CRUISE REPORT: P10_2005

(Updated MAY 2009)
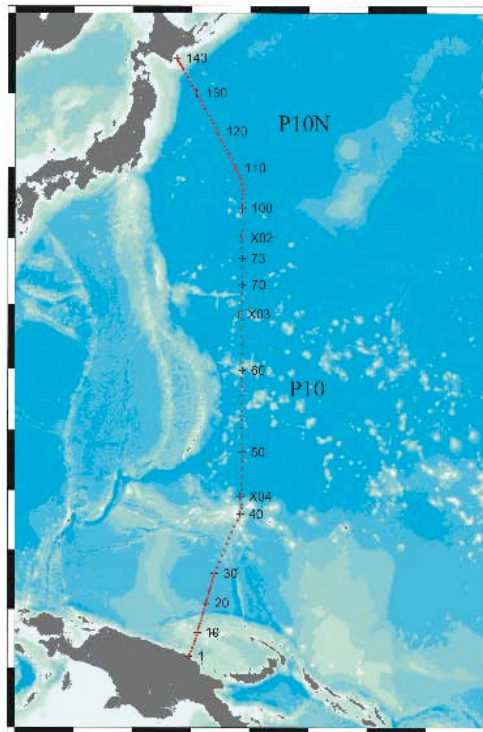
A.   HIGHLIGHTS

A.1.   CRUISE SUMMARY INFORMATION

Section designation	**P10_2005**
Expedition designation (ExpoCode)	**49NZ20050525**
Chief Scientist	**Takeshi Kawano / IORGC / JAMSTEC**
Date	25 MAY 2005 – 2 JUL 2005
Ship	*R/V Marai*
Ports of call	Sekinehama, Japan – Hachinohe, Japan – Guam, U.S.A.
Geographic boundaries	42° 15.20' N 143° 44.01' E 149° 23.31' E 4° 00.90' S
Stations	124
Floats and drifters deployed	2 Argo Floats
Moorings deployed or recovered	0

Chief Scientist Contact Information:

Takeshi Kawano

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CRUISE AND DATA INFORMATION

Links to text locations. Shaded sections are not relevant to this cruise or were not available when this report was compiled

Cruise Summary Information	Hydrographic Measurements
Description of Scientific Program	**CTD Data:**
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Salinities Temperature
Bottle Depth Distributions (Figure)	Oxygens Pressure
Floats and Drifters Deployed	**Bottle Data**
Moorings Deployed or Recovered	Salanity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	13C / 14C

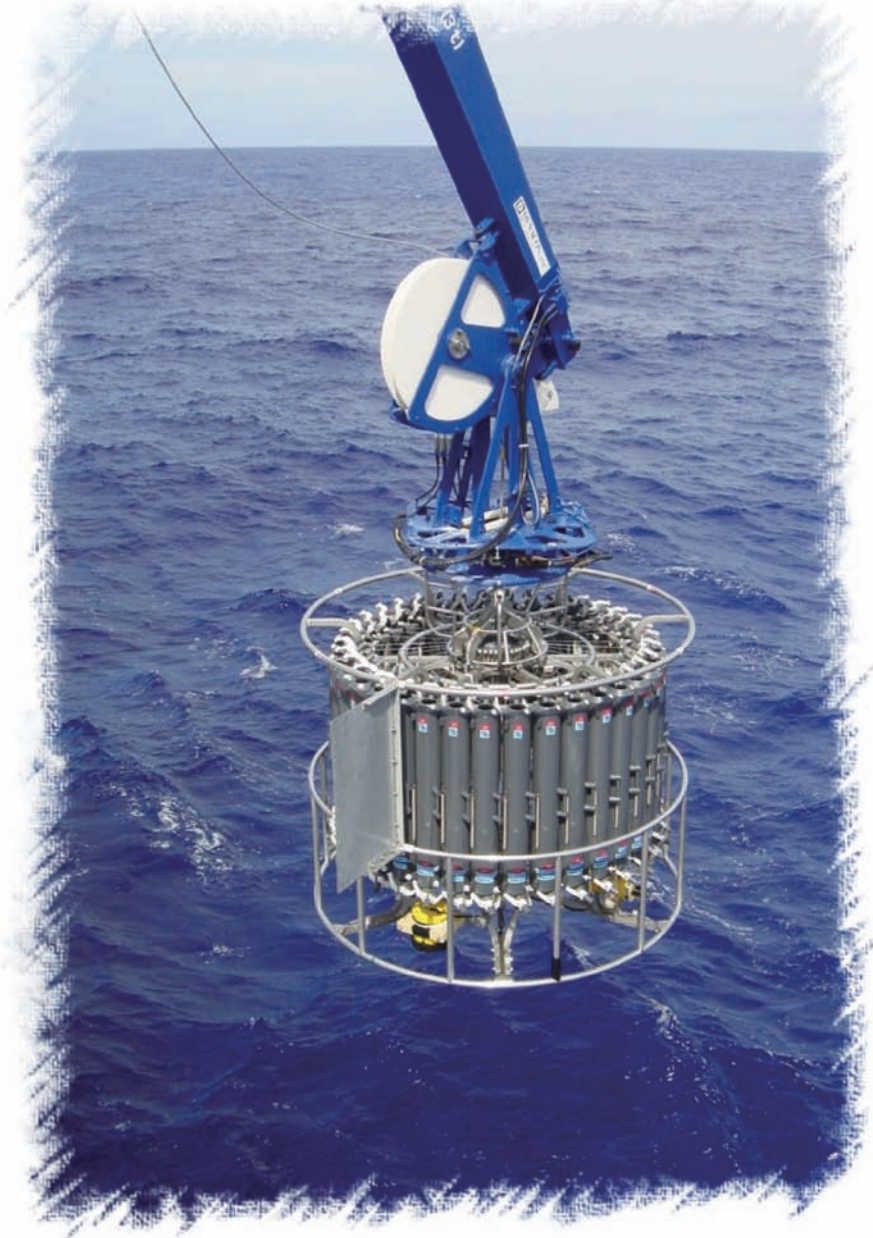| Underway Data Information	References	
Navigation / Bathymetry	Navigation / Bathymetry	pCO$_2$
Acoustic Doppler Current Profiler (ADCP)	Nutrients	DIC
Thermosalinograph	CTD	pH
XBT and/or XCTD	Salanity	CFCs
Meteorological Observations	Oxygen	LADCP
Atmospheric Chemistry Data	Hydrographic Measurements	

Data Processing Notes	Acknowledgments

WHP P10 REVISIT DATA BOOK

Field Activity of JAMSTEC towards International Repeat Hydrography and Carbon Program
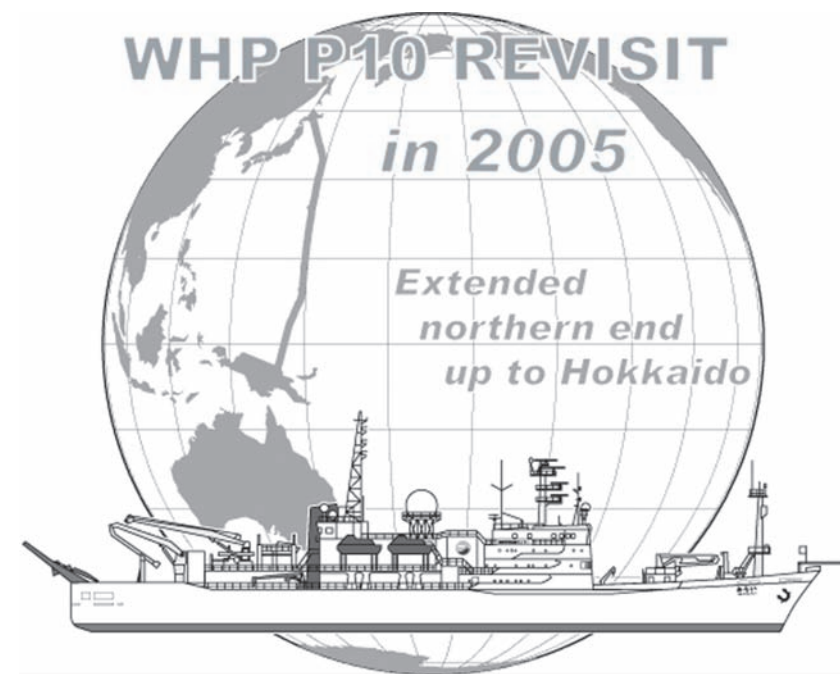
WHP P10 REVISIT

in 2005

Extended
northern end
up to Hokkaido

WHP P10 REVISIT DATA BOOK

Edited by
Takeshi Kawano (JAMSTEC),
Hiroshi Uchida (JAMSTEC)

WHP P10 REVISIT
in 2005

Extended
northern end
up to Hokkaido

Contents

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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E-mail: kawanot@jamstec.go.jp

Ship: R/V MIRAI

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

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

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

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

4° 00.90' S - 42° 15.20' N

Floats and drifters deployed: 2 Argo Floats

Mooring deployed or recovered mooring: NONE

1.2 Cruise Summary

(1) Geographic boundaries

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

(2) Station occupied

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

(3) Sampling and measurements

Water samples were analyzed for salinity, oxygen, nutrients, CFC11, CFC12, CFC113, total alkalinity, DIC and pH. The sampling layers in dbar were 10, 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000, 3250, 3500, 3750, 4000, 4250, 4500, 4750, 5000, 5250, 5500, 5750 and bottom (minus 10 m). Samples for PON, ^{14}C, ^{13}C, ^{15}N, Pu and ^{137}Cs were also collected. The bottle depth diagram is shown in Fig. 1.2.2. Underway measurements of pCO_2, temperature, salinity, oxygen, surface current, bathymetry and meteorological parameters were made along the cruise track. Biological parameters such as chlorophyll a and nitrogen fixation rate were measured at the selected stations.
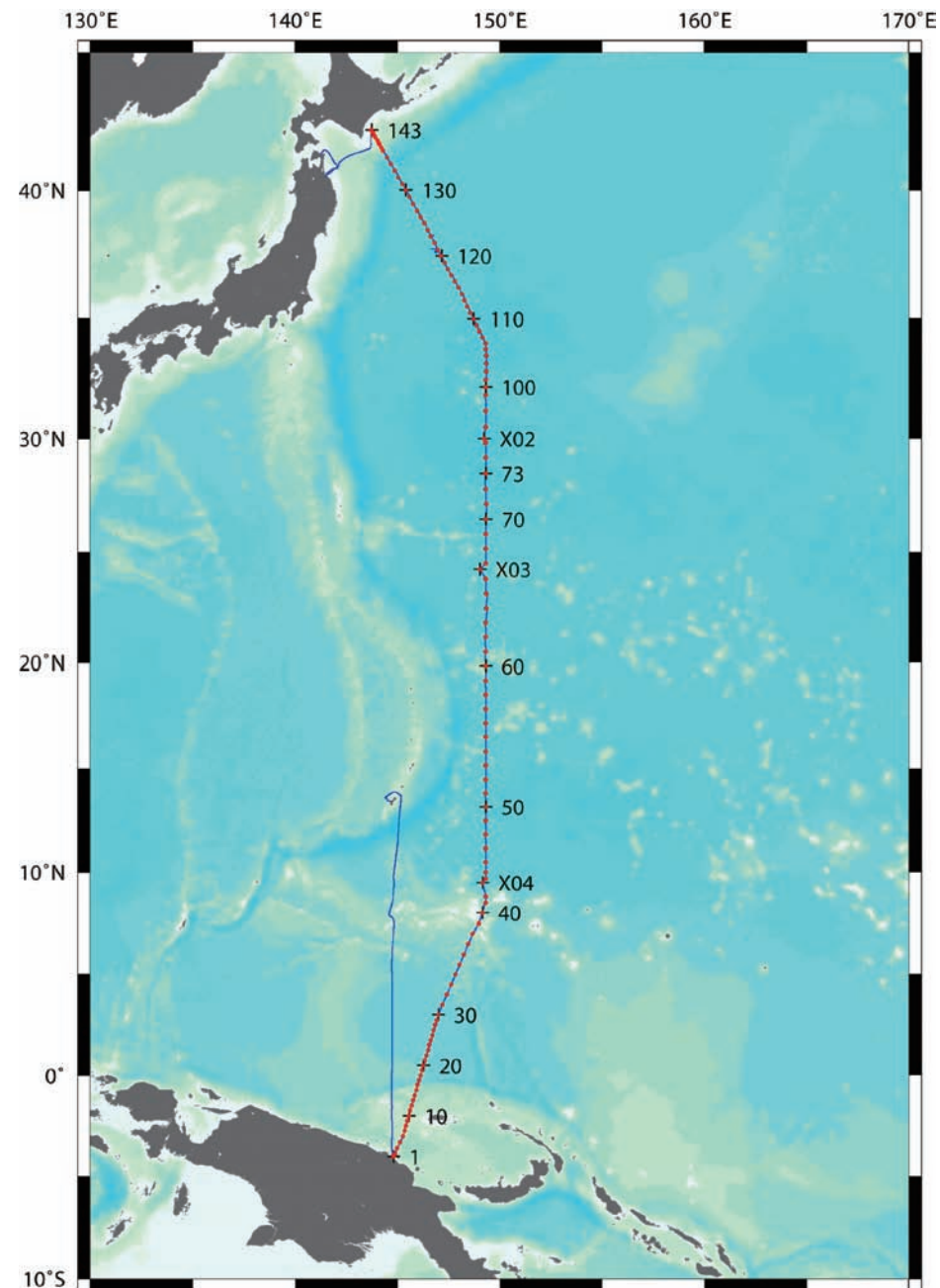
Figure 1.2.1. Cruise track.
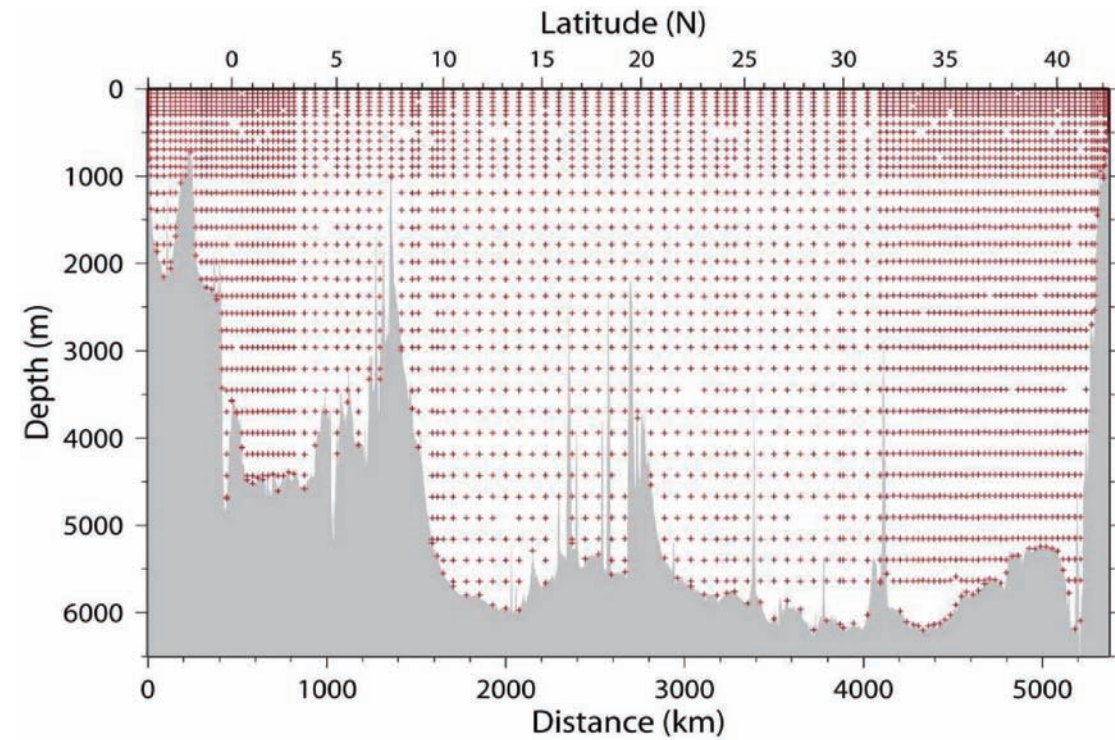
Figure 1.2.2. Bottle depth diagram.

(4) Floats and Drifters deployed

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

Table 1.2.1. Launched positions of the ARGO floats.

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

(5) Moorings deployed or recovered

No mooring was deployed nor recovered during the cruise.

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

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

Table 1.3.1. List of Principal Investigator and Person in Charge on the ship.

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

GODI: Global Ocean Development Inc.

JAMSTEC: Japan Agency for Marine-Earth Science and Technology

MRI: Meteorological Research Institute, Japan Meteorological Agency

MWJ: Marine Works Japan, Ltd.

Univ. Ryukyus: University of the Ryukyus

1.4 Scientific Program and Methods

(1) Objectives of MR05-02 cruise project

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

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

The other objectives of this cruise are as follows;

1) to observe surface meteorological and hydrogical parameters as a basic data of the meteorology and the oceangraphy,

2) to observe sea bottom topography, gravity and magnetic fields along the cruise track to understand the dynamics of ocean plate and the accompanying geophysical activities,

3) to contribute to establishment of data base for model validation,

4) ARGO sensor calibration and its deployment in the western Pacific.

(2) Cruise overview

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

(3) Cruise narrative

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

1.5 Major Problems and Goals not Achieved

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

1.6 List of Participants

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

Table 1.6.1. List of cruise participants.

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

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

2 Underway Measurements

2.1 Navigation and Bathymetry

2 August 2005

(1) Personnel

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

Yasutaka Imai (GODI)

Shinya Okumura (GODI)

Ryo Ohyama (GODI)

(2) Navigation

(2.1) Overview of the equipment

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

(2.2) Data period

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

(3) Bathymetry

(3.1) Overview of the equipment

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

(3.2) System configuration and performance

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

(3.3) Data period

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

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

(3.4) Data processing

(3.4.1) Editing for the navigation data

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

(3.4.2) Sound velocity correction

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

(3.4.3) Gridding

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

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

Degree of polynomial: 1 (tiled plane)

Cleaning

Shallow threshold: 1.000, sigma = 68.26 [%]

Deep threshold: 1.000, sigma = 68.26 [%]

Minimum residual required for rejection: 10.000 [m]

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

Matrix size: 5×5

Number of nearneighbors: 18

Reference

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

2.2 Surface Meteorological Observation

27 September 2006

(1) Personnel

Kunio Yoneyama (JAMSTEC)

Yasutaka Imai (GODI)

Shinya Okumura (GODI)

Ryo Ohyama (GODI)

Norio Nagahama (GODI)

(2) Objective

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

(3) Methods

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

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

SOAR system was designed and constructed by the Brookhaven National Laboratory (BNL), USA, for an accurate measurement of solar radiation on the ship. Details of SOAR can be found at http://www.gim.bnl.gov/soar/.

SOAR consists of 1) Portable Radiation Package (PRP) that measures short and long wave downwelling radiation, 2) Zeno meteorological system that measures pressure, air temperature, relative humidity, wind speed/direction, and rainfall, and 3) Scientific Computer System (SCS) developed by the National Oceanic and Atmospheric Administration (NOAA), USA, for data collection, management, real-time monitoring, and so on. Information on sensors used here is listed in Table 2.2.2.

Table 2.2.1. Instruments and locations of SMET.

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

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

[2] There are two thermometers at starboard and port sides.

Table 2.2.2. Instruments and locations of SOAR.

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

(4) Data processing and data format

All raw data were recorded every 6 seconds. Datasets produced here are 1-minute mean values (time stamp at the beginning of the average). They are simple mean of 8 samples (10 samples minus maximum/minimum values) to exclude singular values. Liner interpolation onto missing values was applied only when their interval is less than 4 minutes.

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

No adjustment to sea level values is applied except pressure data.

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

Missing values are expressed as "9999".

(5) Data Quality

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

T/RH sensor:

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

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

Temperature (°C)

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

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

Relative Humidity (%)

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

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

Pressure sensor:

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

Anemometer:

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

Post-calibration date:	Sep. 7, 2005
Starting threshold wind speed:	0.9 m/sec for clockwise
	0.9 m/sec for counter-clockwise
Wind direction check:	better than ± 2 °

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

Precipitation:

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

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

Radiation sensors:

Short wave and long wave radiometers were calibrated by the manufacturer, Remote Measurement and Research

Company, USA, prior to the cruise.

(6) Data periods

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

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

(7) Point of contact

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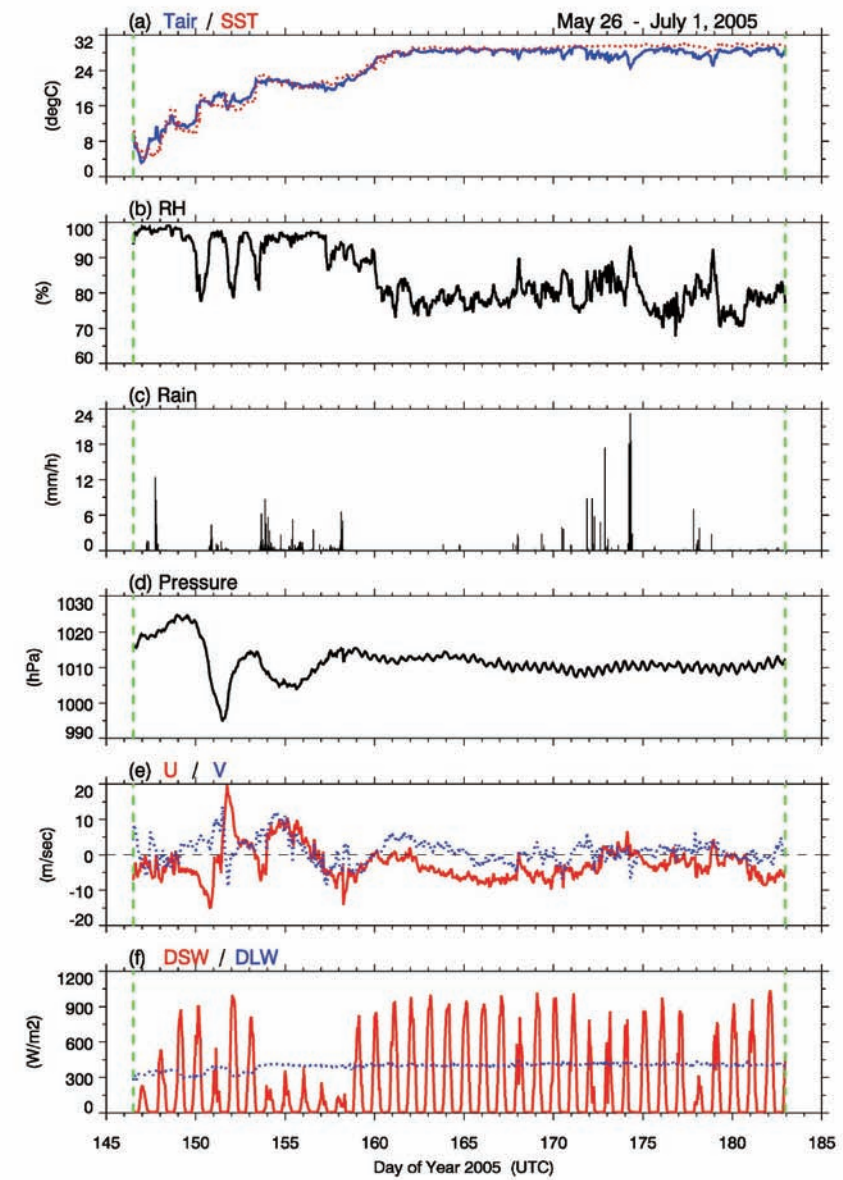
Figure 2.2.1. Time series of (a) air and sea surface temperature, (b) relative humidity, (c) precipitation, (d) pressure, (e) zonal and meridional wind components, and (e) short and long wave radiation. Day 146 corresponds to May 26, 2006.

2.3 Thermosalinograph and related measurements

22 January 2004

(1) Personnel

Takayoshi Seike (MWJ)

Takeshi Kawano (JAMSTEC)

(2) Objective

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

(3) Methods

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

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

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

a) Temperature and Salinity sensors

SEACAT THERMOSALINOGRAPH

Model: SBE-21, Sea-Bird Electronics, Inc.

Serial number: 2126391-2641

Measurement range: Temperature –5 to +35 °C

Salinity 0 to 6.5 S m^{-1}

Accuracy: Temperature 0.01 °C 6 month^{-1}

Salinity 0.001 S m^{-1} month^{-1}

Resolution: Temperatures 0.001 °C

Salinity 0.0001 S m^{-1}

b) Bottom of ship thermometer

Model: SBE 3S, Sea-Bird Electronics, Inc.

Serial number: 032175

Measurement range: –5 to +35 °C

Resolution: ± 0.001 °C

Stability: 0.002 °C year^{-1}

c) Dissolved oxygen sensor

Model: 2127A, Oubisufair Laboratories Japan Inc.

Serial number: 44733

Measurement range: 0 to 14 ppm

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

Stability: 1 % month^{-1}

d) Fluorometer

Model: 10-AU-005, Turner Designs

Serial number: 5562 FRXX

Detection limit: 5 ppt or less for chlorophyll-a

Stability: 0.5 % month^{-1} of full scale

e) Particle Size sensor

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

    Serial number: P5024

    Measurement range: 0.02681 mm to 6.666 mm

    Accuracy: ± 10 % of range

    Reproducibility: ± 5 %

    Stability: 5 % week^{-1}

f) Flow meter

    Model: EMARG2W, Aichi Watch Electronics Ltd.

    Serial number: 8672

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

    Accuracy: ± 1 %

    Stability: ± 1 % day^{-1}

The monitoring periods (UTC) are listed below.

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

(4) Comparison of salinity data with sampled salinity

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

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

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

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

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

2.4 Underway pCO₂

(1) Personnel

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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 pCO₂ (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 pCO₂ 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 (xCO₂a), 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(ClO₄)₂). The flow rate of the air was 500 ml min^{-1}. To measure surface seawater concentrations of CO_2 in dry air (xCO₂s), 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 xCO₂a. 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), xCO₂a (twice), xCO₂s (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 xCO₂s were adjusted based on Gordon and Jones (1973), although the temperature increases were slight, being ~ 0.3 °C.

We checked values of xCO₂a and xCO₂s by examining signals of NDIR on recorder charts, and by plotting the xCO₂a and xCO₂s 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 $\times$ 90 bin from about 23 m to 735 m in depth. Typical sampling interval was 3.5 seconds. Bottom track mode was added in the northernmost shallow water region. GPS gave navigation data. Two kinds of compass data were recorded. One compass was the ship's gyrocompass, which is connected the ADCP system directory, and its data were stored with the ADCP data. Current field based on the gyrocompass was used to check the operation and the performance on board. Another compass used was Inertial Navigation Unit (INU), DRU-H, Honeywell Inc. Its accuracy is 1.0 mile (about 0.056 degree) and had already set on zero bias before the beginning of the cruise. The INU compass data were stored independently, and combined with the ADCP data after the cruise.

