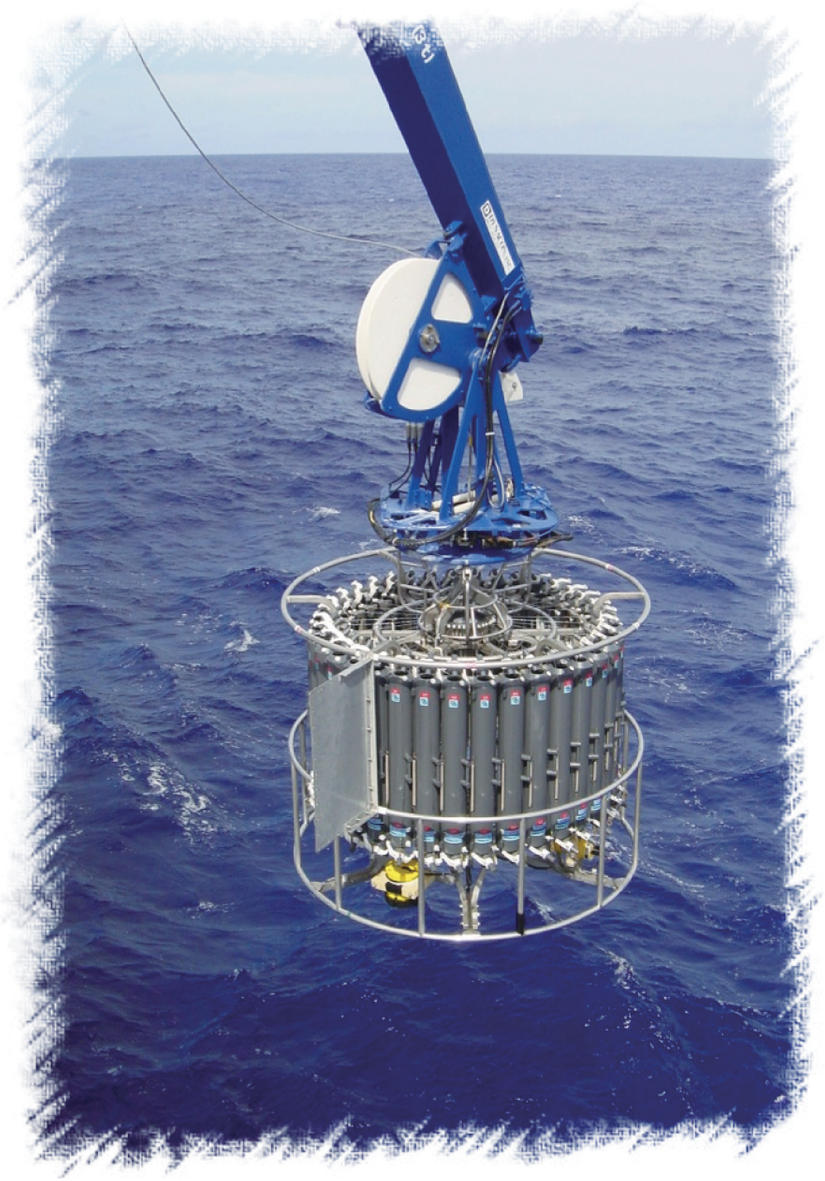
WHP P10 REVISIT DATA BOOK

Field Activity of JAMSTEC towards International Repeat Hydrography and Carbon Program

WHP P10 REVISIT DATA BOOK



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Takeshi Kawano (JAMSTEC),
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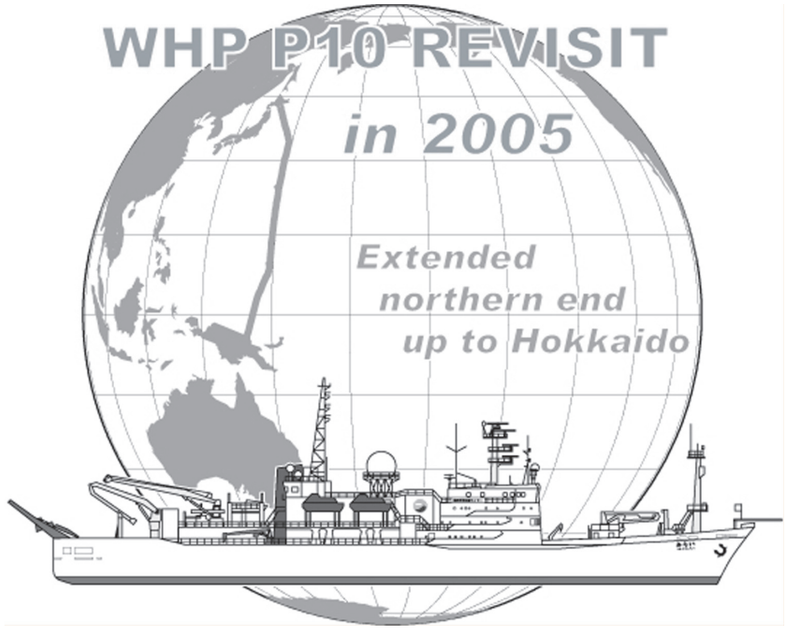

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Preface

The observation line that we occupied during the period from 25th May to 2nd July, 2005 was mostly along the meridian of 149°20'E and was overlaid on WOCE Hydrographic Program: WHP P10 line with the northern extension to the coast of the Hokkaido, Japan. As the result, 30 new stations were added to the former P10 stations and the total number of WHP stations has increased to 124.

P10 is the third WHP line that IORGC/JAMSTEC occupied by following the CLIVAR/Carbon Repeat Hydrography Program (currently renamed as International Repeat Hydrography and Carbon Program: IRHC), which was advocated at OceanObs99.

The objectives of the program were defined as follows:

Comprehensive objectives of repeat hydrography were proposed/defined

1) to investigate inter annual and longer-term variations in the ocean circulation and associated net property transports and their divergences,
2) to quantify net changes in water mass inventories and renewal rates on seasonal to decadal time series, and to explore their relationships to estimated ocean transport divergences and air-sea exchanges.

After OceanObs99, the Argo project has started and is getting the right track now. Argo has much more frequency of observation than any other hydrographic observation under IRHC. However, hydrographic observation still remains and will remain to be the only mean to directly measure the full suite of water characteristics with vertical high resolution and with high accuracy of measurements. Therefore, the IRHC and Argo Project are complementary to each other toward understanding of phenomena at shallower and intermediate depths. On the other hand, the unique long-term objectives of IRHC could be sharpened as "To investigate inter-annual and long-term variations in the ocean circulation and associated net property transports and their divergence, and to explore their relationships to air-sea exchange". These unique objectives can be supported only through a global network of the core ship-based hydrography, which follows the traditional WOCE manner with full suite of its measurements.

The Ocean General Circulation Observational Research Program of IORGC*/JAMSTEC** has a plan to carry out seven core ship-based hydrography along WHP P6, A10, I4+I3, P10, P3, P1 and P14 until 2007. Of these lines, re-visits of P6, A10, I4+I3, P10 and P3 were completed and quite a few excellent scientific results have already published by numerous number of scientists, not only of IORGC but also of other institutions throughout the world. Anyone can refer and use data from these re-visits without any restriction through data books we already published and through web sites of IORGC ***, CCHDO****, and CDIAC*****.

Lastly, we would heartily ask favors of all scientists to refer these data books as often as possible. Such references are the only proof that this repeat hydrography activity is closely connected to the science and makes all of us brave enough to continue to maintain the IRHC net work.

On Christmas Day of 2006, at Yokosuka.

Masao Fukasawa

Deputy Director-General IORGC/JAMSTEC,

Program Director Ocean General Circulation Observational Research Program

IORGC/JAMSTEC

*Institute of Observational Research for Global Change

**Japan Agency for Marine-Earth Science and Technology

*** http://www.jamstec.go.jp/iorgc/ocorp/data/post-woce.html

****CLIVAR and Carbon Hydrographic Data Office (http://whpo.ucsd.edu/)

*****Carbon Dioxide Information Analysis Center (http://cdiac.ornl.gov/)

1 Cruise Narrative

1.1 Highlight

WOCE Line Designation: P10 (Extended to northern end of Japanese mainland up to Hokkaido)

Expedition Designation: MR05-02

Chief Scientist and Affiliation:

Takeshi Kawano

Institute of Observational Research for Global Change (IORGC)

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

2-15, Natsushima, Yokosuka, 237-0061, Japan

Tel: +81-46-867-9471, Fax: +81-46-867-9455

E-mail: kawanot@jamstec.go.jp

Ship: R/V MIRAI

Ports of Call: Sekinehama, Japan – Hachinohe, Japan – Guam, U.S.A.

Cruise Dates: May 25, 2005 –July 2, 2005

Number of Stations: 124 stations for CTD/Carousel Water Sampler

Geographic boundaries: 143° 44.01’ E - 149° 23.31’ E

4° 00.90’ S - 42° 15.20’ N

Floats and drifters deployed: 2 Argo Floats

Mooring deployed or recovered mooring: NONE

1.2 Cruise Summary

(1) Geographic boundaries

MR05-02 occupied stations along about 149° 20’ E, from 42° 15’ N to 4° 00’ S.

(2) Station occupied

A total of 124 stations were occupied using a Sea-Bird Electronics 36 bottle carousel equipped with 12 liter Niskin X water sample bottles, a SBE911plus equipped with SBE35 deep ocean standards thermometer, SBE43 oxygen sensor, Seapoint sensors Inc. Chlorophyll Fluorometer and Benthos Inc. Altimeter and RDI Monitor ADCP. Cruise track and station location are shown in Fig. 1.2.1. The stations south of 28 °N were revist of the previous P10 cruise conducted in 1994. The stations north of 34 °N were designed to trace the track of Jason-1 altimeter.

(3) Sampling and measurements

Water samples were analyzed for salinity, oxygen, nutrients, CFC11, CFC12, CFC113, total alkalinity, DIC and pH. The sampling layers in dbar were 10, 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000, 3250, 3500, 3750, 4000, 4250, 4500, 4750, 5000, 5250, 5500, 5750 and bottom (minus 10 m). Samples for PON, ^{14}C, ^{13}C, ^{15}N, Pu and ^{137}Cs were also collected. The bottle depth diagram is shown in Fig. 1.2.2. Underway measurements of pCO_2, temperature, salinity, oxygen, surface current, bathymetry and meteorological parameters were made along the cruise track. Biological parameters such as chlorophyll a and nitrogen fixation rate were measured at the selected stations.

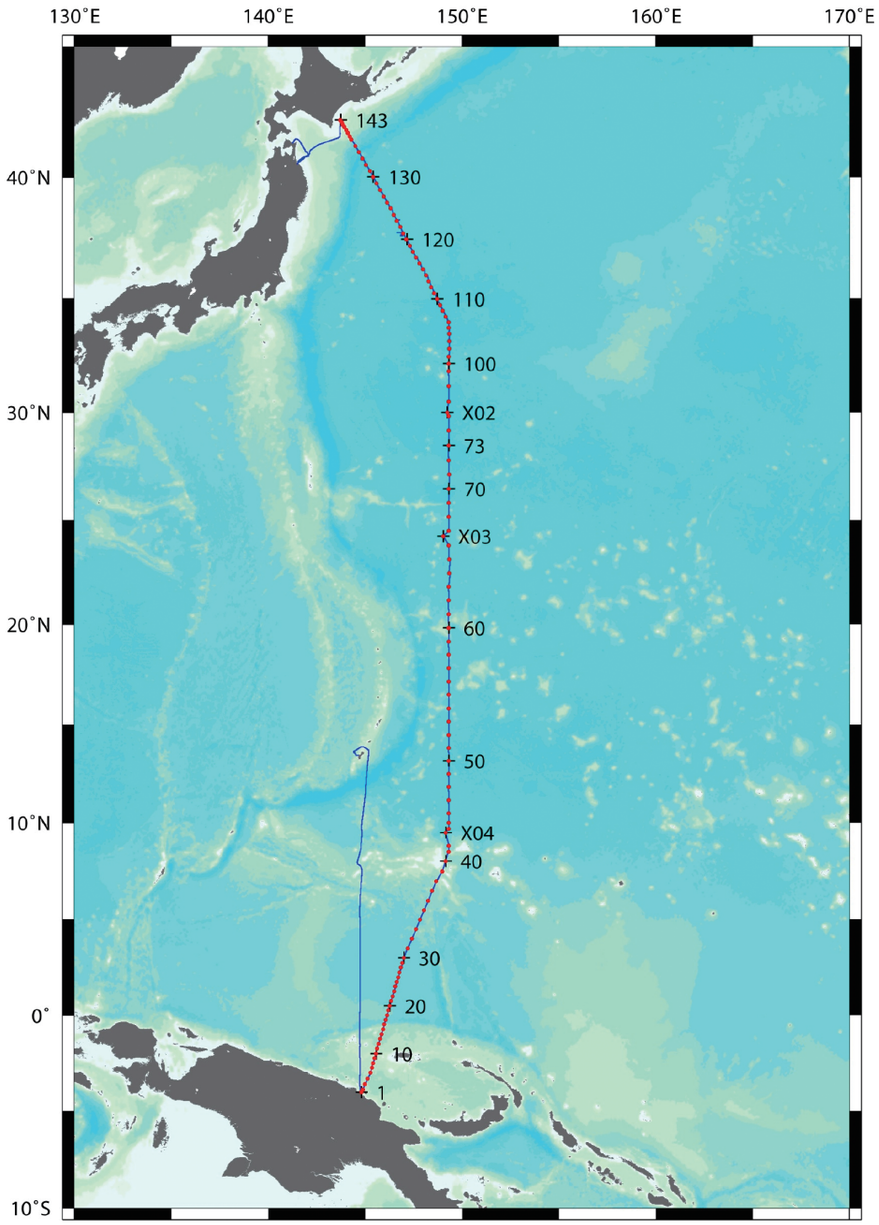

Figure 1.2.1. Cruise track.

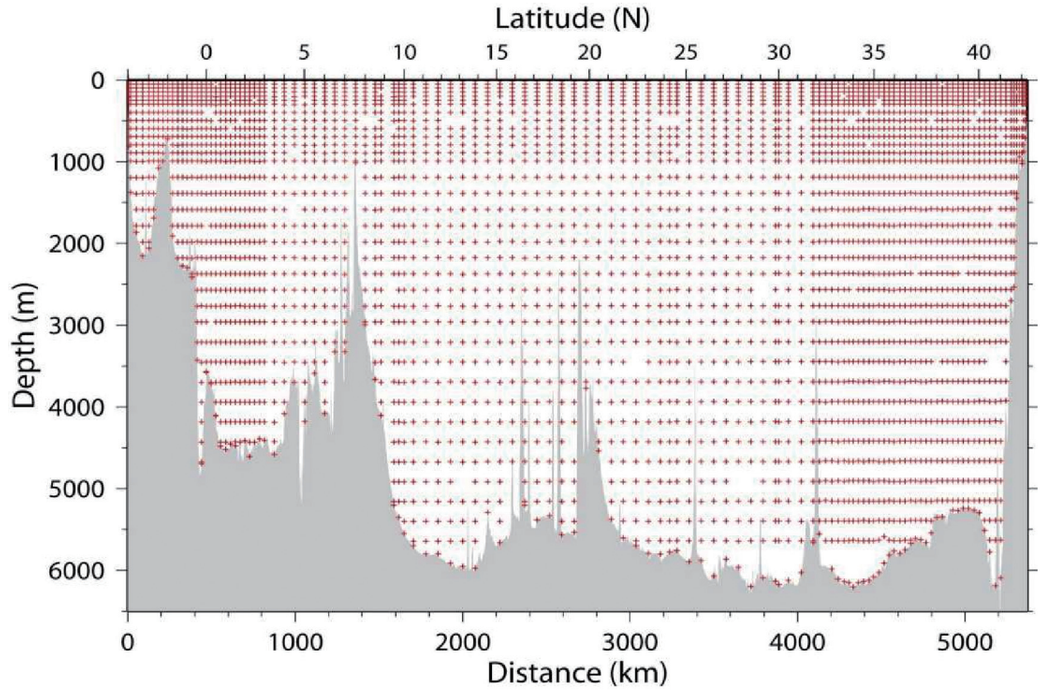

Figure 1.2.2. Bottle depth diagram.

(4) Floats and Drifters deployed

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

Table 1.2.1. Launched positions of the ARGO floats.

Float S/N	ARGOS PTT ID	Date and Time of Reset (UTC)	Date and Time of Launch (UTC)	Location of Launch	CTD St. No.
1575	23732	15:03, Jun. 13	17:09, Jun. 13	19-50.14 N, 149-19.62 E	P10-60
223	6497	19:37, Jun. 15	23:44, Jun. 15	15-15.25 N, 149-20.00 E	P10-53

(5) Moorings deployed or recovered

No mooring was deployed nor recovered during the cruise.

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

The principal investigator (PI) and the person in charge responsible for the 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	Yasushi Yoshikawa (JAMSTEC) *yoshikaway@jamstec.go.jp*	Yasutaka Imai (GODI)
Bathymetry	Takeshi Matsumoto (Univ. Ryukyus) *tak@sci.u-ryukyu.ac.jp*	Yasutaka Imai (GODI)
Meteorology	Kunio Yoneyama (JAMSTEC) *yoneyamak@jamstec.go.jp*	Yasutaka Imai (GODI)
T-S	Takeshi Kawano (JAMSTEC) *kawanot@jamstec.go.jp*	Takayoshi Seike (MWJ)
pCO_2	Akihiko Murata (JAMSTEC) *akihiko.murata@jamstec.go.jp*	Mikio Kitada (MWJ)
Hydrography		
CTD/O_2	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Satoshi Ozawa (MWJ)
Salinity	Takeshi Kawano (JAMSTEC) *kawanot@jamstec.go.jp*	Fujio Kobayashi (MWJ)
Oxygen	Ikuo Kaneko (JAMSTEC) *Ikuo-kaneko@jamstec.go.jp*	Takayoshi Seike (MWJ)
Nutrients	Michio Aoyama (MRI) *maoyama@mri-jma.go.jp*	Junko Hamanaka (MWJ)
DIC	Akihiko Murata (JAMSTEC) *akihiko.murata@jamstec.go.jp*	Mikio Kitada (MWJ)
Alkalinity	Akihiko Murata (JAMSTEC) *akihiko.murata@jamstec.go.jp*	Fuyuki Shibata (MWJ)
pH	Akihiko Murata (JAMSTEC) *akihiko.murata@jamstec.go.jp*	Taeko Ohama (MWJ)
CFCs	Kenichi Sasaki (JAMSTEC) *ksasaki@jamstec.go.jp*	Katsunori Sagishima (MWJ)
LADCP	Shinya Kouketsu (JAMSTEC) *skouketsu@jamstec.go.jp*	Shinya Kouketsu (JAMSTEC)
$\Delta^{14}C$ & $\delta^{13}C$	Yuichiro Kumamoto(JAMSTEC) *kumamoto@jamstec.go.jp*	Akihiko Murata (JAMSTEC)
^{137}Cs & Pu	Michio Aoyama (MRI) *maoyama@mri-jma.go.jp*	Akihiko Murata (JAMSTEC)
^{15}N	Hisayuki Yoshikawa (Hokkaido Univ.) *hyoshika@ees.hokudai.ac.jp*	Tomomi Takamura (Hokkaido Univ.)
Biology	Ken Furuya (Univ. Tokyo) *furuya@fs.a.u-tokyo.ac.jp*	Satoshi Kitajima (Univ. Tokyo)
Floats, Drifters		
Argo float	Nobuyuki Shikama (JAMSTEC) *nshikama@jamstec.go.jp*	Naoko Takahashi (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.

Univ. Ryukyus: University of the Ryukyus

1.4 Scientific Program and Methods

(1) Objectives of MR05-02 cruise project

It is well known that the oceans play a central role in determining global climate. However, heat and material transports in the ocean and their temporal changes have not yet been sufficiently quantified. Therefore, the global climate change is not understood satisfactorily. The purposes of this research are to evaluate heat and material transports including carbon, nutrients, etc., in the North Pacific and to detect its long term changes and basin-scale biogeochemical changes since the 1990s.

P10 is the hydrographic section nominally along 149 °E from Hokkaido, Japan, to the coast of Papua New Guinea. The P10 cruise was the first in two WHP re-visit cruise aboard R/V MIRAI in 2005 followed by P3.

The other objectives of this cruise are as follows;

1) to observe surface meteorological and hydrogical parameters as a basic data of the meteorology and the oceangraphy,
2) to observe sea bottom topography, gravity and magnetic fields along the cruise track to understand the dynamics of ocean plate and the accompanying geophysical activities,
3) to contribute to establishment of data base for model validation,
4) ARGO sensor calibration and its deployment in the western Pacific.

(2) Cruise overview

MR05-02 cruise was carried out during the period from May 25, 2005 to July 2, 2005. The cruise started from the coast of Hokkaido and sailed towards southeast along the track of Jason-1 (TOPEX/POSEIDON). This line was observed several times during the period from 1997–2000 as a part of the SAGE (Sub-Arctic Gyre Experiment) and called OICE (Oyashio Intensive observation line off Cape Eriomo). The cruise course was changed southward at Station 105 (33° 45'N, 149° 20'E) and the stations from Station 73 (28° 30'N, 149° 20'E) were revisit of WOCE Hydrographic Program section P10. A total of 124 stations were observed. At each station, full-depth CTD profile and up to 36 water samples were taken and analyzed. Water samples were obtained from fixed layers with 12-liter Niskin bottles attached to 36-position SBE carousel water sampler. The sampling layers were 10, 50, 100, 150, 200, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000, 3250, 3500, 3750, 4000, 4250, 4500, 4750, 5000, 5250, 5500, 5750 dbar and about 10 dbar above the bottom. Scientists of JAMSTEC and Meteorological Research Institute and technicians of Marine Works Japan Ltd. (MWJ) were responsible for analyzing water sample for salinity, dissolved oxygen, nutrients, CFCs, total carbon contents, alkalinity and pH. They also contributed to sampling for total organic carbon, radiocarbon and so on. Students of University of Tokyo and Hokkaido University joined the cruise for their research on chemical and biological oceanography. A scientist from University of the Ryukyus was a principal investigator for geological parameters (topography, geo-magnetic field and gravity). Technicians from Global Ocean Development Inc. (GODI) had responsibility on a part of underway measurements such as current velocity by Acoustic Doppler Current Profiler (ADCP) geological parameters (topography, geo-magnetic field and gravity), and meteorological parameters. Two ARGO floats prepared by JAMSTEC were launched by MWJ technicians and ship crew.

(3) Cruise narrative

R/V Mirai departed Sekinehama (Japan) on May 25, 2005. She called on the port of Hachinohe (Japan) on May 26, 2005 for bunkering. She arrived at the first station on May 27 and made a cast for 445m. Before the first station, all watchstanders were drilled in the method of sample drawing. We made a cast at Station P10-1 on June 28, 2005 and then went to Guam, U.S.A. We observed 124 stations along approximately 149° 20'E, which is, namely WHP P10. She arrived at Guam on July 2, 2005.

1.5 Major Problems and Goals not Achieved

Water sampler miss-fired 15 times, and consequently, samples were not obtained at 13 layers.

1.6 List of Participants

The members of the scientific party are listed in Table 1.6.1 along with their main tasks undertaken on the cruise.

Table 1.6.1. List of cruise participants.

Name	Main tasks	Affiliation
Hideyuki FUTAMURA	Water Sampling	MWJ
Junko HAMANAKA	Nutrients	MWJ
Miyo IKEDA	Water Sampling	MWJ
Yasutaka IMAI	Meteorology	GODI
Tetsuya INABA	Water Sampling	MWJ
Yoshiko ISHIKAWA	Carbon	MWJ
Kenichi KATAYAMA	Salinity	MWJ
Takeshi KAWAO	Chief Scientist / Salinity	IORGC/JAMSTEC
Mikio KITADA	Carbon	MWJ
Satoshi KITAJIMA	Biology	University of Tokyo
Fujio KOBAYASHI	Salinity	MWJ
Shinya KOUKETSU	LADCP/ADCP	IORGC/JAMSTEC
Asako KUBO	Nutrients	MWJ
Kazuma KUDO	Water Sampling	MWJ
Akihiko MURATA	Carbon	IORGC/JAMSTEC
Kimiko NISHIJIMA	Dissolved Oxygen	MWJ
Tomohide NOGUCHI	CTD	MWJ
Taeko OHAMA	Carbon	MWJ
Shinya OKUMURA	Meteorology	GODI
Kentaro OYAMA	CTD	MWJ
Ryo OYAMA	Meteorology	GODI
Satoshi OZAWA	CTD	MWJ
Katsunori SAGISHIMA	CFCs	MWJ
Kenichi SASAKI	CFCs	MIO/JAMSTEC
Kenichiro SATO	Chief Technologist / Water Sampling	MWJ
Takayoshi SEIKE	Dissolved Oxygen	MWJ
Fuyuki SHIBATA	Carbon	MWJ
Naoko TAKAHASHI	CTD	MWJ
Tomomi TAKAMURA	C-13	Hokkaido University
Ayumi TAKEUCHI	Nutrients	MWJ
Tatsuya TANAKA	Salinity	MWJ
Tomokazu TANIGUCHI	Water Sampling	MWJ
Hiroshi UCHIDA	LADCP/CTD	IORGC/JAMSTEC
Satoshi UDA	Water Sampling	MWJ
Masahide WAKITA	CFCs	MIO/JAMSTEC
Hideki YAMAMOTO	CFCs	MWJ
Ai YASUDA	Dissolved Oxygen	MWJ
Masashi YASUNAGA	Water Sampling	MWJ
Atsushi YOSHIMURA	Water Sampling	MWJ

GODI: Global Ocean Development Inc.
MWJ: Marine Works Japan Ltd.
JAMSTEC: Japan Agency for Marine-Earth Science and Technology
IORGC: Institute of Observational Research for Global Change
MIO: Mutsu Institute for Oceanography

2 Underway Measurements

2.1 Navigation and Bathymetry

2 August 2005

(1) Personnel

Takeshi Matsumoto (University of the Ryukyus), PI for bathymetry

Yasutaka Imai (GODI)

Shinya Okumura (GODI)

Ryo Ohyama (GODI)

(2) Navigation

(2.1) Overview of the equipment

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

(2.2) Data period

07:00, 25 May 2005 to 00:00, 2 July 2005 (UTC)

(3) Bathymetry

(3.1) Overview of the equipment

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

(3.2) System configuration and performance

System:	SEABEAM 2112.004
Frequency:	12 kHz
Transmit beam width:	2 degree
Transmit power:	20 kW
Transmit pulse length:	3 to 20 msec.
Depth range:	100 to 11,000 m
Beam spacing:	1 degree athwart ship
Swath width:	150 degree (max)
	120 degree to 4,500 m
	100 degree to 6,000 m
	90 degree to 11,000 m
Depth accuracy	Within < 0.5 % of depth or ±1m, whichever is greater, over the entire swath.
	(Nadir beam has greater accuracy; typically within < 0.2 % of depth or ±1m, whichever is greater)

(3.3) Data period

Bathymetric survey was carried out on the CTD observation line during the cruise.

26 May 2005 (P10N_143) to 28 June 2005 (P10_1)

(3.4) Data processing

(3.4.1) Editing for the navigation data

Erroneous data in the navigation data are manually removed (by using “mbedit” module of the mbsystem) and linearly interpolated.

(3.4.2) Sound velocity correction

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

(3.4.3) Gridding

Gridding for the bathymetry data are carried out using the HIPS software version 5.4 (CARIS, Canada). Firstly, low-quality data during the CTD cast and the ship’s drift are removed. Secondly, spikes in the data are removed by “Surface Cleaning” function of the software with following parameters.

Tiling: by size (Minimum size of tile: 163.84 [m])

Degree of polynomial: 1 (tiled plane)

Cleaning

Shallow threshold: 1.000, sigma = 68.26 [%]

Deep threshold: 1.000, sigma = 68.26 [%]

Minimum residual required for rejection: 10.000 [m]

Thirdly, remaining erroneous data are manually removed and normal data, which have been removed by the “Surface Cleaning” function, are manually recovered by “Swath Editor” and “Subset Editor” functions of the software. Finally, the bathymetry data are gridded by “Interpolate” function of the software with following parameters.

Matrix size: 5 × 5

Number of nearneighbors: 18

Reference

Mackenzie, K.V. (1981): Nine-term equation for the sound speed in the oceans, J. Acoust. Soc. Am., 70 (3), pp 807-812.

2.2 Surface Meteorological Observation

27 September 2006

(1) Personnel

Kunio Yoneyama (JAMSTEC)

Yasutaka Imai (GODI)

Shinya Okumura (GODI)

Ryo Ohyama (GODI)

Norio Nagahama (GODI)

(2) Objective

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

(3) Methods

There are two different surface meteorological observation systems on 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 2.2.1. All SMET data were collected and processed by KOAC-7800 weather data processor made by Koshin Denki, Japan. Note that although SMET contains rain gauge, anemometer and radiometers in their system, we adopted those data from not SMET but SOAR due to the following reasons; 1) Since SMET rain gauge is located near the base of the mast, there is a possibility that its capture rate might be affected (the location possibly affect on the accuracy of the capture rate of the gauge), 2) SOAR's anemometer has better starting threshold wind speed (1 m/sec) comparing to SMET's anemometer (2 m/sec), and 3) SMET's radiometers record data with 10 W/m^2 unit, while SOAR takes 1 W/m^2 unit.

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

Table 2.2.1. Instruments and locations of SMET.

Sensor	Parameter	Manufacturer / type	Location / height from sea level
Thermometer*1	air temperature	Vaisala, Finland / HMP45A	compass deck*2 / 21 m
	relative humidity		
Thermometer	sea temperature	Koshin Denki, Japan / RFN1-0	4th deck / –5 m
Barometer	pressure	Yokogawa, Japan / F-451	captain deck / 13 m

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

*2 There are two thermometers at starboard and port sides.

Table 2.2.2. Instruments and locations of SOAR.

Sensor	Parameter	Manufacturer / type	Location / height from sea level
Anemometer	wind speed/direction	R. M. Young, USA / 05106	foremast / 25 m
Rain gauge	rainfall accumulation	R. M. Young, USA / 50202	foremast / 24 m
Radiometer	short wave radiation	Eppley, USA / PSP	foremast / 25 m
	long wave radiation	Eppley, USA / PIR	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 beginning of the average). They are simple 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 on the deck, we used air temperature/relative humidity data taken at upwind side. Dew point temperature was produced 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 contains following parameters.

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

Missing values are expressed as “9999”.

(5) Data Quality

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

T/RH sensor:

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

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

Temperature (°C)

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

–0.3 ± 0.1 (°C) at port side, –0.2 ± 0.4 (°C) at starboard side.

Relative Humidity (%)

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

0 ± 1 (%) at port side, 0 ± 0 (%) at starboard side.

Pressure sensor:

Using calibrated portable barometer (Vaisala, Finland / PTB220, certificated accuracy is better than ± 0.1 hPa), pressure sensor was checked before/after the cruise. Mean difference of SMET pressure sensor and portable sensor is 0.0 ± 0.1 hPa.

Anemometer:

Using digital tester (Hioki, Japan / 3805), post calibration was conducted by the GODI.

Post-calibration date: Sep. 7, 2005

Starting threshold wind speed: 0.9 m/sec for clockwise

0.9 m/sec for counter-clockwise

Wind direction check: better than ± 2 °

Set value	6	36	64	96	126	156	185	215	244	275	306	336
Measured value	6	30	68	97	127	156	186	216	245	275	306	337
Difference	0	0	–4	–1	–1	0	–1	–1	–1	0	0	–1

Precipitation:

Before the cruise, we put water into the rain gauge to check their linearity between the indicated values and water amount input. Expected accuracy is better than ± 1 mm corresponding to the sensor’s specification. The results are as follows, and data were corrected using this relationship.

	1st	2nd	3rd	Mean
minimum input water volume (cc)	0.0	0.0	0.0	0.0
minimum measured value (mm)	0.7	0.7	0.8	0.8
maximum input water volume (cc)	516.0	514.5	513.0	514.5
maximum measured value (mm)	51.2	51.1	51.2	51.2

Radiation sensors:

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

(6) Data periods

1200 UTC, May 26, 2006-2300 UTC, July 1, 2006

Only SST data is available from 1230 UTC, May 26, 2006.

(7) Point of contact

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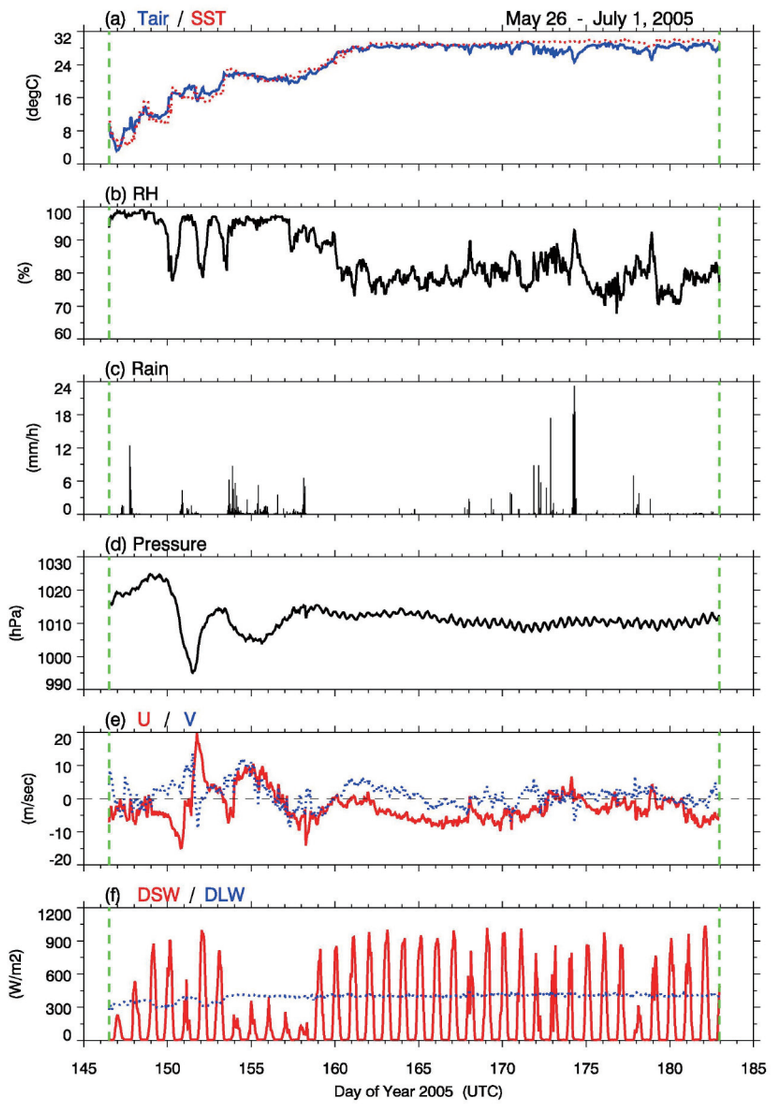

Figure 2.2.1. Time series of (a) air and sea surface temperature, (b) relative humidity, (c) precipitation, (d) pressure, (e) zonal and meridional wind components, and (e) short and long wave radiation. Day 146 corresponds to May 26, 2006.

2.3 Thermosalinograph and related measurements

22 January 2004

(1) Personnel

Takayoshi Seike (MWJ)

Takeshi Kawano (JAMSTEC)

(2) Objective

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

(3) Methods

Continuous Sea Surface Water Monitoring System (Nippon Kaiyo Co., Ltd.) has six kinds of sensors and can automatically and continuously measure salinity, temperature, dissolved oxygen, fluorescence and particle size of plankton in near-sea surface water every 1-minute. This system is located in *"sea surface monitoring laboratory"* on R/V Mirai and connected to shipboard LAN-system. Measured data is stored in a hard disk of PC every 1-minute together with time and position of the ship, and displayed in the data management PC machine.

Near-surface water was continuously pumped up to the laboratory and flowed into the *Continuous Sea Surface Water Monitoring System* through a vinyl-chloride pipe. The flow rate for the system is controlled by several valves and is set at 12 l/min except with fluorometer (about 0.3 l/min). The flow rate is measured with two flow meters and each value is checked every day.

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

a) Temperature and Salinity sensors

SEACAT THERMOSALINOGRAPH

Model:	SBE-21, Sea-Bird Electronics, Inc.
Serial number:	2126391-2641
Measurement range:	Temperature –5 to +35 °C
	Salinity 0 to 6.5 S m^{-1}
Accuracy:	Temperature 0.01 °C 6 $month^{-1}$
	Salinity 0.001 S m^{-1} $month^{-1}$
Resolution:	Temperatures 0.001 °C
	Salinity 0.0001 S m^{-1}

b) Bottom of ship thermometer

Model:	SBE 3S, Sea-Bird Electronics, Inc.
Serial number:	032175
Measurement range:	–5 to +35 °C
Resolution:	± 0.001 °C
Stability:	0.002 °C $year^{-1}$

c) Dissolved oxygen sensor

Model:	2127A, Oubisufair Laboratories Japan Inc.
Serial number:	44733
Measurement range:	0 to 14 ppm
Accuracy:	± 1 % at 5 °C of correction range
Stability:	1 % $month^{-1}$

d) Fluorometer

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

e) Particle Size sensor

Model: P-05, Nippon Kaiyo Co., Ltd.

