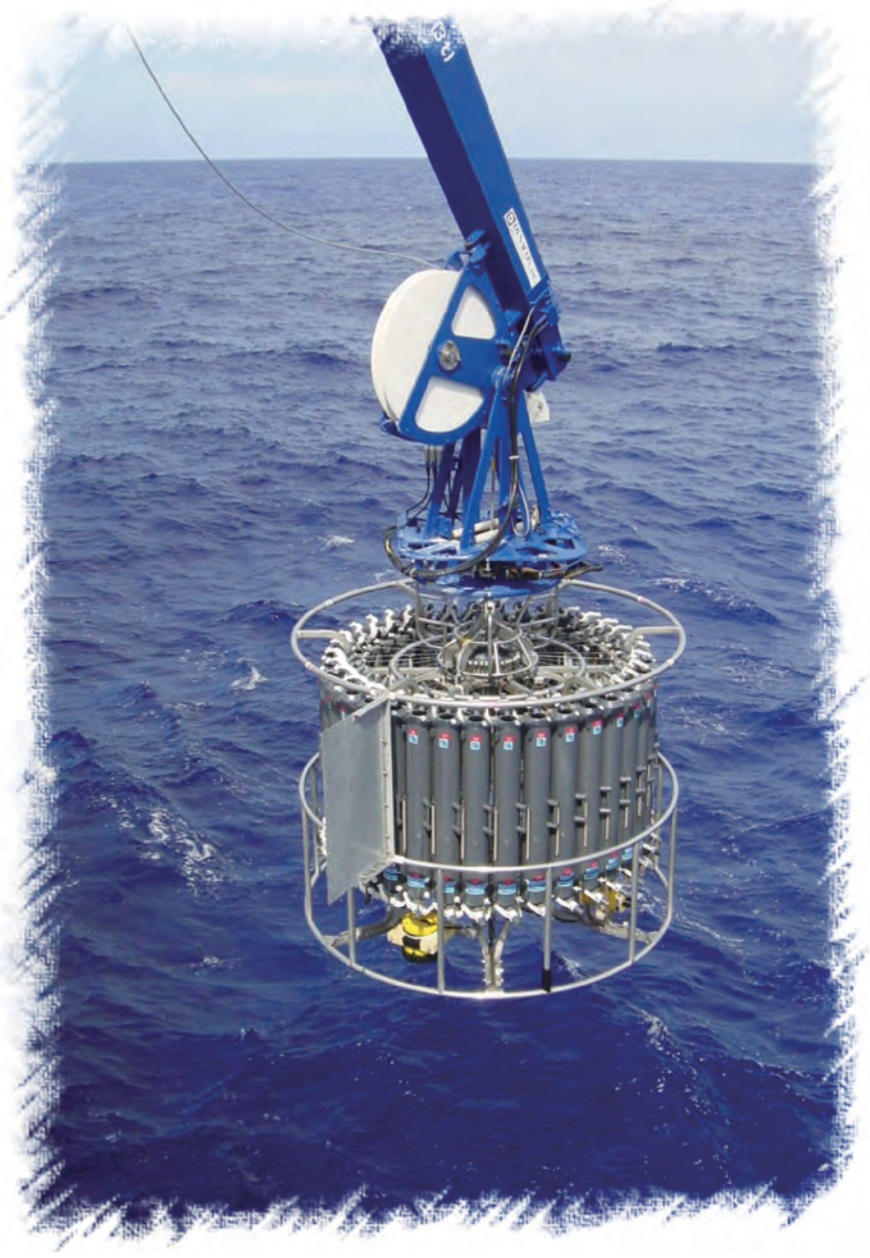
WHP P10 REVISIT DATA BOOK

Field Activity of JAMSTEC towards International Repeat Hydrography and Carbon Program



WHP P10 REVISIT DATA BOOK

Edited by
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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
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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.

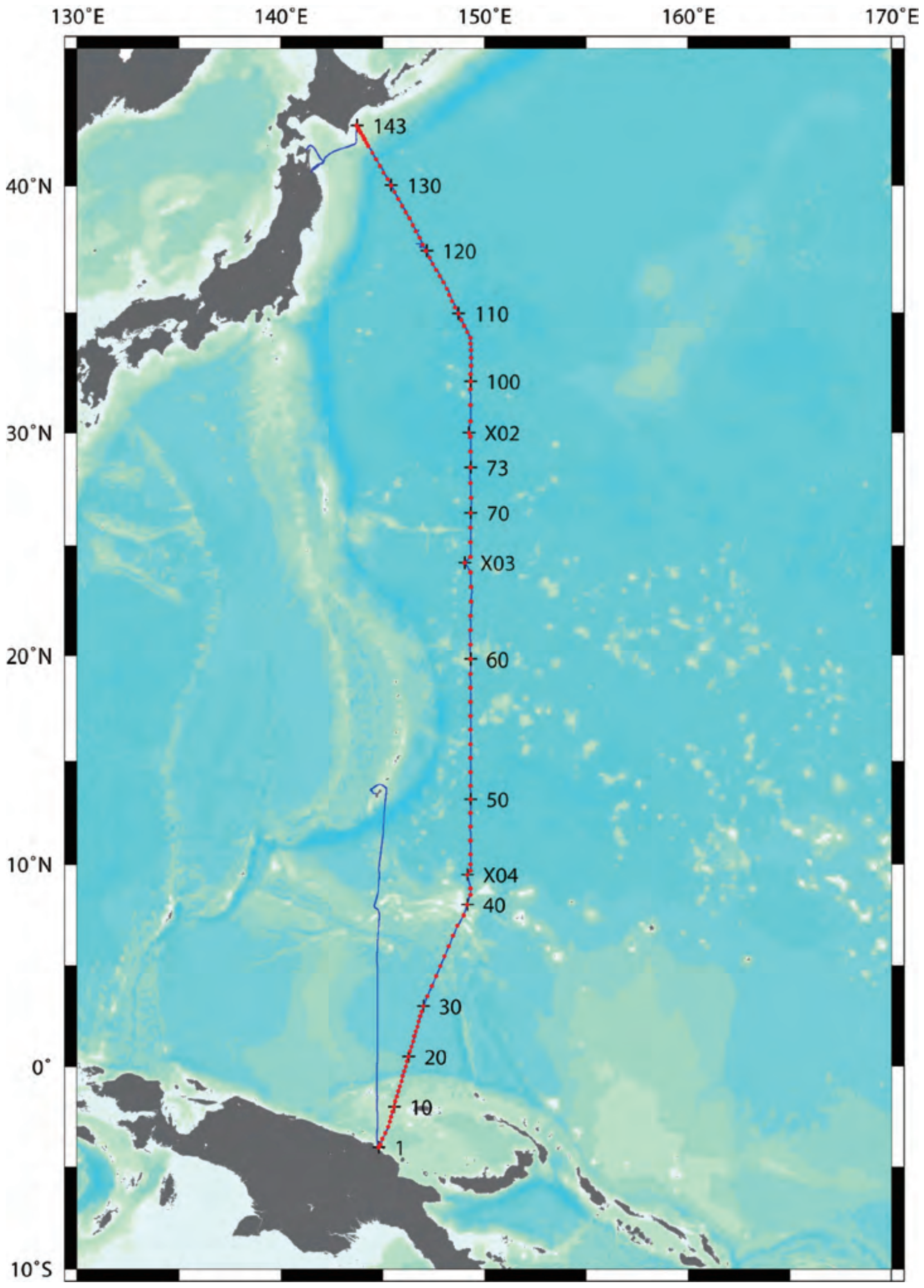

Figure 1.2.1. Cruise track.

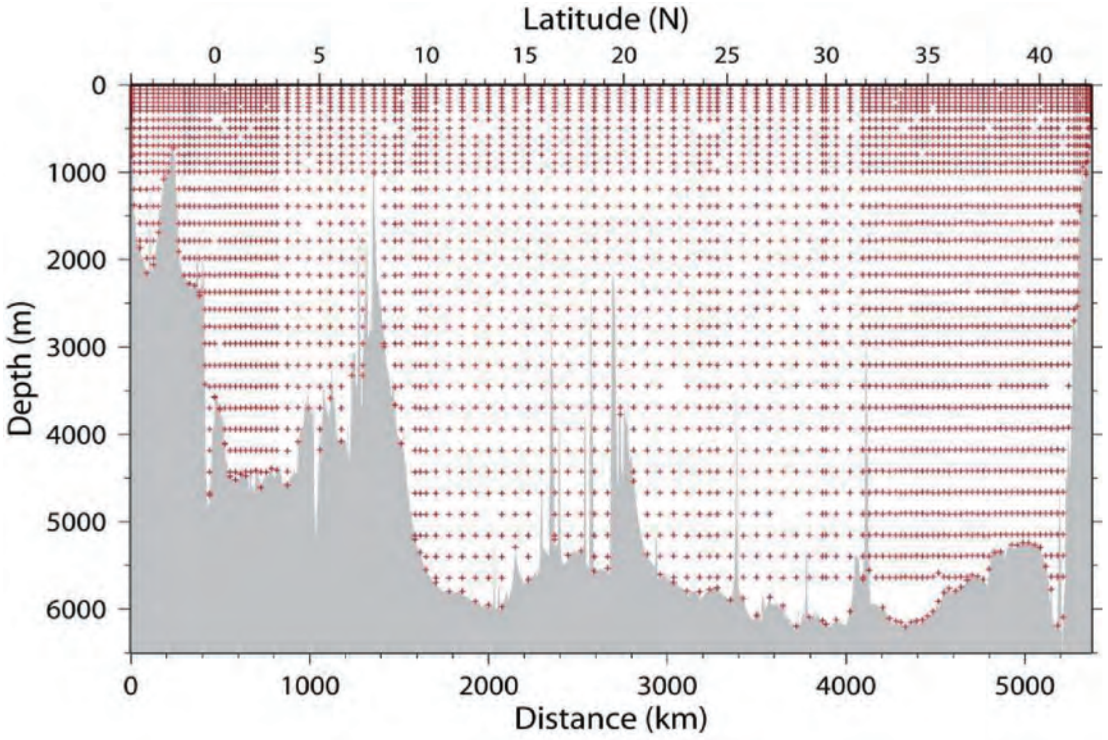

Figure 1.2.2. Bottle depth diagram.

(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)
Δ^{14}C & δ^{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 relative humidity	Vaisala, Finland / HMP45A	compass deck*[2] / 21 m
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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JAMSTEC / IORGC, 2-15, Natsushima, Yokosuka 237-0061, Japan

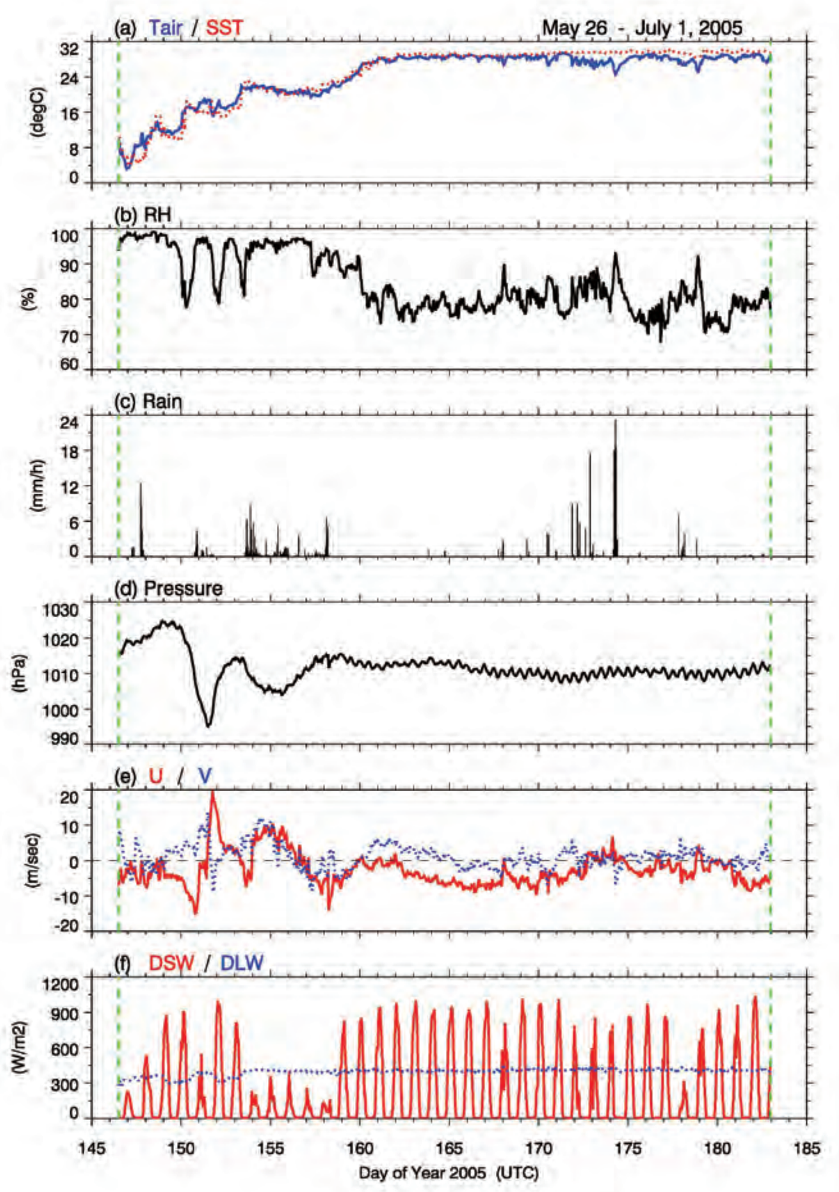

Figure 2.2.1. Time series of (a) air and sea surface temperature, (b) relative humidity, (c) precipitation, (d) pressure, (e) zonal and meridional wind components, and (e) short and long wave radiation. Day 146 corresponds to May 26, 2006.

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

Akihiko Murata (IORGC, JAMSTEC)
Fuyuki Shibata (MWJ)
Mikio Kitada (MWJ)
Taeko Ohama (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

Yasushi Yoshikawa (JAMSTEC)
Shinya Kouketsu (JAMSTEC)
Yasutaka Imai (GODI)
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)

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$$$$$'.

[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)

3 Hydrographic Measurement Techniques and Calibrations

3.1 CTD/O$_2$ Measurements

25 October 2005

(1) Personnel

Hiroshi Uchida (JAMSTEC)
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Naoko Takahashi (MWJ)
Kentaro Oyama (MWJ)
Tomohide Noguchi (MWJ)

(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)

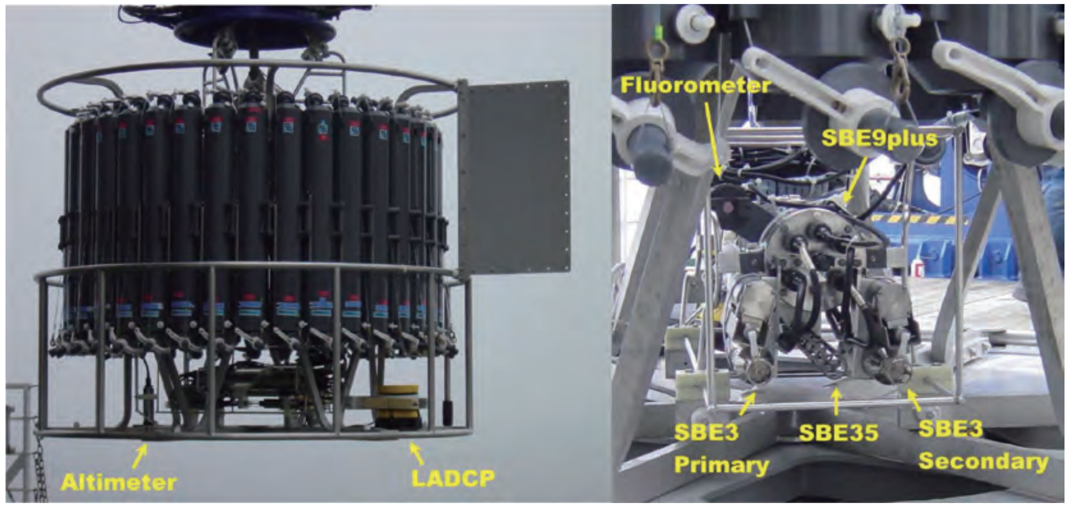

Figure 3.1.1. The CTD package (left) and the SBE 35 position in regard to the SBE 3 temperature sensors (right).

(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 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

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

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.

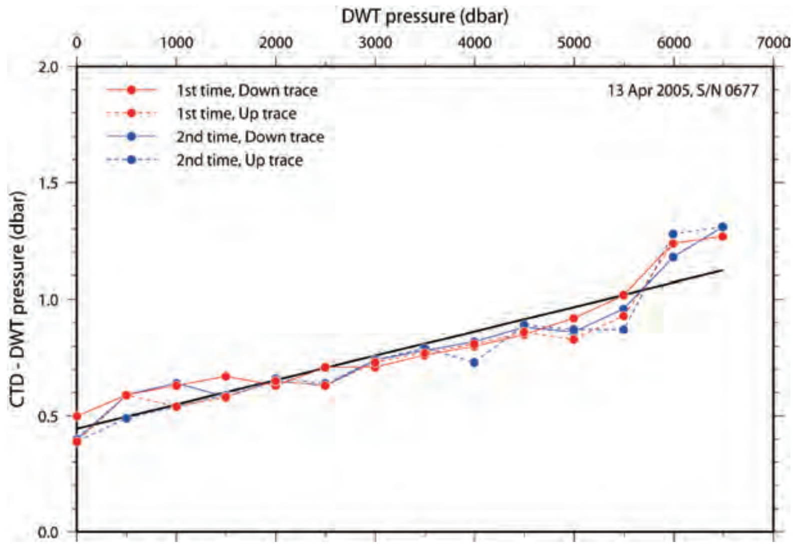

Figure 3.1.2. The residual pressures between the dead weight piston gauge and the CTD pressure (S/N 0677). The calibration line (black line) is also shown.

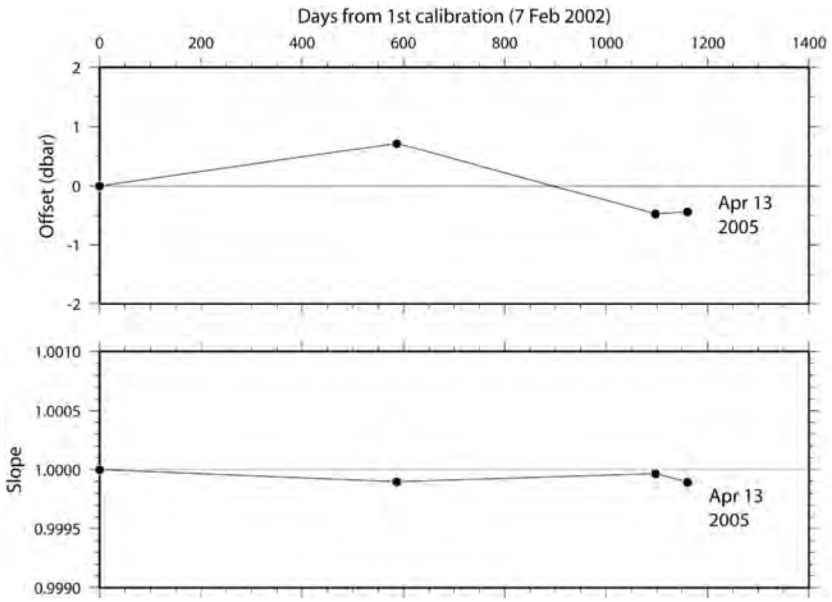

Figure 3.1.3. Pressure sensor (S/N 0677) time drift of offset (upper panel) and slope (lower panel) based on laboratory calibrations.

(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) =

$$1 / \{g + h * [\ln(f_0 / f)] + i * [\ln^2(f_0 / f)] + j * [\ln^3(f_0 / f)]\} - 273.15$$

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.

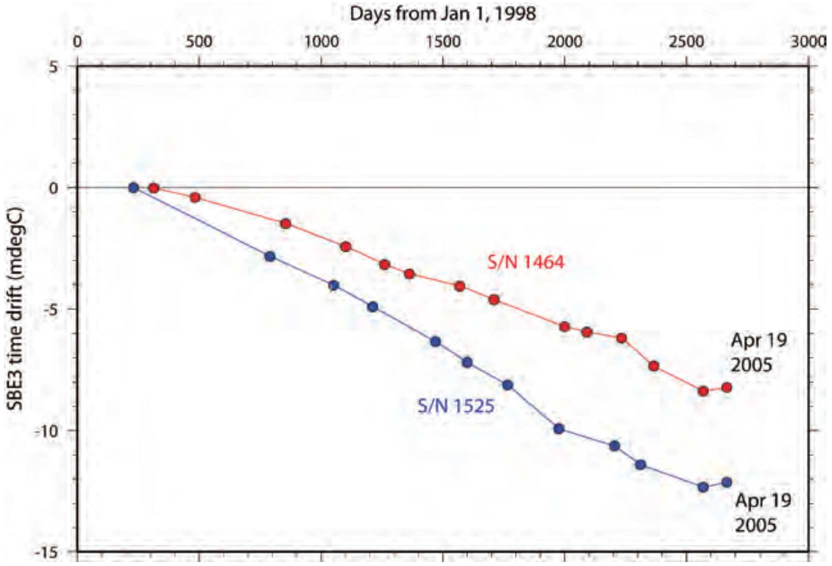

Figure 3.1.4. Time drift of SBE 3 temperature sensors (S/N 1464 and S/N 1525) based on laboratory calibrations performed by SBE, Inc.

(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

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

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

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 / $\text{NCYCLES}^{1/2}$ 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.

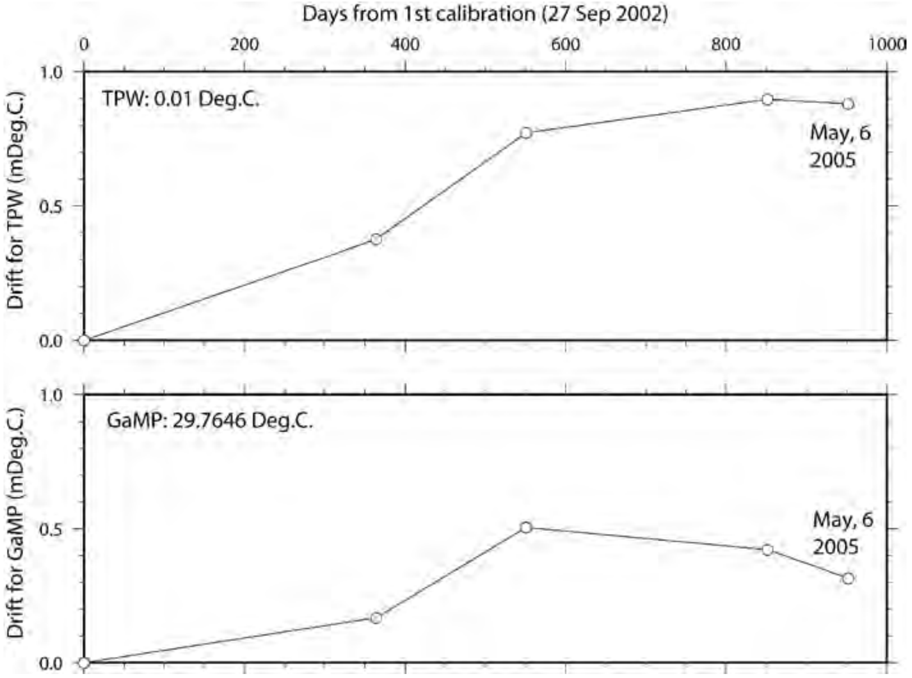

Figure 3.1.5. SBE35 (S/N 0045) time drift based on laboratory fixed point calibrations (triple point of water, TPW and gallium melt point, GaMP) performed by SBE, Inc.