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

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

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

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

(4) Data Processing

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

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

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

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

(5) Current distributions observed

Current fields at 100 m is shown in Fig 6 (p.97). The major currents were clearly observed by the ADCP; the Oyashio, the Kuroshio Extension and the equatorial currents. The Oyashio appeared near the southern coast off the Hokkaido. The southern westward current was barotropic and it penetrated the deepest layer measured. The Kuroshio Extension existed around 36 °N across the ship track. The maximum speed near the sea surface was 1.8 m/s at 36° 22' N. The southern shift of the maximum speed with depth was observed; the maximum speed at 600 m depth was 0.5 m/s at 35° 52' N. The eddy-like flow pattern appeared in the mixed water region between the Oyashio and the Kuroshio Extension. The westward flow was dominant in the south of the Kuroshio Extension. The flow was almost barotropic in the subtropical region. However, the flow showed baroclinic feature in the region between 5 °N and

20 °N. The North Equatorial Current was seen around 10 °N. The Equatorial Counter Current was seen between 1 °N and 6 °N. The eastward flow of the Equatorial Under Current distributed just north of the equator, whose core appeared at 240 m at 1° 53' N with a zonal speed of 0.79 cm/s. On the other hand, the core of the meridional component existed around the equator clearly. It might be an eddy or a meander feature of the current. The South Equatorial Current was seen from the equator to the southern hemisphere. The strong current along the coast was observed near the coast of the Papua New Guinea.

(6) Data Structure

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

[data structure of the data set A]

Line 1: header 1

    Column 01-10: cruise code

    Column 12-15: WHP line name

    Column 17-27: analyzed site

Line 2: header 2

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

    Column 12-16: time (hh:mm)

Line 3: header 3

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

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

Line 4-38: flow data in each depth level

    Column 01-05: depth (m)

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

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

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

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

Line 1: header 1

    Column 01-10: cruise code

    Column 12-15: WHP line name

    Column 17-27: analyzed site

Line 2: header 2

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

    Column 12-16: time (hh:mm)

Line 3: header 3

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

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

Line 4-38: flow data in each depth level

    Column 01-05: depth (m)

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

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

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

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

3 Hydrographic Measurement Techniques and Calibrations

3.1 CTD/O₂ Measurements

25 October 2005

(1) Personnel

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(2) Winch arrangements

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

(3) Overview of the equipment

The CTD system, SBE 911plus system (Sea-Bird Electronics, Inc., USA), is a real time data system with the CTD data transmitted from a SBE 9plus underwater unit via a conducting cable to the SBE 11plus deck unit.

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

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

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

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

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

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

Summary of the system used in this cruise

Deck unit:

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

Under water unit:

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

Temperature sensor:

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

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

Conductivity sensor:

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

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

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

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

Oxygen sensor:

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

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

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

Pump:

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

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

Altimeter:

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

Deep Ocean Standards Thermometer:

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

Fluorometer:

Seapoint sensors, Inc., S/N 2579

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

Carousel Water Sampler:

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

Water sample bottle:

General Oceanics, Inc., 12-litre Niskin-X (no TEFLON coating)
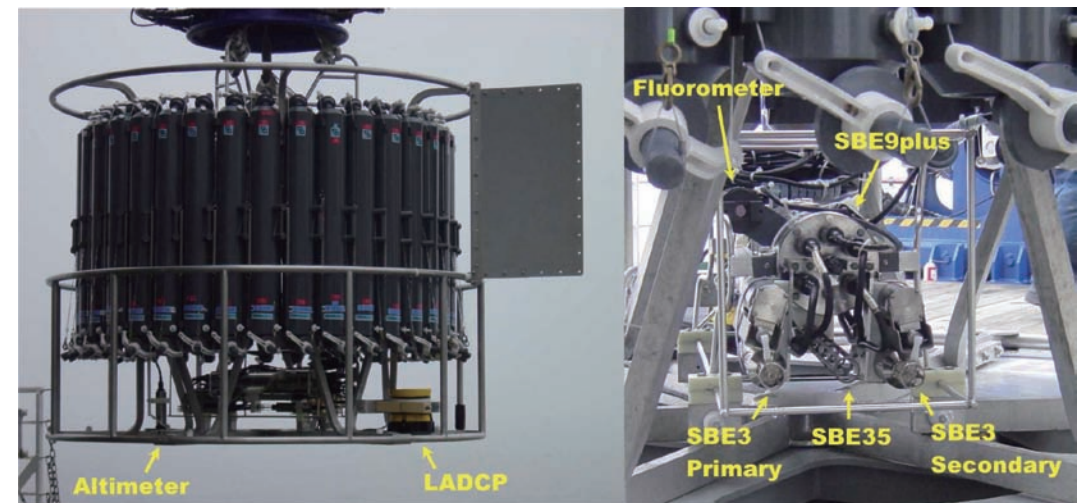
Figure 3.1.1. The CTD package (left) and the SBE 35 position in regard to the SBE 3 temperature sensors (right).

(4) Pre-cruise calibration

(4.1) Pressure

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

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

S/N 0677, 2 July 2002

$c_1 = -62072.94$

$c_2 = -1.176956$

$c_3 = 1.954420e{-}02$

$d_1 = 0.027386$

$d_2 = 0.0$

$t_1 = 30.05031$

$t_2 = -4.744833e{-}04$

$t_3 = 3.757590e{-}06$

$t_4 = 3.810700e{-}09$

$t_5 = 0.0$

Pressure coefficients are first formulated into

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

$d = d_1 + d_2 * U$

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

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

U (°C) = M * (12 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

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

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

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

S/N 0677, 13 April 2005

slope = 0.9998953

offset = –0.44425

The drift-corrected pressure is computed as

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

Result of the pressure sensor calibration against the dead weight piston gauge is shown in Figure 3.1.2. Time drift of the pressure sensor based on the offset and the slope of the calibrations is also shown in Figure 3.1.3.
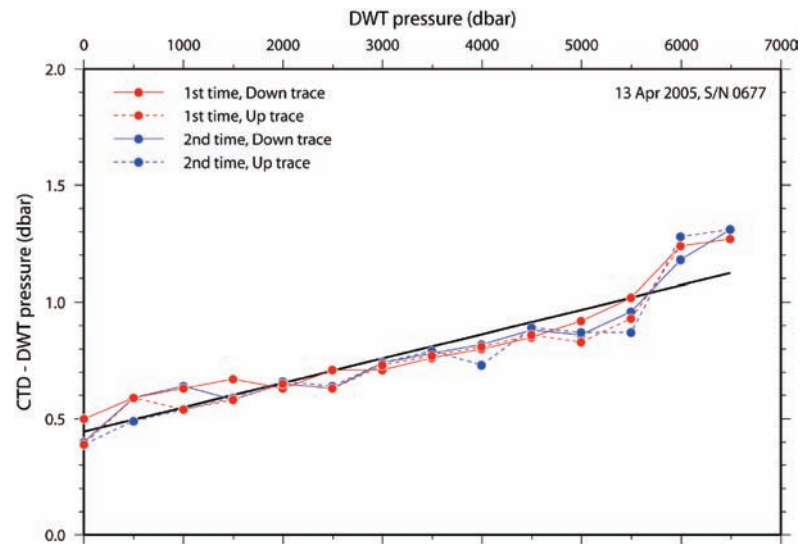
Figure 3.1.2. The residual pressures between the dead weight piston gauge and the CTD pressure (S/N 0677). The calibration line (black line) is also shown.
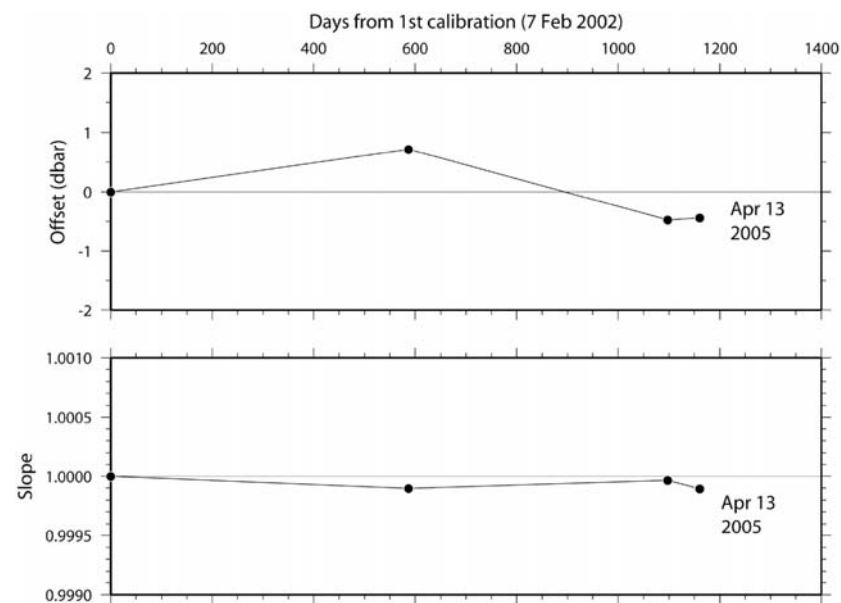
Figure 3.1.3. Pressure sensor (S/N 0677) time drift of offset (upper panel) and slope (lower panel) based on laboratory calibrations.

(4.2) Temperature (SBE 3)

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

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

S/N 1464 (primary), 19 April 2005

$g = 4.84385804e{-}03$

$h = 6.80766786e{-}04$

$i = 2.69831319e{-}05$

$j = 2.13061451e{-}06$

$f_0 = 1000.000$

S/N 1525 (secondary), 19 April 2005

$g = 4.84608198e{-}03$

$h = 6.75358139e{-}04$

$i = 2.65523364e{-}05$

$j = 2.13525896e{-}06$

$f_0 = 1000.000$

Temperature (ITS-90) is computed according to

Temperature (ITS-90) =

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

where f is the instrument frequency (kHz).

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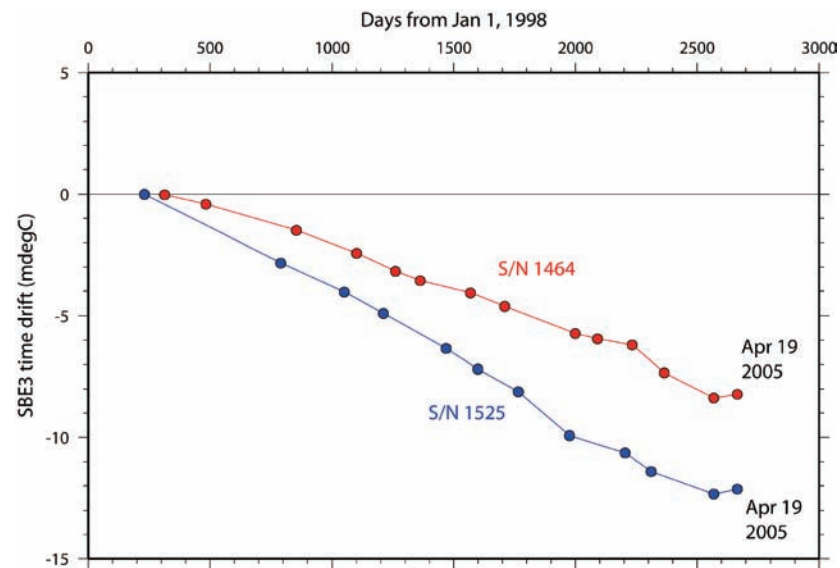
Figure 3.1.4. Time drift of SBE 3 temperature sensors (S/N 1464 and S/N 1525) based on laboratory calibrations performed by SBE, Inc.

(4.3) Conductivity (SBE 4)

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

stability of 0.0003 S/m/month and resolution of 0.00004 S/m at 24 samples per second.

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

S/N 1203 (primary), 19 April 2005

g = –4.05393563e+00

h = 4.93901550e–01

i = 1.74707654e–05

j = 2.56674141e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

S/N 3036 (secondary), 20 January 2005

g = –1.03104164e+01

h = 1.42680631e+00

i = 2.61243729e–04

j = 5.17689837e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

S/N 1088 (secondary), 10 March 2005

g = –4.21020837e+00

h = 5.77013782e–01

i = –1.87512042e–04

j = 4.10775826e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

S/N 2854 (secondary), 22 June 2004

g = –1.02670783e+01

h = 1.41649193e+00

i = –3.19882205e–04

j = 7.82222198e–05

CPcor = –9.57e–08 (nominal)

CTcor = 3.25e–06 (nominal)

Conductivity of a fluid in the cell is expressed as:

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

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 / $NCYCLES^{1/2}$ in μK. In this cruise NCYCLES was set to 4 and the rms noise is estimated to be 0.04 m°C.

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

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

Time drift of the SBE 35 based on the fixed point calibrations is shown in Figure 3.1.5.
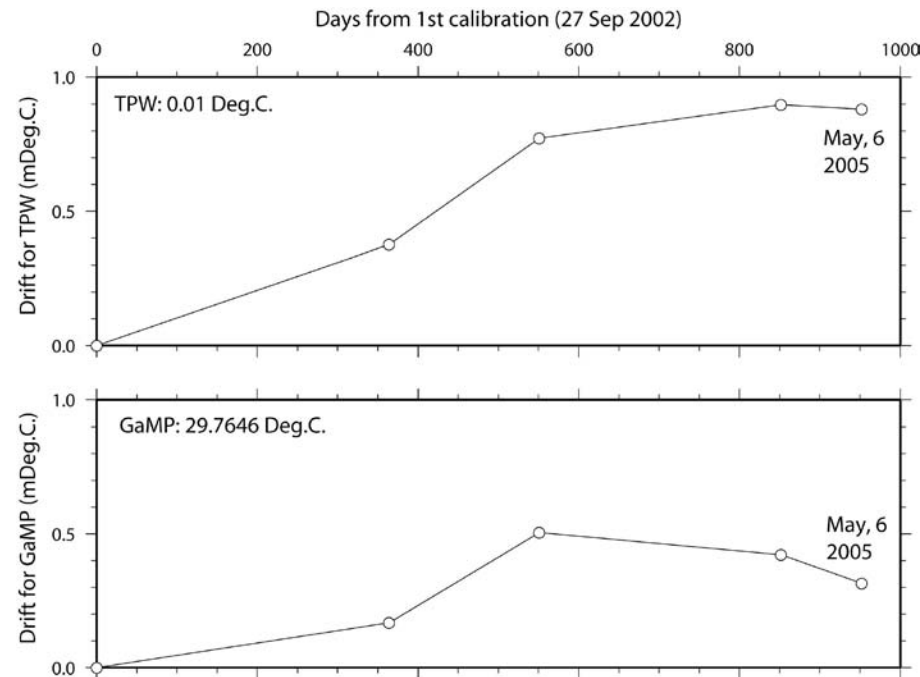
Figure 3.1.5. SBE35 (S/N 0045) time drift based on laboratory fixed point calibrations (triple point of water, TPW and gallium melt point, GaMP) performed by SBE, Inc.

(4.6) Altimeter

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

± 0.4 cm total distance. Since the total travel time is divided by two, the jitter error is ± 0.2 cm.

The following scale factors were used in SEASOFT:

S/N 1157

FSVolt * 300 / FSRange = 15

Offset = 0.0

(4.7) Fluorometer

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

The following coefficients were used in SEASOFT:

S/N 2579

Gain = 30

Offset = 0.0

Chlorophyll-a concentration is computed as

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

(5) Data collection and processing

(5.1) Data collection

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

was mounted horizontally in a 36-position carousel frame.

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

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

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

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

Data acquisition software

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

(5.2) Data collection problems

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

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

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

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

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

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

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

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

(5.3) Data processing

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

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

Data processing software

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

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

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

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

ALIGNCTD converted the time-sequence of conductivity and oxygen sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9plus CTD with the ducted temperature and conductivity sensors and a 3,000-rpm pump, typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit was set to advance the primary and the secondary conductivity for 1.73 scans (1.75/24 = 0.073 seconds). Oxygen data are also systematically delayed with respect to depth mainly because of the long time constant of the oxygen sensor and of an additional delay from the transit time of water in the pumped plumbing line. This delay was compensated by 6 seconds advancing oxygen sensor output (oxygen voltage) relative to the temperature.

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

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

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

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

SECTION selected a time span of data based on scan number in order to reduce a file size. The minimum number was set to be the start time when the CTD package was beneath the sea-surface after activation of the pump. The maximum number was set to be the end time when the package came up from the surface. Data for estimation of the CTD pressure drift were prepared before SECTION.

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

DERIVE was used to compute oxygen.

BINAVG averaged the data into 1-dbar pressure bins. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center value plus and minus half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data record could exist every dbar.

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

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

Remaining spikes in the salinity data were manually eliminated for the raw data. When number of data in the 1-dbar-pressure bin was less than 10, the data of the bin was not used. For remaining spikes in the Fluorometer data near surface, quality flags of the Fluorometer data were set to 4. Remaining spikes in the oxygen data were eliminated for a 1-dbar averaged data when the difference between original data and low-pass (7-dbar median) filtered data was greater than or equal to 0.003 (voltage) at the pressure level greater or equal to 1,200 dbar (1,150 dbar for station X03). The data gap over 1-dbar was linearly interpolated with a quality flag of 6.

(6) Post-cruise calibration

(6.1) Pressure

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

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

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

S/N	Mean deck Pressure (dbar)	Standard deviation (dbar)	Residual pressure (dbar)	Estimated offset (dbar)
0677	–0.42	0.05	–0.02	–0.40
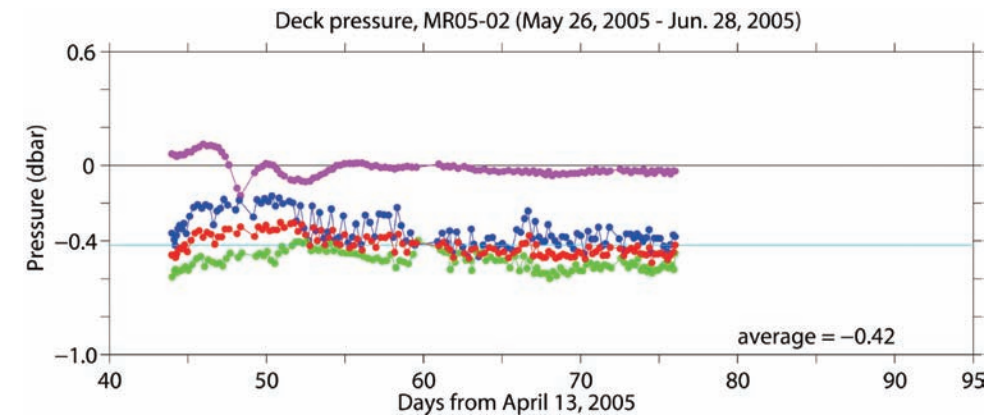
Figure 3.1.6. Time series of the CTD deck pressure. Pink dot indicates atmospheric pressure anomaly. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dot indicates an average of the pre- and the post-cast deck pressures.

(6.2) Temperature

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

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

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

Slope = 1.000011

Offset = –0.000973

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

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

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

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

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

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

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

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

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

Table 3.1.3. Calibration coefficients for the CTD temperature sensors.

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

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

S/N	Pressure >= 1,950 dbar			Pressure < 1,950 dbar		
	Num	Mean (m°C)	Sdev (m°C)	Num	Mean (m°C)	Sdev (m°C)
1464	1586	0.00	0.14	2171	−0.35	8.3
1525	1583	0.00	0.13	2153	−0.52	6.3
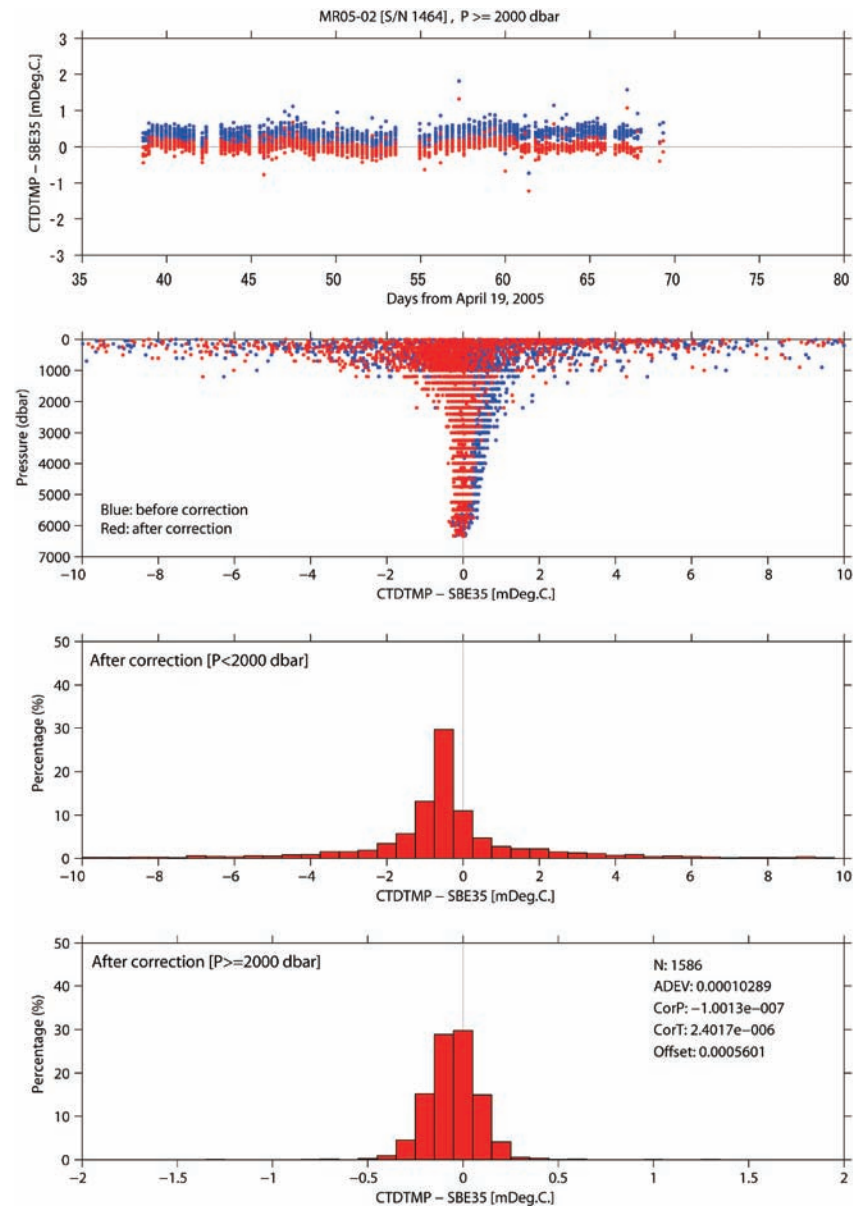
Figure 3.1.7. Difference between the CTD temperature (primary) and the Deep Ocean Standards thermometer (SBE 35). Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Lower two panels show histogram of the difference after the calibration.
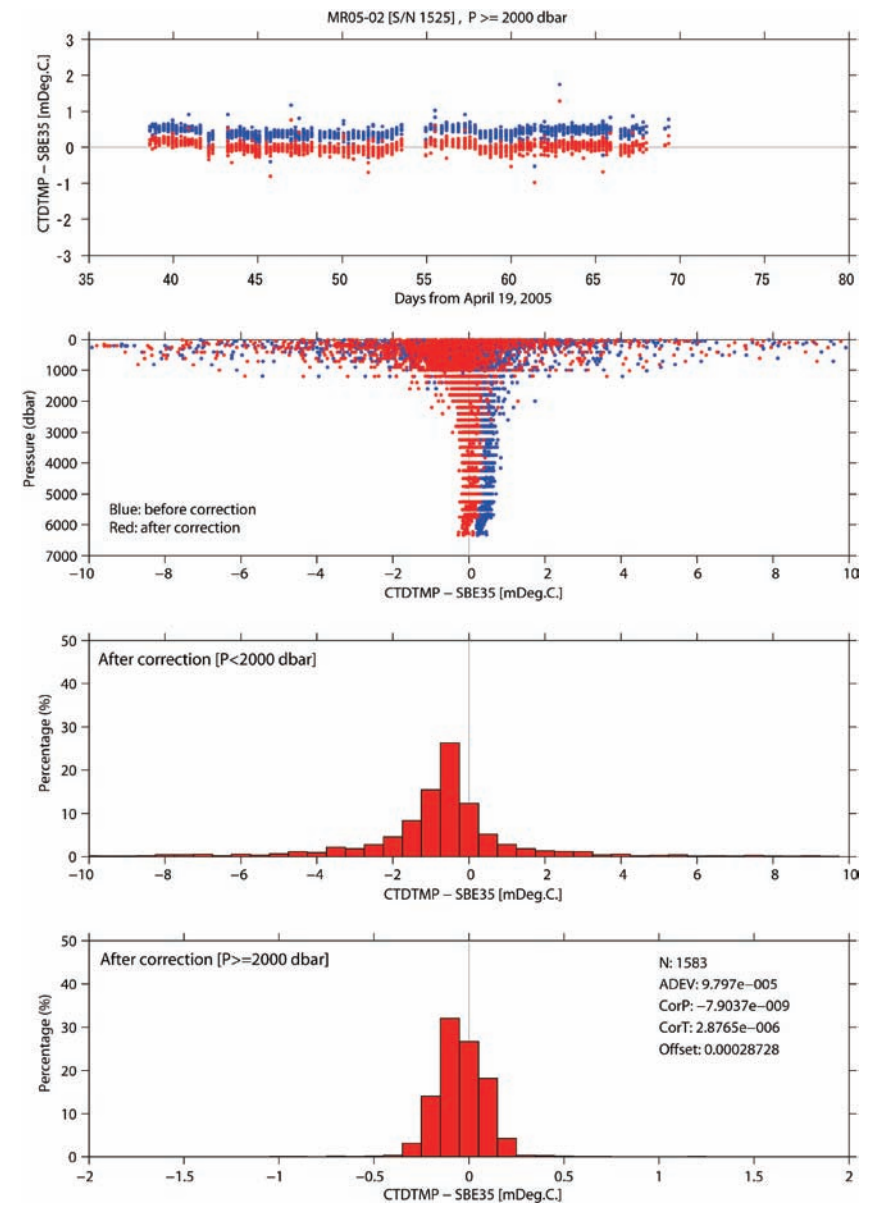
Figure 3.1.8. Same as Figure 3.1.7, but for the secondary CTD temperature.

(6.3) Salinity

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

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

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

where Grad is vertical oxygen gradient in μmol kg^{-1} dbar^{-1}, P is pressure in dbar. Gr and PR are threshold of the

oxygen gradient (0.3 μmol kg^{-1} dbar^{-1}) and pressure (1,000 dbar), respectively. When oxygen gradient is small (large)

and pressure is large (small), the weight is large (small) at maximum (minimum) value of 16 (1). The oxygen gradient

is calculated using up-cast CTD oxygen data. The up-cast CTD oxygen data is low-pass filtered with a 3-point

(weights are 1/4, 1/2, 1/4) triangle filter before the calculation.

The calibration is basically performed for the output from secondary oxygen sensor. On stations P10N_101 and

P10N_100, data quality of the secondary oxygen sensor were bad, so the data from the primary oxygen sensor are

used for the stations. The down-cast CTD data sampled at same density of the up-cast CTD data created by the

software module ROSSUM are used after the post-cruise calibration for the CTD temperature and salinity.

The coefficients are basically determined on each station. Some stations, especially on shallow stations, are

grouped for determining the calibration coefficients. The results of the post-cruise calibration for the CTD oxygen are

summarized in Table 3.1.7 and shown in Figure 3.1.10. And the calibration coefficients and number of the data used

for the calibration are listed in Table 3.1.8.

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

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

Table 3.1.8. Calibration coefficients for the CTD oxygen.