Serial number: P5024

Measurement range: 0.02681 mm to 6.666 mm

Accuracy: ± 10 % of range

Reproducibility: ± 5 %

Stability: 5 % $week^{-1}$

f) Flow meter

Model: EMARG2W, Aichi Watch Electronics Ltd.

Serial number: 8672

Measurement range: 0 to 30 l min^{-1}

Accuracy: ± 1 %

Stability: ± 1 % day^{-1}

The monitoring periods (UTC) are listed below.

26-Mar-05 13:31 to 30-Jun-05 02:45

(4) Comparison of salinity data with sampled salinity

We sampled seawater for salinity measurement about twice a day for salinity sensor calibration. All salinity samples were collected from the course of the system while on station or from regions with weak horizontal gradients. All samples were analyzed on Guildline 8400B. The results were shown in Table 2.3.1.

Table 2.3.1. Comparison of salinity between data obtained from *Continuous Sea Surface Water Monitoring* and collected samples.

Date [UTC]	Time [UTC]	Salinity data	Bottle Salinity [PSS-78]
27-Mar-05	22:52	32.9296	32.9317
28-Mar-05	12:36	33.6424	33.6306
28-Mar-05	22:55	33.3806	33.3756
29-Mar-05	06:12	33.6521	33.6319
29-Mar-05	22:46	33.3896	33.3984
30-Mar-05	18:49	34.5657	34.5776
30-Mar-05	22:54	34.4765	34.4939
31-Mar-05	04:22	34.5199	34.5350
31-Mar-05	22:40	34.4629	34.4929
1-JUN-05	12:36	34.4079	34.4531
1-JUN-05	22:51	34.4860	34.5147
2-JUN-05	05:02	34.4708	34.4911
3-JUN-05	02:53	34.5825	34.6117
3-JUN-05	09:01	34.5986	34.6273
4-JUN-05	02:47	34.6163	34.6446
5-JUN-05	02:38	34.6549	34.6750
5-JUN-05	15:56	34.6632	34.6873
6-JUN-05	02:31	34.4601	34.5024
6-JUN-05	15:43	34.3304	34.3552
7-JUN-05	02:36	34.3558	34.3859
7-JUN-05	16:51	34.8104	34.8351
8-JUN-05	02:40	34.5198	34.5394

8-JUN-05	18:19	34.8639	34.8893
9-JUN-05	02:48	34.4874	34.5868
9-JUN-05	15:44	34.7581	34.8940
10-JUN-05	02:42	35.0075	35.0049
10-JUN-05	15:24	34.9980	35.0406
11-JUN-05	02:30	34.6205	34.6298
12-JUN-05	08:20	34.5390	34.5625
12-JUN-05	14:32	34.5394	34.5688
13-JUN-05	00:17	34.5725	34.6049
13-JUN-05	14:34	34.9744	35.0077
14-JUN-05	04:12	34.7980	34.8137
14-JUN-05	14:48	34.8969	34.9322
15-JUN-05	03:32	34.5539	34.5324
15-JUN-05	14:49	34.4052	34.4381
16-JUN-05	01:33	34.4143	34.4526
16-JUN-05	14:43	34.4642	34.5038
17-JUN-05	02:51	34.2650	34.3030
17-JUN-05	14:47	34.4193	34.4256
18-JUN-05	00:59	34.1001	34.1407
18-JUN-05	14:46	33.9444	33.9876
19-JUN-05	00:47	33.8548	33.8967
19-JUN-05	14:28	33.8954	33.9374
20-JUN-05	00:37	33.9928	34.0371
20-JUN-05	14:29	33.9209	33.9624
21-JUN-05	02:56	33.9359	33.9764

21-JUN-05	14:48	33.9013	33.9045
22-JUN-05	01:18	33.8159	33.9168
22-JUN-05	14:47	34.1404	34.2044
23-JUN-05	00:52	34.2102	34.2569
23-JUN-05	14:32	34.2208	34.2785
24-JUN-05	01:01	33.9716	34.0119
24-JUN-05	12:51	34.1161	34.1624
25-JUN-05	00:35	34.1160	34.1664
25-JUN-05	14:45	34.0914	34.1350
26-JUN-05	00:26	34.0454	34.1016
26-JUN-05	15:21	34.2297	34.2773
27-JUN-05	04:11	34.1533	34.1756
27-JUN-05	14:38	34.1362	34.2077

2.4 Underway pCO_2

31 August, 2006

(1) Personnel

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Fuyuki Shibata (MWJ)

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(2) Introduction

Concentrations of CO_2 in the atmosphere are now increasing at a rate of 1.5 ppmv y^{-1} due to human activities such as burning of fossil fuels, deforestation, cement production, and so on. It is an urgent task to estimate as accurately as possible the absorption capacity of the ocean against the increased atmospheric CO_2, as well as to clarify the mechanism of CO_2 absorption, because the magnitude of predicted global warming depends on the levels of CO_2 in the atmosphere, and 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 aimed to quantify how much anthropogenic CO_2 is absorbed in the surface ocean of the North 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 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 (NDIR; BINOS® model 4.1, Fisher-Rosemount), 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 600 – 800 ml min^{-1}. The seawater was taken by a pump from an intake placed at approx. 4.5 m below the sea surface. The flow rate of seawater in the equilibrator was 500 – 800 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 2.4.1), 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 2.4.1, which were calibrated by JAMSTEC primary standard gases. The CO_2 concentrations of the primary standard gases were calibrated by C.D. Keeling of the Scripps Institution of Oceanography, La Jolla, CA, USA.

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

In actual shipboard observations, signals of NDIR usually reveal a trend. The trend was adjusted linearly using 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 Gordon and Jones (1973), although the temperature increases were slight, being ~ 0.3 °C.

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

Table 2.4.1. Concentrations of CO_2 standard gases used in the P10 revisit cruise.

Cylinder no.	Concentrations (ppmv)
CQB17639	262.94
CQB09291	320.42
CQB09292	381.04
CQB09293	420.76

Reference

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

2.5 Acoustic Doppler Current Profiler

23 August 2006

(1) Personnel

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Shinya Okumura (GODI)

Ryo Ohyama (GODI)

(2) Instrument and method

The instrument used was an RDI 76.8 kHz unit, hull-mounted on the centerline and approximately 23 m aft of the bow at the water line. The firmware version was 5.59 and the data acquisition software was RDI VMDAS Version. 1.4. Operation was made from the first CTD station to the last CTD station. The instrument was used in water-tracking mode during the most of operations, recording each ping raw data in 8 m × 90 bin from about 23 m to 735 m in depth. Typical sampling interval was 3.5 seconds. Bottom track mode was added in the northernmost shallow water region. GPS gave navigation data. Two kinds of compass data were recorded. One compass was the ship's gyrocompass, which is connected the ADCP system directory, and its data were stored with the ADCP data. Current field based on the gyrocompass was used to check the operation and the performance on board. Another compass used was Inertial Navigation Unit (INU), DRU-H, Honeywell Inc. Its accuracy is 1.0 mile (about 0.056 degree) and had already set on zero bias before the beginning of the cruise. The INU compass data were stored independently, and combined with the ADCP data after the cruise.

(3) Performance and quick view of the ADCP data on board

The performance of the ADCP instrument was almost good throughout the cruise: on streaming, profiles usually reached about 600 m (652384 pings of all 953103 pings till June, 27). Profiles were sometimes rather bad on CTD station. The profiles did not reach so far, from 200 m to 500 m and the ADCP signal was typically weak at about 350 m in depth. It is probably due to babbles from the bow-thruster. Echo intensity was relatively weak in the sea south of 35 °N in the subtropical and tropical North Pacific. It is probably due to weak reflection of the echo. The performance of the ADCP was relatively bad on streaming in these regions.

We processed the ADCP data in this cruise on board as described below. ADCP-coordinate velocities were converted to the earth-coordinate velocities using the ship's heading, roll and pitch data form the INU. The earth-coordinate currents were obtained by subtracting ship velocities from the earth-coordinate velocities. The ship velocities were obtained from the moving distances for 5 minutes, which were measured by GPS data. The noise of the GPS position data was filtered out by 15-sec running mean. The errors of the estimated ship velocities are within 10 cm/s. The currents obtained in this cruise were shown in the preliminary report on the ship (figures are not shown here).

After this cruise the parameters of the misalignment and the scale factor would be evaluated by using the bottom track data obtained both in this cruise and in the engineering test cruise made just before this cruise.

(4) Data Processing

Corrections of the misalignment and the scale factor were made after the cruise using the bottom track data. The bottom track data used was obtained during the engineering test cruise carried out just before the P10_revisit cruise. The misalignment angle calculated was 0.05 degree and the scale factor was 0.975. These parameters were similar to those calculated in August 2003. Criteria for the correlation less than 64 and error velocity more than 20 mm/s are removed here. Therefore the error is estimated at 20 mm/s.

Raw data are filtered using the median filter on every 3 minutes. There are about 90 data in one ensemble. In vertical direction, 3 bins data are used, which would mean 24 m averaging in the filtering process. Time series of upper 25 bins average flow are calculated using the 3 minutes sub set. The continuity of the series is examined in order to use each to average on the CTD sites and on streaming between the sites. Typically, the time series of the flow are stable on the CTD sites, where the standard deviation is 38 mm/s. The variability is likely to correspond to the temporal tidal motion. The data of almost all time stamps are used for averaging. On the other hand, the time

series of that on streaming between the CTD sites are somewhat irregular, where the standard deviation is 63 mm/s. It is likely to be due to the variability in space with temporal tidal motion. The mismatch between the ship velocity obtained from the GPS and water column velocity of ADCP was found when the ship was accelerated and/or decelerated. Available time stamp was found using the continuity of the time series when the ship speed was almost constant. In the averaging process, we use the 40 % criterion of the maximum frequency. In the next step, we averaged the subset at each CTD station and at streaming between the stations. Each mean profile is calculated with depth correction using the CTD data. Vertical grids are put on every 20 m. Available frequency for averaging was set as 40 % of the most counts. It concludes almost good continuity of the vertical profile.

Following is the features of the analyzed dataset. The mean available depth range is 642 m on the CTD stations and 576 m on streaming, respectively. There are non-available layer in the subsurface around 350 m between 10 °N and 23 °N. It appears more on streaming case, and sometimes the subsurface hole connects to the deeper non-available depth. The reason of the appearing hole should be the weak signal of reflection, which is associated with the meridional structure or distribution of the reflector. The available depth range is full in the subtropical region between 25 °N and 35 °N. Standard deviation of the flow is 4.0 cm/s and 6.4 cm/s. They are almost same of those of sub-set. Vertical profile of the standard deviation is similar to each other, except of the bias. It is shown in Fig B. The value is relative bigger where the strong flow exists, especially around 29 °N, 23 °N, 19 °N and 8 °N.

(5) Current distributions observed

Current fields at 100 m is shown in Fig 6 (p.97). The major currents were clearly observed by the ADCP; the Oyashio, the Kuroshio Extension and the equatorial currents. The Oyashio appeared near the southern coast off the Hokkaido. The southern westward current was barotropic and it penetrated the deepest layer measured. The Kuroshio Extension existed around 36 °N across the ship track. The maximum speed near the sea surface was 1.8 m/s at 36° 22’ N. The southern shift of the maximum speed with depth was observed; the maximum speed at 600 m depth was 0.5 m/s at 35° 52’ N. The eddy-like flow pattern appeared in the mixed water region between the Oyashio and the Kuroshio Extension. The westward flow was dominant in the south of the Kuroshio Extension. The flow was almost barotropic in the subtropical region. However, the flow showed baroclinic feature in the region between 5 °N and 20 °N. The North Equatorial Current was seen around 10 °N. The Equatorial Counter Current was seen between 1 °N and 6 °N. The eastward flow of the Equatorial Under Current distributed just north of the equator, whose core appeared at 240 m at 1° 53’ N with a zonal speed of 0.79 cm/s. On the other hand, the core of the meridional component existed around the equator clearly. It might be an eddy or a meander feature of the current. The South Equatorial Current was seen from the equator to the southern hemisphere. The strong current along the coast was observed near the coast of the Papua New Guinea.

(6) Data Structure

The record structure of the data set A, where file name is ‘ADCP_A’, is described below. The file consists of 259 profiles, 130 of the CTD sites and 129 of the streaming. Each profile consists of header and data. The header has three lines representing analyzed site, date and time, and position. The data has 35 layers in which depth, zonal velocity, meridional velocity, and standard error of each grid are stored. Unit of depth is in meter. Unit of flow is in m/s. On the CTD station, the CTD station name (e.g. ‘143_1’) is recorded as the analyzed site in the header. Mean time and position were calculated and recorded using the ADCP profiles during the CTD operation was made. On the way to next CTD station, hyphened two CTD station names (e.g. ‘143_1-142_1’) are recorded as the analyzed site in the header. Recorded time and position are mean for the available ADCP profiles. The ’99.999’ in the data represents no available data stored.

[data structure of the data set A]

Line 1: header 1

Column 01-10: cruise code

Column 12-15: WHP line name

Column 17-27: analyzed site

Line 2: header 2

Column 01-10: date (mm/dd/yyyy)

Column 12-16: time (hh:mm)

Line 3: header 3

Column 01-09: latitude (deg,min,N/S)

Column 11-20: longitude (deg,min,E/W)

Line 4-38: flow data in each depth level

Column 01-05: depth (m)

Column 07-12: zonal velocity (m/s)

Column 14-19: meridional velocity (m/s)

Column 21-26: standard error (m/s)

[data structure of the data set B: every 3 minutes]

Line 1: header 1

Column 01-10: cruise code

Column 12-15: WHP line name

Column 17-27: analyzed site

Line 2: header 2

Column 01-10: date (mm/dd/yyyy)

Column 12-16: time (hh:mm)

Line 3: header 3

Column 01-09: latitude (deg,min,N/S)

Column 11-20: longitude (deg,min,E/W)

Line 4-38: flow data in each depth level

Column 01-05: depth (m)

Column 07-12: zonal velocity (m/s)

Column 14-19: meridional velocity (m/s)

Column 21-26: standard error (m/s)

Flow data processed in every three minutes are stored in the data set B, where the file name is ‘ADCP_B’. The data structure is the same as that of the data set B, except for the analyzed site in the header 1. Sequential number is written in the record as `E$$$$$’.

3 Hydrographic Measurement Techniques and Calibrations

3.1 CTD/O_2 Measurements

25 October 2005

(1) Personnel

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(2) Winch arrangements

The CTD package was deployed by using 4.5 Ton Traction Winch System (Dynacon, Inc., USA), which was installed on the R/V Mirai in April 2001. The CTD Traction Winch System with the Heave Compensation Systems (Dynacon, Inc., USA) is designed to reduce cable stress resulting from load variation caused by wave or vessel motion. The system is operated passively by providing a nodding boom crane that moves up or down in response to line tension variations. Primary system components include a complete CTD Traction Winch System with up to 10 km of 9.53 mm armored cable (Ocean Cable and Communication Co.), a cable rocker and Electro-Hydraulic Power Unit, a nodding-boom crane assembly, two hydraulic cylinders and two hydraulic oil/nitrogen accumulators mounted within a single frame assembly. The system also contains related electronic hardware interface and a heave compensation computer control program.

(3) Overview of the equipment

The CTD system, SBE 911plus system (Sea-Bird Electronics, Inc., USA), is a real time data system with the CTD data transmitted from a SBE 9plus underwater unit via a conducting cable to the SBE 11plus deck unit. The SBE 11plus deck unit is a rack-mountable interface which supplies DC power to underwater unit, decodes serial data stream, formats data under microprocessor control, and passes the data to a companion computer. The serial data from the underwater unit is sent to the deck unit in RS-232 NRZ format using a 34,560 Hz carrier-modulated differential-phase-shift-keying (DPSK) telemetry link. The deck unit decodes the serial data and sends them to a personal computer to display, at the same time, to storage in a disk file using SBE SEASOFT software.

The SBE 911plus system acquires data from primary, secondary and auxiliary sensors in the form of binary numbers corresponding to the frequency or the voltage outputs from those sensors at 24 samples per second. The calculations required to convert raw data to engineering units of the parameters are performed by the SBE SEASOFT in real-time. The same calculations can be carried out after the observation using data stored in a disk file.

The SBE 911plus system controls 36-position SBE 32 Carousel Water Sampler. The Carousel accepts 12-litre water sample bottles. Bottles are fired through the RS-232C modem connector on the back of the SBE 11plus deck unit while acquiring real time data. The 12-litre Niskin-X water sample bottle (General Oceanics, Inc., USA) is equipped externally with two stainless steel springs. The external springs are ideal for applications such as trace metal analysis because the inside of the sampler is free from contaminants from springs.

SBE's temperature (SBE 3) and conductivity (SBE 4) sensor modules were used with the SBE 9plus underwater unit fixed by a single clamp and "L" bracket to the lower end cap. The conductivity cell entrance is co-planar with the tip of the temperature sensor's protective steel sheath. The pressure sensor is mounted in the main housing of the underwater unit and is ported to outside through the oil-filled plastic capillary tube. A compact, modular unit consisting of a centrifugal pump head and a brushless DC ball bearing motor contained in an aluminum underwater housing pump (SBE 5T) flushes water through sensor tubing at a constant rate independent of the CTD's motion. Motor speed and pumping rate (3,000 rpm) remain nearly constant over the entire input voltage range of 12-18 volts DC. Flow speed of pumped water in standard TC duct is about 2.4 m/s. SBE's dissolved oxygen sensor (SBE 43) was placed between the conductivity sensor module and the pump. Auxiliary sensors, Deep Ocean Standards Thermometer (SBE 35), altimeter and fluorometer, were also used with the SBE 9plus underwater unit. The SBE 35

position in regard to the SBE 3 is shown in Figure 3.1.1.

It is known that the CTD temperature data is influenced by motion (pitching and rolling) of the CTD package. In order to reduce the motion of the CTD package, a heavy stainless frame (total weight of the CTD package without sea water in the bottles is about 1,000 kg) was used and an aluminum plate (54 × 90 cm) was attached to the frame (Figure 3.1.1).

Summary of the system used in this cruise

Deck unit:

SBE, Inc., SBE 11plus, S/N 0308

Under water unit:

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

Temperature sensor:

SBE, Inc., SBE 3, S/N 1464 (primary)

SBE, Inc., SBE 3, S/N 1525 (secondary)

Conductivity sensor:

SBE, Inc., SBE 4, S/N 1203 (primary)

SBE, Inc., SBE 4, S/N 3036 (secondary, from P10N_143 to P10_53)

SBE, Inc., SBE 4, S/N 1088 (secondary, from P10_52 to P10_27)

SBE, Inc., SBE 4, S/N 2854 (secondary, from P10_26 to P10_1)

Oxygen sensor:

SBE, Inc., SBE 43, S/N 0391 (primary, from P10N_143 to P10N_122)

SBE, Inc., SBE 43, S/N 0767 (primary, from P10N_121 to P10_1)

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

Pump:

SBE, Inc., SBE 5T, S/N 3118 (primary)

SBE, Inc., SBE 5T, S/N 3293 (secondary)

Altimeter:

Benthos Inc., PSA-916T, S/N 1157

Deep Ocean Standards Thermometer:

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

Fluorometer:

Seapoint sensors, Inc., S/N 2579

(without fluorometer from P10N_134 to132, P10N_112 to P10_68, and P10_28 to 1)

Carousel Water Sampler:

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

Water sample bottle:

General Oceanics, Inc., 12-litre Niskin-X (no TEFLON coating)

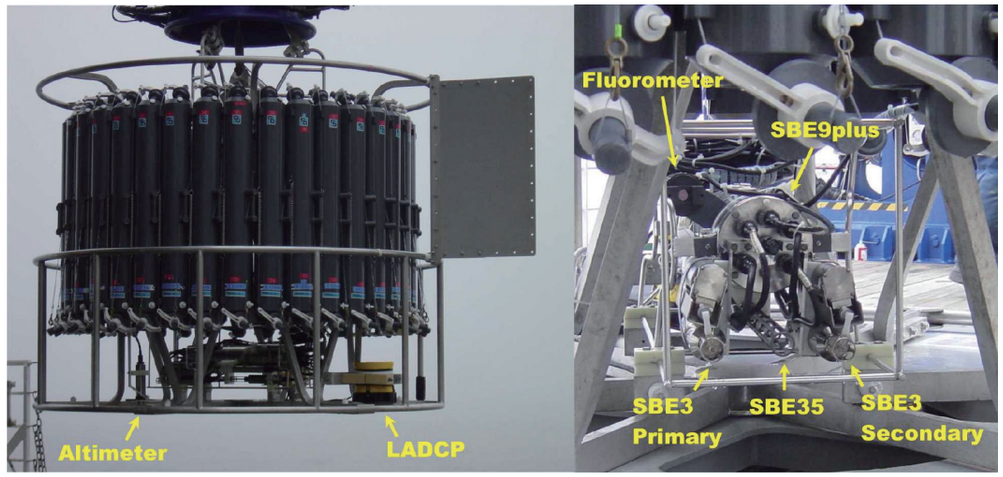

Figure 3.1.1. The CTD package (left) and the SBE 35 position in regard to the SBE 3 temperature sensors (right).

(4) Pre-cruise calibration

(4.1) Pressure

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

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

S/N 0677, 2 July 2002

$c_1 = -62072.94$

$c_2 = -1.176956$

$c_3 = 1.954420e-02$

$d_1 = 0.027386$

$d_2 = 0.0$

$t_1 = 30.05031$

$t_2 = -4.744833e-04$

$t_3 = 3.757590e-06$

$t_4 = 3.810700e-09$

$t_5 = 0.0$

Pressure coefficients are first formulated into

$$c = c_1 + c_2 * U + c_3 * U^2$$

$$d = d_1 + d_2 * U$$

$$t_0 = t_1 + t_2 * U + t_3 * U^2 + t_4 * U^3 + t_5 * U^4$$

where U is temperature in degrees Celsius. The pressure temperature, U, is determined according to

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

The following coefficients were used in SEASOFT:

S/N 0677

$M = 0.0128041$

$B = -9.324136$

(in the underwater unit system configuration sheet dated on 22 February 2002)

Finally, pressure is computed as

$$P\ (psi) = c * [1 - (t_0^2 / t^2)] * \{1 - d * [1 - (t_0^2 / t^2)]\}$$

where t is pressure period (msec). Since the pressure sensor measures the absolute value, it inherently includes atmospheric pressure (about 14.7 psi). SEASOFT subtracts 14.7 psi from computed pressure above automatically.

Pressure sensor calibrations against a dead-weight piston gauge (Bundenberg Gauge Co. Ltd., UK; Model 480DA, S/N 23906) are performed at JAMSTEC (Yokosuka, Kanagawa, JAPAN) by Marine Works Japan Ltd. (MWJ), usually once in a year in order to monitor sensor time drift and linearity. The pressure sensor drift is known to be primarily an offset drift at all pressures rather than a change of span slope. The pressure sensor hysterisis is typically 0.2 dbar. The following coefficients for the sensor drift correction were also used in SEASOFT:

S/N 0677, 13 April 2005

slope = 0.9998953

offset = –0.44425

The drift-corrected pressure is computed as

Drift-corrected pressure (dbar) = slope * (computed pressure in dbar) + offset

Result of the pressure sensor calibration against the dead weight piston gauge is shown in Figure 3.1.2. Time drift of the pressure sensor based on the offset and the slope of the calibrations is also shown in Figure 3.1.3.

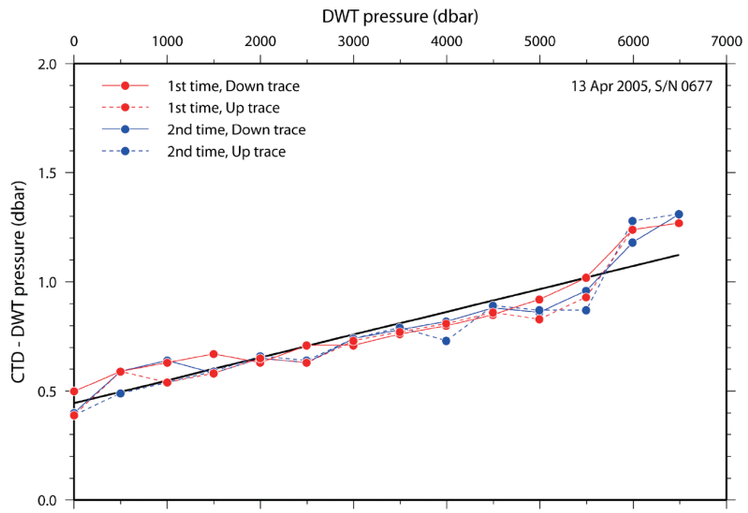

Figure 3.1.2. The residual pressures between the dead weight piston gauge and the CTD pressure (S/N 0677). The calibration line (black line) is also shown.

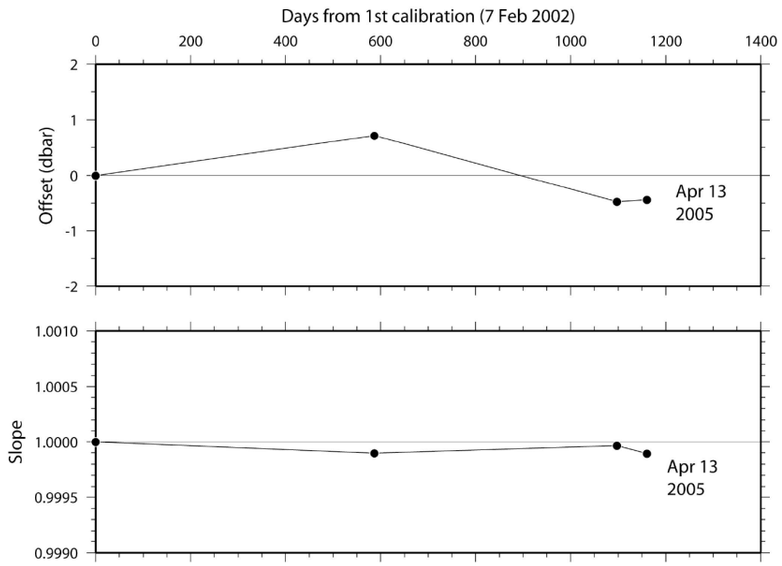

Figure 3.1.3. Pressure sensor (S/N 0677) time drift of offset (upper panel) and slope (lower panel) based on laboratory calibrations.

(4.2) Temperature (SBE 3)

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

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

S/N 1464 (primary), 19 April 2005

g = 4.84385804e–03

h = 6.80766786e–04

i = 2.69831319e–05

j = 2.13061451e–06

f_0 = 1000.000

S/N 1525 (secondary), 19 April 2005

g = 4.84608198e–03

h = 6.75358139e–04

i = 2.65523364e–05

j = 2.13525896e–06

f_0 = 1000.000

Temperature (ITS-90) is computed according to

Temperature (ITS-90) =

$$1 / \{g + h * [\ln(f_0 / f)] + i * [\ln2(f_0 / f)] + j * [\ln3(f_0 / f)]\} - 273.15$$

where f is the instrument frequency (kHz).

Time drift of the SBE 3 temperature sensors based on the laboratory calibrations is shown in Figure 3.1.4.

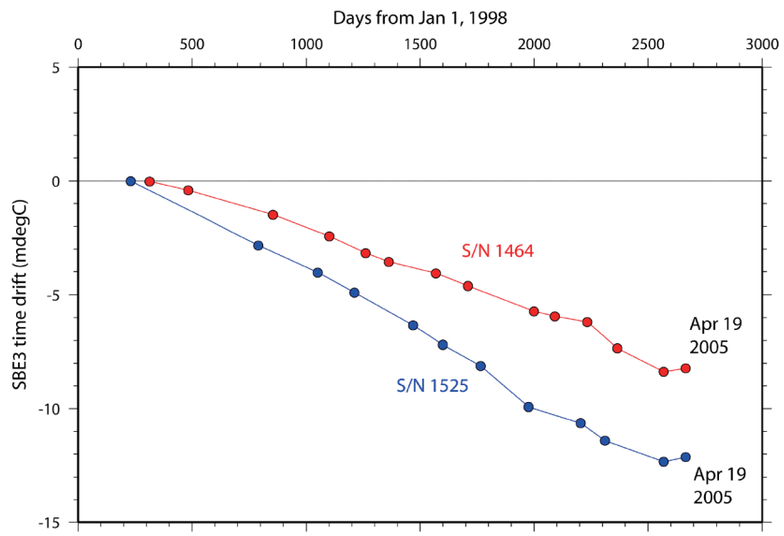

Figure 3.1.4. Time drift of SBE 3 temperature sensors (S/N 1464 and S/N 1525) based on laboratory calibrations performed by SBE, Inc.

(4.3) Conductivity (SBE 4)

The flow-through conductivity sensing element is a glass tube (cell) with three platinum electrodes to provide in-situ measurements at depths up to 10,500 meters. The impedance between the center and the end electrodes is determined by the cell geometry and the specific conductance of the fluid within the cell. The conductivity cell composes a Wien Bridge circuit with other electric elements of which frequency output is approximately 3 to 12 kHz corresponding to conductivity of the fluid of 0 to 7 S/m. The SBE 4 has a nominal accuracy of 0.0003 S/m, typical stability of 0.0003 S/m/month and resolution of 0.00004 S/m at 24 samples per second.

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

S/N 1203 (primary), 19 April 2005

g = –4.05393563e+00

h = 4.93901550e–01

i = 1.74707654e–05

j = 2.56674141e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

S/N 3036 (secondary), 20 January 2005

g = –1.03104164e+01

h = 1.42680631e+00

i = 2.61243729e–04

j = 5.17689837e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

S/N 1088 (secondary), 10 March 2005

g = –4.21020837e+00

h = 5.77013782e–01

i = –1.87512042e–04

j = 4.10775826e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

S/N 2854 (secondary), 22 June 2004

g = –1.02670783e+01

h = 1.41649193e+00

i = –3.19882205e–04

j = 7.82222198e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

Conductivity of a fluid in the cell is expressed as:

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

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

(4.4) Oxygen (SBE 43)

The SBE 43 oxygen sensor uses a Clark polarographic element to provide in-situ measurements at depths up to 7,000 meters. Calibration stability is improved by an order of magnitude, and pressure hysterisis is largely eliminated in the upper ocean (1,000 m) compared with the previous oxygen sensor (SBE 13). Continuous polarization eliminates wait-time for stabilization after power-up. Signal resolution is increased by on-board temperature compensation. The oxygen sensor is also included in the path of pumped sea water. The oxygen sensor determines dissolved oxygen concentration by counting the number of oxygen molecules per second (flux) that diffuse through a membrane, where the permeability of the membrane to oxygen is a function of temperature and ambient pressure. Computation of dissolved oxygen in engineering units is done in SEASOFT software. The range for dissolved oxygen is 120 % of surface saturation in all natural waters; nominal accuracy is 2 % of saturation; typical stability is 2 % per 1,000 hours.

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

S/N 0391 (primary), 8 April 2005

Soc = 0.3525

Offset = –0.4761

TCor = 0.0010

PCor = 1.350e–04

S/N 0767 (primary), 11 February 2005

Soc = 0.4320

Offset = –0.4889

TCor = 0.0002

PCor = 1.350e–04

S/N 0390 (secondary), 8 April 2005

Soc = 0.3567

Offset = –0.4965

TCor = 0.0013

PCor = 1.350e–04

Oxygen (ml/l) is computed as

$$Oxygen\ (ml/l) = \{Soc * (v + Offset)\} * \exp(TCor * t + PCor * p) * Oxsat(t, s)$$

$$Oxsat(t, s) = \exp[A_1 + A_2 * (100 / t) + A_3 * \ln(t / 100) + A_4 * (t / 100) + s * \{B_1 + B_2 * (t / 100) + B_3 * (t / 100) * (t / 100)\}]$$

A_1 = –173.4292

A_2 = 249.6339

A_3 = 143.3483

A_4 = –21.8482

B_1 = –0.033096

B_2 = –0.00170

where p is pressure in dbar, t is absolute temperature and s is salinity in psu. Oxsat is oxygen saturation value minus the volume of oxygen gas (STP) absorbed from humidity-saturated air.

(4.5) 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 6,800 m.

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

The SBE 35 communicates via a standard RS-232 interface at 300 baud, 8 bits, no parity. The SBE 35 can be used with the SBE 32 Carousel Water Sampler and SBE 911plus CTD system. The SBE 35 makes a temperature measurement each time when a bottle fire confirmation is received, and stores the value in EEPROM. Calibration coefficients stored in EEPROM allow the SBE 35 to transmit data in engineering units. Commands can be sent to SBE 35 to provide status display, data acquisition setup, data retrieval, and diagnostic test by using terminal software.

Following the methodology used for standards-grade platinum resistance thermometers (SPRT), calibration of the SBE 35 is accomplished in two steps. The first step is to characterize and capture the non-linear resistance vs temperature response of the sensor. The SBE 35 calibrations are performed at SBE, Inc., in a low-gradient temperature bath and against ITS-90 certified SPRTs maintained at Sea-Bird's primary temperature metrology laboratory. The second step is frequent certification of the sensor by measurements in thermodynamic fixed-point cells. Triple point of water (TPW) and gallium melt point (GaMP) cells are appropriate for the SBE 35. The SBE 35 resolves temperature in the fixed-point cells to approximately 25 µK. Like SPRTs, slow time drift of the SBE 35 is adjusted by a slope and offset correction to the basic non-linear calibration equation.

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

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

a_0 = 5.84093815e–03

a_1 = –1.65529280e–03

a_2 = 2.37944937e–04

a_3 = –1.32611385e–05

a_4 = 2.83355203e–07

Linearized temperature (ITS-90) is computed according to

Linearized temperature (ITS-90) =

$$1 / \{a_0 + a_1 * [\ln(n)] + a_2 * [\ln^2(n)] + a_3 * [\ln^3(n)] + a_4 * [\ln^4(n)]\} - 273.15$$

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

S/N 0045, 6 May 2005 (2nd step: fixed point calibration)

Slope = 1.000019

Offset = –0.000881

Temperature (ITS-90) is calibrated according to

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

The SBE 35 has a time constant of 0.5 seconds. The time required per sample = 1.1 * NCYCLES + 2.7 seconds. The 1.1 seconds is total time per an acquisition cycle. NCYCLES is the number of acquisition cycles per sample. The 2.7 seconds is required for converting the measured values to temperature and storing average in EEPROM. Root mean square (rms) temperature noise for a SBE 35 in a Triple Point of Water cell is typically expressed as 82 / $NCYCLES^{1/2}$ in µK. In this cruise NCYCLES was set to 4 and the rms noise is estimated to be 0.04 m°C.

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

JAPAN) was used between the under water unit and the deck unit.

Time drift of the SBE 35 based on the fixed point calibrations is shown in Figure 3.1.5.

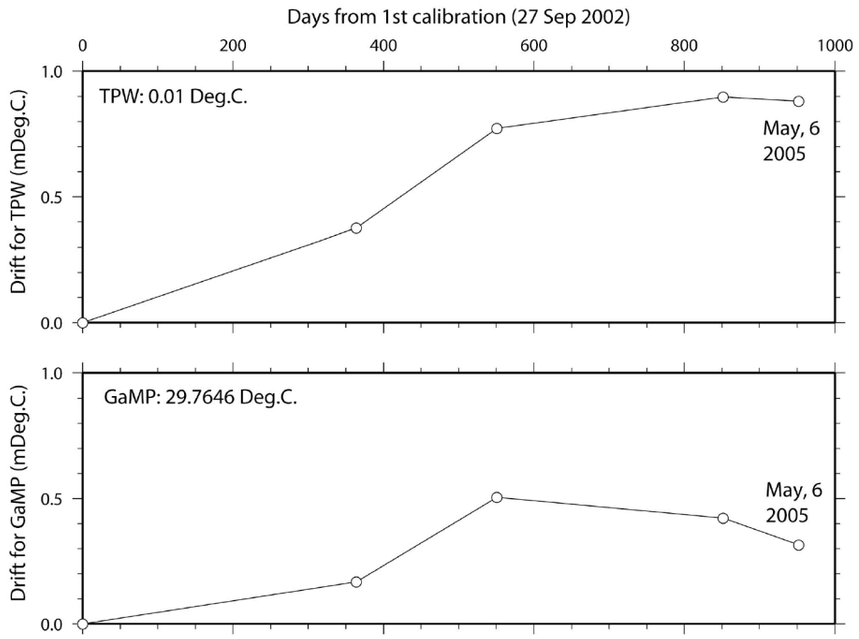

Figure 3.1.5. SBE35 (S/N 0045) time drift based on laboratory fixed point calibrations (triple point of water, TPW and gallium melt point, GaMP) performed by SBE, Inc.

(4.6) Altimeter

Benthos PSA-916T Sonar Altimeter (Benthos, Inc., USA) 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. The PSA-916T is the same as the standard PSA-916 Sonar Altimeter except that it is housed in a corrosion-resistant titanium pressure case. It is O-ring-sealed and rated for operation in water depths up to 10,000 meters. In this unit, a 250 microseconds pulse at 200 kHz is transmitted 5 times in a second. The PSA-916T uses the nominal speed of sound of 1,500 m/s. Thus the unit itself, neglecting variations in the speed of sound, can be considered accurate to 5 % or 0.1 meter, whichever is greater. In the PSA-916T the jitter of the detectors is approximately 5 microseconds or ± 0.4 cm total distance. Since the total travel time is divided by two, the jitter error is ± 0.2 cm.