(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

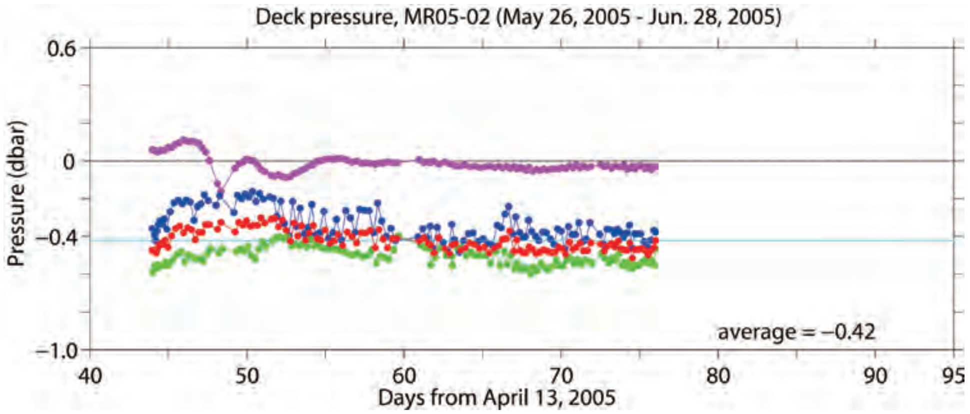

Figure 3.1.6. Time series of the CTD deck pressure. Pink dot indicates atmospheric pressure anomaly. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dot indicates an average of the pre- and the post-cast deck pressures.

(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

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

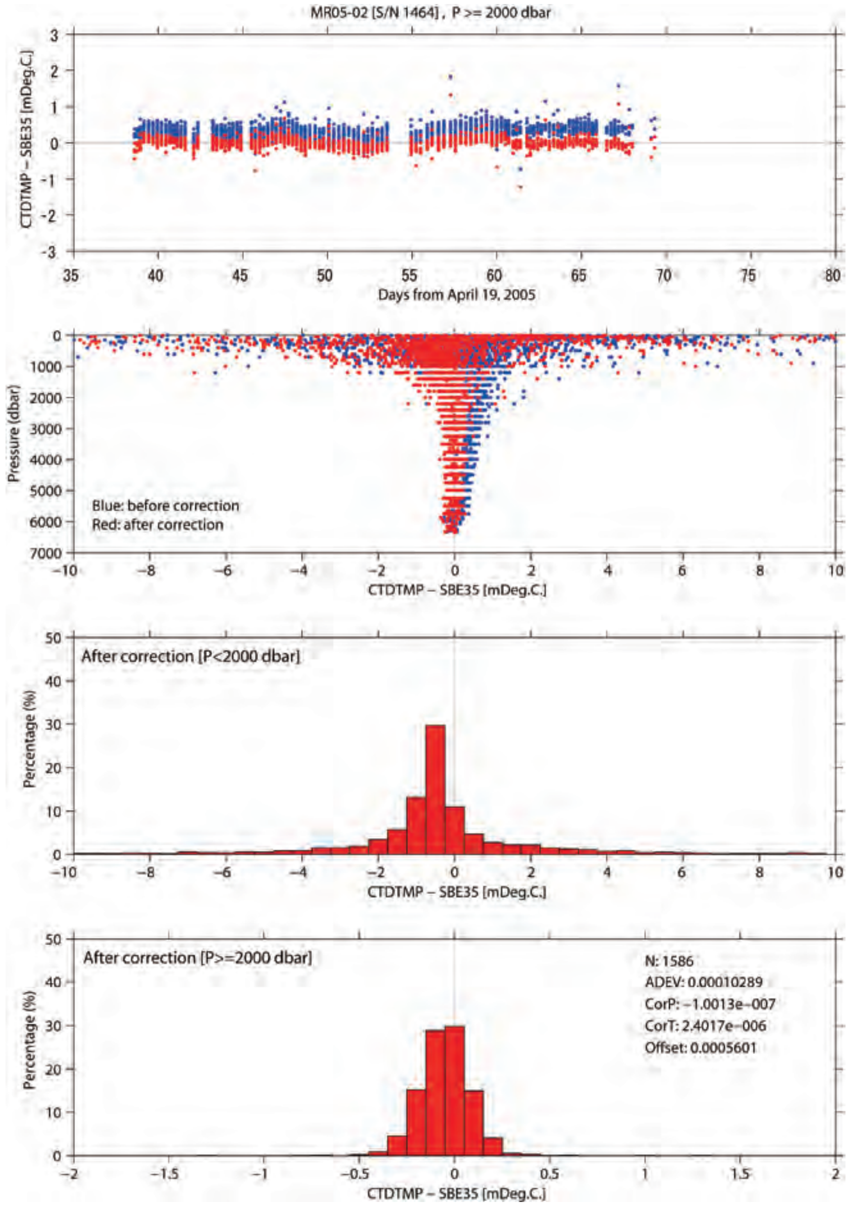

Figure 3.1.7. Difference between the CTD temperature (primary) and the Deep Ocean Standards thermometer (SBE 35). Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Lower two panels show histogram of the difference after the calibration.

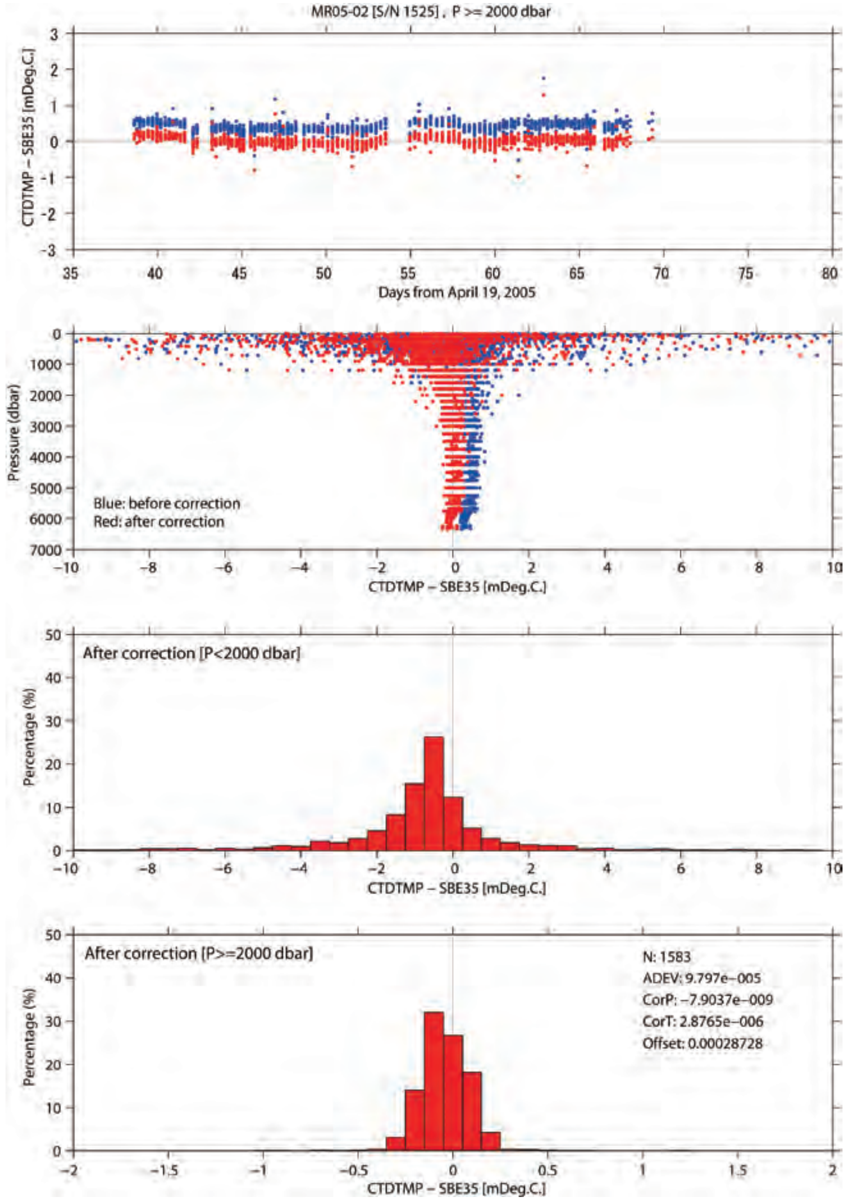

Figure 3.1.8. Same as Figure 3.1.7, but for the secondary CTD temperature.

(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

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

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

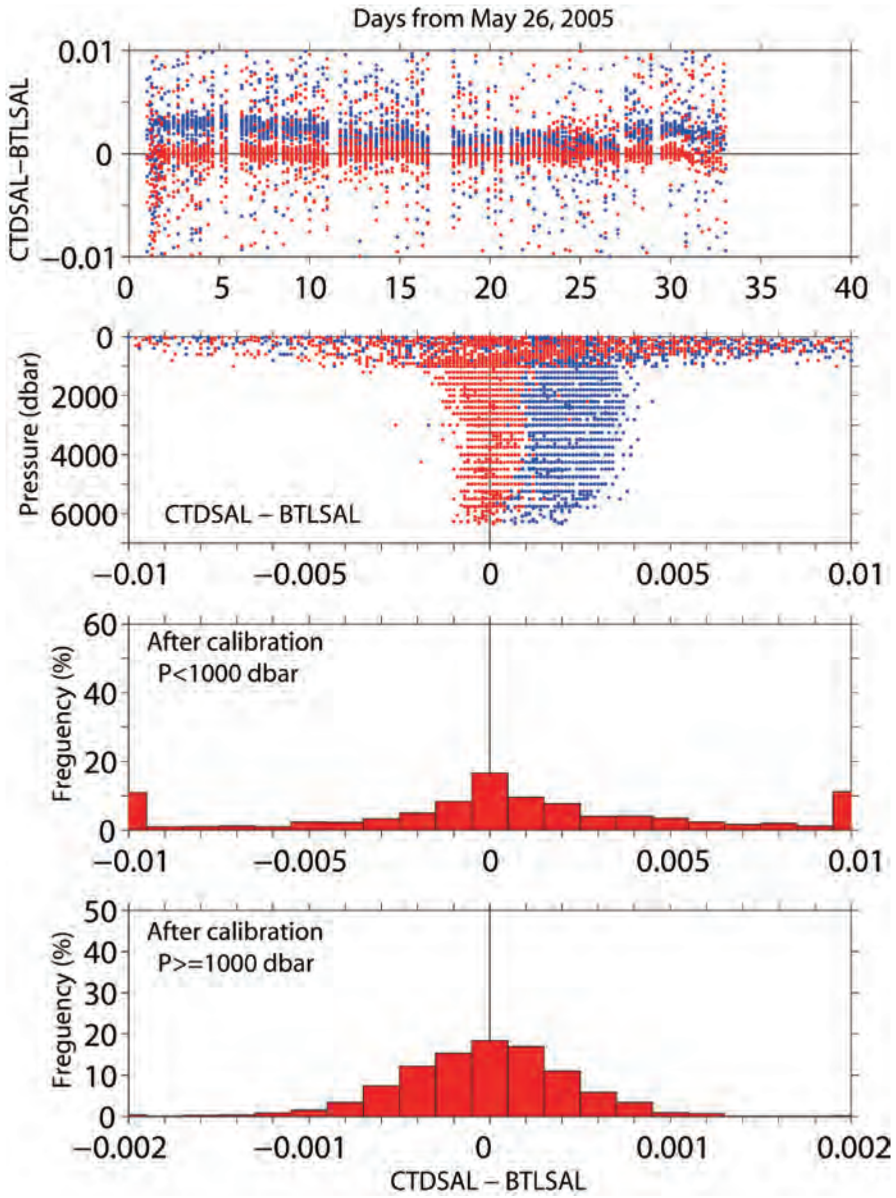

Figure 3.1.9. Difference between the CTD salinity and the bottle salinity. Blue and red dots indicate before and after the post-cruise calibration using the bottle salinity data, respectively. Lower two panels show histogram of the difference after the calibration.

(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

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

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

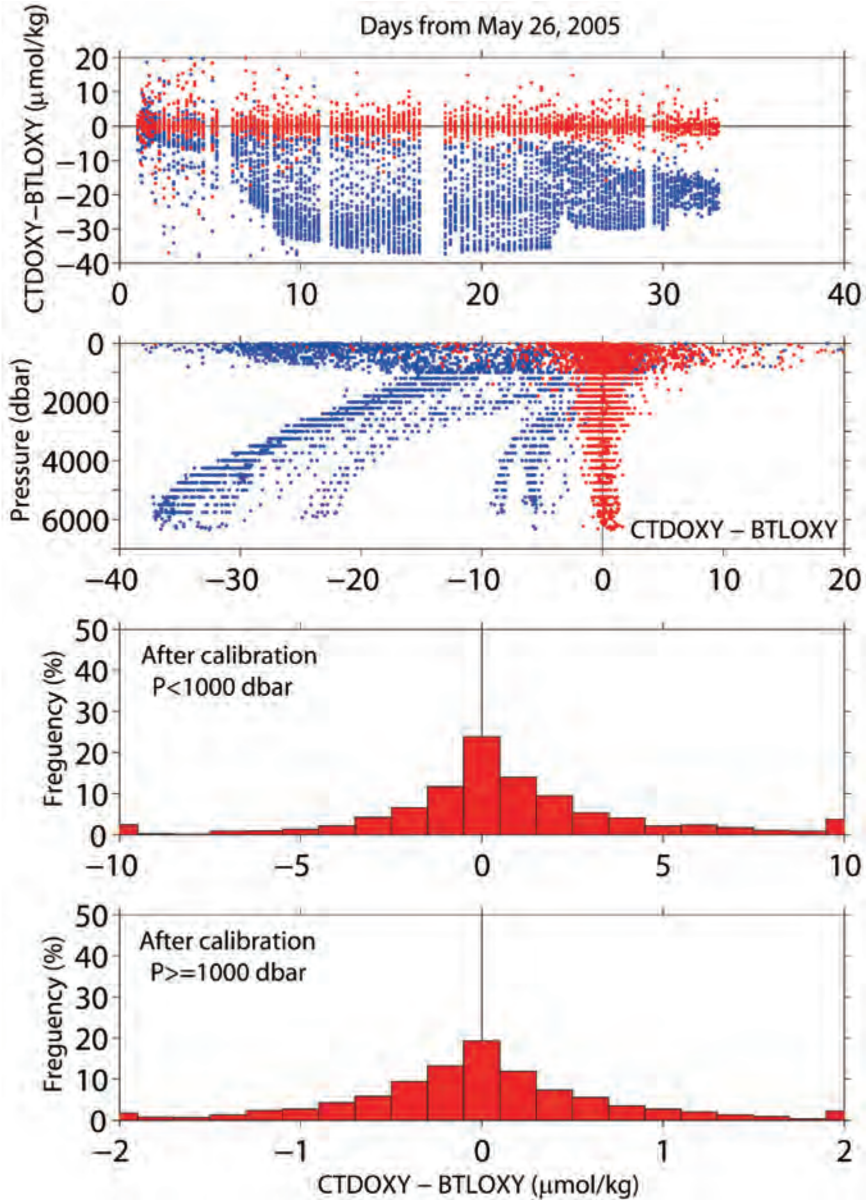

Figure 3.1.10. Difference between the CTD oxygen and the bottle oxygen. Blue and red dots indicate before and after the post-cruise calibration using the bottle oxygen data, respectively. Lower two panels show histogram of the difference after the calibration.

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3.2 Salinity

13 October 2006

(1) Personnel

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(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.

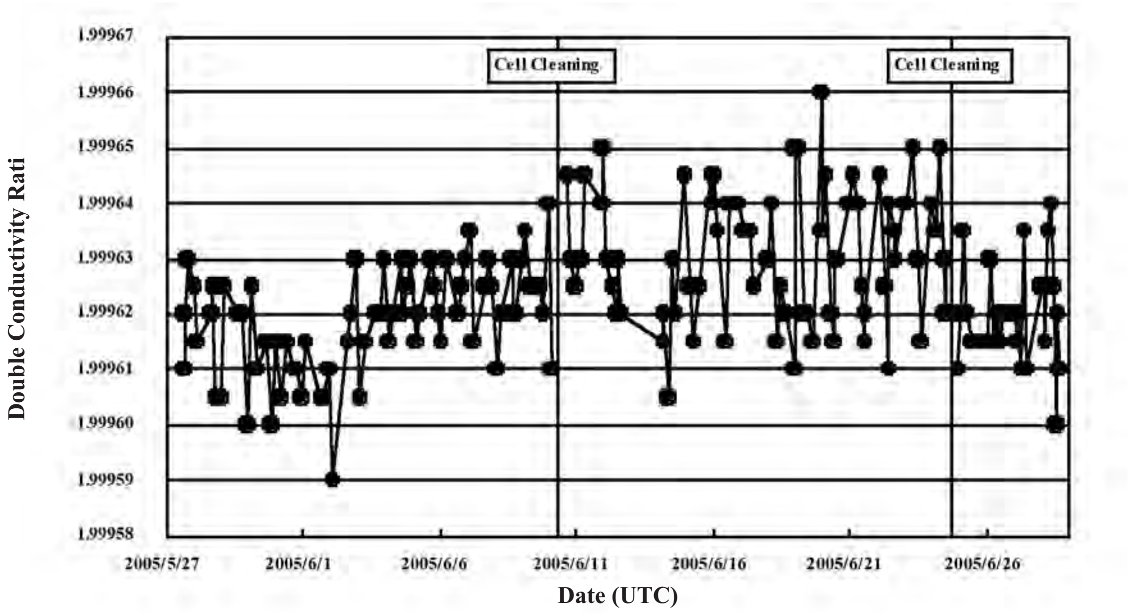

Figure 3.2.1. The history of double conductivity ratio of the Standard Seawater batch P145.

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.

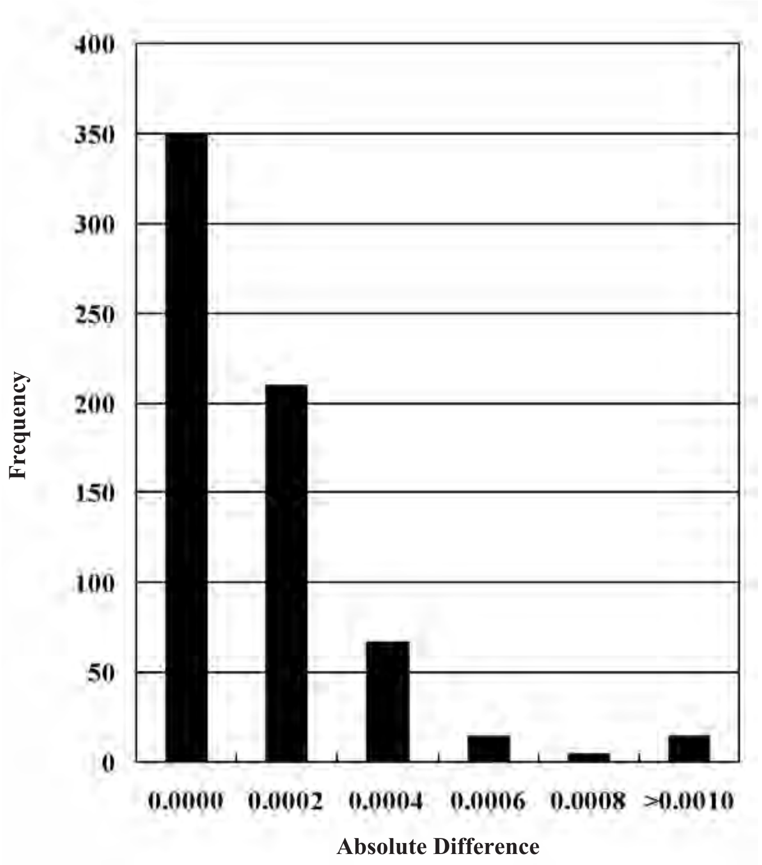

Figure 3.2.2 (a). The histogram of the absolute difference between replicate samples.

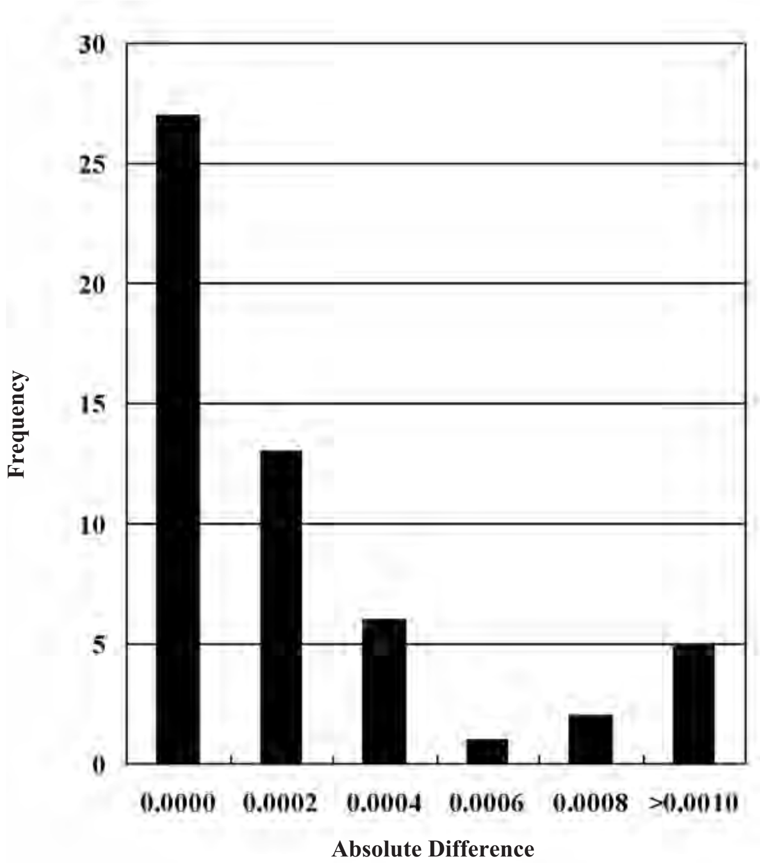

Figure 3.2.2 (b). The histogram of the absolute difference between duplicate samples.

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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 ($\mu mol\ kg^{-1}$) 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.

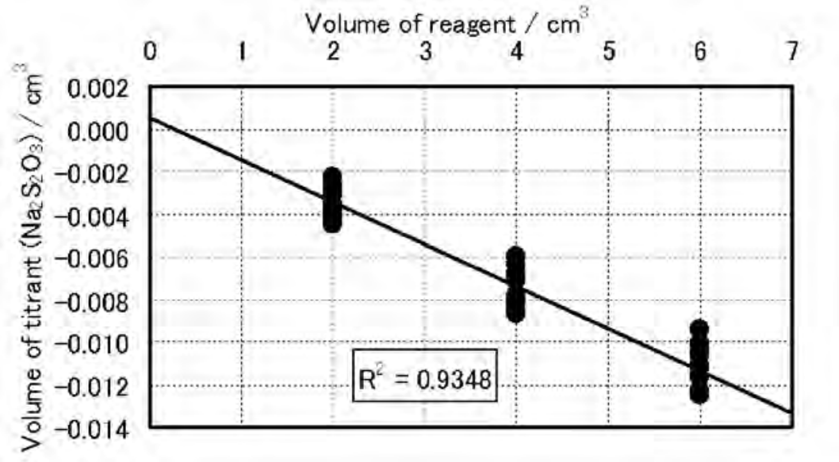

Figure 3.3.1. Blank (cm^3) due to redox species apart from oxygen in the reagents.

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.

