values were 0.0007 and 0.0008 pH unit (n = 225). We compared observed pH and pH calculated from C_T and A_T. The average and standard deviation was 0.0102 and 0.0072 pH unit, respectively. Thus the accuracy of pH was estimated to be 0.01 pH unit at best.

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.

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.

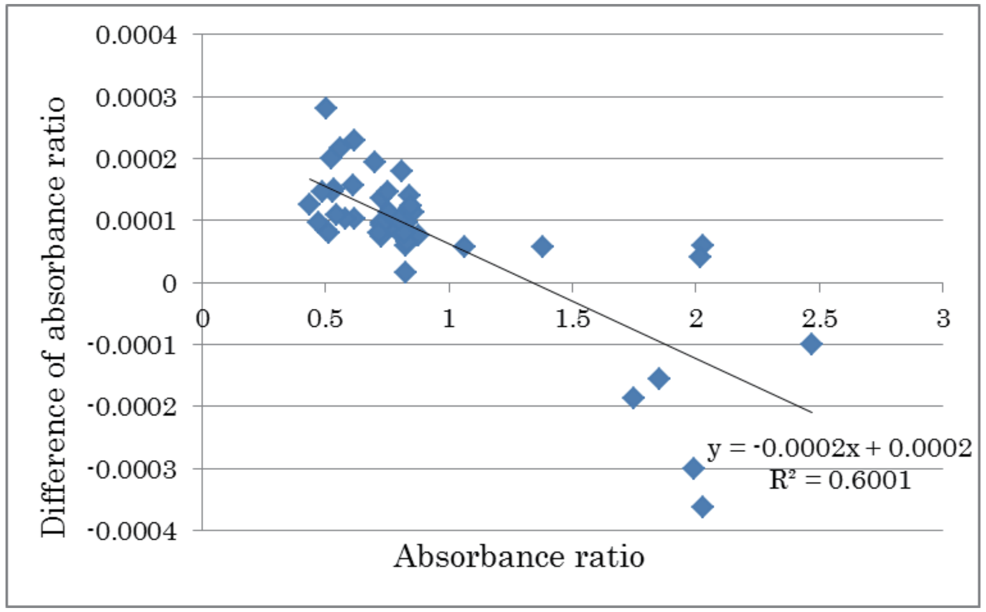

Figure 3.9.1. Perturbation of absorbance ratios by adding indicator solutions. The line was determined by the method of least squares.

3.10 Chlorophyll *a*

February 6, 2014

(1) Personnel

Osamu Yoshida1 (Rakuno Gakuen University) (Principal Investigator)
Hiroshi Uchida (JAMSTEC) (co-Principal Investigator)
Yuki Okazaki (Rakuno Gakuen University)
Shinichi Oikawa (Rakuno Gakuen University)
Hikari Shimizu (Rakuno Gakuen University)
Chisato Yoshikawa (Tokyo Institute of Technology /
Japan Society for the Promotion of Science) (Not on board)
Shoko Tatamisashi (MWJ)
Masahiro Orui (MWJ)
Naohiro Yoshida (Tokyo Institute of Technology) (Not on board)

(2) Sampling elements

The Rakuno Gakuen University (RGU) group collected chlorophyll *a* samples at CTD/CWS stations 1, 29, 45, 58, 71, 88, and 114 for bucket and Niskin bottles of 36, 35, 34, 33 and 32. The JAMSTEC collected chlorophyll *a* samples at CTD/CWS stations 2, 9, 15, 19, 24, 59, 62, 65, 68, 77, 79, 82, 84, 90, 94, 100, 106, and 112 for a Niskin bottle closed near chlorophyll *a* maximum to calibrate CTD fluorometer data. The JAMSTEC also collected chlorophyll a samples from the sea surface water monitoring system once in a day at night to calibrate the fluorometer of the sea surface water monitoring system.

(3) Objective

Chlorophyll *a* is one of the most convenient indicators of phytoplankton stock, and has been used extensively for the estimation of phytoplankton abundance in various aquatic environments. The object of this study is to investigate the vertical distribution of phytoplankton in various light intensity depth and the horizontal distribution of phytoplankton at sea surface along the cruise track.

(4) Materials and methods

Seawater samples were collected 250 mL at 6 depths from surface to about 200 m with Niskin bottles, except for the Surface water, which was taken by the bucket. For JAMSTEC stations, water samples were collected 500 mL bottle. The samples were gently filtrated by low vacuum pressure (<0.02 MPa) through Whatman GF/F filter (diameter 25 mm) in the dark room. Phytoplankton pigments were immediately extracted in 7 mL of N,N-dimethylformamide (DMF) after filtration and then, the samples were stored at –20°C under the dark condition to extract chlorophyll *a* for 24 hours or more. The extracted samples are measured the fluorescence by Turner fluorometer (10-AU-005, TURNER DESIGNS) which was previously calibrated against a pure chlorophyll a (Sigma-Aldrich Co.). We applied the fluorometric "Non-acidification method" (Welschmeyer, 1994).

(5) Results

The results of chlorophyll a at RGU sampling stations and relationship between chlorophyll *a* concentrations and chlorophyll *a* estimated from CTD fluorometer were shown in Figures 3.10.1 and 3.10.2, respectively.

Reference

Welschmeyer, N. A. (1994): Fluorometric analysis of chlrophyll *a* in the presence of chlorophyll *b* and pheopigments. *Limnol. Oceanogr.*, 39, 1985-1992.

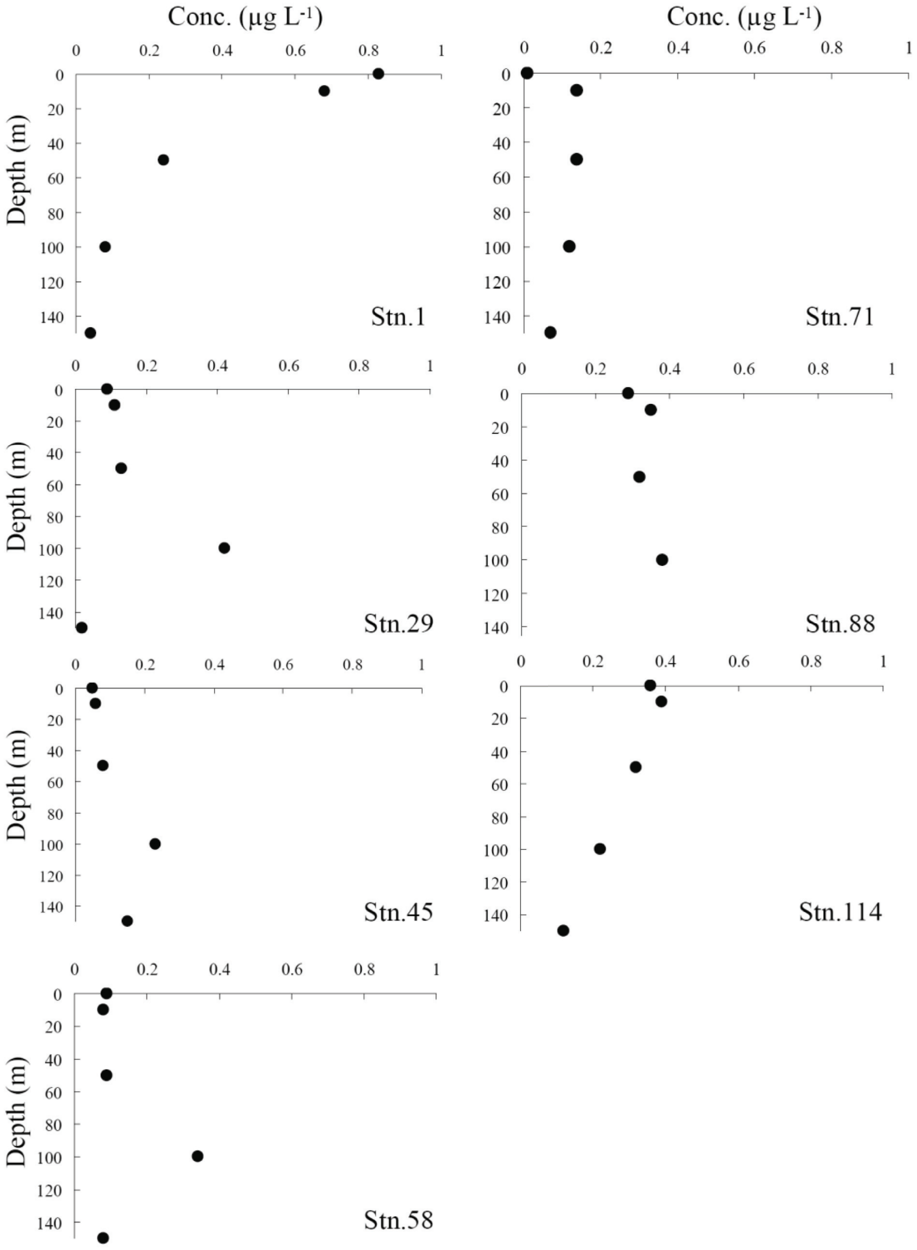

Figure 3.10.1. Vertical distributions of chlorophyll *a* at RGU stations.

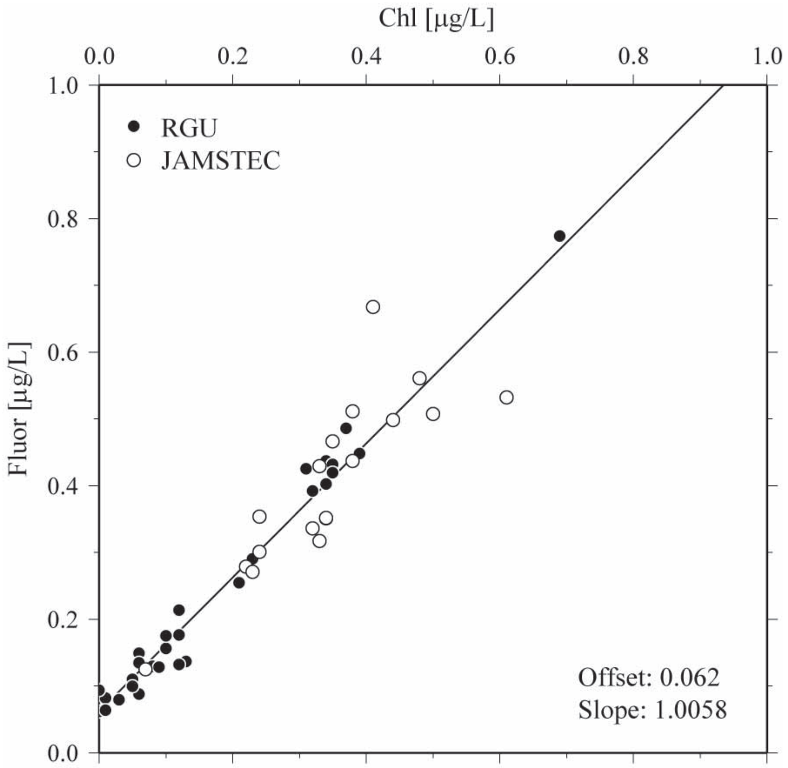

Figure 3.10.2. Relationship between fluorescent values of seawater and chlorophyll a concentrations at RGU (solid circles) and JAMSTEC (open circles) stations.

3.11 LADCP

August 13, 2013

(1) Personnel

Shinya Kouketsu (JAMSTEC)

Hiroshi Uchida (JAMSTEC)

Katsurou Katsumata (JAMSTEC)

Toshimasa Doi (JAMSTEC)

(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 expendable Alkali 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 were Teledyne RD Instruments, WHM300(S/N 183240).

(3) Data collection

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

Bin size: 4 m

Number of bins: 25

Pings per ensemble: 1

Ping interval: 1 sec

(4) Data collection problems

Echo intensities are sufficiently high along the section (Fig. 3.11.1), except at the stations of 9. Since the weak echo were observed for all the beams, the weakness was not due to the instrument problem.

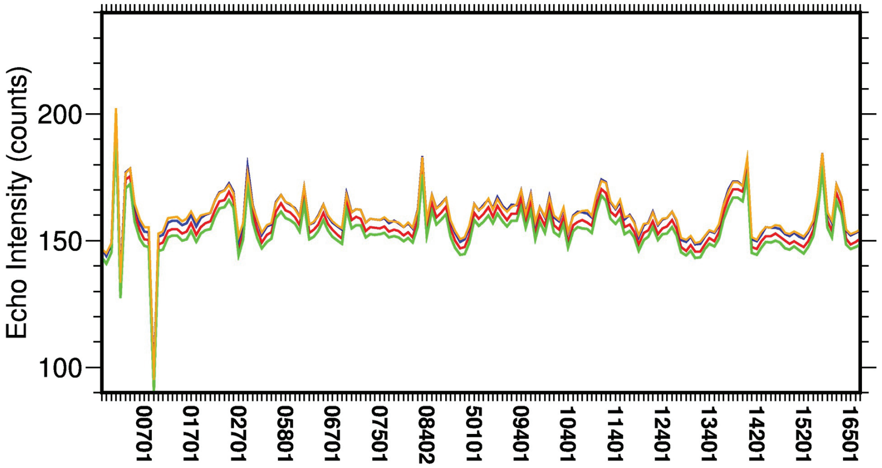

Figure 3.11.1. Cast-averaged echo intensities at the first bin. Red, blue, green and orange denote beam 1, 2, 3, and 4 respectively.

(5) 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 minute 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.