The following scale factors were used in SEASOFT:

S/N 1157

FSVolt * 300 / FSRange = 15

Offset = 0.0

(4.7) Fluorometer

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

The following coefficients were used in SEASOFT:

S/N 2579

Gain = 30

Offset = 0.0

Chlorophyll-a concentration is computed as

Chlorophyll-a (μg/l) = (Voltage * 30 / Gain) + Offset

(5) Data collection and processing

(5.1) Data collection

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

was mounted horizontally in a 36-position carousel frame.

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

The package was lowered into the water from the starboard side and held 10 m beneath the surface for about one minute in order to activate the pump. After the pump was activated, the package was lifted to the surface and lowered at a rate of 1.0 m/s to 200 m then the package was stopped in order to operate the heave compensator of the crane. The package was lowered again at a rate of 1.2 m/s to the bottom. The position of the package relative to the bottom was monitored by the altimeter reading. Also the bottom depth was monitored by the SEABEAM multi-narrow beam sounder on board. For the up cast, the package was lifted at a rate of 1.2 m/s except for bottle firing stops. At each bottle firing stops, the bottle was fired after waiting from the stop for 30 seconds and the package was stayed 5 seconds for measurement of the Deep Ocean Standards Thermometer. At 200 m from the surface, the package was stopped in order to stop the heave compensator of the crane.

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

The SBE 11plus deck unit received the data signal from the CTD. Digitized data were forwarded to a personal computer running the SEASAVE data acquisition software. Temperature, conductivity, salinity, oxygen and descent rate profiles were displayed in real-time with the package depth and altimeter reading. Differences in temperature salinity and oxygen between primary and secondary sensor were also displayed in order to monitor the status of the sensors.

Data acquisition software

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

(5.2) Data collection problems

At station P10N_142, bottle #1 did not fire at the beginning of the up cast. The first cast was aborted and Y-cable was replaced.

At station P10N_137, the primary temperature showed abnormal values at depths between 450 and 430 dbar in the up cast. The connecting cable and connector for the primary temperature sensor was checked and cleaned.

At station P10N_122, the primary oxygen sensor was replaced because the difference between the sensor output and the bottle oxygen was gradually becoming greater (40 μmol/kg near the bottom).

At station P10N_113, the primary temperature data was slightly noisy during up cast. And at station P10N_112, the primary temperature signal was lost near the bottom. The connecting cable for the temperature sensor was replaced after the cast.

At station P10N_101 and 100, the secondary temperature and conductivity were very noisy from the up cast of P10N_101 because of something in the secondary TC duct. The TC duct was flushed well after the cast.

At station P10_62, the CTD signal was lost at 1,270 dbar in the down cast and the cast was aborted. The second cast was carried out after re-connecting the armored cable and pigtail.

At station P10_53, the secondary conductivity was abnormally biased near the bottom. The conductivity sensor was replaced after the cast.

At station P10_27, the secondary conductivity was abnormally biased near the bottom. The conductivity sensor was replaced after the cast.

(5.3) Data processing

SEASOFT consists of modular menu driven routines for acquisition, display, processing, and archiving of oceanographic data acquired with SBE equipment, and is designed to work with a compatible personal computer. Raw data are acquired from instruments and are stored as unmodified data. The conversion module DATCNV uses the instrument configuration and calibration coefficients to create a converted engineering unit data file that is operated on by all SEASOFT post processing modules. Each SEASOFT module that modifies the converted data file adds proper information to the header of the converted file permitting tracking of how the various oceanographic parameters were obtained. The converted data is stored in rows and columns of ASCII numbers. The last data column is a flag field used to mark scans as good or bad.

The followings are the SEASOFT data processing module sequence and specifications used in the reduction of CTD data in this cruise.

Data processing software

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

DATCNV converted the raw data to scan number, pressure, depth, temperatures, conductivities, oxygen voltage, descent rate, altitude and fluorescence. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition.

The duration was set to 4.4 seconds, and the offset was set to 0.0 seconds.

ROSSUM created a summary of the bottle data. The bottle position, date, time were output as the first two columns. Scan number, pressure, depth, temperatures, conductivities, oxygen voltage, descent rate, altitude and fluorescence were averaged over 4.4 seconds. And salinity, potential temperature, density (σ_θ) and oxygen were computed.

ALIGNCTD converted the time-sequence of conductivity and oxygen sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9plus CTD with the ducted temperature and conductivity sensors and a 3,000-rpm pump, 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 oxygen sensor output (oxygen voltage) relative to the temperature.

WILDEDIT marked extreme outliers in the data files. The first pass of WILDEDIT obtained an accurate estimate of the true standard deviation of the data. The data were read in blocks of 1000 scans. Data greater than 10 standard deviations were flagged. The second pass computed a standard deviation over the same 1000 scans excluding the flagged values. Values greater than 20 standard deviations were marked bad. This process was applied to all variables.

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

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

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

SECTION selected a time span of data based on scan number in order to reduce a file size. The minimum number was set to be the 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 package came up from the surface. Data for estimation of the CTD pressure drift were prepared before SECTION.

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

DERIVE was used to compute oxygen.

BINAVG averaged the data into 1-dbar pressure bins. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center value plus and minus half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data record could 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 salinity data were manually eliminated for the raw data. When number of data in the 1-dbar-pressure bin was less than 10, the data of the bin was not used. For remaining spikes in the Fluorometer data near surface, quality flags of the Fluorometer data were set to 4. Remaining spikes in the oxygen data were eliminated for a 1-dbar averaged data when the difference between original data and low-pass (7-dbar median) filtered data was greater than or equal to 0.003 (voltage) at the pressure level greater or equal to 1,200 dbar (1,150 dbar for station X03). The data gap over 1-dbar was linearly interpolated with a quality flag of 6.

(6) Post-cruise calibration

(6.1) Pressure

The CTD pressure sensor offset in the period of the cruise is estimated from the pressure readings on the ship deck. For best results the Paroscientific sensor has to be powered for at least 10 minutes before the operation and carefully temperature equilibrated. However, CTD system was powered only several minutes before the operation at most of stations. In order to get the calibration data for the pre- and post-cast pressure sensor drift, the CTD deck pressure is averaged over first and last two minutes, respectively. Then the atmospheric pressure deviation from a standard atmospheric pressure (14.7 psi) is subtracted from the CTD deck pressure. The atmospheric pressure was measured at the captain deck (20 m high from the base line) and sub-sampled one-minute interval as a meteorological data. Time series of the CTD deck pressure is shown in Figure 3.1.6.

The CTD pressure sensor offset is estimated from the deck pressure obtained above. Mean of the pre- and the post-casts data over the whole period gave an estimation of the pressure sensor offset from the pre-cruise calibration. Mean residual pressure between the dead weight piston gauge and the calibrated CTD data at 0 dbar of the pre-cruise calibration is subtracted from the mean deck pressure. Offset of the pressure data is estimated to be –0.40 dbar (Table 3.1.1). So the post-cruise correction of the pressure data is not deemed necessary for the pressure sensor.

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

S/N	Mean deck Pressure (dbar)	Standard deviation (dbar)	Residual pressure (dbar)	Estimated offset (dbar)
0677	–0.42	0.05	–0.02	–0.40

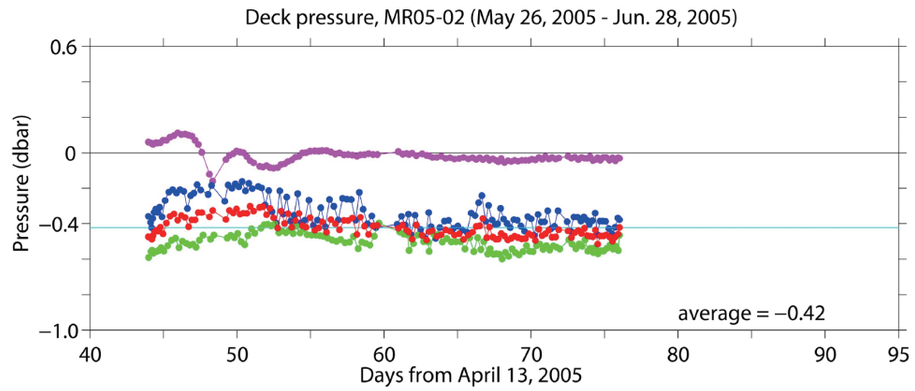

Figure 3.1.6. Time series of the CTD deck pressure. Pink dot indicates atmospheric pressure anomaly. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dot indicates an average of the pre- and the post-cast deck pressures.

(6.2) Temperature

The CTD temperature sensor (SBE 3) is made with a glass encased thermistor bead in a needle. The needle protects the thermistor from seawater. If the thermistor bead is slightly large of specification it receives mechanical stress when the needle is compressed at high pressure (Budeus and Schneider, 1998). The pressure sensitivity for a SBE 3 sensor is usually less than +2 m°C / 6000 dbar. It is somewhat difficult to measure this effect in the laboratory and it the difficulty is one of the primary reasons to use the SBE 35 at sea for critical work. Also SBE 3 measurements may be affected by viscous heating (about +0.5 m°C) that occurs in a TC duct and does not occur for un-pumped SBE 35 measurements (Larson and Pederson, 1996). Furthermore, the SBE 35 calibrations have some uncertainty (about 0.2 m°C) and SBE 3 calibrations have some uncertainty (about 1 m°C). So the practical corrections for CTD temperature data can be made by using a SBE 35, correcting the SBE 3 to agree with the SBE 35 (a linear pressure correction, a viscous heating correction and an offset for drift and/or calibration uncertainty).

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

S/N 0045, 15 August 2005 (2nd step: fixed point calibration)

Slope = 1.000011

Offset = –0.000973

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

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

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

where T is CTD temperature in °C, P is pressure in dbar, t is time in days from pre-cruise calibration date of CTD temperature and c_0, c_1, and c_2 are calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation from the SBE 35 data. The MATLAB® function FMINSEARCH is used to determine the sets. The FMINSEARCH uses the simplex search method (Lagarias et al., 1998). This is a direct search method that does not use numerical or analytic gradients.

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

The number of data used for the calibration and the mean absolute deviation from the SBE 35 are listed in Table 3.1.2 and the calibration coefficients are listed in Table 3.1.3. The results of the post-cruise calibration for the CTD temperature are summarized in Table 3.1.4 and shown in Figure 3.1.7 and 3.1.8.

Basically, the secondary temperature data is used for the dataset. For the station P10N_101, P10N_100, P10_53 and P10_27, the primary temperature data is used instead of the secondary temperature data because the quality of the secondary conductivity data at these stations was bad.

Table 3.1.2. Number of data used for the calibration (pressure >= 1,950 dbar) and mean absolute deviation (ADEV) between the CTD temperature and the SBE 35.

S/N	Number of data	ADEV (m°C)	Note
1464	1586	0.10	for P10N_101, P10N_100, P10_53 and P10_27
1525	1583	0.10	

Table 3.1.3. Calibration coefficients for the CTD temperature sensors.

S/N	c_0 (°C/dbar)	c_1 (°C/day)	c_2 (°C)
1464	–1.0013e–7	2.4017e–6	0.56e–3
1525	–7.9037e–9	2.8765e–6	0.29e–3

Table 3.1.4. Difference between the CTD temperature and the SBE 35 after the post-cruise calibration. Mean and standard deviation (Sdev) are calculated for the data below and above 1,950 dbar. Number of data used is also shown.

S/N	Pressure >= 1,950 dbar			Pressure < 1,950 dbar		
	Num	Mean (m°C)	Sdev (m°C)	Num	Mean (m°C)	Sdev (m°C)
1464	1586	0.00	0.14	2171	–0.35	8.3
1525	1583	0.00	0.13	2153	–0.52	6.3

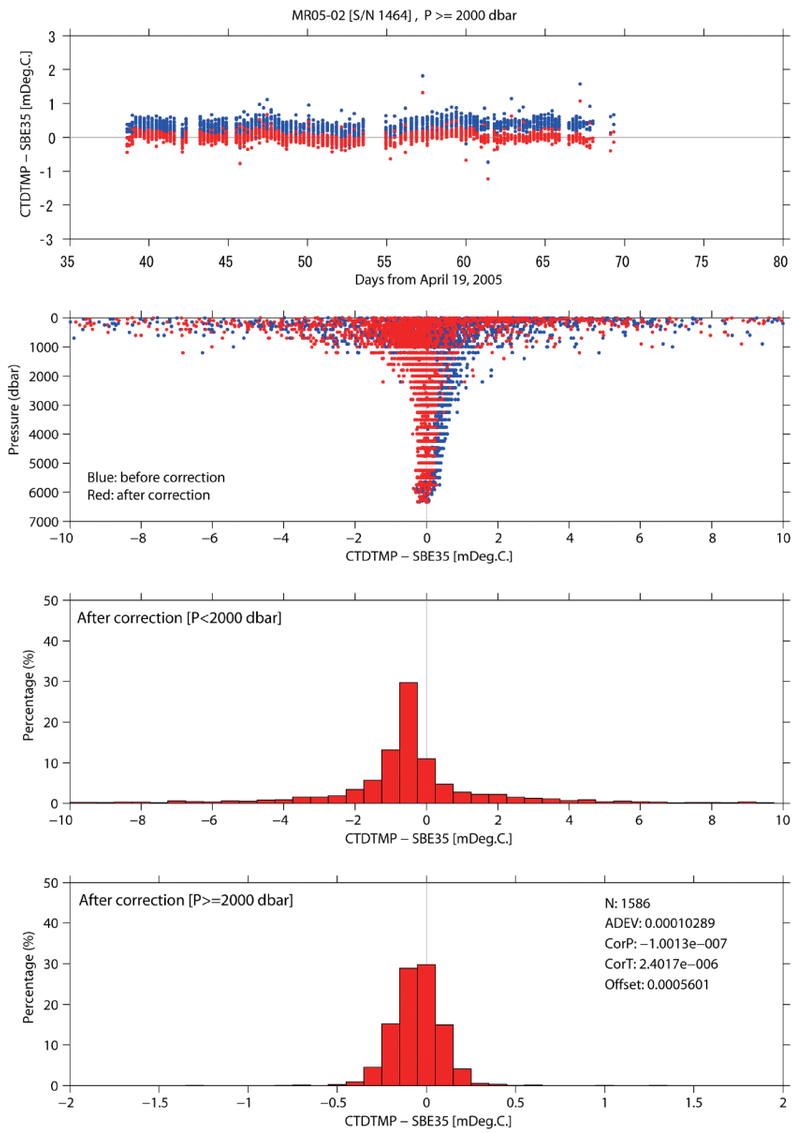

Figure 3.1.7. Difference between the CTD temperature (primary) and the Deep Ocean Standards thermometer (SBE 35). Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Lower two panels show histogram of the difference after the calibration.

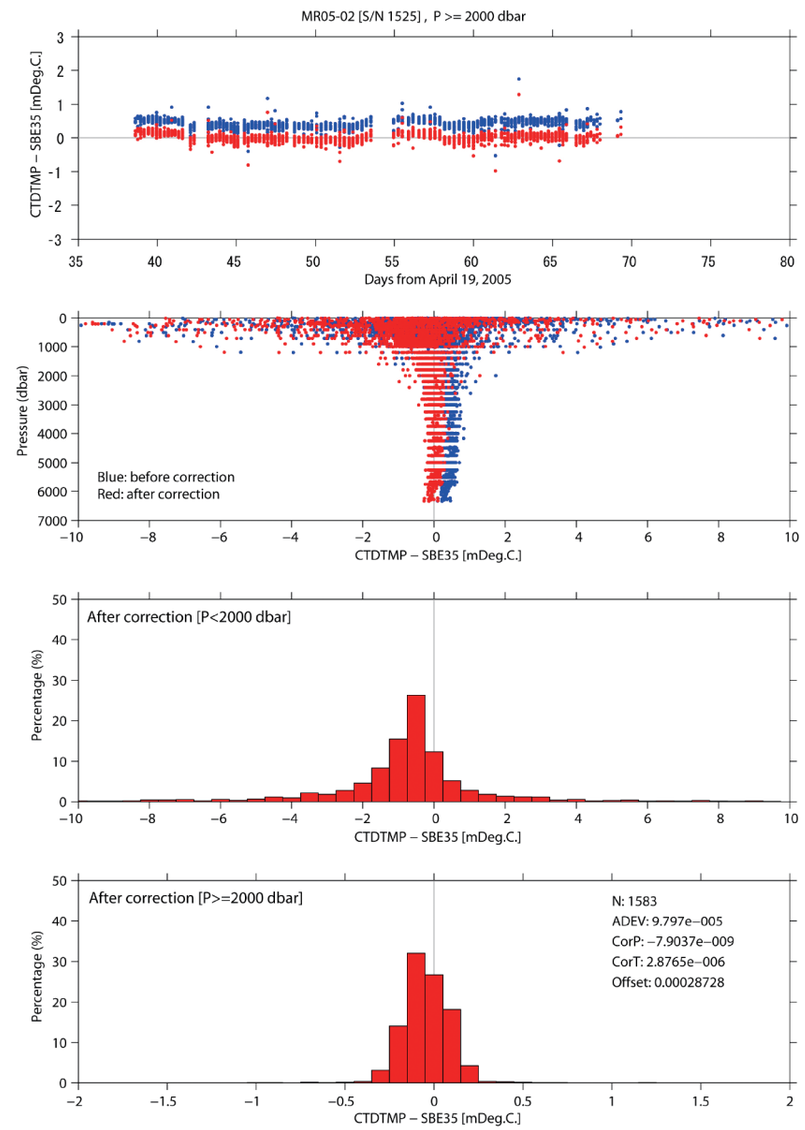

Figure 3.1.8. Same as Figure 3.1.7, but for the secondary CTD temperature.

(6.3) Salinity

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

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

where S is CTD salinity, P is pressure in dbar, C is conductivity in S/m and c_0, c_1, c_2 and c_3 are calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation with a weight from the bottle salinity data. The MATLAB® function FMINSEARCH is used to determine the sets. The weight is given as a function of vertical salinity gradient and pressure as

$$\text{Weight} = \min[4, \exp\{\log(4) * Gr / Grad\}] * \min[4, \exp\{\log(4) * P^2 / PR^2\}]$$

where Grad is vertical salinity gradient in PSU $dbar^{-1}$, P is pressure in dbar. Gr and PR are threshold of the salinity gradient (0.5 mPSU $dbar^{-1}$) and pressure (1,000 dbar), respectively. When salinity gradient is small (large) and pressure is large (small), the weight is large (small) at maximum (minimum) value of 16 (1). The salinity gradient is calculated using up-cast CTD salinity data. The up-cast CTD salinity data is low-pass filtered with a 3-point (weights are 1/4, 1/2, 1/4) triangle filter before the calculation.

The calibration is performed for the salinity derived from the following conductivity sensor.

Secondary (S/N 3036): from P10N_143 to P10_54 except for P10N_101 and P10N_100

Secondary (S/N 1088): from P10_52 to P10_28

Secondary (S/N 2854): from P10_26 to P10_1

Primary (S/N 1203): for P10N_101, P10N_100, P10_53 and P10_27

The CTD data created by the software module ROSSUM are used after the post-cruise calibration for the CTD temperature. On stations P10N_101, P10N_100, P10_53 and P10_27, data quality of the secondary conductivity sensor was bad, so the data from the primary conductivity sensor are used for the stations.

The coefficients are determined for some groups of the CTD station. The results of the post-cruise calibration for the CTD salinity are summarized in Table 3.1.5 and shown in Figure 3.1.9. And the calibration coefficients and the number of the data (Num) used for the calibration are listed in Table 3.1.6.

Table 3.1.5. Difference between the CTD salinity and the bottle salinity after the post-cruise calibration. Mean and standard deviation (Sdev) are calculated for the data below and above 1,000 dbar. Number of data used is also shown.

Pressure >= 1,000 dbar			Pressure < 1,000 dbar		
Num	Mean (mPSU)	Sdev (mPSU)	Num	Mean (mPSU)	Sdev (mPSU)
2031	–0.03	0.50	1548	–0.38	15.6

Table 3.1.6. Calibration coefficients for the CTD salinity.

Stations (Num)	c_0	c_1	c_2	c_3
143_1-122_1 (598)	1.0131034690e–5	8.0275830498e–4	–3.1419321824e–6	–1.7267523622e–4
121_1-102_1 (709)	1.1573101209e–6	–5.5651332935e–4	–4.1004021024e–7	4.8048881814e–3
101_1-100_1, 53_1, 27_1 (134)	7.0963418115e–7	–1.4372272016e–3	–1.9540013620e–7	6.9910914220e–3
99_1-61_1 (695)	–7.2653193556e–7	–4.6533749916e–4	1.6408648275e–7	3.6992027960e–3
60_1-54_1 (228)	4.2743744355e–6	–1.0727071488e–3	–1.3910765762e–6	5.0556686130e–3
52_1-40_1 (436)	–1.9442243171e–6	–2.9304615120e–3	6.6566837298e–7	1.0095656997e–2
39_1-28_1 (334)	–7.0071602987e–6	–3.1405026102e–3	2.2878224338e–6	1.0159646236e–2
26_1-1_1 (578)	–7.0377497246e–6	–2.4744338608e–3	2.1748120985e–6	1.0327699240e–2

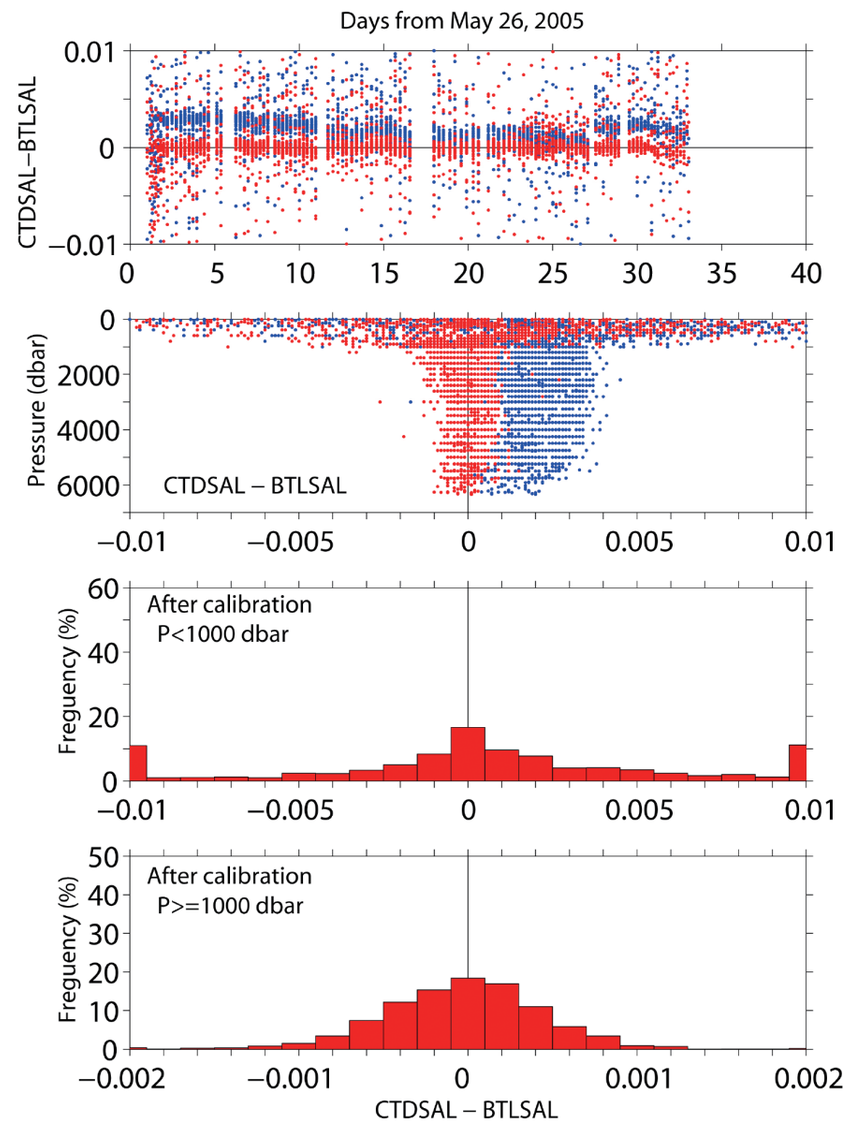

Figure 3.1.9. Difference between the CTD salinity and the bottle salinity. Blue and red dots indicate before and after the post-cruise calibration using the bottle salinity data, respectively. Lower two panels show histogram of the difference after the calibration.

(6.4) Oxygen

The CTD oxygen is calibrated using the oxygen model (see 3.1.3(4)) as

Calibrated oxygen (ml/l)

= {(Soc + dSoc) * {v + offset + doffset} * exp{(TCor + dTCor) * t + (PCor + dPCor) * p}}

* Oxsat(t, s)

where p is pressure in dbar, t is absolute temperature and s is salinity in psu. Oxsat is oxygen saturation value minus the volume of oxygen gas (STP) absorbed from humidity-saturated air (see 3.1.3(4)). Soc, offset, TCor and PCor are the pre-cruise calibration coefficients (see 3.1.3(4)), and dSoc, doffset, dTCor and dPCor are calibration coefficients. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation with a weight from the bottle oxygen data. The MATLAB® function FMINSEARCH is used to determine the sets. The weight is given as a function of vertical oxygen gradient and pressure as

$$\text{Weight} = \min[4, \exp\{\log(4) * Gr / Grad\}] * \min[4, \exp\{\log(4) * P^2 / PR^2\}]$$

where Grad is vertical oxygen gradient in μmol kg^{-1} $dbar^{-1}$, P is pressure in dbar. Gr and PR are threshold of the oxygen gradient (0.3 μmol kg^{-1} $dbar^{-1}$) and pressure (1,000 dbar), respectively. When oxygen gradient is small (large) and pressure is large (small), the weight is large (small) at maximum (minimum) value of 16 (1). The oxygen gradient is calculated using up-cast CTD oxygen data. The up-cast CTD oxygen data is low-pass filtered with a 3-point (weights are 1/4, 1/2, 1/4) triangle filter before the calculation.

The calibration is basically performed for the output from secondary oxygen sensor. On stations P10N_101 and P10N_100, data quality of the secondary oxygen sensor were bad, so the data from the primary oxygen sensor are used for the stations. The down-cast CTD data sampled at same density of the up-cast CTD data created by the software module ROSSUM are used after the post-cruise calibration for the CTD temperature and salinity.

The coefficients are basically determined on each station. Some stations, especially on shallow stations, are grouped for determining the calibration coefficients. The results of the post-cruise calibration for the CTD oxygen are summarized in Table 3.1.7 and shown in Figure 3.1.10. And the calibration coefficients and number of the data used for the calibration are listed in Table 3.1.8.

Table 3.1.7. Difference between the CTD oxygen and the bottle oxygen after the post-cruise calibration. Mean and standard deviation (Sdev) are calculated for the data below and above 1,000 dbar. Number of data used is also shown.

Pressure >= 1,000 dbar			Pressure < 1,000 dbar		
Num	Mean (μmol/kg)	Sdev (μmol/kg)	Num	Mean (μmol/kg)	Sdev (μmol/kg)
2091	–0.01	0.89	1586	–0.74	6.10

Table 3.1.8. Calibration coefficients for the CTD oxygen.

Stations (Num)	dSoc	dTCor	dPCor	doffset
143_1-135_1(150)	8.4629646531e–3	5.8573110490e–5	8.5929128792e–6	–2.5296856384e–2
134_1 (33)	1.1267442718e–2	–6.2548916427e–3	3.5064120727e–6	–9.4194921754e–3
133_1 (35)	1.6126510125e–2	3.5398495888e–4	2.1736462754e–6	–1.4625220328e–2
132_1 (34)	2.3848796038e–2	–7.2897960077e–4	1.4777271150e–7	–1.7971132206e–2
131_1-130_1 (70)	2.5787931229e–2	–1.1510003784e–3	1.7500494703e–6	–2.5297499910e–2
129_1 (35)	2.5699254255e–2	–2.4457679187e–3	3.1376007240e–6	–2.8137637876e–2
128_1 (36)	2.7101839015e–2	–5.3160010276e–3	1.0471669748e–6	–2.1112173634e–2
127_1-124_1(140)	3.2771370687e–2	–1.4194990742e–3	4.3317721484e–7	–3.1264320130e–2
123_1 (34)	1.3461831314e–2	1.2534561726e–3	3.4977813378e–6	–1.1130414739e–2
122_1-121_1 (67)	2.4505139384e–2	–7.6774993155e–6	4.0666037955e–6	–1.9391470346e–2
120_1-118_1(106)	2.4393648003e–2	3.8668328581e–4	4.8139225402e–6	–2.2964168413e–2
117_1 (36)	6.4297501230e–2	–6.0748102232e–3	1.2321533791e–5	–4.3578232477e–2
116_1-115_1 (69)	6.1728950413e–2	–2.4236972142e–3	8.4116664417e–6	–2.8152202106e–2
114_1 (36)	7.0360855399e–2	–1.9473306036e–3	7.1904905368e–6	–3.4375305778e–2
113_1 (36)	5.7514523169e–2	–1.3251658263e–3	1.1702324658e–5	–2.8436450647e–2
112_2 (36)	6.1225526921e–2	–1.1296247021e–3	1.5631766694e–5	–2.7485442452e–2

111_1 (32)	7.3605378139e–2	–2.3174647896e–3	1.4955041317e–5	–3.2962769302e–2
110_1-109_1 (72)	7.9506816981e–2	–3.0313412311e–3	1.2917095934e–5	–2.9537356741e–2
108_1 (34)	7.4044802064e–2	–2.9826802903e–3	1.3439480159e–5	–2.3326579573e–2
107_1 (36)	8.4416077466e–2	–3.7442549024e–3	1.2133117223e–5	–2.8990559091e–2
106_1 (36)	8.1559536467e–2	–3.7947285403e–3	1.0482801323e–5	–2.1130113322e–2
105_1 (36)	7.7977171662e–2	–3.5083314252e–3	1.2290289395e–5	–2.1629039232e–2
104_1 (35)	9.2261453429e–2	–4.7148684849e–3	1.0265062864e–5	–2.8761859259e–2
103_1 (36)	8.8878333181e–2	–4.1826341574e–3	1.1136323966e–5	–2.8237527730e–2
102_1-99_1 (67)	9.9200594712e–2	–5.0484640984e–3	8.8915471090e–6	–3.1905045411e–2
101_1 (34)	3.0129338190e–1	–1.1653504238e–2	1.1882141679e–5	–1.9842437289e–2
100_1 (35)	2.7158568330e–1	–9.6766702665e–3	1.8657995745e–5	–1.6643920468e–2
98_1-97_1 (72)	8.9242241499e–2	–4.1223589541e–3	1.3047469365e–5	–3.0402717515e–2
X02_1 (35)	9.1123725963e–2	–4.2545430365e–3	1.2211179226e–5	–2.9045382383e–2
96_1 (36)	8.6671887501e–2	–2.7985557054e–3	1.4356440319e–5	–2.9380552239e–2
95_1 (35)	9.1098196385e–2	–4.1664253311e–3	1.3708853093e–5	–3.2666306600e–2
73_1 (34)	8.6129574441e–2	–3.5603954781e–3	1.4574878522e–5	–2.9862423005e–2
72_1 (35)	1.0036481344e–1	–5.1093500434e–3	1.1666319684e–5	–3.6207838465e–2
71_1 (36)	8.4173654695e–2	–3.8092086700e–3	1.1274443416e–5	–1.8669779770e–2
70_1 (36)	1.0186076918e–1	–5.1541833011e–3	9.1342978652e–6	–3.1135324237e–2
69_1-68_1 (72)	8.9917533040e–2	–3.9168184780e–3	1.5457399284e–5	–3.5731052554e–2
67_1-X03_1 (72)	9.1207184596e–2	–4.1992442894e–3	1.1874997453e–5	–2.7891215819e–2
66_1-57_1 (343)	9.3811168599e–2	–3.9222893217e–3	1.3665539977e–5	–3.4973063121e–2
56_1 (35)	8.3919270521e–2	–3.0577403931e–3	1.2497919350e–5	–2.3422736496e–2
55_1 (35)	6.3554451043e–2	–1.6679231971e–3	1.4967295161e–5	–5.8774789743e–3
54_1-53_1 (67)	7.9632995540e–2	–2.6792794668e–3	1.4076926317e–5	–2.4184137595e–2
52_1-50_1 (105)	1.0468035054e–1	–4.2252408010e–3	1.0992132766e–5	–4.3523806492e–2
49_1 (36)	1.0325878768e–1	–3.9694348381e–3	1.4354033024e–5	–5.2396627173e–2
48_1 (36)	9.2004545333e–2	–3.5974926447e–3	1.1472902153e–5	–3.3149352166e–2
47_1 (36)	1.0423026238e–1	–4.1495148297e–3	9.6837199865e–6	–4.0672124901e–2
46_1 (35)	1.0055879128e–1	–3.8195756827e–3	1.1737826935e–5	–4.4066183201e–2
45_1 (36)	9.9165776795e–2	–3.8067274203e–3	1.2457982576e–5	–4.3479339238e–2
44_1 (35)	9.4137904347e–2	–3.4233002647e–3	1.3312121974e–5	–3.9890841285e–2
X04_1 (35)	1.0425859813e–1	–3.9296966528e–3	1.2713132819e–5	–5.0123360653e–2
42_1 (30)	1.0867593096e–1	–4.1215117254e–3	1.0764968338e–5	–5.2204671557e–2
41_1-33_1 (237)	9.3225751360e–2	–3.2381566447e–3	1.4385618009e–5	–4.2285094417e–2
32_1-31_1 (62)	9.6439233248e–2	–3.7464841484e–3	1.2562011963e–5	–4.3757150045e–2
30_1-27_1 (124)	7.9094998661e–2	–2.3057878654e–3	1.4624201939e–5	–2.6435707440e–2
26_1-24_1 (94)	7.4299364827e–2	–2.1170662031e–3	1.5207952108e–5	–2.1468378127e–2
23_1-21_1 (96)	7.8997591888e–2	–2.2185575199e–3	1.6807682992e–5	–3.1972596525e–2
20_1-18_1 (86)	6.2467592016e–2	–1.2496499182e–3	1.6052290286e–5	–5.3975020163e–3
17_1-16_1 (60)	8.8214792922e–2	–2.7635515096e–3	1.4852006762e–5	–3.9218993513e–2
15_1-1_1 (253)	5.8505595375e–2	–7.9127988583e–4	2.4416439079e–5	–1.2472116837e–2

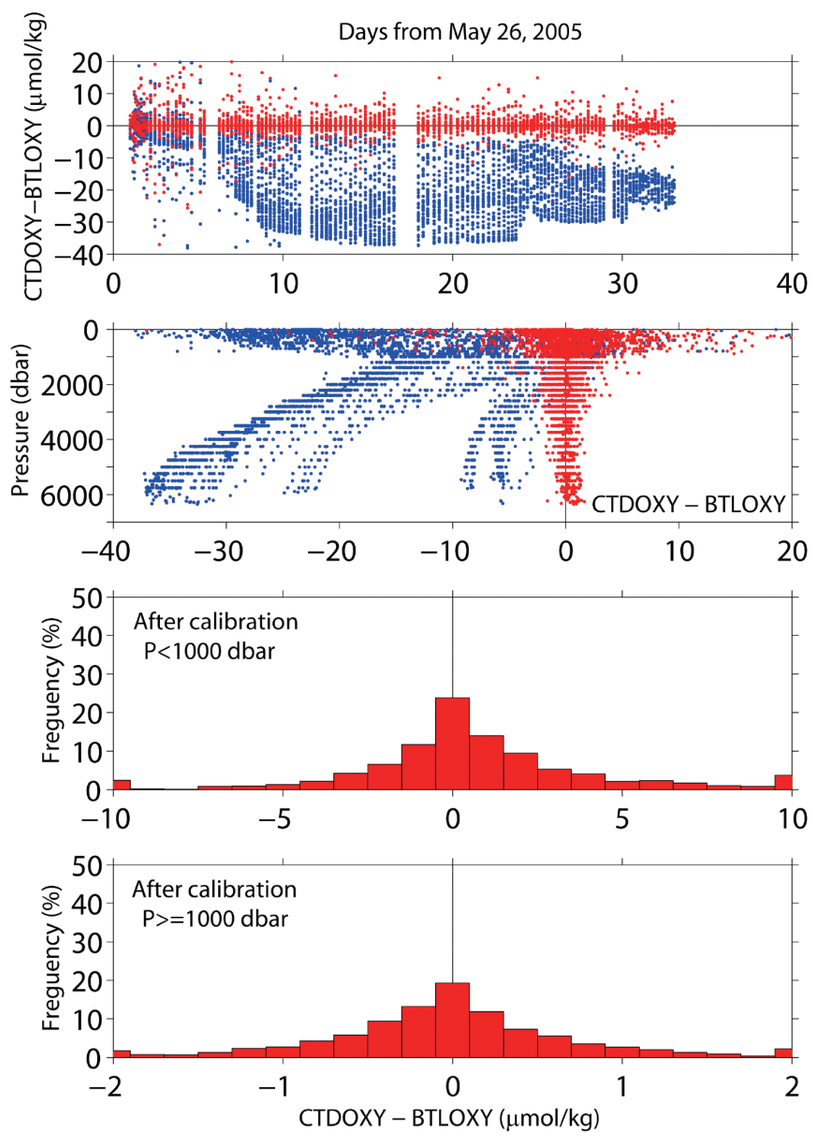

Figure 3.1.10. Difference between the CTD oxygen and the bottle oxygen. Blue and red dots indicate before and after the post-cruise calibration using the bottle oxygen data, respectively. Lower two panels show histogram of the difference after the calibration.