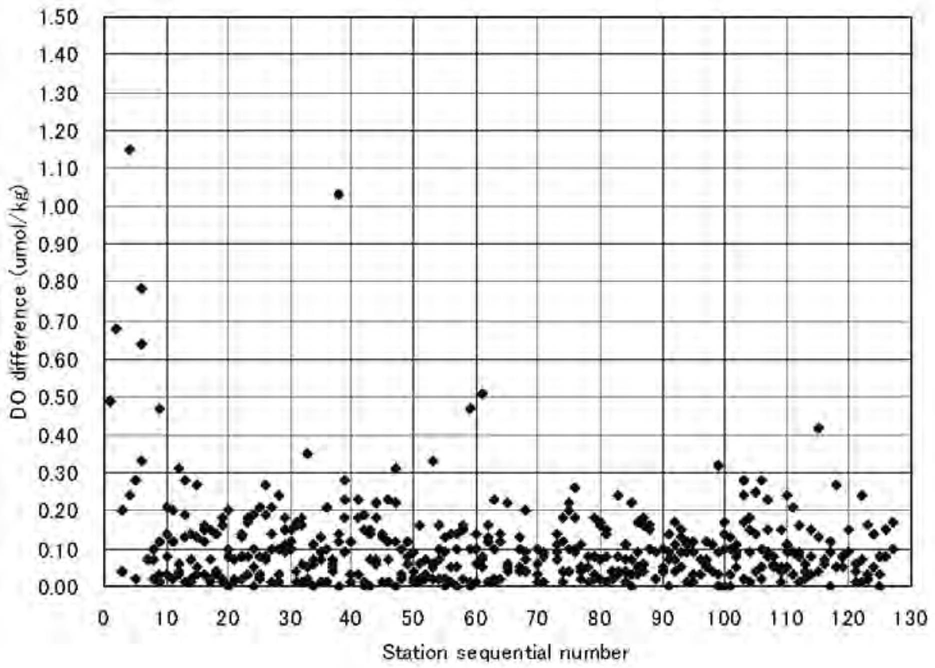

Figure 3.3.2. Difference in the replicate measurements against station sequential number.

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.

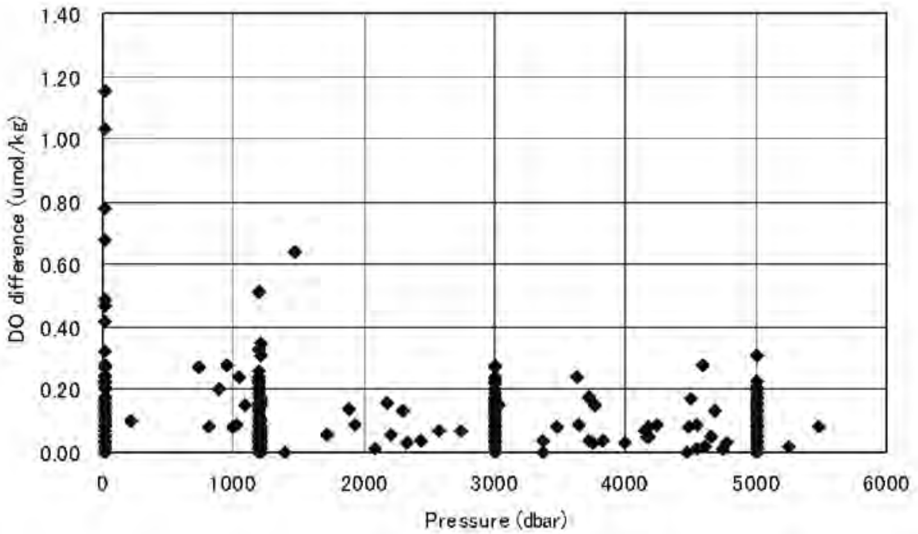

Figure 3.3.3. Difference in the replicate measurements against sampling depth (pressure).

(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.

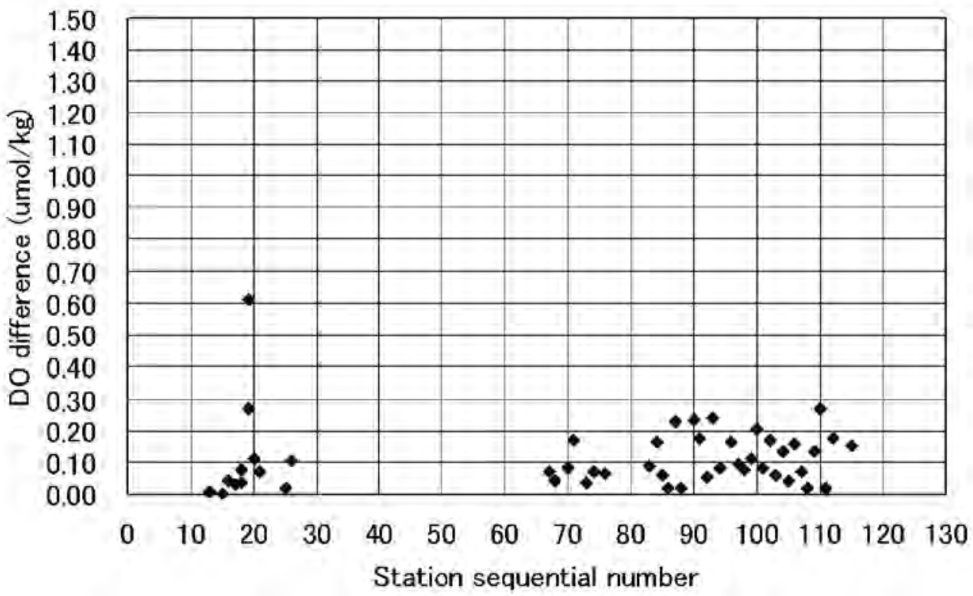

Figure 3.3.4. Difference in the duplicate measurements against station sequential number.

(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

(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.

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

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Culberson, A.H., G. Knapp, M.C. Stalcup, R.T. Williams, F. Zemlyak (1991): A comparison of methods for the determination of dissolved oxygen in seawater, WHPO Pub. 91-2, August 1991, Woods Hole, Mass., USA.

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DOE (1994): Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74.

Joyce, T., and C. Corry, eds., C. Corry, A. Dessier, A. Dickson, T. Joyce, M. Kenny, R. Key, D. Legler, R. Millard, R. Onken, P. Saunders, M. Stalcup, contrib. (1994): Requirements for WOCE Hydrographic Programme Data Reporting, WHPO Pub. 90-1 Rev. 2, May 1994 Woods Hole, Mass., USA.

3.4 Nutrients

2 July 2005

(1) Personnel

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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.

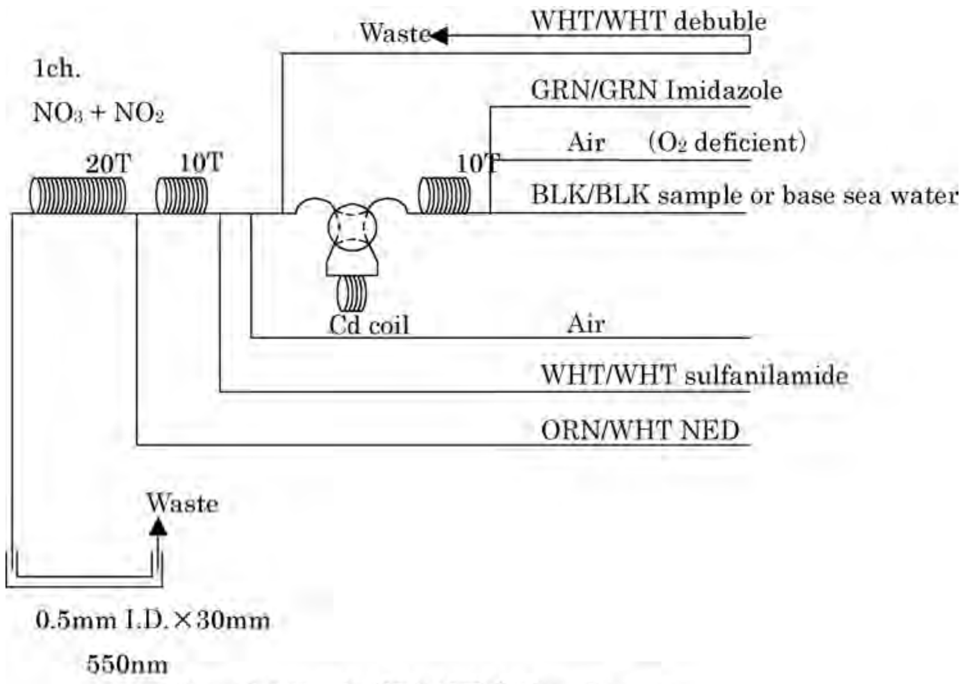

Figure3.4.1: 1ch. (NO_3+NO_2) Flow diagram.

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.

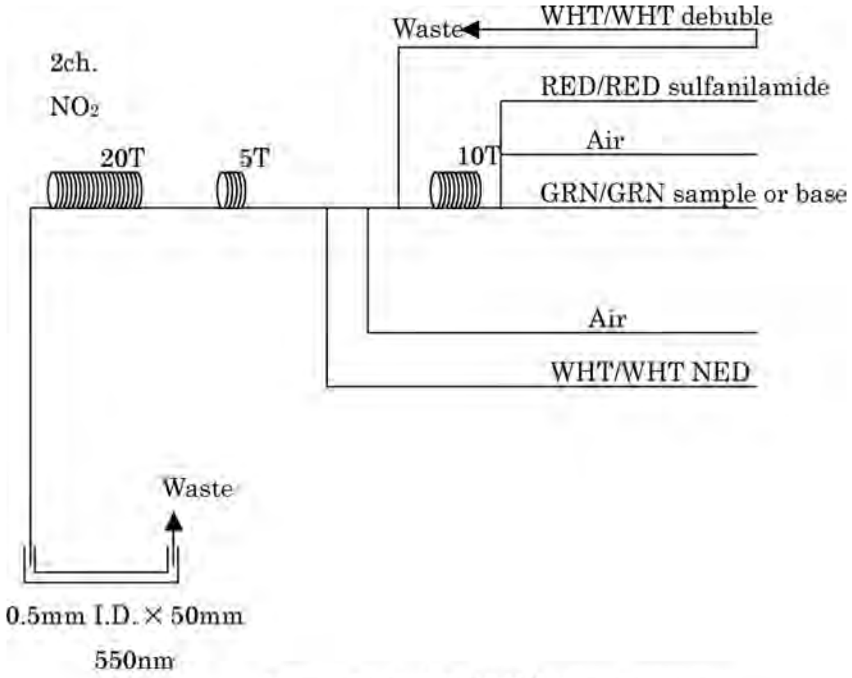

Figure 3.4.2: 2ch. (NO_2) Flow diagram.

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.

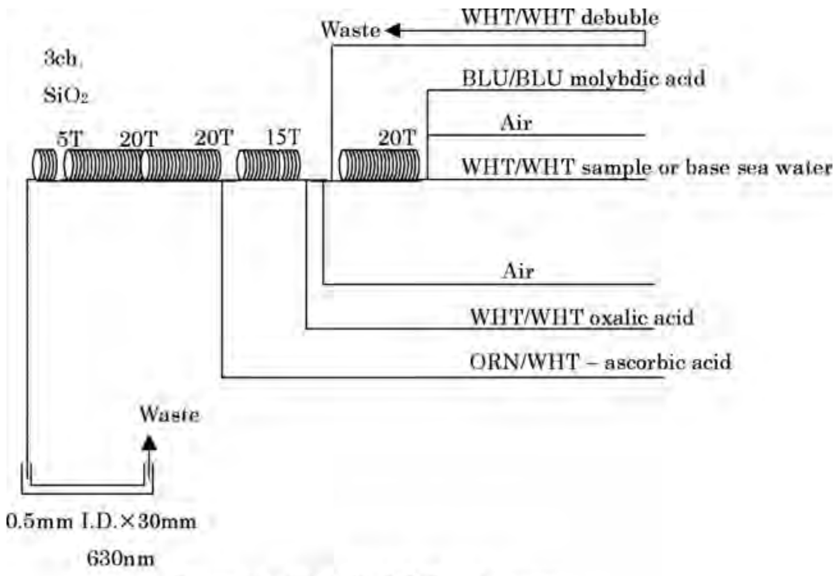

Figure 3.4.3. 3ch. (SiO_2) Flow diagram.

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.

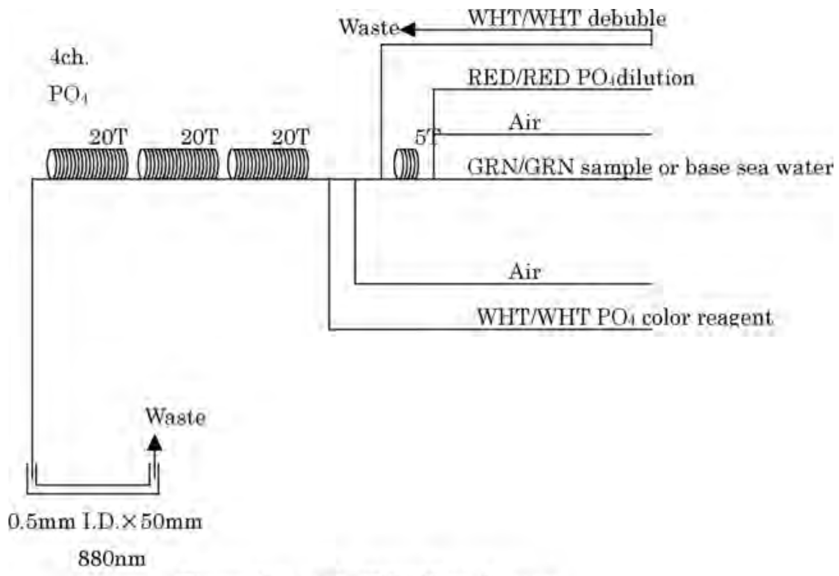

Figure 3.4.4. 4ch. (PO_4) Flow diagram.

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

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 CV %	Phosphate CV %	Silcate 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

(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 CV %	Phosphate CV %	Silicate 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

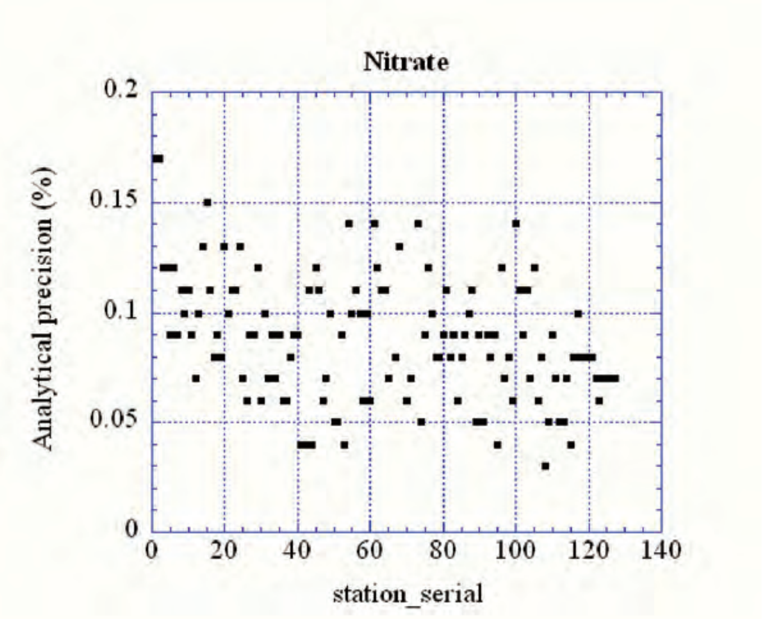

Figure 3.4.5. Time series of precision of nitrate.

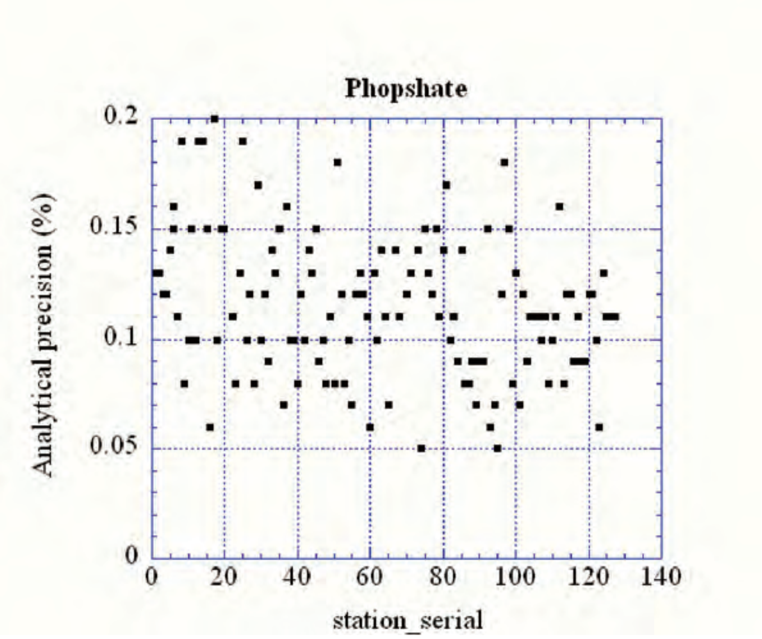

Figure 3.4.6. Time series of precision of phosphate.

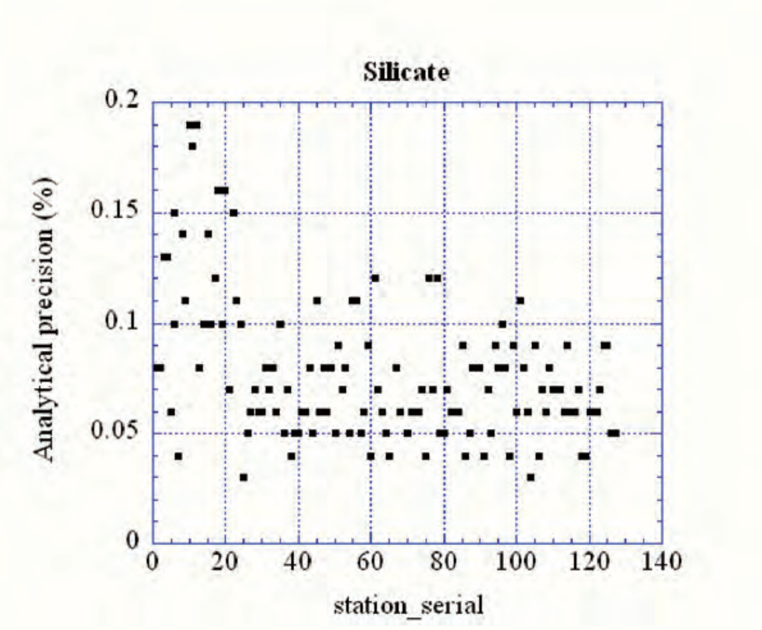

Figure 3.4.7. Time series of precision of silicate.

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).

$$\text{Uncertainties (\%)} = 0.13 + 1.66 / \mathrm{Cnitrate} \qquad \cdot\cdot\cdot \qquad (1)$$

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

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

$$\text{Uncertainties(\%)} = -0.11 + 1.032 / \mathrm{Cphos} \qquad \cdot\cdot\cdot \qquad (2)$$

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

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

$$\text{Uncertainties (\%)} = 0.095 + 4.92 / \mathrm{Csilicate} \qquad \cdot\cdot\cdot \qquad (3)$$

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.

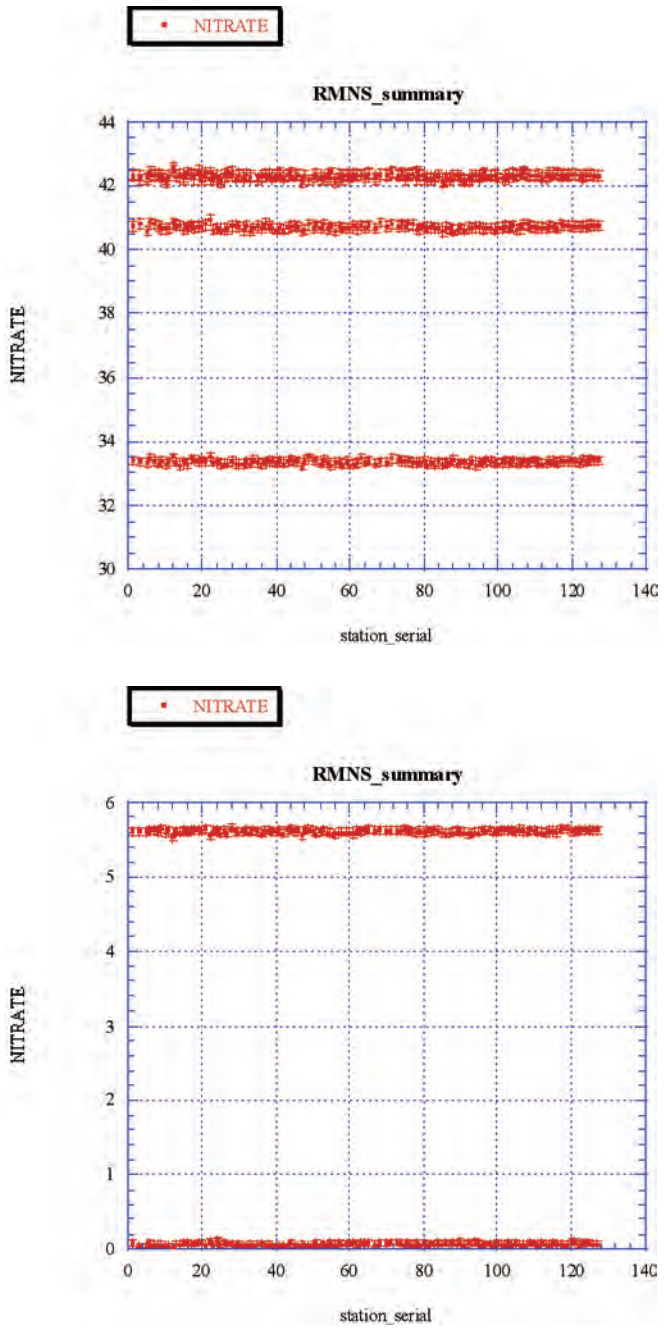

Figure 3.4.8. Time series of nitrate concentration for RMNSs.

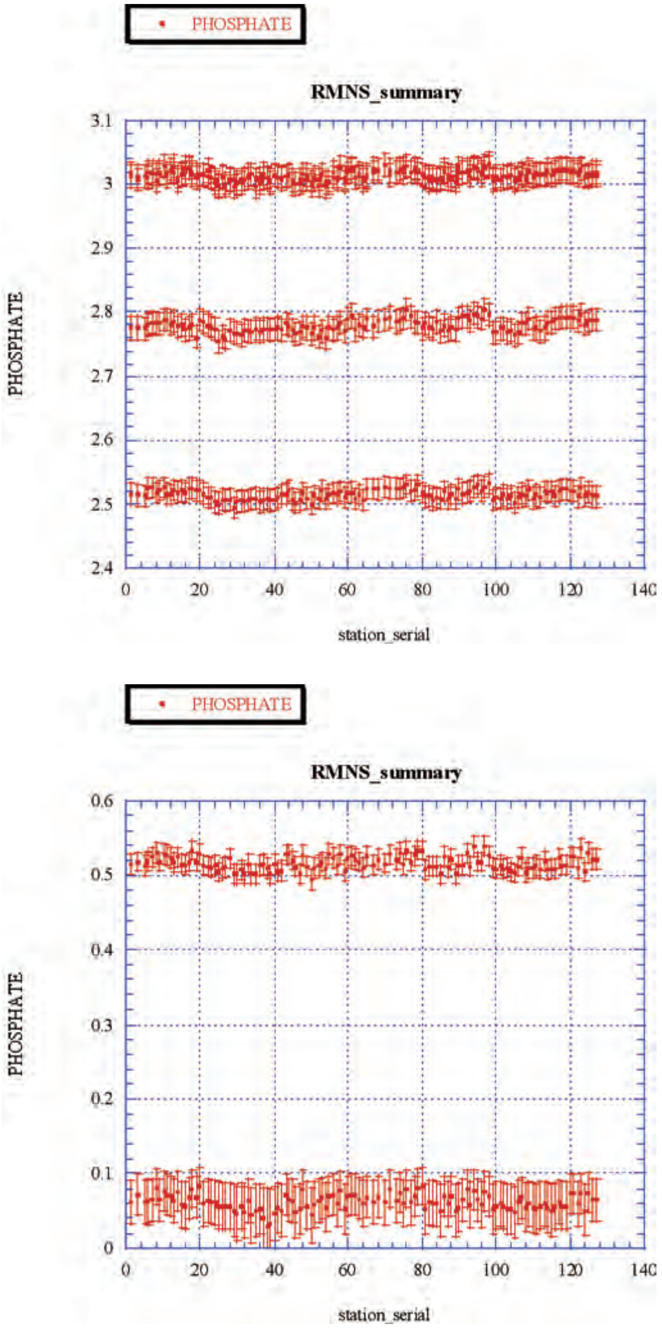

Figure 3.4.9. Same as Figure 3.4.8, but for phosphate.