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

```
P10 REV R/V MIRAI CRUISE MR1108 LEG2
SHIP/CRS     WOCE                CAST          UTC EVENT          POSITION              UNC    COR HT ABOVE  WIRE     MAX  NO. OF
EXPOCODE     SECT  STNNBR CASTNO TYPE DATE    TIME  CODE LATITUDE   LONGITUDE   NAV  DEPTH  DEPTH    BOTTOM   OUT  PRESS BOTTLES PARAMETERS                                      COMMENTS
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
49NZ20111220  P10      59      1  ROS 122311 2000    BE  19 10.14 N 149 20.11 E GPS   5566   5560
49NZ20111220  P10      59      1  BUC 122311 2009    UN  19 10.24 N 149 20.11 E GPS   5560   5556                                 1                                             27.6C
49NZ20111220  P10      59      1  ROS 122311 2126    BO  19 10.39 N 149 20.23 E GPS   5551   5548        9   5536   5643       36 1-8,27,93                                     #1=#2 DUPL BTLS
49NZ20111220  P10      59      1  ROS 122311 2345    EN  19 10.70 N 149 20.47 E GPS   5553   5548
49NZ20111220  P10      58      1  ROS 122411 0254    BE  18 29.95 N 149 22.94 E GPS   5641   5643
49NZ20111220  P10      58      1  BUC 122411 0302    UN  18 29.98 N 149 22.99 E GPS   5640   5642                                 1                                             28.1C
49NZ20111220  P10      58      1  ROS 122411 0419    BO  18 30.08 N 149 23.14 E GPS   5645   5645       10   5628   5739       36 1-8,23,24,26,27,31,33,34,82                   #2=#3 DUPL BTLS
49NZ20111220  P10      58      1  ROS 122411 0640    EN  18 30.30 N 149 23.19 E GPS   5641   5644
49NZ20111220  P10      58      1  UNK 122411 0705    UN  18 25.90 N 149 23.20 E GPS   4669   4671                                                                               AIR 13CH4/CH3D/15N2O/N218O/COS SMPL
49NZ20111220  P10      57      1  ROS 122411 0940    BE  17 50.05 N 149 23.15 E GPS   5216   5217
49NZ20111220  P10      57      1  BUC 122411 0948    UN  17 50.09 N 149 23.17 E GPS   5225   5225                                 1                                             28.0C
49NZ20111220  P10      57      1  ROS 122411 1101    BO  17 50.38 N 149 23.15 E GPS   5255   5252        9   5225   5317       35 1-8,27,93                                     #2=#4 DUPL BTLS
49NZ20111220  P10      57      1  ROS 122411 1309    EN  17 51.15 N 149 23.38 E GPS   5249   5249
49NZ20111220  P10      56      1  ROS 122411 1614    BE  17  9.83 N 149 25.94 E GPS   5315   5316
49NZ20111220  P10      56      1  BUC 122411 1622    UN  17  9.84 N 149 25.87 E GPS   5322   5322                                 1,9,22,89                                     27.7C
49NZ20111220  P10      56      1  ROS 122411 1735    BO  17  9.95 N 149 25.88 E GPS   5342   5343       10   5331   5434       35 1-8,12,13,23,24,26,27,92
49NZ20111220  P10      56      1  ROS 122411 1950    EN  17 10.14 N 149 25.74 E GPS   5369   5370
49NZ20111220  P10      55      1  ROS 122411 2256    BE  16 29.84 N 149 35.01 E GPS   5611   5611
49NZ20111220  P10      55      1  BUC 122411 2303    UN  16 29.84 N 149 34.98 E GPS   5609   5609                                 1                                             28.0C
49NZ20111220  P10      55      1  ROS 122511 0022    BO  16 29.82 N 149 34.99 E GPS   5611   5610        9   5590   5703       36 1-8,27,93                                     #2=#6 DUPL BTLS
49NZ20111220  P10      55      1  ROS 122511 0236    EN  16 29.83 N 149 35.00 E GPS   5611   5612
49NZ20111220  P10      54      1  ROS 122511 0532    BE  15 50.05 N 149 35.16 E GPS   5247   5246
49NZ20111220  P10      54      1  BUC 122511 0539    UN  15 50.10 N 149 35.16 E GPS   5243   5243                                 1,31,33                                       28.4C
49NZ20111220  P10      54      1  ROS 122511 0651    BO  15 50.09 N 149 35.00 E GPS   5248   5249       10   5233   5331       35 1-8,27,31,34,93                               #2=#7 DUPL BTLS
49NZ20111220  P10      54      1  ROS 122511 0903    EN  15 50.25 N 149 34.92 E GPS   5241   5240
49NZ20111220  P10      53      1  ROS 122511 1158    BE  15 10.03 N 149 29.98 E GPS   5707   5707
49NZ20111220  P10      53      1  ROS 122511 1216    BO  15 10.04 N 149 29.93 E GPS   5717   5718       -9    825    832       18 22,89                                         FOR R.N.
49NZ20111220  P10      53      1  ROS 122511 1245    EN  15 10.08 N 149 29.86 E GPS   5711   5711
49NZ20111220  P10      53      2  ROS 122511 1343    BE  15  9.87 N 149 30.05 E GPS   5711   5710
49NZ20111220  P10      53      2  BUC 122511 1350    UN  15  9.89 N 149 30.04 E GPS   5716   5715                                 1,9,22,89                                     28.1C
49NZ20111220  P10      53      2  ROS 122511 1510    BO  15 10.08 N 149 29.90 E GPS   5713   5712        9   5699   5810       36 1-8,23,24,26,27,92                            #2=#8 DUPL BTLS
49NZ20111220  P10      53      2  ROS 122511 1734    EN  15 10.41 N 149 29.76 E GPS   5698   5697
49NZ20111220  P10      52      1  ROS 122511 2036    BE  14 29.98 N 149 20.31 E GPS   5330   5330
49NZ20111220  P10      52      1  BUC 122511 2045    UN  14 29.99 N 149 20.31 E GPS   5327   5328                                 1                                             28.4C
49NZ20111220  P10      52      1  ROS 122511 2159    BO  14 30.19 N 149 20.13 E GPS   5303   5304        9   5296   5394       35 1-8,27,93                                     #2=#9 DUPL BTLS
49NZ20111220  P10      52      1  ROS 122611 0006    EN  14 30.44 N 149 20.02 E GPS   5298   5298
49NZ20111220  P10      51      1  ROS 122611 0307    BE  13 49.95 N 149 19.23 E GPS   5990   5989
49NZ20111220  P10      51      1  BUC 122611 0314    UN  13 50.02 N 149 19.18 E GPS   5987   5987                                 1                                             28.6C
49NZ20111220  P10      51      1  ROS 122611 0418    BO  13 50.30 N 149 18.94 E GPS   5994   5992       -9   2370   2392                                                        CAST WAS ABORTED DUE TO WINCH TROUBLE
49NZ20111220  P10      51      1  ROS 122611 0451    EN  13 50.49 N 149 18.81 E GPS   5991   5992
49NZ20111220  P10      51      2  ROS 122611 0536    BE  13 50.03 N 149 19.10 E GPS   5989   5989
49NZ20111220  P10      51      2  ROS 122611 0712    BO  13 50.37 N 149 18.84 E GPS   5990   5989        9   5977   6096       36 1-8,12,13,23,24,26,27
49NZ20111220  P10      51      2  ROS 122611 0938    EN  13 50.80 N 149 18.73 E GPS   5986   5987
49NZ20111220  P10      50      1  ROS 122611 1243    BE  13 10.01 N 149 19.98 E GPS   5962   5964
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49NZ20111220  P10        50      1  BUC 122611 1303    UN  13 10.03 N 149 19.96 E GPS   5966   5966                                   1,9,22,89                           28.5C
49NZ20111220  P10        50      1  ROS 122611 1413    BO  13 10.02 N 149 20.02 E GPS   5965   5967        10   5944   6069      36 1-8,27,93
49NZ20111220  P10        50      1  ROS 122611 1637    EN  13 10.15 N 149 19.75 E GPS   5965   5967
49NZ20111220  P10        49      1  ROS 122611 1944    BE  12 29.80 N 149 19.92 E GPS   5923   5922
49NZ20111220  P10        49      1  BUC 122611 1953    UN  12 29.85 N 149 19.87 E GPS   5924   5920                                   1                                   28.4C
49NZ20111220  P10        49      1  ROS 122611 2115    BO  12 30.01 N 149 19.76 E GPS   5924   5922        10   5906   6024      36 1-8,23,24,26,27,31,33,92
49NZ20111220  P10        49      1  ROS 122611 2337    EN  12 30.34 N 149 19.66 E GPS   5924   5921
49NZ20111220  P10        48      1  ROS 122711 0238    BE  11 49.93 N 149 19.52 E GPS   5815   5816
49NZ20111220  P10        48      1  BUC 122711 0245    UN  11 49.99 N 149 19.45 E GPS   5817   5818                                   1                                   28.6C
49NZ20111220  P10        48      1  ROS 122711 0404    BO  11 50.13 N 149 19.48 E GPS   5816   5816         8   5793   5912      36 1-8,27,93
49NZ20111220  P10        48      1  ROS 122711 0626    EN  11 50.30 N 149 19.40 E GPS   5818   5816
49NZ20111220  P10        47      1  ROS 122711 0931    BE  11  9.51 N 149 19.93 E GPS   5806   5807
49NZ20111220  P10        47      1  ROS 122711 0951    BO  11  9.71 N 149 19.79 E GPS   5811   5810        -9    826    831      18 22,89                               FOR R.N.
49NZ20111220  P10        47      1  ROS 122711 1022    EN  11 10.03 N 149 19.58 E GPS   5808   5807
49NZ20111220  P10        47      2  ROS 122711 1117    BE  11  9.15 N 149 20.06 E GPS   5811   5809
49NZ20111220  P10        47      2  BUC 122711 1125    UN  11  9.20 N 149 19.98 E GPS   5812   5812                                   1,9,22,89                           28.3C
49NZ20111220  P10        47      2  ROS 122711 1245    BO  11  9.42 N 149 19.99 E GPS   5812   5813         9   5796   5911      36 1-8,12,13,23,24,26,27
49NZ20111220  P10        47      2  ROS 122711 1509    EN  11  9.67 N 149 20.10 E GPS   5808   5810
49NZ20111220  P10        46      1  ROS 122711 1809    BE  10 29.93 N 149 20.03 E GPS   5714   5713
49NZ20111220  P10        46      1  BUC 122711 1817    UN  10 29.96 N 149 19.99 E GPS   5715   5713                                   1,22,89                             28.4C
49NZ20111220  P10        46      1  ROS 122711 1936    BO  10 30.10 N 149 19.92 E GPS   5714   5714        10   5697   5808      36 1-8,27,93
49NZ20111220  P10        46      1  ROS 122711 2151    EN  10 30.63 N 149 19.59 E GPS   5716   5716
49NZ20111220  P10        45      1  ROS 122811 0015    BE  09 59.94 N 149 20.11 E GPS   5574   5576
49NZ20111220  P10        45      1  BUC 122811 0022    UN  09 59.97 N 149 20.10 E GPS   5574   5574                                   1,31,33,34,82,92                    28.7C
49NZ20111220  P10        45      1  ROS 122811 0141    BO  10  0.02 N 149 20.03 E GPS   5567   5568         9   5559   5668      35 1-8,23,24,26,27,31,33,34,82,92      #11 MISS TRIP
49NZ20111220  P10        45      1  ROS 122811 0402    EN  10  0.43 N 149 19.82 E GPS   5551   5551
49NZ20111220  P10        45      1  UNK 122811 0434    UN  09 55.90 N 149 19.90 E GPS   5507   5505                                                                       AIR 13CH4/CH3D/15N2O/N218O/COS SMPL
49NZ20111220  P10        44      1  ROS 122811 0606    BE  09 41.76 N 149 19.99 E GPS   5358   5358
49NZ20111220  P10        44      1  BUC 122811 0613    UN  09 41.81 N 149 19.98 E GPS   5359   5359                                   1                                   28.7C
49NZ20111220  P10        44      1  ROS 122811 0727    BO  09 41.93 N 149 19.88 E GPS   5359   5359        10   5344   5442      35 1-8,27,93                           #2=#10 DUPL BTLS