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(http://www.seabird.com/technical_references/paperindex.htm)

3.2 Salinity

13 October 2006

(1) Personnel

Takeshi Kawano (JAMSTEC)

Fujio Kobayashi (MWJ)

Kenichi Katayama (MWJ)

Tatsuya Tanaka (MWJ)

(2) Objectives

Measurement of bottle salinities in order to calibrate CTD salinities and to identify leaking bottles.

(3) Instrument and Method

(3.1) Salinity Sample Collection

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

(3.2) Instruments and Method

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

The measurement was conducted for about 16hours per day (typically from 7:00 to 23:00) and the cell was cleaned with ethanol or soap or both after the measurement of the day.

(3.3) Preliminary Result

Standard Seawater

Standardization control was set to 491 and all the measurements were done by this setting. During the whole measurement, STANDBY was 5509 ± 0001 and ZERO was 0.00001. We used IAPSO Standard Seawater batch P145 whose conductivity ratio was 0.99981 (double conductivity ratio is 1.99962) as the standard for salinity. We measured 177 ampoules of P145. There were 5 bad bottles whose conductivities are extremely high or low. Data of these 5 bottles are not taken into consideration hereafter.

Fig.3.2.1 shows the history of double conductivity ratio of the Standard Seawater batch P145. During this cruise, we did flushing the cell twice for cleaning using ultrasonic washing machine. The average of double conductivity ratio from Stn.143 to Stn.071 was 1.99962 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity. The average from Stn.070 to Stn.023 was 1.99963 and the standard deviation was 0.00001. We reduce 0.00001 to the measured double conductivity ratio during this period. The average of double conductivity ratio from Stn.022 to Stn.001 was 1.99962 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity.

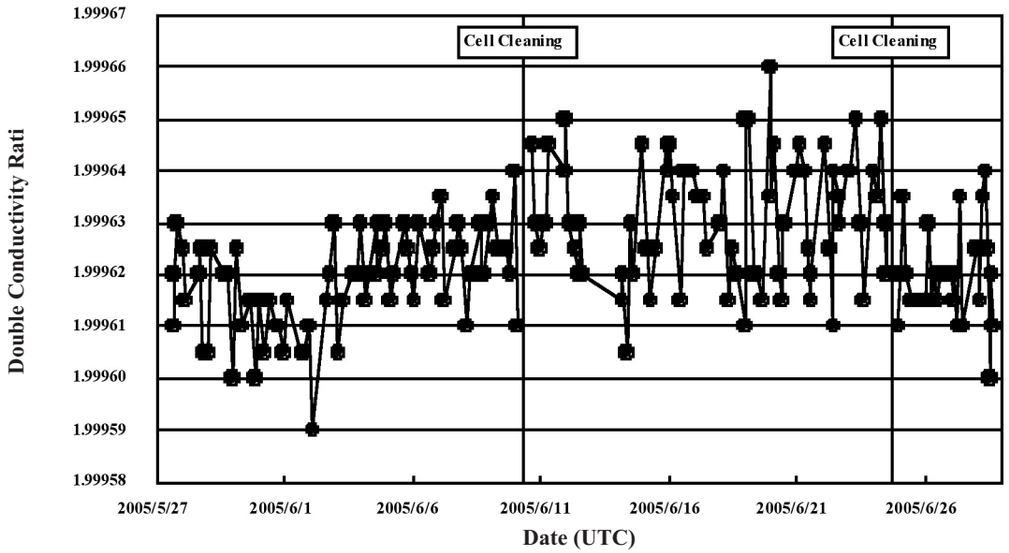

Figure 3.2.1. The history of double conductivity ratio of the Standard Seawater batch P145.

Sub-Standard Seawater

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

Replicate and Duplicate Samples

We took 666 pairs of replicate samples and 55 pairs of duplicate samples. Figure 3.2.2 (a) and (b) show the histogram of the absolute difference among replicate samples and among duplicate ones, respectively. There were six bad measurements and 18 questionable measurements in replicate samples and six questionable measurements in duplicate samples. Excluding these bad and questionable measurements, the standard deviation of the absolute deference of 642 pairs of replicate samples was 0.0002 in salinity and that of 48 pairs of duplicate samples was 0.0002 in salinity. The results of replicate samples were averaged and flagged as 6 in the seafile.

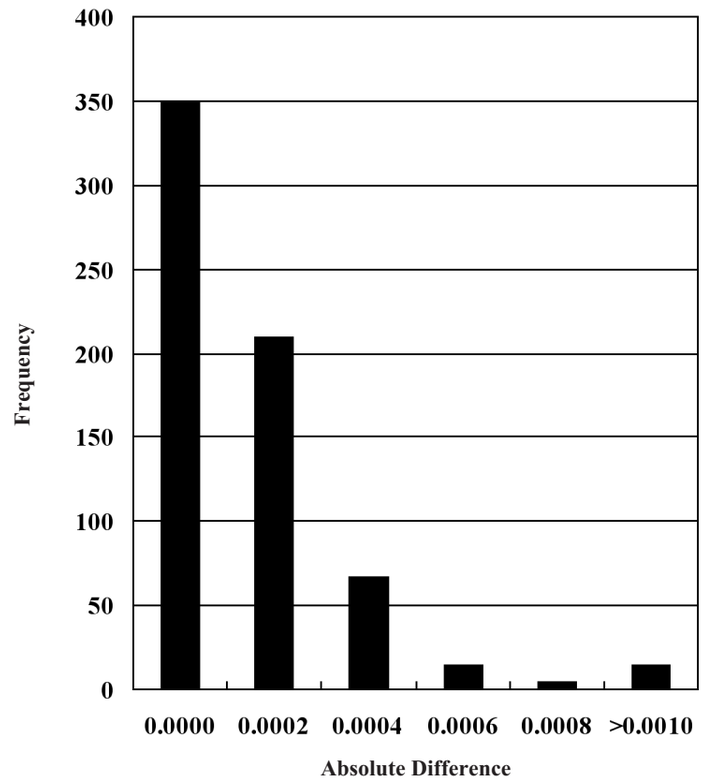

Figure 3.2.2 (a). The histogram of the absolute difference between replicate samples.

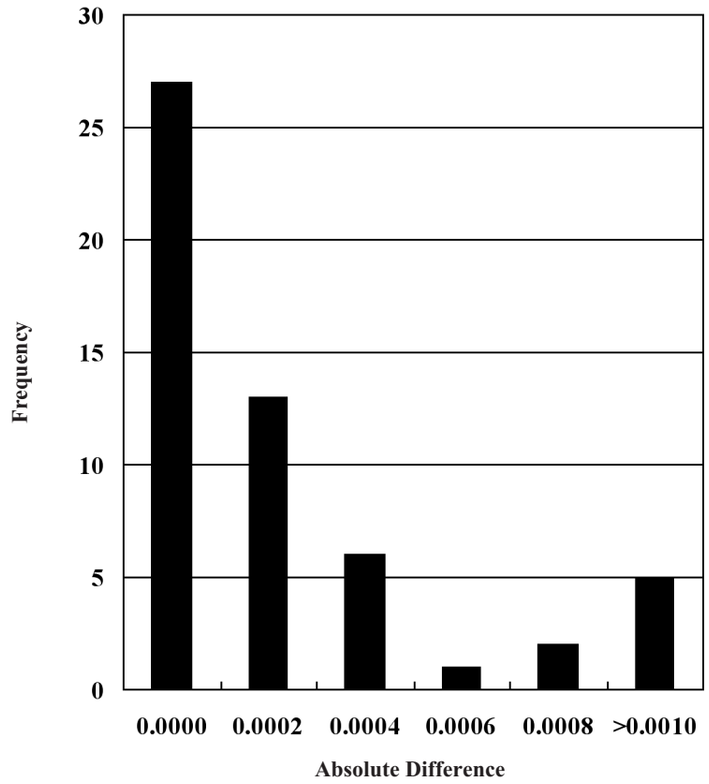

Figure 3.2.2 (b). The histogram of the absolute difference between duplicate samples.

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

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

3.3 Oxygen

17 October 2006

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(2) Objectives

Dissolved oxygen is a significant tracer for the ocean circulation study. Recent studies in the North Pacific indicated that dissolved oxygen concentration in intermediate layers decreased in basin wide scale during the past decades. The causes of the decrease, however, are still unclear. During MR05-02, we measured dissolved oxygen concentration from surface to bottom layers at all hydrocast stations. The stations from 29 °N to 4 °S reoccupied WHP P10 stations in 1993. Our purpose is to evaluate decadal change of dissolved oxygen in the western Pacific.

(3) Regent

Pickling Reagent I: Manganous chloride solution (3M)

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

Sulfuric acid solution (5M)

Sodium thiosulfate (0.025M)

Potassium iodate (0.001667M)

CSK standard of potassium iodate: Lot ASE8280, Wako Pure Chemical Industries Ltd., 0.0100N

(4) Instruments

Burette for sodium thiosulfate;

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

Burette for potassium iodate;

APB-410 manufactured by Kyoto Electronic Co. Ltd. / 20 cm^3 of titration vessel

Detector; Automatic photometric titrator manufactured, Kimoto Electronic Co. Ltd

(5) Seawater Sample

Following procedure is based on a determination method in the WHP Operations Manual (Dickson, 1996). Seawater samples were collected from Niskin sampler bottles attached to the CTD-system. Seawater for bottle oxygen measurement was transferred from the Niskin sampler bottle to a volume calibrated glass flask (ca. 100 cm^3). Three times volume of the flask of seawater was overflowed. Sample temperature was measured by a thermometer during the overflow. Then two reagent solutions (Reagent I, II) of 0.5 cm^3 each were added immediately to 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 and throughout. After the precipitate settled at least halfway down the flask, the flask was vigorously 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 to the sample flask and stirring began. Samples were titrated by with sodium thiosulfate solution whose molarity was determined by potassium iodate solution (section 3.3.6). Temperature of sodium thiosulfate during titration was recorded by a thermometer. During this cruise we measured dissolved oxygen concentration using two sets of the titration apparatus, DOT-1 and DOT-2. Dissolved oxygen concentration (μmol kg^{-1}) was calculated by sample temperature during the sampling, CTD salinity, flask volume, and titrated volume of the sodium thiosulfate solution.

(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 accurately weighed An acculately weighted 1.7835 g of potassium iodate was dissolved in deionized water and diluted to final volume of 5 dm^3 in a calibrated volumetric flask (0.001667M). 10 cm^3 of the standard potassium iodate solution was added to a flask using a 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 gave the molarity of the sodium thiosulfate titrant. Table 3.3.1 shows result of the standardization during this cruise. Error (C.V.) of the each standardization was less than 0.08 % (n = 5).

(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 3.8×10^{-8} mol (Dickson, 1996). 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 solutions were added to two flasks respectively. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were added to the two flasks in order. The blank was determined by difference between the two times of the first (1 cm^3 of KIO_3) titrated volume of the sodium thiosulfate and the second (2 cm^3 of KIO_3) one. The results of the blank determination are also shown in Table 3.3-1. The averaged blank of DOT-1 and DOT-2 were –0.007 and –0.010 cm^3, respectively.

Table 3.3.1. Results of the standardization and the blank determinations during MR05-02.

Date	KIO3		DOT-1 (cm^3)			DOT-2 (cm^3)			Samples
(UTC)	#	bottle	Na2S2O3	E.P.	blank	Na2S2O3	E.P.	blank	(Stations)
2005/5/26	1	20050420-01	20050523-1	3.959	–0.006	20050523-2	3.961	–0.011	135-143
2005/5/28		20050420-02	20050523-1	3.960	–0.005	20050523-2	3.961	–0.008	131-134
2005/5/29		20050420-03	20050523-3	3.957	–0.008	20050523-4	3.961	–0.011	127-130
2005/5/30		20050420-04	20050523-3	3.960	–0.006	20050523-4	3.964	–0.008	123-126
2005/5/31		20050420-05	20050529-1	3.959	–0.006	20050529-2	3.961	–0.009	119-122
2005/6/2		20050420-06	20050529-1	3.959	–0.006	20050529-2	3.959	–0.009	115-118
2005/6/3		20050420-07	20050529-3	3.959	–0.007	20050529-4	3.960	–0.008	111-114
2005/6/4		20050420-08	20050529-3	3.958	–0.006	20050529-4	3.961	–0.009	107-110
2005/6/5	2	20050420-13	20050603-1	3.954	–0.007	20050603-2	3.957	–0.011	103-106
2005/6/6		20050420-14	20050603-1	3.956	–0.006	20050603-2	3.956	–0.011	99-102
2005/6/7		20050420-15	20050603-3	3.956	–0.007	20050603-4	3.958	–0.011	96,X02,97,98
2005/6/8		20050420-16	20050603-3	3.955	–0.008	20050603-4	3.959	–0.009	69-73,95
2005/6/10		20050420-17	20050609-1	3.953	–0.009	20050609-2	3.955	–0.010	66,X03,67,68
2005/6/10		20050420-17	20050609-1	3.961	–0.008	20050609-2	3.960	–0.011	67
2005/6/11		20050420-18	20050609-1	3.953	–0.005	20050609-2	3.955	–0.010	62-65
2005/6/13		20050420-19	20050609-3	3.952	–0.008	20050609-4	3.954	–0.009	58-61
2005/6/14		20050420-20	20050609-3	3.954	–0.008	20050609-4	3.956	–0.010	54-57
2005/6/16	3	20050420-25	20050613-1	3.951	–0.007	20050613-2	3.953	–0.009	50-53
2005/6/17		20050420-26	20050613-1	3.953	–0.006	20050613-2	3.954	–0.009	46-49
2005/6/18		20050420-27	20050613-3	3.953	–0.008	20050613-4	3.954	–0.010	42,X04,44,45
2005/6/19		20050420-28	20050613-3	3.953	–0.008	20050613-4	3.954	–0.008	36-41
2005/6/20		20050420-29	20050618-1	3.960	–0.008	20050618-2	3.962	–0.010	31-35
2005/6/21		20050420-30	20050618-1	3.960	–0.007	20050618-2	3.962	–0.010	27-30
2005/6/22		20050420-32	20050618-3	3.960	–0.009	20050618-4	3.962	–0.010	23-26
2005/6/23		20050420-31	20050618-3	3.959	–0.009	20050618-4	3.960	–0.010	18-22
2005/6/25	4	20050420-40	20050622-1	3.958	–0.007	20050622-2	3.960	–0.010	12-17
2005/6/26		20050420-39	20050622-1	3.957	–0.005	20050622-2	3.959	–0.010	5-11
2005/6/27		20050420-38	20050622-3	3.957	–0.009	20050622-4	3.961	–0.008	1-4

(9) Reagent blank

The blank determined in the section 3.3.7, pure water blank ($V_{blk,\,dw}$) can be represented by equation 1,

$$V_{blk,\,dw} = V_{blk,\,ep} + V_{blk,\,reg} \qquad (1)$$

where

$V_{blk,\ ep}$ = blank due to differences between the measured end-point and the equivalence point;

$V_{blk,\ reg}$ = blank due to oxidants or reductants in the reagent.

Here, the reagent blank ($V_{blk,\ reg}$) was determined by following procedure. 1 cm^3 of the standard potassium iodate solution and 100 cm^3 of deionized water were added to two flasks. 1 cm^3 of sulfuric acid solution and 0.5 cm^3 of pickling reagent solution II and I each were added to the first flask in order. Then to the second flask, two times volume of the reagents (2 cm^3 of sulfuric acid solution, and 1.0 cm^3 of pickling reagent solution II and I each) was added. The reagent blank was determined by difference between the first (2 cm^3 of the total reagent volume added) titrated volume of the sodium thiosulfate and the second (4 cm^3 of the total reagent volume added) one. We also carried out experiments for three and four times volume of the reagents. The results are shown in Figure 3.3.1.

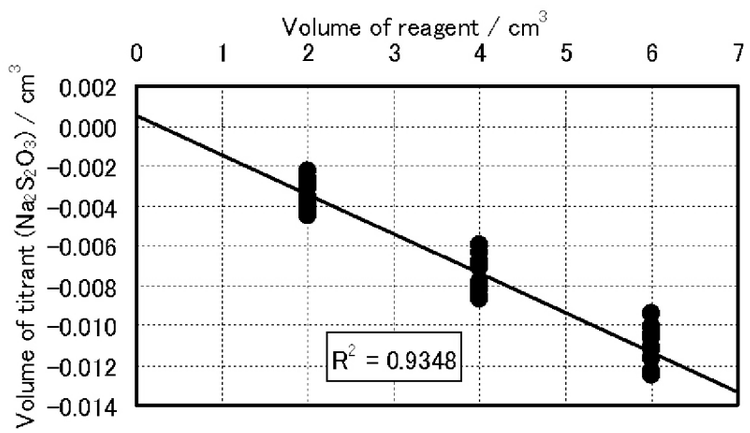

Figure 3.3.1. Blank (cm^3) due to redox species apart from oxygen in the reagents.

The relation between the reagent blank ($V_{blk,\ reg}$) and the volume of the reagents ($V_{reagent}$) is expressed by equation 2,

$$V_{blk,\ reg} = -0.0020\ V_{reagent} + 0.0005 \qquad (2).$$

There was no difference between the results of DOT-1 and DOT-2. $V_{blk,\ reg}$ was estimated to be about -0.004 cm^3, suggesting that about 0.02 μmol of reductants was contained in every 2 cm^3 of the reagents added. In other words, the difference of the pure water blank ($V_{blk,\ dw}$) between DOT-1 and DOT-2, determined in the section 3.3.7, was due to the difference of the end-point blank ($V_{blk,\ ep}$) between the two titration apparatus (-0.003 and -0.006 cm^3 for DOT-1 and DOT-2, respectively).

(10) Sample blank

Blank due to redox species other than oxygen in the sample ($V_{blk,\ spl}$) can be a potential source of measurement error. Total blank during the seawater measurement, seawater blank ($V_{blk,\ sw}$) can be represented by equation 3,

$$V_{blk,\ sw} = V_{blk,\ spl} + V_{blk,\ ep} + V_{blk,\ reg} \qquad (3).$$

If the end-point blank ($V_{blk,\ ep}$) is identical in pure water and in seawater, the difference between the seawater blank and the pure water one gives the sample blank ($V_{blk,\ spl}$),

$$V_{blk,\ sw} - V_{blk,\ dw} = V_{blk,\ spl} \qquad (4).$$

$V_{blk,\ spl}$ was determined by following procedure. Seawater sample was collected in the volume calibrated glass flask (ca. 100 cm^3) without the pickling. Then 1 cm^3 of the standard potassium iodate solution, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I each were added to the flask in order. Additionally, a flask contained 1 cm^3 of the standard potassium iodate solution, 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were prepared. The difference in the titrant volumes between the seawater flask and the deionized water one gave the sample blank ($V_{blk,\ spl}$).

During this cruise we measured vertical profiles of the sample blanks at two stations (Table 3.3.2) using DOT-1

system. The sample blank ranged from 0.4 to 0.9 µmol kg^{-1} and its vertical and horizontal variations are small. There are a few reports of the sample blank estimation of oxygen analysis in the open ocean. Our results agree with reported values ranged from 0.4 to 0.8 µmol kg^{-1} (Culberson *et al*., 1991). Even if we ignore the sample blank which introduce systematic errors in the oxygen calculations, these errors are expected to be the same for all investigators and not to affect the comparison of results by different investigators (Culberson, 1994).

Table 3.3.2. Results of the sample blank determinations during MR05-02.

Station: P10N-097 30.5 °N / 149.3 °E			Station: P10-019 0.3 °N / 146.2 °E		
Sample No. (Niskin No.)	CTD Pres. dbar	Sample blank µmol kg^{-1}	Sample No. (Niskin No.)	CTD Pres. dbar	Sample blank µmol kg^{-1}
5	51	0.5	35	51	0.4
33	151	0.6	33	150	0.7
31	249	0.6	31	251	0.7
29	402	0.7	29	401	0.9
27	602	0.6	27	601	0.7
25	800	0.6	25	801	0.7
23	1001	0.6	23	1001	0.7
21	1400	0.7	21	1400	0.7
17	2200	0.7	19	1802	0.7
15	2599	0.7	17	2200	0.7
13	3000	0.7	15	2600	0.7
11	3499	0.6	13	2999	0.7
9	4002	0.7	11	3499	0.7
7	4502	0.7	1	3770	0.9
5	4999	0.7			
3	5500	0.7			
	6251	0.7			

(11) Replicate sample measurement

Replicate samples were taken at every CTD cast. Total amount of the replicate sample pairs in good measurement (flag=2) was 452. The standard deviation of the replicate measurement was 0.11 µmol/kg and there was no significant difference between DOT-1 and DOT-2 measurements. The standard deviation was calculated by a procedure (SOP23) in DOE (1994). Figure 3.3.2 is plots of oxygen difference in the replicate measurement as a function of station sequential number and indicates the improvement of measurement skill during the cruise. There found large differences during the primary stage of the cruise. If we exclude the data at the initial ten stations from the calculation of standard deviation, it decreases to 0.09 µmol/kg.

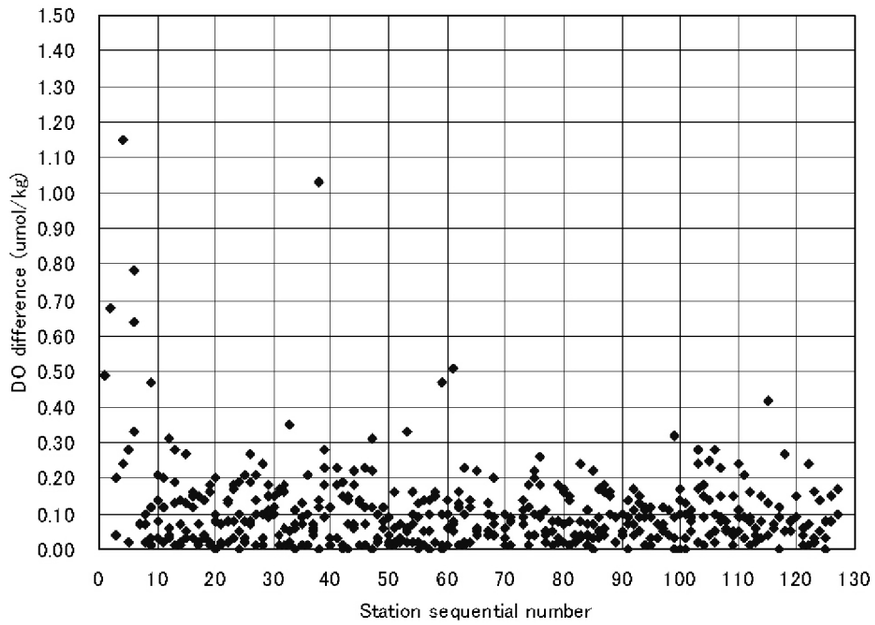

Figure 3.3.2. Difference in the replicate measurements against station sequential number.

As is shown in Figure 3.3.3, the layers of replicate sampling are localized at the surface layer, 1200, 3000 and 5000 dbar depths. Since scattering of the plots somewhat depend on depths, we classified replicate data in the following categories: surface (<20 dbar), intermediate (500-1500 dbar) and deep (>1500 dbar) layers. Standard deviation for each category is 0.16, 0.11, and 0.07 µmol/kg, respectively.

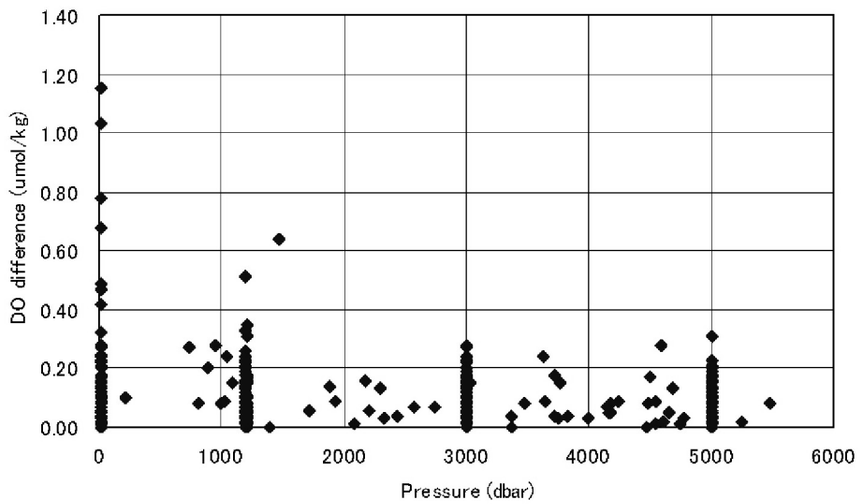

Figure 3.3.3. Difference in the replicate measurements against sampling depth (pressure).

(12) Duplicate sample measurement

We also collected seawater samples from two Niskin samplers that were fired at same depth (duplicate sampling). Duplicate samples were taken at 49 stations in the deep layer below 2000 dbar, and 48 duplicate sample pairs were obtained successfully. From Figure 3.3.4, variation in measurement resolution is not clear during the period of this cruise. The standard deviation of the total duplicate measurement was about 0.11 µmol/kg. This value is roughly close to the standard deviation of the replicate measurement for the intermediate and deep layers (>500 dbar). Thus, we conclude that our measurement resolution of bottle oxygen is about 0.1 µmol/kg or less for MR05-02 cruise.

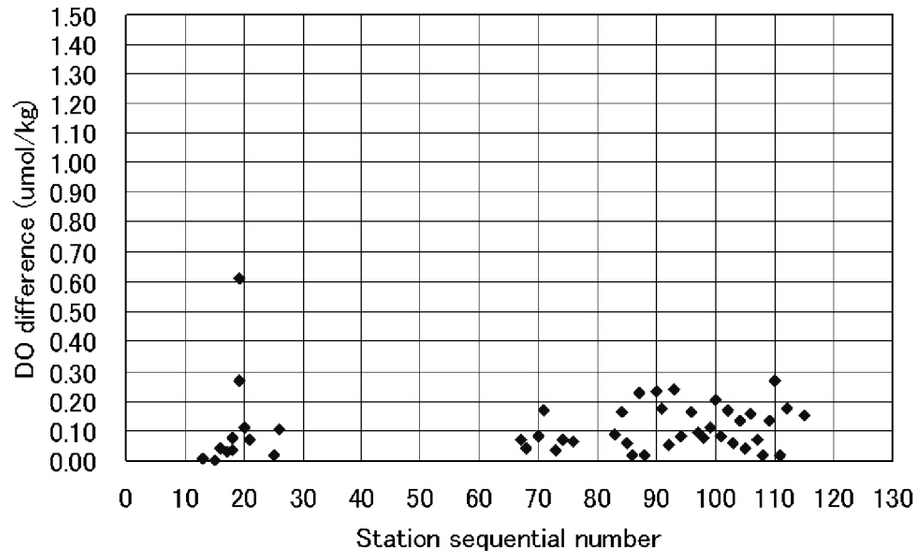

Figure 3.3.4. Difference in the duplicate measurements against station sequential number.

(13) CSK standard measurements

The CSK standard solution is a commercial potassium iodate solution (0.0100 N) for analysis of oxygen in seawater. During this cruise, we measured concentration of the CSK standard solution (Lot ASE8280) against our KIO3 standard in order to confirm accuracy of our oxygen measurement on board (Table 3.3.3). Averaged values of DOT-1 and DOT-2 were 0.009999 ± 0.000002 N and 0.009999 ± 0.000002 N respectively, which indicates that there was no systematic difference between DOT-1 and DOT-2 measurements. The averaged value of the CSK standard solution was so close to the certified value (0.0100 N) that we did not correct sample measurements with the CSK standard measurements. Additionally, we also measured another batch of the CSK standard solution, Lot TCK8677 that was also measured during our last cruise in 2003 (MR03-K04). We found that the measurements of the two batches of the CSK standard agreed well, suggesting that there was no systematic difference between our oxygen measurements in 2003 and in 2005.

Table 3.3.3. Results of the CSK standard measurements.

Date (UTC)	KIO3 batch#	DOT-1		DOT-2	
		Conc. (N)	error (N)	Conc. (N)	error (N)
2005/6/2	ASE8280-1	0.009997	0.000003	0.010002	0.000003
2005/6/11	ASE8280-2	0.010002	0.000003	0.009997	0.000003
2005/6/21	ASE8280-3	0.009999	0.000003	0.009997	0.000003
2005/6/27	ASE8280-4	0.009999	0.000005	0.009999	0.000003
Average		0.009999	0.000002	0.009999	0.000002
2005/6/11	TCK8677	0.009999	0.000003	0.009997	0.000003

Table 3.3.4. Summary of assigned quality control flags.

Flag	Definition	
2	Good	3294
3	Questionable	8
4	Bad	14
5	Not report (missing)	14
6	Mean of replicate	452
	Total	3782

(14) 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, 3, 4, 5 and 6 have been assigned (Table 3.3.4). For the choice between 2 (good), 3 (questionable) or 4 (bad), we basically followed a flagging procedure as listed below:

a. On a station-by-station basis, bottle oxygen and difference between bottle oxygen and CTD oxygen at the time of rosette sampling were plotted against CTD pressure. Any points not lying on a generally smooth trend were noted.

b. Dissolved oxygen was then plotted against potential temperature for several stations. If a datum deviated from a group of plots, it was flagged 3 or 4.

c. If the bottle flag was 4 (Did not trip correctly), a datum was noted and flagged 4, respectively. In case of the bottle flag 3 (Leaking), a datum was flagged based on steps a. and b.

Before the publishing of these data, as a post-cruise quality control for bottle oxygen, we carried out one more pass of flagging with the data at all stations. The following step was added.

d. In the oxygen-silicate diagram, data flagged 3 and 4 were examined once more in the mass of all data.

However, we found that all flaggings for 3 and 4 during the cruise were correct, therefore no data was upgraded to flag 2. Lastly, pairs of replicate both flagged 2 were averaged and flagged 6.

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3.4 Nutrients

2 July 2005

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(2) Objectives

The objectives of nutrients analyses during the R/V Mirai MR0502 cruise along 149 °E line in the Western North Pacific are as follows;

Describe the present status of nutrients in good traceability.

The target nutrients are nitrate, nitrite, phosphate and silicate (Although silicic acid is correct, we use silicate because a term of silicate is widely used in oceanographic community).

Study temporal and spatial variations of nutrients based on the previous high quality experiments data of WOCE, 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, phosphate and silicate in the interested area.

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

(3) Equipment and techniques

a. Analytical detail using TRAACS 800 systems (BRAN+LUEBBE)

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

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

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

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

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

The flow diagrams and regents for each parameter are shown in Figures 3.4.1-3.4.4.

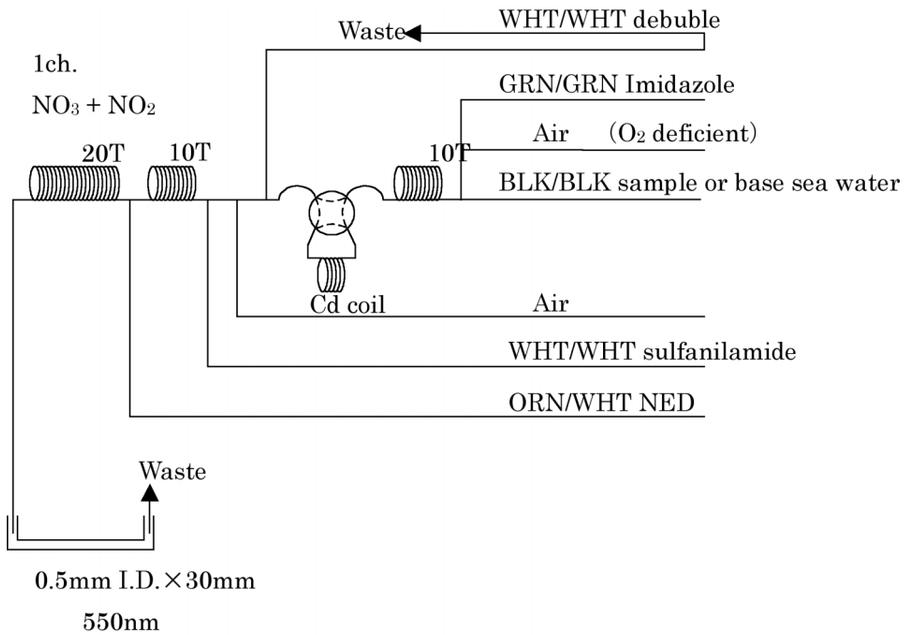

Figure3.4.1: 1ch. (NO_3+NO_2) Flow diagram.

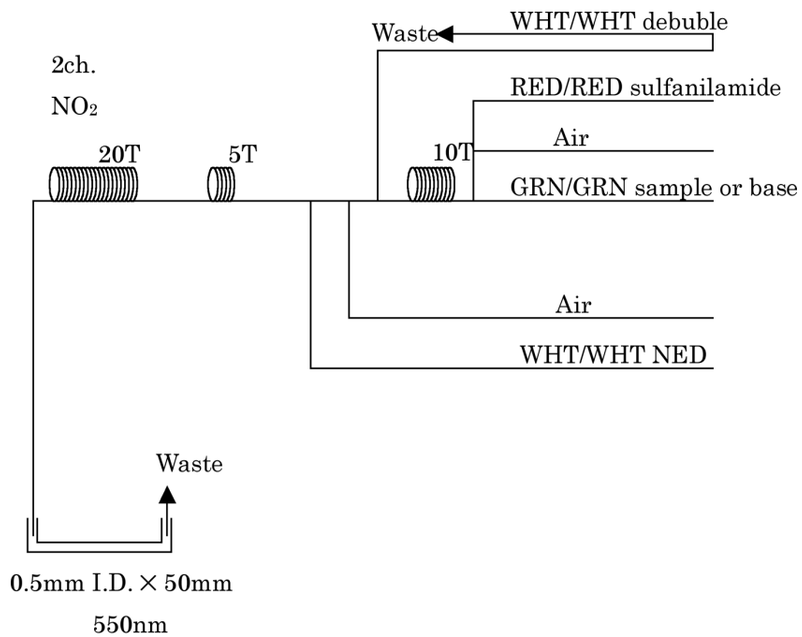

Figure 3.4.2: 2ch. (NO_2) Flow diagram.

Nitrate Reagents

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

Dissolve 4 g imidazole, $C_3H_4N_2$, in ca. 900 ml DIW; add 2 ml concentrated HCl; make up to 1000 ml with DIW. After mixing, 1 ml Triton®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 1000 ml of 1.2 M (10 %) HCl. After mixing, 1ml Triton®X-100 (50 % solution in ethanol) is added.

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

Dissolve 1 g NEDA, $C_{10}H_7NHCH_2CH_2NH_2$・2HCl, in 1000 ml of DIW; containing 10 ml concentrated HCl. Stored in a dark bottle.

Nitrite Reagents

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

Dissolve 10 g sulfanilamide, 4-$NH_2C_6H_4SO_3H$, in 1000 ml of 1.2 M (10 %) HCl. After mixing, 1ml Triton®X-100 (50 % solution in ethanol) is added.

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

Dissolve 1 g NEDA, $C_{10}H_7NHCH_2CH_2NH_2$・2HCl, in 1000 ml of DIW; containing 10 ml concentrated HCl. Stored in a dark bottle.

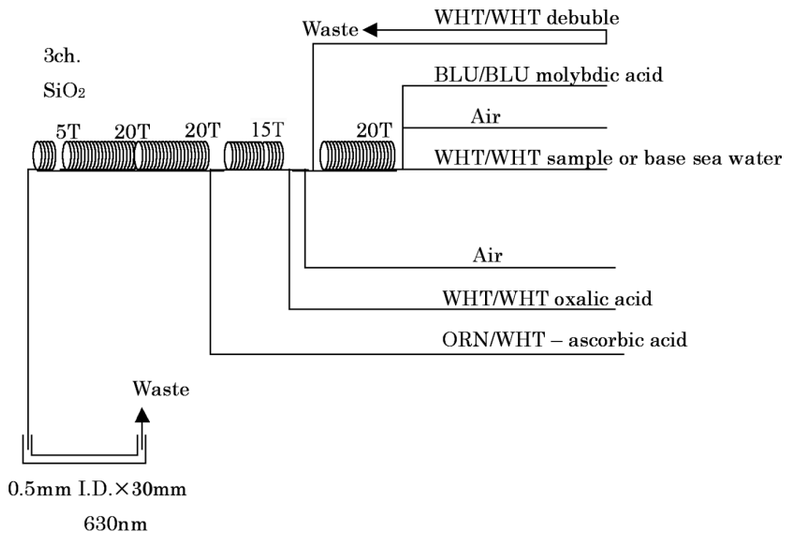

Figure 3.4.3. 3ch. (SiO_2) Flow diagram.

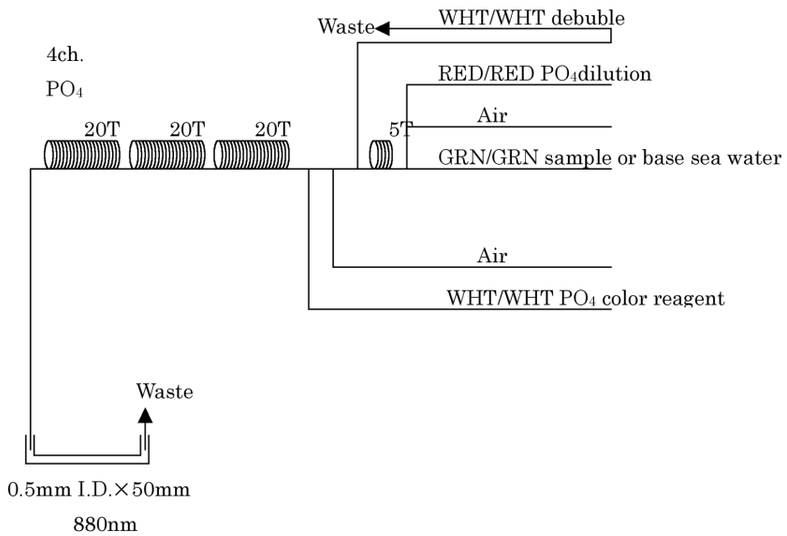

Figure 3.4.4. 4ch. (PO_4) Flow diagram.

