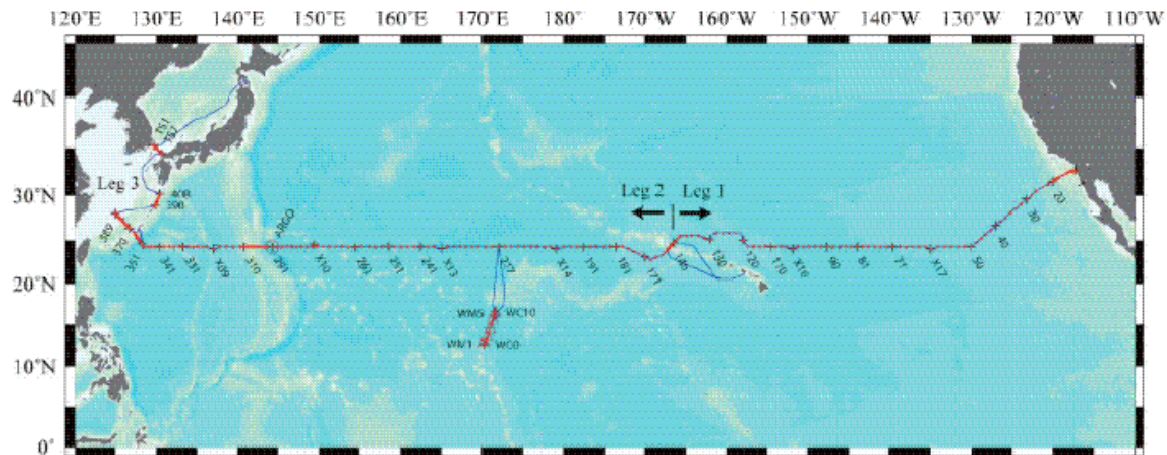


# CRUISE REPORT: P03

(updated JAN 2009)



## A.1. HIGHLIGHTS

### WHP CRUISE SUMMARY INFORMATION

Section designation	<b>P03</b>		
Expedition designation (EXPOCODE)	<b>PO3E (Leg.1): 49NA20051031</b>		
	<b>P03C (Leg.2): 49NZ20051127</b>		
	<b>P03W (Leg.3): 49NZ20060120</b>		
Chief Scientists & affiliations	<b>PO3E (Leg.1): Takeshi Kawano, JAMSTEC*</b>		
	<b>P03C (Leg.2): Akihiko Murata, JAMSTEC*</b>		
	<b>Ikuo Kaneko, JAMSTEC*</b>		
	<b>P03W (Leg.3): Shuichi Watanabe, JAMSTEC*</b>		
Dates	2005 OCT 31 - 2006 JAN 30		
Ship	R/V MIRAI		
Ports of call	San Diego, U.S.A. to Honolulu, U.S.A.		
	to Okinawa, Sekinehama		
Number of stations	237		
Geographic boundaries of the stations	12°43.32'N		
	124°59.27'E	117°19.84'W	
	32°16.29'N		
Floats and drifters deployed	1 Floats, 0 Drifters		
Moorings deployed or recovered	0 Deployed, 5 recovered		

Takeshi Kawano \* E-mail: kawanot@jamstec.go.jp • Tel: +81-46-867-9471

Akihiko Murata • E-mail: akihiko.murata@jamstec.go.jp

Ocean General Circulation Observational Research Program

Institute of Observational Research for Global Change

Japan Agency for Marine-earth Science and Technology

2-15, Natsushima, Yokosuka, Japan 237-0061 • Fax. +81-46-867-9455

Dr. Ikuo Kaneko • Oceanographic Research Division  
 Meteorological Research Institute • Japan Meteorological Agency  
 1-1 Nagamine Tsukuba City, Ibaragi 305 • JAPAN  
 Tel: +81-298-53-8658 • Fax: +81-298-55-1439  
 Email: [ikuo-kaneko@met.kishou.go.jp](mailto:ikuo-kaneko@met.kishou.go.jp)

Dr. Shuichi Watanabe • Senior Scientist  
 Japan Agency for Marine-Earth Science and Technology  
 690 Kitasekine, Sekine, Mutsu, 035-0022, Japan  
 Tel: +81-468-67-9500 • Fax: +81-468-67-9455 • Email: [swata@jamstec.go.jp](mailto:swata@jamstec.go.jp)