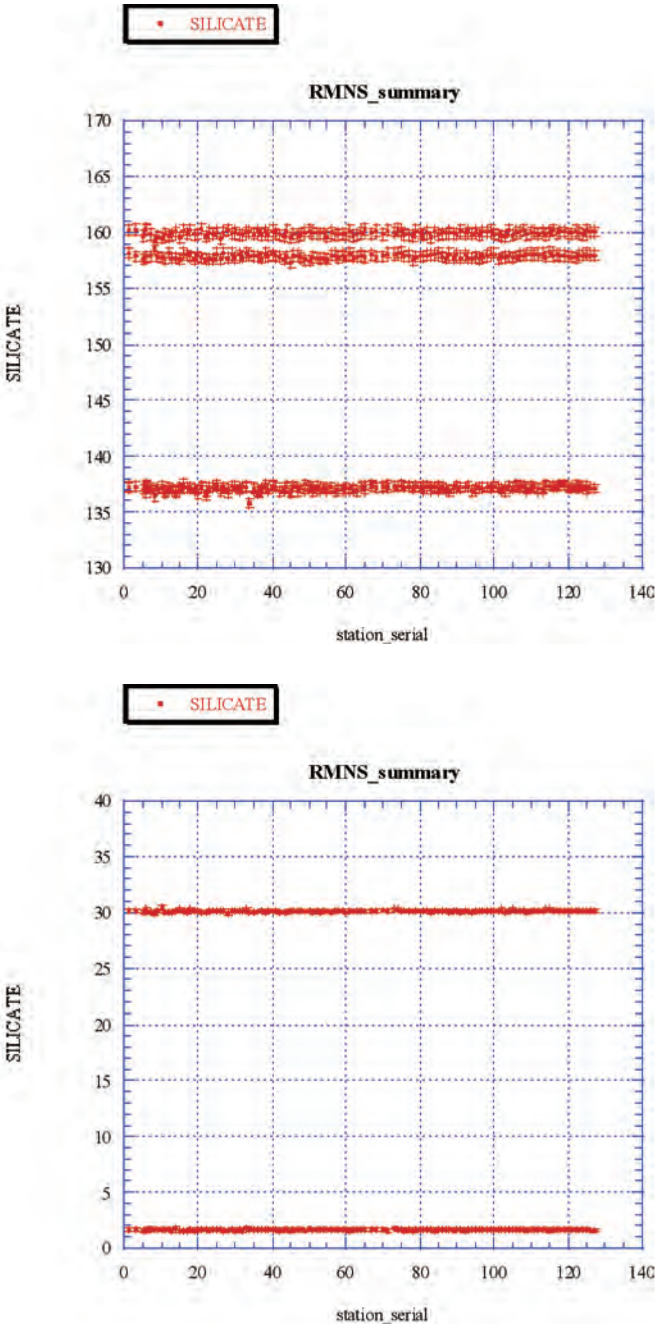

Figure 3.4.10. Same as Figure 3.4.8, but for silicic acid.

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

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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.

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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	

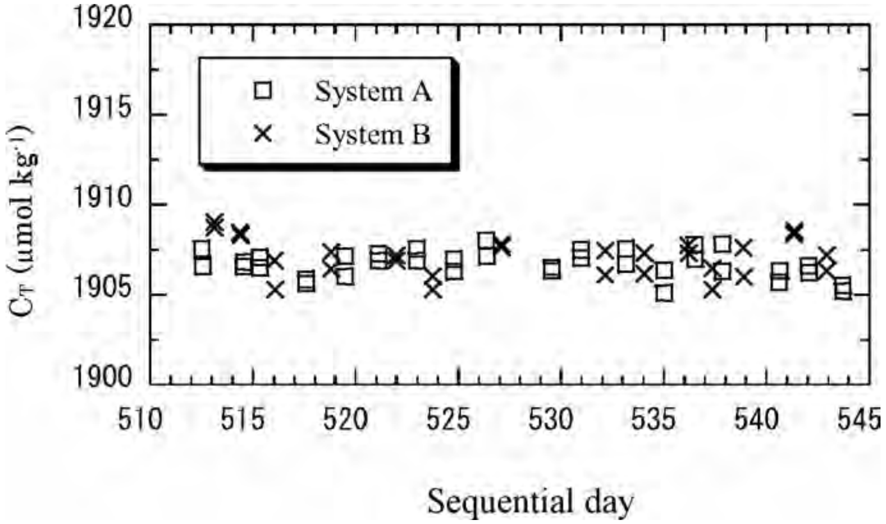

Figure 3.5.1. Temporal variations of CRM (Batch 69) C_T measured by the systems A and B.

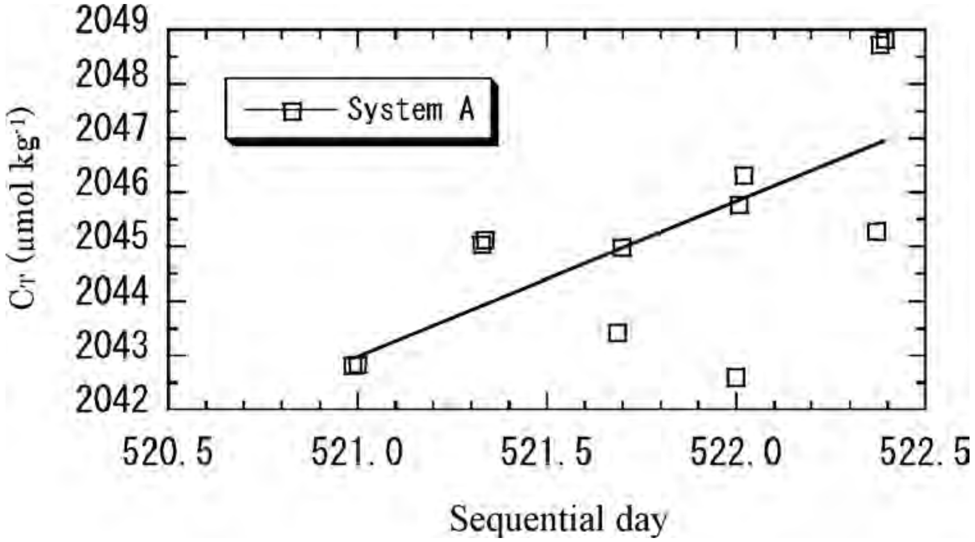

Figure 3.5.2. An example of temporal variations of RM C_T. The line was determined by the least squared method. C_T increased at a rate of approx. 2.9 µmol kg^{-1} per day.

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

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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).

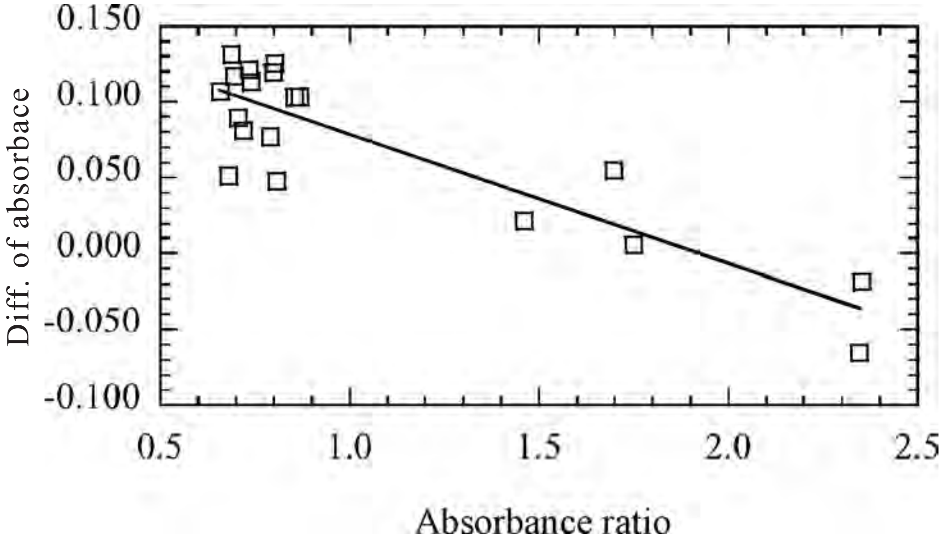

Figure 3.7.1. Perturbation of absorbance ratios by adding indicator solutions. The line ($y = -0.0848x + 0.1633$, $R^2 = 0.7703$) was determined by the method of least squares.

3.8 Chlorofluorocarbons (CFCs)

2 October 2006

(1) Personnel

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Yuichi SONOYAMA (MWJ)

(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

Shinya Kouketsu (JAMSTEC)

Yasushi Yoshikawa (JAMSTEC)

(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.

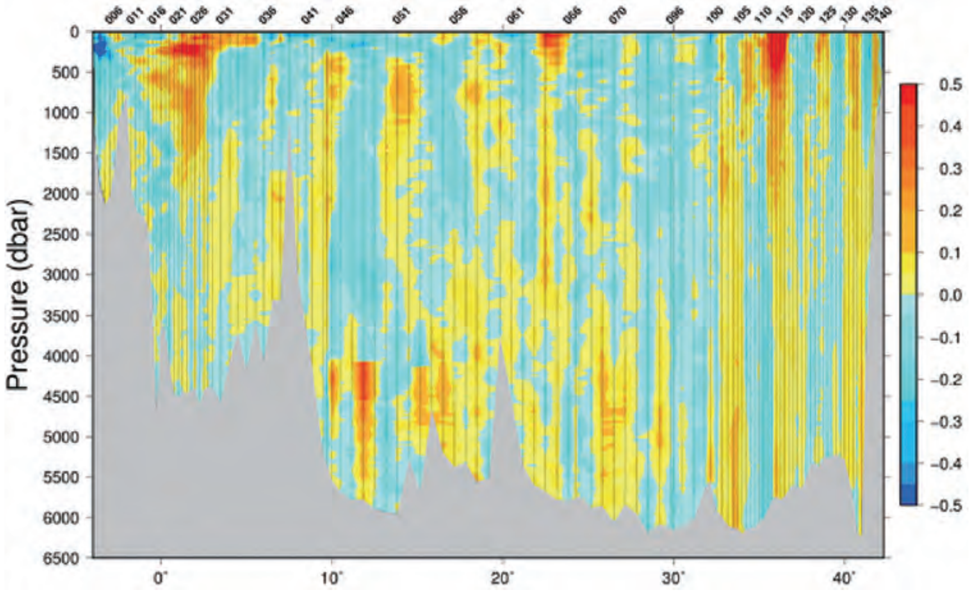

Figure 3.9.1. The cross-section of zonal velocity (eastward is positive).

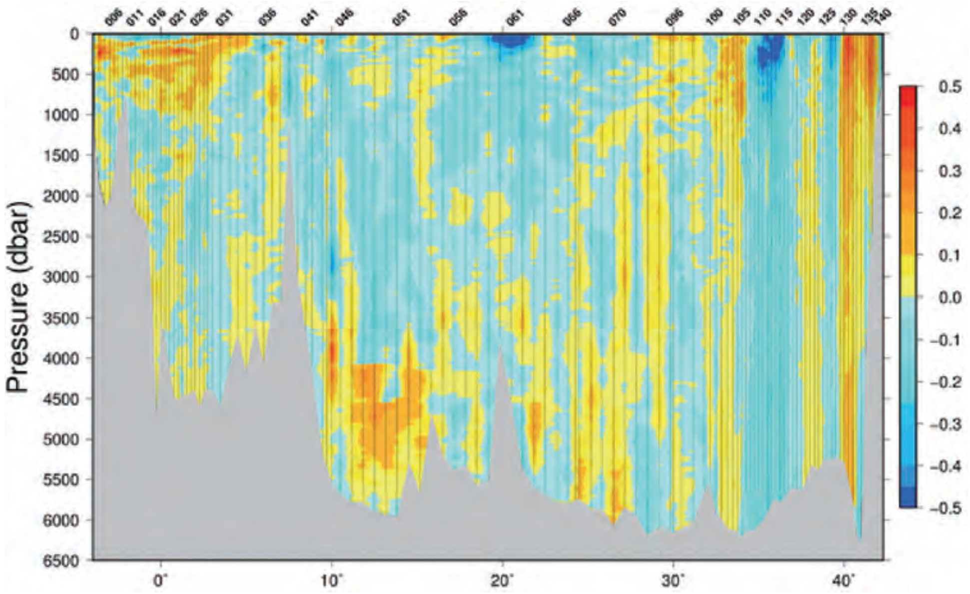

Figure 3.9.2. The cross-section of merdiornal velocity (northward is positive).

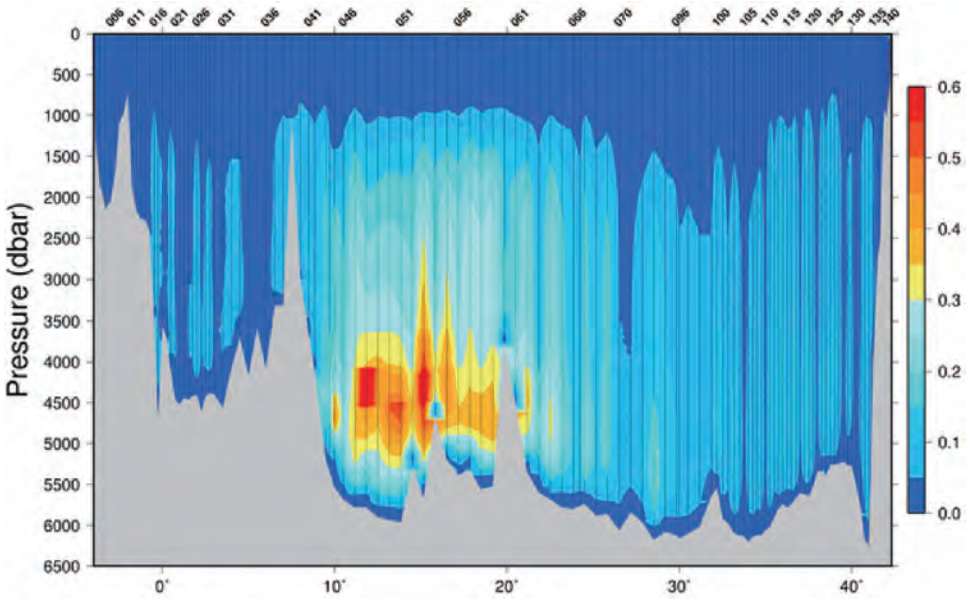

Figure 3.9.3. Cross-section of error velocity estimated by the inversion method.