Silicic Acid Reagents

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

Dissolve 15 g Disodium Molybdate(VI) Dihydrate, $Na_2MoO_4 \cdot 2H_2O$, in 1000 ml DIW containing 6 ml H_2SO_4. After mixing, 20 ml sodium dodecyl sulphate (15 % solution in water) is added.

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

Dissolve 50 g Oxalic Acid Anhydrous, HOOC: COOH, in 1000 ml of DIW.

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

Dissolve 2.5 g L (+)-Ascorbic Acid, $C_6H_8O_6$, in 100 ml of DIW. Stored in a dark bottle and freshly prepared before every measurement.

Phosphate Reagents

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

Dissolve 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 1000 ml of DIW containing 50 ml concentrated H_2SO_4.

Mixed Reagent

Dissolve 0.8 g L (+)-Ascorbic Acid, $C_6H_8O_6$, in 100 ml of stock molybdate solution. After mixing, 2 ml sodium dodecyl sulphate (15 % solution in water) is added. Stored in a dark bottle and freshly prepared before every measurement.

PO_4 dilution

Dissolve Sodium Hydrate, NaCl, 10 g in ca. 900 ml, add 50 ml Acetone and 4 ml concentrated H_2SO_4, make up to 1000 ml. After mixing, 5 ml sodium dodecyl sulphate (15 % solution in water) is added.

b. Sampling procedures

Sampling of nutrients followed that of oxygen, trace gases and salinity. Samples were drawn into two of virgin 10 ml polyacrylates vials without sample drawing tubes. These were rinsed three times before filling and vials were capped immediately after the drawing. The vials are put into water a bath at 26 °C for 10 minutes before using to stabilize the temperature of samples.

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

c. Data processing

Raw data from TRAACS800 were treated as follows;

Check baseline shift.

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

Carryover correction and baseline drift correction were applied to peak heights of each samples followed by sensitivity correction.

Baseline correction and sensitivity correction were done, basically using liner regression.

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

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

(4) Nutrients standards

a. In-house standards

(i) Volumetric Laboratory Ware

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

Volumetric flasks

Volumetric flasks of Class quality (Class A) are used because their nominal tolerances are 0.05 % or less over the size ranges, which is likely to be used in this work. Class A flasks are made of borosilicate glass, and the standard solutions were transferred to plastic bottles as quickly as possible after they are made up to volume and well mixed in order to prevent excessive dissolution of silicic acid from the glass. High quality plastic (polymethylpentene, PMP, or polypropylene) volumetric flasks were gravimetrically calibrated and used only within 3-4 K of the calibration temperature.

The computation of volume contained by glass flasks at various temperatures other than the calibration temperatures was 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 3-4 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.

(ii) Reagents, General considerations

General Specifications

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

For the silicate standards solution, we use commercial available silicon standard solution for atomic absorption spectrometry of 1000 mg l^{-1}. Since this solution is alkaline solution of 0.5 M KOH, an aliquot of 40 ml solution was diluted to 500 ml as B standard together with an aliquot of 20 ml of 1M HCl. Then the pH of B standard for silicate prepared to be 6.9.

Ultra pure water

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

Low-Nutrient Seawater (LNSW)

Surface water with 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 carefully measured in March 2005.

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

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

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

	A	B	C-1	C-2	C-3	C-4	C-5
NO_3 (μM)	45000	900	0	9	27	45	54
NO_2 (μM)	4000	20	0	0.2	0.6	1.0	1.2
SiO_2 (μM)	36000	2880	0	29	86	143	172
PO_4 (μM)	3000	60	0	0.6	1.8	3.0	3.6

Table 3.4.2. Working calibration standard recipes.

C-STD	B-1 STD	B-2 STD	MAT
C-1	0 ml	0 ml	60 ml
C-2	5 ml	5 ml	50 ml
C-3	15 ml	15 ml	30 ml
C-4	25 ml	25 ml	10 ml
C-5	30 ml	30 ml	0 ml

B-1 STD: Mixture of nitrate, silicate and phosphate

B-2 STD: Nitrite

(iv) Renewal of in-house standard solutions

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

Table 3.4.3. 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 NO3, SiO2, PO4)	3 days
B-2 Std. (NO2)	6 days

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

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

b. RMNS

To get more accurate and high quality nutrients data for achieving the objectives stated above, huge numbers of the bottles of the reference material of nutrients in seawater (hereafter RMNS) are prepared (Aoyama et al., submitted). In the previous world wide expeditions, such as WOCE cruises, higher reproducibility and precision of nutrients measurements were required (Joyce and Corry, 1994). Since no standards were available for the measurement of nutrients in seawater at that time, the requirements were described in term of reproducibility. The required reproducibility was 1 %, 1-2 %, 1-3 % for nitrate, phosphate and silicate, respectively. Although nutrient data from the WOCE one-time survey had unprecedented quality and coverage due to the uttermost 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 the 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 °C in potential temperature (Aoyama and Joyce, 1996).

(i) RMNS preparation

RMNS preparation and homogeneity for previous lots

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

In the R/V Mirai BEAGLE2003 cruise, which was round-the-world cruise along ca. 30 °S and conducted in 2003 and 2004, RMNS was analyzed at about 500 stations during the cruises. The results of BEAGLE2003 cruise will be available soon. (Databook of BEAGLE2003, 2005)

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

RMNSs for this cruise

RMNS lots BC, AV, AX, AY and BA, which covers full range of nutrients concentrations in the western North Pacific are prepared as packages. These packages were renewed daily and analyzed every 2-6 runs on the same day. 150 bottles of RMNS lot AZ are prepared to use every analysis at every hydrographic station. These RMNS assignment were completely done based on random number. The RMNS bottles were stored at a room, REGENT STORE, where the temperature was maintained at around 26-28 °C.

(ii) The homogeneity of RMNS and consensus values of the lot AH

The homogeneity of lot BC and analytical precisions are shown in Table 3.4.4. These are for the assessment of the magnitude of homogeneity of the RMNS bottles that are used during the cruise. As shown in Table3.4.4, the homogeneity of RMNS lot BC for nitrate and silicate are the same magnitude

Table 3.4.4. Homogeneity of lot BC and previous lots derived from simultaneous 30 samples measurements and analytical precision onboard R/V Mirai in May 2005.

	Nitrate	Phosphate	Silcate
	CV %	CV %	CV %
BC	0.22 %	0.32 %	0.19 %
(AH)	(0.39 %)	(0.83 %)	(0.13 %)
(K)	(0.3 %)	(1.0 %)	(0.2 %)
Precision	0.22 %	0.22 %	0.12 %

Note: N = 30 × 2

of analytical precision derived from fresh raw seawater. The homogeneity for phosphate, however, exceeded the analytical precision at some extent.

(5) Quality control

a. Precision of nutrients analyses during the cruise

Precision of nutrients analyses during the cruise was evaluated based on the 12 measurements, which were measured every 12 samples, during a run at the concentration of C-5. We also evaluated the reproducibility based on the replicate analyses of five samples in each run. Summary of precisions are shown in Table 3.4.5. As shown in Table 3.4.5 and Figures 3.4.5-3.4.7, the precisions for each parameter are generally good, considering the analytical precisions estimated from the simultaneous analyses of 60 samples in May 2005. Analytical precisions previously evaluated were 0.22 % for phosphate, 0.22 % for nitrate and 0.12 % for silicate, respectively. During this cruise, analytical precisions were 0.12 % for phosphate, 0.09 % for nitrate and 0.08 % for silicate in terms of median of precision, respectively. Then we can conclude that the analytical precisions for phosphate, nitrate and silicate were maintained or better throughout this cruise, comparing the pre-cruise evaluations. The time series of precision are shown in Figures 3.4.5-3.4.7.

Table 3.4.5. Summary of precision based on the replicate analyses of 12 samples in each run through out cruise.

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
Median	0.09	0.11	0.07
Mean	0.09	0.12	0.08
Maximum	0.17	0.29	0.19
Minimum	0.03	0.05	0.03
N	126	126	126

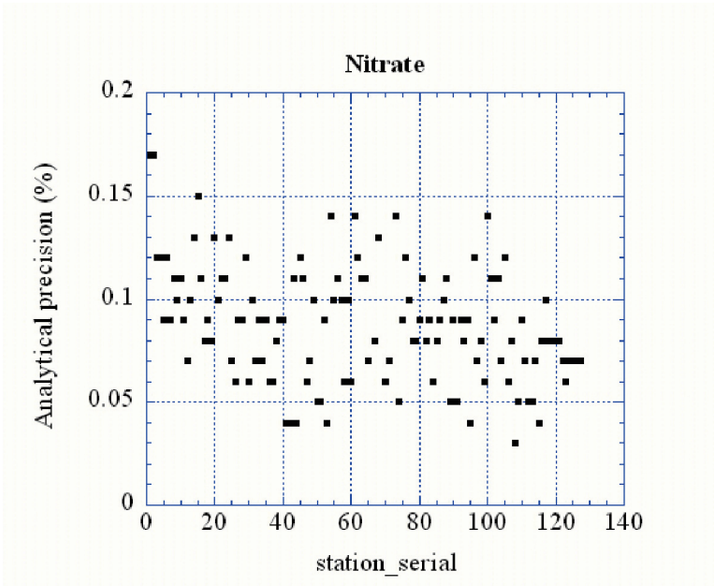

Figure 3.4.5. Time series of precision of nitrate.

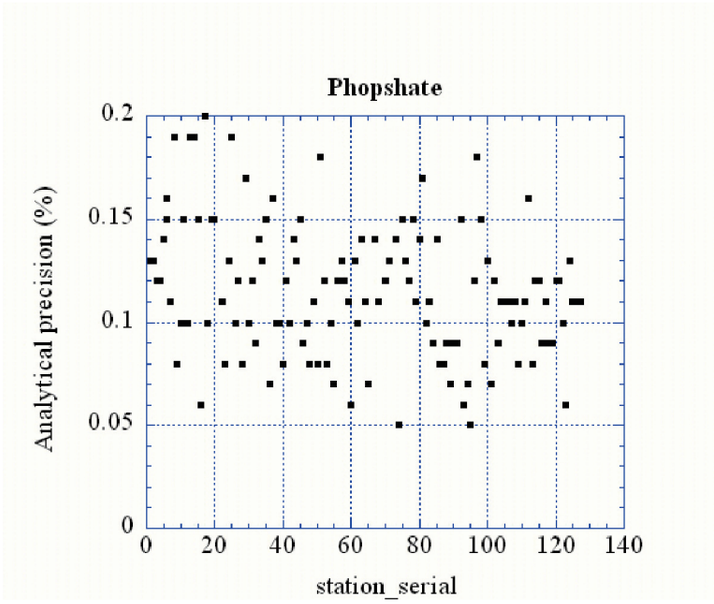

Figure 3.4.6. Time series of precision of phosphate.

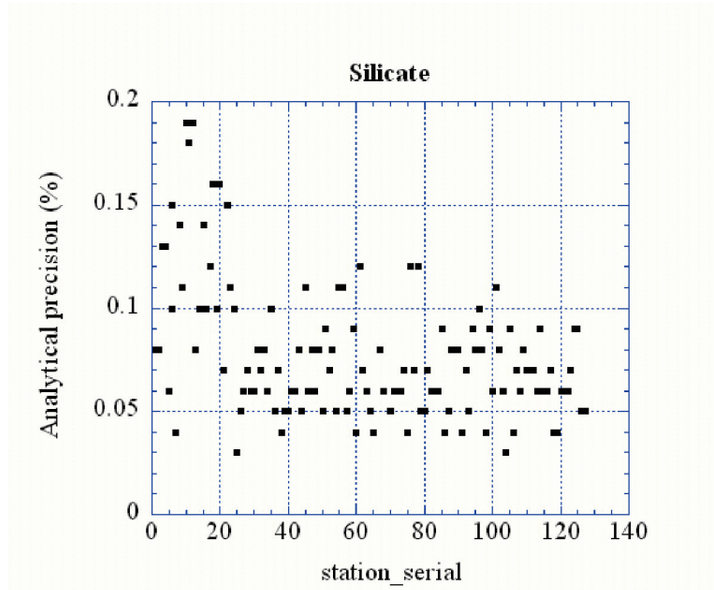

Figure 3.4.7. Time series of precision of silicate.

b. Carry over

We can also summarize the magnitudes of carryover throughout the cruise. These are as shown in Table 3.4.6.

Table 3.4.6. Summary of carry over through out cruise.

	Nitrate	Phosphate	Silicate
	%	%	%
Median	0.30	0.24	0.21
Mean	0.30	0.25	0.21
Maximum	0.50	0.71	0.38
Minimum	0.10	0.00	0.03
N	126	126	126

(6) Evaluation of trueness of nutrients concentrations using RMNSs

We have been using RMNS for all runs, then, we can evaluate the trueness of nutrients concentration throughout the cruise. Results of RMNS measurements are shown in Figures 3.4.8-3.4.10.

The uncertainties of nitrate, phosphate and silicate measurements for this cruise were evaluated as functions of concentrations of those. Uncertainties of nitrate measurement are expressed by eq. (1).

$$\text{Uncertainties (\%)} = 0.13 + 1.66 / \text{Cnitrate} \quad \cdots \quad (1)$$

where Cnitrate is nitrate concentration in µmol kg^{-1}.

Uncertainties of phosphate measurement are expressed eq. (2).

$$\text{Uncertainties(\%)} = -0.11 + 1.032 / \text{Cphos} \quad \cdots \quad (2)$$

where Cphos is phosphate concentration in µmol kg^{-1}.

Uncertainties of silicate measurement are expressed eq. (3).

$$\text{Uncertainties (\%)} = 0.095 + 4.92 / \text{Csilicate} \quad \cdots \quad (3)$$

where Csilicate is silicate concentration in µmol kg^{-1}.

Then, three columns to show the uncertainties of nutrients measurement were created in the sea file of this cruise.

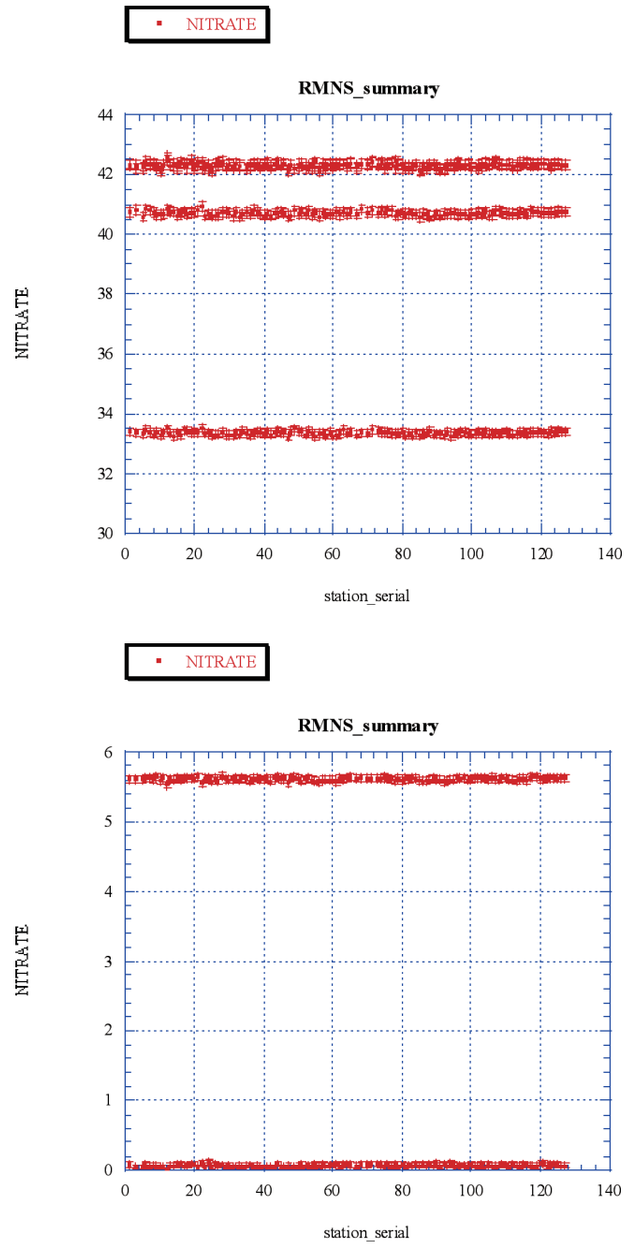

Figure 3.4.8. Time series of nitrate concentration for RMNSs.

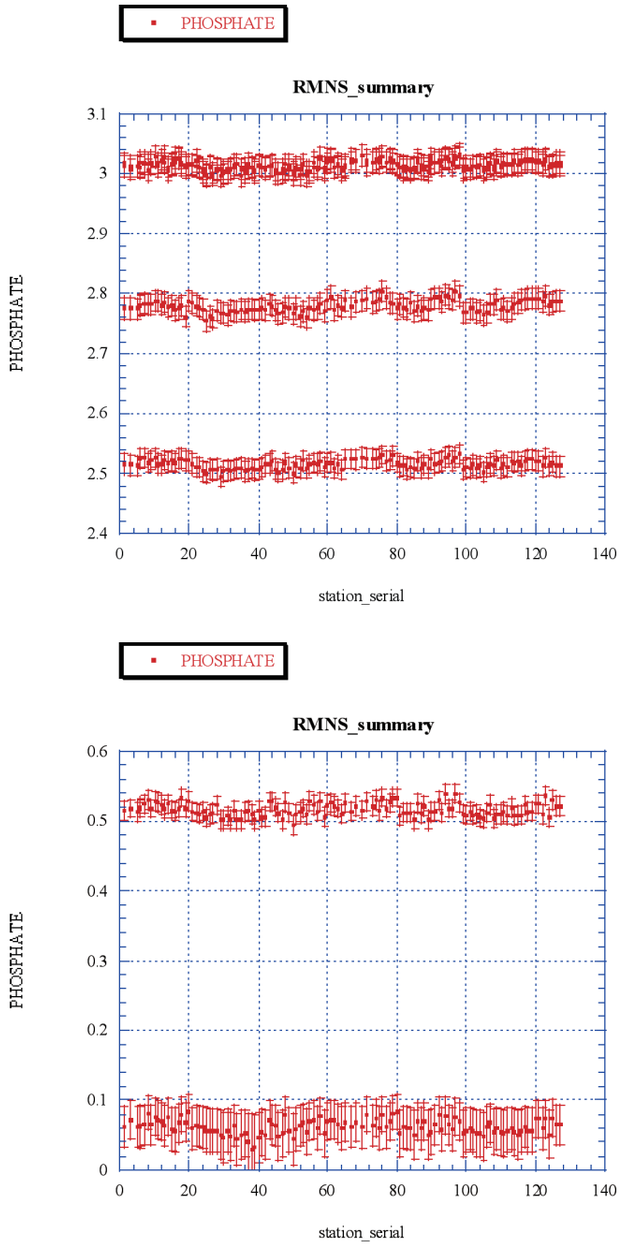

Figure 3.4.9. Same as Figure 3.4.8, but for phosphate.

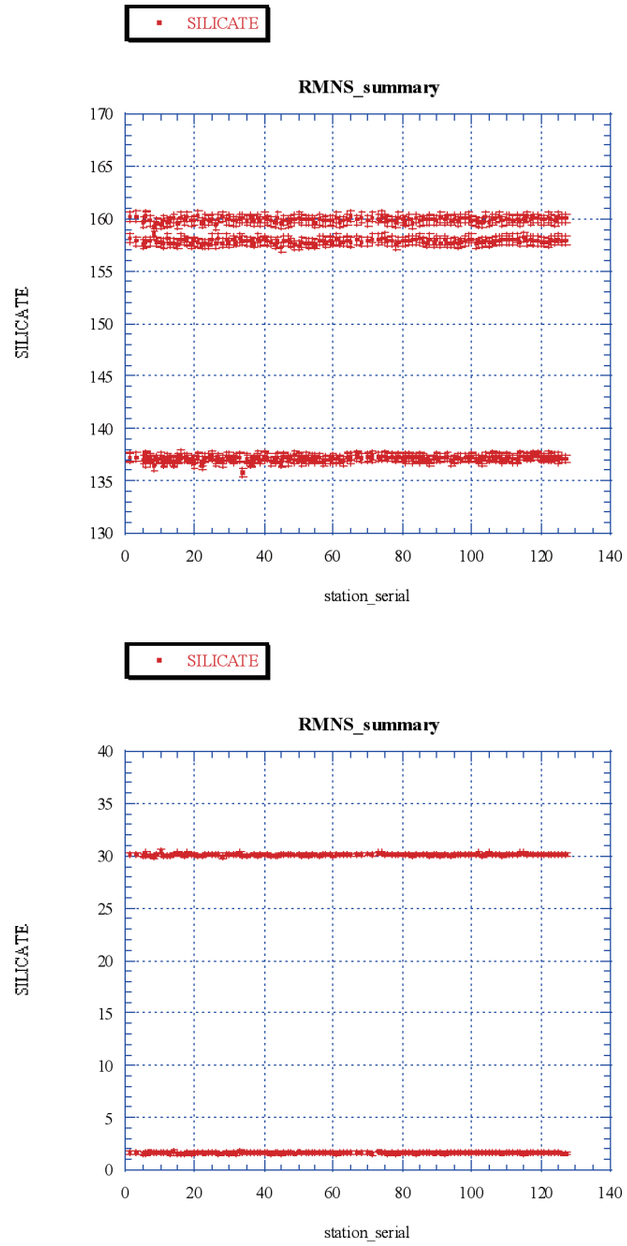

Figure 3.4.10. Same as Figure 3.4.8, but for silicic acid.

Table 3.4.7. Cruise to cruise tracerbility.

Cruise/Lab	RM Lots				
	AX	AV	BC	AZ	AH
			Nitrate		
BEAGLE2003					35.3
RY0501	21.8			41.9	35.5
MR0501	21.5	33.4			35.5
Pre-MR0502			40.8		
KANSO2005	21.4	33.2	40.5	41.9	35.9
MR0502	21.5	33.4	40.7	32.3	
			Phosphate		
BEAGLE2003					2.10
RY0501	1.52			2.99	2.08
MR0501	1.62	2.52			2.13
Pre-MR0502			2.78		
KANSO2005	1.59	2.48	2.72	3.01	2.03
MR0502	1.61	2.52	2.78	3.01	
			Silicate		
BEAGLE2003					133.8
RY0501	59.9			135.6	133.8
MR0501	59.4	157.7			135.5
Pre-MR0502			160.7		
KANSO2005	59.5	156.6	159.5	136.3	135.4
MR0502	59.5	157.9	159.9	137.1	

(7) Cruise-to-cruise traceability

Cruise-to-cruise traceability was examined based on the previous results of RMNSs obtained from several cruises and laboratory analyses. As shown in table 3.4.7, the nutrients concentration of RMNSs was in good agreement among experiments.

(8) Problems/improvements occurred and solutions

As shown in Figure 3.4.7, the precisions of silicate concentration reached 0.15-0.19 % at several stations before station 118, where serial number of the station is 26. The cause of relatively higher precisions was attributed to be larger ambient temperature variability up to 1 °C around 30 minutes interval. We re-arranged a setting of room temperature control to be more stable and obtained less room temperature variability around 0.5 °C. Then we can see much better precision of silicate analyses after re-arrangement as shown in Figure 3.4.7.

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3.5 Dissolved Inorganic Carbon (C_T)

31 August, 2006

(1) Personnel

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Mikio Kitada (MWJ)

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(2) Introduction

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

In this cruise (revisit of WOCE P10 line), we aimed to quantify how much anthropogenic CO_2 is absorbed in North Pacific Intermediate Water, which is one of characteristic waters in the North Pacific. 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.

(2) Apparatus

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

The seawater dispensing system has an auto-sampler (6 ports), which takes seawater from a 300 ml borosilicate glass bottle and dispenses the seawater to a pipette of nominal 20 or 28 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. To degas CO_2 as quickly as possible, a heating wire kept at 40 °C was rolled from the bottom to a 1/3 height of the stripping chamber. The acid is added to the stripping chamber from the bottom of the chamber by pressurizing an acid bottle for a given time to push out 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 (flow rates of 130 ml min^{-1} and 140 ml min-1 for the systems A and B, respectively) to the coulometer through a dehydrating module. For the system A, the module consists of two electric dehumidifiers (kept at 1 - 2 °C) and a chemical desiccant ($Mg(ClO_4)_2$). For the system B, it consists of three electric dehumidifiers with a chemical desiccant.

(3) Shipboard measurement

Sampling

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

At a chemical laboratory on the ship, a headspace of approx. 1 % of the bottle volume was made by removing seawater with a plastic pipette. A saturated mercuric chloride of 100 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 4 °C in a refrigerator until analysis. A few hours just before analysis, the seawater samples were kept at 20 °C in a water bath.

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), 2 % CO_2 gas in a nitrogen base, seawater samples (6) was programmed to repeat. The measurement of 2 % CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc.). For every renewal of coulometer solutions, certified reference materials (CRM, batch 69) provided by Prof. A. G. Dickson of Scripps Institution of Oceanography were analyzed. In addition, reference materials (RM) provided by JAMSTEC (2 kinds) and KANSO 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 that we had to abandon the measurement due to time limitation. However, we experienced some malfunctions of the measuring systems during the cruise, which are described in the followings:

There occurred lowering of repeatability, mostly due to dirt. This situation was recovered by cleaning the measuring systems. For the system B, we could not recover good repeatability (~1.5 µmol kg^{-1}). To obtain good repeatability, we changed the pipette of a volume of 20 ml to that of a volume of 28 ml;

The "undershooting" of coulometer detection was often found. This happened in measuring seawater samples subsequent to the measurement of phosphoric acid blank. To avoid the "undershooting" occurred in seawater sample measurement, we measured a dummy seawater sample subsequent to the bank measurement.

(4) Quality control

Calibration factors of the systems A and B were listed in Table 3.5.1. With these factors, we calculated C_T of CRM (batch 69), and plotted the values as a function of sequential day (Fig. 3.5.1). From Fig. 3.5.1, it is found that there were no trends of CRM measurements for both the systems. The averages and standard deviations were 1906.7 and 0.7 µmol kg^{-1} (n = 36), respectively, for the system A and 1907.2 and 1.1 µmol kg^{-1} (n = 28), respectively for the system B. Since the certified value of the batch 69 is 1907.63 µmol kg^{-1}, very close to the averages, it implies that the measurements had been conducted in a good condition during the cruise.

Based on the results of CRM measurements stated above, we re-calculated the calibration factors so that measurements of seawater samples become traceable to the certified value of batch 69.

Temporal variations of RM measurements are shown in Fig. 3.5.2. From Fig. 3.5.2, it is evident that RM measurements had a linear trend, implying that measurements of seawater samples also have the trend. The trend was also found in temporal changes of 2 % 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 to be traceable to the certified value of batch 69, although the adjustments were usually slight.

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

The average and standard deviation of absolute values of differences of C_T analyzed consecutively were 1.2 and 1.1 µmol kg^{-1} (n = 209), respectively.

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.

Table 3.5.1. Calibration factors determined from Na_2CO_3 solutions.

Cruise Name.	Calibration factors		Remarks
	A	B	
MR05-02	0.24479	0.25114	A pipette for the system B was replaced
		0.31326	

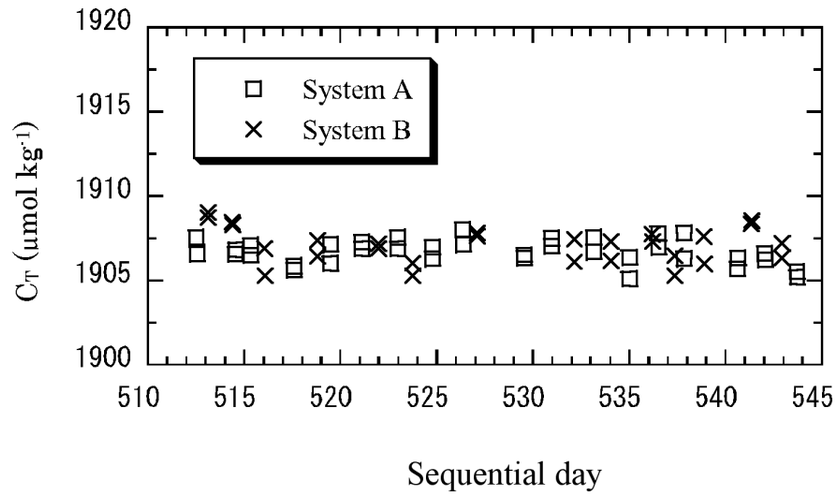

Figure 3.5.1. Temporal variations of CRM (Batch 69) C_T measured by the systems A and B.

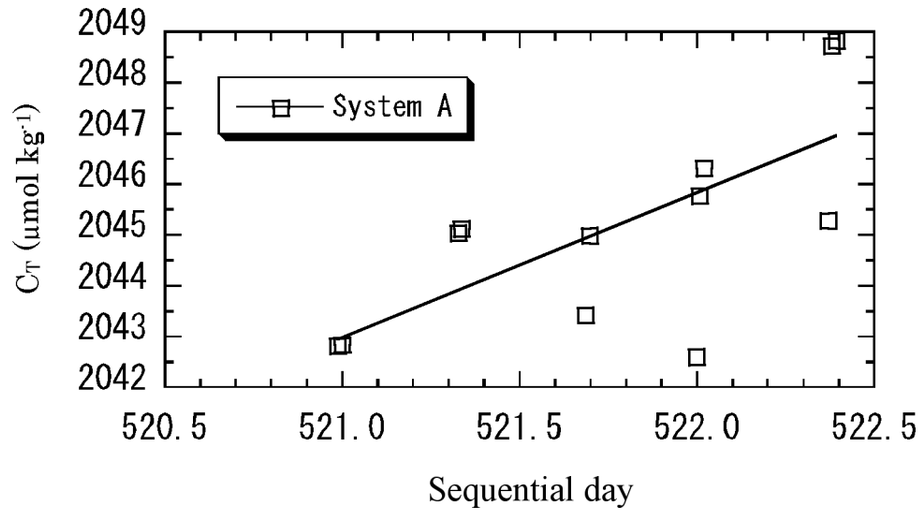

Figure 3.5.2. An example of temporal variations of RM C_T. The line was determined by the least squared method. C_T increased at a rate of approx. 2.9 μmol kg^{-1} per day.

3.6 Total Alkalinity (A_T)

10 October, 2006

(1) Personnel

Akihiko Murata (IORGC/ JAMSTEC)

Fuyuki Shibata (MWJ)

Taeko Ohama (MWJ)

(2) Introduction

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

In this cruise (revisit of WOCE P10 line), we aimed to quantify how much anthropogenic CO_2 is absorbed in North Pacific Intermediate Water, which is one of the characteristic waters in the North Pacific. For the purpose, we measured CO_2-system properties such as dissolved inorganic carbon (C_T), total alkalinity (A_T), pH and underway pCO_2.

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

(2) Apparatus

The measuring system for A_T (customized by Nippon ANS, Inc.) comprises of a water dispensing unit, an auto-burette (Metrohm), a pH meter (Thermo Orion) and auto-sampler (6 ports). They are automatically controlled by a PC. Separate electrodes (Reference electrode: REF201, (Radiometer), Glass pH electrode: pHG201-7 (Radiometer)), or combined electrodes (ROSS 8102BN, Thermo Orion) were used.

A seawater of approx. 40 ml is transferred from a sample bottle (borosilicate glass bottle; 130 ml) into a water-jacketed (25 °C) by pressurized N_2 gas, and is introduced into a water-jacketed (25 °C) titration cell. Next, a given volume of titrant is injected into the titration cell. By this, pH of a seawater sample becomes 4.5-4.0. The seawater sample mixed with the titrant is stirred for three minutes by a stirring chip. Then a small volume of titrant (~0.1 ml) is injected until pH or e.m.f. reaches a given value. The concentration of the acid titrant is nominally 0.05 M HCl in 0.65 M NaCl.

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

(3) Shipboard measurement

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 seawater of a half a or a full bottle volume. A few hours before analysis, the seawater samples were kept at 25 °C in a water bath.

Analysis

For A_T measurement, we selected electrodes, which showed signals close to theoretical Nernstian behavior.

At the start of each leg, we conducted calibration of the acid titrant, which was prepared on land. The calibration was made by measuring A_T of 5 solutions of Na_2CO_3 in 0.7 M NaCl solutions. The computed A_Ts were approx. 0, 100, 1000, 2000 and 2500 μmol kg^{-1}. The measured values of A_T (calculated by assuming 0.05 M acid titrant) should be a linear function of the A_T contributed by the Na_2CO_3. The linear function was fitted by the method of least squares. Theoretically, the slope of the linear function should be unity. If the measured slope is not equal to unity, the acid normality should be adjusted by dividing initial normality by the slope, and the whole set of calculations is repeated until the slope = 1.

Before starting analyses of seawater samples, we measured A_T of dummy seawater samples to confirm a

condition of the measuring system. If repeat measurements of A_T were constant within ~3 μmol kg^{-1}, we initiated measurement of seawater samples. 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, batch 69, certified value = 2114.42 μmol kg^{-1}) 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.

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 such serious problems that we had to give up the analyses. However, we experienced some malfunctions of the system during the cruise, which are listed in the followings:

After analyses of a large number of samples, we often experienced a drift of an electrode, which appeared as differences of pH or e.m.f. against a constant volume of titrant injected into a seawater sample. In this case, we changed pH or e.m.f. ranges for the subsequent calculation of A_T.

(4) Quality control

We examined vertical profiles of A_T. Then, taking other information of analyses into account, we determined a flag of each value of A_T.

The average and standard deviation of absolute values of differences of A_T analyzed consecutively were 1.8 and 1.6 μmol kg^{-1} (n = 207), respectively.

3.7 pH

12 October, 2006

(1) Personnel

Akihiko Murata (IORGC, JAMSTEC)

Fuyuki Shibata (MWJ)

Taeko Ohama (MWJ)

(2) Introduction

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

In this cruise (revisit of WOCE P10 line), we aimed to quantify how much anthropogenic CO_2 absorbed in North Pacific Intermediate Water, which is one of the characteristic waters in the North Pacific. 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 the 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 absorbance of seawater + indicator are measured at the same wavelengths.

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

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

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

(3) Shipboard measurement

Sampling

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

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

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 initially in the range 1.4 - 1.6, and decreased to 1.1.

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 alone and seawater + indicator solutions were measured 15 times each, and averages computed from the last five values of absorbance were 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 such a serious problem that we had to give up the analyses. However, we sometimes experienced malfunctions of the system during the cruise:

Differences between absorbances of seawater alone and those of seawater + indicator solution were infrequently greater than ± 0.001. This implies dirt of the cell. In this case, we cleaned or replaced the cell.

(4) Quality control

It is recommended that correction for pH change resulting from addition of indicator solutions is made (DOE, 1994). To check 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). Figure 3.7.1 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 average and standard deviation of absolute values of differences of pH analyzed consecutively were 0.0006 and 0.0006 pH unit (n = 203), respectively.

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.

DOE (1994): Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water, version 2, A. G. Dickson & C. Goyet, eds. (unpublished manuscript).

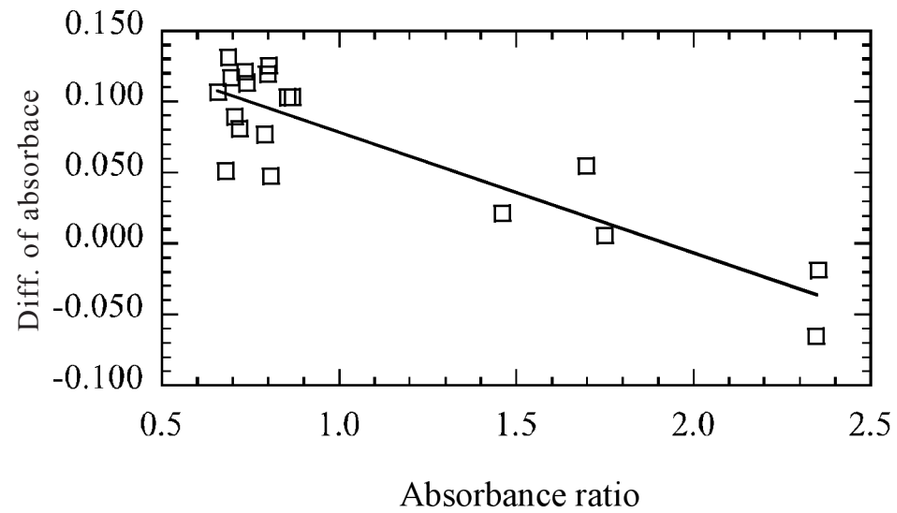

Figure 3.7.1. Perturbation of absorbance ratios by adding indicator solutions. The line ($y = -0.0848x + 0.1633$, $R^2 = 0.7703$) was determined by the method of least squares.