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

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

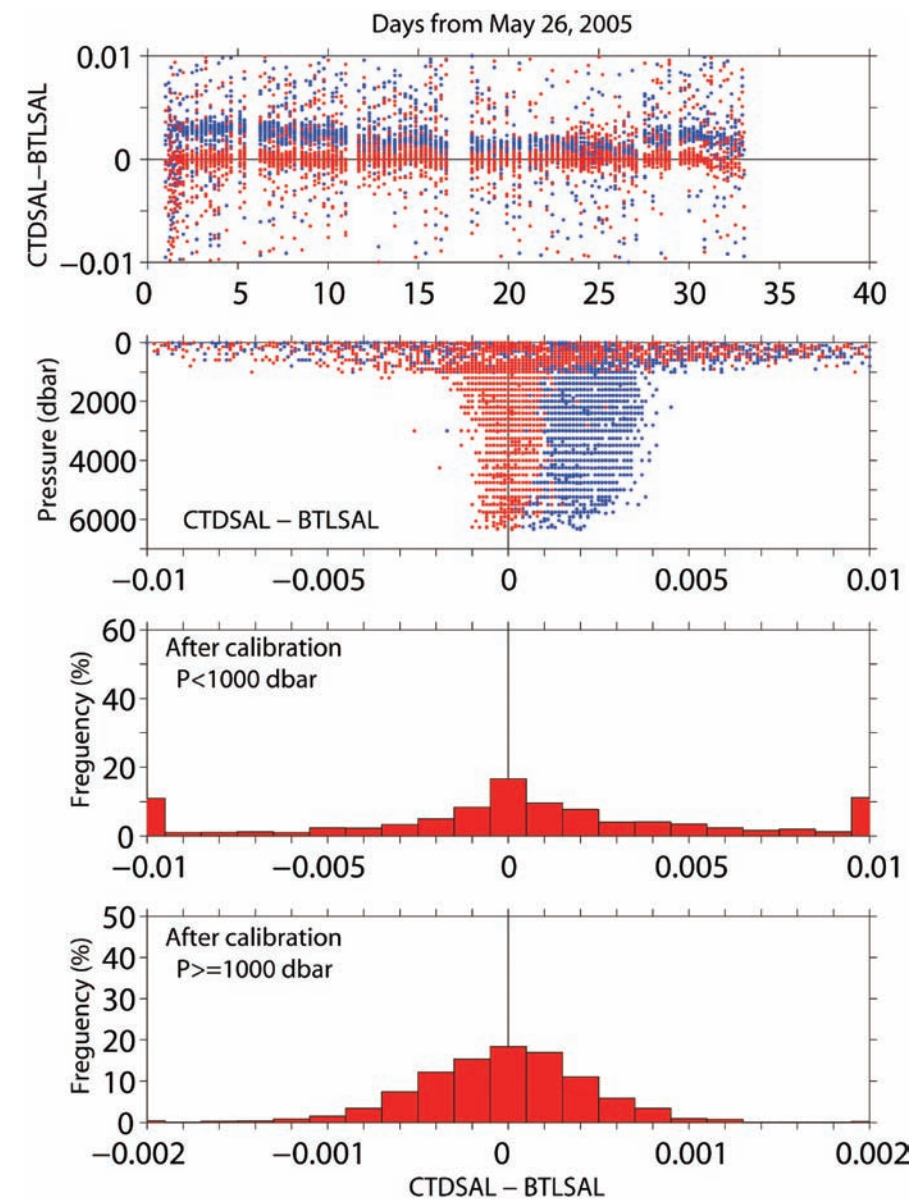Figure 3.1.10. Difference between the CTD oxygen and the bottle oxygen. Blue and red dots indicate before and after the post-cruise calibration using the bottle oxygen data, respectively. Lower two panels show histogram of the difference after the calibration.

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

3.2 Salinity

13 October 2006

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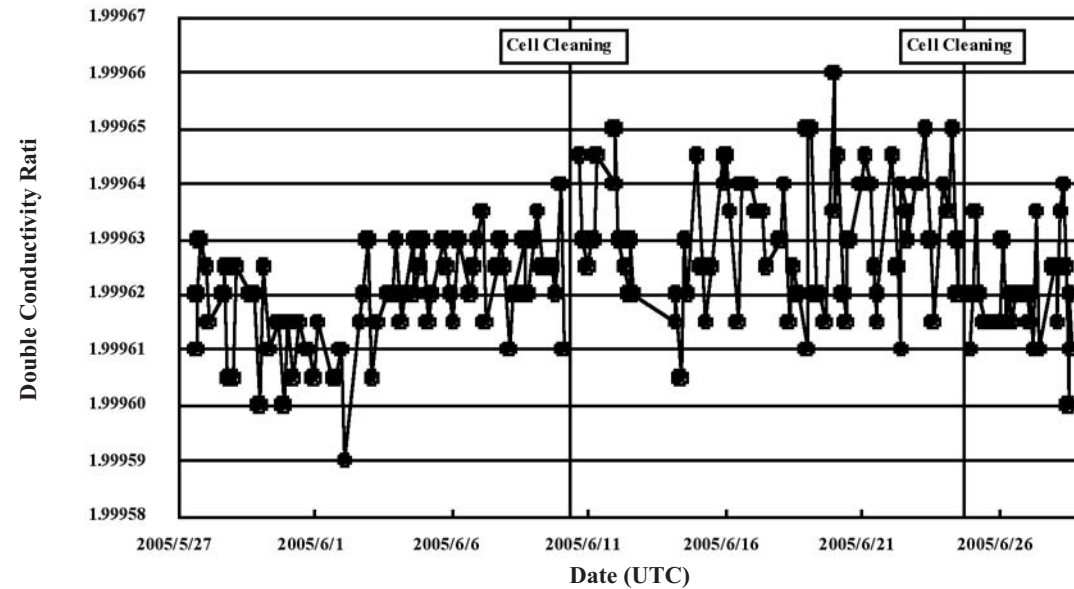
Figure 3.2.1. The history of double conductivity ratio of the Standard Seawater batch P145.

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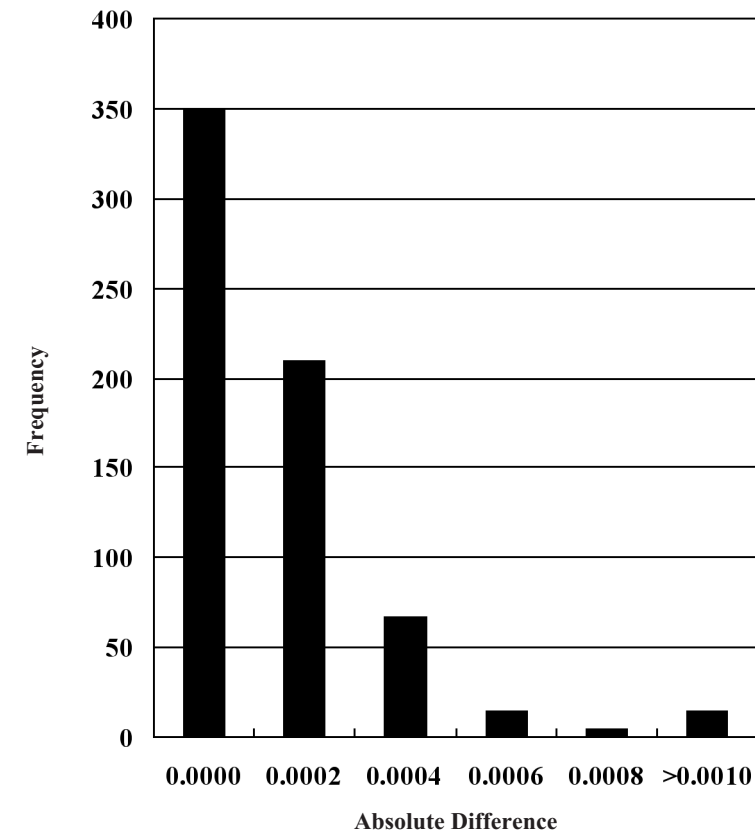
Figure 3.2.2 (a). The histogram of the absolute difference between replicate samples.
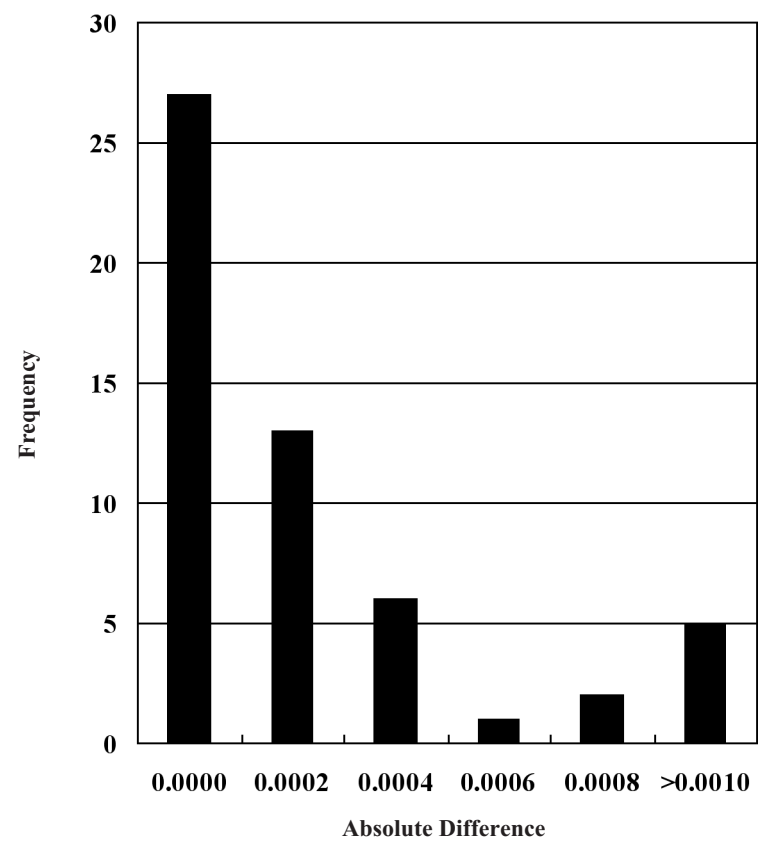
Figure 3.2.2 (b). The histogram of the absolute difference between duplicate samples.

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Sci., 36, 25 pp., 1981

3.3 Oxygen

17 October 2006

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(2) Objectives

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

(3) Regent

Pickling Reagent I: Manganous chloride solution (3M)

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

Sulfuric acid solution (5M)

Sodium thiosulfate (0.025M)

Potassium iodate (0.001667M)

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

(4) Instruments

Burette for sodium thiosulfate;

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

Burette for potassium iodate;

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

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

(5) Seawater Sample

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

(6) Sample measurement

At least two hours after the re-shaking, the pickled samples were measured on board. A magnetic stirrer bar and 1 cm^3 sulfuric acid solution were added to the sample flask and stirring began. Samples were titrated by with sodium thiosulfate solution whose molarity was determined by potassium iodate solution (section 3.3.6). Temperature of sodium thiosulfate during titration was recorded by a thermometer. During this cruise we measured dissolved oxygen concentration using two sets of the titration apparatus, DOT-1 and DOT-2. Dissolved oxygen concentration (μmol kg^{-1}) was calculated by sample temperature during the sampling, CTD salinity, flask volume, and titrated volume of the sodium thiosulfate solution.

(7) Standardization

Concentration of sodium thiosulfate titrant (ca. 0.025M) was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130 °C. 1.7835 g potassium iodate accurately weighed An acculately weighted 1.7835 g of potassium iodate was dissolved in deionized water and diluted to final volume of 5 dm³ in a calibrated volumetric flask (0.001667M). 10 cm³ of the standard potassium iodate solution was added to a flask using a volume-calibrated dispenser. Then 90 cm³ of deionized water, 1 cm³ of sulfuric acid solution, and 0.5 cm³ 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 cm³) and II (0.5 cm³) 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 cm³ of the standard potassium iodate solutions were added to two flasks respectively. Then 100 cm³ of deionized water, 1 cm³ of sulfuric acid solution, and 0.5 cm³ 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 cm³ of KIO₃) titrated volume of the sodium thiosulfate and the second (2 cm³ of KIO₃) 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 cm³, respectively.

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

Date	KIO3		DOT-1 (cm³)			DOT-2 (cm³)			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 cm³ of the standard potassium iodate solution and 100 cm³ of deionized water were added to two flasks. 1 cm³ of sulfuric acid solution and 0.5 cm³ 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 cm³ of sulfuric acid solution, and 1.0 cm³ of pickling reagent solution II and I each) was added. The reagent blank was determined by difference between the first (2 cm³ of the total reagent volume added) titrated volume of the sodium thiosulfate and the second (4 cm³ 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.
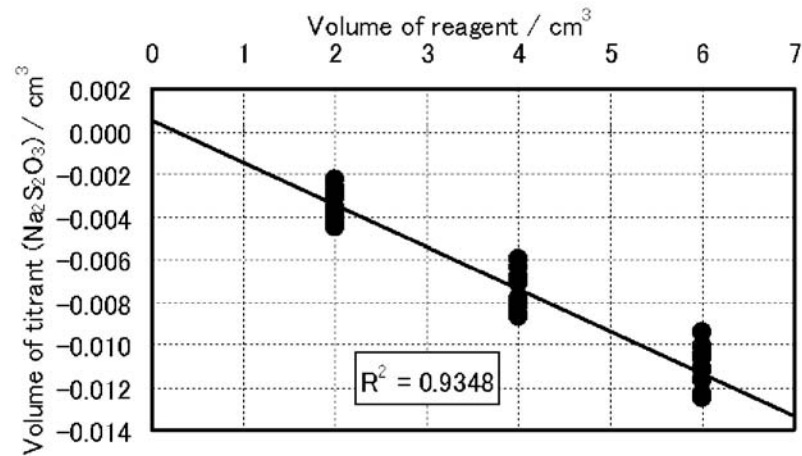
Figure 3.3.1. Blank (cm³) due to redox species apart from oxygen in the reagents.

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 cm³, suggesting that about 0.02 μmol of reductants was contained in every 2 cm³ 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 cm³ 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 cm³) without the pickling. Then 1 cm³ of the standard potassium iodate solution, 1 cm³ of sulfuric acid solution, and 0.5 cm³ of pickling reagent solution II and I each were added to the flask in order. Additionally, a flask contained 1 cm³ of the standard potassium iodate solution, 100 cm³ of deionized water, 1 cm³ of sulfuric acid solution, and 0.5 cm³ 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 | | | Station: P10-019 | | |
| 30.5 °N / 149.3 °E | | | 0.3 °N / 146.2 °E | | |
Sample No. (Niskin No.)	CTD Pres. dbar	Sample blank µmol kg^{-1}	Sample No. (Niskin No.)	CTD Pres. dbar	Sample blank µmol kg^{-1}
5	51	0.5	35	51	0.4
33	151	0.6	33	150	0.7
31	249	0.6	31	251	0.7
29	402	0.7	29	401	0.9
27	602	0.6	27	601	0.7
25	800	0.6	25	801	0.7
23	1001	0.6	23	1001	0.7
21	1400	0.7	21	1400	0.7
17	2200	0.7	19	1802	0.7
15	2599	0.7	17	2200	0.7
13	3000	0.7	15	2600	0.7
11	3499	0.6	13	2999	0.7
9	4002	0.7	11	3499	0.7
7	4502	0.7	1	3770	0.9
5	4999	0.7			
3	5500	0.7			
	6251	0.7			

(11) Replicate sample measurement

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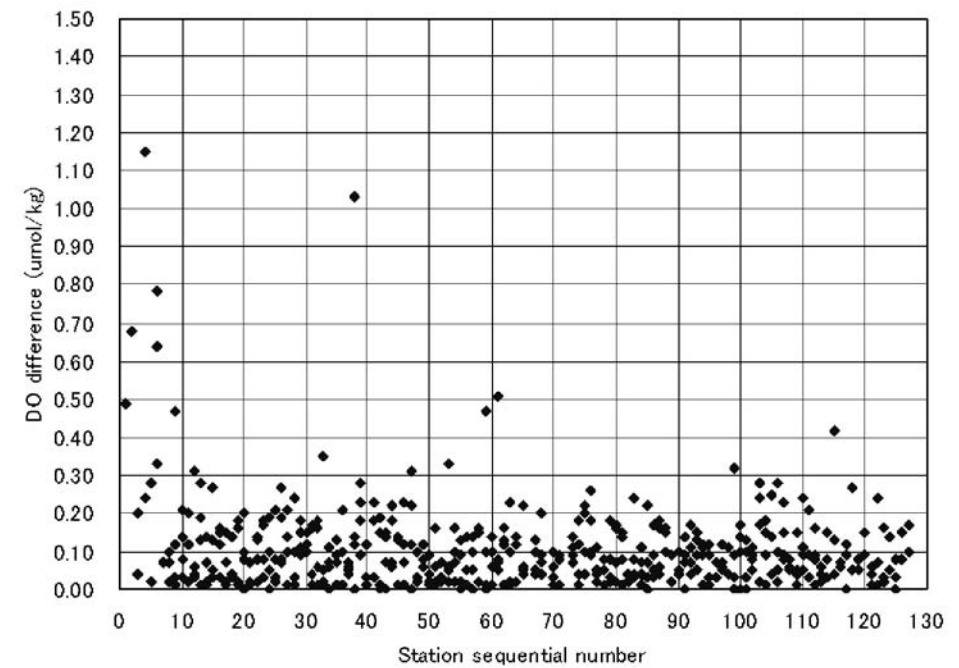
Figure 3.3.2. Difference in the replicate measurements against station sequential number.

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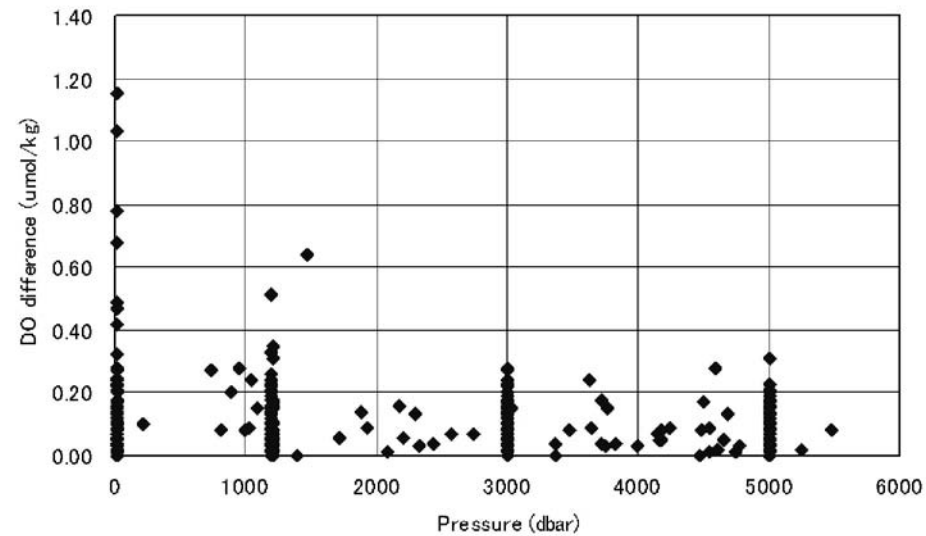
Figure 3.3.3. Difference in the replicate measurements against sampling depth (pressure).

(12) Duplicate sample measurement

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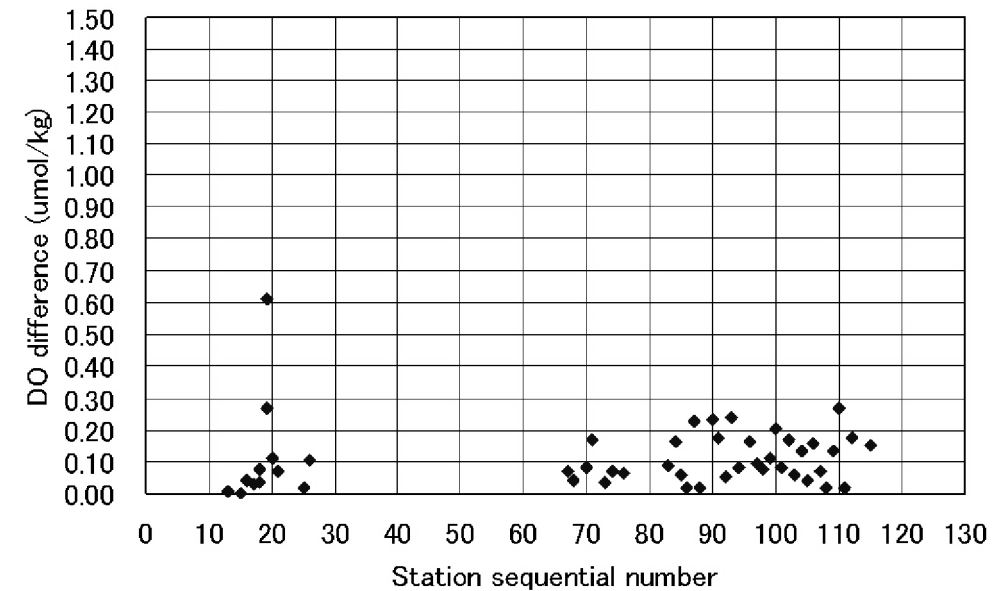
Figure 3.3.4. Difference in the duplicate measurements against station sequential number.

(13) CSK standard measurements

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

Table 3.3.3. Results of the CSK standard measurements.

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

Table 3.3.4. Summary of assigned quality control flags.

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

(14) Quality control flag assignment

Quality flag values were assigned to oxygen measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev.2 section 4.5.2 (Joyce *et al*., 1994). Measurement flags of 2, 3, 4, 5 and 6 have been assigned (Table 3.3.4). For the choice between 2 (good), 3 (questionable) or 4 (bad), we basically followed a flagging procedure as listed below:

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

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

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

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

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

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

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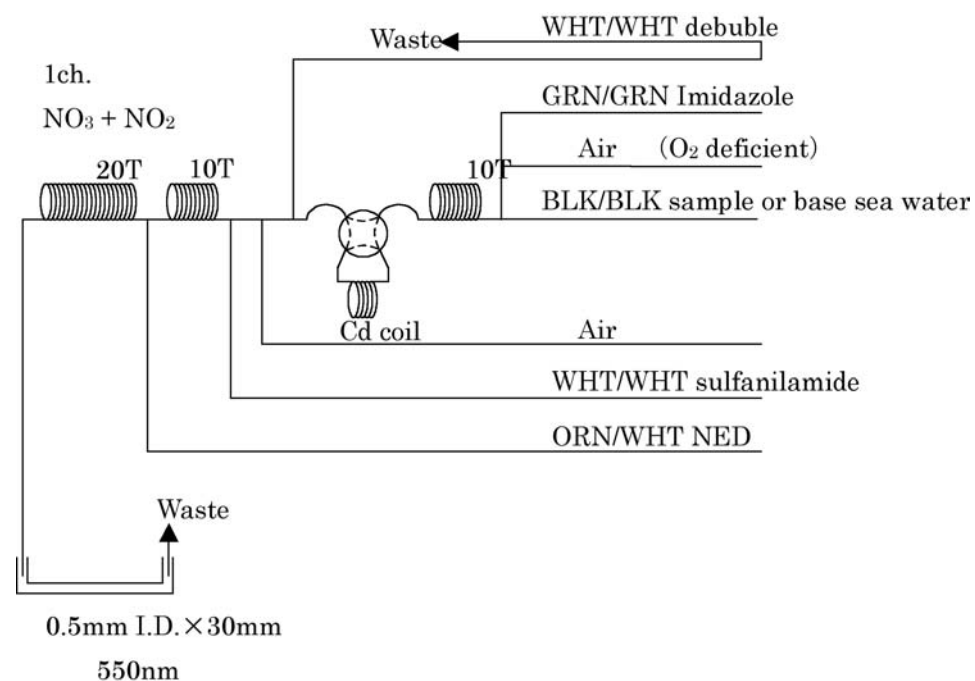
Figure 3.4.1: 1ch. (NO_3+NO_2) Flow diagram.

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

Nitrate Reagents

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

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

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

Dissolve 10 g sulfanilamide, $4\text{-}NH_2C_6H_4SO_3H$, 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, $C_{10}H_7NHCH_2CH_2NH_2 \cdot 2HCl$, in 1000 ml of DIW; containing 10 ml concentrated HCl. Stored in a dark bottle.

Nitrite Reagents

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

Dissolve 10 g sulfanilamide, $4\text{-}NH_2C_6H_4SO_3H$, 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, $C_{10}H_7NHCH_2CH_2NH_2 \cdot 2HCl$, in 1000 ml of DIW; containing 10 ml concentrated HCl. Stored in a dark bottle.

Figure 3.4.3. 3ch. (SiO₂) Flow diagram.
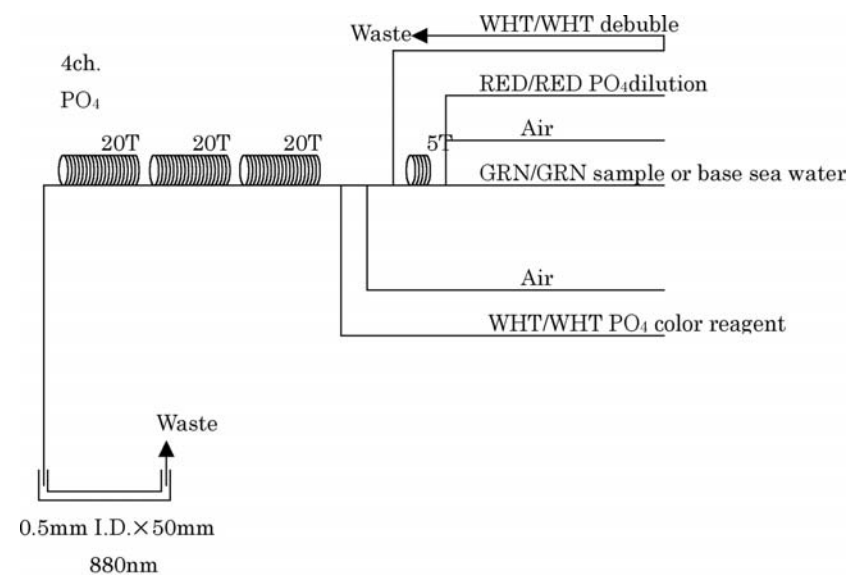
Figure 3.4.4. 4ch. (PO₄) Flow diagram.

Silicic Acid Reagents

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

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

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

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

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

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

Phosphate Reagents

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

Dissolve 8 g Disodium Molybdate (VI) Dihydrate, Na_2MoO_4 $2H_2O$, and 0.17 g Antimony Potassium Tartrate, $C_8H_4K_2O_{12}Sb_2$ $3H_2O$, 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.

PO₄ dilution

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

b. Sampling procedures

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

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

c. Data processing

Raw data from TRAACS800 were treated as follows;

Check baseline shift.

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

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

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

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

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

(4) Nutrients standards

a. In-house standards

(i) Volumetric Laboratory Ware

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

Volumetric flasks

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

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

Because of their larger temperature coefficients of cubical expansion and lack of tables constructed for these materials, the plastic volumetric flasks were gravimetrically calibrated over the temperature range of intended use and used at the temperature of calibration within 3-4 K. The weights obtained in the calibration weightings were corrected for the density of water and air buoyancy.

Pipettes and pipettors

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

(ii) Reagents, General considerations

General Specifications

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

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

Ultra pure water

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

Low-Nutrient Seawater (LNSW)

Surface water with low nutrient concentration was taken and filtered using 0.45 µm pore size membrane filter. This water is stored in 20 liter cubitainer with paper box. The concentrations of nutrient of this water were carefully measured in March 2005.

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

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

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

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

Table 3.4.2. Working calibration standard recipes.

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

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

B-2 STD: Nitrite

(iv) Renewal of in-house standard solutions

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

Table 3.4.3. Timing of renewal of in-house standards.