49NZ20111220  P10        44      1  ROS 122811 0936    EN  09 42.42 N 149 19.84 E GPS   5375   5373
49NZ20111220  P10        43      1  ROS 122811 1143    BE  09 29.31 N 149 10.07 E GPS   5225   5223
49NZ20111220  P10        43      1  BUC 122811 1151    UN  09 29.30 N 149 10.03 E GPS   5224   5223                                   1,9,22,89,90                        28.6C
49NZ20111220  P10        43      1  ROS 122811 1303    BO  09 29.38 N 149  9.97 E GPS   5233   5232        11   5206   5304      35 1-8,23,24,26,27                     #2=#11 DUPL BTLS
49NZ20111220  P10        43      1  ROS 122811 1516    EN  09 29.47 N 149  9.80 E GPS   5225   5224
49NZ20111220  P10        42      1  ROS 122811 1822    BE  08 49.88 N 149 19.92 E GPS   4119   4119
49NZ20111220  P10        42      1  BUC 122811 1830    UN  08 49.92 N 149 19.92 E GPS   4119   4119                                   1                                   28.9C
49NZ20111220  P10        42      1  ROS 122811 1927    BO  08 50.13 N 149 19.89 E GPS   4122   4120        10   4116   4169      31 1-8,27,93                           #5=#12 DUPL BTLS
49NZ20111220  P10        42      1  ROS 122811 2119    EN  08 50.44 N 149 19.70 E GPS   4124   4124
49NZ20111220  P10        41      1  ROS 122811 2303    BE  08 30.10 N 149 19.96 E GPS   3614   3616
49NZ20111220  P10        41      1  BUC 122811 2311    UN  08 30.15 N 149 19.92 E GPS   3666   3666                                   1                                   28.9C
49NZ20111220  P10        41      1  ROS 122911 0002    BO  08 30.26 N 149 19.80 E GPS   3650   3652         9   3640   3692      29 1-8,12,13,23,24,26,27,92            #2=#13 DUPL BTLS
49NZ20111220  P10        41      1  ROS 122911 0140    EN  08 30.49 N 149 19.74 E GPS   3679   3680
49NZ20111220  P10        40      1  ROS 122911 0404    BE  07 59.91 N 149  9.96 E GPS   3028   3028
49NZ20111220  P10        40      1  BUC 122911 0411    UN  07 59.96 N 149  9.94 E GPS   3021   3019                                   1                                   29.1C
49NZ20111220  P10        40      1  ROS 122911 0453    BO  08  0.00 N 149  9.93 E GPS   3020   3021         9   3012   3055      36 1-8,22,27,89,93
49NZ20111220  P10        40      1  ROS 122911 0618    EN  08  0.20 N 149  9.92 E GPS   3006   3005
49NZ20111220  P10        39      1  ROS 122911 0844    BE  07 29.96 N 148 55.94 E GPS   1315   1314
49NZ20111220  P10        39      1  BUC 122911 0853    UN  07 29.99 N 148 55.87 E GPS   1314   1315                                   1,31,33                             29.0C
49NZ20111220  P10        39      1  ROS 122911 0913    BO  07 30.04 N 148 55.84 E GPS   1314   1313         9   1311   1324      16 1-8,23,24,26,27,31,33
49NZ20111220  P10        39      1  ROS 122911 0959    EN  07 30.24 N 148 55.71 E GPS   1324   1321
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49NZ20111220  P10      38       1  ROS 122911 1226    BE  06 59.97 N 148 41.67 E GPS   3226   3227
49NZ20111220  P10      38       1  BUC 122911 1234    UN  07  0.01 N 148 41.62 E GPS   3201   3203                                  1,9,22,89                                      29.1C
49NZ20111220  P10      38       1  ROS 122911 1318    BO  07  0.08 N 148 41.56 E GPS   3245   3246        12   3199   3242       26 1-8,27,93                                      #4=#14 DUPL BTLS
49NZ20111220  P10      38       1  ROS 122911 1448    EN  07  0.21 N 148 41.49 E GPS   3262   3261
49NZ20111220  P10      37       1  ROS 122911 1714    BE  06 29.93 N 148 29.03 E GPS   3400   3399
49NZ20111220  P10      37       1  BUC 122911 1721    UN  06 29.95 N 148 28.99 E GPS   3424   3424                                  1                                              29.1C
49NZ20111220  P10      37       1  ROS 122911 1808    BO  06 30.01 N 148 29.06 E GPS   3366   3366        10   3352   3401       27 1-8,23,24,26,27,92                             #2=#15 DUPL BTLS
49NZ20111220  P10      37       1  ROS 122911 1938    EN  06 30.26 N 148 28.88 E GPS   3327   3327
49NZ20111220  P10      36       1  ROS 122911 2205    BE  05 59.91 N 148 16.41 E GPS   4096   4098
49NZ20111220  P10      36       1  BUC 122911 2213    UN  05 59.98 N 148 16.40 E GPS   4097   4096                                  1                                              29.1C
49NZ20111220  P10      36       1  ROS 122911 2310    BO  06  0.15 N 148 16.37 E GPS   4094   4093         9   4085   4143       30 1-8,23,24,26,27                                #2=#16 DUPL BTLS
49NZ20111220  P10      36       1  ROS 123011 0058    EN  06  0.58 N 148 16.46 E GPS   4096   4094
49NZ20111220  P10      35       1  ROS 123011 0332    BE  05 29.88 N 148  3.83 E GPS   3632   3633
49NZ20111220  P10      35       1  BUC 123011 0340    UN  05 29.93 N 148  3.93 E GPS   3626   3627                                  1                                              29.3C
49NZ20111220  P10      35       1  ROS 123011 0429    BO  05 30.00 N 148  3.97 E GPS   3635   3637        10   3588   3643       28 1-8,27,93                                      #2=#17 DUPL BTLS
49NZ20111220  P10      35       1  ROS 123011 0606    EN  05 30.05 N 148  3.99 E GPS   3641   3642
49NZ20111220  P10      34       1  ROS 123011 0839    BE  04 59.97 N 147 51.22 E GPS   4199   4200
49NZ20111220  P10      34       1  ROS 123011 0858    BO  05  0.00 N 147 51.29 E GPS   4129   4130        -9    793    800       18 22,89                                          FOR R.N.
49NZ20111220  P10      34       1  ROS 123011 0927    EN  05  0.05 N 147 51.48 E GPS   4112   4113
49NZ20111220  P10      34       2  ROS 123011 1022    BE  05  0.09 N 147 51.08 E GPS   4253   4254
49NZ20111220  P10      34       2  BUC 123011 1029    UN  05  0.13 N 147 51.19 E GPS   4187   4188                                  1,9,22,89                                      29.3C
49NZ20111220  P10      34       2  ROS 123011 1127    BO  05  0.12 N 147 51.22 E GPS   4191   4192         9   4179   4246       32 1-8,12,13,23,24,26,27                          #2=#18 DUPL BTLS
49NZ20111220  P10      34       2  ROS 123011 1318    EN  05  0.07 N 147 51.49 E GPS   4120   4122
49NZ20111220  P10      33       1  ROS 123011 1555    BE  04 29.92 N 147 38.49 E GPS   3707   3709
49NZ20111220  P10      33       1  BUC 123011 1603    UN  04 29.98 N 147 38.52 E GPS   3704   3704                                  1                                               29.4C
49NZ20111220  P10      33       1  ROS 123011 1654    BO  04 30.11 N 147 38.50 E GPS   3709   3710        10   3694   3747       31 1-8,23,24,26,27                                #2=#19 DUPL BTLS
49NZ20111220  P10      33       1  ROS 123011 1834    EN  04 30.20 N 147 38.60 E GPS   3710   3713
49NZ20111220  P10      32       1  ROS 123011 2107    BE  04  0.07 N 147 25.63 E GPS   4113   4113
49NZ20111220  P10      32       1  BUC 123011 2114    UN  04  0.12 N 147 25.68 E GPS   4098   4099                                  1                                              29.3C
49NZ20111220  P10      32       1  ROS 123011 2213    BO  04  0.32 N 147 25.64 E GPS   4108   4108         9   4097   4155       32 1-8,27,93                                      #2=#20 DUPL BTLS
49NZ20111220  P10      32       1  ROS 123111 0002    EN  04  0.64 N 147 25.73 E GPS   4113   4114
49NZ20111220  P10      31       1  ROS 123111 0235    BE  03 30.26 N 147 12.93 E GPS   4597   4597
49NZ20111220  P10      31       1  BUC 123111 0242    UN  03 30.30 N 147 12.97 E GPS   4604   4603                                  1,90                                           29.3C
49NZ20111220  P10      31       1  ROS 123111 0346    BO  03 30.40 N 147 12.94 E GPS   4603   4604         9   4578   4654       34 1-8,23,24,26,27,92                             #2=#21 DUPL BTLS
49NZ20111220  P10      31       1  ROS 123111 0543    EN  03 30.54 N 147 13.01 E GPS   4597   4598
49NZ20111220  P10      30       1  ROS 123111 0815    BE  03  0.20 N 146 59.92 E GPS   4424   4425
49NZ20111220  P10      30       1  BUC 123111 0823    UN  03  0.25 N 146 59.91 E GPS   4426   4428                                  1,9,22,89                                      29.2C
49NZ20111220  P10      30       1  ROS 123111 0923    BO  03  0.39 N 146 59.89 E GPS   4432   4431         9   4412   4484       34 1-8,27,93                                      #2=#22 DUPL BTLS
49NZ20111220  P10      30       1  ROS 123111 1112    EN  03  0.65 N 146 59.95 E GPS   4446   4447
49NZ20111220  P10      29       1  ROS 123111 1302    BE  02 45.08 N 146 55.88 E GPS   4408   4408
49NZ20111220  P10      29       1  BUC 123111 1309    UN  02 45.10 N 146 55.87 E GPS   4404   4404                                  1,31,33,34,82                                  29.4C
49NZ20111220  P10      29       1  ROS 123111 1409    BO  02 45.05 N 146 55.85 E GPS   4409   4409        10   4389   4459       31 1-8,23,24,26,27,31,33,34,82
49NZ20111220  P10      29       1  ROS 123111 1600    EN  02 45.08 N 146 55.93 E GPS   4408   4406
49NZ20111220  P10      29       1  UNK 123111 1615    UN  02 44.40 N 146 56.10 E GPS   4367   4366                                                                                 AIR 13CH4/CH3D/15N2O/N218O/COS SMPL
49NZ20111220  P10      28       1  ROS 123111 1831    BE  02 29.87 N 146 51.58 E GPS   4445   4446
49NZ20111220  P10      28       1  BUC 123111 1840    UN  02 29.86 N 146 51.56 E GPS   4439   4438                                  1                                              29.6C
49NZ20111220  P10      28       1  ROS 123111 1942    BO  02 29.92 N 146 51.59 E GPS   4438   4440         9   4430   4502       33 1-8,27,93
49NZ20111220  P10      28       1  ROS 123111 2133    EN  02 30.09 N 146 51.49 E GPS   4444   4445
49NZ20111220  P10      27       1  ROS 123111 2329    BE  02 15.08 N 146 46.92 E GPS   4625   4625
49NZ20111220  P10      27       1  BUC 123111 2337    UN  02 15.10 N 146 46.88 E GPS   4624   4623                                  1                                              29.6C
49NZ20111220  P10      27       1  ROS 010112 0040    BO  02 15.17 N 146 46.98 E GPS   4625   4625         9   4605   4683       33 1-8,12,13,23,24,26,27,92
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49NZ20111220  P10      27      1  ROS 010112 0235    EN  02 15.28 N 146 46.98 E GPS   4626   4625
49NZ20111220          801      1  UNK 010112 0355    BE  02 15.99 N 146 46.35 E GPS   4602   4602                                                                     3-AXIS MAGNETOMETER CALIBRATION
49NZ20111220          801      1  UNK 010112 0428    EN  02 15.97 N 146 45.37 E GPS   4607   4606