3.8 Chlorofluorocarbons (CFCs)

2 October 2006

(1) Personnel

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(2) Introduction

Chlorofluorocarbons (CFCs) are completely man-made gasses that are chemically and biologically stable gasses in the environment. The CFCs have accumulated in the atmosphere since 1930s (Walker et al., 2000) and the atmospheric CFCs can slightly dissolve in sea surface water. The dissolved CFCs concentrations in sea surface water should have changed year by year and then penetrate into the ocean interior by water circulation. Three chemical species of CFCs, namely CFC-11 (CCl_3F), CFC-12 (CCl_2F_2) and CFC-113 ($C_2Cl_3F_3$), dissolved in seawater are useful transient tracers for the ocean circulation with times scale on the order of decades.

In this cruise, we determined concentrations of these CFCs in seawater on board.

(3) Apparatus

Dissolved CFCs were measured by a typical method modified from the original design of Bullister and Weiss (1988). Two systems were used for CFCs measurement. A custom made purging and trapping system was attached to gas chromatograph (GC-14B: Shimadzu Ltd) having an electron capture detector (ECD-14: Shimadzu Ltd). Stainless steel tube packed Porapak T® was used as a cold trap. Silica Plot capillary column [i.d.: 0.53 mm, length: 4 m, tick: 0.25 µm] and a complex capillary column (Pola Bond-Q [i.d.: 0.53 mm, length: 7 m, tick: 6.0 µm] followed by Silica Plot [i. d.: 0.53 mm, length: 22 m, tick: 0.25 µm]) was used as a pre-column and main column, respectively.

(4) Shipboard measurement

Sampling

Before casting CTD, the water sampling system was cleaned by diluted acetone to remove any oils which could cause contaminations of CFCs. Seawater sub-samples for CFCs measurement were collected from 12 liter Niskin bottles into 300ml glass bottle. The bottle had been filled with pure nitrogen gas before the sub-sampling. The two times bottle volumes of seawater sample were overflowed. The bottles filled with seawater were kept in water bathes roughly controlled on the sample temperature. The CFCs concentrations were determined as soon as possible.

Analysis

Constant volume of sample water (50ml) was taken into the purging & trapping system. Dissolved CFCs were de-gassed by nitrogen gas purge and concentrated in a trap column cooled to –40 °C. The CFCs were desorbed by electrically heating the trap column to 140 °C within 1.5 minutes, and led into the pre-column. CFCs and other compounds were roughly separated in the pre-column and the compounds having earlier retention time than CFCs were sent to main analytical column. And then the pre-column was flushed buck by counter flow of pure nitrogen gas (Back flush system). The back flush system prevented any compounds that had higher retention time than CFCs from entering main analytical column and allowed short time analysis. CFCs which were sent into main column were separated further and detected by an electron capture detector (ECD). Retention time of each CFC was around 1.5, 4.2 and 10.5 minutes for CFC-12, CFC-11 and CFC-113, respectively. Temperatures of an analytical column and a detector were 95 and 240 °C, respectively. Pure nitrogen gas (99.9999) was purified by a molecular sieve 13X gas purifier and was used for CFCs analysis. Mass flow rates of nitrogen gas were 21, 16, 20 and 200 ml/min for carrier, detector make up, back flush and sample purging gasses, respectively.

Gas loops whose volumes were around 1, 3 and 10 ml were used for introducing standard gases into the analytical system. The standard gasses had been made by Japan Fine Products co. ltd. Cylinder numbers of CPB30524 and CPB30525 of standard gasses were used for reference gas and running gas, respectively. These gasses contained roughly 300, 160 and 30 ppt (v/v) of CFC-11, CFC-12 and CFC-113, respectively (nitrogen base). Precise mixing ratios of the standard gasses were calculated by gravimetric data. The standard gases used in this cruise have

not been calibrated to SIO scale standard gases yet because SIO scale standard gasses is hard to obtain due to legal difficulties for CFCs import into Japan. The data will be corrected as soon as possible when we obtain the standard gasses.

(4) Quality control

Blank

Some blank water samples which were made by nitrogen purge of seawater in CFCs sample bottle were analyzed and any CFCs were not detected. Significant increase in CFCs concentration during keeping sampling bottle in a water bath was not found for around one week. CFCs concentrations in deep water which was one of the oldest water masses in the ocean were low but not zero for CFC-11 and -12. Average concentrations of CFC-11, 12 in denser water than 27.5 sigma-0 were 0.022 ± 0.011, 0.004 ± 0.004 (n = 449). These values were assumed as sampling blanks which was contaminations from Niskin bottle and/or during sub-sampling and were subtracted from all data.

Interfering compound for CFC-113 analysis

A large and broad peak was interfered determining CFC-113 peak area for samples collected from surface 200 m depth in the latitude band between 33 °N and 8 °N,. Retention time of the interfering peak was around 3 % shorter than that of CFC-113. The peak of a compound interfering CFC-113 determination could not be completely separated from the peak of CFC-113 by our analytical condition. We tried to split these peaks on chromatogram analysis and give flag “4”. In the case of the interfering peak completely covering the CFC-113 peak, we could not determine CFC-113 peak area and give flag “5”.

Precisions

The analytical precisions were estimated from replicate sample analyses. The replicate samples were basically collected from two sampling depths which is around 250 m and 800 m depth. Because lateral and vertical variations of CFC concentrations were very large, CFC data were divided into two groups for the estimation based on concentration ranges, i.e. high concentration group which was more than 1.0 pmol kg^{-1} of CFC-11 and -12 and 0.1 pmol kg^{-1} of CFC-113 and low concentration group which was below the above concentrations. The precisions were estimated by two methods. One (A) is estimated by following equation, $s= (\sum (\Delta C^2) / (2n-1))^{0.5}$, where ΔC is difference between replicate analyses (Table 1). Another (B) is average difference of replicate analyses (with standard deviation, SD) (Table 2).

Table 1. Analytical precisions of CFC concentrations estimated from method (A).

CFCs	Conc. Range (pmol kg^{-1})	Mean (SD) (pmol kg^{-1})	Precisions (pmol kg^{-1})	Data number
CFC-11	Whole	1.33 (1.13)	0.008	219
	≥ 1.0	2.17 (0.80)	0.009	121
	< 1.0	0.29 (0.29)	0.005	98
CFC-12	Whole	0.71 (0.61)	0.006	219
	≥ 1.0	1.46 (0.33)	0.008	69
	< 1.0	0.36 (0.34)	0.005	150
CFC-113	Whole	0.08 (0.09)	0.005	155
	≥ 0.1	0.20 (0.08)	0.007	43
	< 0.1	0.04 (0.02)	0.000	112

Table 2. Analytical precisions of CFC concentrations estimated from method (B).

CFCs	Conc. Range (pmol kg^{-1})	Mean (SD) (pmol kg^{-1})	Precisions (SD) (pmol kg^{-1})	Data number
CFC-11	Whole	1.33 (1.13)	0.007 (0.008)	219
	≥ 1.0	2.17 (0.80)	0.010 (0.009)	121
	< 1.0	0.29 (0.29)	0.004 (0.005)	98
CFC-12	Whole	0.71 (0.61)	0.006 (0.006)	219
	≥ 1.0	1.46 (0.33)	0.008 (0.007)	69
	< 1.0	0.36 (0.34)	0.004 (0.005)	150
CFC-113	Whole	0.08 (0.09)	0.005 (0.005)	155
	≥ 0.1	0.20 (0.08)	0.007 (0.006)	43
	< 0.1	0.04 (0.02)	0.004 (0.005)	112

Reference

Walker, S.J., Weiss, R.F. and Salameh, P.K., Reconstructed histories of the annual mean atmospheric mole fractions for the halocarbons CFC-11, CFC-12, CFC-113 and Carbon Tetrachloride, Journal of Geophysical Research, 105, 14,285-14,296, (2000).

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

3.9 Lowered Acoustic Doppler Current Profiler

25 August 2006

(1) Personnel

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(2) Instrument and measurement

Direct flow measurement from sea surface to the bottom was carried out using a lowered acoustic Doppler current profiler (LADCP). The instrument used was the RDI Workhorse Monitor 307.2 kHz unit (RD Instruments, USA). The instrument was attached on the CTD/RMS frame, orientating downward. The CPU firmware version was 16.05. The firmware was updated at station P10-002 to version 16.27.

One ping raw data were recorded. Settings for the collecting data are listed in Table 3.9.1. A total of 128 operations were made with the CTD observations. The performance of the LADCP instrument was good in northern stations (in the subarctic region of North Pacific). Profiles were obtained over 100 m distance from LADCP in shallow depth and almost 60 m in deeper depth. On the other hand, the performance was bad in southern stations in the subtropical region of North Pacific. In the deeper depth, good quality data were obtained only 3 or 4 bins, which means the LADCP could observe only about 25 m. It would due to a weak echo intensity, which agreed with ship's ADCP. Data transfer errors were often occurred during upload process from the LADCP to PC.

(3) Data process and result

Vertical profiles of velocity are obtained by the inversion method (Visbeck, 2002). Both the up and down casts are used for the inversion. Since the first bin from LADCP is influenced by the turbulence generated by CTD frame, the weight for the inversion is set to small value of 0.1. The GPS navigation data are used in the calculation of the reference velocities and the bottom-track data are used for the correction of the reference velocities. Shipboard ADCP (SADCP) data averaged for 3 minites are also included in the calculation. The CTD data are used for the sound speed and depth calculation. IGRF (International Geomagnetic Reference Field) 10th generation data are used for calculating magnetic deviation to correct the direction of velocity. In the processing, we use Matlab routines provided from M. Visbeck and G. Krahmann (http://ladcp.ldeo.columbia.edu/ladcp/).

Table 3.9.1. LADCP Settings for the collecting data.

Station	143-50, 48,47	49	46	45	44,X04	42-
Bin length	8 m	8 m	12 m	12 m	12 m	16 m
Bin number	24	20	16	20	16	10
Standard deviation	2 cm/s	2 cm/s	1.6 cm/s	1.6 cm/s	1.6 cm/s	1.4 cm/s
Ping interval	1.2 sec	1 sec	1.2 sec	1.2 sec	1.2 sec	1 sec
Percent Good	Collect	Collect	Collect	Collect	Not collect	Not collect

Figure 3.9.1 and 3.9.2 show the results of the cross-section velocity (eastward is positive) and the along-section velocity (northward is positive). The major currents in the Western Pacific such as the Kuroshio Extension (P10N-116-114), the Equatorial Under Current (around P10-18), and New Guinea Coastal Under Current (P10-002) appeared in the figures. Figure 3.9.3 shows error velocity estimated by the inversion method. The error velocities are very small (less than 5 cm/s) upper 1000 dbar and adjacent to the bottom. Since the absolute velocities are obtained only by LADCP data from bottom track, the error velocity near the bottom is small. Upper 1000 dbar, the error velocity is small due to SADCP data. The velocity profile obtained from LADCP without SADCP resembles the one from SADCP. The uncertainty of velocity from SADCP is about 10 cm/s. So we think the error velocity from LADCP upper 1000 dbar is about 10 cm/s. The error velocities are less than 10 cm/s on the northern side of the Kuroshio Extension. However, error velocities are large in the subtropical gyre. It is probably due to the short range of the LADCP signal, which makes the shears suspicious. In the estimation of the velocity from LADCP data, it is the biggest problem that there is less information of the CTD frame motion, which is only determined from bottom track data and GPS 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.

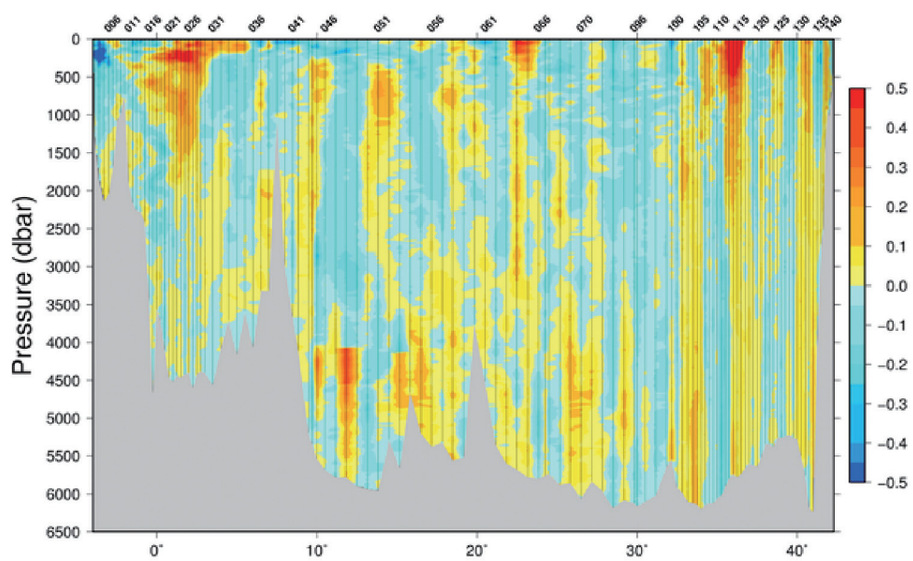

Figure 3.9.1. The cross-section of zonal velocity (eastward is positive).

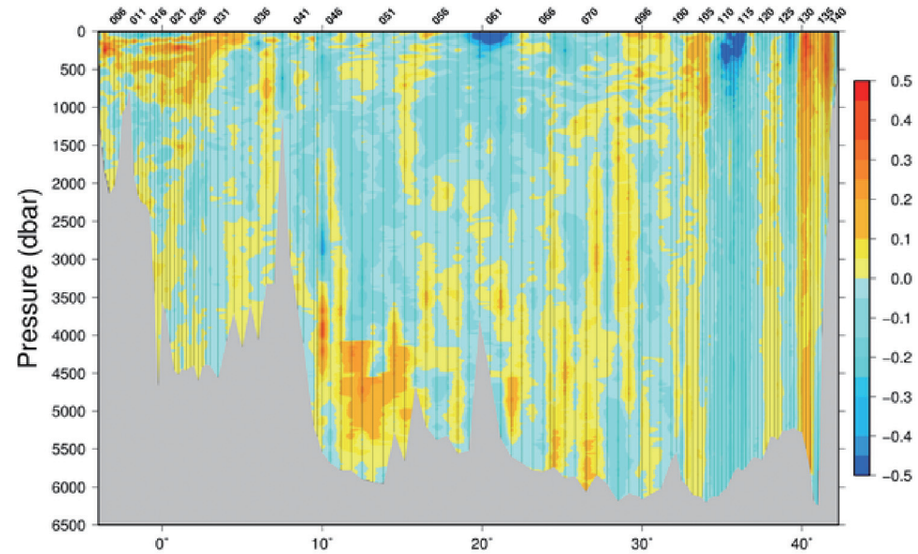

Figure 3.9.2. The cross-section of merdiornal velocity (northward is positive).

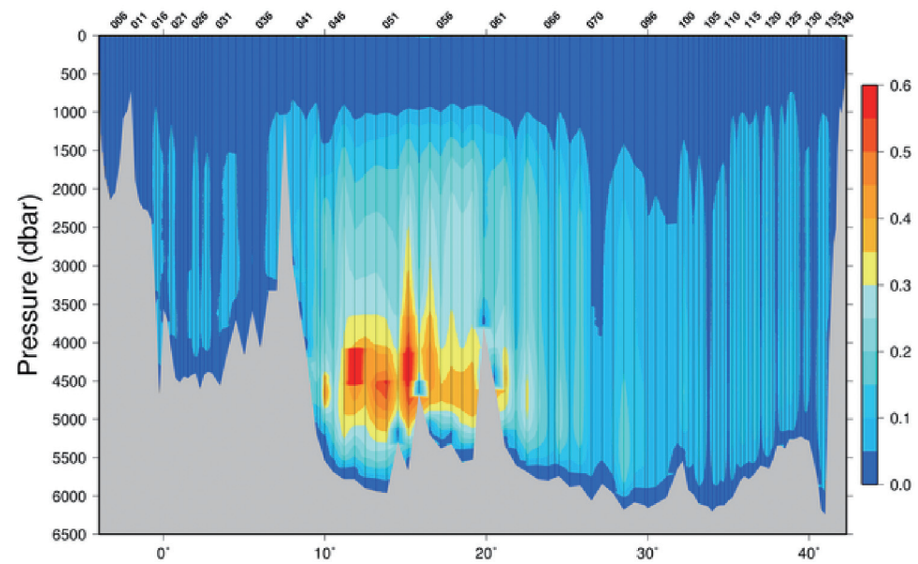

Figure 3.9.3. Cross-section of error velocity estimated by the inversion method.

Station Summary

P10 REV R/V MIRAI CRUISE MR0502

SHIP/CRS EXPOCODE	WOCE SECT	STNNBR	CASTNO	CAST TYPE	DATE	UTC TIME	EVENT CODE	POSITION LATITUDE	POSITION LONGITUDE	NAV	UNC DEPTH	COR DEPTH	HT ABOVE BOTTOM	WIRE OUT	MAX PRESS	NO. OF BOTTLES	PARAMETERS	COMMENTS
49MR0502_1		201	1	XBT	052605	2211	DE	42 4.58 N	143 43.33 E	GPS	420	422						FOR SOUND SPEED CORRECTION, TSK T-7
49MR0502_1	P10N	143	1	ROS	052605	2302	BE	42 15.16 N	143 44.43 E	GPS	481	482				9	1-8,23,24,26,27	
49MR0502_1	P10N	143	1	ROS	052605	2315	BO	42 15.19 N	143 44.28 E	GPS	471	472	9	465	467			
49MR0502_1	P10N	143	1	BUC	052605	2316	UN	42 15.20 N	143 44.28 E	GPS	471	471				1		5.6C
49MR0502_1	P10N	143	1	ROS	052605	2342	EN	42 15.17 N	143 44.01 E	GPS	459	460						
49MR0502_1	P10N	142	1	ROS	052705	0105	BE	42 9.99 N	143 48.46 E	GPS	722	721				0		NO WATER SMPL
49MR0502_1	P10N	142	1	ROS	052705	0124	BO	42 9.96 N	143 48.29 E	GPS	716	716	8	710	714			UP-CAST FAILS
49MR0502_1	P10N	142	1	BUC	052705	0125	UN	42 9.95 N	143 48.29 E	GPS	715	715				1		3.9C
49MR0502_1	P10N	142	1	ROS	052705	0155	EN	42 9.90 N	143 48.09 E	GPS	710	710						
49MR0502_1	P10N	142	2	ROS	052705	0258	BE	42 10.06 N	143 48.57 E	GPS	724	724				11	1-6,23,24,26	REPLACED Y-CABLE
49MR0502_1	P10N	142	2	BUC	052705	0314	UN	42 9.95 N	143 48.56 E	GPS	724	725				1		3.9C
49MR0502_1	P10N	142	2	ROS	052705	0316	BO	42 9.94 N	143 48.56 E	GPS	724	725	11	717	718			
49MR0502_1	P10N	142	2	ROS	052705	0349	EN	42 9.90 N	143 48.61 E	GPS	728	727						
49MR0502_1	P10N	141	1	ROS	052705	0435	BE	42 5.03 N	143 52.29 E	GPS	902	902				13	1-8,23,24,26,27	
49MR0502_1	P10N	141	1	BUC	052705	0444	UN	42 4.99 N	143 52.20 E	GPS	893	893				1		4.0C
49MR0502_1	P10N	141	1	ROS	052705	0455	BO	42 4.95 N	143 52.04 E	GPS	884	886	10	886	883			
49MR0502_1	P10N	141	1	ROS	052705	0533	EN	42 4.82 N	143 51.40 E	GPS	865	866						
49MR0502_1	P10N	140	1	ROS	052705	0623	BE	42 0.17 N	143 56.19 E	GPS	1044	1044				15	1-8,23,24,26,27	
49MR0502_1	P10N	140	1	BUC	052705	0633	UN	42 0.17 N	143 56.07 E	GPS	1040	1040				1		6.6C
49MR0502_1	P10N	140	1	ROS	052705	0648	BO	42 0.21 N	143 55.85 E	GPS	1034	1035	9	1040	1037			
49MR0502_1		202	1	UNK	052705	0702	UN	42 0.26 N	143 55.65 E	GPS	1026	1027						RAIN SAMPLING (3.2MM/HR)
49MR0502_1	P10N	140	1	ROS	052705	0738	EN	42 0.42 N	143 55.27 E	GPS	1011	1013						
49MR0502_1	P10N	139	1	ROS	052705	0849	BE	41 52.64 N	144 1.99 E	GPS	953	952				14	1-6,23,24,26	
49MR0502_1	P10N	139	1	BUC	052705	0857	UN	41 52.65 N	144 1.93 E	GPS	951	952				1		6.4C
49MR0502_1	P10N	139	1	ROS	052705	0911	BO	41 52.76 N	144 1.83 E	GPS	950	949	9	948	949			
49MR0502_1	P10N	139	1	ROS	052705	0958	EN	41 53.21 N	144 1.63 E	GPS	957	956						
49MR0502_1	P10N	138	1	ROS	052705	1109	BE	41 45.20 N	144 7.70 E	GPS	1471	1470				17	1-8,23,24,26,27	
49MR0502_1	P10N	138	1	BUC	052705	1118	UN	41 45.32 N	144 7.66 E	GPS	1466	1464				1		5.3C
49MR0502_1	P10N	138	1	ROS	052705	1139	BO	41 45.45 N	144 7.74 E	GPS	1464	1463	11	1452	1463			
49MR0502_1	P10N	138	1	ROS	052705	1241	EN	41 45.96 N	144 7.78 E	GPS	1446	1448						
49MR0502_1	P10N	137	1	ROS	052705	1402	BE	41 37.72 N	144 13.72 E	GPS	2623	2622				22	1-6	
49MR0502_1	P10N	137	1	BUC	052705	1410	UN	41 37.78 N	144 13.70 E	GPS	2608	2605				1		3.0C
49MR0502_1	P10N	137	1	ROS	052705	1451	BO	41 38.08 N	144 13.54 E	GPS	2552	2555	10	2543	2569			
49MR0502_1	P10N	137	1	ROS	052705	1622	EN	41 38.74 N	144 13.15 E	GPS	2510	2512						
49MR0502_1	P10N	136	1	ROS	052705	1747	BE	41 30.03 N	144 19.16 E	GPS	2697	2702				23	1-8,12,13,23,24,26,27	
49MR0502_1	P10N	136	1	BUC	052705	1755	UN	41 30.11 N	144 19.07 E	GPS	2702	2704				1		6.0C
49MR0502_1	P10N	136	1	ROS	052705	1832	BO	41 30.34 N	144 18.76 E	GPS	2728	2729	11	2717	2743			
49MR0502_1	P10N	136	1	ROS	052705	2003	EN	41 31.09 N	144 17.83 E	GPS	2817	2820						
49MR0502_1	P10N	135	1	ROS	052705	2139	BE	41 15.06 N	144 30.69 E	GPS	4031	4032				28	1-8,27	
49MR0502_1	P10N	135	1	BUC	052705	2146	UN	41 15.08 N	144 30.58 E	GPS	4021	4021				1		3.9C
49MR0502_1	P10N	135	1	ROS	052705	2245	BO	41 15.48 N	144 29.87 E	GPS	3932	3936	67	4011	3992			LADCP SOUNDING
49MR0502_1	P10N	135	1	ROS	052805	0041	EN	41 16.50 N	144 28.76 E	GPS	4214	4218						
49MR0502_1		203	1	UNK	052805	0150	UN	41 3.80 N	144 38.99 E	GPS	5811	5810						RAIN SAMPLING (14.0MM/HR)
49MR0502_1	P10N	134	1	ROS	052805	0226	BE	41 0.13 N	144 41.99 E	GPS	6320	6313				35	1-8,23,24,26,27	REMOVED FLUOROMETER, #11 MISS FIRE

49MR0502_1	P10N	134	1	BUC	052805	0233	UN	41 0.20 N	144 41.96 E	GPS	6316	6318				1		9.0C
49MR0502_1	P10N	134	1	ROS	052805	0403	BO	41 0.98 N	144 41.97 E	GPS	6111	6118	111	6158	6230			LADCP SOUNDING
49MR0502_1	P10N	134	1	ROS	052805	0701	EN	41 2.29 N	144 41.62 E	GPS	6020	6020						
49MR0502_1	P10N	133	1	ROS	052805	0842	BE	40 45.45 N	144 53.44 E	GPS	6225	6219				35	1-8,27	#11 MISS FIRE
49MR0502_1	P10N	133	1	BUC	052805	0849	UN	40 45.59 N	144 53.48 E	GPS	6218	6217				1		12.1C
49MR0502_1	P10N	133	1	ROS	052805	1021	BO	40 46.20 N	144 53.11 E	GPS	6167	6167	8	6236	6325			
49MR0502_1	P10N	133	1	ROS	052805	1318	EN	40 47.23 N	144 52.61 E	GPS	5990	5990						
49MR0502_1	P10N	132	1	ROS	052805	1505	BE	40 30.10 N	145 4.14 E	GPS	5824	5827				35	1-8,23,24,26,27	#11 MISS FIRE
49MR0502_1	P10N	132	1	BUC	052805	1513	UN	40 30.18 N	145 4.11 E	GPS	5810	5814				1		14.3C
49MR0502_1	P10N	132	1	ROS	052805	1638	BO	40 30.75 N	145 4.00 E	GPS	5777	5778	9	5789	5900			
49MR0502_1	P10N	132	1	ROS	052805	1933	EN	40 32.27 N	145 2.59 E	GPS	5943	5945						
49MR0502_1	P10N	131	1	ROS	052805	2131	BE	40 15.25 N	145 15.22 E	GPS	5541	5538				36	1-8,27	ATTACHED FLUOROMETER, #2=#11 DUPLICATE SMPLS (3500DB)
49MR0502_1	P10N	131	1	BUC	052805	2138	UN	40 15.34 N	145 15.19 E	GPS	5543	5535				1		10.0C
49MR0502_1	P10N	131	1	ROS	052805	2254	BO	40 15.83 N	145 15.19 E	GPS	5533	5530	9	5523	5626			
49MR0502_1	P10N	131	1	ROS	052905	0126	EN	40 17.16 N	145 15.03 E	GPS	5526	5520						
49MR0502_1	P10N	130	1	ROS	052905	0315	BE	40 0.18 N	145 25.88 E	GPS	5308	5307				35	1-8,12,13,23,24,26,27	#3=#11 DUPLICATE SMPLS (3500DB)
49MR0502_1	P10N	130	1	BUC	052905	0320	UN	40 0.24 N	145 25.83 E	GPS	5309	5306				1		11.0C
49MR0502_1	P10N	130	1	ROS	052905	0435	BO	40 1.11 N	145 25.66 E	GPS	5320	5313	9	5353	5405			
49MR0502_1	P10N	130	1	ROS	052905	0711	EN	40 2.85 N	145 25.59 E	GPS	5330	5327						
49MR0502_1	P10N	129	1	ROS	052905	0930	BE	39 45.16 N	145 36.66 E	GPS	5276	5276				36	1-8,27	#2=#3=#11 DUPLICATE SMPLS (3500DB)
49MR0502_1	P10N	129	1	BUC	052905	0938	UN	39 45.22 N	145 36.58 E	GPS	5276	5276				1		10.4C
49MR0502_1	P10N	129	1	ROS	052905	1053	BO	39 45.54 N	145 36.14 E	GPS	5282	5281	11	5289	5365			
49MR0502_1	P10N	129	1	ROS	052905	1330	EN	39 45.96 N	145 35.28 E	GPS	5283	5283						
49MR0502_1	P10N	128	1	ROS	052905	1502	BE	39 30.01 N	145 47.29 E	GPS	5259	5259				36	1-8,23,24,26,27	#2=#3=#11 DUPLICATE SMPLS (3500DB)
49MR0502_1	P10N	128	1	BUC	052905	1510	UN	39 29.98 N	145 47.20 E	GPS	5260	5258				1		10.1C
49MR0502_1	P10N	128	1	ROS	052905	1625	BO	39 30.03 N	145 47.01 E	GPS	5259	5259	9	5258	5345			
49MR0502_1	P10N	128	1	ROS	052905	1858	EN	39 30.08 N	145 46.70 E	GPS	5262	5260						
49MR0502_1	P10N	127	1	ROS	052905	2025	BE	39 14.93 N	145 57.92 E	GPS	5270	5266				35	1-8,27	#16 MISS FIRE
49MR0502_1	P10N	127	1	BUC	052905	2033	UN	39 14.90 N	145 57.96 E	GPS	5267	5266				1		9.7C
49MR0502_1	P10N	127	1	ROS	052905	2145	BO	39 14.75 N	145 58.09 E	GPS	5262	5261	10	5255	5345			
49MR0502_1	P10N	127	1	ROS	053005	0015	EN	39 14.25 N	145 59.07 E	GPS	5248	5246						
49MR0502_1	P10N	126	1	ROS	053005	0133	BE	38 59.84 N	146 8.36 E	GPS	5286	5287				36	1-8,23,24,26,27	#2=#11 (3500DB), #3=#16 (2400DB) DUPLICATE SMPLS
49MR0502_1	P10N	126	1	BUC	053005	0143	UN	38 59.88 N	146 8.46 E	GPS	5290	5287				1		16.1C
49MR0502_1	P10N	126	1	ROS	053005	0254	BO	39 0.09 N	146 8.76 E	GPS	5286	5284	8	5303	5376			
49MR0502_1	P10N	126	1	ROS	053005	0522	EN	39 1.12 N	146 9.87 E	GPS	5299	5300						
49MR0502_1	P10N	125	1	ROS	053005	0700	BE	38 45.13 N	146 18.98 E	GPS	5285	5285				36	1-8,27	#2=#11 (3500DB), #3=#16 (2400DB) DUPLICATE SMPLS
49MR0502_1	P10N	125	1	BUC	053005	0708	UN	38 45.24 N	146 19.19 E	GPS	5278	5285				1,4-6,30,34		18.6C, 9L FOR BIO
49MR0502_1	P10N	125	1	BIO	053005	0708	UN	38 45.24 N	146 19.19 E	GPS	5278	5285						PLANKTON NET
49MR0502_1	P10N	125	1	ROS	053005	0824	BO	38 45.81 N	146 19.95 E	GPS	5274	5283	11	5363	5371			
49MR0502_1	P10N	125	1	ROS	053005	1059	EN	38 47.06 N	146 21.11 E	GPS	5281	5286						
49MR0502_1	P10N	124	1	ROS	053005	1244	BE	38 30.01 N	146 28.81 E	GPS	5414	5418				35	1-8,23,24,26,27	#2=#11 (3500DB), #3=#16 (2400DB) DUPLICATE SMPLS,
																		#1 MISS FIRE
49MR0502_1	P10N	124	1	BUC	053005	1253	UN	38 30.09 N	146 28.80 E	GPS	5413	5415				1		17.4C
49MR0502_1	P10N	124	1	ROS	053005	1408	BO	38 30.56 N	146 28.88 E	GPS	5394	5393	7	5427	5502			
49MR0502_1	P10N	124	1	ROS	053005	1646	EN	38 31.56 N	146 29.19 E	GPS	5357	5355						
49MR0502_1		204	1	UNK	053005	2320	UN	38 16.73 N	146 43.08 E	GPS	5363	5363						RAIN SAMPLING (6.0MM/HR)
49MR0502_1	P10N	123	1	ROS	053105	0059	BE	38 15.25 N	146 37.80 E	GPS	5355	5360				34	1-8,27	#1=#2 DUPLICATE SMPLS (B-10DB), NO SMPL AT
																		50DB (#35 AT 10DB)
49MR0502_1	P10N	123	1	BUC	053105	0109	UN	38 15.30 N	146 37.83 E	GPS	5357	5360				1		16.7C
49MR0502_1	P10N	123	1	ROS	053105	0223	BO	38 15.82 N	146 38.31 E	GPS	5363	5362	9	5423	5451			
49MR0502_1	P10N	123	1	ROS	053105	0447	EN	38 17.38 N	146 39.97 E	GPS	5323	5326						

49MR0502_1	P10N	122	1	ROS	053105	0632	BE	37 59.98 N	146 49.16 E	GPS	5367	5372			34	1-8,23,24,26,27	
49MR0502_1	P10N	122	1	BUC	053105	0641	UN	37 59.98 N	146 49.32 E	GPS	5366	5366				1	15.9C
49MR0502_1	P10N	122	1	ROS	053105	0758	BO	38 0.33 N	146 49.50 E	GPS	5367	5363	9	5371 5458			
49MR0502_1	P10N	122	1	ROS	053105	1029	EN	38 0.19 N	146 49.40 E	GPS	5368	5363					
49MR0502_1		205	1	UNK	053105	2130	UN	37 45.60 N	146 52.50 E	GPS	5568	5564					RAIN SAMPLING (0.2MM/HR)
49MR0502_1	P10N	121	1	ROS	060105	0357	BE	37 44.97 N	146 58.73 E	GPS	5542	5543			35	1-8,27	REPLACED OXYGEN(PRI) SENSOR, #11 MISS FIRE, #2 AT 3500DB
49MR0502_1	P10N	121	1	BUC	060105	0406	UN	37 44.81 N	146 58.68 E	GPS	5550	5549				1	15.6C
49MR0502_1	P10N	121	1	ROS	060105	0524	BO	37 44.15 N	146 58.73 E	GPS	5593	5585	10	5625 5655			
49MR0502_1	P10N	121	1	ROS	060105	0805	EN	37 44.24 N	146 59.19 E	GPS	5588	5588					
49MR0502_1	P10N	120	1	ROS	060105	0940	BE	37 29.87 N	147 8.79 E	GPS	5674	5675			35	1-8,12,13,23,24,26,27	#2 MISS FIRE, ATTACHED 5 OPTODES
49MR0502_1	P10N	120	1	BUC	060105	0948	UN	37 29.88 N	147 8.86 E	GPS	5675	5672				1	15.2C
49MR0502_1	P10N	120	1	ROS	060105	1110	BO	37 29.57 N	147 9.14 E	GPS	5679	5675	10	5682 5776			
49MR0502_1	P10N	120	1	ROS	060105	1356	EN	37 28.03 N	147 10.14 E	GPS	5664	5666					
49MR0502_1	P10N	119	1	ROS	060105	1553	BE	37 14.59 N	147 18.79 E	GPS	5648	5650			36	1-8,27	#2=#11 DUPLICATE SMPLS (3500DB)
49MR0502_1	P10N	119	1	BUC	060105	1601	UN	37 14.52 N	147 18.91 E	GPS	5652	5652				1	16.4C
49MR0502_1	P10N	119	1	ROS	060105	1721	BO	37 13.72 N	147 18.79 E	GPS	5649	5645	10	5715 5746			
49MR0502_1	P10N	119	1	ROS	060105	1957	EN	37 12.32 N	147 17.76 E	GPS	5645	5646					
49MR0502_1	P10N	118	1	ROS	060105	2120	BE	36 59.63 N	147 28.05 E	GPS	5632	5631			35	1-8,23,24,26,27	#16 MISS FIRE, #2=#11 DUPLICATE SMPLS (3500DB)
49MR0502_1	P10N	118	1	BUC	060105	2128	UN	36 59.52 N	147 28.04 E	GPS	5626	5629				1,4-6,30,34	17.2C, 9L FOR BIO
49MR0502_1	P10N	118	1	BIO	060105	2128	UN	36 59.52 N	147 28.04 E	GPS	5626	5629					PLANKTON NET
49MR0502_1	P10N	118	1	ROS	060105	2247	BO	36 59.15 N	147 28.53 E	GPS	5625	5625	9	5642 5727			
49MR0502_1	P10N	118	1	ROS	060205	0121	EN	36 58.96 N	147 28.08 E	GPS	5629	5624					
49MR0502_1	P10N	117	1	ROS	060205	0307	BE	36 44.95 N	147 37.89 E	GPS	5688	5690			36	1-8,27	
49MR0502_1	P10N	117	1	BUC	060205	0314	UN	36 45.01 N	147 37.87 E	GPS	5690	5689				1	17.6C
49MR0502_1	P10N	117	1	ROS	060205	0432	BO	36 45.27 N	147 38.15 E	GPS	5687	5686	9	5699 5787			
49MR0502_1	P10N	117	1	ROS	060205	0701	EN	36 45.79 N	147 40.06 E	GPS	5683	5682					
49MR0502_1	P10N	116	1	ROS	060205	0823	BE	36 29.93 N	147 47.59 E	GPS	5767	5767			36	1-8,23,24,26,27	
49MR0502_1	P10N	116	1	BUC	060205	0830	UN	36 29.90 N	147 47.84 E	GPS	5764	5764				1	20.7C
49MR0502_1	P10N	116	1	ROS	060205	0953	BO	36 29.41 N	147 49.21 E	GPS	5766	5766	9	5829 5866			
49MR0502_1	P10N	116	1	ROS	060205	1237	EN	36 28.83 N	147 51.73 E	GPS	5773	5774					
49MR0502_1	P10N	115	1	ROS	060205	1358	BE	36 15.14 N	147 57.25 E	GPS	5781	5787			36	1-8,27	
49MR0502_1	P10N	115	1	BUC	060205	1406	UN	36 15.13 N	147 57.73 E	GPS	5784	5792				1	23.0C
49MR0502_1	P10N	115	1	ROS	060205	1529	BO	36 14.75 N	147 59.52 E	GPS	5809	5814	8	5906 5915			
49MR0502_1	P10N	115	1	ROS	060205	1808	EN	36 13.84 N	148 3.26 E	GPS	5795	5804					
49MR0502_1	P10N	114	1	ROS	060205	1922	BE	35 59.87 N	148 6.73 E	GPS	5809	5811			36	1-8,23,24,26,27	
49MR0502_1	P10N	114	1	BUC	060205	1928	UN	35 59.87 N	148 7.13 E	GPS	5801	5806				1	22.5C
49MR0502_1		206	1	UNK	060205	1940	UN	35 59.92 N	148 7.82 E	GPS	5801	5802					RAIN SAMPLING (7.5MM/HR)
49MR0502_1	P10N	114	1	ROS	060205	2054	BO	35 59.08 N	148 9.61 E	GPS	5789	5794	7	6160 5881			
49MR0502_1	P10N	114	1	ROS	060205	2338	EN	35 57.81 N	148 13.12 E	GPS	5748	5755					
49MR0502_1	P10N	113	1	ROS	060305	0058	BE	35 44.83 N	148 15.68 E	GPS	5807	5811			36	1-8,27	
49MR0502_1	P10N	113	1	BUC	060305	0106	UN	35 44.81 N	148 15.90 E	GPS	5813	5822				1,4-6,30,34	22.6C, 9L FOR BIO
49MR0502_1	P10N	113	1	BIO	060305	0106	UN	35 44.81 N	148 15.90 E	GPS	5813	5822					PLANKTON NET
49MR0502_1	P10N	113	1	ROS	060305	0229	BO	35 44.31 N	148 17.66 E	GPS	5826	5830	11	5981 5935			
49MR0502_1		207	1	UNK	060305	0350	UN	35 43.62 N	148 19.21 E	GPS	5791	5795					RAIN SAMPLING (13.0MM/HR)
49MR0502_1	P10N	113	1	ROS	060305	0502	EN	35 43.05 N	148 21.29 E	GPS	5863	5866					REMOVED 5 OPTODES
49MR0502_1	P10N	112	1	ROS	060305	0616	BE	35 29.98 N	148 24.88 E	GPS	5940	5943			0		REMOVED FLUOROMETER
49MR0502_1	P10N	112	1	BUC	060305	0623	UN	35 29.97 N	148 25.14 E	GPS	5939	5942					21.6C
49MR0502_1	P10N	112	1	ROS	060305	0748	BO	35 29.18 N	148 26.46 E	GPS	5939	5945	9	6036 6021			LOST TMP(PRI) SIGNAL ON UPCAST
49MR0502_1	P10N	112	1	ROS	060305	0942	EN	35 28.14 N	148 27.82 E	GPS	5976	5978					
49MR0502_1	P10N	112	2	ROS	060305	1057	BE	35 30.29 N	148 24.13 E	GPS	5940	5942			36	1-8,23,24,26,27	REPLACED A CABLE FOR TMP(PRI) SENSOR