NO_3, NO_2, SiO_2, PO_4	Renewal
A-1 Std. (NO_3)	maximum 1 month
A-2 Std. (NO_2)	maximum 1 month
A-3 Std. (SiO_2)	commercial prepared solution
A-4 Std. (PO_4)	maximum 1 month
B-1 Std.	
(mixture of NO3, SiO2, PO4)	3 days
B-2 Std. (NO2)	6 days

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

Reduction estimation	Renewal
D-1 Std.	when A-1renewed
43 µM NO$_3$	when C-std renewed
47 µM NO$_2$	when C-std renewed

b. RMNS

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

(i) RMNS preparation

RMNS preparation and homogeneity for previous lots

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

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

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

RMNSs for this cruise

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

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

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

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

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

Note: N = 30 × 2

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

(5) Quality control

a. Precision of nutrients analyses during the cruise

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

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

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
Median	0.09	0.11	0.07
Mean	0.09	0.12	0.08
Maximum	0.17	0.29	0.19
Minimum	0.03	0.05	0.03
N	126	126	126
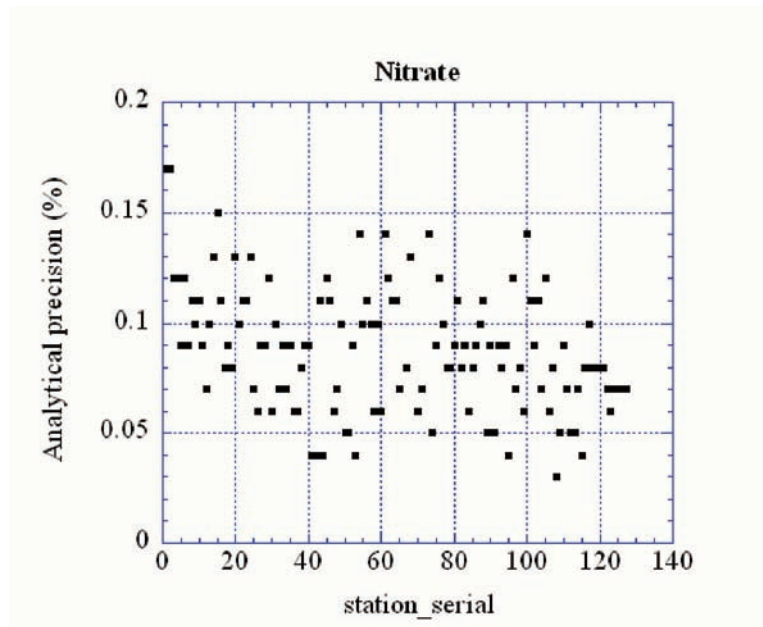
Figure 3.4.5. Time series of precision of nitrate.
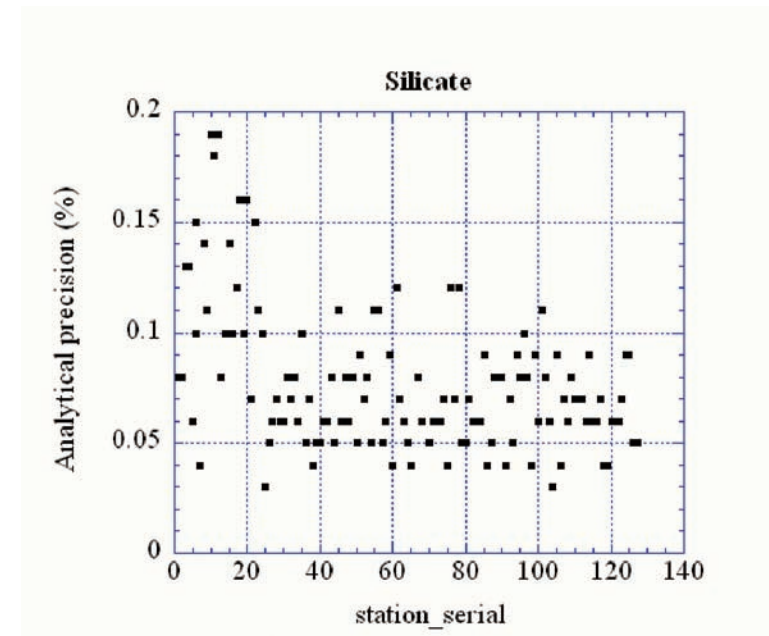
Figure 3.4.7. Time series of precision of silicate.
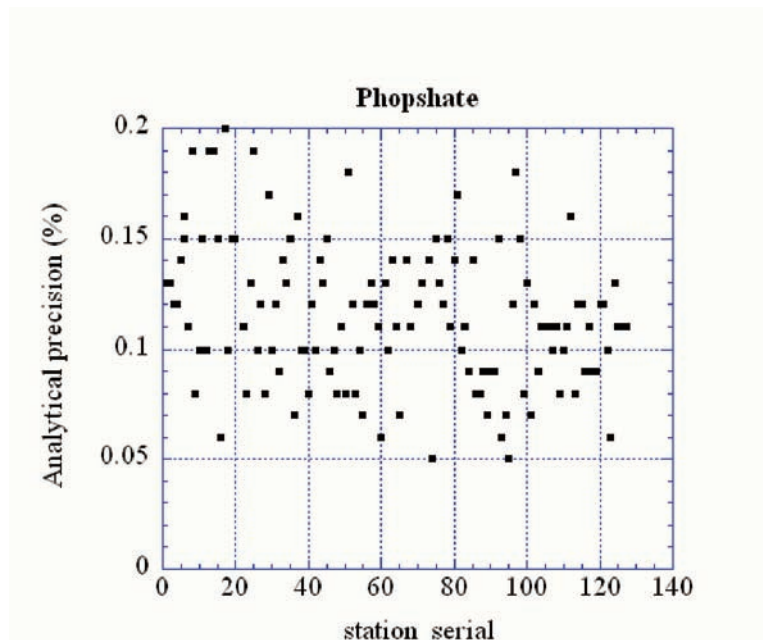
Figure 3.4.6. Time series of precision of phosphate.

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).

$$\text{Uncertainties (\%)} = 0.13 + 1.66 / C_{nitrate} \qquad (1)$$

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

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

$$\text{Uncertainties(\%)} = -0.11 + 1.032 / C_{phos} \qquad (2)$$

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

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

$$\text{Uncertainties (\%)} = 0.095 + 4.92 / C_{silicate} \qquad (3)$$

where $C_{silicate}$ 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.
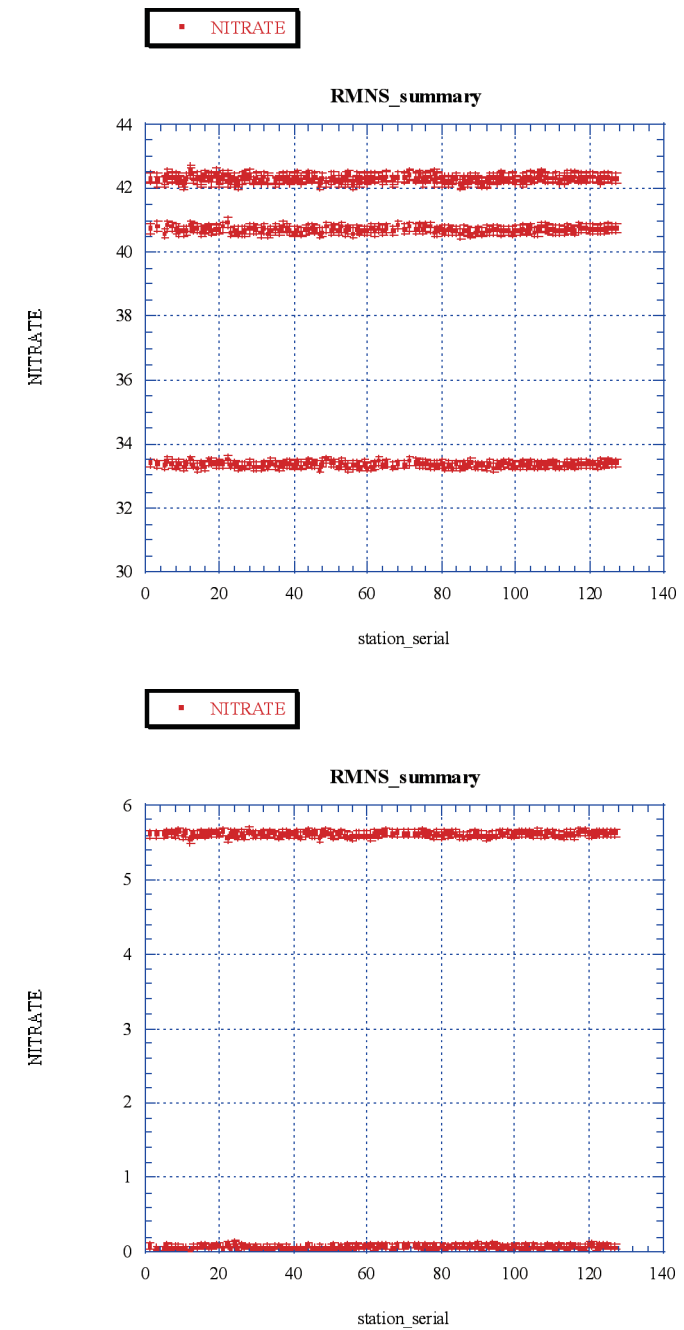
Figure 3.4.8. Time series of nitrate concentration for RMNSs.
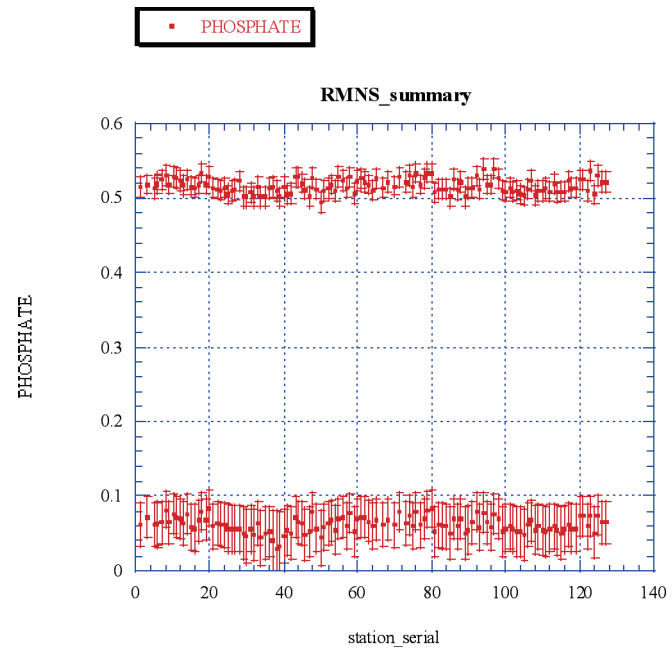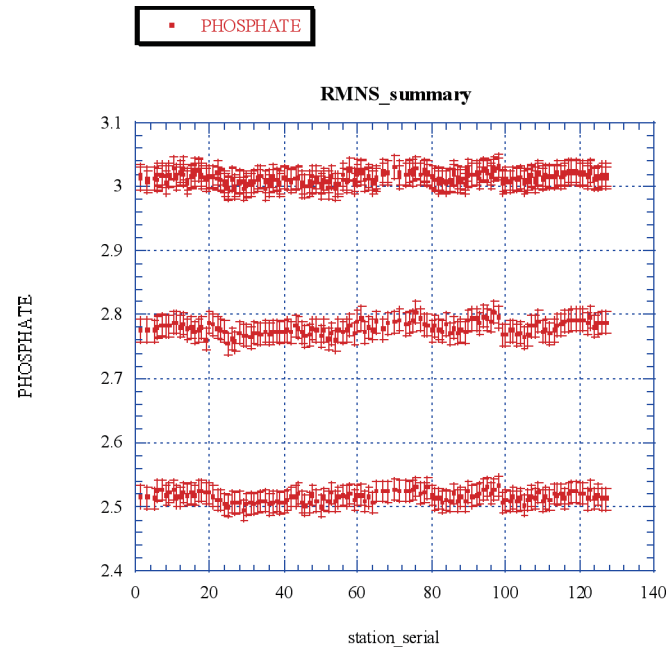
Figure 3.4.9. Same as Figure 3.4.8, but for phosphate.
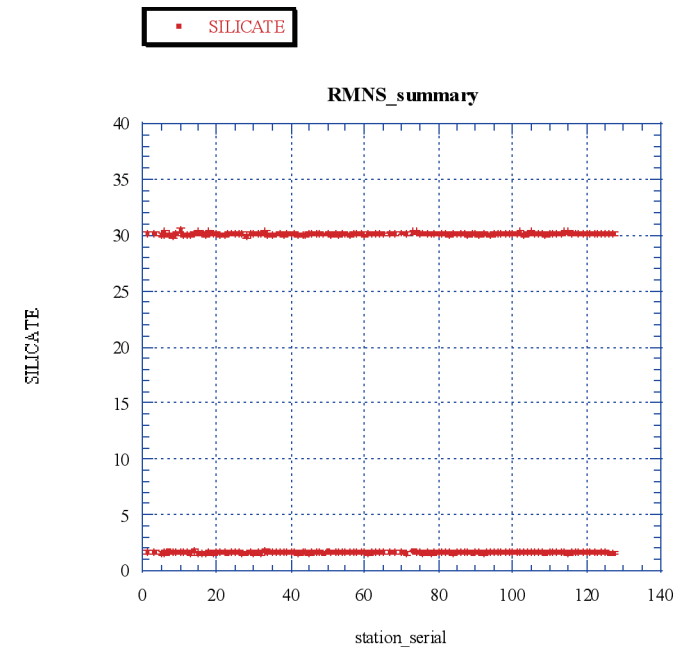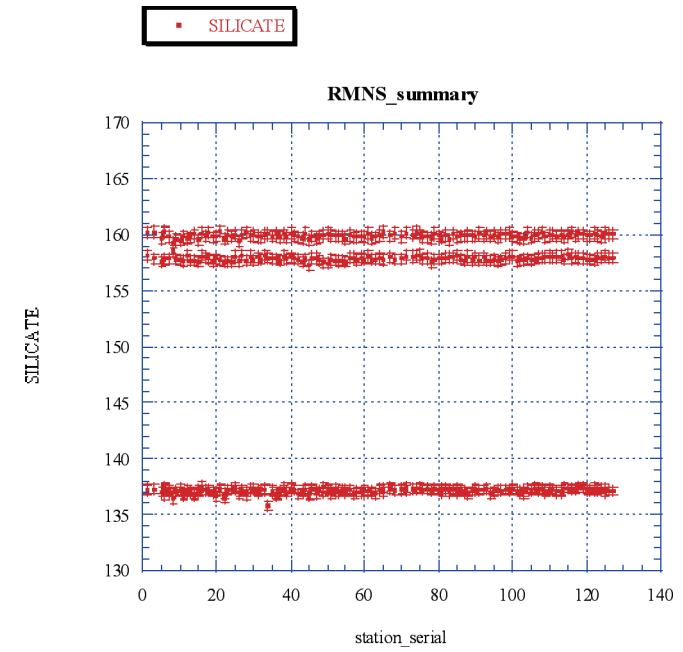
Figure 3.4.10. Same as Figure 3.4.8, but for silicic acid.

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)

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(2) Introduction

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

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

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

(2) Apparatus

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

The seawater dispensing system has an auto-sampler (6 ports), which takes seawater from a 300 ml borosilicate glass bottle and dispenses the seawater to a pipette of nominal 20 or 28 ml volume by a PC control. The pipette is kept at 20 °C by a water jacket, where water from a water bath set at 20 °C is circulated.

CO_2 dissolved in a seawater sample is extracted in a stripping chamber of a CO_2 extraction system by adding phosphoric acid (10 % v/v). The stripping chamber is approx. 25 cm long and has a fine frit at the bottom. To degas CO_2 as quickly as possible, a heating wire kept at 40 °C was rolled from the bottom to a 1/3 height of the stripping chamber. The acid is added to the stripping chamber from the bottom of the chamber by pressurizing an acid bottle for a given time to push out a right amount of acid. The pressurizing is made with nitrogen gas (99.9999 %). After the acid is transferred to the stripping chamber, a seawater sample kept in a pipette is introduced to the stripping chamber by the same method as in adding an acid. The seawater reacted with phosphoric acid is stripped of CO_2 by bubbling the nitrogen gas through a fine frit at the bottom of the stripping chamber. The CO_2 stripped in the stripping chamber is carried by the nitrogen gas (flow rates of 130 ml min^{-1} and 140 ml min-1 for the systems A and B, respectively) to the coulometer through a dehydrating module. For the system A, the module consists of two electric dehumidifiers (kept at 1 - 2 °C) and a chemical desiccant (Mg $(ClO_4)_2$). For the system B, it consists of three electric dehumidifiers with a chemical desiccant.

(3) Shipboard measurement

Sampling

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

At a chemical laboratory on the ship, a headspace of approx. 1 % of the bottle volume was made by removing seawater with a plastic pipette. A saturated mercuric chloride of 100 µl was added to poison seawater samples. The

glass bottles were sealed with a greased (Apiezon M, M&I Materials Ltd.) ground glass stopper and the clips were secured. The seawater samples were kept at 4 °C in a refrigerator until analysis. A few hours just before analysis, the seawater samples were kept at 20 °C in a water bath.

Analysis

At the start of each leg, we calibrated the measuring systems by blank and 5 kinds of Na_2CO_3 solutions (nominally 500, 1000 1500, 2000, 2500 µmol/l). As it was empirically known that coulometers do not show a stable signal (low repeatability) with fresh (low absorption of carbon) coulometer solutions. Therefore we measured 2 % CO_2 gas repeatedly until the measurements became stable. Then we started the calibration.

The measurement sequence such as system blank (phosphoric acid blank), 2 % CO_2 gas in a nitrogen base, seawater samples (6) was programmed to repeat. The measurement of 2 % CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc.). For every renewal of coulometer solutions, certified reference materials (CRM, batch 69) provided by Prof. A. G. Dickson of Scripps Institution of Oceanography were analyzed. In addition, reference materials (RM) provided by JAMSTEC (2 kinds) and KANSO were measured at the initial, intermediate and end times of a coulometer solution's lifetime.

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

In the cruise, we finished all the analyses for C_T on board the ship. As we used two systems, we had not encountered such a situation that we had to abandon the measurement due to time limitation. However, we experienced some malfunctions of the measuring systems during the cruise, which are described in the followings:

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

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

(4) Quality control

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

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

Temporal variations of RM measurements are shown in Fig. 3.5.2. From Fig. 3.5.2, it is evident that RM measurements had a linear trend, implying that measurements of seawater samples also have the trend. The trend was also found in temporal changes of 2 % CO_2 gas measurements. The trend seems to be due to "cell age" change (Johnson *et al*., 1998) of a coulometer solution.

Considering the trends, we adjusted measurements of seawater samples to be traceable to the certified value of batch 69, although the adjustments were usually slight.

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

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

Reference

Johnson, K.M., A.G. Dickson, G. Eischeid, C. Goyet, P. Guenther, R.M. Key, F. J. Millero, D. Purkerson, C.L. Sabine, R.G. Schottle, D.W.R. Wallace, R.J. Wilke and C.D. Winn (1998): Coulometric total carbon dioxide analysis for marine studies: assessment of the quality of total inorganic carbon measurements made during the US Indian Ocean CO_2 survey 1994-1996, Mar. Chem., 63, 21-37.

Table 3.5.1. Calibration factors determined from Na_2CO_3 solutions.

Cruise Name.	Calibration factors		Remarks
	A	B	
MR05-02	0.24479	0.25114	A pipette for the system B was replaced
		0.31326	
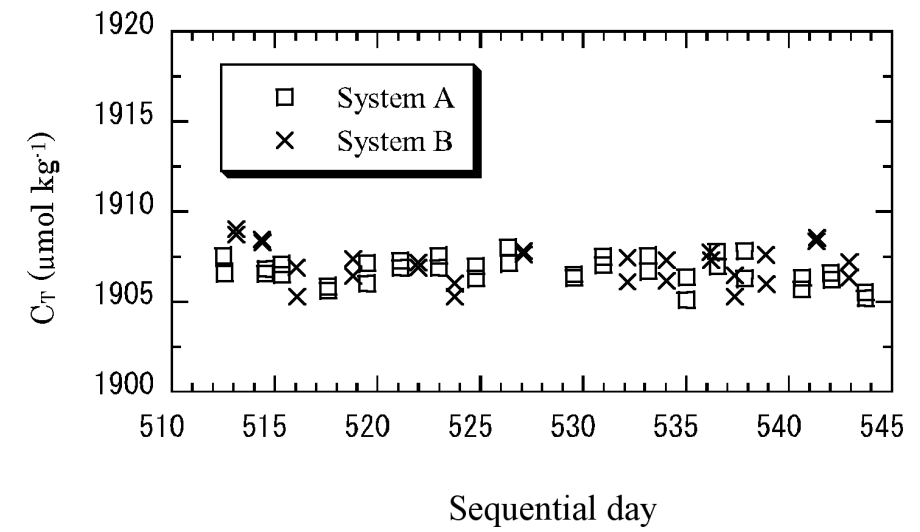
Figure 3.5.1. Temporal variations of CRM (Batch 69) C_T measured by the systems A and B.
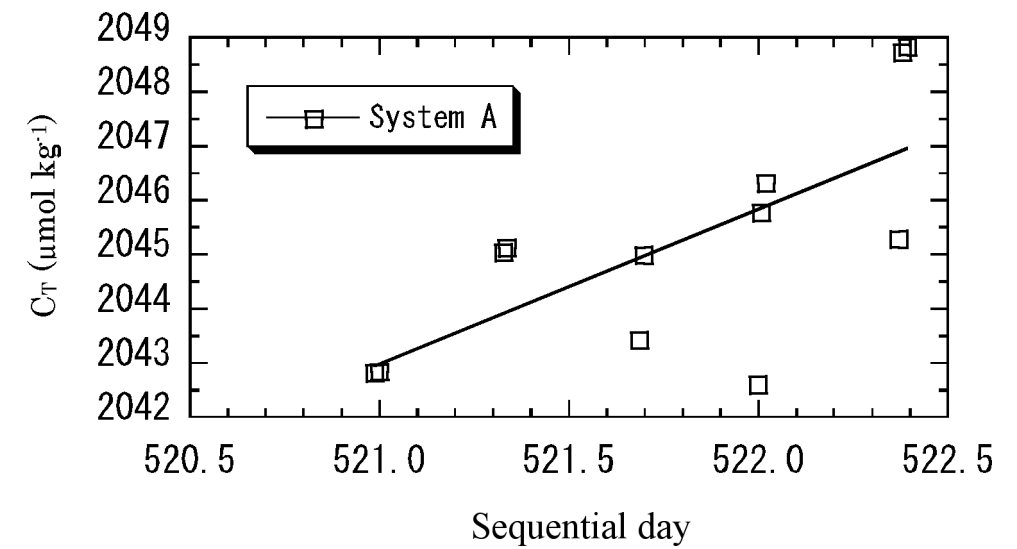
Figure 3.5.2. An example of temporal variations of RM C_T. The line was determined by the least squared method. C_T increased at a rate of approx. 2.9 $\mu mol\ kg^{-1}$ per day.

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):

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

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

(3) Shipboard measurement

Sampling

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

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

Analysis

For an indicator solution, *m*-cresol purple (2 mM) was used. The indicator solution was produced on board a ship, and retained in a 1000 ml DURAN® laboratory bottle. We renewed an indicator solution 3 times when the headspace of the bottle became large, and monitored pH or absorbance ratio of the indicator solution by another spectrophotometer (Carry 50 Scan, Varian) using a cell with a short path length of 0.5 mm. In most indicator solutions, the absorbance ratios of the indicator solution were initially in the range 1.4 - 1.6, and decreased to 1.1.

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

Absorbances of seawater alone and seawater + indicator solutions were measured 15 times each, and averages computed from the last five values of absorbance were used for the calculation of pH (Eq. 1).

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

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

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

(4) Quality control

It is recommended that correction for pH change resulting from addition of indicator solutions is made (DOE, 1994). To check perturbation of pH due to the addition, we measured absorbance ratios by doubling the volume of indicator solutions added to a same seawater sample. We corrected absorbance ratios based on an empirical method (DOE, 1994). Figure 3.7.1 illustrates an example of perturbation of absorbance ratios by adding indicator solutions.

We surveyed vertical profiles of pH. In particular, we examined whether systematic differences between before and after the renewal of indicator solutions existed or not. Then taking other information of analyses into account, we determined a flag of each value of pH.

The average and standard deviation of absolute values of differences of pH analyzed consecutively were 0.0006 and 0.0006 pH unit (n = 203), respectively.

References

Clayton, T.D. and R.H. Byrne (1993): Spectrophotometric seawater pH measurements: total hydrogen ion concentration scale calibration of *m*-cresol purple and at-sea results. Deep-Sea Research 40, 2115-2129.

DOE (1994): Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water, version 2, A. G. Dickson & C. Goyet, eds. (unpublished manuscript).
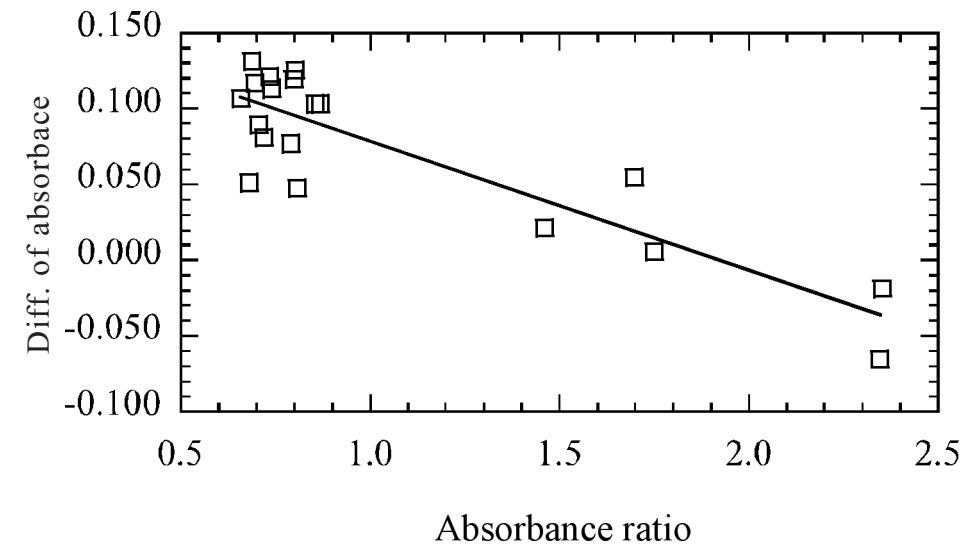
Figure 3.7.1. Perturbation of absorbance ratios by adding indicator solutions. The line (y = –0.0848x + 0.1633, R^2 = 0.7703) was determined by the method of least squares.

3.8 Chlorofluorocarbons (CFCs)

2 October 2006

(1) Personnel

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(2) Introduction

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

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

(3) Apparatus

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

(4) Shipboard measurement

Sampling

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

Analysis

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

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

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

(4) Quality control

Blank

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

Interfering compound for CFC-113 analysis

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

Precisions

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

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

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

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

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

Reference

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

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

3.9 Lowered Acoustic Doppler Current Profiler

25 August 2006

(1) Personnel

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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

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

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/).