49NZ20111220  P10       1      1  ROS 010312 1504    BE  04  0.96 S 144 48.68 E GPS    216    218
49NZ20111220  P10       1      1  BUC 010312 1505    UN  04  0.96 S 144 48.68 E GPS    219    218                             1,31,33,34,82                           30.2C
49NZ20111220  P10       1      1  ROS 010312 1509    BO  04  0.98 S 144 48.69 E GPS    216    217      9    202    206       5 1-8,23,24,26,27,31,33,34,82,92
49NZ20111220  P10       1      1  ROS 010312 1521    EN  04  1.00 S 144 48.74 E GPS    222    223
49NZ20111220  P10       1      1  UNK 010312 1535    UN  04  0.48 S 144 48.78 E GPS    361    361                                                                     AIR 13CH4/CH3D/15N2O/N218O/COS SMPL
49NZ20111220  P10       2      1  ROS 010312 1731    BE  03 58.86 S 144 49.93 E GPS    781    780
49NZ20111220  P10       2      1  ROS 010312 1749    BO  03 58.91 S 144 49.92 E GPS    768    767     11    758    764      27  9,22,89                                FOR R.N.
49NZ20111220  P10       2      1  ROS 010312 1818    EN  03 59.01 S 144 49.89 E GPS    727    730
49NZ20111220  P10       2      2  ROS 010312 1916    BE  03 58.78 S 144 49.98 E GPS    806    805
49NZ20111220  P10       2      2  BUC 010312 1924    UN  03 58.80 S 144 49.98 E GPS    799    799                             1,9,22,89,90                            29.0C
49NZ20111220  P10       2      2  ROS 010312 1937    BO  03 58.85 S 144 49.98 E GPS    794    795      9    798    804      12  1-8,23,24,26,27,34
49NZ20111220  P10       2      2  ROS 010312 2013    EN  03 58.96 S 144 49.93 E GPS    749    750
49NZ20111220  P10       3      1  ROS 010312 2216    BE  03 53.48 S 144 53.59 E GPS   1396   1395
49NZ20111220  P10       3      1  BUC 010312 2224    UN  03 53.50 S 144 53.61 E GPS   1395   1396                             1                                       29.3C
49NZ20111220  P10       3      1  ROS 010312 2247    BO  03 53.53 S 144 53.59 E GPS   1394   1394      9   1380   1393      17  1-8,23,24,26,27
49NZ20111220  P10       3      1  ROS 010312 2338    EN  03 53.69 S 144 53.65 E GPS   1383   1382
49NZ20111220  P10       4      1  ROS 010412 0133    BE  03 36.87 S 145  0.92 E GPS   1890   1889
49NZ20111220  P10       4      1  BUC 010412 0141    UN  03 36.88 S 145  0.96 E GPS   1885   1885                             1                                       29.3C
49NZ20111220  P10       4      1  ROS 010412 0208    BO  03 36.90 S 145  0.87 E GPS   1888   1890      9   1877   1894      22  1-8,27,93                              #2=#21 DUPL BTLS
49NZ20111220  P10       4      1  ROS 010412 0307    EN  03 37.01 S 145  0.79 E GPS   1890   1889
49NZ20111220  P10       5      1  ROS 010412 0500    BE  03 18.52 S 145  9.15 E GPS   2173   2173
49NZ20111220  P10       5      1  BUC 010412 0508    UN  03 18.56 S 145  9.22 E GPS   2173   2174                             1                                       29.6C
49NZ20111220  P10       5      1  ROS 010412 0539    BO  03 18.56 S 145  9.14 E GPS   2172   2171      9   2158   2181      23  1-8,12,13,23,24,26,27,92               #2=#20 DUPL BTLS
49NZ20111220  P10       5      1  ROS 010412 0642    EN  03 18.73 S 145  9.04 E GPS   2170   2169
49NZ20111220  P10       6      1  ROS 010412 0846    BE  03  0.05 S 145 17.24 E GPS   2073   2073
49NZ20111220  P10       6      1  BUC 010412 0854    UN  03  0.07 S 145 17.26 E GPS   2074   2073                             1                                       29.7C
49NZ20111220  P10       6      1  ROS 010412 0922    BO  03  0.18 S 145 17.22 E GPS   2073   2073     10   2063   2080      23  1-6,93                                 #2=#19 DUPL BTLS
49NZ20111220  P10       6      1  ROS 010412 1023    EN  03  0.34 S 145 17.20 E GPS   2075   2076
49NZ20111220  P10       7      1  ROS 010412 1222    BE  02 44.97 S 145 21.59 E GPS   1709   1709
49NZ20111220  P10       7      1  BUC 010412 1230    UN  02 45.00 S 145 21.64 E GPS   1709   1709                             1                                       29.8C
49NZ20111220  P10       7      1  ROS 010412 1253    BO  02 45.05 S 145 21.61 E GPS   1710   1710     10   1696   1712      20  1-8,23,24,26,27
49NZ20111220  P10       7      1  ROS 010412 1348    EN  02 45.21 S 145 21.67 E GPS   1721   1721
49NZ20111220  P10       8      1  ROS 010412 1547    BE  02 30.02 S 145 25.62 E GPS   1087   1087
49NZ20111220  P10       8      1  BUC 010412 1554    UN  02 30.03 S 145 25.63 E GPS   1088   1089                             1,31,33                                 30.0C
49NZ20111220  P10       8      1  ROS 010412 1610    BO  02 30.08 S 145 25.63 E GPS   1091   1091      9   1076   1087      14  1-8,23,24,26,27,31,34
49NZ20111220  P10       8      1  ROS 010412 1650    EN  02 30.17 S 145 25.67 E GPS   1098   1098
49NZ20111220  P10       9      1  ROS 010412 1849    BE  02 14.99 S 145 29.99 E GPS   1002   1003
49NZ20111220  P10       9      1  BUC 010412 1858    UN  02 15.02 S 145 29.96 E GPS   1003   1004                             1                                       29.8C
49NZ20111220  P10       9      1  ROS 010412 1912    BO  02 15.04 S 145 30.02 E GPS   1010   1008      9    992   1000      14  1-8,27,34,93
49NZ20111220  P10       9      1  ROS 010412 1947    EN  02 15.22 S 145 30.04 E GPS   1017   1017
49NZ20111220  P10      10      1  ROS 010412 2148    BE  02  0.01 S 145 34.09 E GPS    736    737
49NZ20111220  P10      10      1  ROS 010412 2207    BO  02  0.11 S 145 34.08 E GPS    734    734      9    725    729      27  9,22,89                                FOR R.N.
49NZ20111220  P10      10      1  ROS 010412 2236    EN  02  0.22 S 145 34.10 E GPS    734    734
49NZ20111220  P10      10      2  ROS 010412 2341    BE  02  0.07 S 145 34.16 E GPS    737    738
49NZ20111220  P10      10      2  BUC 010412 2348    UN  02  0.10 S 145 34.13 E GPS    736    736                             1,9,22,89                               29.9C
49NZ20111220  P10      10      2  ROS 010412 2359    BO  02  0.14 S 145 34.13 E GPS    735    737      9    726    731       1  1-8,12,13,23,24,26,27,92
49NZ20111220  P10      10      2  ROS 010512 0026    EN  02  0.26 S 145 34.07 E GPS    732    734
49NZ20111220  P10      11      1  ROS 010512 0223    BE  01 44.86 S 145 38.56 E GPS   1923   1923
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49NZ20111220  P10        11       1  BUC 010512 0231     UN  01 44.89 S 145 38.54 E GPS    1923    1923                               1                                               29.8C
49NZ20111220  P10        11       1  ROS 010512 0257     BO  01 45.02 S 145 38.53 E GPS    1920    1921     10   1916   1929       21 1-8,27,93
49NZ20111220  P10        11       1  ROS 010512 0358     EN  01 45.29 S 145 38.50 E GPS    1915    1916
49NZ20111220  P10        12       1  ROS 010512 0547     BE  01 29.82 S 145 42.59 E GPS    2193    2193
49NZ20111220  P10        12       1  BUC 010512 0554     UN  01 29.85 S 145 42.56 E GPS    2195    2194                               1                                               29.9C
49NZ20111220  P10        12       1  ROS 010512 0624     BO  01 29.93 S 145 42.50 E GPS    2193    2193      9   2182   2203       24 1-8,23,24,26,27                                 #2=#18 DUPL BTLS
49NZ20111220  P10        12       1  ROS 010512 0729     EN  01 30.24 S 145 42.41 E GPS    2186    2186
49NZ20111220  P10        13       1  ROS 010512 0933     BE  01 14.88 S 145 47.11 E GPS    2290    2290
49NZ20111220  P10        13       1  BUC 010512 0941     UN  01 14.88 S 145 47.04 E GPS    2289    2290                               1                                               30.0C
49NZ20111220  P10        13       1  ROS 010512 1013     BO  01 14.90 S 145 47.00 E GPS    2292    2290     10   2277   2301       24 1-8,27,93                                       #2=#17 DUPL BTLS
49NZ20111220  P10        13       1  ROS 010512 1119     EN  01 14.84 S 145 46.96 E GPS    2289    2289
49NZ20111220  P10        14       1  ROS 010512 1326     BE  00 59.80 S 145 51.31 E GPS    2309    2310
49NZ20111220  P10        14       1  BUC 010512 1334     UN  00 59.78 S 145 51.22 E GPS    2309    2310                               1                                               30.1C
49NZ20111220  P10        14       1  ROS 010512 1406     BO  00 59.83 S 145 51.23 E GPS    2310    2310      9   2296   2331       22 1-8,23,24,26,27
49NZ20111220  P10        14       1  ROS 010512 1512     EN  00 59.94 S 145 51.18 E GPS    2304    2305
49NZ20111220  P10        15       1  ROS 010512 1747     BE  00 44.81 S 145 55.80 E GPS    2425    2424
49NZ20111220  P10        15       1  BUC 010512 1755     UN  00 44.83 S 145 55.70 E GPS    2424    2424                               1                                               29.9C
49NZ20111220  P10        15       1  ROS 010512 1829     BO  00 44.89 S 145 55.54 E GPS    2426    2425      9   2417   2438       25 1-8,23,24,26,27,34                              #2=#16 DUPL BTLS
49NZ20111220  P10        15       1  ROS 010512 1940     EN  00 45.07 S 145 55.41 E GPS    2425    2425
49NZ20111220  P10        16       1  ROS 010512 2215     BE  00 28.52 S 146  0.43 E GPS    3440    3439
49NZ20111220  P10        16       1  BUC 010512 2223     UN  00 28.54 S 146  0.37 E GPS    3443    3442                               1                                               29.8C
49NZ20111220  P10        16       1  ROS 010512 2312     BO  00 28.59 S 146  0.30 E GPS    3415    3417      9   3407   3464       29 1-8,27,93
49NZ20111220  P10        16       1  ROS 010612 0044     EN  00 28.63 S 146  0.05 E GPS    3497    3496
49NZ20111220  P10        17       1  ROS 010612 0322     BE  00 14.90 S 146  4.16 E GPS    4716    4714
49NZ20111220  P10        17       1  BUC 010612 0330     UN  00 14.91 S 146  4.09 E GPS    4718    4719                               1,9,22,89                                       29.8C
49NZ20111220  P10        17       1  ROS 010612 0435     BO  00 14.79 S 146  4.00 E GPS    4718    4718      9   4700   4778       34 1-8,12,13,23,24,26,27                           #2=#14 DUPL BTLS
49NZ20111220  P10        17       1  ROS 010612 0635     EN  00 14.67 S 146  3.72 E GPS    4725    4725
49NZ20111220  P10        18       1  ROS 010612 0917     BE  00  0.00 S 146  8.44 E GPS    3621    3620
49NZ20111220  P10        18       1  BUC 010612 0925     UN  00  0.04 S 146  8.38 E GPS    3625    3626                               1,31,33,90                                      29.8C
49NZ20111220  P10        18       1  ROS 010612 1016     BO  00  0.00 N 146  8.29 E GPS    3623    3625     10   3628   3673       30 1-8,23,24,26,27,31,34                           #2=#13 DUPL BTLS