49MR0502_1	P10N	112	2	BUC	060305	1106	UN	35 30.23 N	148 24.48 E	GPS	5945	5942			1	21.6C
49MR0502_1	P10N	112	2	ROS	060305	1231	BO	35 29.27 N	148 25.62 E	GPS	5911	5914	9	6027	6035	
49MR0502_1	P10N	112	2	ROS	060305	1511	EN	35 27.51 N	148 27.40 E	GPS	5972	5978				
49MR0502_1	P10N	111	1	ROS	060305	1622	BE	35 14.83 N	148 33.90 E	GPS	6054	6058			35 1-8,27	#30 MISS FIRE
49MR0502_1	P10N	111	1	ROS	060305	1802	BO	35 13.56 N	148 35.14 E	GPS	6008	6010	10	6207	6156	
49MR0502_1	P10N	111	1	ROS	060305	2044	EN	35 11.74 N	148 36.38 E	GPS	6032	6030				
49MR0502_1	P10N	110	1	ROS	060305	2203	BE	34 59.78 N	148 43.07 E	GPS	6091	6091			36 1-8,12,13,23,24,26,27	
49MR0502_1	P10N	110	1	BUC	060305	2212	UN	34 59.64 N	148 43.20 E	GPS	6096	6098			1,4-6,30,34	21.6C, 9L FOR BIO
49MR0502_1	P10N	110	1	BIO	060305	2212	UN	34 59.64 N	148 43.20 E	GPS	6096	6098				PLANKTON NET
49MR0502_1		208	1	UNK	060305	2240	UN	34 59.29 N	148 43.59 E	GPS	6100	6104				RAIN SAMPLING (2.5MM/HR)
49MR0502_1	P10N	110	1	ROS	060305	2337	BO	34 58.96 N	148 43.99 E	GPS	6104	6105	8	6138	6209	
49MR0502_1	P10N	110	1	ROS	060405	0213	EN	34 58.43 N	148 45.10 E	GPS	6105	6105				
49MR0502_1	P10N	109	1	ROS	060405	0345	BE	34 44.97 N	148 51.94 E	GPS	6139	6138			36 1-8,27	
49MR0502_1	P10N	109	1	BUC	060405	0356	UN	34 44.89 N	148 52.12 E	GPS	6140	6141			1	21.5C
49MR0502_1	P10N	109	1	ROS	060405	0521	BO	34 44.32 N	148 52.77 E	GPS	6143	6146	10	6172	6255	
49MR0502_1	P10N	109	1	ROS	060405	0759	EN	34 43.08 N	148 54.07 E	GPS	6157	6152				
49MR0502_1	P10N	108	1	ROS	060405	0928	BE	34 29.83 N	149 0.99 E	GPS	6148	6147			35 1-8,23,24,26,27	REPLACED A CABLE FOR OXY(SEC) SENSOR, #29 MISS FIRE
49MR0502_1	P10N	108	1	BUC	060405	0936	UN	34 29.72 N	149 1.04 E	GPS	6139	6143			1	21.3C
49MR0502_1	P10N	108	1	ROS	060405	1102	BO	34 29.31 N	149 1.70 E	GPS	6168	6164	10	6162	6269	
49MR0502_1		209	1	UNK	060405	1148	UN	34 29.14 N	149 2.05 E	GPS	6164	6161				RAIN SAMPLING (5.0MM/HR)
49MR0502_1	P10N	108	1	ROS	060405	1348	EN	34 28.60 N	149 3.15 E	GPS	6143	6140				
49MR0502_1	P10N	107	1	ROS	060405	1608	BE	34 14.92 N	149 9.87 E	GPS	6168	6165			36 1-8,27	
49MR0502_1	P10N	107	1	BUC	060405	1618	UN	34 14.92 N	149 9.94 E	GPS	6172	6174			1	20.3C
49MR0502_1	P10N	107	1	ROS	060405	1743	BO	34 14.40 N	149 10.43 E	GPS	6170	6171	9	6194	6285	
49MR0502_1	P10N	107	1	ROS	060405	2026	EN	34 13.82 N	149 11.24 E	GPS	6170	6171				
49MR0502_1	P10N	106	1	ROS	060405	2149	BE	33 59.82 N	149 18.67 E	GPS	6222	6223			36 1-8,13,23,24,26,27	
49MR0502_1		210	1	UNK	060405	2155	UN	33 59.80 N	149 18.76 E	GPS	6225	6225				RAIN SAMPLING (2.5MM/HR)
49MR0502_1	P10N	106	1	BUC	060405	2156	UN	33 59.80 N	149 18.74 E	GPS	6224	6226			1,4-6,30,34,41	20.2C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10N	106	1	BIO	060405	2156	UN	33 59.80 N	149 18.74 E	GPS	6224	6226				PLANKTON NET
49MR0502_1	P10N	106	1	ROS	060405	2323	BO	33 59.91 N	149 19.20 E	GPS	6225	6230	9	6223	6341	
49MR0502_1	P10N	106	1	ROS	060505	0201	EN	34 0.14 N	149 19.51 E	GPS	6233	6235				
49MR0502_1	P10N	105	1	ROS	060505	0343	BE	33 44.95 N	149 19.89 E	GPS	6165	6166			36 1-8,27	
49MR0502_1	P10N	105	1	BUC	060505	0350	UN	33 44.98 N	149 19.92 E	GPS	6168	6169			1	20.5C
49MR0502_1	P10N	105	1	ROS	060505	0516	BO	33 45.20 N	149 20.30 E	GPS	6171	6165	9	6163	6280	
49MR0502_1		211	1	UNK	060505	0548	UN	33 45.21 N	149 20.52 E	GPS	6163	6167				RAIN SAMPLING (2.0MM/HR)
49MR0502_1	P10N	105	1	ROS	060505	0753	EN	33 45.48 N	149 21.48 E	GPS	6156	6157				
49MR0502_1	P10N	104	1	ROS	060505	0913	BE	33 29.86 N	149 20.00 E	GPS	6162	6158			35 1-8,27	#32 MISS FIRE
49MR0502_1	P10N	104	1	BUC	060505	0921	UN	33 29.84 N	149 20.10 E	GPS	6159	6162			1	20.9C
49MR0502_1	P10N	104	1	ROS	060505	1048	BO	33 29.99 N	149 20.86 E	GPS	6163	6159	9	6160	6268	
49MR0502_1	P10N	104	1	ROS	060505	1330	EN	33 30.02 N	149 21.92 E	GPS	6161	6161				
49MR0502_1	P10N	103	1	ROS	060505	1527	BE	33 9.97 N	149 20.08 E	GPS	6129	6127			36 1-8,13,23,24,26,27	
49MR0502_1	P10N	103	1	BUC	060505	1535	UN	33 9.93 N	149 20.10 E	GPS	6129	6126			1,4-6,30,34	21.2C, 9L FOR BIO
49MR0502_1	P10N	103	1	BIO	060505	1535	UN	33 9.93 N	149 20.10 E	GPS	6129	6126				PLANKTON NET
49MR0502_1	P10N	103	1	ROS	060505	1702	BO	33 9.72 N	149 21.04 E	GPS	6123	6123	10	6206	6235	
49MR0502_1	P10N	103	1	ROS	060505	1942	EN	33 9.30 N	149 22.52 E	GPS	6106	6107				
49MR0502_1		212	1	UNK	060505	2100	UN	32 50.60 N	149 20.00 E	GPS	6008	6009				RAIN SAMPLING (2.5MM/HR)
49MR0502_1	P10N	102	1	ROS	060505	2112	BE	32 49.85 N	149 20.10 E	GPS	6001	6004			36 1-8,27	
49MR0502_1	P10N	102	1	BUC	060505	2119	UN	32 49.85 N	149 20.22 E	GPS	6006	6006			1	21.6C
49MR0502_1	P10N	102	1	ROS	060505	2242	BO	32 50.03 N	149 21.15 E	GPS	6004	6004	9	6031	6108	
49MR0502_1	P10N	102	1	ROS	060605	0116	EN	32 50.40 N	149 22.13 E	GPS	6005	6004				
49MR0502_1	P10N	101	1	ROS	060605	0259	BE	32 29.85 N	149 20.05 E	GPS	5954	5955			36 1-8,27	

49MR0502_1	P10N	101	1	BUC	060605	0307	UN	32 29.83 N	149 20.12 E	GPS	5954	5951				1	21.9C
49MR0502_1	P10N	101	1	ROS	060605	0429	BO	32 29.53 N	149 20.06 E	GPS	5955	5956	9	5969	6058		SOMETHING IN SEC TC DUCT DURING UP-CAST?
49MR0502_1	P10N	101	1	ROS	060605	0703	EN	32 29.36 N	149 18.90 E	GPS	5938	5942					
49MR0502_1	P10N	100	1	ROS	060605	0836	BE	32 10.00 N	149 20.03 E	GPS	5570	5561				35 1-8,12,13,23,24,26,27	
49MR0502_1	P10N	100	1	BUC	060605	0844	UN	32 10.00 N	149 19.84 E	GPS	5553	5555				1,4-6,30,34,41	20.7C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10N	100	1	BIO	060605	0844	UN	32 10.00 N	149 19.84 E	GPS	5553	5555					PLANKTON NET
49MR0502_1	P10N	100	1	ROS	060605	1004	BO	32 10.59 N	149 19.07 E	GPS	5650	5650	12	5671	5669		
49MR0502_1		213	1	UNK	060605	1039	UN	32 10.83 N	149 18.82 E	GPS	5661	5661					RAIN SAMPLING (3.0MM/HR)
49MR0502_1	P10N	100	1	ROS	060605	1238	EN	32 11.76 N	149 17.41 E	GPS	5836	5835					SEC TC DUCT FLUSHED WELL AFTER THE CST
49MR0502_1	P10N	99	1	ROS	060605	1431	BE	31 50.13 N	149 19.92 E	GPS	5677	5678				36 1-8,27	
49MR0502_1	P10N	99	1	BUC	060605	1439	UN	31 50.18 N	149 19.87 E	GPS	5682	5682				1	20.7C
49MR0502_1	P10N	99	1	ROS	060605	1559	BO	31 50.52 N	149 19.28 E	GPS	5665	5667	8	5705	5773		
49MR0502_1	P10N	99	1	ROS	060605	1830	EN	31 50.78 N	149 18.01 E	GPS	5623	5624					
49MR0502_1	P10N	98	1	ROS	060605	2131	BE	31 10.08 N	149 20.11 E	GPS	6041	6041				36 1-8,27	
49MR0502_1	P10N	98	1	BUC	060605	2138	UN	31 10.19 N	149 20.07 E	GPS	6040	6041				1,4-6,30,34	22.2C, 9L FOR BIO
49MR0502_1	P10N	98	1	BIO	060605	2138	UN	31 10.19 N	149 20.07 E	GPS	6040	6041					PLANKTON NET
49MR0502_1		214	1	UNK	060605	2140	UN	31 10.23 N	149 20.08 E	GPS	6042	6040					RAIN SAMPLING (1.0MM/HR)
49MR0502_1	P10N	98	1	ROS	060605	2305	BO	31 10.98 N	149 20.09 E	GPS	6025	6032	9	6123	6153		
49MR0502_1	P10N	98	1	ROS	060705	0139	EN	31 11.43 N	149 19.70 E	GPS	6039	6039					
49MR0502_1	P10N	97	1	ROS	060705	0442	BE	30 29.94 N	149 20.15 E	GPS	6144	6143				36 1-8,13,23,24,26,27	
49MR0502_1	P10N	97	1	BUC	060705	0449	UN	30 29.95 N	149 20.14 E	GPS	6144	6143				1	22.5C
49MR0502_1	P10N	97	1	ROS	060705	0614	BO	30 30.24 N	149 19.65 E	GPS	6146	6145	9	6193	6250		
49MR0502_1		215	1	UNK	060705	0658	UN	30 30.51 N	149 19.56 E	GPS	6145	6147					RAIN SAMPLING (8.0MM/HR)
49MR0502_1	P10N	97	1	ROS	060705	0851	EN	30 30.83 N	149 18.95 E	GPS	6143	6146					
49MR0502_1	P10N	X02	1	ROS	060705	1119	BE	29 59.04 N	149 15.07 E	GPS	6192	6192				36 1-8,13,23,24,26,27	#15 MISS TRIP
49MR0502_1	P10N	X02	1	BUC	060705	1127	UN	29 59.06 N	149 15.01 E	GPS	6188	6188				1,4-6,30,34,41	23.1C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10N	X02	1	BIO	060705	1127	UN	29 59.06 N	149 15.01 E	GPS	6188	6188					PLANKTON NET
49MR0502_1	P10N	X02	1	ROS	060705	1253	BO	29 59.51 N	149 15.01 E	GPS	6184	6185	9	6217	6300		
49MR0502_1	P10N	X02	1	ROS	060705	1535	EN	29 59.81 N	149 13.68 E	GPS	6186	6190					
49MR0502_1	P10N	96	1	ROS	060705	1654	BE	29 50.06 N	149 19.98 E	GPS	6150	6152				36 1-8,27	
49MR0502_1	P10N	96	1	BUC	060705	1701	UN	29 50.10 N	149 19.97 E	GPS	6152	6152				1	23.1C
49MR0502_1	P10N	96	1	BIO	060705	1701	UN	29 50.10 N	149 19.97 E	GPS	6152	6152					PLANKTON NET
49MR0502_1	P10N	96	1	ROS	060705	1828	BO	29 50.28 N	149 19.65 E	GPS	6141	6146	9	6149	6260		
49MR0502_1	P10N	96	1	ROS	060705	2104	EN	29 50.38 N	149 18.85 E	GPS	6125	6128					
49MR0502_1	P10N	95	1	ROS	060805	0012	BE	29 10.08 N	149 20.07 E	GPS	6103	6105				35 1-8,27	#15 MISS FIRE
49MR0502_1	P10N	95	1	BUC	060805	0020	UN	29 10.12 N	149 20.00 E	GPS	6107	6104				1	23.5C
49MR0502_1	P10N	95	1	ROS	060805	0143	BO	29 10.21 N	149 19.65 E	GPS	6113	6113	7	6113	6224		
49MR0502_1	P10N	95	1	ROS	060805	0415	EN	29 9.89 N	149 19.58 E	GPS	6103	6101					
49MR0502_1	P10	73	1	ROS	060805	0712	BE	28 29.98 N	149 19.82 E	GPS	6228	6230				36 1-8,12,13,23,24,26,27	#5 MISS TRIP
49MR0502_1	P10	73	1	BUC	060805	0720	UN	28 29.97 N	149 19.77 E	GPS	6229	6228				1,4-6,30,34,41	24.2C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10	73	1	BIO	060805	0720	UN	28 29.97 N	149 19.77 E	GPS	6229	6228					PLANKTON NET
49MR0502_1	P10	73	1	ROS	060805	0850	BO	28 29.83 N	149 19.23 E	GPS	6215	6217	10	6214	6333		
49MR0502_1	P10	73	1	ROS	060805	1131	EN	28 29.07 N	149 17.79 E	GPS	6219	6223					
49MR0502_1	P10	72	1	ROS	060805	1423	BE	27 49.99 N	149 19.94 E	GPS	5990	5983				35 1-8,27	#5 MISS FIRE
49MR0502_1	P10	72	1	BUC	060805	1431	UN	27 49.97 N	149 19.93 E	GPS	5979	5979				1	23.8C
49MR0502_1	P10	72	1	ROS	060805	1556	BO	27 49.85 N	149 19.89 E	GPS	5969	5969	10	5969	6086		
49MR0502_1	P10	72	1	ROS	060805	1835	EN	27 49.28 N	149 20.02 E	GPS	5955	5953					
49MR0502_1	P10	71	1	ROS	060805	2125	BE	27 9.96 N	149 20.09 E	GPS	5883	5884				36 1-8,27	
49MR0502_1	P10	71	1	BUC	060805	2132	UN	27 9.94 N	149 20.12 E	GPS	5880	5879				1	25.4C
49MR0502_1	P10	71	1	ROS	060805	2255	BO	27 9.97 N	149 20.67 E	GPS	5860	5860	9	5883	5980		
49MR0502_1	P10	71	1	ROS	060905	0125	EN	27 9.99 N	149 21.60 E	GPS	5860	5860					

49MR0502_1	P10	70	1	ROS	060905	0422	BE	26 29.88 N 149 19.98 E	GPS	6093	6090			36	1-8,13,23,24,26,27	
49MR0502_1	P10	70	1	BUC	060905	0430	UN	26 29.84 N 149 19.98 E	GPS	6088	6089				1,4-6,30,34,41	26.2C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10	70	1	BIO	060905	0430	UN	26 29.84 N 149 19.98 E	GPS	6088	6089					PLANKTON NET
49MR0502_1	P10	70	1	ROS	060905	0556	BO	26 29.56 N 149 20.11 E	GPS	6079	6077	9	6090	6197		
49MR0502_1	P10	70	1	ROS	060905	0835	EN	26 29.19 N 149 20.63 E	GPS	5973	5970					
49MR0502_1	P10	69	1	ROS	060905	1123	BE	25 49.93 N 149 19.99 E	GPS	5893	5893			36	1-8,27	ATTACHED 2 OPTODES
49MR0502_1	P10	69	1	BUC	060905	1131	UN	25 49.92 N 149 19.98 E	GPS	5893	5891				1	25.5C
49MR0502_1	P10	69	1	ROS	060905	1254	BO	25 49.84 N 149 19.78 E	GPS	5898	5895	10	5892	5998		
49MR0502_1	P10	69	1	ROS	060905	1530	EN	25 49.98 N 149 19.70 E	GPS	5897	5894					
49MR0502_1	P10	68	1	ROS	060905	1821	BE	25 10.01 N 149 20.02 E	GPS	5909	5908			36	1-8,12,13,23,24,26,27	
49MR0502_1	P10	68	1	BUC	060905	1828	UN	25 10.02 N 149 20.02 E	GPS	5906	5908				1,4-6,30,34,41	27.0C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10	68	1	BIO	060905	1828	UN	25 10.02 N 149 20.02 E	GPS	5906	5908					PLANKTON NET
49MR0502_1	P10	68	1	ROS	060905	1952	BO	25 9.97 N 149 19.77 E	GPS	5904	5903	9	5910	6016		
49MR0502_1	P10	68	1	ROS	060905	2231	EN	25 10.02 N 149 19.60 E	GPS	5905	5905					
49MR0502_1	P10	67	1	ROS	061005	0151	BE	24 30.02 N 149 19.94 E	GPS	5769	5767			36	1-8,27	ATTACHED FLUOROMETER
49MR0502_1	P10	67	1	BUC	061005	0202	UN	24 30.12 N 149 19.93 E	GPS	5769	5770				1	28.3C
49MR0502_1	P10	67	1	ROS	061005	0319	BO	24 30.34 N 149 20.26 E	GPS	5782	5783	9	5772	5872		
49MR0502_1	P10	67	1	ROS	061005	0547	EN	24 30.86 N 149 21.34 E	GPS	5781	5781					
49MR0502_1	P10	X03	1	ROS	061005	0741	BE	24 14.57 N 149 1.72 E	GPS	5794	5790			36	1-8,13,23,24,26,27	
49MR0502_1	P10	X03	1	BUC	061005	0749	UN	24 14.57 N 149 1.74 E	GPS	5788	5790				1,4-6,30,34,41	28.6C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10	X03	1	BIO	061005	0749	UN	24 14.57 N 149 1.74 E	GPS	5788	5790					PLANKTON NET
49MR0502_1	P10	X03	1	ROS	061005	0912	BO	24 14.44 N 149 1.86 E	GPS	5788	5787	7	5789	5892		
49MR0502_1	P10	X03	1	ROS	061005	1152	EN	24 14.58 N 149 1.71 E	GPS	5792	5790					REMOVED 2 OPTODES
49MR0502_1	P10	66	1	ROS	061005	1403	BE	23 49.79 N 149 20.03 E	GPS	5831	5827			36	1-8,27	
49MR0502_1	P10	66	1	BUC	061005	1414	UN	23 49.66 N 149 20.07 E	GPS	5821	5820				1,4-6,30,34	27.7C, 9L FOR BIO
49MR0502_1	P10	66	1	ROS	061005	1534	BO	23 49.44 N 149 19.76 E	GPS	5817	5818	9	5808	5921		
49MR0502_1	P10	66	1	ROS	061005	1812	EN	23 49.41 N 149 19.06 E	GPS	5848	5850					
49MR0502_1	P10	65	1	ROS	061005	2057	BE	23 10.78 N 149 20.50 E	GPS	5801	5803			36	1-8,27	
49MR0502_1	P10	65	1	BUC	061005	2104	UN	23 10.78 N 149 20.67 E	GPS	5804	5804				1	28.1C
49MR0502_1	P10	65	1	ROS	061005	2229	BO	23 10.43 N 149 21.80 E	GPS	5795	5797	8	5924	5903		
49MR0502_1	P10	65	1	ROS	061105	0057	EN	23 9.88 N 149 23.31 E	GPS	5785	5787					
49MR0502_1	P10	64	1	ROS	061105	0400	BE	22 29.95 N 149 20.02 E	GPS	5709	5712			36	1-9,12,13,22-24,26,27,47	
49MR0502_1	P10	64	1	BUC	061105	0407	UN	22 29.99 N 149 20.09 E	GPS	5712	5711				1,4-6,30,34,41	29.2C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10	64	1	BIO	061105	0407	UN	22 29.99 N 149 20.09 E	GPS	5712	5711					PLANKTON NET
49MR0502_1	P10	64	1	ROS	061105	0528	BO	22 30.13 N 149 21.08 E	GPS	5703	5709	10	5788	5811		
49MR0502_1	P10	64	1	ROS	061105	0756	EN	22 30.25 N 149 22.93 E	GPS	5691	5692					
49MR0502_1		216	1	UNK	061105	0925	BE	22 9.90 N 149 21.58 E	GPS	5697	5697					100L THROUGH HULL PUMP FOR R.N.
49MR0502_1		216	1	UNK	061105	0950	EN	22 3.68 N 149 20.94 E	GPS	5580	5583					FOR P10_64
49MR0502_1	P10	63	1	ROS	061105	1054	BE	21 50.00 N 149 20.02 E	GPS	5619	5621			35	1-8,27	
49MR0502_1	P10	63	1	BUC	061105	1100	UN	21 49.94 N 149 19.98 E	GPS	5621	5619				1	28.7C
49MR0502_1	P10	63	1	ROS	061105	1219	BO	21 49.89 N 149 19.58 E	GPS	5616	5616	10	5624	5713		
49MR0502_1	P10	63	1	ROS	061105	1553	EN	21 49.63 N 149 18.50 E	GPS	5601	5603					ASCENT RATE 0.5M/S DUT TO WINCH TROUBLE
49MR0502_1		217	1	UNK	061205	0452	BE	21 7.88 N 149 18.81 E	GPS	5346	5347					MAGNETOMETER CALIBRATION
49MR0502_1		217	1	UNK	061205	0520	EN	21 7.18 N 149 19.32 E	GPS	5388	5389					
49MR0502_1		218	1	UNK	061205	1652	BE	21 9.78 N 149 20.35 E	GPS	5406	5401					CTD CABLE RESPOOLING (WO 2000M)
49MR0502_1		218	1	UNK	061205	1805	EN	21 8.89 N 149 19.89 E	GPS	5391	5391					
49MR0502_1	P10	62	1	ROS	061205	1856	BE	21 9.89 N 149 20.00 E	GPS	5391	5389			0		LOST CTD SIGNAL ON DOWNCAST
49MR0502_1	P10	62	1	BUC	061205	1905	UN	21 9.70 N 149 19.88 E	GPS	5388	5387				1	28.8C
49MR0502_1	P10	62	1	ROS	061205	1949	EN	21 9.29 N 149 19.37 E	GPS	5349	5351					
49MR0502_1		219	1	UNK	061205	2010	UN	21 9.46 N 149 19.50 E	GPS	5358	5359					RAIN SAMPLING (2.0MM/HR)
49MR0502_1	P10	62	2	ROS	061205	2125	BE	21 10.86 N 149 20.54 E	GPS	5396	5391			34	1-9,22,27,47	

49MR0502_1	P10	62	2	ROS	061205	2248	BO	21 10.39 N	149 19.69 E	GPS	5374	5373	9	5437	5475	
49MR0502_1	P10	62	1	UNK	061205	2250	BE	21 10.39 N	149 19.67 E	GPS	5366	5365				100L THROUGH HULL PUMP FOR R.N.
49MR0502_1	P10	62	1	UNK	061205	2310	EN	21 10.43 N	149 19.51 E	GPS	5349	5351				
49MR0502_1	P10	62	2	ROS	061305	0149	EN	21 10.20 N	149 17.43 E	GPS	4625	4622				
49MR0502_1	P10	61	1	ROS	061305	0434	BE	20 29.87 N	149 20.03 E	GPS	4453	4451			31 1-8,13,23,24,26,27	
49MR0502_1	P10	61	1	BUC	061305	0441	UN	20 29.75 N	149 19.92 E	GPS	4476	4473			1,4-6,30,34	28.1C, 13L FOR BIO
49MR0502_1	P10	61	1	BIO	061305	0441	UN	20 29.75 N	149 19.92 E	GPS	4476	4473				PLANKTON NET
49MR0502_1	P10	61	1	ROS	061305	0546	BO	20 29.60 N	149 19.34 E	GPS	4568	4569	10	4592	4612	
49MR0502_1	P10	61	1	ROS	061305	0813	EN	20 29.54 N	149 17.85 E	GPS	4572	4573				
49MR0502_1	P10	60	1	ROS	061305	1056	BE	19 49.86 N	149 20.00 E	GPS	3675	3680			28 1-8,12,13,23,24,26,27	
49MR0502_1	P10	60	1	BUC	061305	1104	UN	19 49.73 N	149 19.87 E	GPS	3661	3659			1,4-6,23,30,34,41	29.1C, 20L FOR PON, 240L FOR DIC, 41L FOR BIO
49MR0502_1	P10	60	1	ROS	061305	1202	BO	19 49.61 N	149 19.52 E	GPS	3826	3819	13	3790	3829	
49MR0502_1	P10	60	1	UNK	061305	1215	BE	19 49.63 N	149 19.46 E	GPS	3826	3824				100L THROUGH HULL PUMP FOR R.N.
49MR0502_1	P10	60	1	UNK	061305	1233	EN	19 49.65 N	149 19.34 E	GPS	3854	3851				
49MR0502_1	P10	60	1	ROS	061305	1422	EN	19 49.78 N	149 18.58 E	GPS	3965	3964				
49MR0502_1	P10	60	2	ROS	061305	1556	BE	19 50.04 N	149 20.00 E	GPS	3802	3794			16 9,22,47	CST FOR R.N.
49MR0502_1	P10	60	2	ROS	061305	1619	BO	19 50.12 N	149 19.77 E	GPS	3873	3871	-9	1013	1004	
49MR0502_1	P10	60	2	ROS	061305	1700	EN	19 50.33 N	149 19.53 E	GPS	3949	3948				
49MR0502_1	P10	60	1	FLT	061305	1709	DE	19 50.14 N	149 19.62 E	GPS	3782	3781				ARGO#1575/ID23732
49MR0502_1	P10	59	1	ROS	061305	1954	BE	19 10.07 N	149 20.16 E	GPS	5558	5559			36 1-8,13,23,24,26,27	#1=#2 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	59	1	BUC	061305	2000	UN	19 10.07 N	149 20.13 E	GPS	5560	5560			1,4-6,30,34,41	28.5C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10	59	1	BIO	061305	2000	UN	19 10.07 N	149 20.13 E	GPS	5560	5560				PLANKTON NET
49MR0502_1	P10	59	1	ROS	061305	2117	BO	19 9.93 N	149 19.74 E	GPS	5551	5555	10	5549	5640	
49MR0502_1	P10	59	1	ROS	061305	2359	EN	19 10.01 N	149 18.54 E	GPS	5561	5562				
49MR0502_1	P10	58	1	ROS	061405	0249	BE	18 29.85 N	149 19.99 E	GPS	5552	5557			36 1-8,27	#1=#3 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	58	1	BUC	061405	0256	UN	18 29.87 N	149 19.90 E	GPS	5567	5565			1	29.3C
49MR0502_1	P10	58	1	UNK	061405	0401	BE	18 30.37 N	149 19.79 E	GPS	5595	5593				100L THROUGH HULL PUMP FOR R.N.
49MR0502_1	P10	58	1	ROS	061405	0416	BO	18 30.49 N	149 19.81 E	GPS	5603	5604	10	5634	5674	
49MR0502_1	P10	58	1	UNK	061405	0444	EN	18 30.68 N	149 19.86 E	GPS	5613	5616				
49MR0502_1	P10	58	1	ROS	061405	0702	EN	18 31.60 N	149 19.91 E	GPS	5631	5627				#22 DISCONNECTED MIDDLE AND LOWER LANYARD
49MR0502_1	P10	58	2	ROS	061405	0757	BE	18 29.73 N	149 19.95 E	GPS	5539	5545			16 9,22,47	CST FOR R.N.
49MR0502_1	P10	58	2	ROS	061405	0817	BO	18 29.91 N	149 19.89 E	GPS	5569	5569	-9	1014	1006	
49MR0502_1	P10	58	2	ROS	061405	0901	EN	18 30.21 N	149 19.81 E	GPS	5594	5590				
49MR0502_1	P10	57	1	ROS	061405	1157	BE	17 50.01 N	149 19.99 E	GPS	5330	5335			35 1-8,27	#1=#4 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	57	1	BUC	061405	1204	UN	17 50.07 N	149 19.92 E	GPS	5336	5336			1	28.6C
49MR0502_1	P10	57	1	ROS	061405	1320	BO	17 50.51 N	149 19.74 E	GPS	5337	5340	9	5363	5426	
49MR0502_1	P10	57	1	ROS	061405	1630	EN	17 51.39 N	149 19.31 E	GPS	5332	5330				
49MR0502_1	P10	56	1	ROS	061405	1929	BE	17 9.87 N	149 19.92 E	GPS	5402	5399			35 1-8,12,13,23,24,26,27	#1=#5 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	56	1	BUC	061405	1936	UN	17 9.85 N	149 19.87 E	GPS	5403	5403			1,4-6,30,34,41	28.7C, 13L FOR BIO, 20L FOR PON
49MR0502_1	P10	56	1	BIO	061405	1936	UN	17 9.85 N	149 19.87 E	GPS	5409	5403				PLANKTON NET
49MR0502_1	P10	56	1	ROS	061405	2050	BO	17 10.37 N	149 19.50 E	GPS	5394	5395	10	5477	5483	
49MR0502_1	P10	56	1	ROS	061405	2347	EN	17 11.64 N	149 18.82 E	GPS	5396	5394				
49MR0502_1	P10	56	2	ROS	061505	0107	BE	17 10.22 N	149 19.86 E	GPS	5395	5394			14 9,22,47	CST FOR R.N.
49MR0502_1	P10	56	1	UNK	061505	0107	BE	17 10.22 N	149 19.86 E	GPS	5395	5394				100L THROUGH HULL PUMP FOR R.N.
49MR0502_1	P10	56	2	ROS	061505	0124	BO	17 10.42 N	149 19.72 E	GPS	5396	5395	-9	819	802	
49MR0502_1	P10	56	1	UNK	061505	0143	EN	17 10.64 N	149 19.52 E	GPS	5398	5394				
49MR0502_1	P10	56	2	ROS	061505	0156	EN	17 10.79 N	149 19.34 E	GPS	5406	5405				
49MR0502_1	P10	55	1	ROS	061505	0455	BE	16 29.82 N	149 20.02 E	GPS	5212	5213			35 1-8,27	#1=#6 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	55	1	BUC	061505	0503	UN	16 29.85 N	149 19.99 E	GPS	5213	5215			1	28.9C
49MR0502_1	P10	55	1	ROS	061505	0617	BO	16 30.39 N	149 19.93 E	GPS	5185	5178	9	5252	5297	
49MR0502_1	P10	55	1	ROS	061505	0921	EN	16 31.92 N	149 19.55 E	GPS	5259	5257				