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

Figure 3.9.1. The cross-section of zonal velocity (eastward is positive).
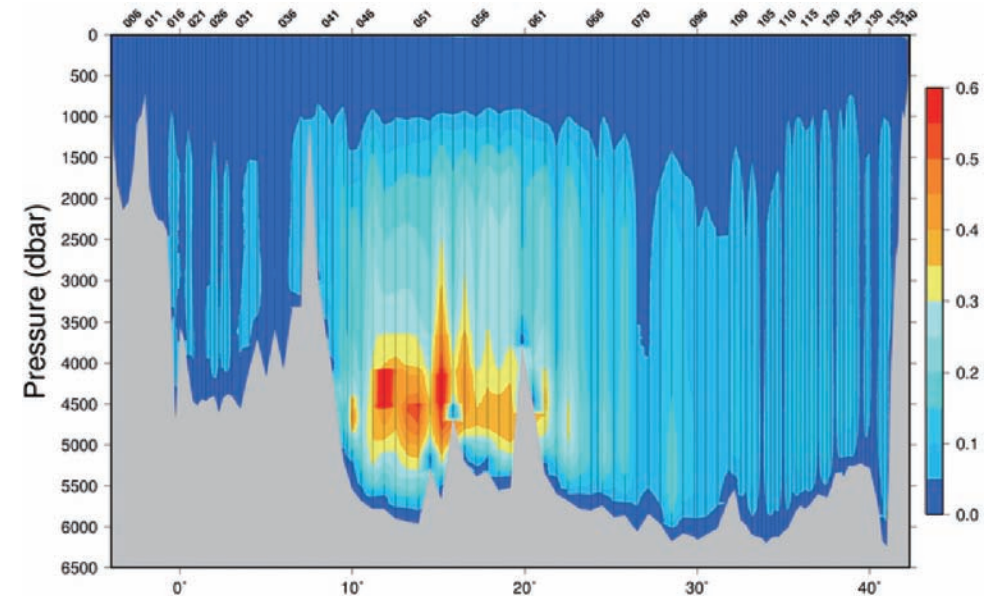
Figure 3.9.3. Cross-section of error velocity estimated by the inversion method.

Station Summary

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P10 REV R/V MIRAI CRUISE MR0502
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SHIP/CRS EXPOCODE	WOCE SECT	STNNBR	CASTNO	CAST TYPE	DATE	UTC TIME	EVENT CODE	LATITUDE	LONGITUDE	NAV	UNC DEPTH	COR DEPTH	HT ABOVE BOTTOM	WIRE OUT	MAX PRESS	NO. OF BOTTLES	PARAMETERS	COMMENTS
49MR0502_1		201	1	XBT	052605	2211	DE	42 4.58 N	143 43.33 E	GPS	420	422						FOR SOUND SPEED CORRECTION, TSK T-7
49MR0502_1	P10N	143	1	ROS	052605	2302	BE	42 15.16 N	143 44.43 E	GPS	481	482				9	1-8,23,24,26,27	
49MR0502_1	P10N	143	1	ROS	052605	2315	BO	42 15.19 N	143 44.28 E	GPS	471	472	9	465	467			
49MR0502_1	P10N	143	1	BUC	052605	2316	UN	42 15.20 N	143 44.28 E	GPS	471	471				1		5.6C
49MR0502_1	P10N	143	1	ROS	052605	2342	EN	42 15.17 N	143 44.01 E	GPS	459	460						
49MR0502_1	P10N	142	1	ROS	052705	0105	BE	42 9.99 N	143 48.46 E	GPS	722	721				0		NO WATER SMPL
49MR0502_1	P10N	142	1	ROS	052705	0124	BO	42 9.96 N	143 48.29 E	GPS	716	716	8	710	714			UP-CAST FAILS
49MR0502_1	P10N	142	1	BUC	052705	0125	UN	42 9.95 N	143 48.29 E	GPS	715	715				1		3.9C
49MR0502_1	P10N	142	1	ROS	052705	0155	EN	42 9.90 N	143 48.09 E	GPS	710	710						
49MR0502_1	P10N	142	2	ROS	052705	0258	BE	42 10.06 N	143 48.57 E	GPS	724	724				11	1-6,23,24,26	REPLACED Y-CABLE
49MR0502_1	P10N	142	2	BUC	052705	0314	UN	42 9.95 N	143 48.56 E	GPS	724	725				1		3.9C
49MR0502_1	P10N	142	2	ROS	052705	0316	BO	42 9.94 N	143 48.56 E	GPS	724	725	11	717	718			
49MR0502_1	P10N	142	2	ROS	052705	0349	EN	42 9.90 N	143 48.61 E	GPS	728	727						
49MR0502_1	P10N	141	1	ROS	052705	0435	BE	42 5.03 N	143 52.29 E	GPS	902	902				13	1-8,23,24,26,27	
49MR0502_1	P10N	141	1	BUC	052705	0444	UN	42 4.99 N	143 52.20 E	GPS	893	893				1		4.0C
49MR0502_1	P10N	141	1	ROS	052705	0455	BO	42 4.95 N	143 52.04 E	GPS	884	886	10	886	883			
49MR0502_1	P10N	141	1	ROS	052705	0533	EN	42 4.82 N	143 51.40 E	GPS	865	866						
49MR0502_1	P10N	140	1	ROS	052705	0623	BE	42 0.17 N	143 56.19 E	GPS	1044	1044				15	1-8,23,24,26,27	
49MR0502_1	P10N	140	1	BUC	052705	0633	UN	42 0.17 N	143 56.07 E	GPS	1040	1040				1		6.6C
49MR0502_1	P10N	140	1	ROS	052705	0648	BO	42 0.21 N	143 55.85 E	GPS	1034	1035	9	1040	1037			
49MR0502_1		202	1	UNK	052705	0702	UN	42 0.26 N	143 55.65 E	GPS	1026	1027						RAIN SAMPLING (3.2MM/HR)
49MR0502_1	P10N	140	1	ROS	052705	0738	EN	42 0.42 N	143 55.27 E	GPS	1011	1013						
49MR0502_1	P10N	139	1	ROS	052705	0849	BE	41 52.64 N	144 1.99 E	GPS	953	952				14	1-6,23,24,26	
49MR0502_1	P10N	139	1	BUC	052705	0857	UN	41 52.65 N	144 1.93 E	GPS	951	952				1		6.4C
49MR0502_1	P10N	139	1	ROS	052705	0911	BO	41 52.76 N	144 1.83 E	GPS	950	949	9	948	949			
49MR0502_1	P10N	139	1	ROS	052705	0958	EN	41 53.21 N	144 1.63 E	GPS	957	956						
49MR0502_1	P10N	138	1	ROS	052705	1109	BE	41 45.20 N	144 7.70 E	GPS	1471	1470				17	1-8,23,24,26,27	
49MR0502_1	P10N	138	1	BUC	052705	1118	UN	41 45.32 N	144 7.66 E	GPS	1466	1464				1		5.3C
49MR0502_1	P10N	138	1	ROS	052705	1139	BO	41 45.45 N	144 7.74 E	GPS	1464	1463	11	1452	1463			
49MR0502_1	P10N	138	1	ROS	052705	1241	EN	41 45.96 N	144 7.78 E	GPS	1446	1448						
49MR0502_1	P10N	137	1	ROS	052705	1402	BE	41 37.72 N	144 13.72 E	GPS	2623	2622				22	1-6	
49MR0502_1	P10N	137	1	BUC	052705	1410	UN	41 37.78 N	144 13.70 E	GPS	2608	2605				1		3.0C
49MR0502_1	P10N	137	1	ROS	052705	1451	BO	41 38.08 N	144 13.54 E	GPS	2552	2555	10	2543	2569			
49MR0502_1	P10N	137	1	ROS	052705	1622	EN	41 38.74 N	144 13.15 E	GPS	2510	2512						
49MR0502_1	P10N	136	1	ROS	052705	1747	BE	41 30.03 N	144 19.16 E	GPS	2697	2702				23	1-8,12,13,23,24,26,27	
49MR0502_1	P10N	136	1	BUC	052705	1755	UN	41 30.11 N	144 19.07 E	GPS	2702	2704				1		6.0C
49MR0502_1	P10N	136	1	ROS	052705	1832	BO	41 30.34 N	144 18.76 E	GPS	2728	2729	11	2717	2743			
49MR0502_1	P10N	136	1	ROS	052705	2003	EN	41 31.09 N	144 17.83 E	GPS	2817	2820						
49MR0502_1	P10N	135	1	ROS	052705	2139	BE	41 15.06 N	144 30.69 E	GPS	4031	4032				28	1-8,27	
49MR0502_1	P10N	135	1	BUC	052705	2146	UN	41 15.08 N	144 30.58 E	GPS	4021	4021				1		3.9C
49MR0502_1	P10N	135	1	ROS	052705	2245	BO	41 15.48 N	144 29.87 E	GPS	3932	3936	67	4011	3992			LADCP SOUNDING
49MR0502_1	P10N	135	1	ROS	052805	0041	EN	41 16.50 N	144 28.76 E	GPS	4214	4218						
49MR0502_1		203	1	UNK	052805	0150	UN	41 3.80 N	144 38.99 E	GPS	5811	5810						RAIN SAMPLING (14.0MM/HR)
49MR0502_1	P10N	134	1	ROS	052805	0226	BE	41 0.13 N	144 41.99 E	GPS	6320	6313				35	1-8,23,24,26,27	REMOVED FLUOROMETER, #11 MISS FIRE

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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   BE 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)
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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
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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
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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, $\Delta pCO2$.

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**
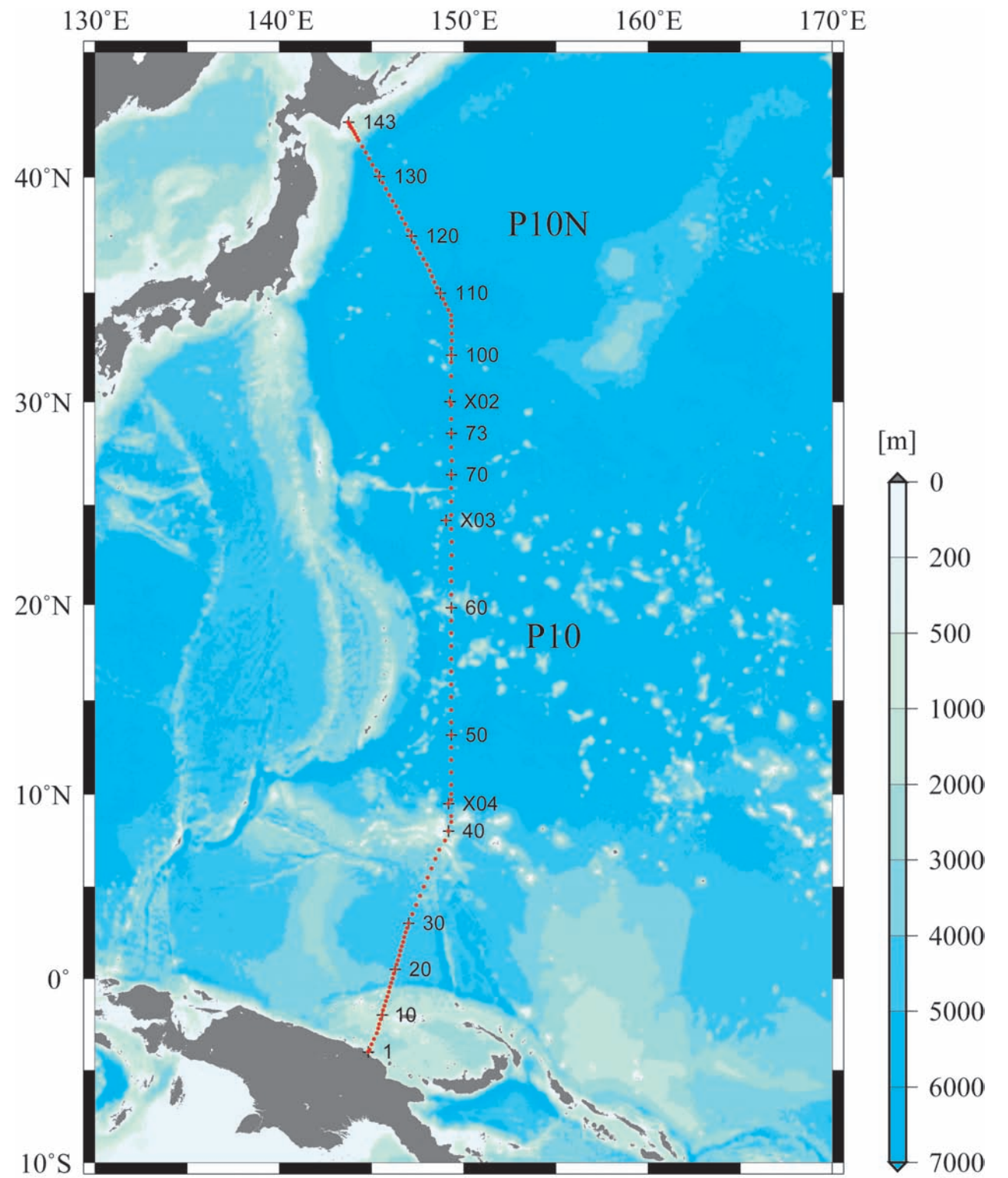
Figure 2

Bathymetry measured by Multi Narrow Beam Echo Sounding system
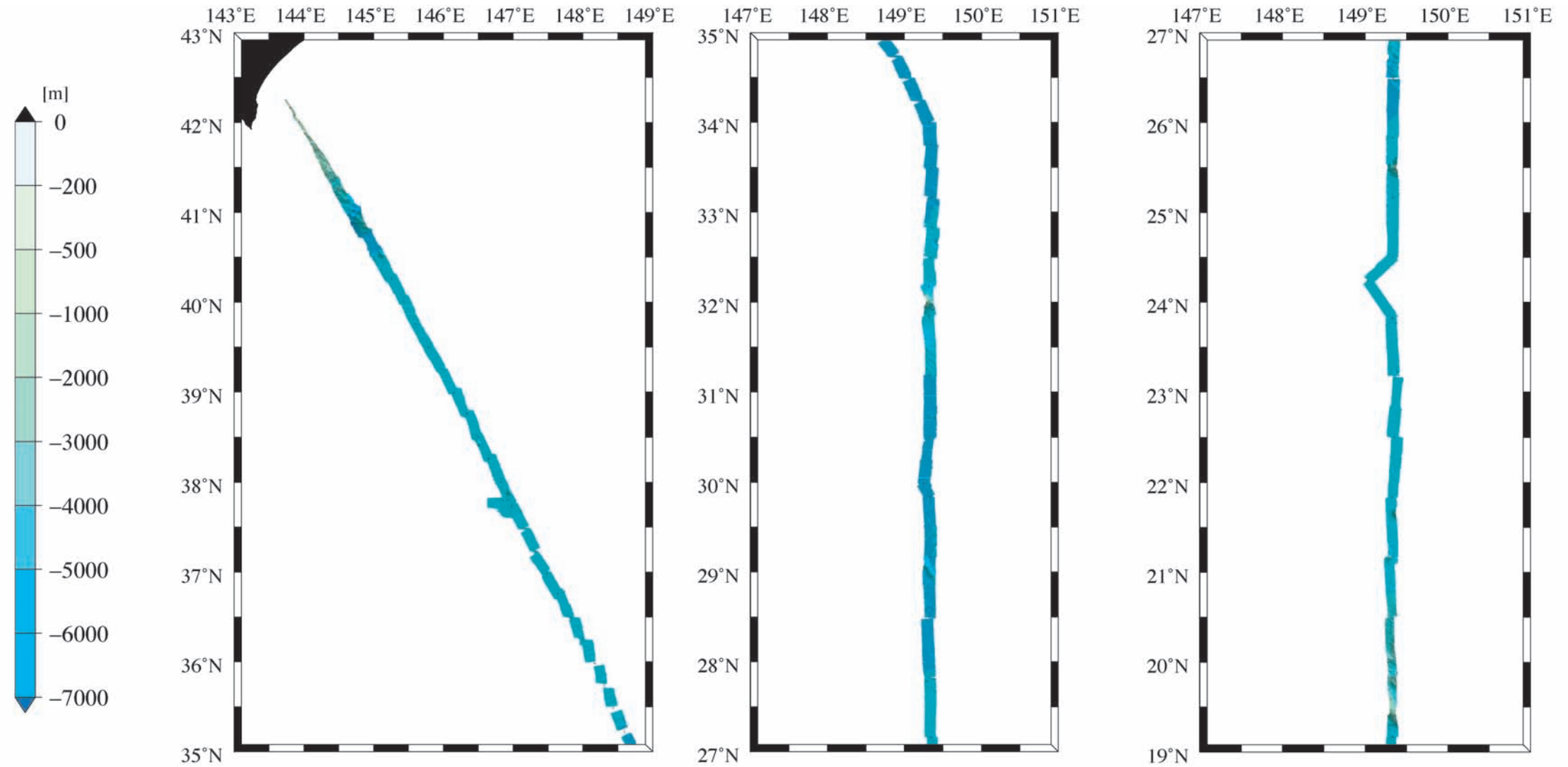
Figure 2

continued
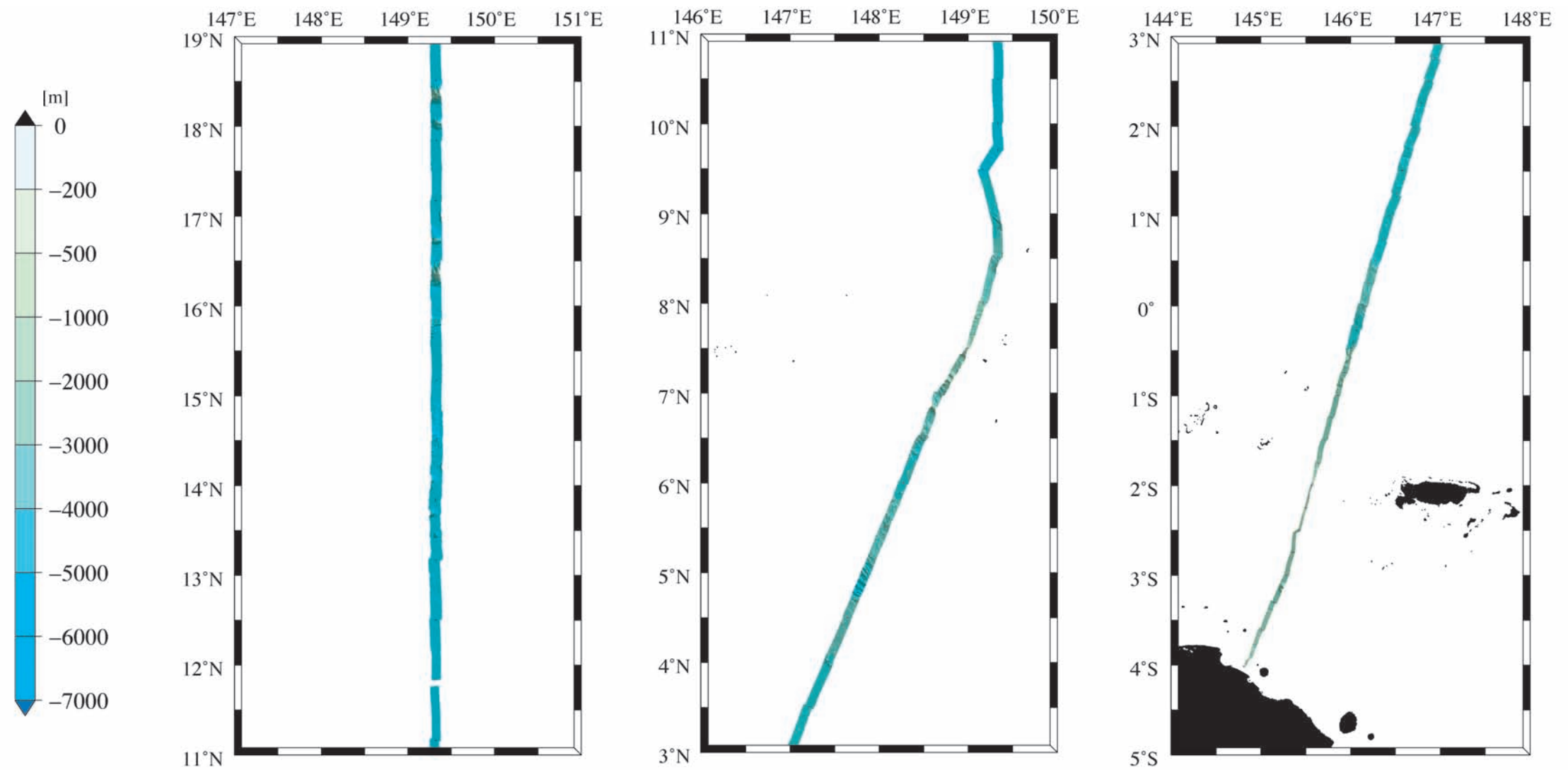
Figure 3

Surface wind measured at 25 m above sea level
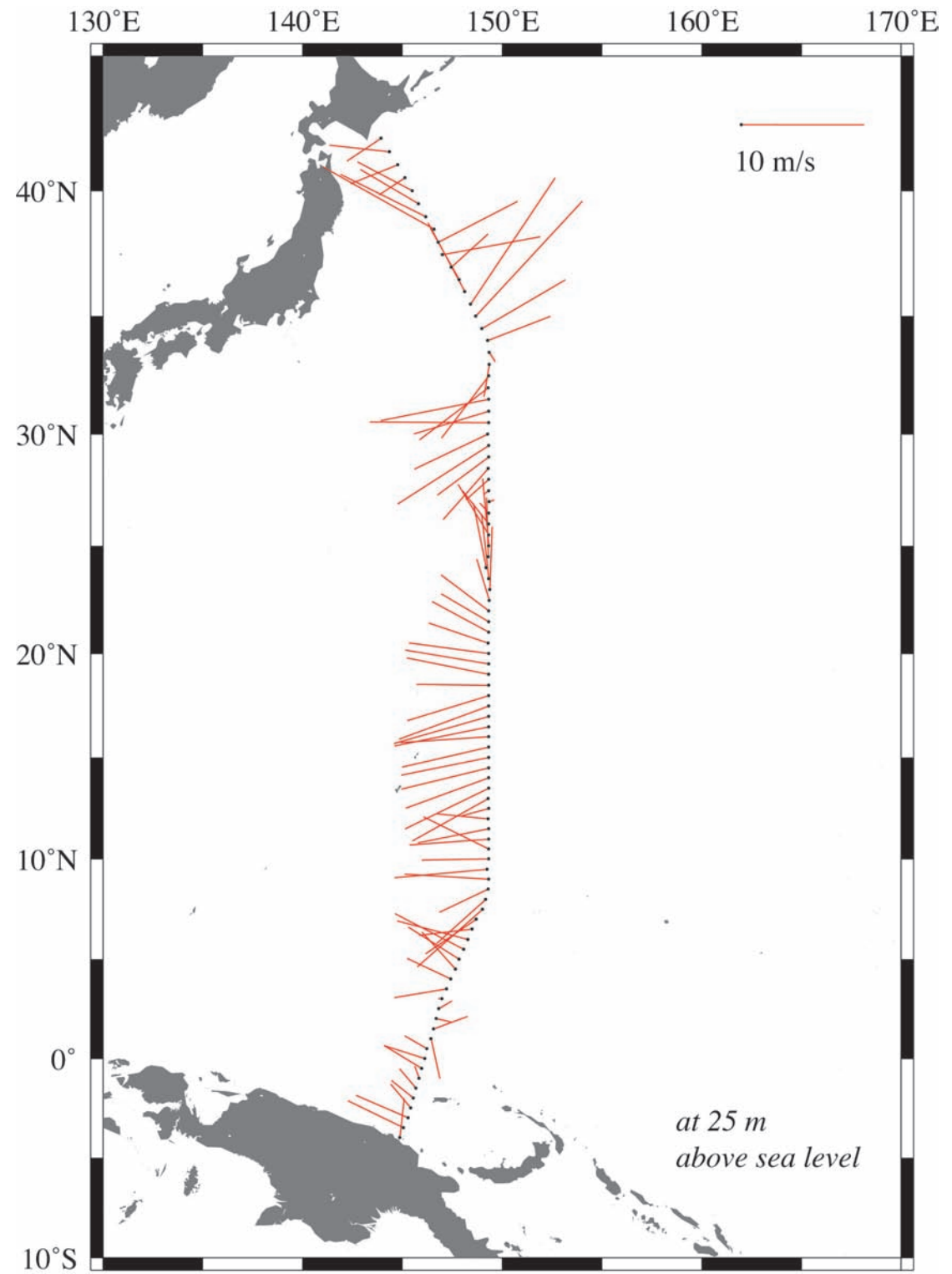
Figure 4

Sea surface temperature (SST) and salinity (SSS)