49NZ20111220  P10        18       1  ROS 010612 1156     EN  00  0.00 N 146  7.88 E GPS    3706    3705
49NZ20111220  P10        19       1  ROS 010612 1432     BE  00 15.04 N 146 12.74 E GPS    3727    3726
49NZ20111220  P10        19       1  BUC 010612 1440     UN  00 14.99 N 146 12.66 E GPS    3718    3719                               1                                               29.7C
49NZ20111220  P10        19       1  ROS 010612 1530     BO  00 15.05 N 146 12.59 E GPS    3728    3729     10   3707   3758       30 1-8,27,34,93                                    #2=#12 DUPL BTLS
49NZ20111220  P10        19       1  ROS 010612 1706     EN  00 15.18 N 146 12.41 E GPS    3727    3725
49NZ20111220  P10        20       1  ROS 010612 1854     BE  00 30.06 N 146 16.95 E GPS    4125    4126
49NZ20111220  P10        20       1  BUC 010612 1902     UN  00 30.07 N 146 16.86 E GPS    4132    4130                               1                                               29.6C
49NZ20111220  P10        20       1  ROS 010612 1959     BO  00 30.13 N 146 16.79 E GPS    4125    4126     10   4108   4171       29 1-8,27,93
49NZ20111220  P10        20       1  ROS 010612 2221     EN  00 30.23 N 146 16.55 E GPS    4111    4110
49NZ20111220  P10        21       1  ROS 010712 0020     BE  00 44.97 N 146 21.29 E GPS    4504    4504
49NZ20111220  P10        21       1  BUC 010712 0028     UN  00 44.98 N 146 21.21 E GPS    4489    4489                               1                                               29.7C
49NZ20111220  P10        21       1  ROS 010712 0131     BO  00 45.05 N 146 21.26 E GPS    4494    4495      9   4474   4548       34 1-8,23,24,26,27,92                              #2=#9 DUPL BTLS
49NZ20111220  P10        21       1  ROS 010712 0325     EN  00 45.06 N 146 21.27 E GPS    4494    4493
49NZ20111220  P10        22       1  ROS 010712 0518     BE  00 59.94 N 146 25.60 E GPS    4530    4529
49NZ20111220  P10        22       1  BUC 010712 0526     UN  00 59.94 N 146 25.54 E GPS    4528    4529                               1                                               29.6C
49NZ20111220  P10        22       1  ROS 010712 0629     BO  00 59.98 N 146 25.48 E GPS    4532    4529      9   4513   4589       34 1-8,27,93                                       #2=#7 DUPL BTLS
49NZ20111220  P10        22       1  ROS 010712 0821     EN  01  0.15 N 146 25.41 E GPS    4518    4516
49NZ20111220  P10        23       1  ROS 010712 1015     BE  01 14.94 N 146 30.13 E GPS    4468    4468
49NZ20111220  P10        23       1  ROS 010712 1034     BO  01 15.01 N 146 30.10 E GPS    4469    4468     -9    825    830       28 9,22,89                                         FOR R.N.
49NZ20111220  P10        23       1  ROS 010712 1103     EN  01 15.15 N 146 30.07 E GPS    4466    4469
49NZ20111220  P10        23       2  ROS 010712 1201     BE  01 14.81 N 146 30.12 E GPS    4475    4475
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49NZ20111220	P10	23	2	BUC	010712	1210	UN	01 14.83 N	146 30.06 E	GPS	4473	4473					1,9,22,89	29.5C
49NZ20111220	P10	23	2	ROS	010712	1311	BO	01 14.90 N	146 30.10 E	GPS	4477	4476	9	4456	4527	33	1-8,12,13,23,24,26,27	#2=#8 DUPL BTLS
49NZ20111220	P10	23	2	ROS	010712	1508	EN	01 15.07 N	146 29.99 E	GPS	4471	4469						
49NZ20111220	P10	24	1	ROS	010712	1712	BE	01 30.08 N	146 34.26 E	GPS	4486	4483						
49NZ20111220	P10	24	1	BUC	010712	1719	UN	01 30.12 N	146 34.18 E	GPS	4482	4481					1	29.6C
49NZ20111220	P10	24	1	ROS	010712	1823	BO	01 30.18 N	146 34.21 E	GPS	4480	4479	10	4463	4538	35	1-8,27,34,93	#2=#10 DUPL BTLS, #5 CHLORA MAX
49NZ20111220	P10	24	1	ROS	010712	2026	EN	01 30.49 N	146 34.13 E	GPS	4465	4465						
49NZ20111220	P10	25	1	ROS	010712	2222	BE	01 45.00 N	146 38.55 E	GPS	4456	4455						
49NZ20111220	P10	25	1	BUC	010712	2231	UN	01 45.01 N	146 38.54 E	GPS	4453	4454					1	29.7C
49NZ20111220	P10	25	1	ROS	010712	2331	BO	01 45.05 N	146 38.65 E	GPS	4449	4454	9	4430	4502	32	1-8,23,24,26,27	
49NZ20111220	P10	25	1	ROS	010812	0124	EN	01 45.17 N	146 38.54 E	GPS	4454	4455						
49NZ20111220	P10	26	1	ROS	010812	0320	BE	01 59.81 N	146 42.94 E	GPS	4448	4448						
49NZ20111220	P10	26	1	BUC	010812	0328	UN	01 59.81 N	146 42.86 E	GPS	4441	4441					1	29.7C
49NZ20111220	P10	26	1	ROS	010812	0430	BO	01 59.83 N	146 42.98 E	GPS	4442	4441	10	4422	4495	32	1-8,27,93	
49NZ20111220	P10	26	1	ROS	010812	0620	EN	01 59.95 N	146 42.96 E	GPS	4439	4437						
49NZ20111220		802	1	UNK	011012	0310	BE	12 1.97 N	145 19.87 E	GPS	7234	7230						RELEASING EXCESS TWIST OF CTD CABLE
49NZ20111220		802	1	UNK	011012	0640	EN	12 2.55 N	145 19.21 E	GPS	7278	7275						WOUT 6500M

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P10 REV R/V MIRAI CRUISE MR1108 LEG3
SHIP/CRS      WOCE                 CAST          UTC EVENT          POSITION                UNC    COR HT ABOVE   WIRE    MAX  NO. OF
EXPOCODE      SECT  STNNBR CASTNO TYPE DATE     TIME  CODE LATITUDE    LONGITUDE   NAV   DEPTH  DEPTH   BOTTOM    OUT  PRESS BOTTLES PARAMETERS                                      COMMENTS
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49NZ20120113  P10        59       2  ROS 011412 0719    BE  19 10.07 N 149 20.12 E GPS   5566   5565
49NZ20120113  P10        59       2  BUC 011412 0727    UN  19 10.05 N 149 20.08 E GPS   5559   5556                                 1                                             27.4C
49NZ20120113  P10        59       2  ROS 011412 0843    BO  19 10.05 N 149 19.82 E GPS   5556   5556         9   5540   5647      36 1-8,27,93                                     #2 CHL MAX (130DB)
49NZ20120113  P10        59       2  ROS 011412 1107    EN  19  9.91 N 149 19.22 E GPS   5562   5562
49NZ20120113  P10        59       2  BIO 011412 1133    BE  19 10.11 N 149 19.31 E GPS   5556   5556                                                                                 ORI NET
49NZ20120113  P10        59       2  BIO 011412 1323    EN  19 12.85 N 149 21.16 E GPS   5624   5623
49NZ20120113  P10        60       1  ROS 011412 1612    BE  19 49.92 N 149 19.96 E GPS   3752   3752
49NZ20120113  P10        60       1  ROS 011412 1628    BO  19 49.89 N 149 19.92 E GPS   3716   3716        -9    765    772      18 22,89                                         FOR R.N.
49NZ20120113  P10        60       1  ROS 011412 1658    EN  19 49.91 N 149 19.87 E GPS   3716   3717
49NZ20120113  P10        60       2  ROS 011412 1758    BE  19 49.85 N 149 20.06 E GPS   3713   3714
49NZ20120113  P10        60       2  BUC 011412 1804    UN  19 49.86 N 149 20.03 E GPS   3695   3695                                 1,9,22,89                                     27.0C
49NZ20120113  P10        60       2  ROS 011412 1854    BO  19 49.86 N 149 19.98 E GPS   3691   3692        11   3652   3707      28 1-8,12,13,23,24,26,27,90,92
49NZ20120113  P10        60       2  ROS 011412 2041    EN  19 49.93 N 149 19.88 E GPS   3723   3721
49NZ20120113  P10        61       1  ROS 011412 2342    BE  20 29.91 N 149 20.03 E GPS   4463   4464
49NZ20120113  P10        61       1  BUC 011412 2350    UN  20 29.90 N 149 20.02 E GPS   4468   4468                                 1                                             27.0C
49NZ20120113  P10        61       1  ROS 011512 0052    BO  20 29.59 N 149 19.93 E GPS   4450   4448        10   4448   4504      30 1-8,27,93
49NZ20120113  P10        61       1  ROS 011512 0241    EN  20 29.50 N 149 19.73 E GPS   4553   4553
49NZ20120113  P10        61       1  XMP 011512 0302    DE  20 29.67 N 149 19.76 E GPS   4541   4542                                                                                 RSI #0020
49NZ20120113  P10        61       2  XMP 011512 0557    DE  20 33.38 N 149 19.85 E GPS   4629   4629                                                                                 RSI #0019
49NZ20120113  P10        62       1  ROS 011512 1102    BE  21 10.88 N 149 20.56 E GPS   5390   5392
49NZ20120113  P10        62       1  BUC 011512 1110    UN  21 10.84 N 149 20.54 E GPS   5390   5390                                 1,31,33                                       26.6C
49NZ20120113  P10        62       1  ROS 011512 1225    BO  21 10.85 N 149 20.53 E GPS   5391   5391         9   5378   5480      35 1-8,23,24,26,27,31,33,34
49NZ20120113  P10        62       1  ROS 011512 1436    EN  21 10.81 N 149 20.42 E GPS   5389   5389
49NZ20120113  P10        62       1  BIO 011512 1452    BE  21 10.84 N 149 20.42 E GPS   5387   5389                                                                                 ORI NET
49NZ20120113  P10        62       1  BIO 011512 1654    EN  21 13.53 N 149 21.33 E GPS   5407   5410
49NZ20120113  P10        63       1  ROS 011512 1946    BE  21 50.03 N 149 20.03 E GPS   5618   5617
49NZ20120113  P10        63       1  BUC 011512 1955    UN  21 49.99 N 149 20.02 E GPS   5620   5619                                 1                                             26.5C
49NZ20120113  P10        63       1  ROS 011512 2113    BO  21 49.93 N 149 20.00 E GPS   5625   5624        11   5607   5716      36 1-8,27,93                                     #5 UPPER AND LOWER CAPS LEAK
49NZ20120113  P10        63       1  ROS 011512 2338    EN  21 49.64 N 149 20.04 E GPS   5628   5629
49NZ20120113  P10        64       1  ROS 011612 0242    BE  22 29.87 N 149 20.00 E GPS   5711   5712
49NZ20120113  P10        64       1  BUC 011612 0249    UN  22 29.79 N 149 20.00 E GPS   5712   5712                                 1                                             25.1C
49NZ20120113  P10        64       1  XCT 011612 0251    DE  22 29.79 N 149 20.00 E GPS   5714   5715                                                                                 TSK XCTD-2 #11022006
49NZ20120113  P10        64       1  ROS 011612 0408    BO  22 29.80 N 149 19.98 E GPS   5712   5712         9   5695   5810      36 1-8,12,13,23,24,26,27,92
49NZ20120113  P10        64       1  ROS 011612 0623    EN  22 29.52 N 149 20.19 E GPS   5716   5715
49NZ20120113  P10        65       1  ROS 011612 0930    BE  23 10.83 N 149 20.52 E GPS   5802   5801
49NZ20120113  P10        65       1  BUC 011612 0938    UN  23 10.85 N 149 20.53 E GPS   5804   5803                                 1                                             25.1C
49NZ20120113  P10        65       1  ROS 011612 1058    BO  23 10.67 N 149 20.48 E GPS   5802   5800         9   5805   5909      36 1-8,27,34,93
49NZ20120113  P10        65       1  ROS 011612 1322    EN  23 10.71 N 149 20.67 E GPS   5805   5803
49NZ20120113  P10        66       1  ROS 011612 1616    BE  23 49.80 N 149 19.96 E GPS   5829   5828