Station Summary

```
P10 REV R/V MIRAI CRUISE MR0502
SHIP/CRS    WOCE                CAST         UTC EVENT         POSITION              UNC    COR HT ABOVE   WIRE    MAX  NO. OF
EXPOCODE    SECT  STNNBR CASTNO TYPE DATE   TIME  CODE LATITUDE   LONGITUDE   NAV  DEPTH  DEPTH   BOTTOM    OUT  PRESS BOTTLES PARAMETERS                               COMMENTS

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
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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
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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
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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
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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
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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
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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
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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
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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
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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)
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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
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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

Jackett, D. R. and R. J. McDougall (1997): A neutral density variable for the world's oceans, Journal of Physical Oceanography, 27, 237-263.

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

Kawano, T., M. Aoyama, T. M. Joyce, H. Uchida, Y. Takatsuki and M. Fukasawa (2006): The Latest Batch-to-batch Difference Table of Standard Seawater and Its Application to the WOCE Onetime Sections, Journal of Oceanography, 62 (6), 777-792.

Figure 1

Station locations for WHP P10 revisit cruise

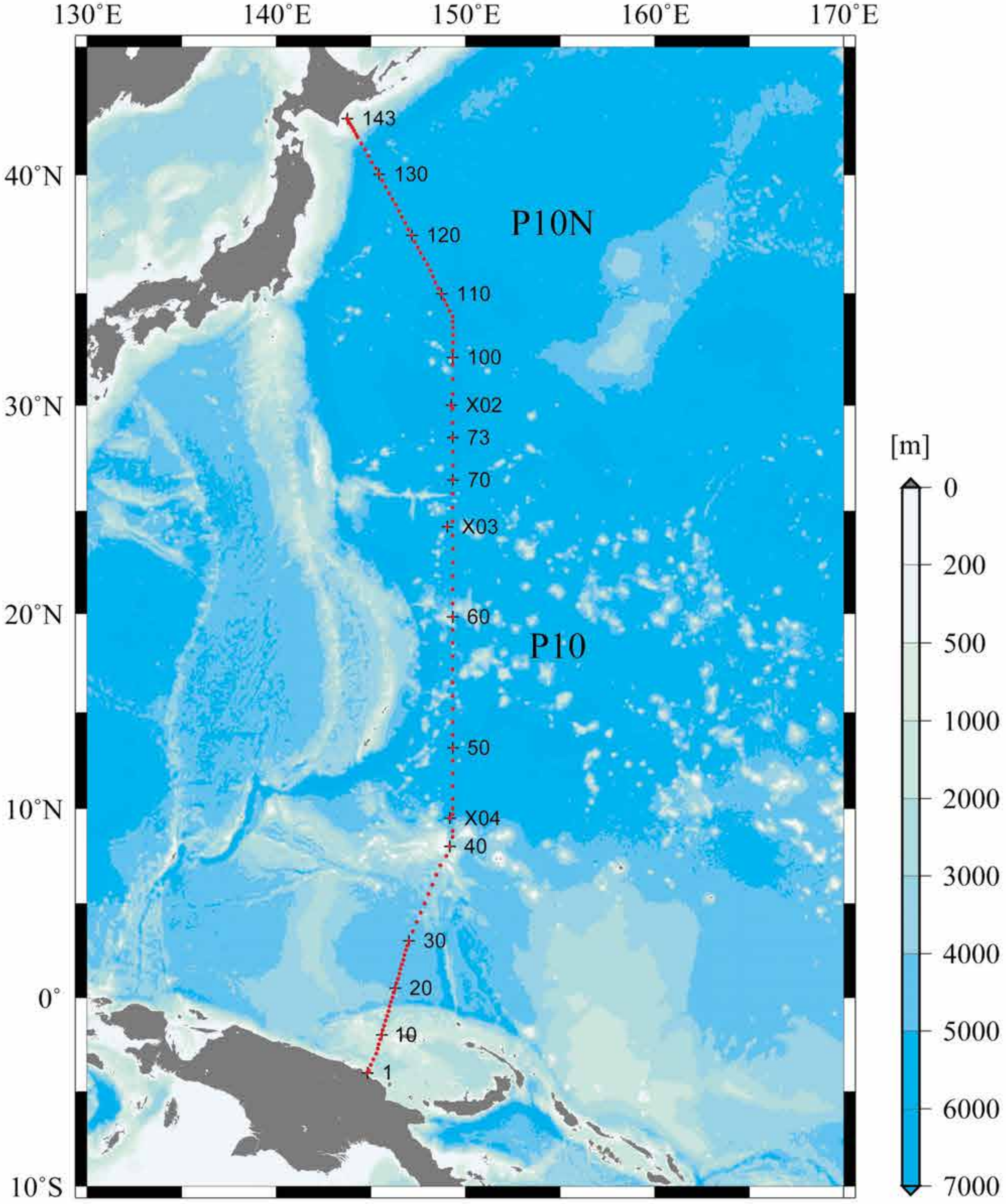


Figure 2

Bathymetry measured by Multi Narrow Beam Echo Sounding system

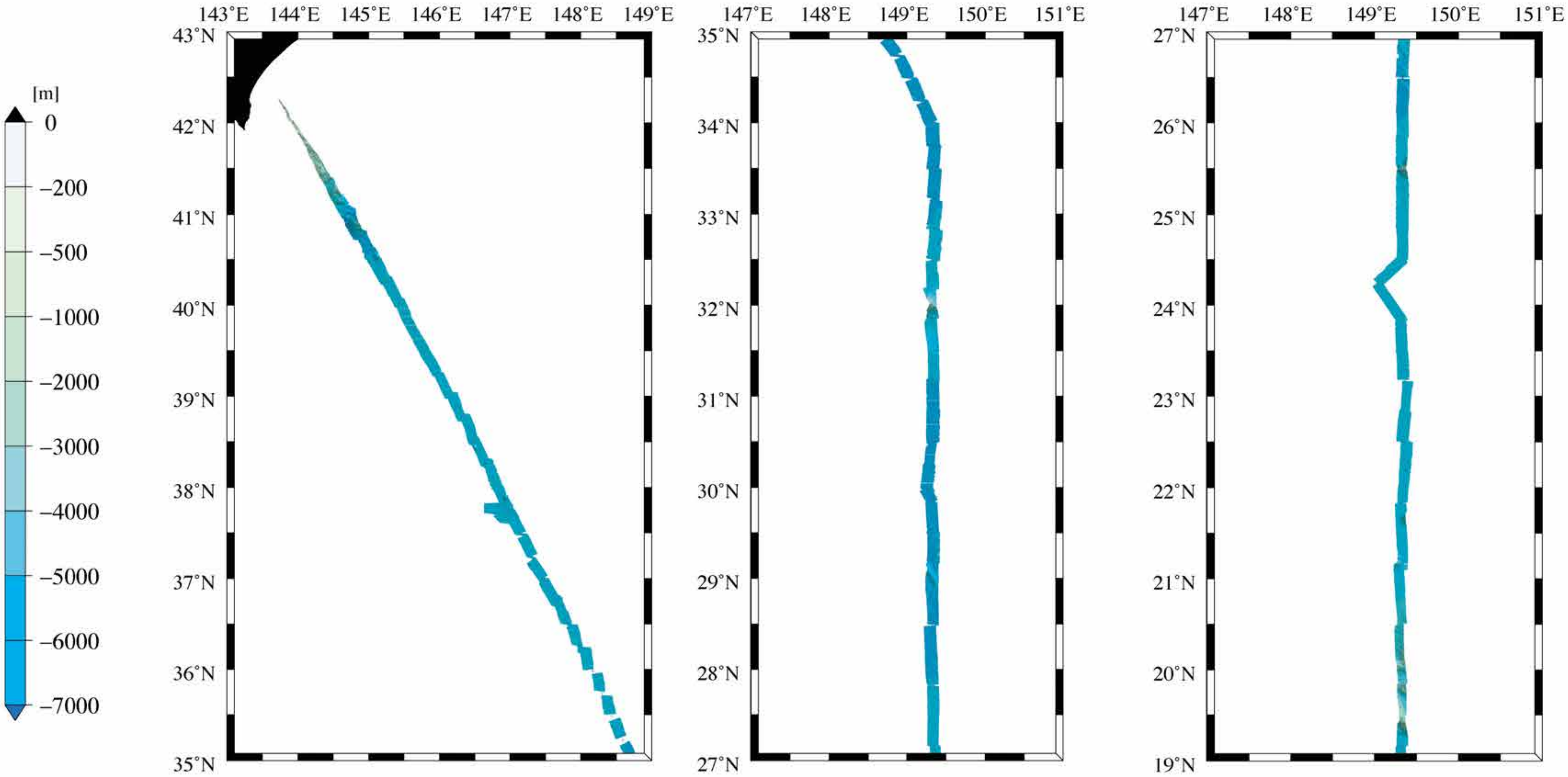


Figure 2

continued

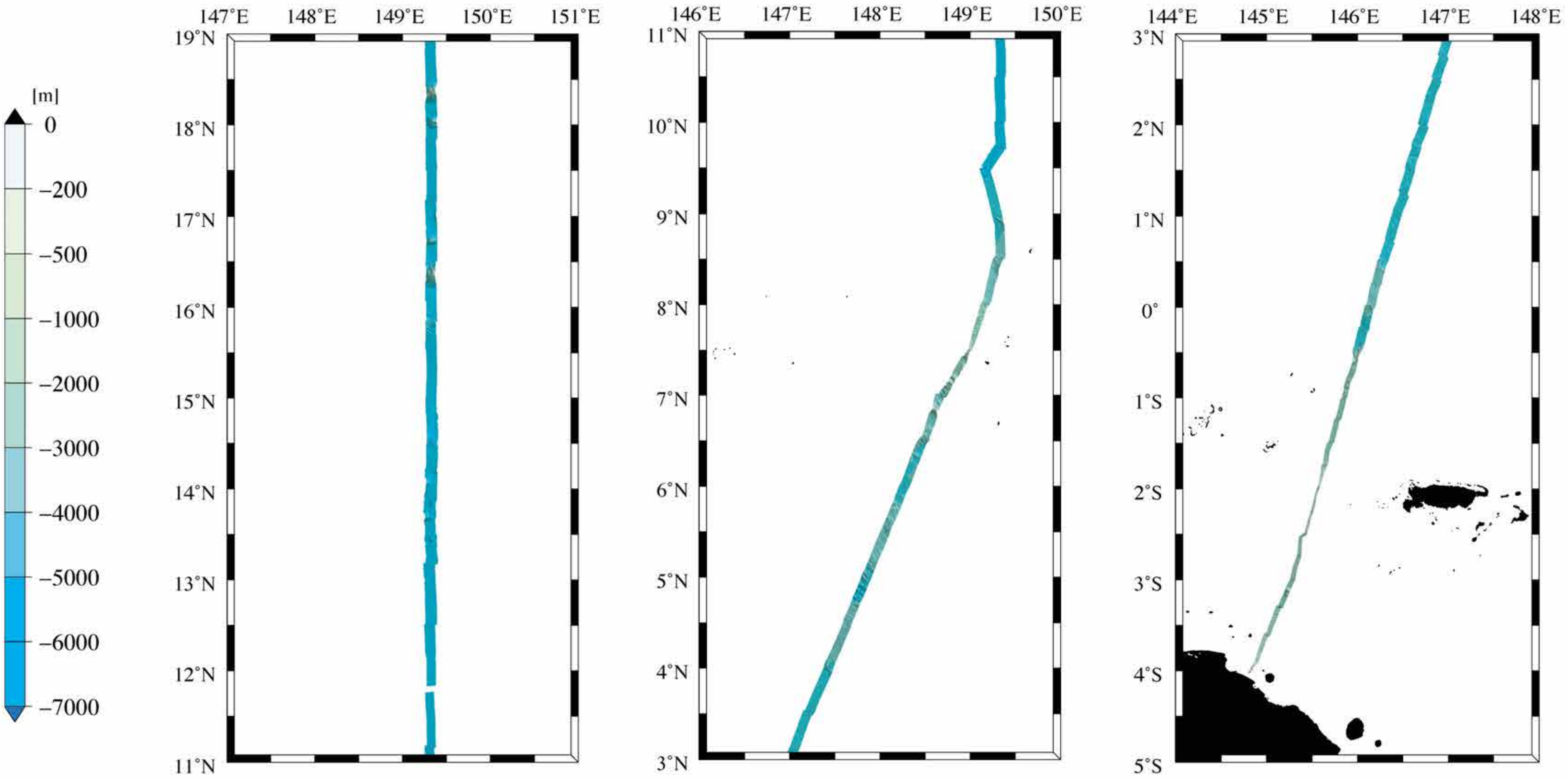


Figure 3

Surface wind measured at 25 m above sea level

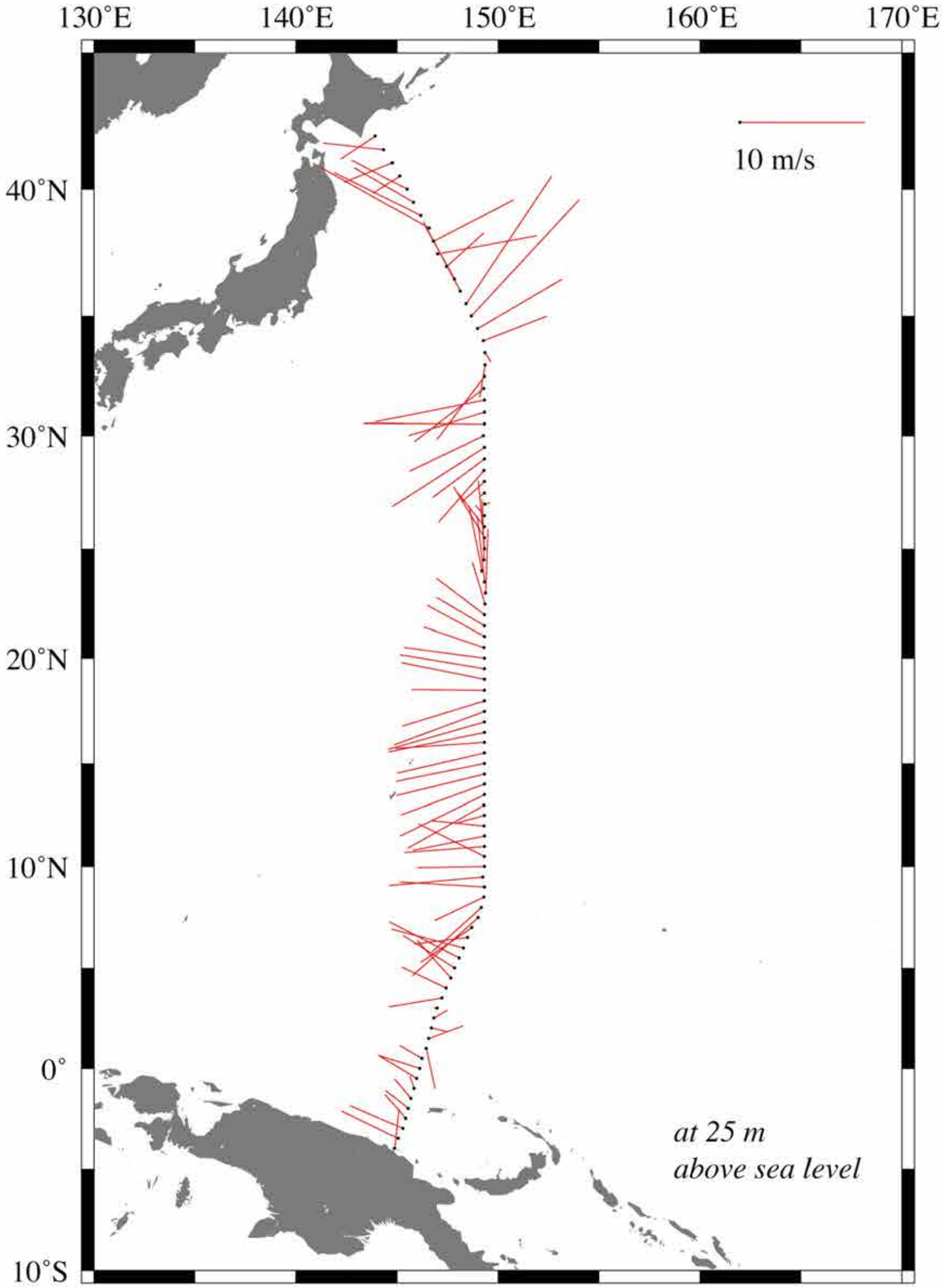