Figure 5

ΔpCO_2
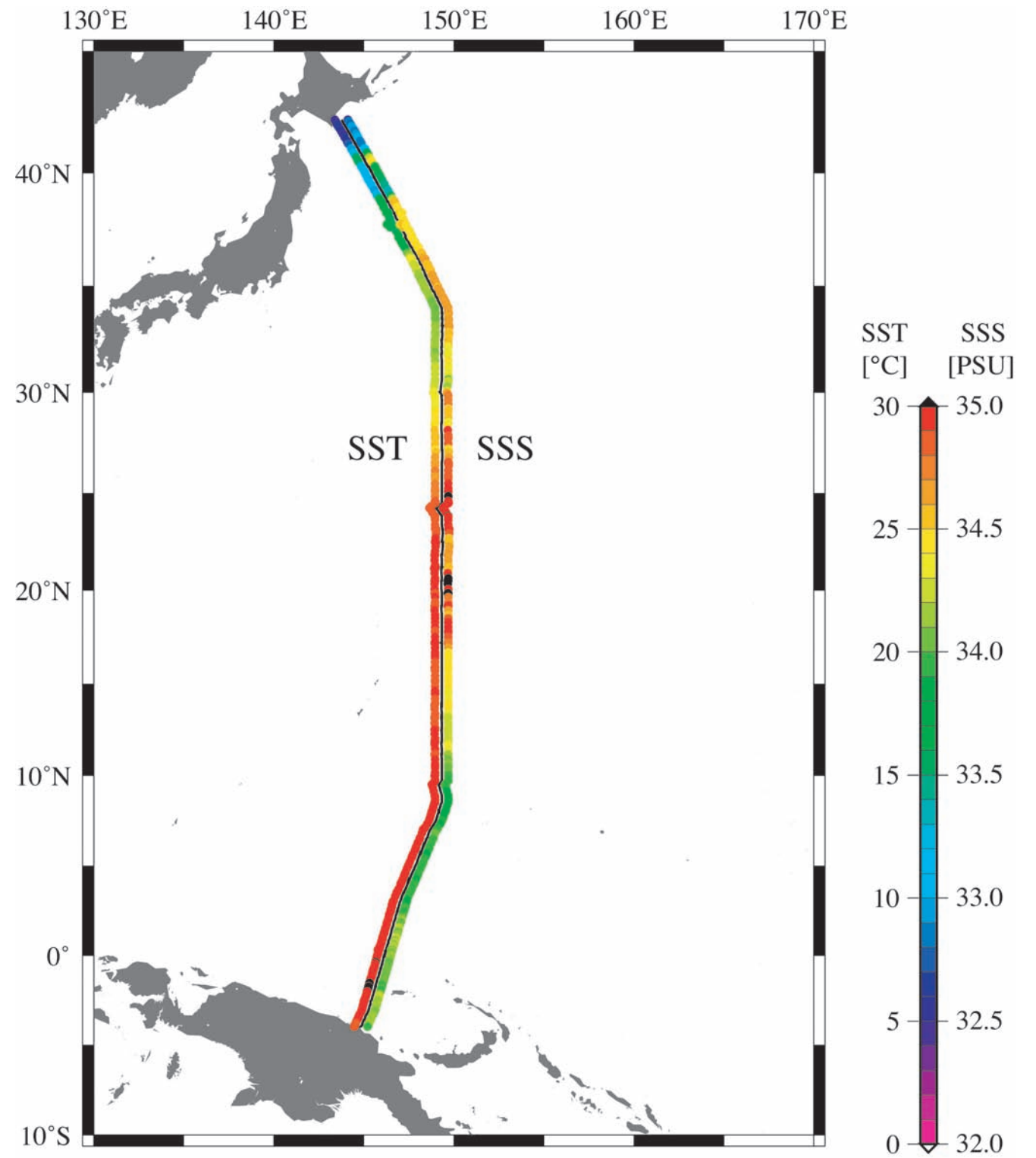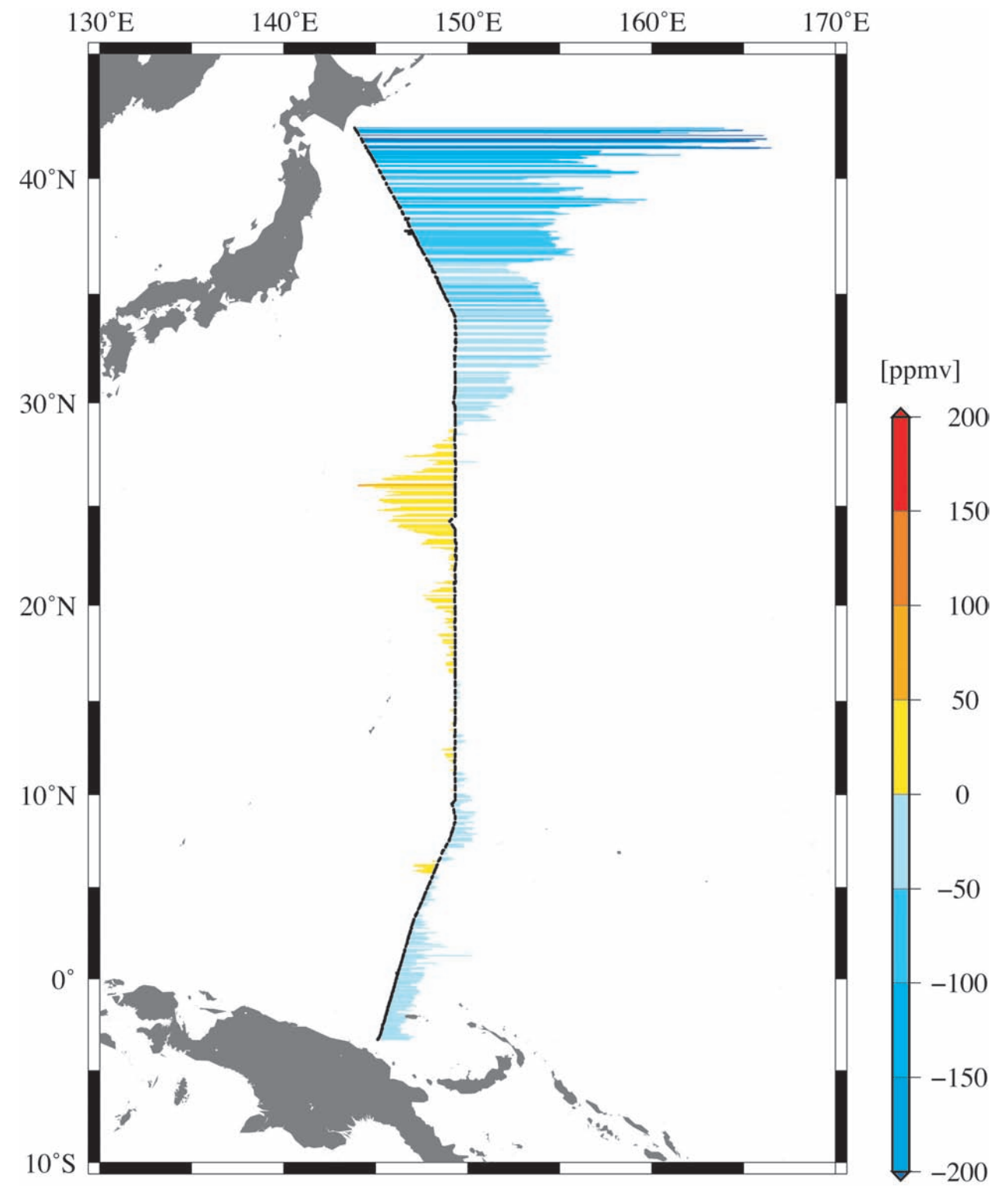
Figure 6

Surface current measured by shipboard ADCP
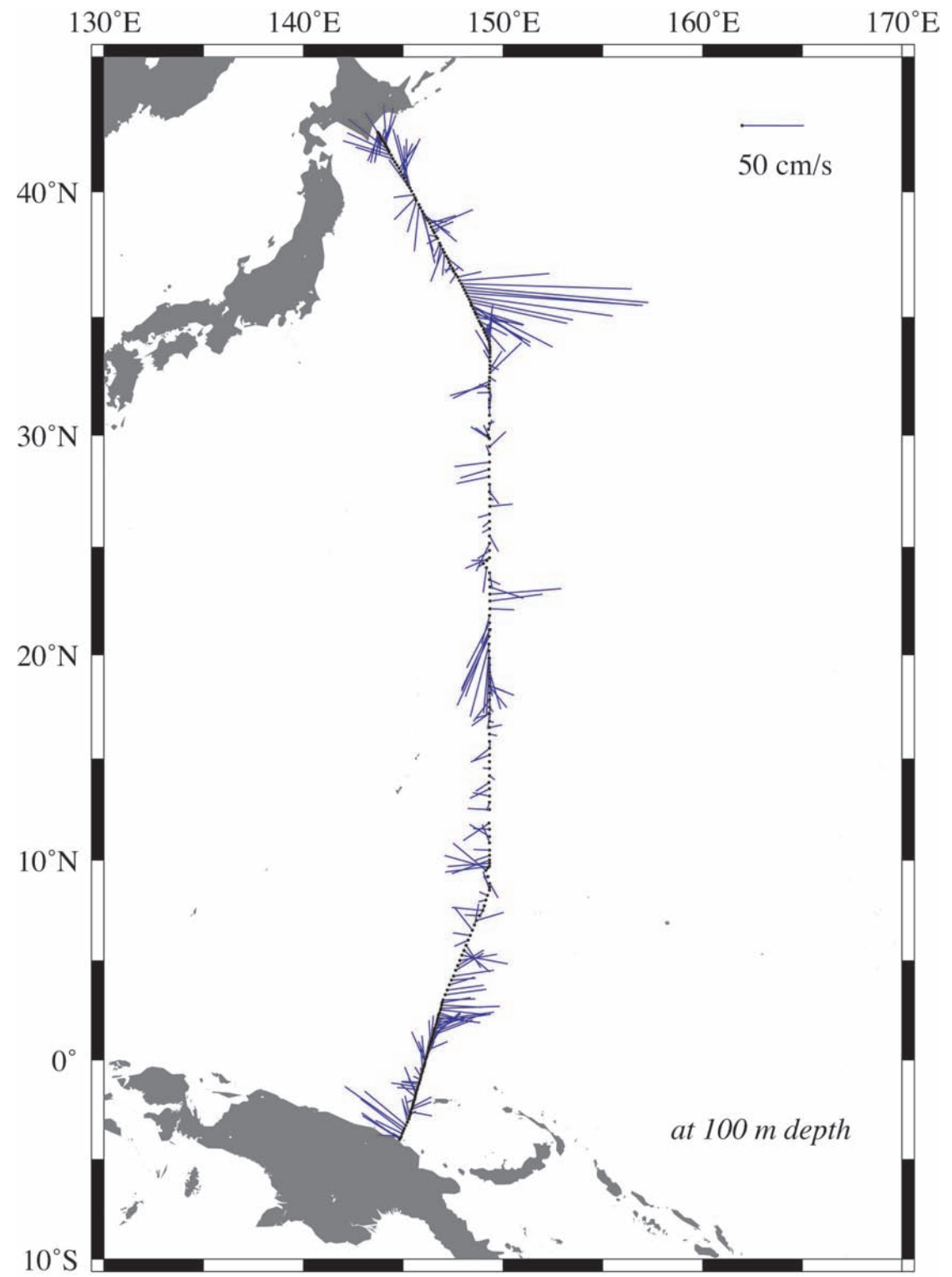
Figure 7

Potential temperature (°C)
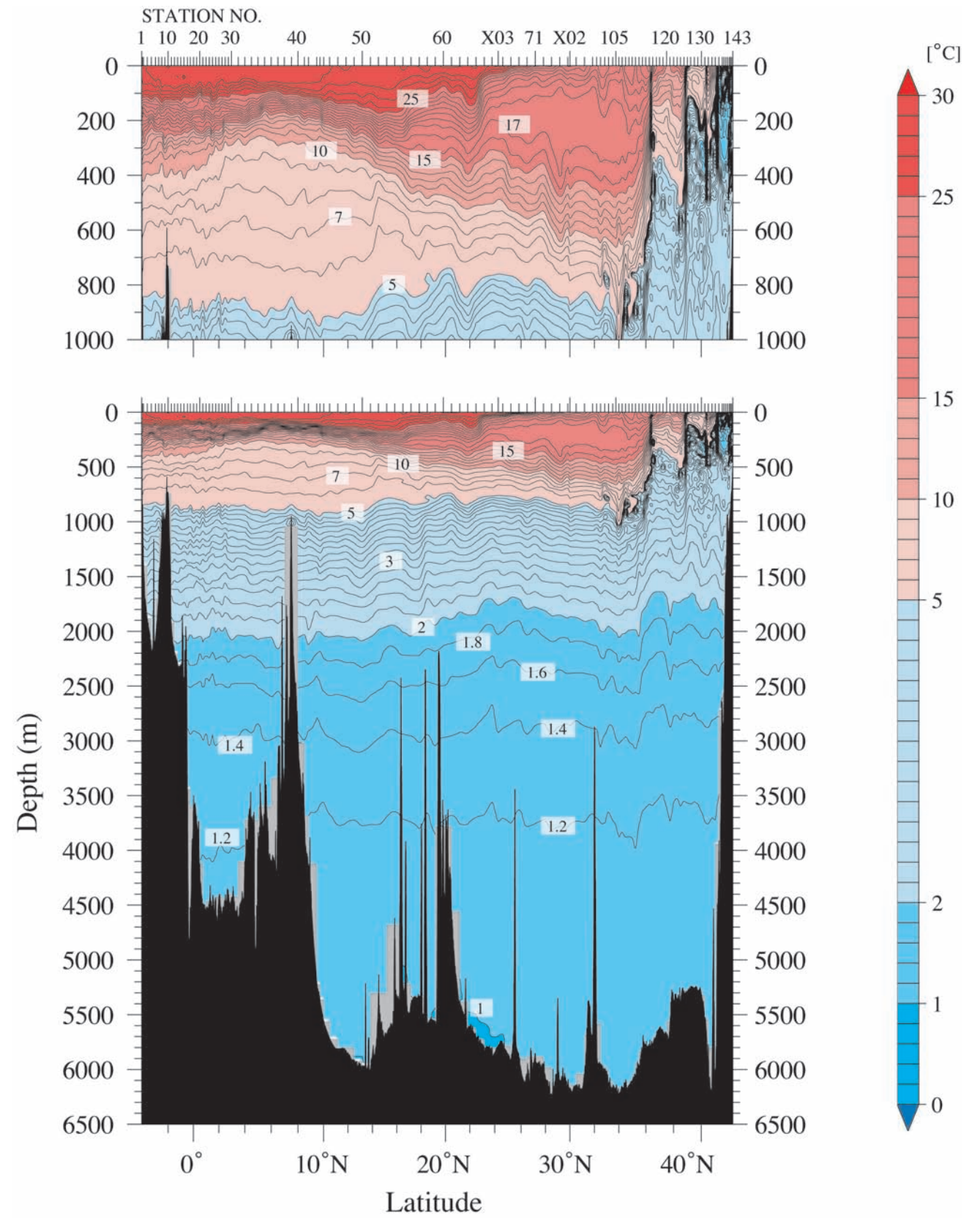
Figure 8

CTD salinity (psu)
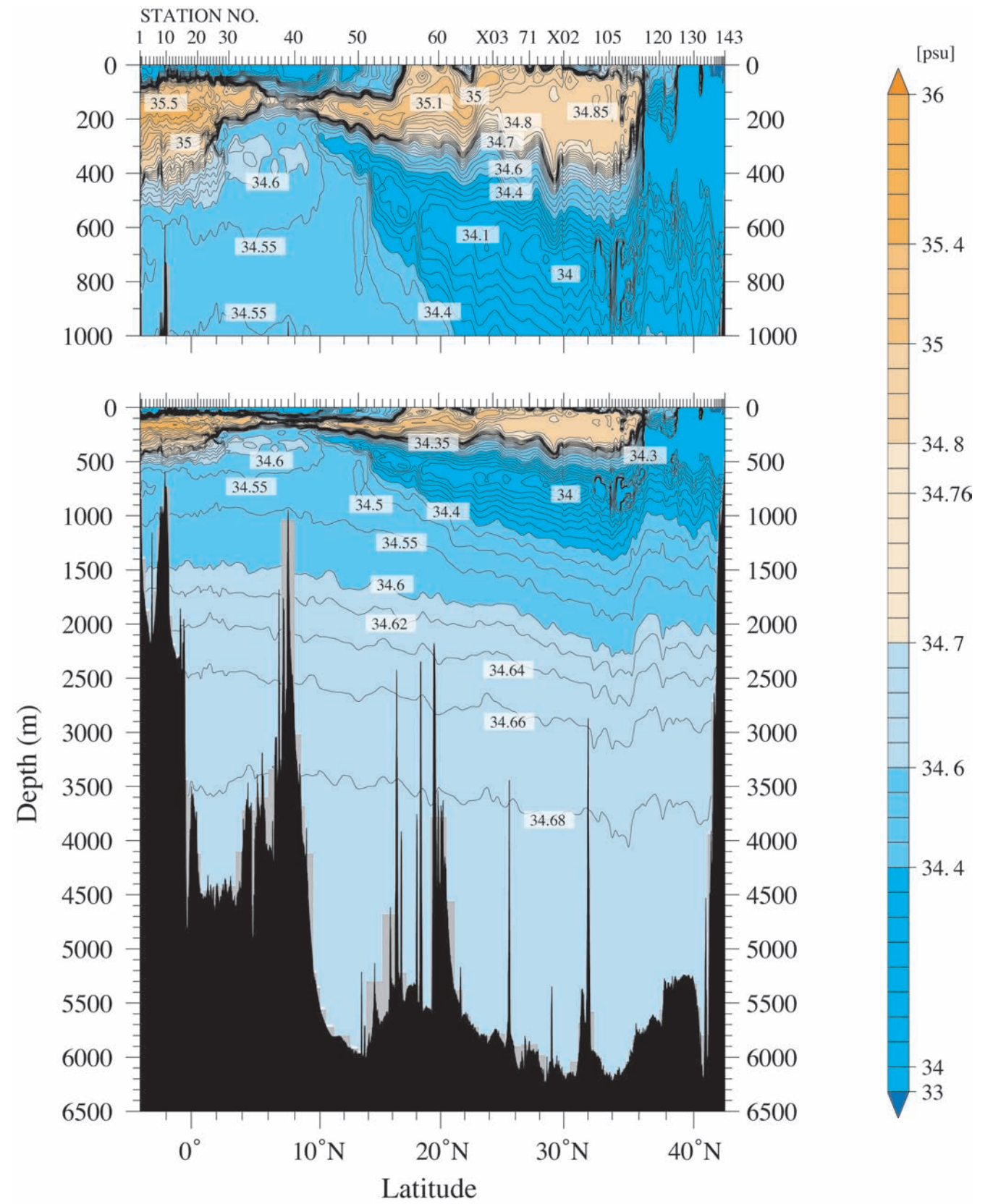
Figure 9

CTD salinity (psu) with SSW batch correction
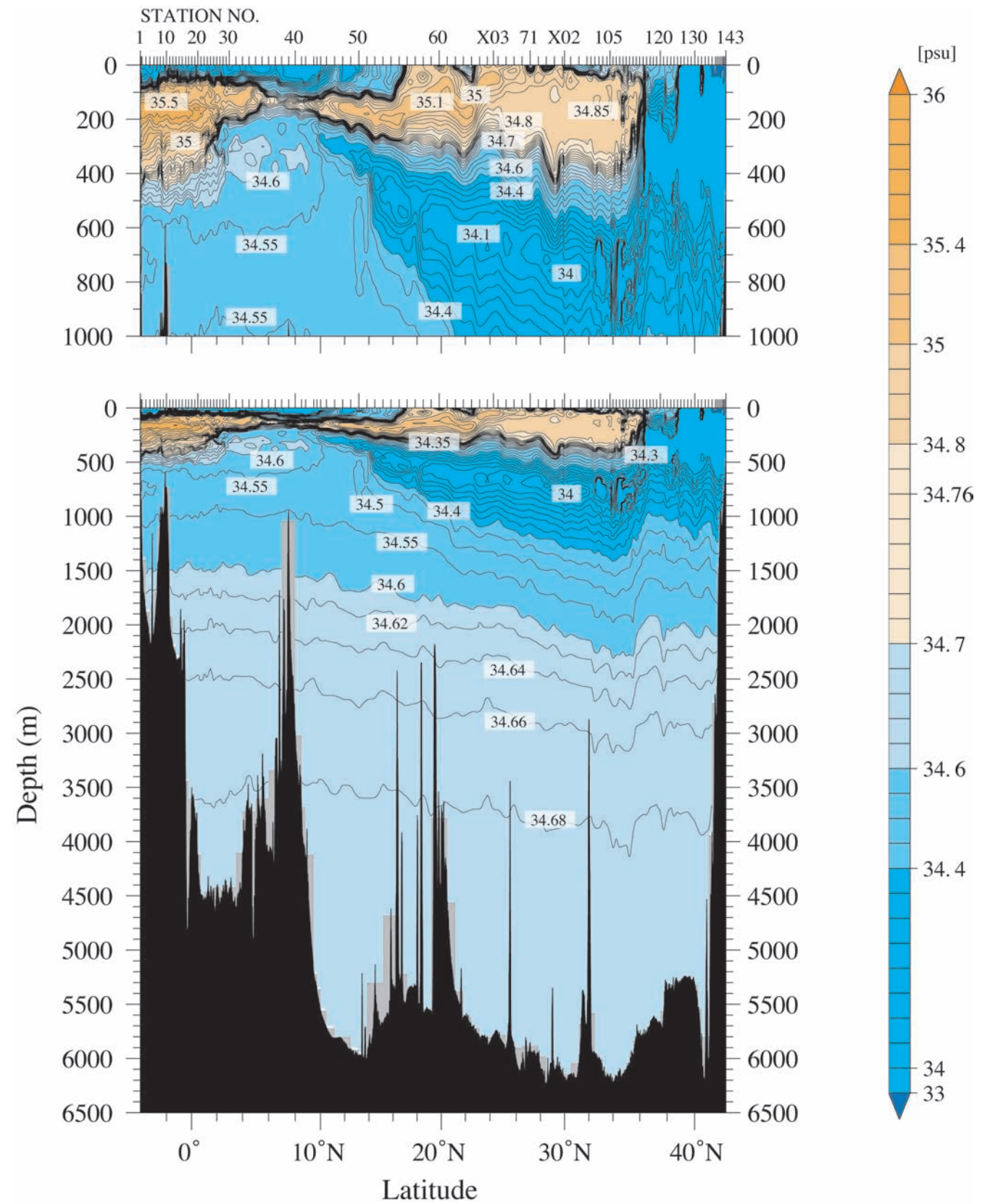
Figure 10