49NZ20120113  P10        66       1  BUC 011612 1623    UN  23 49.79 N 149 19.99 E GPS   5827   5826                                 1,31,33                                       23.6C
49NZ20120113  P10        66       1  ROS 011612 1745    BO  23 49.58 N 149 20.25 E GPS   5808   5806        10   5841   5937      36 1-8,23,24,26,27,31,33
49NZ20120113  P10        66       1  ROS 011612 2016    EN  23 49.44 N 149 20.35 E GPS   5801   5801
49NZ20120113  P10        67       1  ROS 011612 2238    BE  24 14.64 N 149  1.78 E GPS   5789   5790
49NZ20120113  P10        67       1  ROS 011612 2253    EN  24 14.58 N 149  1.90 E GPS   5786   5787                                                                                 CAST WAS ABORTED
                                                                                                                                                                                    DUE TO STEERING TROUBLE
49NZ20120113  P10        67       2  ROS 011612 2318    BE  24 14.58 N 149  2.18 E GPS   5783   5784
49NZ20120113  P10        67       2  ROS 011612 2335    BO  24 14.59 N 149  2.23 E GPS   5782   5784        -9    796    803      18 22,89                                         FOR R.N.
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49NZ20120113	P10	67	2	ROS	011712	0004	EN	24 14.58 N	149 2.29 E	GPS	5782	5783						
49NZ20120113	P10	67	3	ROS	011712	0107	BE	24 14.54 N	149 1.76 E	GPS	5789	5789						
49NZ20120113	P10	67	3	BUC	011712	0113	UN	24 14.53 N	149 1.82 E	GPS	5788	5789					1,9,22,89	23.9C
49NZ20120113	P10	67	3	XCT	011712	0116	DE	24 14.53 N	149 1.83 E	GPS	5786	5785						TSK XCTD-2 #11022005
49NZ20120113	P10	67	3	ROS	011712	0234	BO	24 14.43 N	149 1.99 E	GPS	5784	5786	10	5783	5891	36	1-8,23,24,26,27,93	
49NZ20120113	P10	67	3	ROS	011712	0454	EN	24 14.21 N	149 2.07 E	GPS	5784	5785						
49NZ20120113	P10	68	1	ROS	011712	0702	BE	24 30.18 N	149 20.10 E	GPS	5773	5771						
49NZ20120113	P10	68	1	BUC	011712	0710	UN	24 30.14 N	149 20.12 E	GPS	5771	5771					1	24.1C
49NZ20120113	P10	68	1	ROS	011712	0830	BO	24 30.02 N	149 20.10 E	GPS	5772	5772	11	5769	5876	36	1-8,23,24,26,27,34,92	
49NZ20120113	P10	68	1	ROS	011712	1054	EN	24 29.95 N	149 20.53 E	GPS	5772	5770						
49NZ20120113	P10	68	1	BIO	011712	1107	BE	24 29.94 N	149 20.67 E	GPS	5773	5774						ORI NET
49NZ20120113	P10	68	1	BIO	011712	1252	EN	24 28.39 N	149 17.43 E	GPS	5732	5732						
49NZ20120113	P10	69	1	ROS	011712	1613	BE	25 9.99 N	149 20.00 E	GPS	5904	5904						
49NZ20120113	P10	69	1	BUC	011712	1621	UN	25 9.91 N	149 20.00 E	GPS	5902	5902					1	23.1C
49NZ20120113	P10	69	1	ROS	011712	1743	BO	25 9.82 N	149 19.86 E	GPS	5901	5900	11	5888	6010	36	1-8,27,93	
49NZ20120113	P10	69	1	ROS	011712	2016	EN	25 9.35 N	149 19.70 E	GPS	5911	5912						
49NZ20120113	P10	70	1	ROS	011712	2347	BE	25 49.90 N	149 19.86 E	GPS	5892	5893						
49NZ20120113	P10	70	1	BUC	011812	0000	UN	25 49.91 N	149 19.67 E	GPS	5894	5894					1	22.7C
49NZ20120113	P10	70	1	ROS	011812	0120	BO	25 49.93 N	149 19.30 E	GPS	5891	5891	11	5887	5998	36	1-8,27,93	
49NZ20120113	P10	70	1	ROS	011812	0346	EN	25 49.85 N	149 18.49 E	GPS	5877	5877						
49NZ20120113	P10	71	1	ROS	011812	0720	BE	26 29.89 N	149 19.94 E	GPS	6110	6111						
49NZ20120113	P10	71	1	ROS	011812	0738	BO	26 29.89 N	149 19.92 E	GPS	6100	6099	-9	828	831	18	22,89	FOR R.N.
49NZ20120113	P10	71	1	ROS	011812	0810	EN	26 29.91 N	149 19.93 E	GPS	6104	6104						
49NZ20120113	P10	71	2	ROS	011812	0858	BE	26 29.81 N	149 20.10 E	GPS	6081	6082						
49NZ20120113	P10	71	2	BUC	011812	0906	UN	26 29.81 N	149 20.11 E	GPS	6078	6079					1,9,22,31,33,34,82,89	22.7C
49NZ20120113	P10	71	2	ROS	011812	1030	BO	26 29.80 N	149 19.98 E	GPS	6083	6084	11	6056	6177	36	1-8,23,24,26,27,31,33,34,82,93	
49NZ20120113	P10	71	2	ROS	011812	1303	EN	26 29.87 N	149 20.01 E	GPS	6092	6092						
49NZ20120113	P10	71	2	BIO	011812	1316	BE	26 29.98 N	149 20.15 E	GPS	6080	6079						ORI NET
49NZ20120113	P10	71	2	UNK	011812	1450	UN	26 32.59 N	149 22.78 E	GPS	5768	5767						AIR 13CH4/CH3D/15N2O/N218O/COS SMPL
49NZ20120113	P10	71	2	BIO	011812	1516	EN	26 33.26 N	149 23.34 E	GPS	5788	5790						
49NZ20120113	P10	72	1	ROS	011812	1825	BE	27 10.00 N	149 20.16 E	GPS	5890	5888						
49NZ20120113	P10	72	1	BUC	011812	1834	UN	27 9.97 N	149 20.16 E	GPS	5885	5883					1	21.9C
49NZ20120113	P10	72	1	ROS	011812	1954	BO	27 9.88 N	149 20.06 E	GPS	5891	5889	11	5874	5988	36	1-8,27,93	
49NZ20120113	P10	72	1	ROS	011812	2225	EN	27 9.71 N	149 19.96 E	GPS	5889	5888						
49NZ20120113	P10	73	1	ROS	011912	0133	BE	27 50.01 N	149 19.96 E	GPS	5973	5973						
49NZ20120113	P10	73	1	BUC	011912	0141	UN	27 50.04 N	149 19.95 E	GPS	5974	5972					1	20.1C
49NZ20120113	P10	73	1	ROS	011912	0303	BO	27 49.84 N	149 19.70 E	GPS	5970	5968	10	5963	6078	36	1-8,27,93	
49NZ20120113	P10	73	1	ROS	011912	0525	EN	27 49.79 N	149 19.72 E	GPS	5966	5966						
49NZ20120113	P10	73	1	FLT	011912	0533	DE	27 49.94 N	149 19.73 E	GPS	5968	5967						ARGO #10039/ID97950
49NZ20120113	P10	74	1	CTD	011912	0836	BE	28 29.95 N	149 19.72 E	GPS	6221	6223						FOR FL/TRANS/LADCP
49NZ20120113	P10	74	1	CTD	011912	0845	BO	28 29.90 N	149 19.59 E	GPS	6222	6223	-9	297	301	0		
49NZ20120113	P10	74	1	CTD	011912	0851	EN	28 29.87 N	149 19.52 E	GPS	6219	6218						
49NZ20120113	P10	74	2	ROS	011912	0959	BE	28 29.87 N	149 19.69 E	GPS	6221	6222						
49NZ20120113	P10	74	2	BUC	011912	1007	UN	28 29.83 N	149 19.58 E	GPS	6219	6219					1,9,22,31,33,89	19.6C
49NZ20120113	P10	74	2	ROS	011912	1133	BO	28 29.84 N	149 19.68 E	GPS	6222	6222	12	6204	6334	36	1-8,12,13,23,24,26,27,31,33,92	
49NZ20120113	P10	74	2	ROS	011912	1410	EN	28 29.84 N	149 19.82 E	GPS	6224	6224						
49NZ20120113	P10N	75	1	ROS	011912	1714	BE	29 10.16 N	149 20.11 E	GPS	6093	6094						
49NZ20120113	P10N	75	1	BUC	011912	1721	UN	29 10.15 N	149 20.10 E	GPS	6095	6095					1	20.3C
49NZ20120113	P10N	75	1	ROS	011912	1845	BO	29 10.07 N	149 20.06 E	GPS	6098	6100	10	6085	6213	36	1-8,27,93	
49NZ20120113	P10N	75	1	ROS	011912	2130	EN	29 10.08 N	149 20.08 E	GPS	6100	6101						
49NZ20120113	P10N	76	1	ROS	012012	0038	BE	29 50.10 N	149 20.12 E	GPS	6153	6153						

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49NZ20120113 P10N      76     1  BUC 012012 0046   UN  29 50.08 N 149 20.20 E GPS   6156   6153                               1                                    19.5C
49NZ20120113 P10N      76     1  ROS 012012 0209   BO  29 50.01 N 149 20.35 E GPS   6157   6155      10   6141   6268      36  1-8,27,93
49NZ20120113 P10N      76     1  ROS 012012 0442   EN  29 50.41 N 149 20.06 E GPS   6148   6146
49NZ20120113 P10N      76     1  XMP 012012 0457   DE  29 50.32 N 149 20.14 E GPS   6148   6145                                                                    RSI #0023
49NZ20120113 P10N      76     2  XMP 012012 0721   DE  29 47.56 N 149 23.45 E GPS   6145   6144                                                                    RSI #0021
49NZ20120113 P10N      77     1  ROS 012012 0933   BE  29 59.09 N 149 15.37 E GPS   6190   6190                                                                    WIND 20M/S
49NZ20120113 P10N      77     1  ROS 012012 0951   BO  29 59.08 N 149 15.55 E GPS   6194   6194      -9    828    831      19  22,34,89                             FOR R.N.
49NZ20120113 P10N      77     1  ROS 012012 1023   EN  29 59.19 N 149 15.87 E GPS   6189   6188
49NZ20120113 P10N      77     1  BIO 012012 1046   BE  29 59.13 N 149 16.09 E GPS   6186   6184                                                                    ORI NET
49NZ20120113 P10N      77     1  BIO 012012 1238   EN  29 55.81 N 149 19.59 E GPS   6149   6148
49NZ20120113 P10N      77     2  ROS 012112 2231   BE  29 58.94 N 149 15.04 E GPS   6192   6194
49NZ20120113 P10N      77     2  BUC 012112 2242   UN  29 58.88 N 149 14.98 E GPS   6194   6194                               1,9,22,89,90                         19.4C
49NZ20120113 P10N      77     2  ROS 012212 0006   BO  29 58.84 N 149 15.12 E GPS   6193   6194      10   6180   6312      36  1-8,23,24,26,27,90,92
49NZ20120113 P10N      77     2  ROS 012212 0247   EN  29 58.97 N 149 15.17 E GPS   6196   6197
49NZ20120113 P10N      78     1  ROS 012212 0539   BE  30 29.97 N 149 20.08 E GPS   6141   6140
49NZ20120113 P10N      78     1  BUC 012212 0549   UN  30 30.00 N 149 20.06 E GPS   6138   6138                               1                                    18.9C
49NZ20120113 P10N      78     1  ROS 012212 0712   BO  30 30.08 N 149 19.92 E GPS   6142   6143      12   6121   6251      36  1-8,27,93
49NZ20120113 P10N      78     1  ROS 012212 0944   EN  30 30.05 N 149 20.23 E GPS   6137   6136
49NZ20120113 P10N      79     1  ROS 012212 1300   BE  31 10.12 N 149 20.10 E GPS   6040   6039
49NZ20120113 P10N      79     1  BUC 012212 1309   UN  31 10.10 N 149 20.10 E GPS   6037   6038                               1,9,22,89                            18.3C
49NZ20120113 P10N      79     1  ROS 012212 1433   BO  31  9.98 N 149 20.19 E GPS   6042   6044      11   6034   6154      36  1-8,23,24,26,27,31,33,92
49NZ20120113 P10N      79     1  ROS 012212 1654   EN  31 10.05 N 149 20.16 E GPS   6038   6040
49NZ20120113 P10N      80     1  ROS 012212 2306   BE  31 50.33 N 149 19.70 E GPS   5669   5670
49NZ20120113 P10N      80     1  BUC 012212 2318   UN  31 50.36 N 149 19.76 E GPS   5675   5676                               1                                    17.9C
49NZ20120113 P10N      80     1  ROS 012312 0035   BO  31 49.96 N 149 19.65 E GPS   5694   5695      12   5683   5771      35  1-8,27,93
49NZ20120113 P10N      80     1  ROS 012312 0249   EN  31 49.56 N 149 19.86 E GPS   5683   5684
49NZ20120113 P10N      80     1  FLT 012312 0255   DE  31 49.61 N 149 19.74 E GPS   5681   5682                                                                    ARGO #10041/ID97952
49NZ20120113 P10N      81     1  ROS 012312 0436   BE  32 10.06 N 149 19.92 E GPS   5576   5574
49NZ20120113 P10N      81     1  ROS 012312 0453   BO  32  9.92 N 149 19.77 E GPS   5546   5547      -9    762    770      18  22,34,89                             FOR R.N.
49NZ20120113 P10N      81     1  ROS 012312 0519   EN  32  9.73 N 149 19.58 E GPS   5511   5512
49NZ20120113 P10N      81     2  ROS 012312 0603   BE  32  9.76 N 149 19.96 E GPS   5530   5528
49NZ20120113 P10N      81     2  BUC 012312 0610   UN  32  9.70 N 149 19.87 E GPS   5516   5517                               1,9,22,89                            18.5C
49NZ20120113 P10N      81     2  ROS 012312 0726   BO  32  9.67 N 149 19.47 E GPS   5493   5492      11   5518   5606      35  1-8,12,13,23,24,26,27
49NZ20120113 P10N      81     2  ROS 012312 0933   EN  32  9.38 N 149 19.03 E GPS   5403   5402
49NZ20120113 P10N      82     1  ROS 012312 1121   BE  32 29.85 N 149 19.96 E GPS   5948   5948
49NZ20120113 P10N      82     1  BUC 012312 1129   UN  32 29.74 N 149 19.98 E GPS   5947   5948                               1                                    18.6C