Figure 4

Sea surface temperature (SST) and salinity (SSS)

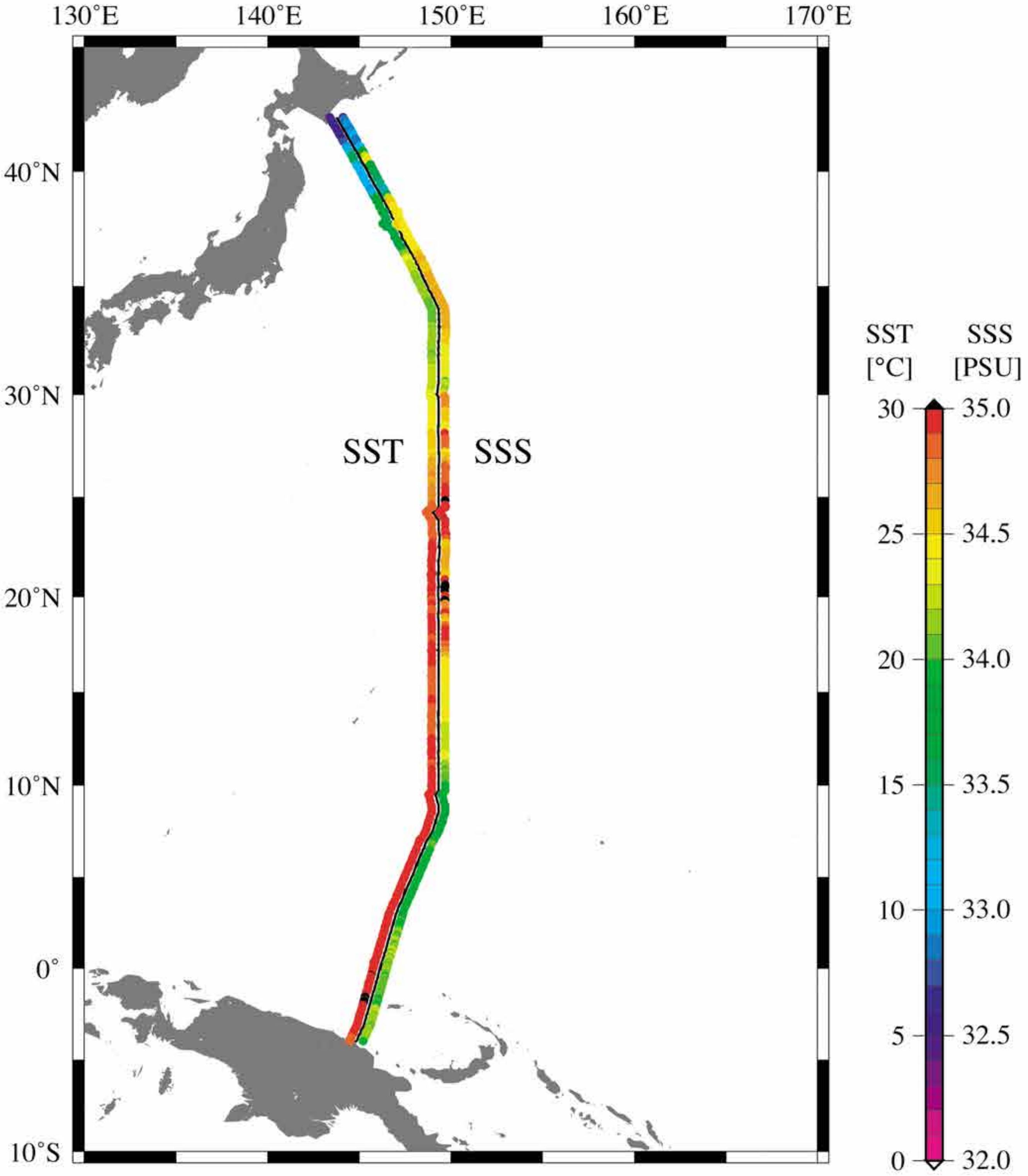


Figure 5

***Δ*pCO₂**

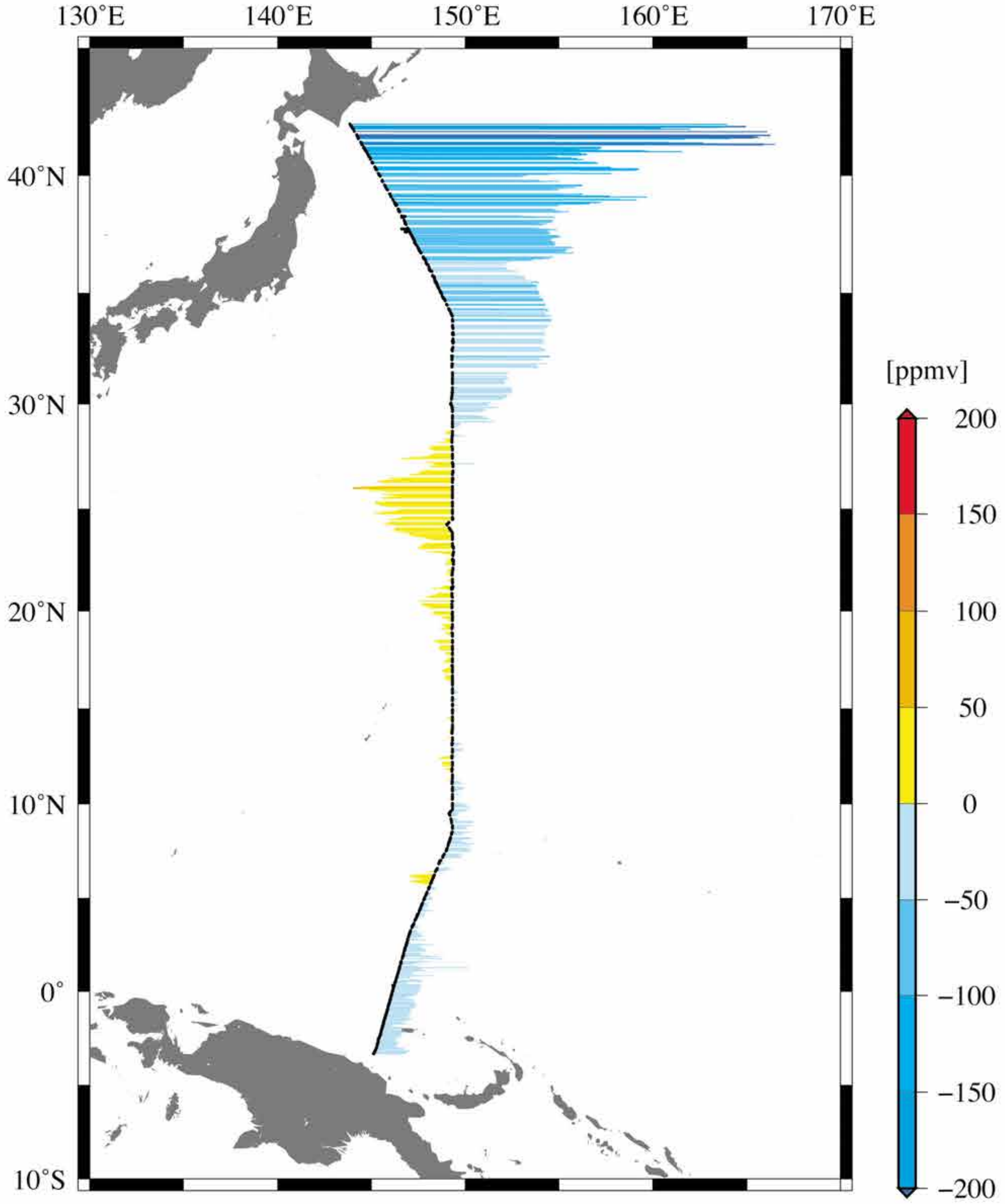


Figure 6

Surface current measured by shipboard ADCP

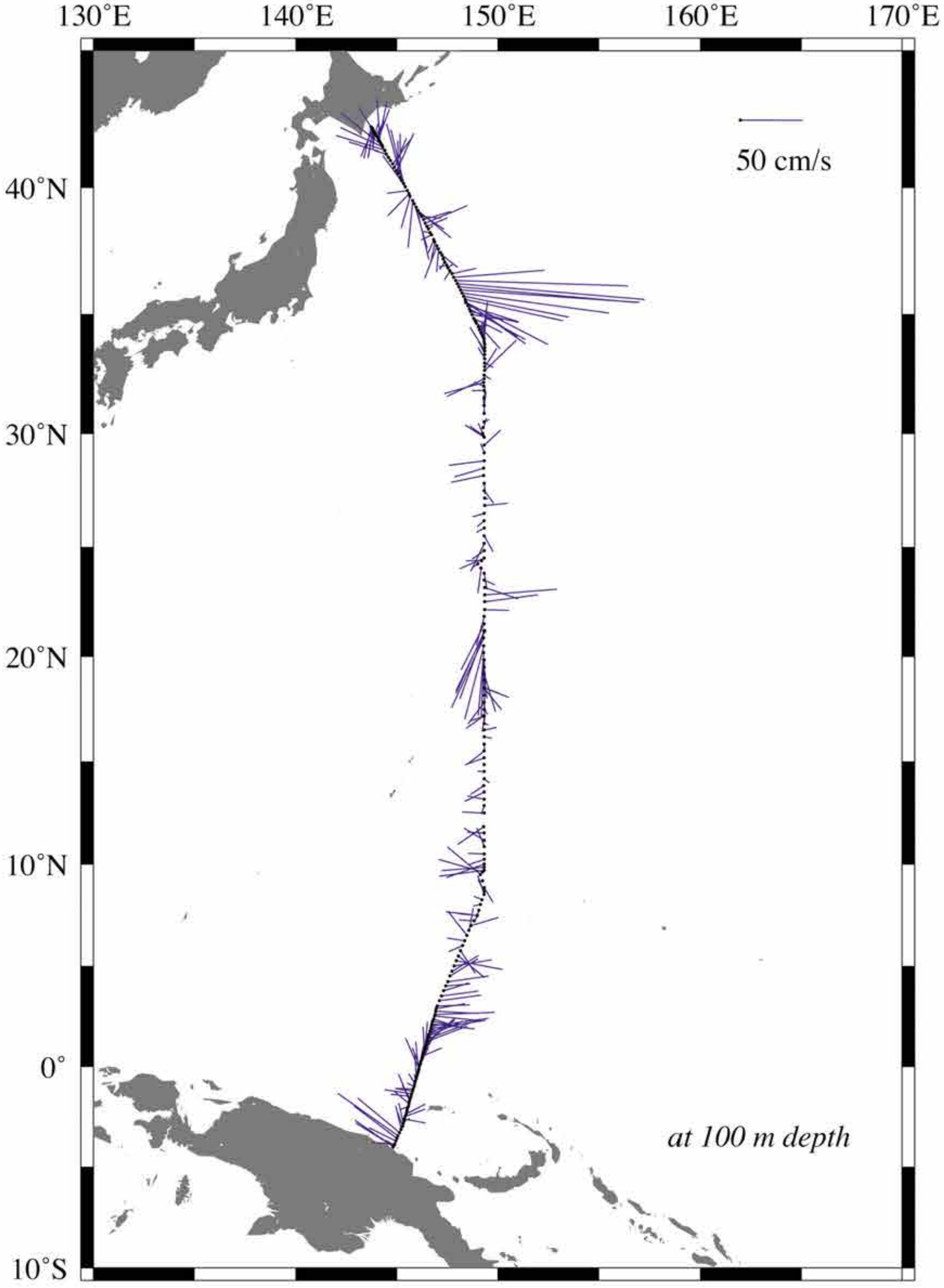


Figure 7

Potential temperature (°C)

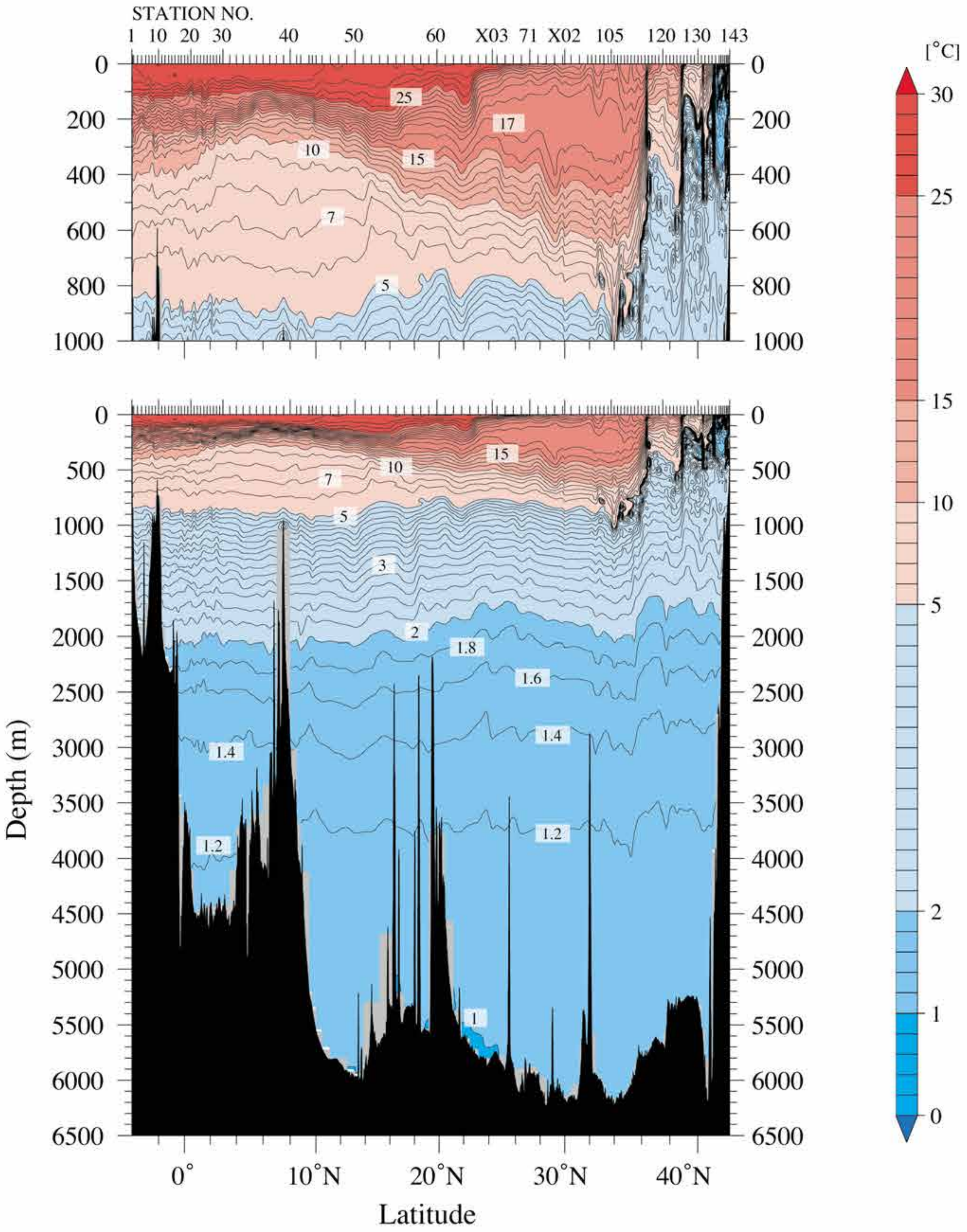


Figure 8

CTD salinity (psu)

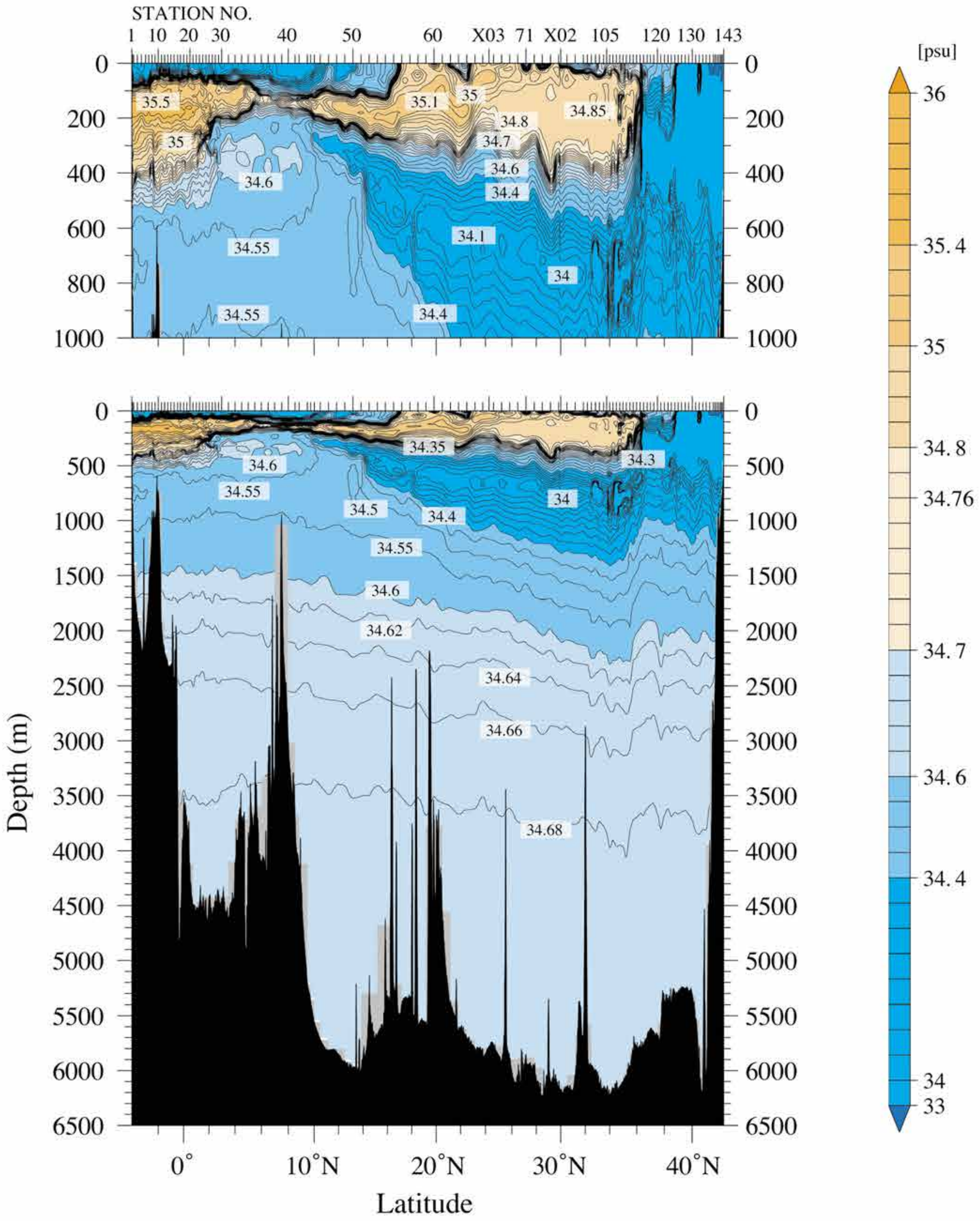


Figure 9

CTD salinity (psu) with SSW batch correction

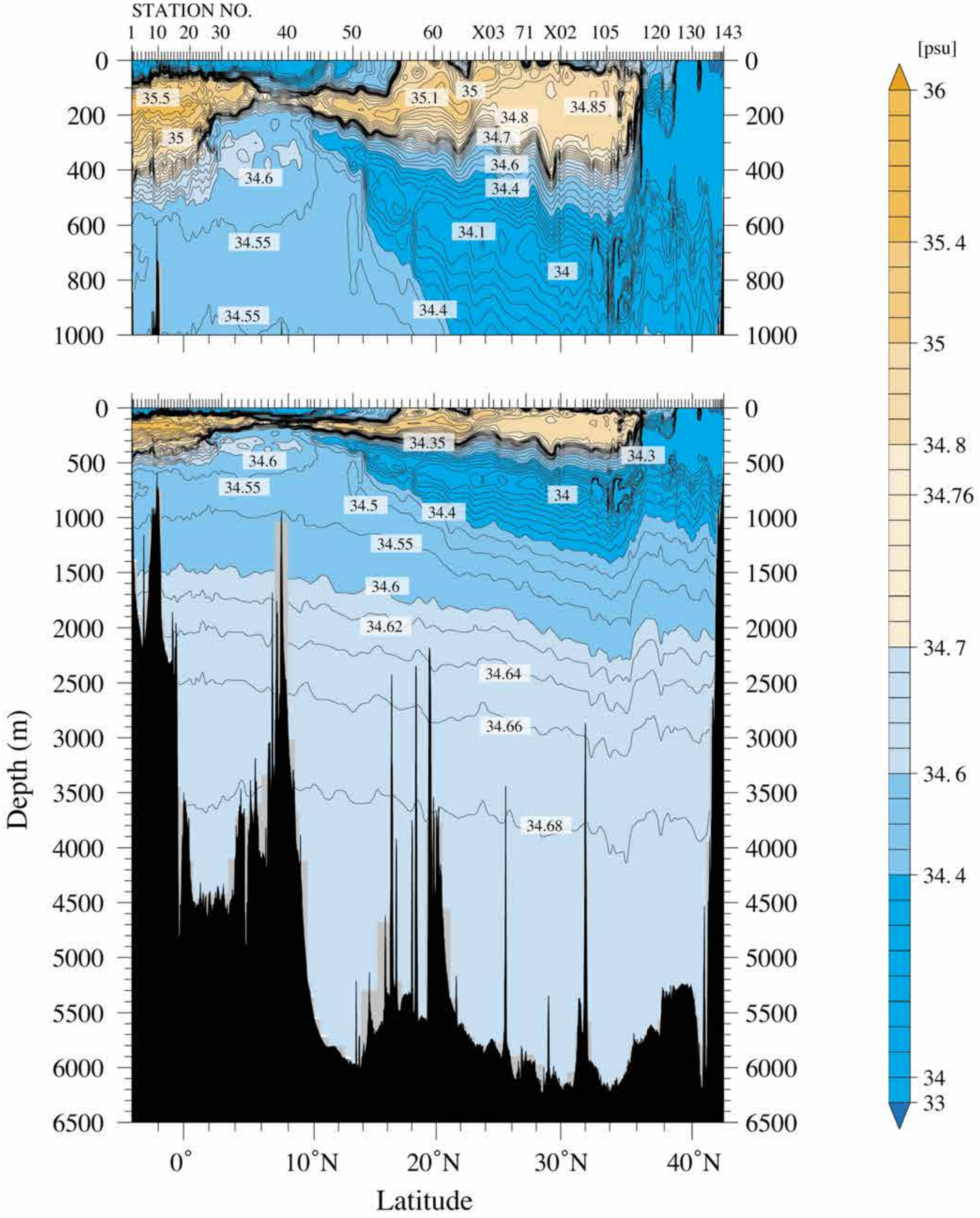


Figure 10

Density (σ_0) (kg/m^3)

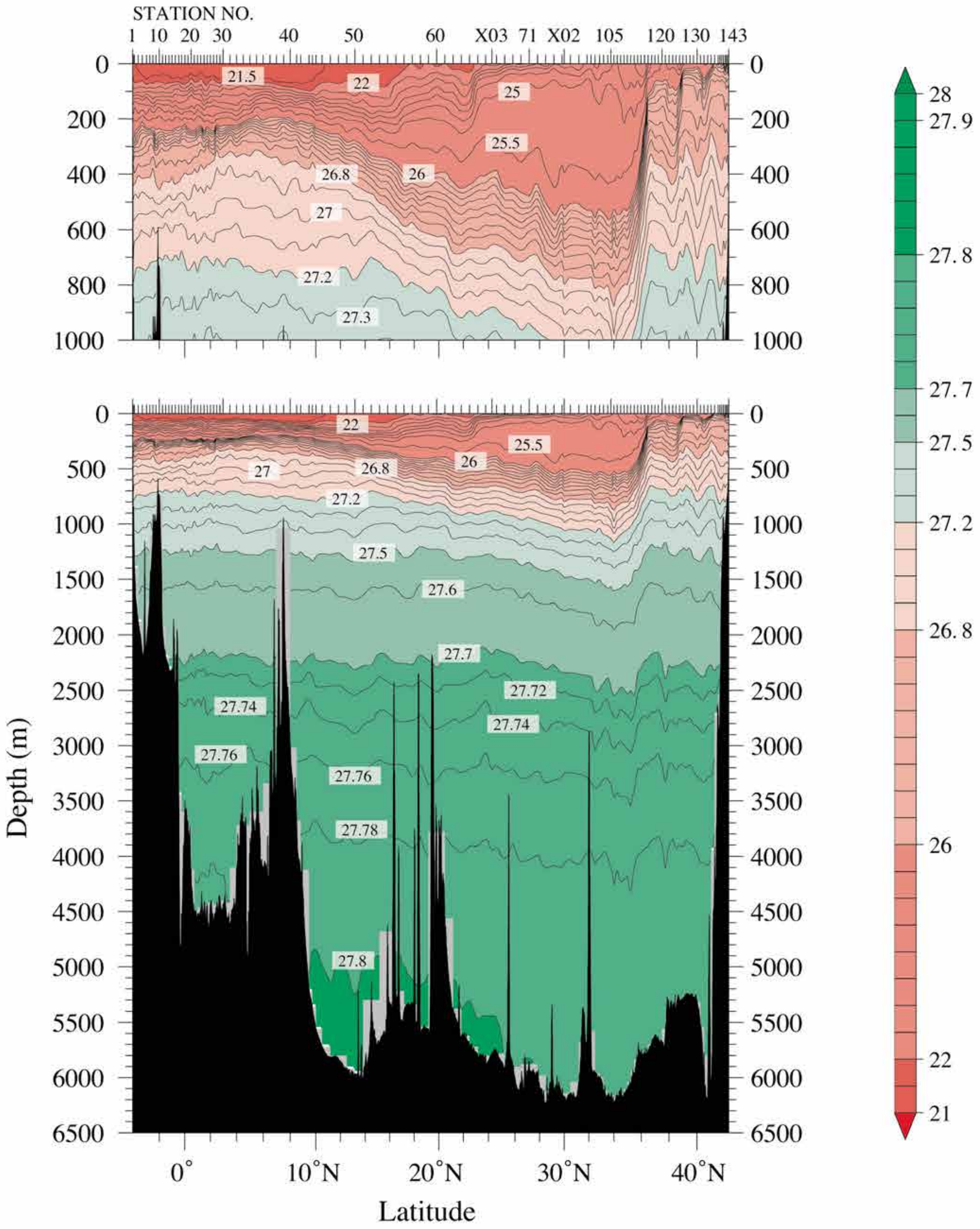


Figure 11

Density (σ_4) (kg/m^3)

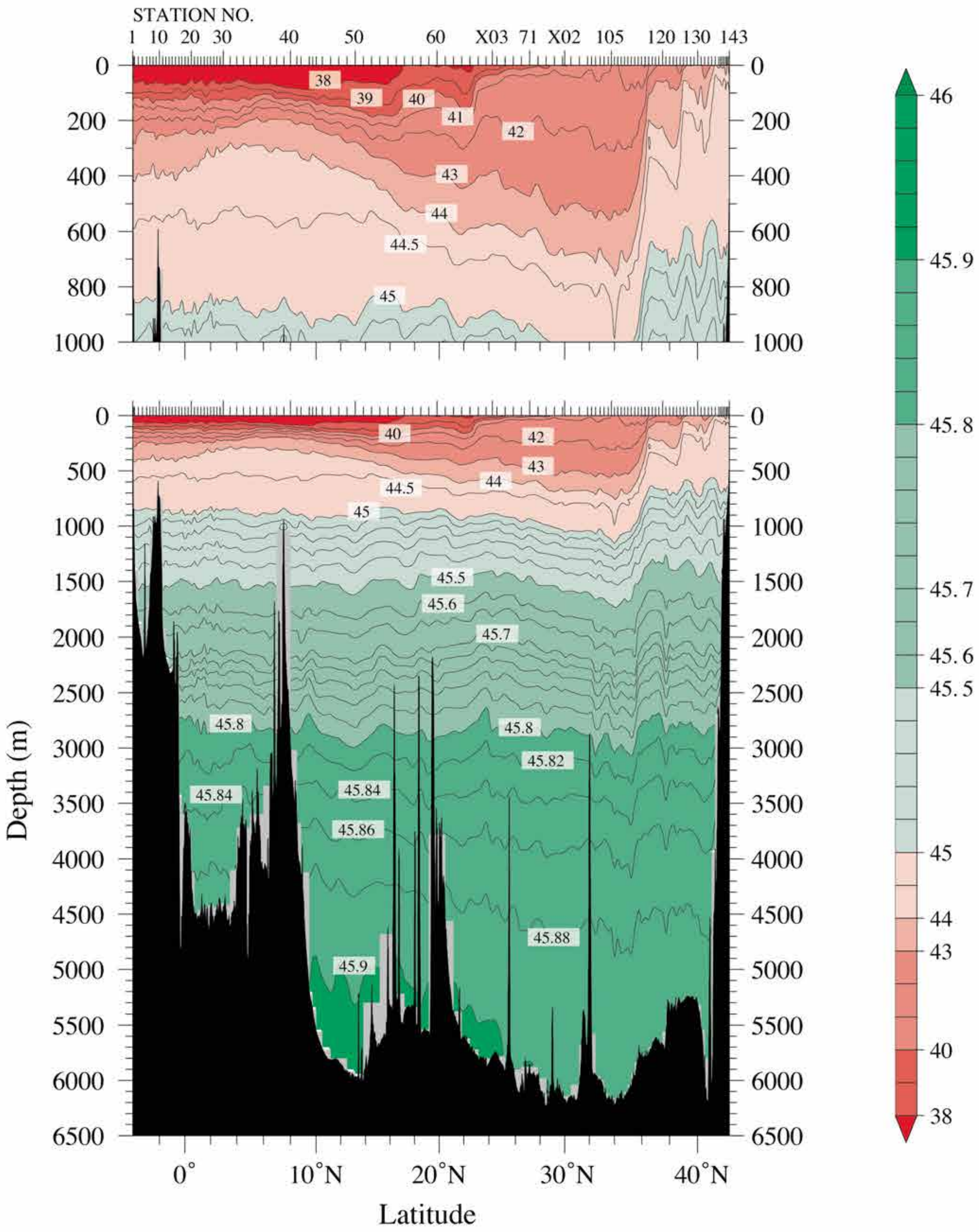


Figure 12

Neutral density (γ^n) (kg/m³)

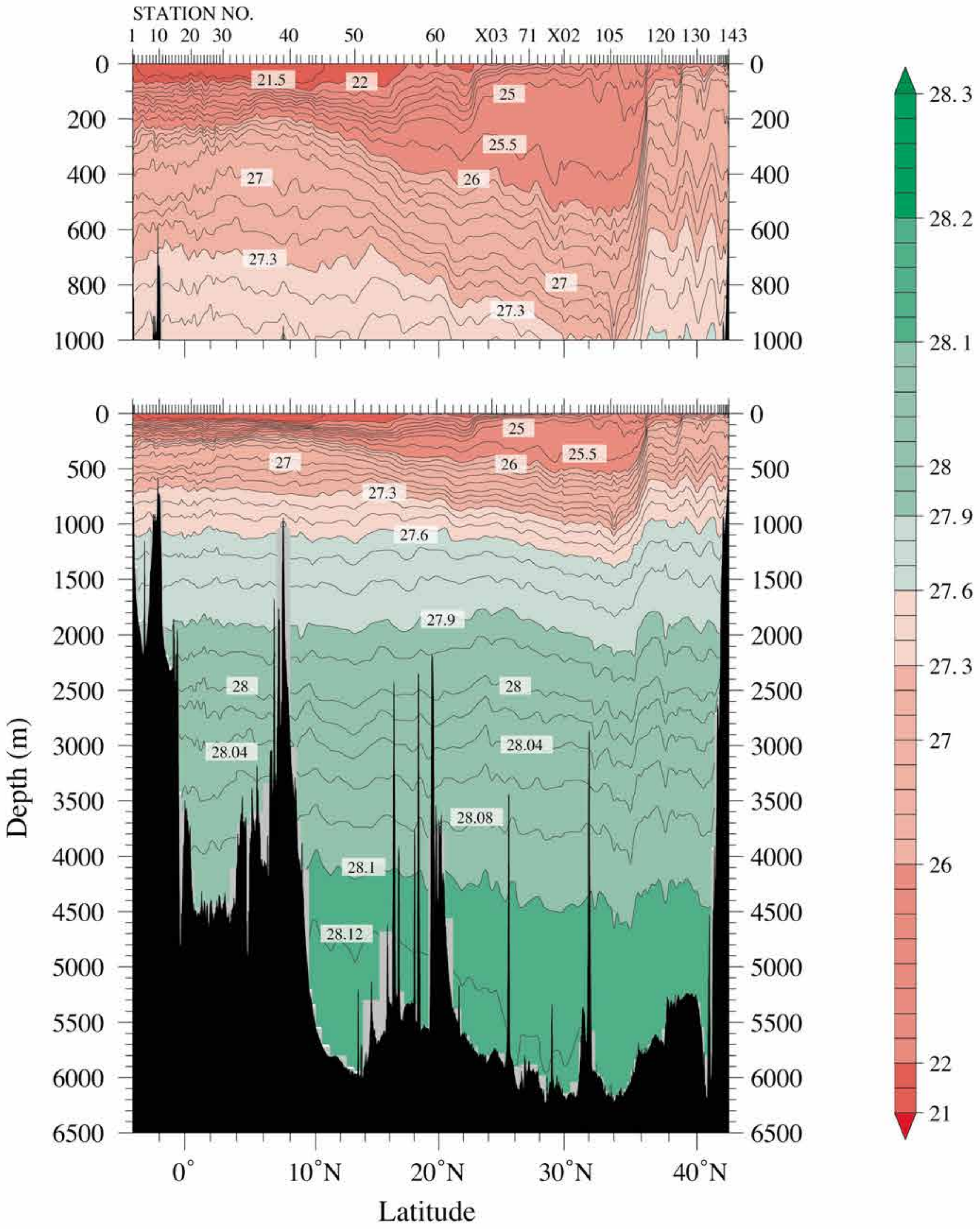


Figure 13

Bottle sampled dissolved oxygen (µmol/kg)

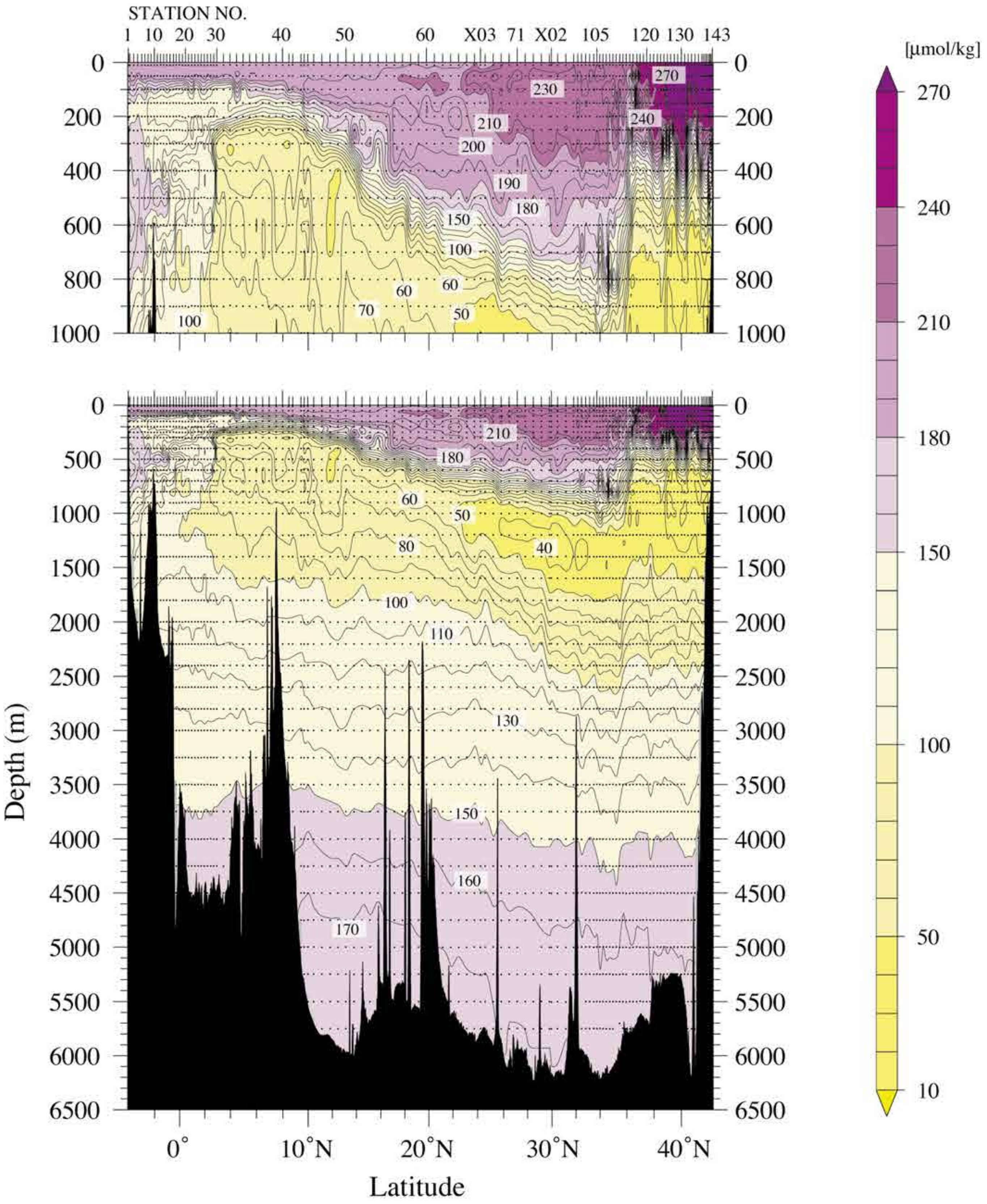


Figure 14

Silicate (µmol/kg)

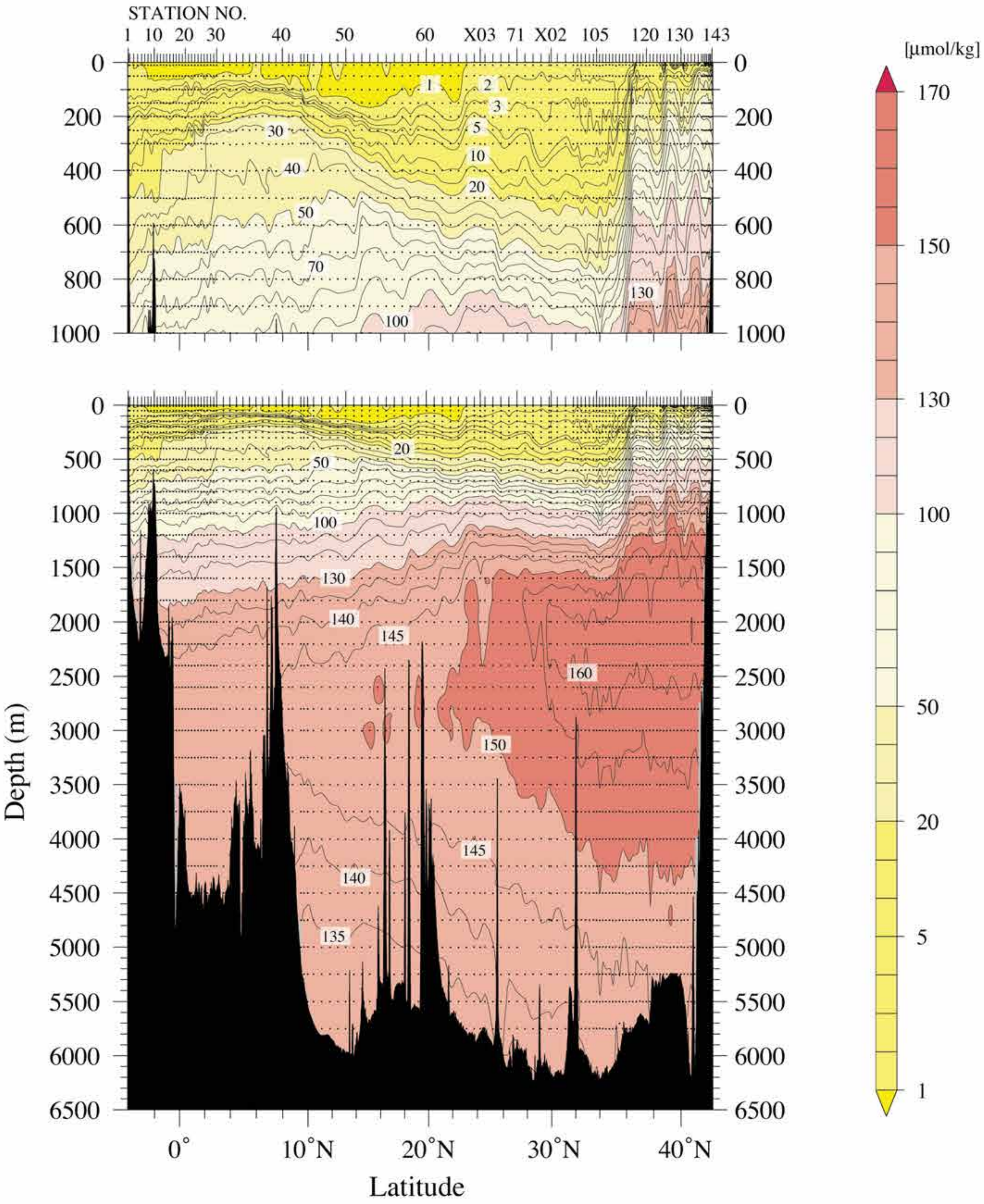


Figure 15

Nitrate (µmol/kg)

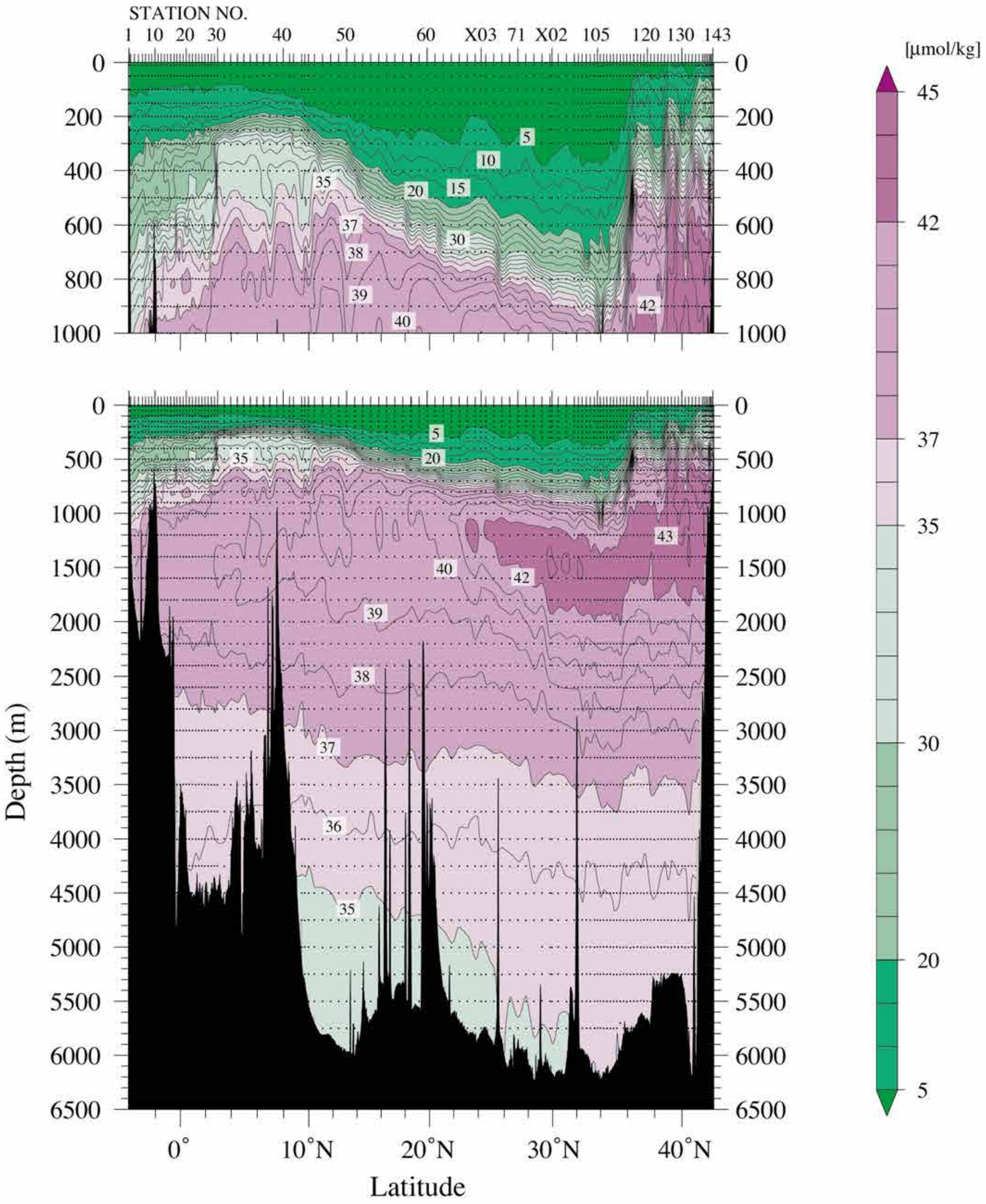


Figure 16

Nitrite (µmol/kg)

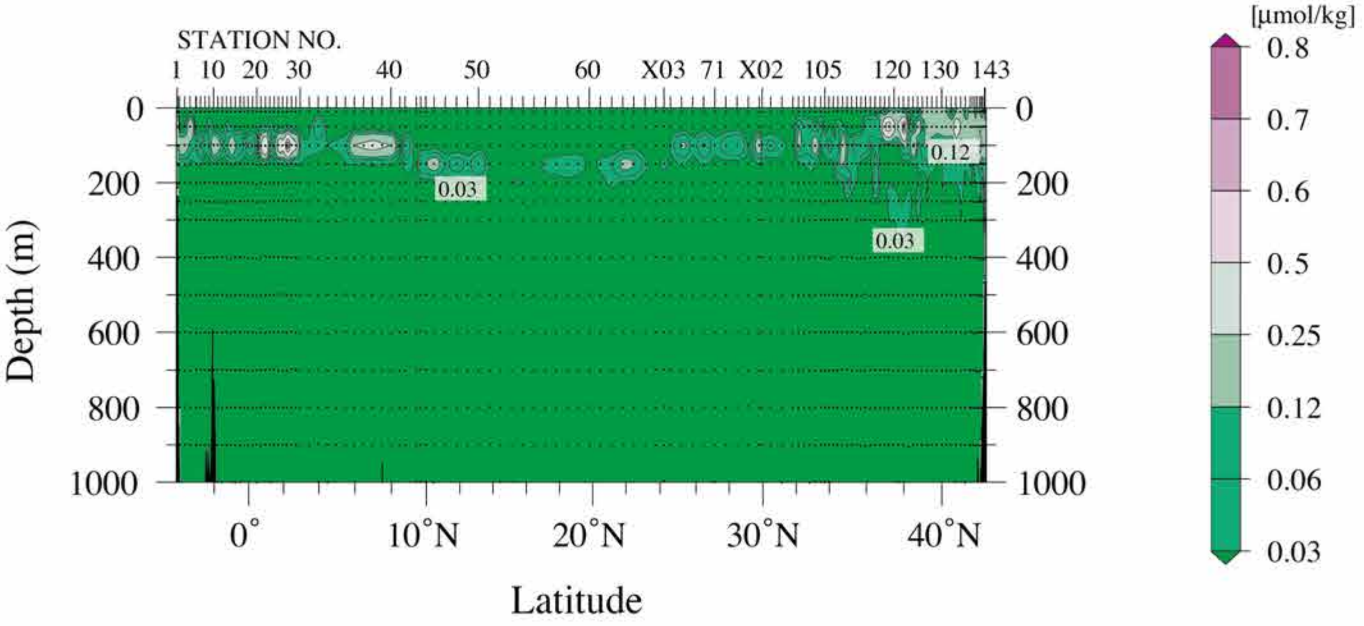


Figure 17

Phosphate (µmol/kg)

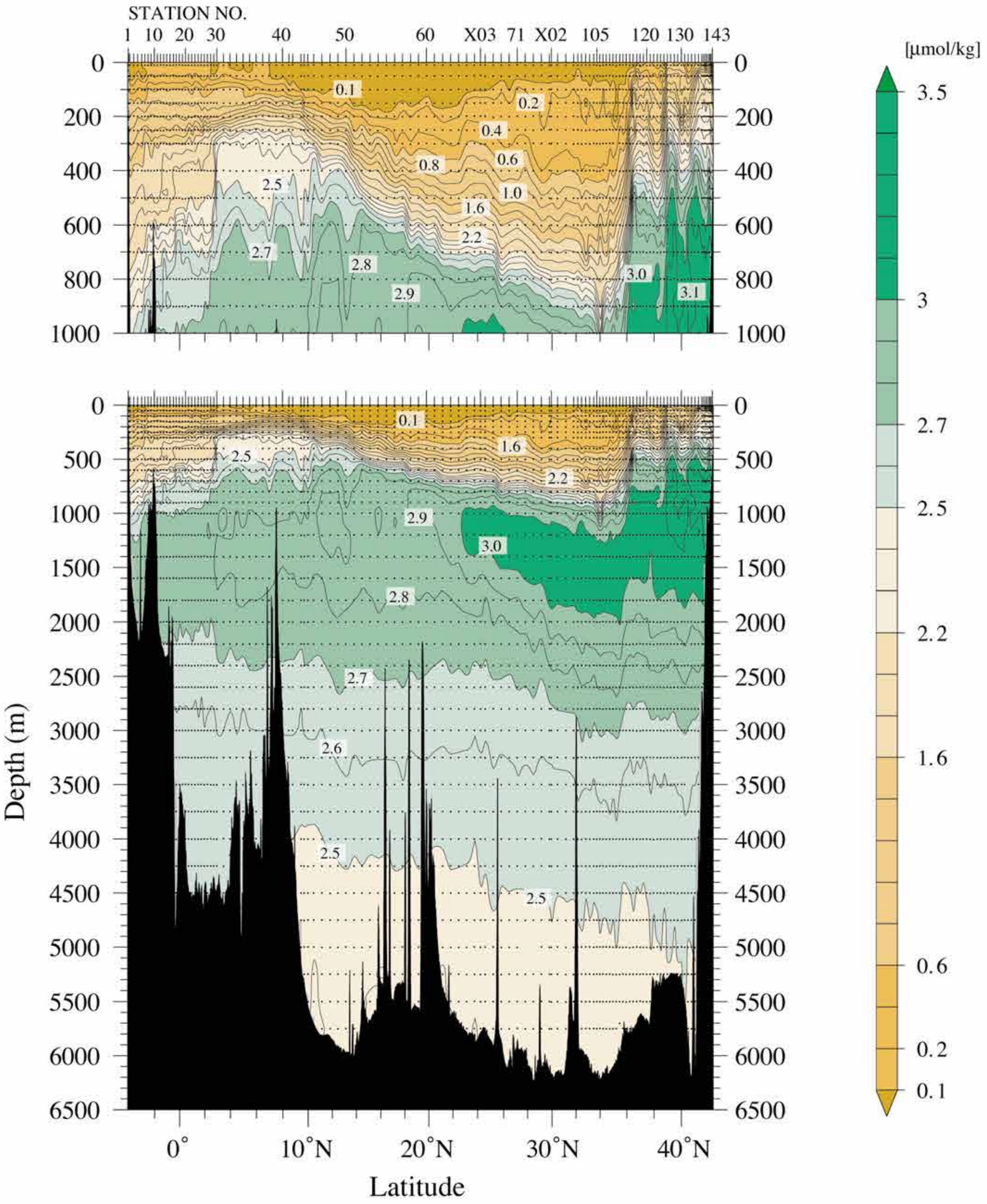


Figure 18

Dissolved inorganic carbon (µmol/kg)