Density (σ_0) (kg/m³)
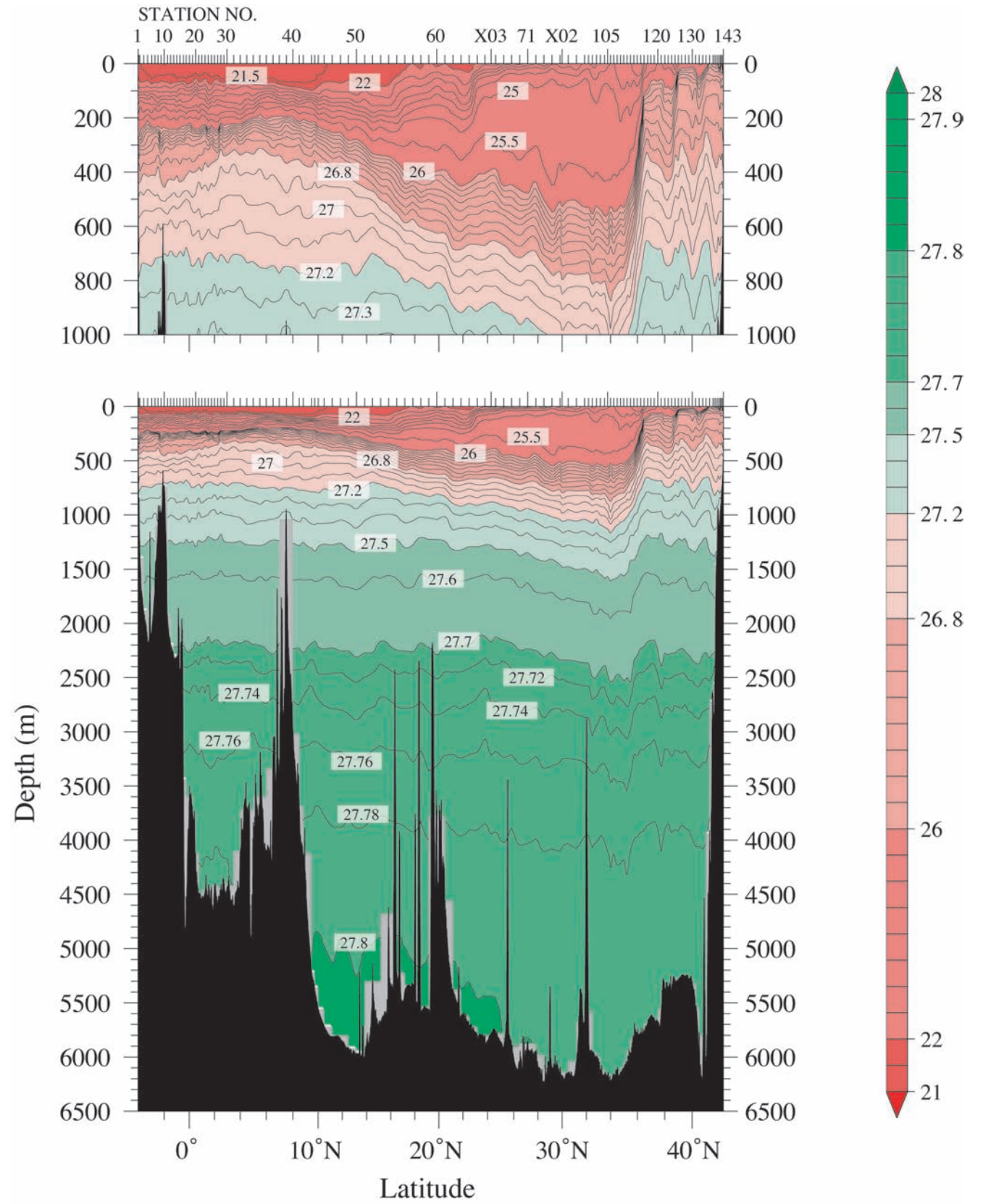
Figure 11

Density (σ_4) (kg/m³)
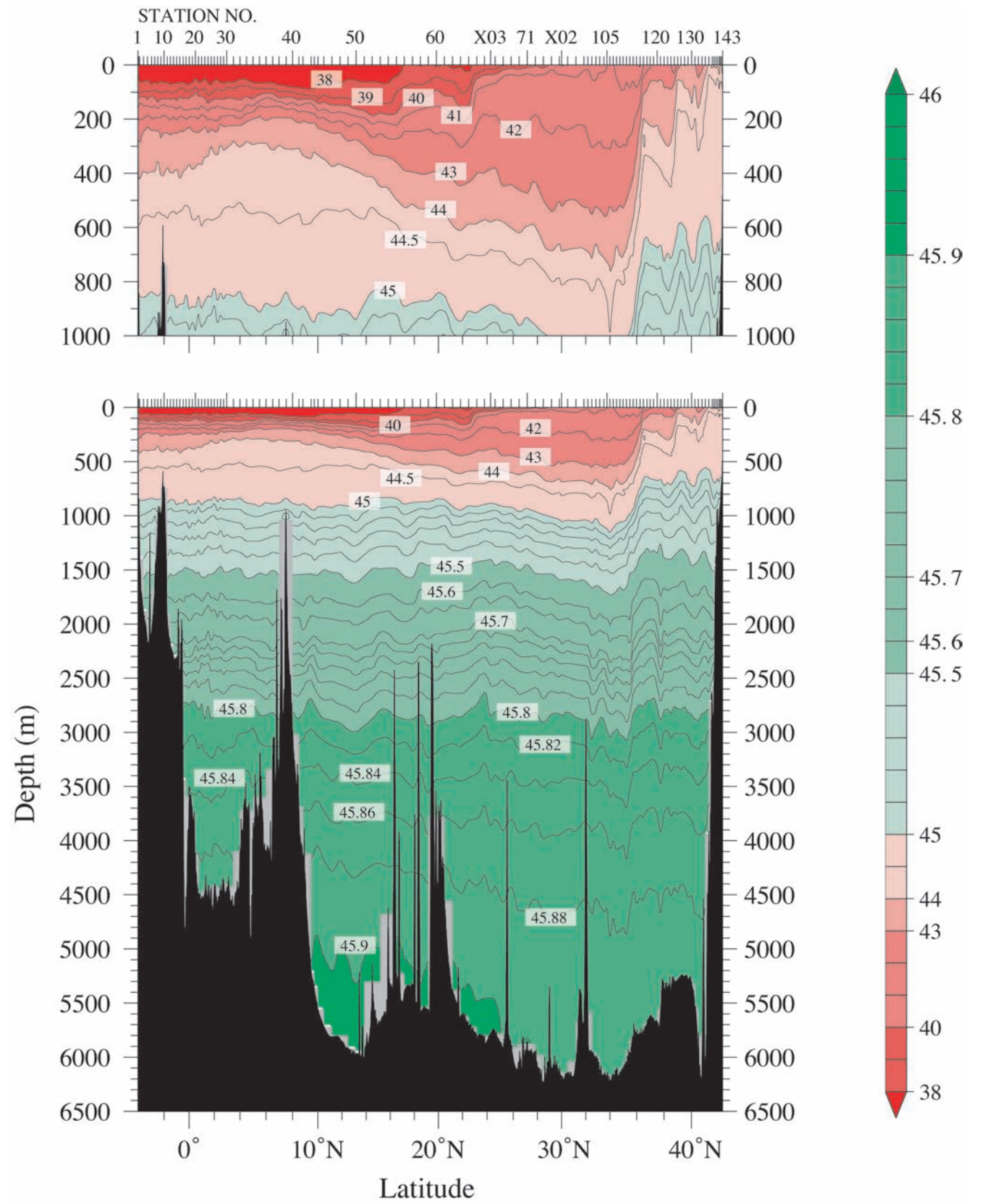
Figure 12

Neutral density (γ^n) (kg/m³)
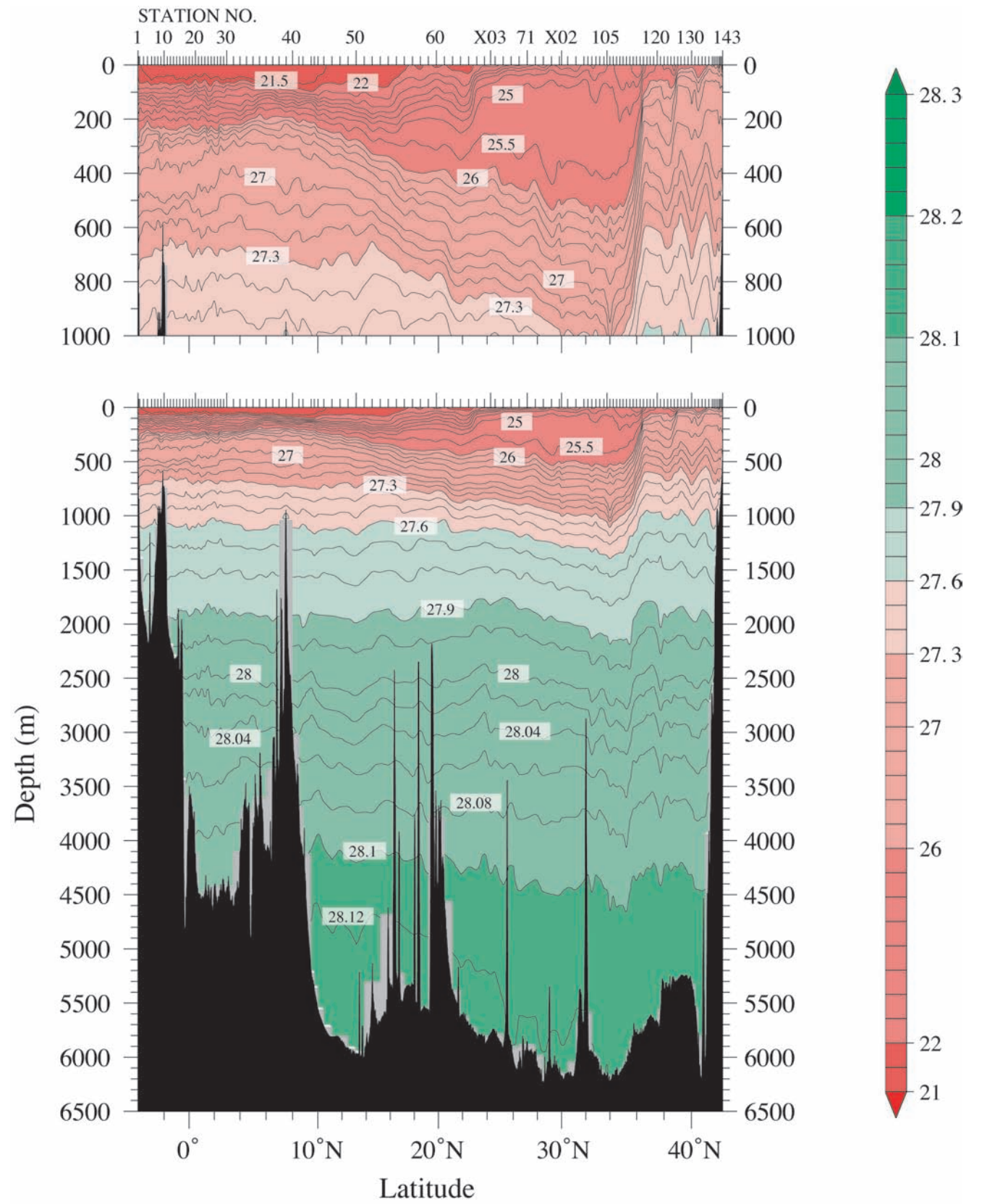
Figure 13

Bottle sampled dissolved oxygen (µmol/kg)
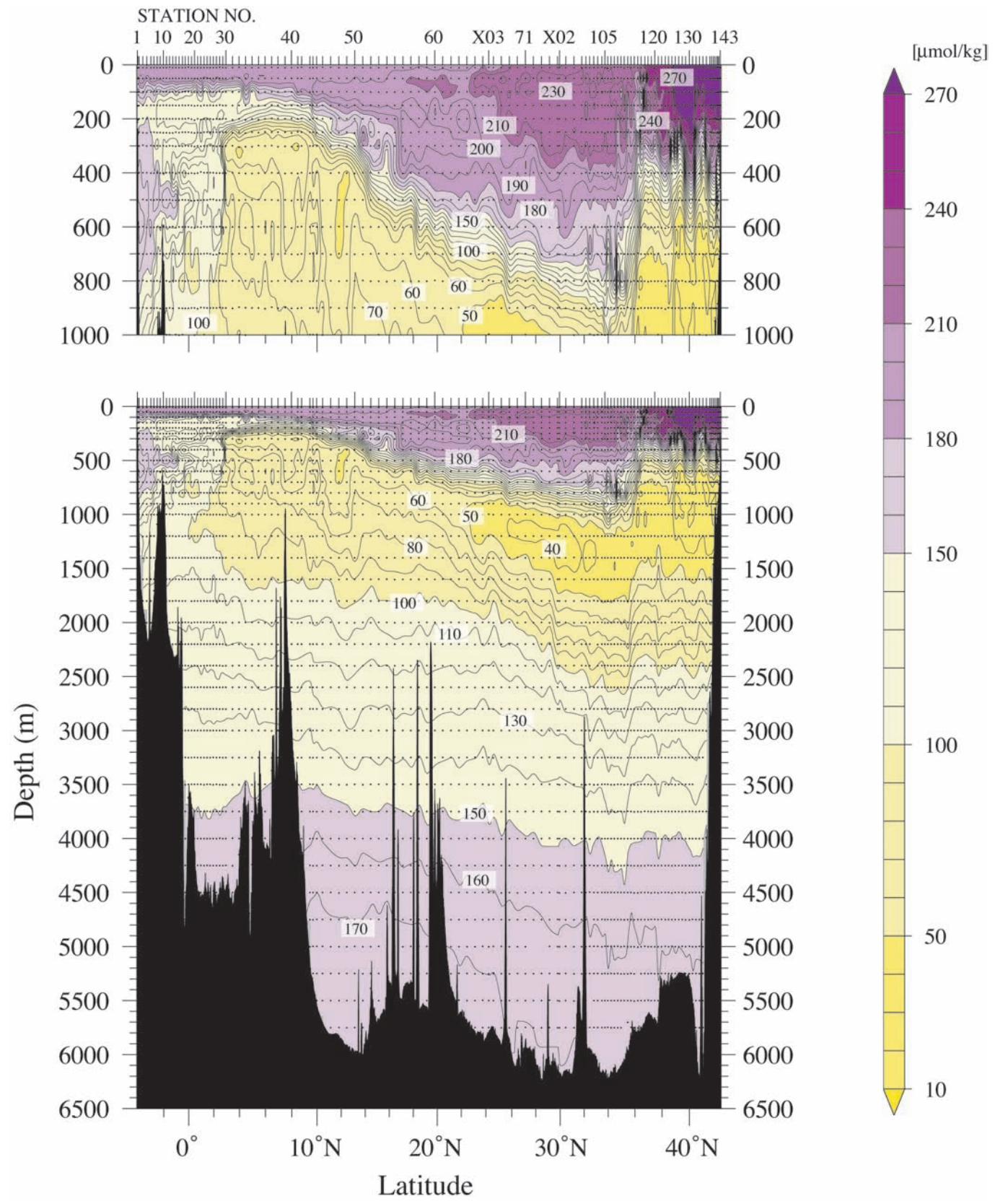
Figure 14

Silicate (µmol/kg)
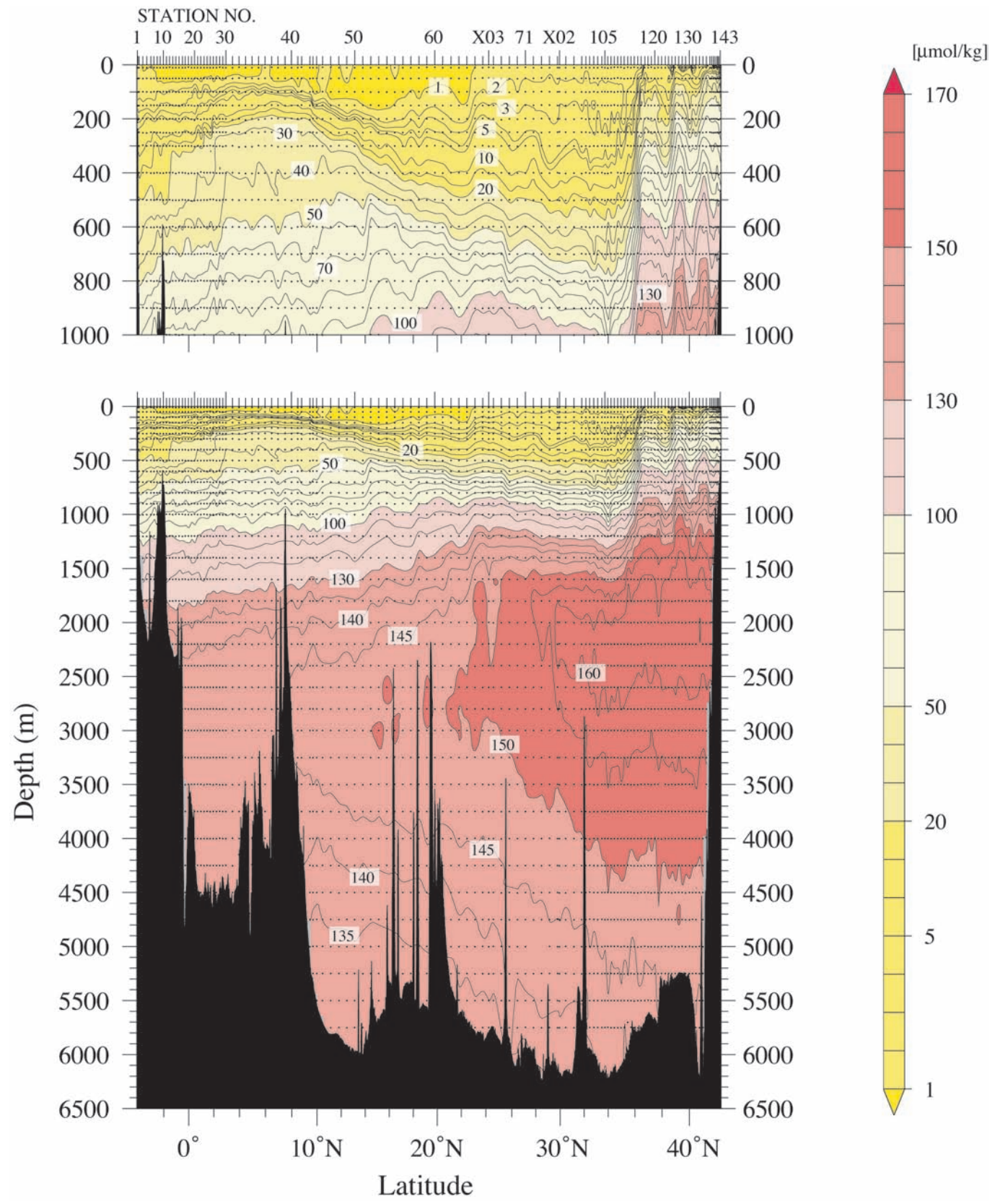
Figure 15

Nitrate (μmol/kg)
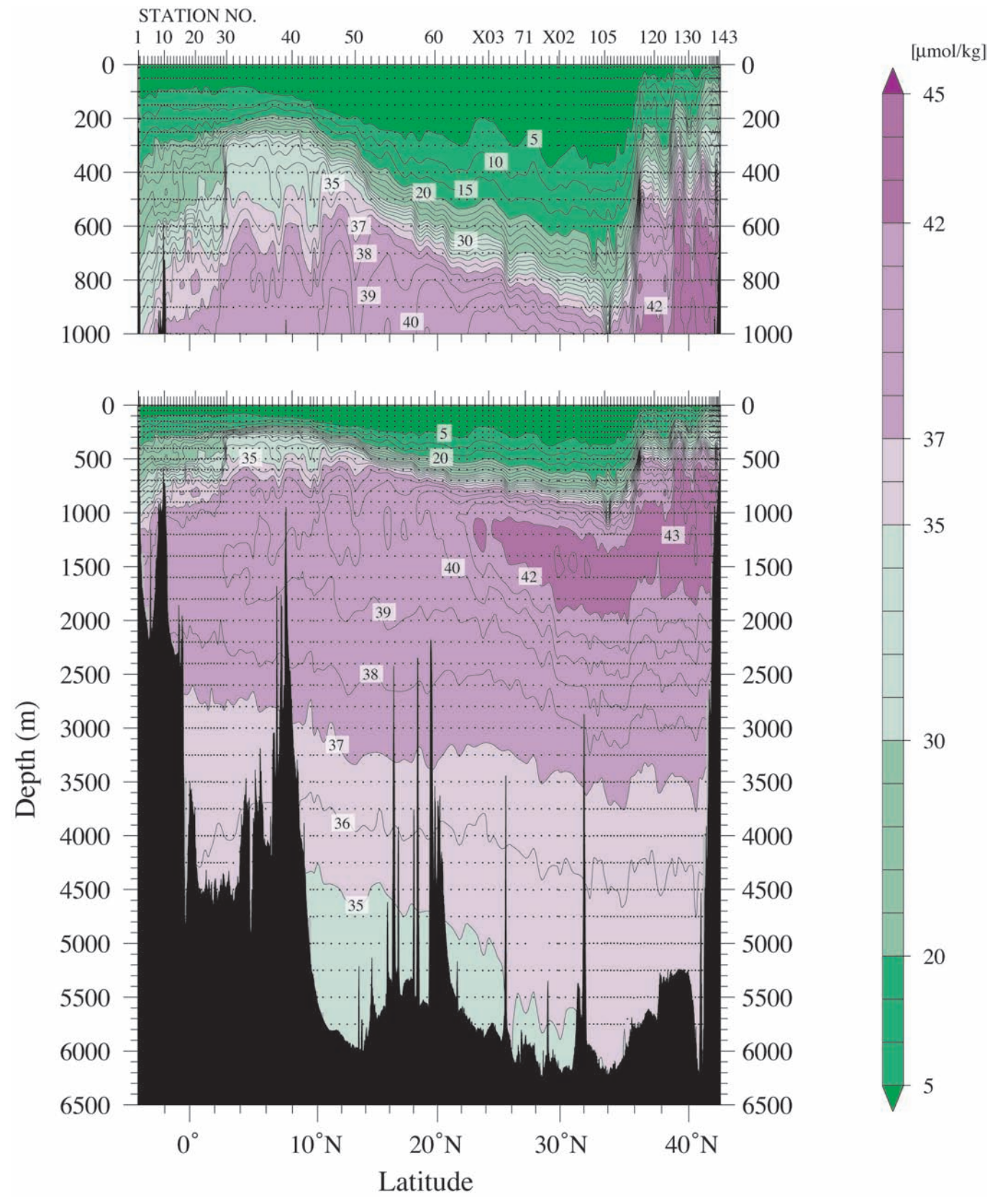
Figure 16

Nitrite (μmol/kg)
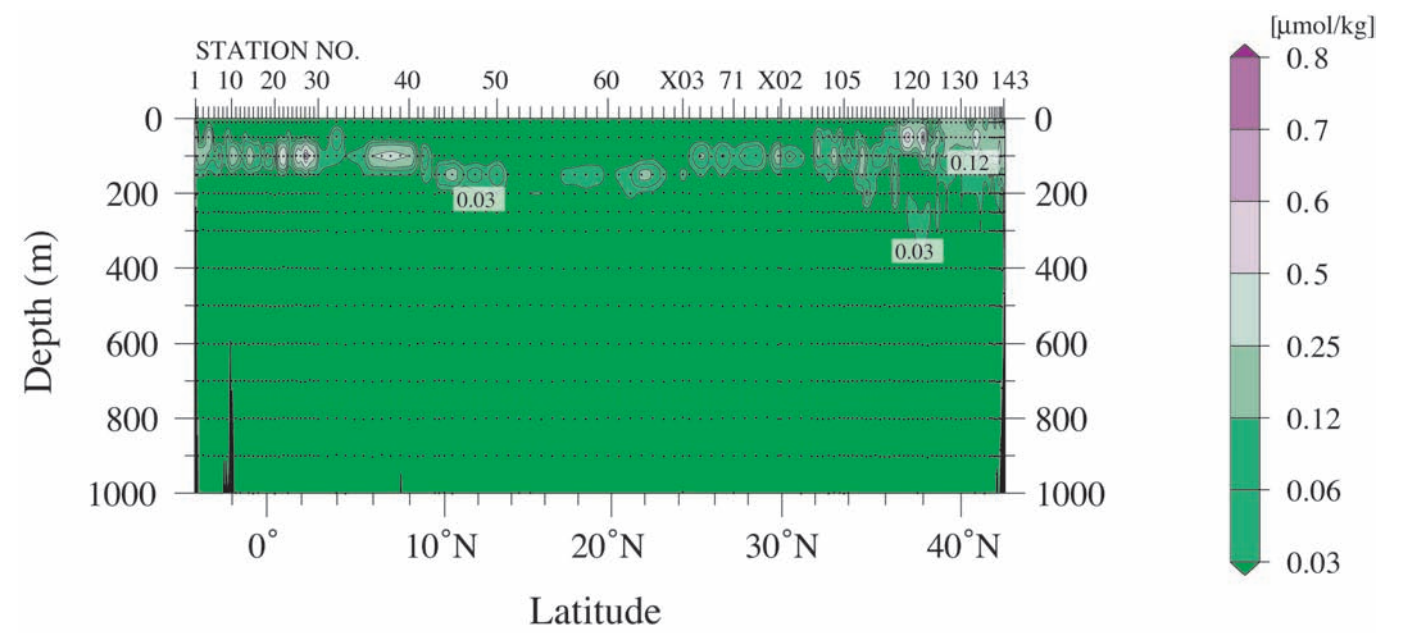
Figure 17

Phosphate (µmol/kg)
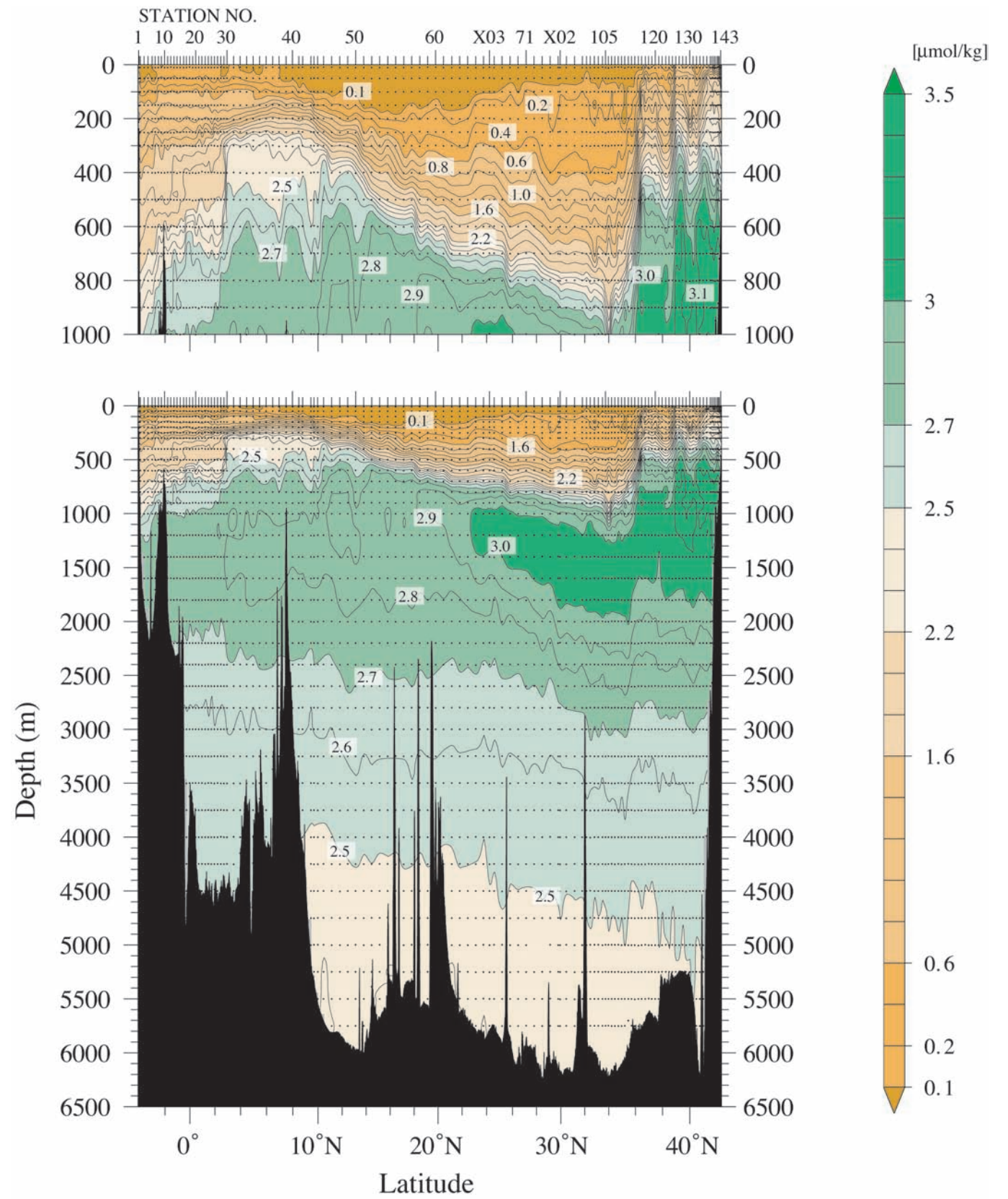
Figure 18

Dissolved inorganic carbon (µmol/kg)
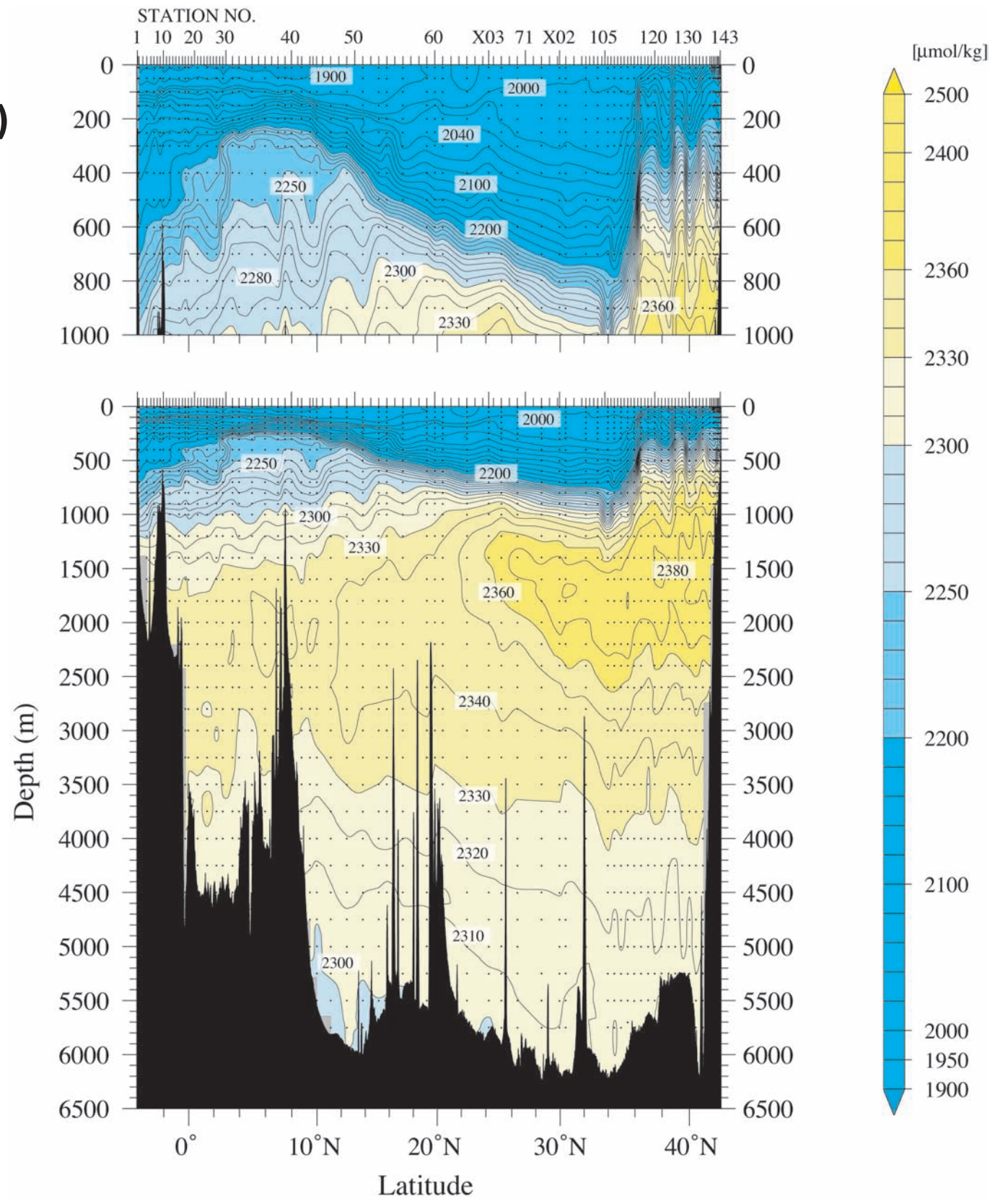
Figure 19