49NZ20120113 P10N      82     1  ROS 012312 1251   BO  32 29.70 N 149 20.03 E GPS   5948   5951      11   5942   6059      36  1-8,27,34,93                         SEC COND SENSOR FAILURE
                                                                                                                                                                DUE TO JELLYFISH
49NZ20120113 P10N      82     1  ROS 012312 1517   EN  32 29.71 N 149 20.10 E GPS   5952   5953
49NZ20120113 P10N      82     1  BIO 012312 1531   BE  32 29.68 N 149 20.08 E GPS   5952   5953                                                                    ORI NET
49NZ20120113 P10N      82     1  BIO 012312 1708   EN  32 25.83 N 149 20.73 E GPS   5936   5936
49NZ20120113 P10N      83     1  ROS 012312 1916   BE  32 49.83 N 149 20.08 E GPS   6002   6002
49NZ20120113 P10N      83     1  BUC 012312 1927   UN  32 49.66 N 149 20.06 E GPS   6002   6003                               1                                    18.4C
49NZ20120113 P10N      83     1  ROS 012312 2049   BO  32 49.04 N 149 20.11 E GPS   6005   6006      10   6009   6110      36  1-8,23,24,26,27,92                   BAD SEA CONDITION
49NZ20120113 P10N      83     1  ROS 012312 2304   EN  32 47.78 N 149 20.34 E GPS   5978   5978
49NZ20120113 P10N      84     1  ROS 012412 0546   BE  33  9.70 N 149 20.06 E GPS   6125   6124
49NZ20120113 P10N      84     1  BUC 012412 0600   UN  33  9.47 N 149 20.00 E GPS   6122   6120                               1,9,22,89                            19.0C
49NZ20120113 P10N      84     1  ROS 012412 0705   BO  33  9.19 N 149 19.74 E GPS   6115   6115      -9   4978   5070       0                                       ABORTED DUE TO BAD WEATHER
49NZ20120113 P10N      84     1  ROS 012412 0823   EN  33  8.76 N 149 19.21 E GPS   6122   6122
49NZ20120113          803     1  UNK 012412 1220   BE  33 10.76 N 149 18.75 E GPS   6132     -9                                                                    3-AXIS MAGNETOMETER CALIBRATION
49NZ20120113          803     1  UNK 012412 1235   EN  33 10.06 N 149 19.07 E GPS   6129     -9
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49NZ20120113	P10N	84	2	ROS	012412	1312	BE	33 9.77 N	149 19.87 E	GPS	6123	6123						
49NZ20120113	P10N	84	2	BUC	012412	1325	UN	33 9.65 N	149 19.69 E	GPS	6120	6120					1	18.4C
49NZ20120113	P10N	84	2	ROS	012412	1448	BO	33 9.31 N	149 19.33 E	GPS	6121	6120	11	6111	6234	36	1-8,27,93	
49NZ20120113	P10N	84	2	ROS	012412	1713	EN	33 8.83 N	149 18.78 E	GPS	6126	6127						
49NZ20120113	P10N	85	1	ROS	012412	1905	BE	33 29.84 N	149 20.09 E	GPS	6154	6156						
49NZ20120113	P10N	85	1	BUC	012412	1917	UN	33 29.74 N	149 20.10 E	GPS	6156	6156					1	18.2C
49NZ20120113	P10N	85	1	ROS	012412	2042	BO	33 29.52 N	149 19.93 E	GPS	6172	6172	10	6164	6281	36	1-8,27,93	
49NZ20120113	P10N	85	1	ROS	012412	2317	EN	33 29.46 N	149 20.49 E	GPS	6155	6156						
49NZ20120113	P10N	86	1	ROS	012512	0054	BE	33 44.80 N	149 19.66 E	GPS	6163	6162						
49NZ20120113	P10N	86	1	ROS	012512	0114	BO	33 44.66 N	149 19.69 E	GPS	6165	6166	-9	829	833	18	22,34,89	FOR R.N.
49NZ20120113	P10N	86	1	ROS	012512	0142	EN	33 44.46 N	149 19.82 E	GPS	6168	6168						
49NZ20120113	P10N	88	1	BIO	012512	1223	BE	34 15.10 N	149 10.18 E	GPS	6170	6170						ORI NET
49NZ20120113	P10N	88	1	BIO	012512	1423	EN	34 18.71 N	149 7.41 E	GPS	6186	6185						
49NZ20120113	P10N	88	1	ROS	012512	1506	BE	34 14.84 N	149 10.15 E	GPS	6168	6169						
49NZ20120113	P10N	88	1	BUC	012512	1514	UN	34 14.88 N	149 10.23 E	GPS	6170	6168					1,9,22,31,33,34,82,89	18.3C
49NZ20120113	P10N	88	1	ROS	012512	1638	BO	34 15.25 N	149 10.04 E	GPS	6173	6173	11	6152	6282	36	1-8,23,24,26,27,31,33,34,82	
49NZ20120113	P10N	88	1	ROS	012512	1921	EN	34 15.99 N	149 9.86 E	GPS	6169	6168						
49NZ20120113	P10N	88	1	UNK	012512	1942	UN	34 13.64 N	149 10.83 E	GPS	6175	6176						AIR 13CH4/CH3D/15N2O/N218O/COS SMPL
49NZ20120113	P10N	86	2	ROS	012512	2151	BE	33 44.84 N	149 19.77 E	GPS	6165	6164						
49NZ20120113	P10N	86	2	BUC	012512	2202	UN	33 44.66 N	149 19.74 E	GPS	6166	6164					1,9,22,89	18.1C
49NZ20120113	P10N	86	2	ROS	012512	2329	BO	33 44.23 N	149 19.38 E	GPS	6170	6171	11	6180	6284	36	1-8,23,24,26,27,92	
49NZ20120113	P10N	86	2	ROS	012612	0212	EN	33 43.30 N	149 18.51 E	GPS	6173	6171						
49NZ20120113	P10N	87	1	ROS	012612	0401	BE	33 59.87 N	149 18.58 E	GPS	6222	6220						
49NZ20120113	P10N	87	1	BUC	012612	0410	UN	33 59.78 N	149 18.56 E	GPS	6221	6222					1	18.0C
49NZ20120113	P10N	87	1	ROS	012612	0535	BO	33 59.84 N	149 18.29 E	GPS	6219	6220	99	6152	6285	36	1-8,27,93	
49NZ20120113	P10N	87	1	ROS	012612	0749	EN	33 59.61 N	149 17.35 E	GPS	6203	6203						
49NZ20120113	P10N	90	1	ROS	012712	0410	BE	34 45.42 N	148 52.10 E	GPS	6141	6135						
49NZ20120113	P10N	90	1	BUC	012712	0424	UN	34 45.70 N	148 52.23 E	GPS	6141	6134					9,22,89	17.6C
49NZ20120113	P10N	90	1	ROS	012712	0431	BO	34 45.83 N	148 52.32 E	GPS	6143	6136	-9	766	774	27	9,22,89	FOR R.N.
49NZ20120113	P10N	90	1	ROS	012712	0459	EN	34 46.46 N	148 52.56 E	GPS	6142	6137						
49NZ20120113	901	901	1	CTD	012812	0420	BE	34 37.00 N	145 48.95 E	GPS	6002	6003						LOAD TEST WITH 4 NISKIN BTLS
49NZ20120113	901	901	1	CTD	012812	0601	BO	34 36.63 N	145 48.98 E	GPS	5977	5976	11	5993	6120	0		
49NZ20120113	901	901	1	CTD	012812	0809	EN	34 35.19 N	145 48.39 E	GPS	5948	5948						
49NZ20120113	P10N	89	1	XCT	012912	1446	DE	34 29.82 N	149 1.25 E	GPS	6145	6146						TSK XCTD-2 #11022004, FAILED (889DB)
49NZ20120113	P10N	89	2	XCT	012912	1501	DE	34 30.80 N	149 1.12 E	GPS	6080	6082						TSK XCTD-2 #11022001, FAILED (655DB)
49NZ20120113	P10N	89	3	XCT	012912	1514	DE	34 31.05 N	149 0.62 E	GPS	6124	6125						TSK XCTD-2 #11021998, BY HAND LAUNCHER, FAILED (823DB)
49NZ20120113	P10N	89	4	XCT	012912	1521	DE	34 31.15 N	149 0.38 E	GPS	6137	6134						TSK XCTD-2 #11022002, BY HAND LAUNCHER, FAILED (846DB)
49NZ20120113	P10N	90	2	ROS	013012	1420	BE	34 45.61 N	148 52.24 E	GPS	6141	6140						SMALL (12x12L) CTD SYSTEM
49NZ20120113	P10N	90	2	BUC	013012	1434	UN	34 46.14 N	148 52.47 E	GPS	6145	6138					1,90,91	17.6C
49NZ20120113	P10N	90	2	ROS	013012	1559	BO	34 47.82 N	148 53.55 E	GPS	6151	6147	11	6363	6247	12	1-8,12,13,23,24,26,27,90,91,92	
49NZ20120113	P10N	90	2	ROS	013012	1801	EN	34 49.82 N	148 54.46 E	GPS	6145	6142						
49NZ20120113	P10N	90	3	ROS	013012	1902	BE	34 45.32 N	148 52.56 E	GPS	6148	6142						
49NZ20120113	P10N	90	3	ROS	013012	1953	BO	34 46.16 N	148 53.85 E	GPS	6146	6142	-9	2990	2931	24	1-8,12,13,23,24,26,27,90,91,92	
49NZ20120113	P10N	90	3	ROS	013012	2108	EN	34 47.46 N	148 55.05 E	GPS	6156	6151						
49NZ20120113	P10N	91	1	XCT	013012	2251	DE	35 5.09 N	148 39.53 E	GPS	6070	6061						TSK XCTD-2 #11021999
49NZ20120113	P10N	92	1	ROS	013112	0045	BE	35 24.91 N	148 27.29 E	GPS	5956	5955						SAMLL (12x12L) CTD SYSTEM
49NZ20120113	P10N	92	1	BUC	013112	0059	UN	35 24.95 N	148 27.27 E	GPS	5958	5954					1,9,22,89	14.7C
49NZ20120113	P10N	92	1	ROS	013112	0222	BO	35 25.19 N	148 27.23 E	GPS	5948	5944	11	5941	6056	12	1-8,23,24,26,27,92,93	
49NZ20120113	P10N	92	1	ROS	013112	0408	EN	35 25.36 N	148 27.42 E	GPS	5952	5952						

49NZ20120113	P10N	92	2	ROS	013112	0454	BE	35 24.88 N	148 27.26 E	GPS	5962	5960						
49NZ20120113	P10N	92	2	ROS	013112	0528	EN	35 24.98 N	148 27.20 E	GPS	5961	5958						ABORTED DUE TO A MISTAKEN SETTING
49NZ20120113	P10N	92	3	ROS	013112	0534	BE	35 24.97 N	148 27.19 E	GPS	5959	5956						
49NZ20120113	P10N	92	3	ROS	013112	0618	BO	35 25.14 N	148 27.25 E	GPS	5953	5951	-9	2961	3000	24	1-8,23,24,26,27,92,93	
49NZ20120113	P10N	92	3	ROS	013112	0730	EN	35 25.27 N	148 27.28 E	GPS	5950	5947						
49NZ20120113	P10N	93	1	XCT	013112	0936	DE	35 45.56 N	148 14.44 E	GPS	5786	5786						TSK XCTD-2 #11021995
49NZ20120113	P10N	94	1	ROS	013112	1126	BE	36 4.92 N	148 2.64 E	GPS	5803	5801						SAMLL (12x12L) CTD SYSTEM
49NZ20120113	P10N	94	1	BUC	013112	1140	UN	36 4.93 N	148 2.82 E	GPS	5802	5803					1,9,22,89	12.8C
49NZ20120113	P10N	94	1	ROS	013112	1256	BO	36 4.83 N	148 2.84 E	GPS	5806	5804	12	5791	5901	12	1-8,23,24,26,27,92	
49NZ20120113	P10N	94	1	ROS	013112	1438	EN	36 4.68 N	148 2.67 E	GPS	5800	5797						
49NZ20120113	P10N	94	2	ROS	013112	1523	BE	36 5.04 N	148 2.45 E	GPS	5811	5810						
49NZ20120113	P10N	94	2	ROS	013112	1534	BO	36 5.05 N	148 2.58 E	GPS	5813	5810	-9	423	433	30	22,89	FOR R.N.
49NZ20120113	P10N	94	2	ROS	013112	1557	EN	36 5.00 N	148 2.61 E	GPS	5813	5809						
49NZ20120113	P10N	94	3	ROS	013112	1652	BE	36 5.06 N	148 2.58 E	GPS	5813	5811						
49NZ20120113	P10N	94	3	ROS	013112	1741	BO	36 5.00 N	148 2.60 E	GPS	5809	5807	-9	3042	3079	36	1-8,22,23,24,26,27,34,89,92,93	
49NZ20120113	P10N	94	3	ROS	013112	1855	EN	36 4.85 N	148 2.51 E	GPS	5804	5802						
49NZ20120113	P10N	95	1	XCT	013112	2123	DE	36 24.96 N	147 50.09 E	GPS	5724	5724						TSK XCTD-2 #11021996
49NZ20120113	P10N	96	1	ROS	013112	2332	BE	36 44.79 N	147 37.74 E	GPS	5683	5683						
49NZ20120113	P10N	96	1	BUC	013112	2343	UN	36 44.67 N	147 37.63 E	GPS	5686	5686					1,9,22,89	11.9C
49NZ20120113	P10N	96	1	ROS	020112	0100	BO	36 44.35 N	147 37.45 E	GPS	5689	5689	9	5681	5795	36	1-8,23,24,26,27,93	
49NZ20120113	P10N	96	1	ROS	020112	0326	EN	36 44.79 N	147 37.13 E	GPS	5687	5686						
49NZ20120113	P10N	97	1	XCT	020112	0523	DE	37 4.68 N	147 24.49 E	GPS	5624	5625						TSK XCTD-2 #11021849
49NZ20120113	P10N	98	1	ROS	020112	0915	BE	37 25.03 N	147 11.72 E	GPS	5674	5672						
49NZ20120113	P10N	98	1	ROS	020112	0934	BO	37 25.07 N	147 11.83 E	GPS	5677	5674	-9	793	799	36	9,22,89	FOR R.N.
49NZ20120113	P10N	98	1	ROS	020112	1001	EN	37 25.03 N	147 11.90 E	GPS	5677	5675						
49NZ20120113	P10N	98	1	BIO	020112	1030	BE	37 25.10 N	147 12.08 E	GPS	5668	5664						ORI NET
49NZ20120113	P10N	98	1	BIO	020112	1228	EN	37 25.00 N	147 9.00 E	GPS	5689	5686						
49NZ20120113	P10N	98	2	ROS	020212	2332	BE	37 25.15 N	147 11.58 E	GPS	5680	5678						
49NZ20120113	P10N	98	2	BUC	020212	2348	UN	37 25.20 N	147 11.57 E	GPS	5680	5678					1,9,22,89	10.3C
49NZ20120113	P10N	98	2	ROS	020312	0105	BO	37 25.00 N	147 11.59 E	GPS	5674	5671	10	5664	5777	35	1-8,12,13,23,24,26,27,31,33,92,93	
49NZ20120113	P10N	98	2	ROS	020312	0340	EN	37 24.83 N	147 11.33 E	GPS	5671	5669						
49NZ20120113	P10N	99	1	XCT	020312	0549	DE	37 44.88 N	146 58.50 E	GPS	5549	5548						TSK XCTD-2 #11021850
49NZ20120113	P10N	100	1	ROS	020312	0759	BE	38 4.87 N	146 45.33 E	GPS	5374	5372						
49NZ20120113	P10N	100	1	BUC	020312	0809	UN	38 4.80 N	146 45.18 E	GPS	5375	5377					1,9,22,89	10.4C
49NZ20120113	P10N	100	1	ROS	020312	0924	BO	38 4.21 N	146 44.65 E	GPS	5421	5421	10	5411	5488	34	1-8,27,34,93	
49NZ20120113	P10N	100	1	ROS	020312	1127	EN	38 3.23 N	146 43.47 E	GPS	5410	5411						
49NZ20120113	P10N	101	1	XCT	020312	1335	DE	38 24.76 N	146 32.25 E	GPS	5457	5458						TSK XCTD-2 #11021851