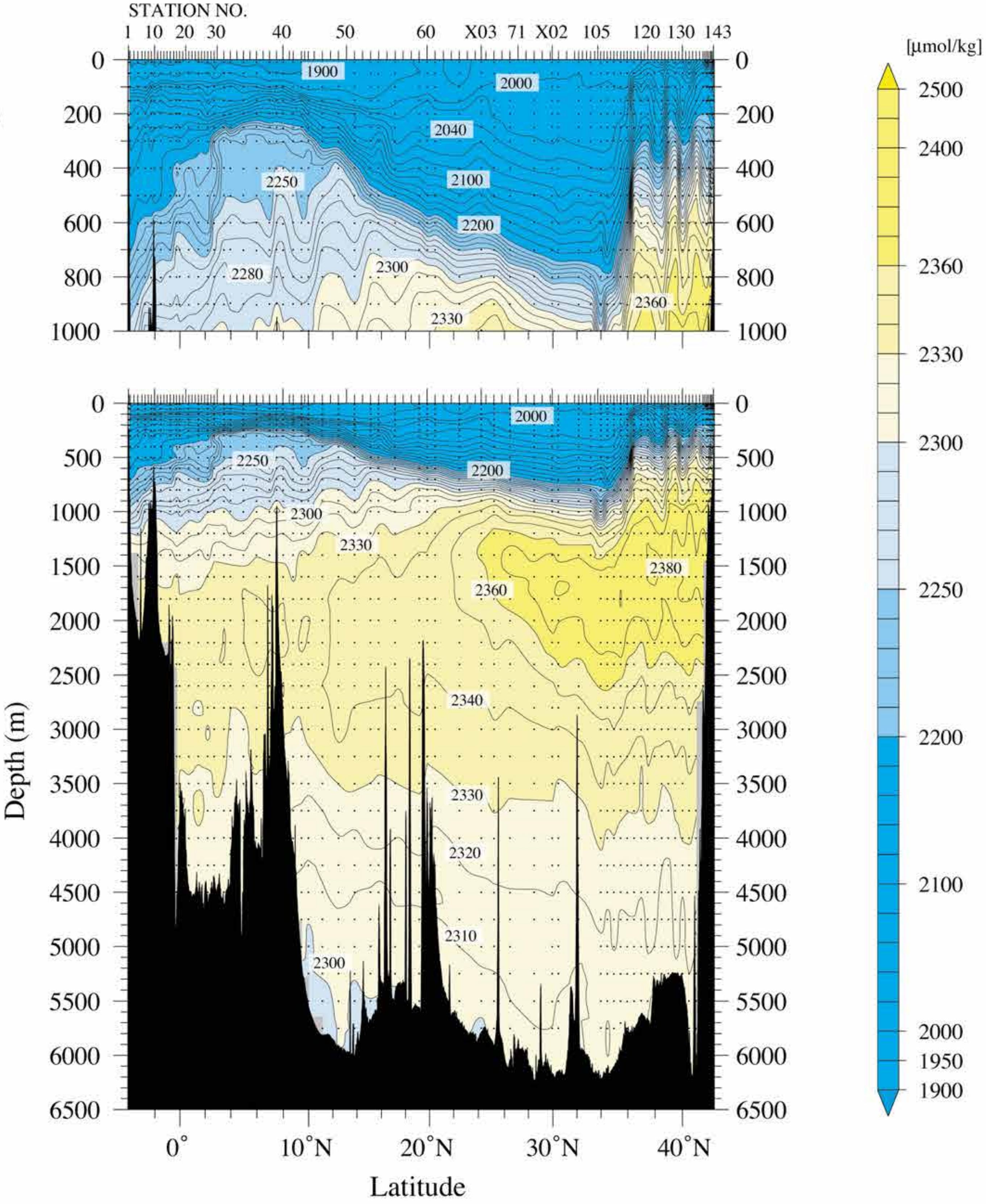


Figure 19

Total alkalinity (μmol/kg)

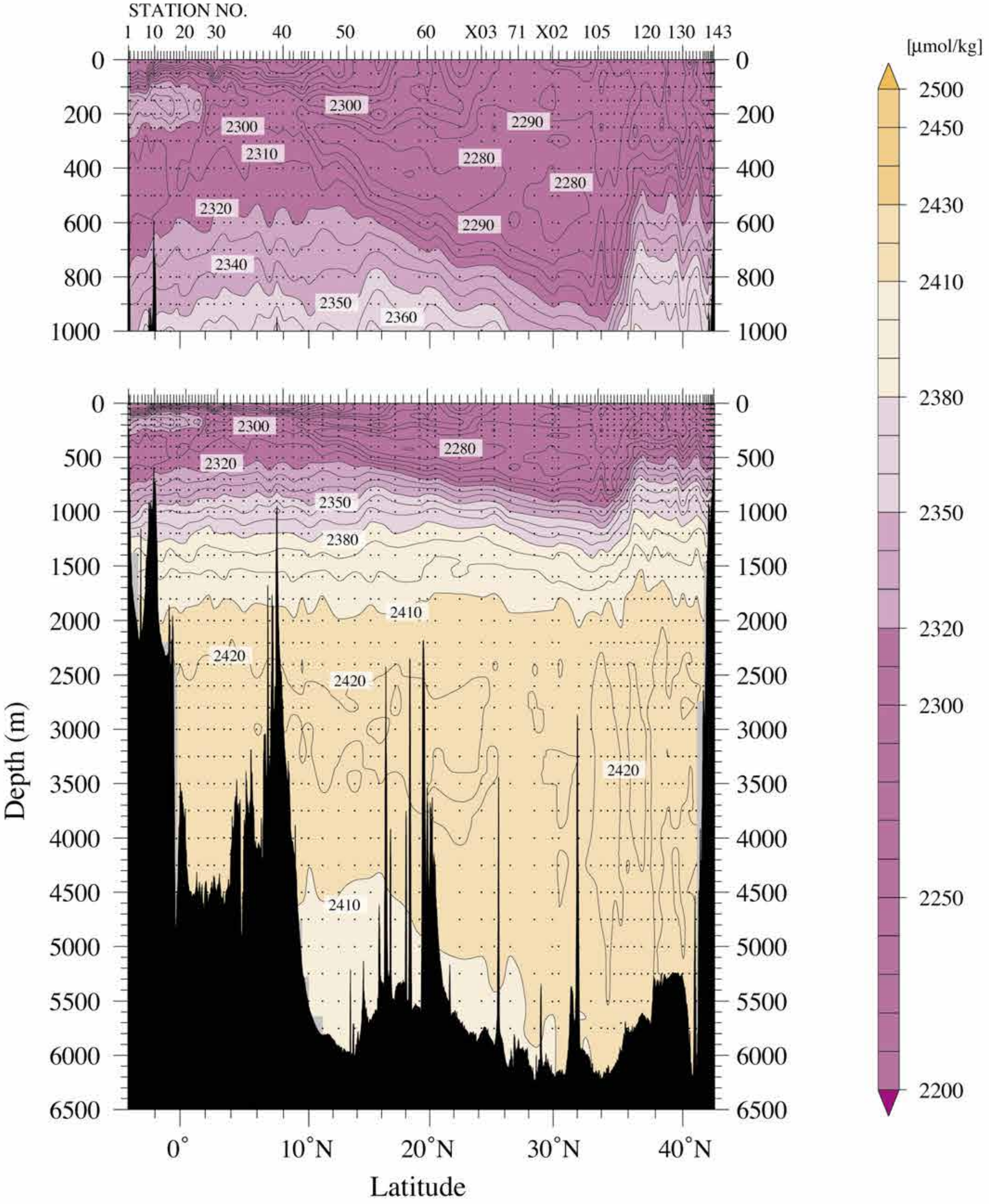
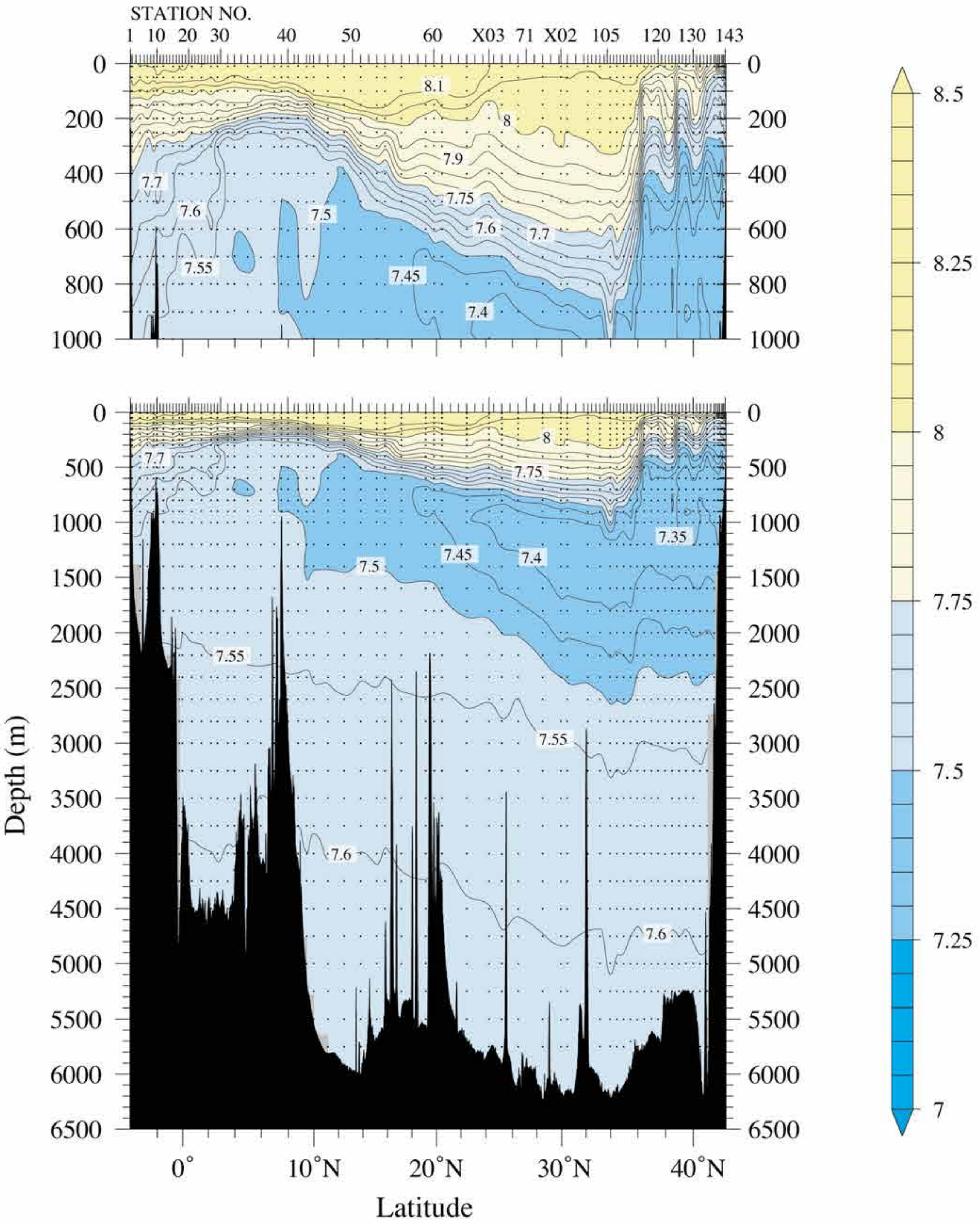


Figure 20

pH


STATION NO.
1 10 20 30 40 50 60 X03 71 X02 105 120 130 143
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200
400
600
800
1000
8.1
8
7.9
7.75
7.7
7.6
7.5
7.55
7.45
7.4
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7.35
Depth (m)
0°
10°N
20°N
30°N
40°N
Latitude
8.5
8.25
8
7.75
7.5
7.25
7

Figure 21

CFC-11 (pmol/kg)

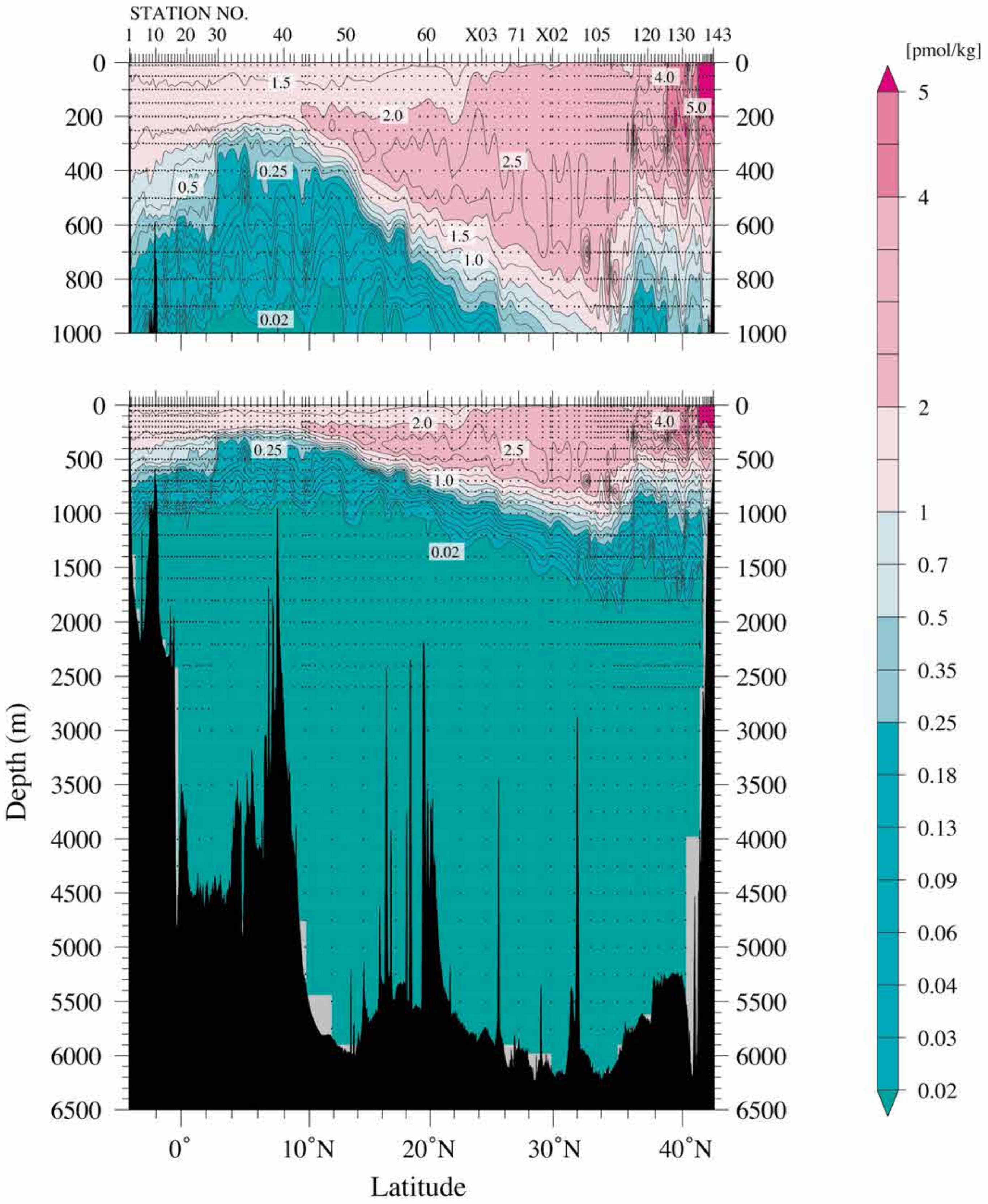

Figure 22

CFC-12 (pmol/kg)

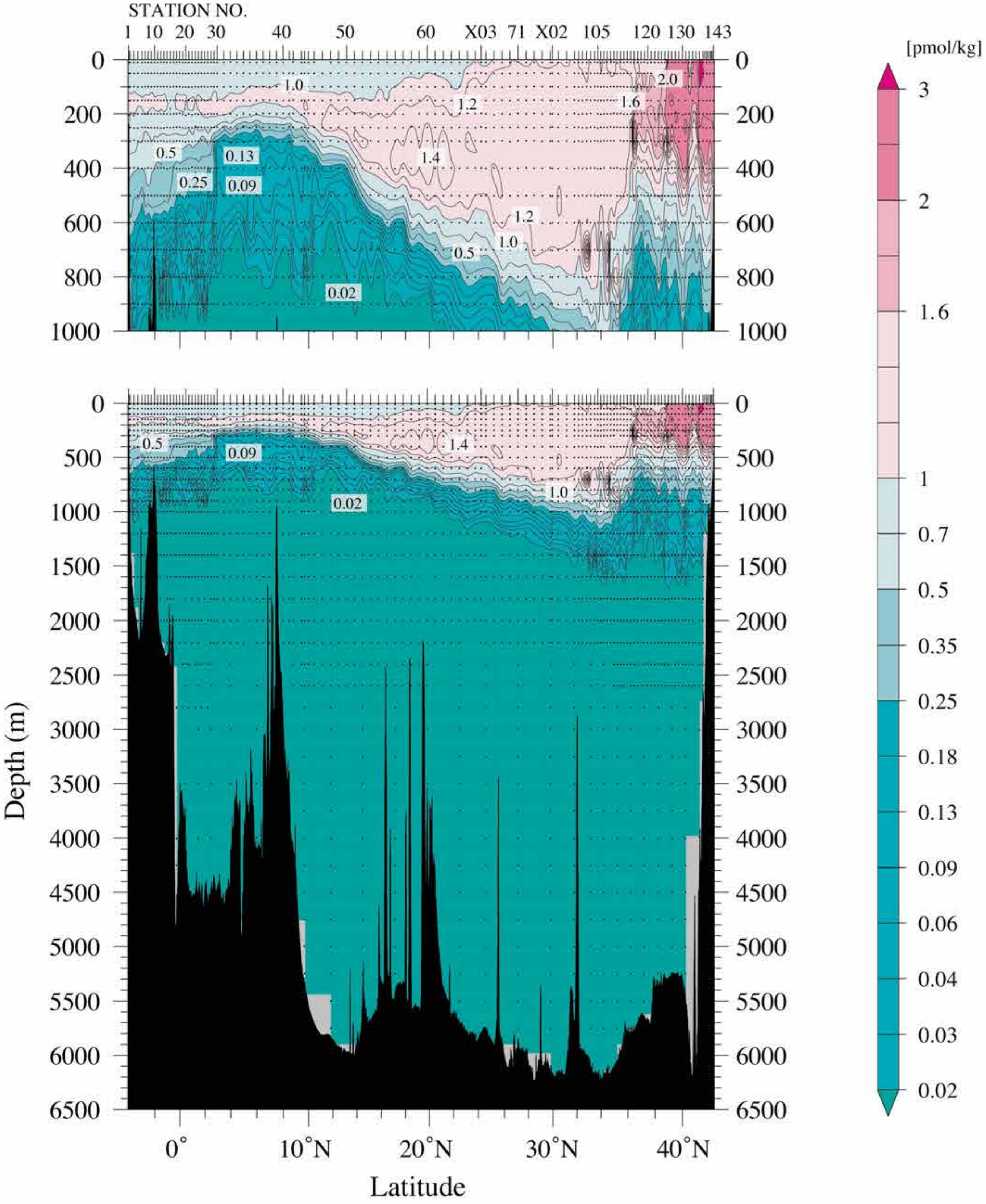

Figure 23

CFC-113 (pmol/kg)

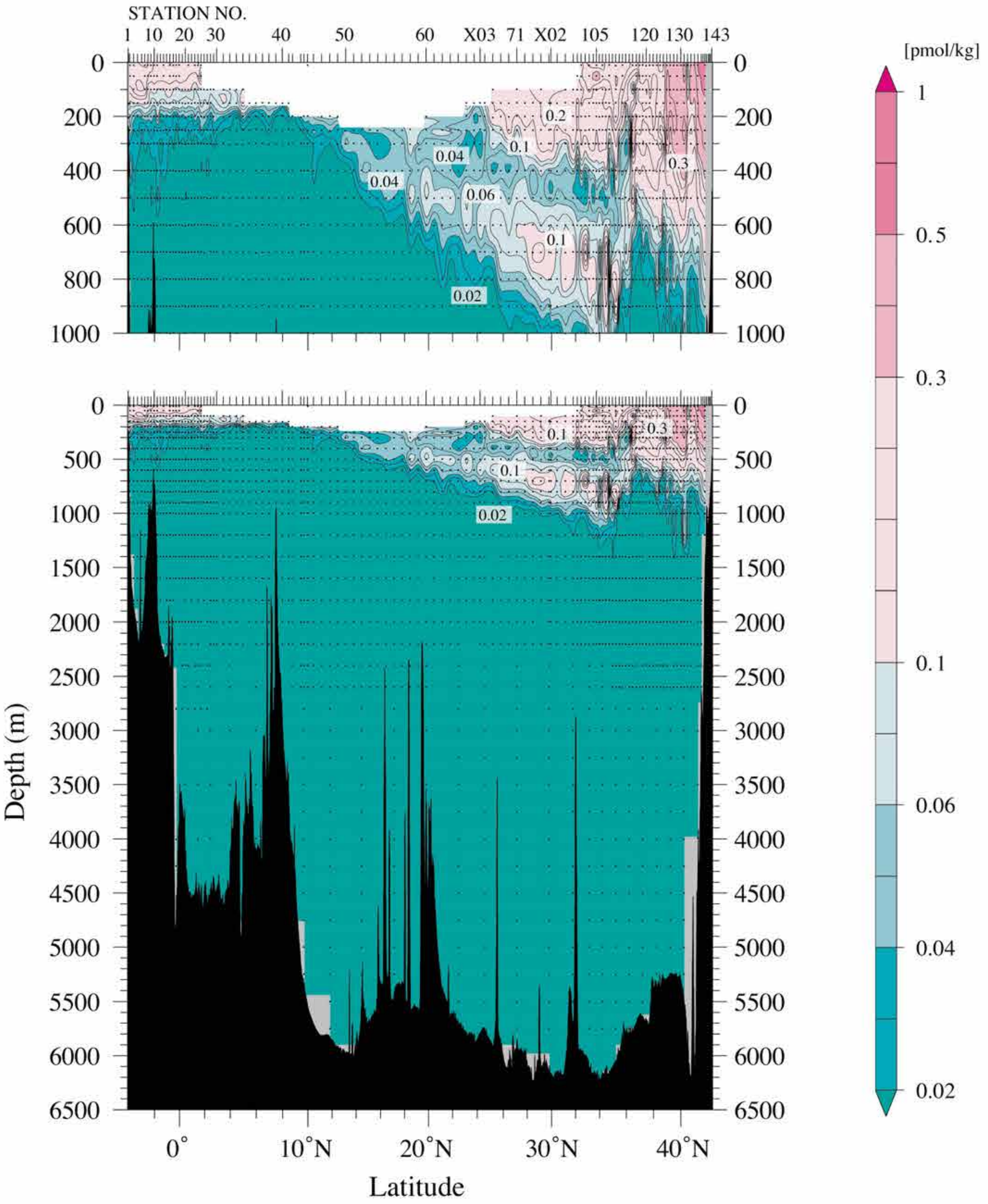

Figure 24

Current velocity (cm/s) normal to the cruise track measured by LADCP (eastward is positive)

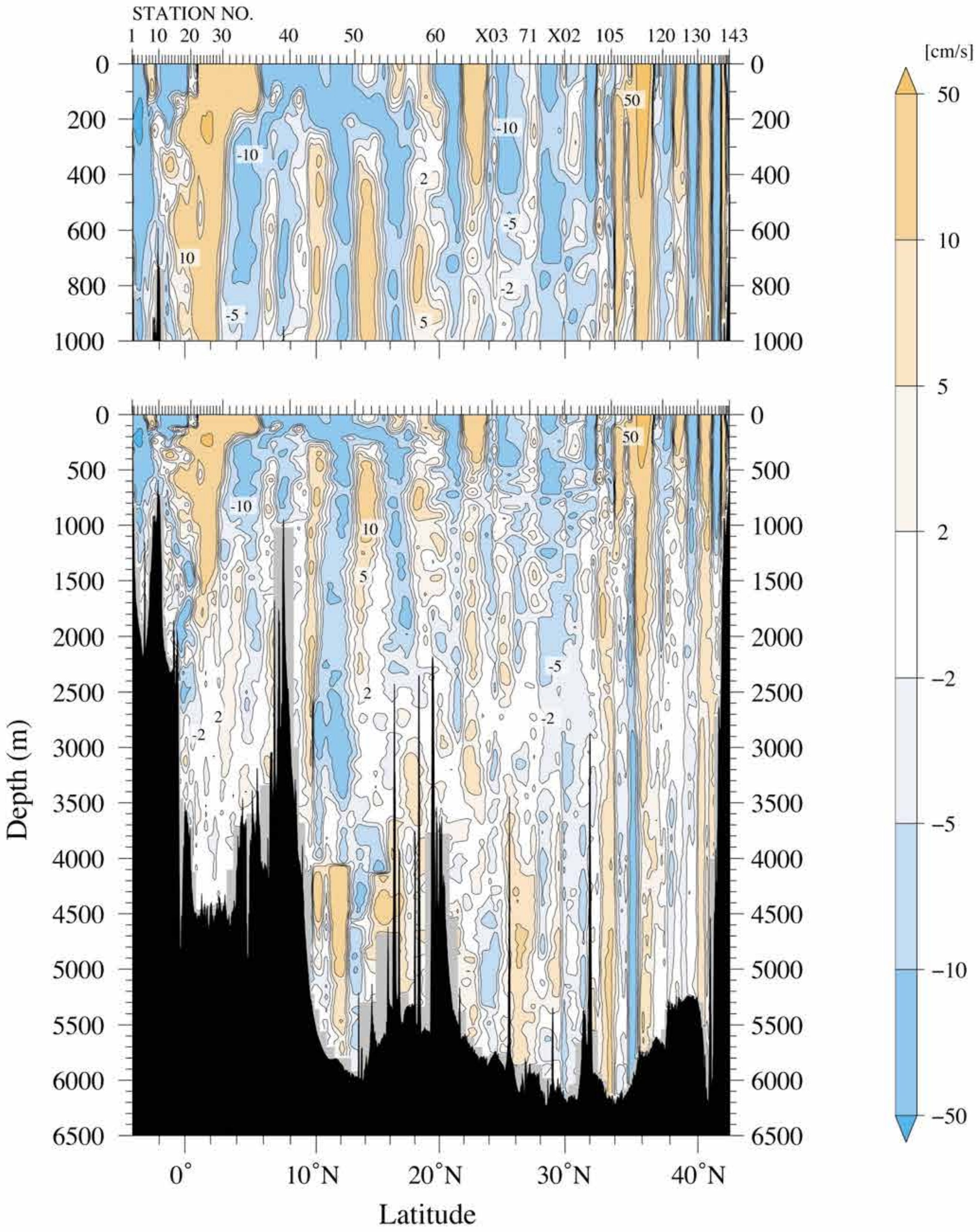

Figure 25

Difference in potential temperature (°C) between results from WOCE and the revisit cruise

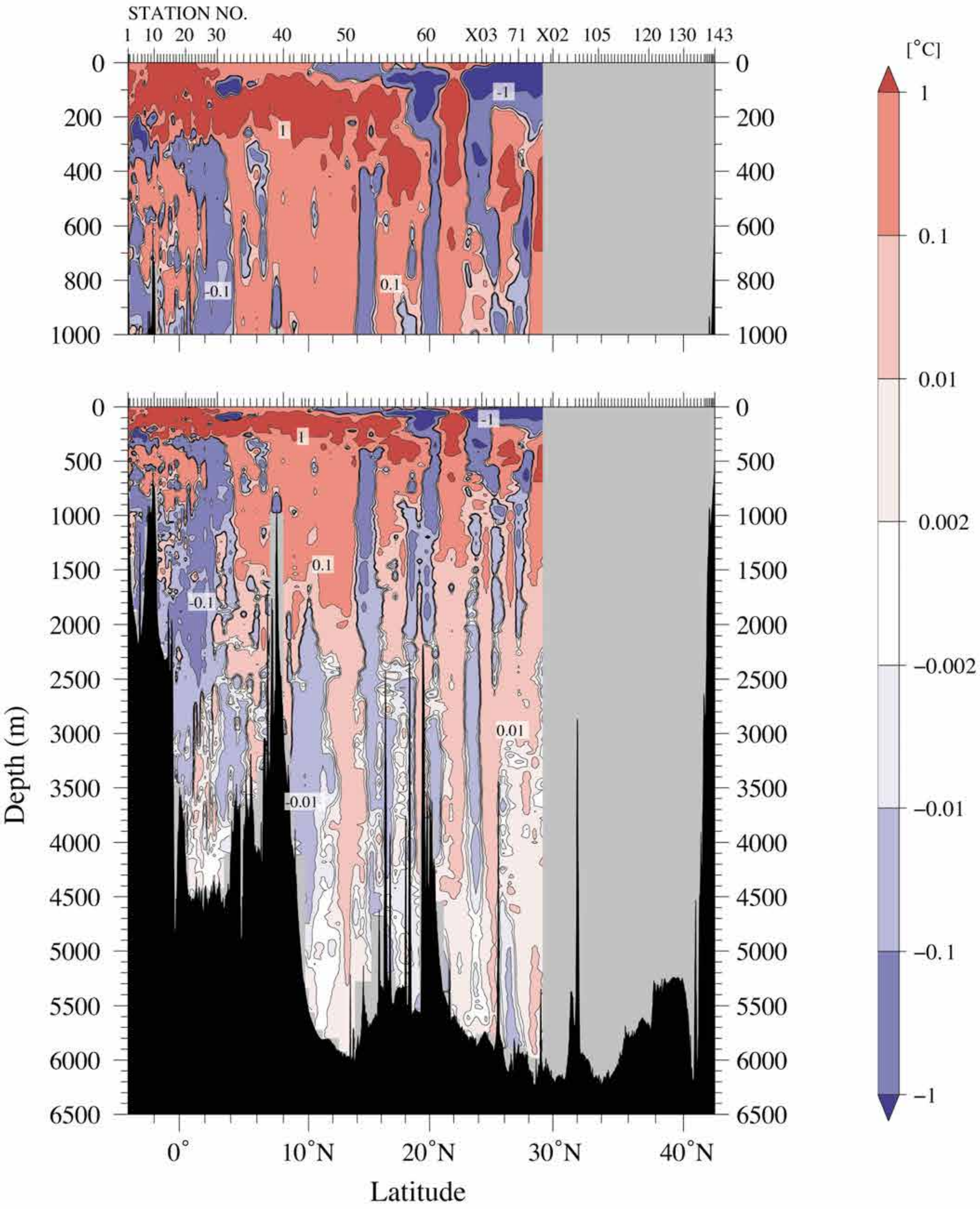

Figure 26

Difference in salinity (psu) between results from WOCE and the revisit

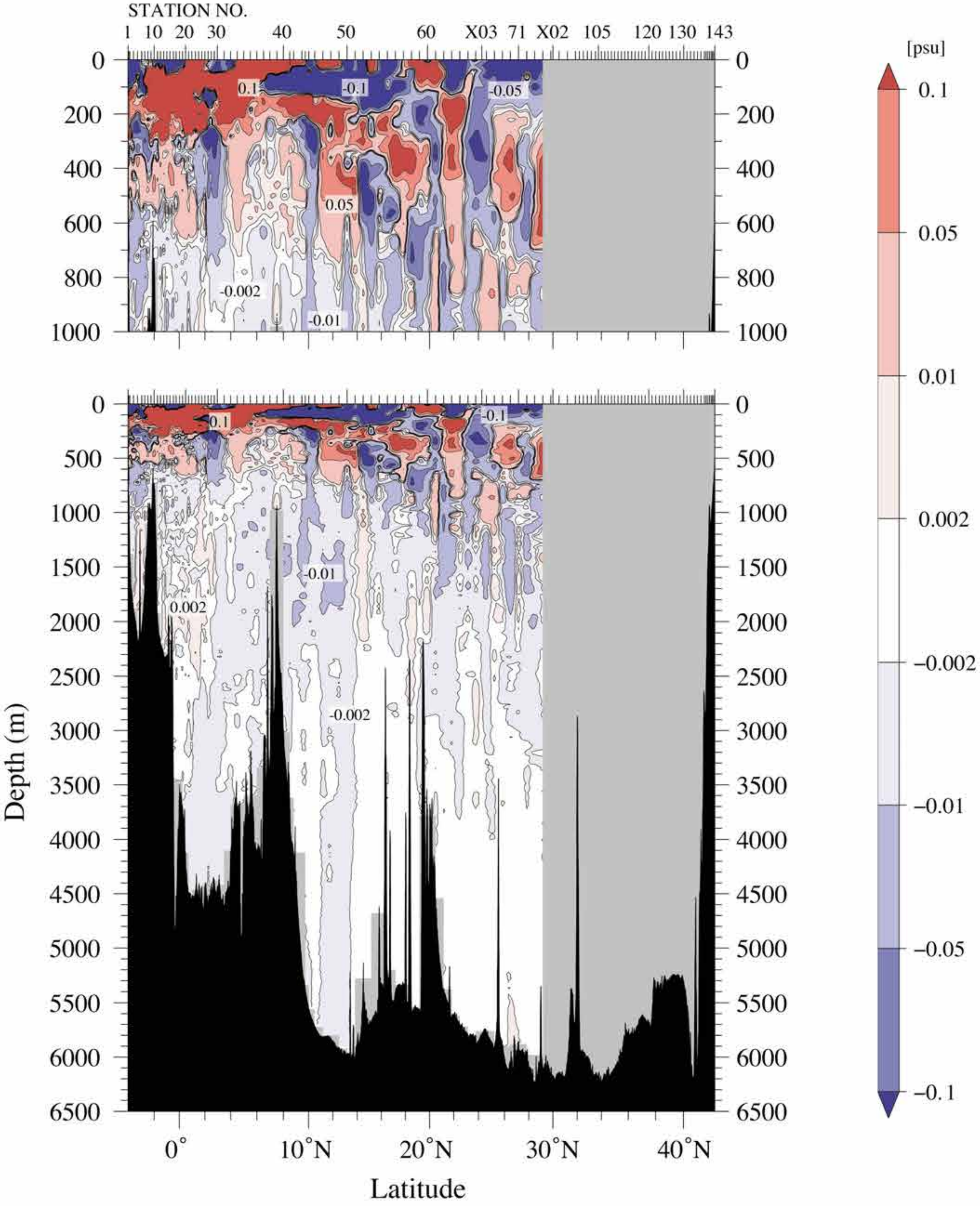

Figure 27

Difference in dissolved oxygen (μmol/kg) between results from WOCE and the revisit.