Total alkalinity (µmol/kg)
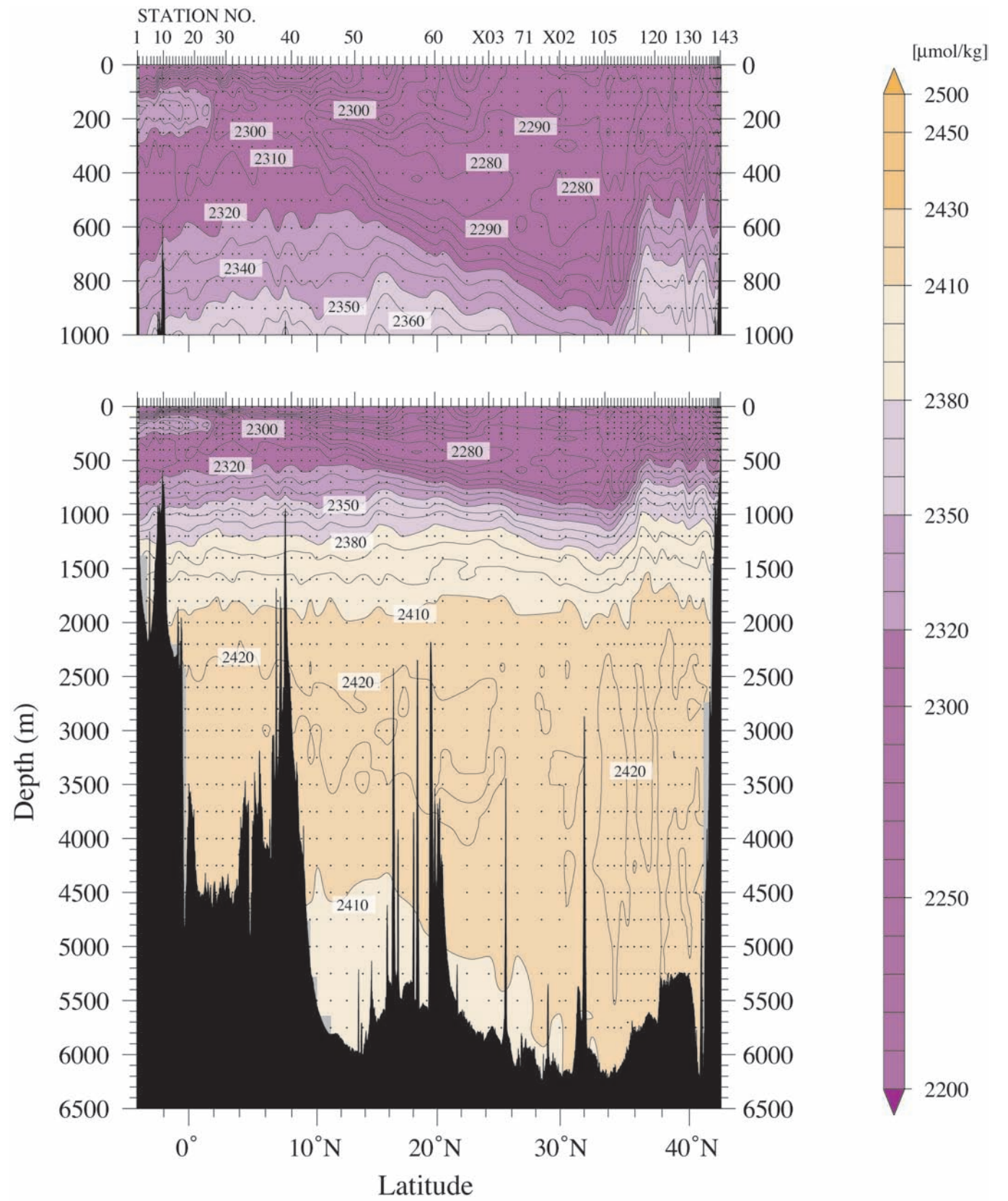
Figure 20

pH
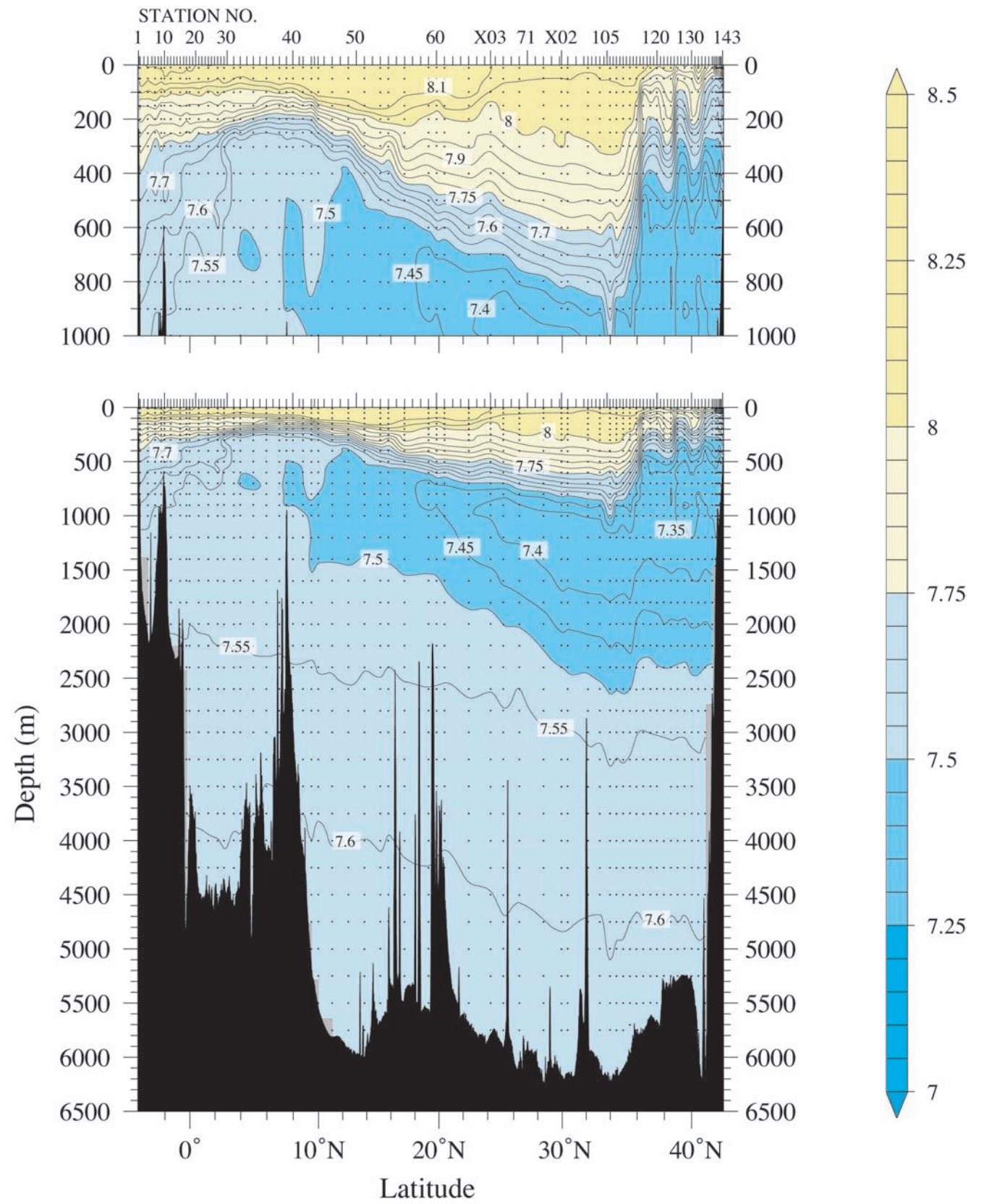
Figure 21

CFC-11 (pmol/kg)
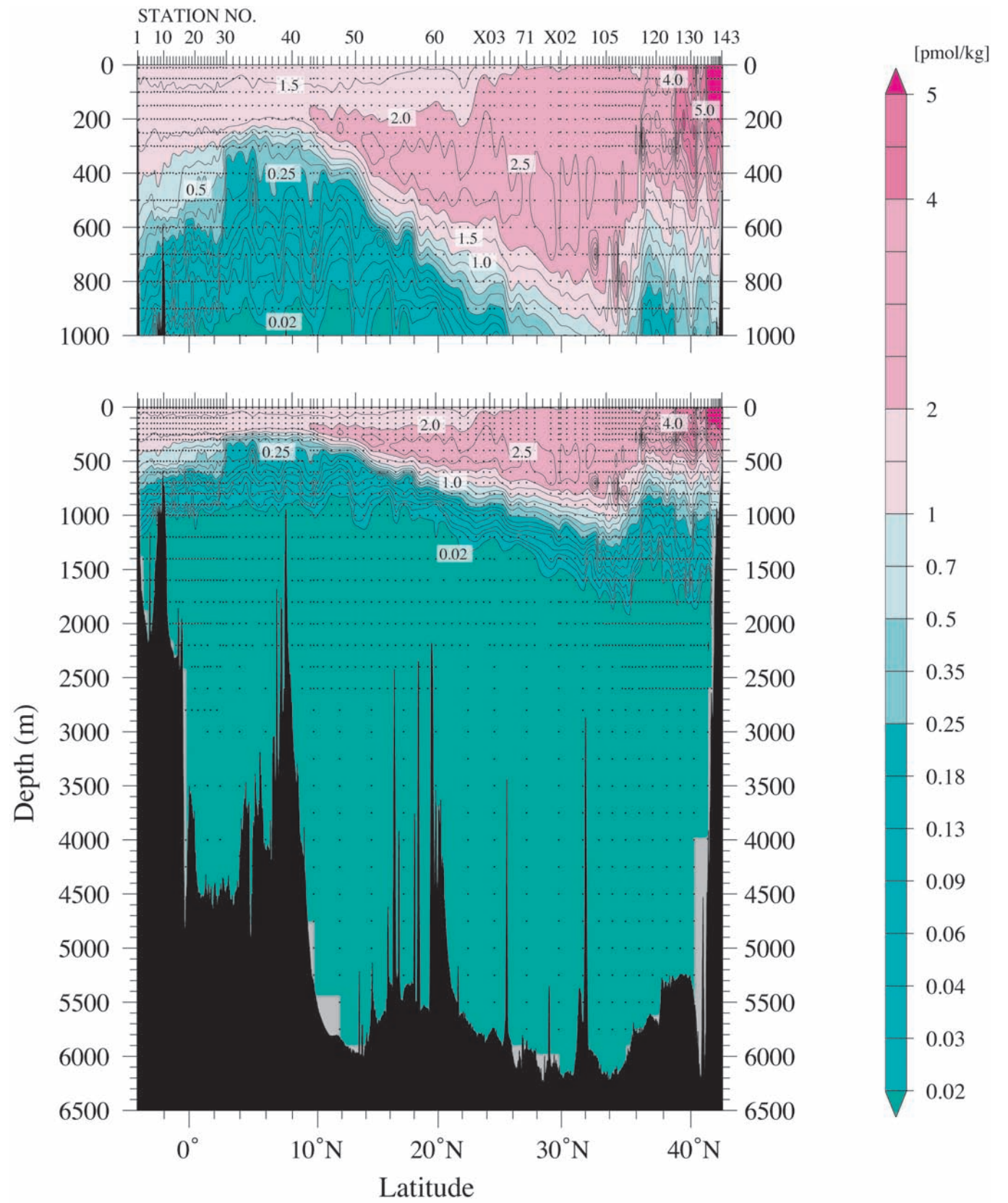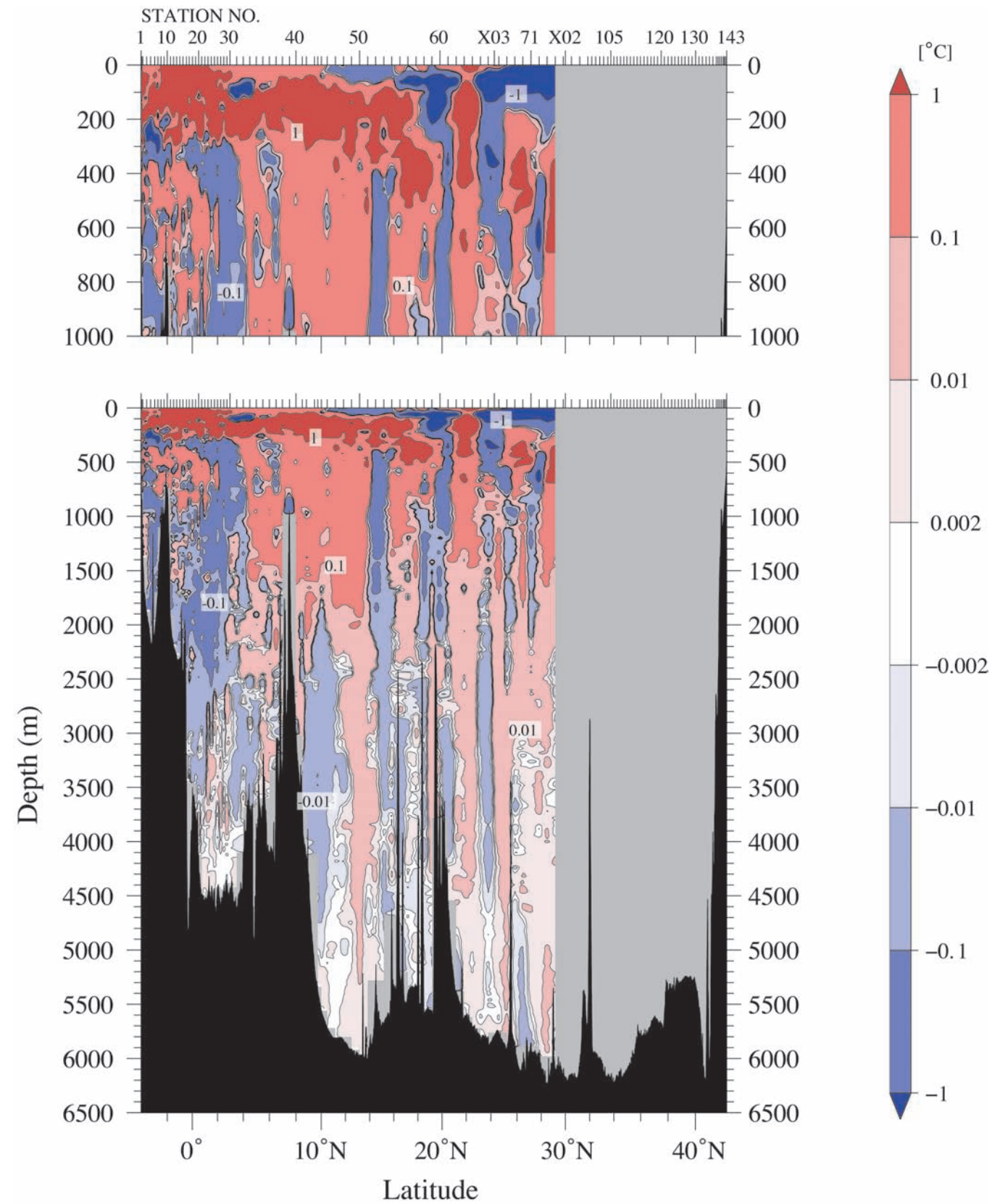
Figure 22

CFC-12 (pmol/kg)
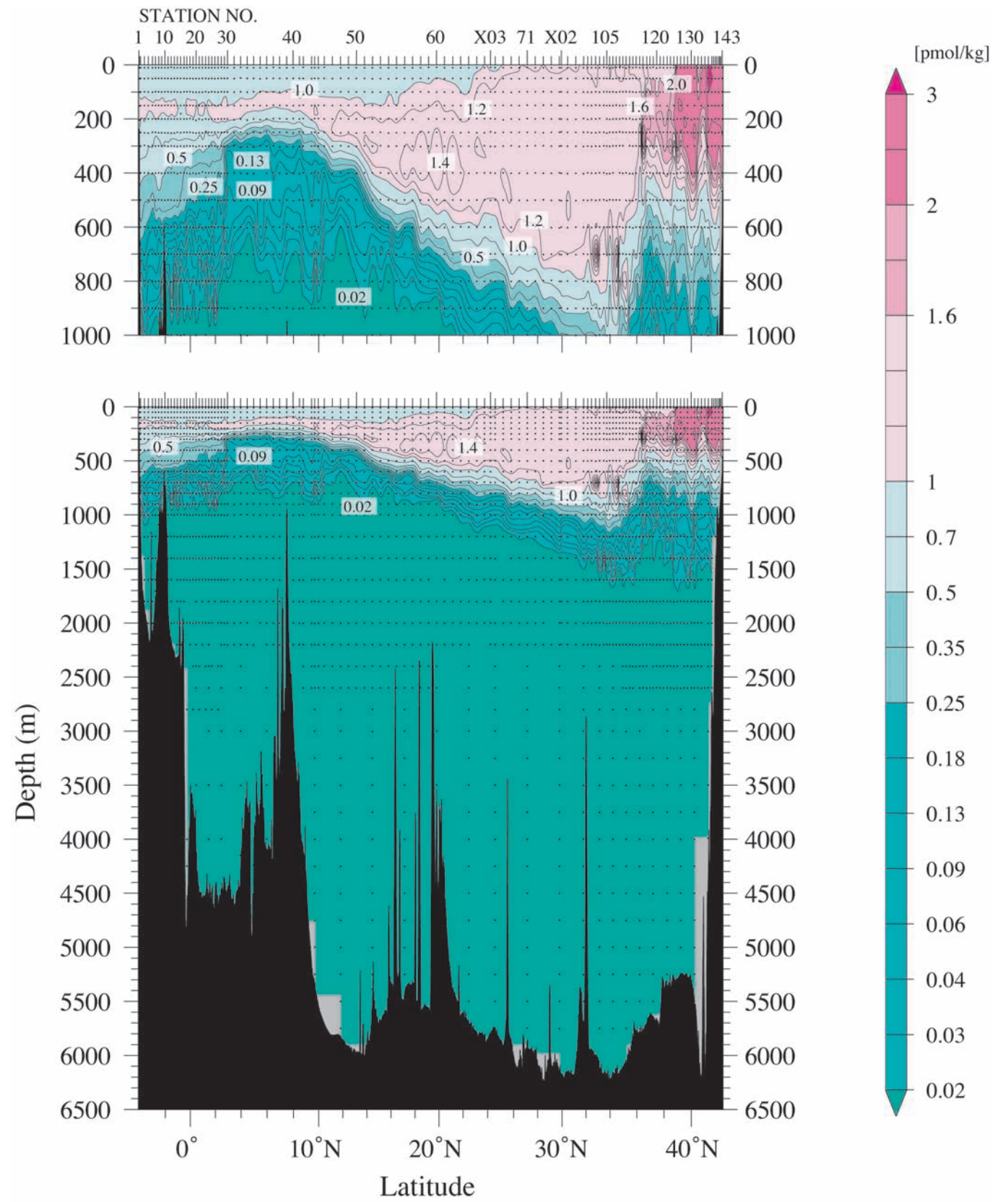
Figure 23

CFC-113 (pmol/kg)
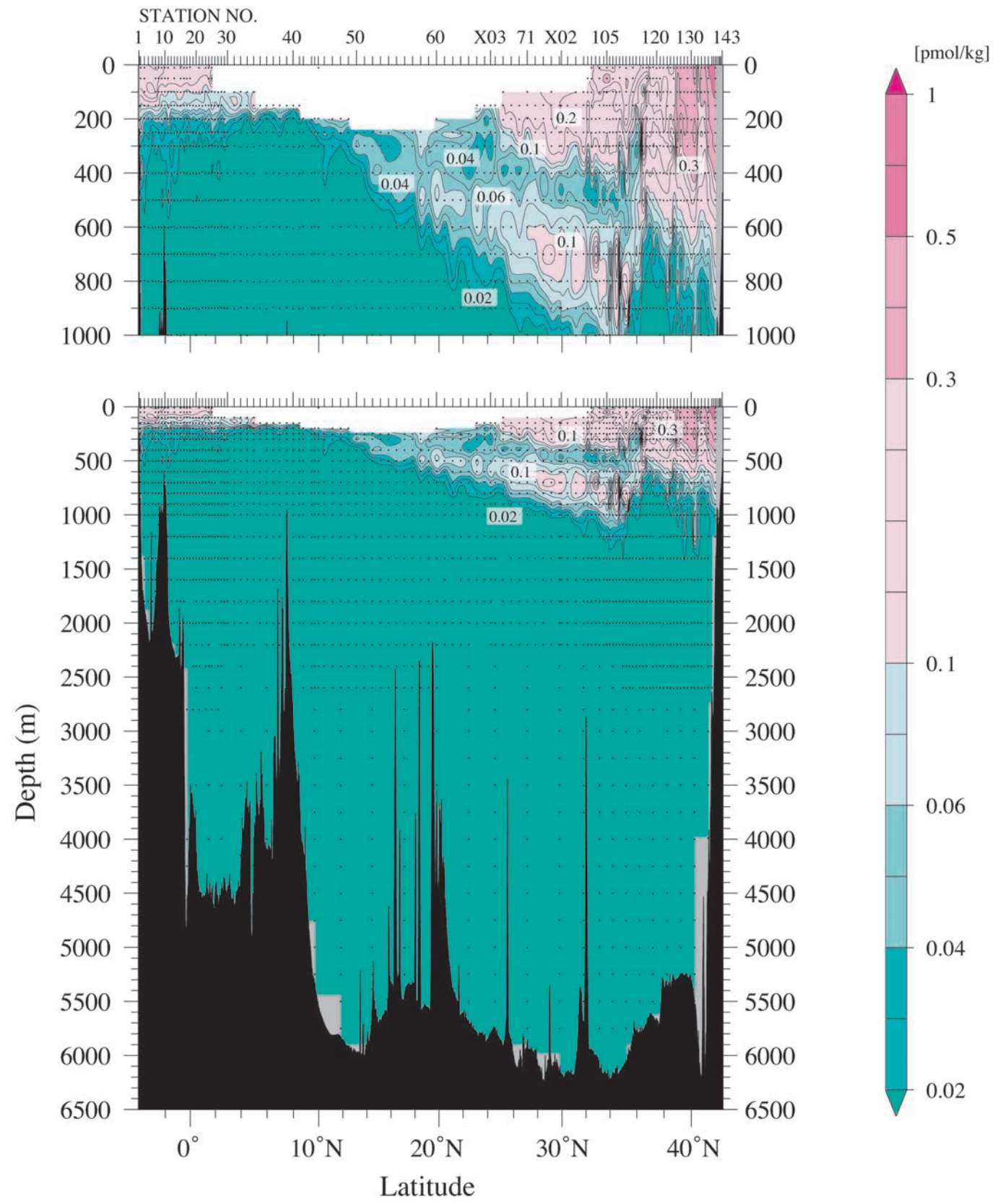
Figure 24

Current velocity (cm/s) normal to the cruise track measured by LADCP (eastward is positive)
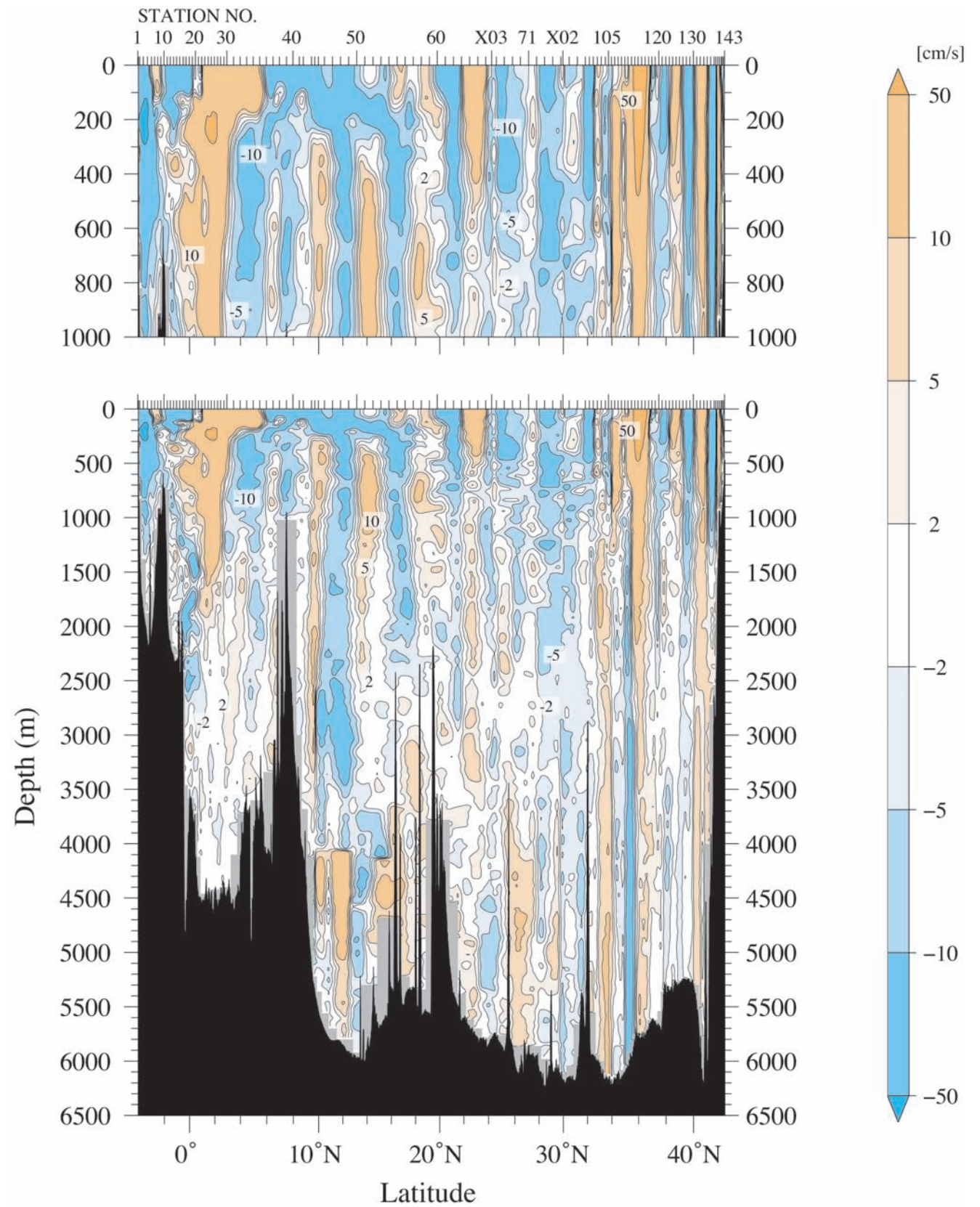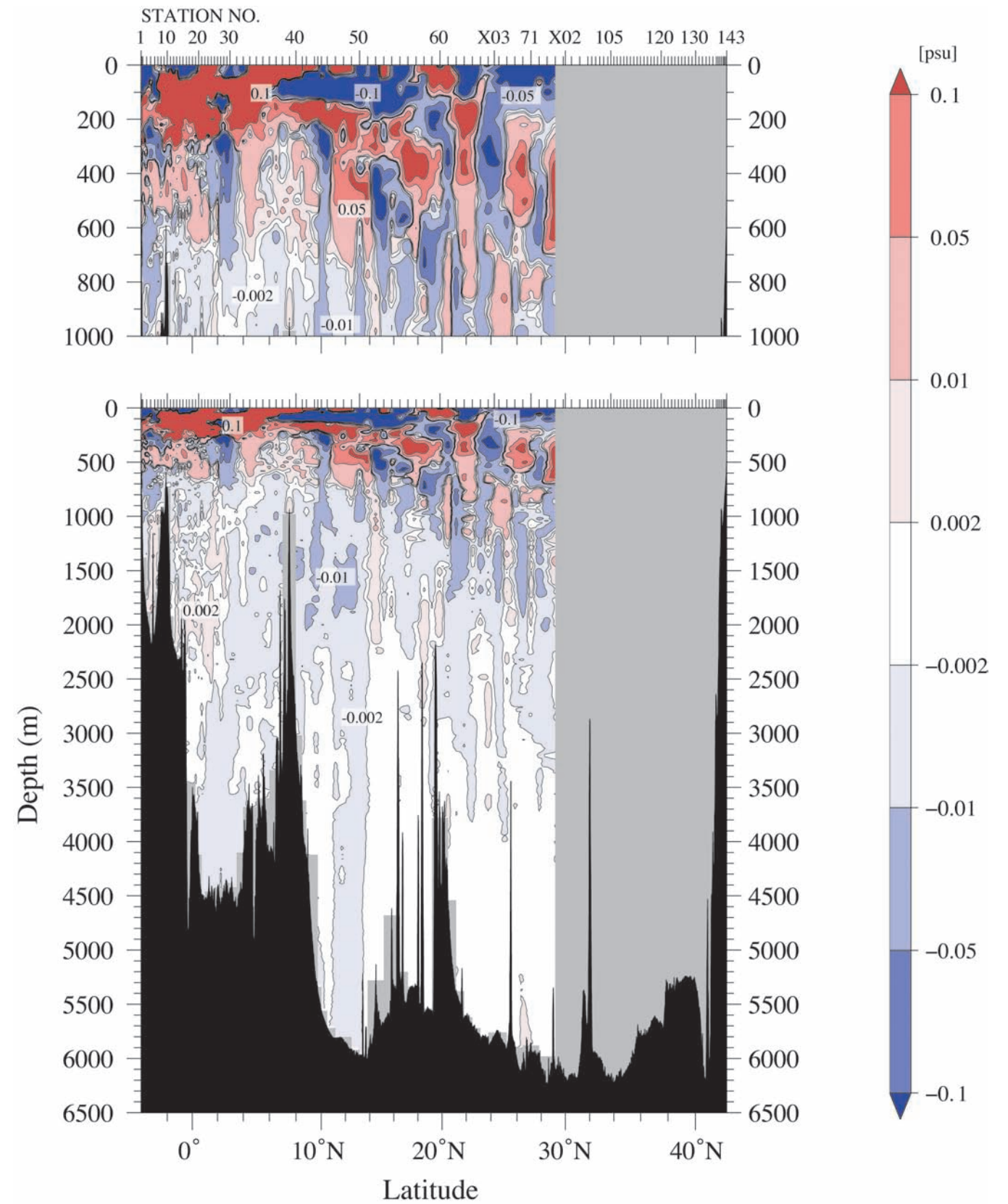
Figure 25

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.