49MR0502_1	P10	54	1	ROS	061505	1222	BE	15 49.98 N	149 20.07 E	GPS	4745	4741				32	1-9,13,22-24,26,27,47	#1=#7 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	54	1	BUC	061505	1229	UN	15 50.02 N	149 20.02 E	GPS	4704	4702					1,41	28.2C, 20L FOR PON
49MR0502_1	P10	54	1	ROS	061505	1336	BO	15 50.50 N	149 19.65 E	GPS	4771	4776	8	4725	4747			
49MR0502_1	P10	54	1	ROS	061505	1612	EN	15 51.50 N	149 19.13 E	GPS	4777	4776						
49MR0502_1		220	1	UNK	061505	1641	BE	15 46.77 N	149 19.25 E	GPS	5216	5216						100L THROUGH HULL PUMP FOR R.N.
49MR0502_1		220	1	UNK	061505	1712	EN	15 38.83 N	149 19.49 E	GPS	5609	5609						FOR P10_54
49MR0502_1	P10	53	1	ROS	061505	1912	BE	15 9.98 N	149 20.06 E	GPS	5683	5685				35	1-8,13,23,24,26,27	
49MR0502_1	P10	53	1	BUC	061505	1920	UN	15 9.98 N	149 20.00 E	GPS	5678	5678					1,4-6,30,34,41	28.7C, 9L FOR BIO, 20L FOR PON
49MR0502_1	P10	53	1	BIO	061505	1920	UN	15 9.98 N	149 20.00 E	GPS	5678	5678						PLANKTON NET
49MR0502_1	P10	53	1	ROS	061505	2037	BO	15 10.25 N	149 19.94 E	GPS	5675	5675	11	5669	5769			
49MR0502_1	P10	53	1	ROS	061505	2337	EN	15 11.30 N	149 19.82 E	GPS	5670	5670						SEC. CONDUCTIVITY BROKEN NEAR BTM (DOWN CST)
49MR0502_1	P10	53	1	FLT	061505	2344	DE	15 11.25 N	149 19.99 E	GPS	5670	5675						ARGO#223/ID6497
49MR0502_1	P10	52	1	ROS	061605	0237	BE	14 30.02 N	149 20.06 E	GPS	5306	5303				35	1-9,22,27,47	REPLACED CONDUCTIVITY (SEC) SENSOR, #1=#8 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	52	1	BUC	061605	0243	UN	14 30.05 N	149 20.07 E	GPS	5306	5304					1	28.8C
49MR0502_1	P10	52	1	ROS	061605	0357	BO	14 30.43 N	149 20.10 E	GPS	5311	5313	8	5315	5387			
49MR0502_1	P10	52	1	UNK	061605	0408	BE	14 30.50 N	149 20.07 E	GPS	5310	5313						100L THROUGH HULL PUMP FOR R.N.
49MR0502_1	P10	52	1	UNK	061605	0442	EN	14 30.67 N	149 20.01 E	GPS	5314	5313						
49MR0502_1	P10	52	1	ROS	061605	0636	EN	14 31.35 N	149 19.93 E	GPS	5152	5153						
49MR0502_1	P10	51	1	ROS	061605	0933	BE	13 49.98 N	149 19.26 E	GPS	5989	5989				36	1-8,12,13,23,24,26,27	
49MR0502_1	P10	51	1	BUC	061605	0940	UN	13 49.98 N	149 19.23 E	GPS	5996	5994					1	28.7C
49MR0502_1	P10	51	1	ROS	061605	1104	BO	13 50.48 N	149 19.11 E	GPS	5990	5990	8	6020	6094			
49MR0502_1	P10	51	1	ROS	061605	1404	EN	13 51.36 N	149 18.74 E	GPS	5987	5989						
49MR0502_1	P10	50	1	ROS	061605	1659	BE	13 9.97 N	149 20.03 E	GPS	5965	5965				36	1-8,27	ATTACHED 1 OPTODE
49MR0502_1	P10	50	1	BUC	061605	1707	UN	13 9.95 N	149 19.92 E	GPS	5968	5968					1	28.8C
49MR0502_1	P10	50	1	ROS	061605	1831	BO	13 10.40 N	149 19.48 E	GPS	5964	5964	10	5993	6067			
49MR0502_1	P10	50	1	ROS	061605	2135	EN	13 11.57 N	149 18.12 E	GPS	5954	5954						
49MR0502_1	P10	49	1	ROS	061705	0033	BE	12 29.71 N	149 19.99 E	GPS	5927	5926				36	1-8,13,23,24,26,27	
49MR0502_1	P10	49	1	BUC	061705	0039	UN	12 29.72 N	149 19.94 E	GPS	5932	5932					1,4-6,30,34,41	28.8C, 13L FOR BIO, 20L FOR PON
49MR0502_1	P10	49	1	ROS	061705	0202	BO	12 30.25 N	149 19.60 E	GPS	5921	5921	8	5963	6024			
49MR0502_1	P10	49	1	ROS	061705	0455	EN	12 31.23 N	149 18.57 E	GPS	5911	5914						
49MR0502_1		221	1	UNK	061705	0516	UN	12 27.86 N	149 18.71 E	GPS	5916	5916						RAIN SAMPLING (4.5MM/HR)
49MR0502_1	P10	48	1	ROS	061705	0752	BE	11 49.97 N	149 19.67 E	GPS	5821	5820				36	1-8,27	
49MR0502_1	P10	48	1	BUC	061705	0759	UN	11 49.99 N	149 19.57 E	GPS	5821	5817					1	29.1C
49MR0502_1	P10	48	1	ROS	061705	0923	BO	11 50.51 N	149 19.03 E	GPS	5821	5821	12	5894	5909			
49MR0502_1	P10	48	1	ROS	061705	1215	EN	11 51.76 N	149 18.32 E	GPS	5826	5826						
49MR0502_1	P10	47	1	ROS	061705	1517	BE	11 9.44 N	149 19.92 E	GPS	5812	5816				36	1-8,12,13,23,24,26,27	
49MR0502_1	P10	47	1	BUC	061705	1525	UN	11 9.49 N	149 19.89 E	GPS	5814	5811					1	28.8C
49MR0502_1	P10	47	1	ROS	061705	1648	BO	11 9.91 N	149 19.36 E	GPS	5814	5814	9	5835	5909			
49MR0502_1	P10	47	1	ROS	061705	1945	EN	11 11.02 N	149 18.22 E	GPS	5813	5813						
49MR0502_1	P10	46	1	ROS	061705	2238	BE	10 29.93 N	149 20.09 E	GPS	5714	5714				36	1-8,27	
49MR0502_1	P10	46	1	BUC	061705	2243	UN	10 29.92 N	149 20.07 E	GPS	5713	5713					1	29.0C
49MR0502_1	P10	46	1	ROS	061805	0005	BO	10 29.98 N	149 19.90 E	GPS	5716	5715	9	5708	5808			
49MR0502_1	P10	46	1	ROS	061805	0234	EN	10 30.18 N	149 19.23 E	GPS	5718	5716						REMOVED 1 OPTODE
49MR0502_1	P10	45	1	ROS	061805	0445	BE	10 0.00 N	149 20.05 E	GPS	5567	5567				36	1-8,13,23,24,26,27	#1=#9 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	45	1	BUC	061805	0452	UN	10 0.01 N	149 19.98 E	GPS	5570	5572					1,4-6,30,34,41	29.2C, 13L FOR BIO, 20L FOR PON
49MR0502_1	P10	45	1	ROS	061805	0610	BO	10 0.30 N	149 19.72 E	GPS	5553	5555	9	5569	5653			
49MR0502_1		222	1	UNK	061805	0837	UN	10 0.85 N	149 19.22 E	GPS	5554	5556						RAIN SAMPLING (0.8MM/HR)
49MR0502_1	P10	45	1	ROS	061805	0854	EN	10 0.86 N	149 19.13 E	GPS	5552	5555						
49MR0502_1	P10	44	1	ROS	061805	1025	BE	9 41.81 N	149 19.96 E	GPS	5362	5359				35	1-8,27	#5=#10 DUPLICATE SMPLS (5000DB)
49MR0502_1	P10	44	1	BUC	061805	1031	UN	9 41.82 N	149 19.89 E	GPS	5360	5359					1	28.9C

49MR0502_1	P10	44	1	ROS	061805	1147	BO	9 42.41 N	149 19.81 E	GPS	5376	5376	7	5412	5449				
49MR0502_1		223	1	UNK	061805	1214	UN	9 42.55 N	149 19.83 E	GPS	5371	5371							RAIN SAMPLING (1.1MM/HR)
49MR0502_1	P10	44	1	ROS	061805	1411	EN	9 43.23 N	149 19.40 E	GPS	5380	5381							
49MR0502_1	P10	X04	1	ROS	061805	1530	BE	9 29.42 N	149 10.04 E	GPS	5228	5227				35	1-8,23,24,26,27		#1=#11 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	X04	1	BUC	061805	1538	UN	9 29.44 N	149 9.94 E	GPS	5224	5223					1		29.0C
49MR0502_1	P10	X04	1	ROS	061805	1651	BO	9 29.70 N	149 9.76 E	GPS	5226	5225	9	5227	5295				
49MR0502_1	P10	X04	1	ROS	061805	1917	EN	9 30.51 N	149 9.08 E	GPS	5188	5187							
49MR0502_1	P10	42	1	ROS	061805	2217	BE	8 49.94 N	149 20.00 E	GPS	4118	4118				30	1-8,23,24,26,27		#1=#12 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	42	1	BUC	061805	2223	UN	8 49.94 N	149 19.94 E	GPS	4117	4118					1		29.1C
49MR0502_1	P10	42	1	ROS	061805	2320	BO	8 50.01 N	149 19.77 E	GPS	4123	4120	9	4124	4169				
49MR0502_1	P10	42	1	ROS	061905	0111	EN	8 50.50 N	149 19.38 E	GPS	4131	4133							
49MR0502_1	P10	41	1	ROS	061905	0246	BE	8 30.02 N	149 19.96 E	GPS	3627	3627				28	1-8,27		#1=#13 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	41	1	BUC	061905	0254	UN	8 30.07 N	149 19.87 E	GPS	3649	3649					1		29.2C
49MR0502_1	P10	41	1	ROS	061905	0346	BO	8 30.53 N	149 19.62 E	GPS	3710	3703	10	3727	3722				
49MR0502_1	P10	41	1	ROS	061905	0526	EN	8 31.27 N	149 18.97 E	GPS	3742	3739							
49MR0502_1	P10	40	1	ROS	061905	0830	BE	8 0.01 N	149 9.98 E	GPS	3016	3016				26	1-8,12,13,23,24,26,27		#2=#18 DUPLICATE SMPLS (2000DB)
49MR0502_1	P10	40	1	BUC	061905	0837	UN	8 0.05 N	149 9.90 E	GPS	3013	3013					1,4-6,30,34,41		29.5C, 13L FOR BIO, 20L FOR PON
49MR0502_1	P10	40	1	ROS	061905	0920	BO	8 0.39 N	149 9.65 E	GPS	2997	2996	6	3048	3034				
49MR0502_1	P10	40	1	ROS	061905	1055	EN	8 1.23 N	149 9.23 E	GPS	2957	2958							
49MR0502_1		224	1	UNK	061905	1150	UN	7 52.02 N	149 6.34 E	GPS	2533	2533							RAIN SAMPLING (5.4MM/HR)
49MR0502_1	P10	39	1	ROS	061905	1359	BE	7 30.01 N	148 59.93 E	GPS	1011	1011				15	1-8,23,24,26,27		
49MR0502_1	P10	39	1	BUC	061905	1406	UN	7 30.06 N	148 59.85 E	GPS	1041	1041					1,4-6,30,34		29.1C, 13L FOR BIO
49MR0502_1		225	1	UNK	061905	1415	UN	7 30.11 N	148 59.74 E	GPS	1065	1065							RAIN SAMPLING (5.5MM/HR)
49MR0502_1	P10	39	1	ROS	061905	1419	BO	7 30.11 N	148 59.71 E	GPS	1075	1075	12	1017	1020				
49MR0502_1	P10	39	1	ROS	061905	1503	EN	7 30.28 N	148 59.24 E	GPS	1031	1031							
49MR0502_1	P10	38	1	ROS	061905	1733	BE	6 59.95 N	148 41.68 E	GPS	3224	3225				27	1-8,23,24,26,27		#5 AT 2400DB, #16 NOT FIRE, #1=#14 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	38	1	BUC	061905	1741	UN	6 59.95 N	148 41.59 E	GPS	3199	3199					1		29.3C
49MR0502_1	P10	38	1	ROS	061905	1830	BO	6 59.90 N	148 41.08 E	GPS	3387	3389	15	3387	3371				
49MR0502_1	P10	38	1	ROS	061905	2004	EN	7 0.20 N	148 40.28 E	GPS	3470	3471							
49MR0502_1	P10	37	1	ROS	061905	2224	BE	6 29.99 N	148 29.08 E	GPS	3385	3383				27	1-8,27		#1=#15 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	37	1	BUC	061905	2230	UN	6 30.05 N	148 29.00 E	GPS	3345	3345					1		29.6C
49MR0502_1	P10	37	1	ROS	061905	2322	BO	6 30.59 N	148 28.77 E	GPS	3184	3162	5	3403	3369				
49MR0502_1		226	1	UNK	061905	2358	UN	6 30.92 N	148 28.73 E	GPS	3234	3230							RAIN SAMPLING (1.0MM/HR)
49MR0502_1		227	1	UNK	062005	0040	UN	6 31.20 N	148 28.65 E	GPS	3166	3165							RAIN SAMPLING (1.0MM/HR)
49MR0502_1	P10	37	1	ROS	062005	0053	EN	6 31.23 N	148 28.65 E	GPS	3161	3160							
49MR0502_1	P10	36	1	ROS	062005	0318	BE	5 59.92 N	148 16.37 E	GPS	4093	4095				30	1-8,13,23,24,26,27		#1=#16 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	36	1	BUC	062005	0325	UN	5 59.94 N	148 16.34 E	GPS	4096	4095					1,4-6,30,34,41		29.6C, 13L FOR BIO, 20L FOR PON
49MR0502_1	P10	36	1	ROS	062005	0423	BO	6 0.05 N	148 16.25 E	GPS	4099	4098	9	4086	4142				
49MR0502_1	P10	36	1	ROS	062005	0614	EN	6 0.64 N	148 16.09 E	GPS	4093	4095							
49MR0502_1	P10	35	1	ROS	062005	0857	BE	5 29.94 N	148 3.70 E	GPS	3637	3636				28	1-8,27		#1=#17 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	35	1	BUC	062005	0904	UN	5 29.97 N	148 3.70 E	GPS	3631	3632					1		29.5C
49MR0502_1	P10	35	1	ROS	062005	0953	BO	5 30.21 N	148 3.65 E	GPS	3663	3665	14	3606	3642				
49MR0502_1	P10	35	1	ROS	062005	1135	EN	5 30.76 N	148 3.82 E	GPS	3597	3603							
49MR0502_1	P10	34	1	ROS	062005	1402	BE	5 0.01 N	147 51.11 E	GPS	4223	4222				30	1-8,12,13,23,24,26,27		#4 MISS FIRE, #1=#18 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	34	1	BUC	062005	1409	UN	5 0.06 N	147 51.17 E	GPS	4200	4199					1		29.6C
49MR0502_1	P10	34	1	ROS	062005	1511	BO	5 0.43 N	147 51.12 E	GPS	4108	4111	7	4196	4242				
49MR0502_1	P10	34	1	ROS	062005	1707	EN	5 0.93 N	147 51.19 E	GPS	3885	3889							
49MR0502_1	P10	33	1	ROS	062005	2001	BE	4 29.96 N	147 38.44 E	GPS	3706	3706				27	1-8,27		#2 MISS FIRE
49MR0502_1	P10	33	1	BUC	062005	2008	UN	4 29.99 N	147 38.49 E	GPS	3704	3705					1		29.5C
49MR0502_1	P10	33	1	ROS	062005	2059	BO	4 30.21 N	147 38.57 E	GPS	3705	3708	9	3715	3752				

49MR0502_1		228	1	UNK	062005	2227	UN	4 30.33 N	147 38.67 E	GPS	3708	3708							RAIN SAMPLING (4.0MM/HR)
49MR0502_1	P10	33	1	ROS	062005	2238	EN	4 30.32 N	147 38.71 E	GPS	3707	3707							
49MR0502_1	P10	32	1	ROS	062105	0132	BE	4 0.06 N	147 25.57 E	GPS	4109	4108				30	1-8,13,23,24,26,27		
49MR0502_1	P10	32	1	BUC	062105	0138	UN	4 0.12 N	147 25.60 E	GPS	4107	4106					1,4-6,30,34		29.5C, 13L FOR BIO
49MR0502_1	P10	32	1	ROS	062105	0235	BO	4 0.39 N	147 26.01 E	GPS	4100	4100	9	4135	4148				
49MR0502_1	P10	32	1	ROS	062105	0424	EN	4 1.32 N	147 26.25 E	GPS	4098	4099							
49MR0502_1	P10	31	1	ROS	062105	0727	BE	3 30.23 N	147 12.82 E	GPS	4607	4607				32	1-8,23,24,26,27		#1=#3 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	31	1	BUC	062105	0734	UN	3 30.24 N	147 12.90 E	GPS	4604	4602					1		29.5C
49MR0502_1	P10	31	1	ROS	062105	0839	BO	3 30.49 N	147 12.80 E	GPS	4602	4605	9	4594	4655				
49MR0502_1		229	1	UNK	062105	0950	UN	3 30.68 N	147 12.60 E	GPS	4604	4603							RAIN SAMPLING (11.0MM/HR)
49MR0502_1	P10	31	1	ROS	062105	1054	EN	3 30.92 N	147 12.14 E	GPS	4606	4604							
49MR0502_1	P10	30	1	ROS	062105	1326	BE	3 0.14 N	146 59.96 E	GPS	4440	4434				31	1-8,27		#1=#4 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	30	1	BUC	062105	1333	UN	3 0.17 N	147 0.00 E	GPS	4433	4431					1,4-6,30,34		29.5C, 13L FOR BIO
49MR0502_1	P10	30	1	ROS	062105	1435	BO	3 0.24 N	147 0.15 E	GPS	4423	4425	9	4417	4481				
49MR0502_1	P10	30	1	ROS	062105	1635	EN	3 0.53 N	147 0.61 E	GPS	4419	4421							
49MR0502_1	P10	29	1	ROS	062105	1840	BE	2 45.05 N	146 55.88 E	GPS	4397	4397				31	1-8,12,13,23,24,26,27		#1=#5 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	29	1	BUC	062105	1848	UN	2 45.12 N	146 55.93 E	GPS	4409	4408					1		29.5C
49MR0502_1	P10	29	1	ROS	062105	1950	BO	2 45.13 N	146 56.24 E	GPS	4424	4424	9	4418	4463				
49MR0502_1	P10	29	1	ROS	062105	2155	EN	2 45.09 N	146 57.16 E	GPS	4437	4439							
49MR0502_1		230	1	UNK	062105	2352	UN	2 29.94 N	146 51.51 E	GPS	4438	4438							RAIN SAMPLING (12.0MM/HR)
49MR0502_1	P10	28	1	ROS	062205	0001	BE	2 29.91 N	146 51.60 E	GPS	4444	4445				31	1-8,27		REMOVED FLUOROMETER, #1=#6 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	28	1	BUC	062205	0008	UN	2 29.93 N	146 51.71 E	GPS	4442	4444					1		29.6C
49MR0502_1	P10	28	1	ROS	062205	0108	BO	2 29.93 N	146 52.08 E	GPS	4453	4453	9	4443	4505				
49MR0502_1	P10	28	1	ROS	062205	0304	EN	2 29.94 N	146 52.77 E	GPS	4444	4443							
49MR0502_1		231	1	UNK	062205	0334	UN	2 25.78 N	146 51.01 E	GPS	4486	4489							RAIN SAMPLING (2.5MM/HR)
49MR0502_1	P10	27	1	ROS	062205	0530	BE	2 15.05 N	146 47.04 E	GPS	4618	4620				32	1-8,23,24,26,27		#1=#7 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	27	1	BUC	062205	0537	UN	2 15.09 N	146 47.07 E	GPS	4618	4621					1		29.4C
49MR0502_1	P10	27	1	ROS	062205	0641	BO	2 15.23 N	146 47.21 E	GPS	4623	4620	9	4611	4682				
49MR0502_1	P10	27	1	ROS	062205	0853	EN	2 15.15 N	146 47.71 E	GPS	4617	4618							SEC. CONDUCTIVITY BROKEN NEAR BTM (DOWN CST)
49MR0502_1	P10	26	1	ROS	062205	1115	BE	1 59.83 N	146 43.00 E	GPS	4438	4437				31	1-8,27		REPLACED CONDUCTIVITY (SEC) SENSOR, #1=#8 DUPLICATE SMPLS (B-10DB), ATTACHED 1 OPTODE
49MR0502_1	P10	26	1	BUC	062205	1122	UN	1 59.84 N	146 43.03 E	GPS	4441	4441					1		29.6C
49MR0502_1	P10	26	1	ROS	062205	1223	BO	1 59.78 N	146 43.28 E	GPS	4442	4441	12	4420	4486				
49MR0502_1	P10	26	1	ROS	062205	1423	EN	1 59.79 N	146 43.98 E	GPS	4421	4421							
49MR0502_1		232	1	UNK	062205	1546	UN	1 48.77 N	146 39.67 E	GPS	4609	4606							RAIN SAMPLING (2.0MM/HR)
49MR0502_1	P10	25	1	ROS	062205	1633	BE	1 45.00 N	146 38.57 E	GPS	4453	4452				31	1-8,27		#1=#9 DUPLICATE SMPLS
49MR0502_1	P10	25	1	BUC	062205	1641	UN	1 45.01 N	146 38.56 E	GPS	4447	4451					1		29.5C
49MR0502_1	P10	25	1	ROS	062205	1743	BO	1 45.24 N	146 38.82 E	GPS	4443	4444	9	4444	4500				
49MR0502_1	P10	25	1	ROS	062205	1946	EN	1 45.75 N	146 39.05 E	GPS	4395	4396							
49MR0502_1	P10	24	1	ROS	062205	2201	BE	1 30.05 N	146 34.37 E	GPS	4488	4486				32	1-8,12,13,23,24,26,27		#1=#10 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	24	1	BUC	062205	2207	UN	1 30.03 N	146 34.34 E	GPS	4492	4494					1		29.6C
49MR0502_1	P10	24	1	ROS	062205	2310	BO	1 30.30 N	146 34.46 E	GPS	4479	4482	9	4482	4549				
49MR0502_1	P10	24	1	ROS	062305	0108	EN	1 30.82 N	146 34.70 E	GPS	4451	4452							
49MR0502_1	P10	23	1	ROS	062305	0330	BE	1 14.91 N	146 30.11 E	GPS	4472	4473				32	1-8,27		#1=#11 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	23	1	BUC	062305	0337	UN	1 14.89 N	146 30.18 E	GPS	4469	4470					1		29.8C
49MR0502_1	P10	23	1	ROS	062305	0440	BO	1 14.71 N	146 30.71 E	GPS	4472	4472	9	4481	4525				
49MR0502_1	P10	23	1	ROS	062305	0639	EN	1 14.42 N	146 31.19 E	GPS	4476	4476							
49MR0502_1	P10	22	1	ROS	062305	0902	BE	0 59.93 N	146 25.63 E	GPS	4521	4521				32	1-8,27		#1=#12 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	22	1	BUC	062305	0909	UN	0 59.93 N	146 25.67 E	GPS	4522	4524					1		29.6C
49MR0502_1	P10	22	1	ROS	062305	1014	BO	0 59.92 N	146 25.76 E	GPS	4521	4523	10	4522	4593				
49MR0502_1		233	1	UNK	062305	1144	UN	0 59.95 N	146 25.78 E	GPS	4522	4522							RAIN SAMPLING (20.0MM/HR)

49MR0502_1	P10	22	1	ROS	062305	1218	EN	0	59.90	N	146	25.84	E	GPS	4519	4520				REMOVED 1 OPTODE
49MR0502_1	P10	21	1	ROS	062305	1429	BE	0	44.89	N	146	21.36	E	GPS	4493	4492		32	1-8,23,24,26,27	#1=#11 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	21	1	BUC	062305	1437	UN	0	44.85	N	146	21.32	E	GPS	4499	4499			1	29.5C
49MR0502_1	P10	21	1	ROS	062305	1541	BO	0	44.59	N	146	21.58	E	GPS	4494	4493	9	4503	4551	
49MR0502_1	P10	21	1	ROS	062305	1747	EN	0	44.04	N	146	21.67	E	GPS	4499	4497				
49MR0502_1	P10	20	1	ROS	062305	1952	BE	0	29.97	N	146	16.98	E	GPS	4129	4130		30	1-8,27	#1=#13 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	20	1	BUC	062305	1958	UN	0	29.93	N	146	16.93	E	GPS	4135	4135			1	29.6C
49MR0502_1	P10	20	1	ROS	062305	2057	BO	0	30.13	N	146	16.76	E	GPS	4132	4123	9	4118	4172	
49MR0502_1	P10	20	1	ROS	062305	2248	EN	0	30.66	N	146	16.48	E	GPS	4162	4164				
49MR0502_1	P10	19	1	ROS	062405	1104	BE	0	15.05	N	146	12.73	E	GPS	3724	3727		29	1-8,27	#1=#14 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	19	1	BUC	062405	1111	UN	0	15.05	N	146	12.71	E	GPS	3729	3730			1	29.6C
49MR0502_1	P10	19	1	ROS	062405	1202	BO	0	15.26	N	146	12.70	E	GPS	3740	3740	10	3727	3770	
49MR0502_1	P10	19	1	ROS	062405	1348	EN	0	15.87	N	146	12.43	E	GPS	3744	3745				
49MR0502_1	P10	18	1	ROS	062405	1631	BE	0	0.00	N	146	8.48	E	GPS	3614	3612		28	1-8,23,24,26,27	#1=#15 DUPLICATE SMPLS (B-10DB), #19 MISS TRIP
49MR0502_1	P10	18	1	BUC	062405	1638	UN	0	0.02	N	146	8.42	E	GPS	3617	3617			1	29.5C
49MR0502_1	P10	18	1	ROS	062405	1737	BO	0	0.33	N	146	8.36	E	GPS	3552	3551	9	3585	3619	
49MR0502_1	P10	18	1	ROS	062405	1916	EN	0	1.04	N	146	8.03	E	GPS	3485	3481				
49MR0502_1	P10	17	1	ROS	062405	2201	BE	0	15.01	S	146	4.26	E	GPS	4715	4714		33	1-8,12,13,23,24,26,27	#1=#16 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	17	1	BUC	062405	2207	UN	0	14.98	S	146	4.18	E	GPS	4719	4716			1	29.6C
49MR0502_1	P10	17	1	ROS	062405	2313	BO	0	14.47	S	146	4.15	E	GPS	4705	4706	10	4737	4776	
49MR0502_1	P10	17	1	ROS	062505	0121	EN	0	13.58	S	146	4.03	E	GPS	4693	4696				
49MR0502_1	P10	16	1	ROS	062505	0359	BE	0	28.51	S	146	0.47	E	GPS	3438	3435		27	1-8,27	#1=#17 DUPLICATE SMPLS (B-10DB)
49MR0502_1	P10	16	1	BUC	062505	0406	UN	0	28.48	S	146	0.40	E	GPS	3451	3456			1	29.9C
49MR0502_1	P10	16	1	ROS	062505	0457	BO	0	28.22	S	146	0.42	E	GPS	3420	3418	34	3444	3478	LADCP SOUNDING
49MR0502_1	P10	16	1	ROS	062505	0630	EN	0	27.48	S	146	0.28	E	GPS	3596	3596				
49MR0502_1	P10	15	1	ROS	062505	0931	BE	0	44.93	S	145	55.90	E	GPS	2423	2422		22	1-8,23,24,26,27	
49MR0502_1	P10	15	1	BUC	062505	0938	UN	0	44.89	S	145	55.85	E	GPS	2422	2423			1	29.6C
49MR0502_1	P10	15	1	ROS	062505	1012	BO	0	44.66	S	145	55.83	E	GPS	2424	2422	10	2427	2437	
49MR0502_1	P10	15	1	ROS	062505	1126	EN	0	44.28	S	145	55.76	E	GPS	2421	2422				
49MR0502_1	P10	14	1	ROS	062505	1419	BE	1	0.00	S	145	51.43	E	GPS	2311	2312		21	1-8,27	
49MR0502_1	P10	14	1	BUC	062505	1426	UN	0	59.98	S	145	51.36	E	GPS	2313	2310			1	29.7C
49MR0502_1	P10	14	1	ROS	062505	1459	BO	0	59.79	S	145	51.28	E	GPS	2309	2309	10	2311	2321	
49MR0502_1	P10	14	1	ROS	062505	1610	EN	0	59.60	S	145	51.04	E	GPS	2299	2299				
49MR0502_1	P10	13	1	ROS	062505	1900	BE	1	15.04	S	145	47.19	E	GPS	2287	2292		22	1-8,27	#4=#18 DUPLICATE SMPLS (2000DB)
49MR0502_1	P10	13	1	BUC	062505	1907	UN	1	15.03	S	145	47.10	E	GPS	2294	2293			1	29.7C
49MR0502_1	P10	13	1	ROS	062505	1939	BO	1	14.78	S	145	46.94	E	GPS	2295	2295	10	2302	2300	
49MR0502_1	P10	13	1	ROS	062505	2045	EN	1	14.22	S	145	46.62	E	GPS	2311	2310				
49MR0502_1	P10	12	1	ROS	062505	2330	BE	1	29.95	S	145	42.62	E	GPS	2187	2186		20	1-8,23,24,26,27	
49MR0502_1	P10	12	1	BUC	062505	2336	UN	1	29.91	S	145	42.53	E	GPS	2200	2198			1	29.7C
49MR0502_1	P10	12	1	ROS	062605	0006	BO	1	29.65	S	145	42.37	E	GPS	2198	2197	9	2208	2202	
49MR0502_1	P10	12	1	ROS	062605	0111	EN	1	29.07	S	145	42.16	E	GPS	2200	2198				
49MR0502_1	P10	11	1	ROS	062605	0409	BE	1	45.04	S	145	38.50	E	GPS	1925	1917		19	1-8,27	
49MR0502_1	P10	11	1	BUC	062605	0416	UN	1	45.00	S	145	38.47	E	GPS	1927	1926			1	30.1C
49MR0502_1	P10	11	1	ROS	062605	0444	BO	1	44.81	S	145	38.35	E	GPS	1927	1928	10	1928	1928	
49MR0502_1	P10	11	1	ROS	062605	0541	EN	1	44.36	S	145	38.01	E	GPS	1933	1932				
49MR0502_1	P10	10	1	ROS	062605	0846	BE	1	59.98	S	145	34.17	E	GPS	746	740		12	1-8,12,13,23,24,26,27	
49MR0502_1	P10	10	1	BUC	062605	0853	UN	1	59.93	S	145	34.13	E	GPS	740	740			1	30.1C
49MR0502_1	P10	10	1	ROS	062605	0904	BO	1	59.87	S	145	34.09	E	GPS	735	739	11	724	728	
49MR0502_1	P10	10	1	ROS	062605	0942	EN	1	59.69	S	145	33.89	E	GPS	735	735				
49MR0502_1	P10	9	1	ROS	062605	1214	BE	2	15.02	S	145	30.08	E	GPS	1003	1004		14	1-8,23,24,26,27	
49MR0502_1	P10	9	1	BUC	062605	1221	UN	2	14.99	S	145	30.05	E	GPS	1002	1003			1	29.7C

49MR0502_1	P10	9	1	ROS	062605	1235	BO	2	14.92 S	145 30.02 E	GPS	997	998	9	993	997					
49MR0502_1	P10	9	1	ROS	062605	1315	EN	2	14.71 S	145 30.01 E	GPS	987	988								
49MR0502_1	P10	8	1	ROS	062605	1645	BE	2	30.10 S	145 25.65 E	GPS	1090	1091				15	1-8,27			
49MR0502_1	P10	8	1	BUC	062605	1652	UN	2	30.11 S	145 25.66 E	GPS	1093	1091					1			29.6C
49MR0502_1	P10	8	1	ROS	062605	1710	BO	2	30.05 S	145 25.71 E	GPS	1092	1091	9	1082	1090					
49MR0502_1	P10	8	1	ROS	062605	1754	EN	2	29.88 S	145 25.81 E	GPS	1090	1091								
49MR0502_1	P10	7	1	ROS	062605	2115	BE	2	45.01 S	145 21.58 E	GPS	1707	1707				18	1-8,23,24,26,27			
49MR0502_1	P10	7	1	BUC	062605	2121	UN	2	44.96 S	145 21.59 E	GPS	1707	1706					1			29.5C
49MR0502_1	P10	7	1	ROS	062605	2148	BO	2	44.71 S	145 21.54 E	GPS	1632	1631	9	1708	1708					
49MR0502_1		234	1	UNK	062605	2153	UN	2	44.64 S	145 21.53 E	GPS	1632	1631								RAIN SAMPLING (7.0MM/HR)
49MR0502_1	P10	7	1	ROS	062605	2241	EN	2	44.11 S	145 21.38 E	GPS	1567	1566								
49MR0502_1	P10	6	1	ROS	062705	0201	BE	3	0.02 S	145 17.27 E	GPS	2072	2072				16	1-8,27			
49MR0502_1	P10	6	1	BUC	062705	0207	UN	2	59.99 S	145 17.29 E	GPS	2071	2070					1			29.4C
49MR0502_1	P10	6	1	ROS	062705	0235	BO	2	59.87 S	145 17.25 E	GPS	2069	2071	9	2062	2079					
49MR0502_1	P10	6	1	ROS	062705	0339	EN	2	59.53 S	145 17.10 E	GPS	2069	2071								
49MR0502_1		235	1	UNK	062705	0406	UN	3	1.94 S	145 16.26 E	GPS	2090	2090								RAIN SAMPLING (1.5MM/HR)
49MR0502_1		236	1	UNK	062705	0507	UN	3	8.03 S	145 13.57 E	GPS	1319	1319								RAIN SAMPLING (7.0MM/HR)
49MR0502_1	P10	5	1	ROS	062705	0702	BE	3	18.52 S	145 8.97 E	GPS	2167	2167				20	1-8,12,13,23,24,26,27			
49MR0502_1	P10	5	1	BUC	062705	0709	UN	3	18.45 S	145 8.92 E	GPS	2169	2165					1			29.1C
49MR0502_1	P10	5	1	ROS	062705	0741	BO	3	18.12 S	145 8.71 E	GPS	2169	2166	9	2185	2173					
49MR0502_1	P10	5	1	ROS	062705	0851	EN	3	17.43 S	145 8.33 E	GPS	2167	2168								
49MR0502_1	P10	4	1	ROS	062705	1219	BE	3	37.03 S	145 0.83 E	GPS	1884	1889				19	1-8,27			
49MR0502_1	P10	4	1	BUC	062705	1226	UN	3	36.97 S	145 0.79 E	GPS	1888	1884					1			29.1C
49MR0502_1	P10	4	1	ROS	062705	1253	BO	3	36.59 S	145 0.53 E	GPS	1880	1882	9	1916	1885					
49MR0502_1	P10	4	1	ROS	062705	1354	EN	3	35.90 S	145 0.17 E	GPS	1886	1885								
49MR0502_1	P10	3	1	ROS	062705	1713	BE	3	53.53 S	144 53.55 E	GPS	1389	1389				16	1-8,23,24,26,27			
49MR0502_1	P10	3	1	BUC	062705	1720	UN	3	53.49 S	144 53.48 E	GPS	1390	1391					1			28.5C
49MR0502_1	P10	3	1	ROS	062705	1741	BO	3	53.35 S	144 53.38 E	GPS	1387	1390	9	1379	1387					
49MR0502_1	P10	3	1	ROS	062705	1831	EN	3	53.16 S	144 53.32 E	GPS	1397	1402								
49MR0502_1		237	1	UNK	062705	2010	UN	3	53.43 S	144 53.94 E	GPS	1405	1405								RAIN SAMPLING (2.5MM/HR)
49MR0502_1	P10	2	1	ROS	062705	2147	BE	3	58.82 S	144 49.93 E	GPS	784	789				13	1-8,23,24,26,27			
49MR0502_1	P10	2	1	BUC	062705	2153	UN	3	58.80 S	144 50.00 E	GPS	806	810					1			28.6C
49MR0502_1	P10	2	1	ROS	062705	2206	BO	3	58.85 S	144 50.04 E	GPS	826	828	10	815	819					
49MR0502_1	P10	2	1	ROS	062705	2240	EN	3	58.95 S	144 50.21 E	GPS	821	821								
49MR0502_1	P10	1	1	ROS	062805	0015	BE	4	0.90 S	144 48.68 E	GPS	223	220				6	1-6			
49MR0502_1	P10	1	1	BUC	062805	0017	UN	4	0.89 S	144 48.69 E	GPS	224	226					1			28.7C
49MR0502_1	P10	1	1	ROS	062805	0022	BO	4	0.90 S	144 48.70 E	GPS	221	224	10	211	212					
49MR0502_1	P10	1	1	ROS	062805	0033	EN	4	0.87 S	144 48.72 E	GPS	226	226								

Parameter number:

1=SALNTY, 2=OXYGEN, 3=SILCAT, 4=NITRAT, 5=NITRIT, 6=PPHSPHT, 7=CFC-11, 8=CFC-12, 12=DELC14, 13=DELC13, 22=CS-137, 23=TCARBN, 24=ALKALI, 26=PH, 27=CFC113, 30=NH4, 34=CHLORA, 41=PON, 47=Plutonium

Figure captions

Figure 1 Station locations for WHP P10 revisit cruise with bottom topography based on Smith and Sandwell (1997).

Figure 2 Bathymetry measured by Multi Narrow Beam Echo Sounding system. Cross mark indicates CTD location.

Figure 3 Surface wind measured at 25 m above sea level. Wind data is averaged over 1-hour and plotted every 0.5 degree in latitude.

Figure 4 Sea surface temperature (SST) and salinity (SSS). Temperature and salinity data are averaged over 1-hour.

Figure 5 Difference in the partial pressure of CO_2 between the ocean and the atmosphere, ΔpCO2.

Figure 6 Surface current at 100 m depth measured by shipboard 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 0-6,500 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 Same as Figure 8 but with SSW batch correction[1].

Figure 10 Density (σ_0) (kg/m^3) cross section calculated using CTD temperature and calibrated salinity data with SSW batch correction. Vertical exaggeration is same as Figure 7.

Figure 11 Same as Figure 10 but for σ_4 (kg/m^3).

Figure 12 Neutral density (γ^n) (kg/m^3) cross section calculated using CTD temperature and calibrated salinity data with SSW batch correction. Vertical exaggeration is same as Figure 7.

Figure 13 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 14 Silicate (µmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 15 Nitrate (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 16 Nitrite (µmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 17 Phosphate (µmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 18 Dissolved inorganic carbon (µmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 19 Total alkalinity (µmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 20 pH cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 21 CFC-11 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 22 CFC-12 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 23 CFC-113 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 7.

Figure 24 Cross section of current velocity (cm/s) normal to the cruise track measured by LADCP (eastward is positive).

Figure 25 Difference in potential temperature (°C) between results from WOCE (from Oct. to Nov., 1993) and the revisit cruise (from May to Jul., 2005). Red and blue areas show the areas where potential temperature increased and decreased in 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 26 Difference in salinity (psu) between results from WOCE and the revisit cruise. Red and blue areas show the areas where salinity increased and decreased in the revisit cruise, respectively. CTD salinity data with SSW batch correction[1] are used. On white areas differences in salinity do not exceed the detection limit of 0.002 psu. Vertical exaggeration is same as Figure 7.

Figure 27 Difference in dissolved oxygen (μmol/kg) between results from WOCE and Revisit. Red and blue areas show the areas where salinity increased and decreased in the revisit cruise, respectively. CTD oxygen data are used. On white areas differences in salinity do not exceed the detection limit of 2 μmol/kg. Vertical exaggeration is same as Figure 7.

Note

1. As for the traceability of SSW to Mantyla's value, the offset for the batches P114 (WOCE P10), and P145 (Revisit) is +0.0007 and -0.0013, respectively (Kawano et al., 2006).

References

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