49NZ20120113	P10N	102	1	ROS	020312	1542	BE	38 45.21 N	146 18.99 E	GPS	5295	5295						
49NZ20120113	P10N	102	1	ROS	020312	1600	BO	38 45.13 N	146 18.98 E	GPS	5297	5295	-9	773	775	18	22,89	FOR R.N.
49NZ20120113	P10N	102	1	ROS	020312	1628	EN	38 45.06 N	146 18.90 E	GPS	5291	5291						
49NZ20120113	P10N	102	2	ROS	020312	1715	BE	38 45.20 N	146 19.05 E	GPS	5289	5290						
49NZ20120113	P10N	102	2	BUC	020312	1722	UN	38 45.17 N	146 19.07 E	GPS	5293	5292					1,9,22,89	10.1C
49NZ20120113	P10N	102	2	ROS	020312	1835	BO	38 45.15 N	146 18.86 E	GPS	5294	5294	10	5281	5380	34	1-8,23,24,26,27,90,92	
49NZ20120113	P10N	102	2	ROS	020312	2036	EN	38 45.00 N	146 18.94 E	GPS	5292	5290						
49NZ20120113	P10N	103	1	XCT	020312	2226	DE	39 4.97 N	146 4.98 E	GPS	5299	5297						TSK XCTD-2 #11022000
49NZ20120113	P10N	104	1	ROS	020412	0032	BE	39 24.97 N	145 50.66 E	GPS	5271	5270						
49NZ20120113	P10N	104	1	BUC	020412	0040	UN	39 24.97 N	145 50.73 E	GPS	5269	5268					1,9,22,89	6.9C
49NZ20120113	P10N	104	1	ROS	020412	0154	BO	39 24.95 N	145 50.68 E	GPS	5271	5268	11	5261	5354	34	1-8,27,93	
49NZ20120113	P10N	104	1	ROS	020412	0355	EN	39 24.68 N	145 50.96 E	GPS	5264	5264						
49NZ20120113	P10N	105	1	XCT	020412	0542	DE	39 45.12 N	145 36.46 E	GPS	5278	5277						TSK XCTD-2 #11021846
49NZ20120113	P10N	106	1	ROS	020412	0734	BE	40 5.02 N	145 22.22 E	GPS	5374	5372						

49NZ20120113	P10N	106	1	ROS	020412	0752	BO	40 5.02 N	145 22.21 E	GPS	5374	5374	-9	826	831	27	9,22,89	FOR R.N.
49NZ20120113	P10N	106	1	ROS	020412	0820	EN	40 4.98 N	145 22.22 E	GPS	5378	5375						
49NZ20120113	P10N	106	2	ROS	020412	0916	BE	40 5.03 N	145 22.16 E	GPS	5376	5375						
49NZ20120113	P10N	106	2	BUC	020412	0924	UN	40 5.01 N	145 22.20 E	GPS	5375	5374					1,9,22,31,33,89,91	3.6C
49NZ20120113	P10N	106	2	ROS	020412	1039	BO	40 5.09 N	145 22.12 E	GPS	5381	5380	11	5371	5469	33	1-8,12,13,23,24,26,27,31,33,91-93	#31 MISS FIRE
49NZ20120113	P10N	106	2	ROS	020412	1245	EN	40 5.09 N	145 22.27 E	GPS	5376	5375						
49NZ20120113	P10N	106	2	BIO	020412	1255	BE	40 5.09 N	145 22.29 E	GPS	5375	5376						ORI NET
49NZ20120113	P10N	106	2	BIO	020412	1355	EN	40 6.35 N	145 19.97 E	GPS	5385	5384						
49NZ20120113	P10N	107	1	XCT	020412	1550	DE	40 24.90 N	145 8.08 E	GPS	5819	5820						TSK XCTD-2 #11021848
49NZ20120113	P10N	108	1	XCT	020512	0106	DE	40 45.18 N	144 53.22 E	GPS	6239	6240						TSK XCTD-2 #11021847
49NZ20120113	P10N	109	1	XCT	020512	0258	DE	40 59.92 N	144 42.15 E	GPS	6338	6340						TSK XCTD-2 #11021844
49NZ20120113	P10N	110	1	ROS	020512	0507	BE	41 15.06 N	144 30.77 E	GPS	4041	4038						
49NZ20120113	P10N	110	1	ROS	020512	0516	BO	41 15.02 N	144 30.71 E	GPS	4045	4044	-9	340	350	30	9,22,89	FOR R.N.
49NZ20120113	P10N	110	1	ROS	020512	0539	EN	41 14.93 N	144 30.54 E	GPS	4052	4051						
49NZ20120113	P10N	110	2	ROS	020512	0628	BE	41 14.97 N	144 30.74 E	GPS	4054	4053						
49NZ20120113	P10N	110	2	XCT	020512	0639	DE	41 14.91 N	144 30.67 E	GPS	4057	4057						TSK XCTD-2 #11021843
49NZ20120113	P10N	110	2	BUC	020512	0639	UN	41 14.91 N	144 30.66 E	GPS	4059	4057					1,9,22,89,90	3.9C
49NZ20120113	P10N	110	2	ROS	020512	0733	BO	41 14.78 N	144 30.64 E	GPS	4110	4110	11	4064	4132	35	1-8,9,12,13,22-24,26,27,89,90,92,93	
49NZ20120113	P10N	110	2	ROS	020512	0910	EN	41 14.35 N	144 30.56 E	GPS	4212	4210						
49NZ20120113	P10N	111	1	XCT	020512	1038	DE	41 29.97 N	144 19.30 E	GPS	2693	2694						TSK XCTD-2 #11021840
49NZ20120113	P10N	112	1	ROS	020512	1216	BE	41 45.17 N	144 7.63 E	GPS	1472	1472						
49NZ20120113	P10N	112	1	BUC	020512	1224	UN	41 45.12 N	144 7.67 E	GPS	1482	1479					1,9,22,89,90	1.6C
49NZ20120113	P10N	112	1	XCT	020512	1226	DE	41 45.12 N	144 7.69 E	GPS	1479	1475						TSK XCTD-2 #11021841
49NZ20120113	P10N	112	1	ROS	020512	1244	BO	41 45.04 N	144 7.61 E	GPS	1484	1484	10	1468	1483	16	1-8,23,24,26,27,90,93	
49NZ20120113	P10N	112	1	ROS	020512	1328	EN	41 44.86 N	144 7.43 E	GPS	1497	1496						
49NZ20120113	P10N	112	1	BIO	020512	1339	BE	41 44.81 N	144 7.47 E	GPS	1502	1502						ORI NET
49NZ20120113	P10N	112	1	BIO	020512	1542	EN	41 42.50 N	144 1.07 E	GPS	1362	1362						
49NZ20120113	P10N	113	1	XCT	020512	1717	DE	42 0.17 N	143 56.22 E	GPS	1050	1048						TSK XCTD-2 #11021842
49NZ20120113	P10N	114	1	ROS	020512	1821	BE	42 10.04 N	143 48.44 E	GPS	723	723						
49NZ20120113	P10N	114	1	BUC	020512	1831	UN	42 10.02 N	143 48.46 E	GPS	723	724					1,31,33,34,82,90	0.5C
49NZ20120113	P10N	114	1	ROS	020512	1837	BO	42 10.05 N	143 48.51 E	GPS	726	726	10	714	720	33	1-8,9,22,23,24,26,27,31,33,34,82,89,90,92	
49NZ20120113	P10N	114	1	ROS	020512	1908	EN	42 10.02 N	143 48.57 E	GPS	726	726						
49NZ20120113	P10N	114	1	UNK	020512	1915	UN	42 9.90 N	143 48.45 E	GPS	727	-9						AIR 13CH4/CH3D/15N2O/N218O/COS SMPL
49NZ20120113	P10N	115	1	ROS	020512	2116	BE	42 15.18 N	143 44.42 E	GPS	484	483						
49NZ20120113	P10N	115	1	BUC	020512	2120	UN	42 15.18 N	143 44.42 E	GPS	482	484					1,90	0.6C
49NZ20120113	P10N	115	1	ROS	020512	2130	BO	42 15.18 N	143 44.43 E	GPS	484	484	11	472	477	9	1-8,27,90,93	
49NZ20120113	P10N	115	1	ROS	020512	2147	EN	42 15.13 N	143 44.37 E	GPS	481	482						
49NZ20120113		804	1	UNK	020612	0110	BE	41 46.36 N	143 12.78 E	GPS	99	-9						3-AXIS MAGNETOMETER CALIBRATION
49NZ20120113		804	1	UNK	020612	0144	EN	41 45.76 N	143 12.05 E	GPS	104	-9						

Water sample parameters:

Number	Parameter	Mnemonic	Mnemonic for expected error
1	Salinity	SALNTY	
2	Oxygen	OXYGEN	
3	Silicate	SILCAT	SILUNC
4	Nitrate	NITRAT	NRAUNC
5	Nitrite	NITRIT	NRIUNC
6	Phosphate	PHSPHT	PHPUNC
7	Freon-11	CFC-11	
8	Freon-12	CFC-12	
9	Tritium	TRITUM	
12	14Carbon	DELC14	C14ERR
13	13Carbon	DELC13	C13ERR
22	137Cs	CS-137	
23	Total carbon	TCARBN	
24	Total alkalinity	ALKALI	
26	pH	PH	
27	Freon-113	CFC113	
31	Methane	CH4	
33	Nitrous oxide	N2O	
34	Chlorophyll a	CHLORA	
82	15N-Nitrate	15NO3	
89	134Cs	CS-134	
90	Perfluorinated acids		
91	129I	I-129	
92	Density salinity	DNSSAL	
93	Sulfur hexafluoride	SF6	

Figure captions

Figure 1	Station locations for WHP P10 revisit in 2011 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 6-hour.
Figure 4	(a) Sea surface temperature (°C), (b) sea surface salinity (psu), (c) sea surface oxygen (μmol/kg), and (d) sea surface chlorophyll a (mg/m^3) measured by the Continuous Sea Surface Water Monitoring System.
Figure 5	Difference in the partial pressure of CO_2 between the ocean and the atmosphere, ΔpCO_2.
Figure 6	Surface current at 100 m depth measured by ship board acoustic Doppler current profiler (ADCP).
Figure 7	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 8	CTD salinity (psu) cross section calibrated by bottle salinity measurements. Vertical exaggeration is same as Figure 7.
Figure 9	Absolute salinity (g/kg) cross section calculated by using CTD salinity data. Vertical exaggeration is same as Figure 7.
Figure 10	Density (σ_0) (kg/m^3) cross section calculated by using CTD temperature and salinity data. Vertical exaggeration is same as Figure 7. (a) EOS-80 and (b) TEOS-10 definition.
Figure 11	Same as Figure 10 but for σ_4 (kg/m^3). (a) EOS-80 and (b) TEOS-10 definition.
Figure 12	Neutral density (γ^n) (kg/m^3) cross section calculated by using CTD temperature and salinity data. Vertical exaggeration is same as Figure 7.
Figure 13	Cross section of CTD oxygen (μmol/kg). Vertical exaggeration is same as Figure 7.
Figure 14	Cross section of CTD chlorophyll a (mg/m^3). Vertical exaggeration of the upper 1000 m section is same as Figure 7.
Figure 15	Cross section of bottle sampled dissolved oxygen (μmol/kg). Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.
Figure 16	Silicate (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.
Figure 17	Nitrate (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.
Figure 18	Nitrite (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration of the upper 1000 m section is same as Figure 7.
Figure 19	Phosphate (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 20 Dissolved inorganic carbon (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 21 Total alkalinity (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 22 pH cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 23 CFC-11 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 24 CFC-12 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 25 CFC-113 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 26 Cross section of current velocity (cm/s) normal to the cruise track measured by LADCP (eastward is positive). Vertical exaggeration is same as Figure 7.

Figure 27 Difference in potential temperature (°C) between results from the previous cruise and the revisit in 2011 (December 2011 – February 2012). The previous cruise is (a) WOCE (October – November 1993) and (b) the first revisit (May – June 2005). 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 °C. Vertical exaggeration is same as Figure 7.

Figure 28 Same as Fig. 27, but for salinity (psu). CTD salinity data with SSW batch correction1 were used. On white areas differences in salinity do not exceed the detection limit of 0.002 psu.

Figure 29 Same as Fig. 27, but for dissolved oxygen (μmol/kg). CTD oxygen data were used. On white areas differences in dissolved oxygen do not exceed the detection limit of 2 μmol/kg.

Note

1. As for the traceability of SSW to Kawano's value (Kawano et al., 2006), the offset for the batches P114 (WOCE P10 stations from 1 to 12), P120 (WOCE P10 stations from 13 to 74), and P145 (the revisit in 2005) and P153 (the revisit in 2011) are 0.0020, –0.0009, –0.0009 and 0.0004, respectively. The offset values for the recent batches are listed in Table A1 (Uchida et al., in preparation). For P120 of WOCE P10 cruise, salinity was corrected with an offset of –0.0015 (cruise report of WOCE P10). Therefore, the salinity data are corrected with an offset of 0.0006 for the stations from 13 to 74 of WOCE P10.

Table A1. SSW batch to batch differences from P145 to P155 (Uchida et al., in preparation). The difference of P145 is reevaluated.

Batch no.	Production date	K15	Sp	Batch to batch difference ($\times 10^{-3}$)	
				Mantyla's standard	Kawano's standard
P145	2004/07/15	0.99981	34.9925	–2.2	–0.9
P146	2005/05/12	0.99979	34.9917	–2.7	–1.4
P147	2006/06/06	0.99982	34.9929	–1.8	–0.5
P148	2006/10/01	0.99982	34.9929	–1.2	0.1
P149	2007/10/05	0.99984	34.9937	–0.6	0.7
P150	2008/05/22	0.99978	34.9913	–0.5	0.8
P151	2009/05/20	0.99997	34.9984	–1.3	0.0
P152	2010/05/05	0.99981	34.9926	–1.3	0.0
P153	2011/03/08	0.99979	34.9918	–0.9	0.4
P154	2011/10/20	0.99990	34.9961	–0.7	0.6
P155	2012/09/19	0.99981	34.9925	–1.1	0.2

References

Kawano, T., M. Aoyama, T. Joyce, H. Uchida, Y. Takatsuki and M. Fukasawa (2006): The latest batch-to-batch difference table of standard seawater and its application to the WOCE onetime sections, *J. Oceanogr.*, 62, 777–792.

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