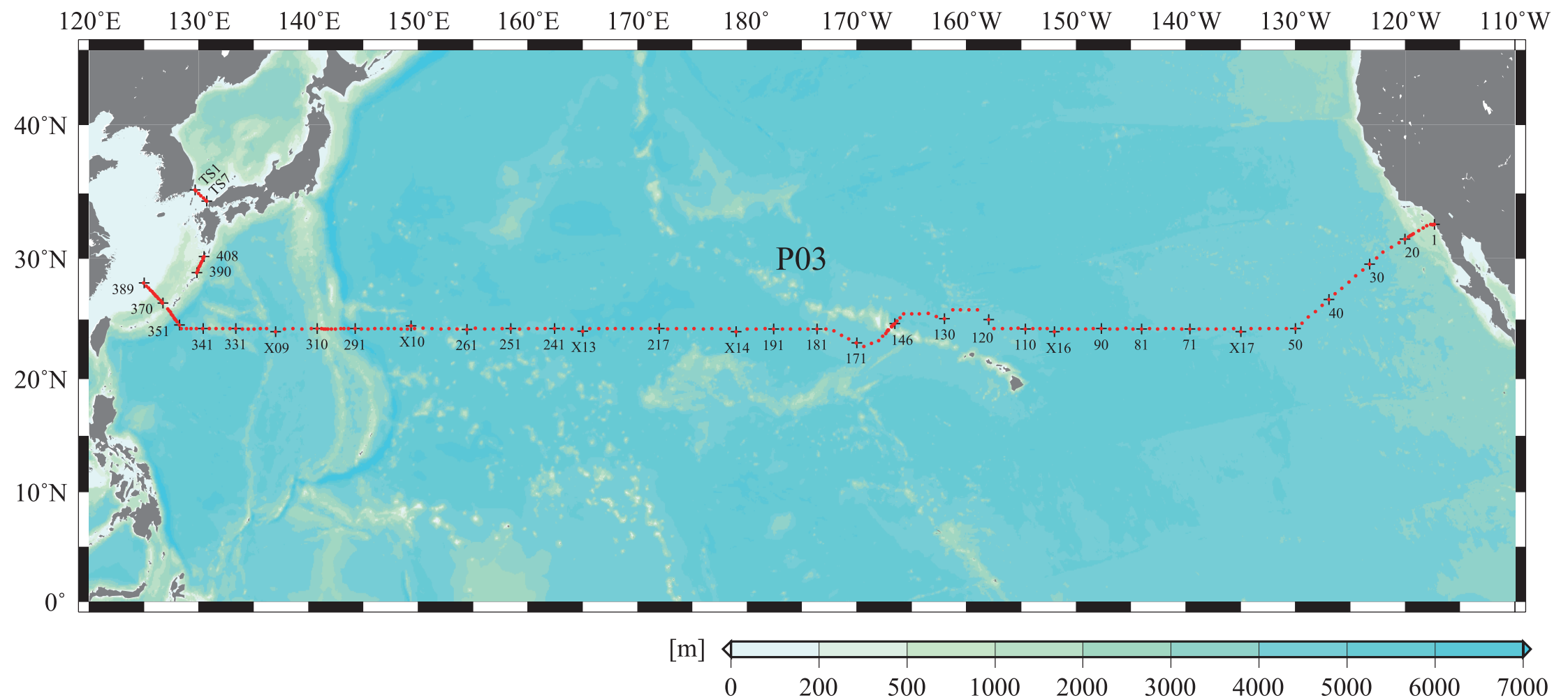
## LINKS TO TEXT LOCATIONS

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	<b>CTD Data:</b>
Geographic Boundaries	Acquisition
Cruise Track (Figure): <a href="#">PI</a> <a href="#">CCHDO</a>	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	<b>Bottle Data</b>
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	References
Navigation Bathymetry	CTD Oxygen
Acoustic Doppler Current Profiler (ADCP)	Bottle Oxygen
Thermosalinograph	pH
XBT and/or XCTD	CFCs
Meteorological Observations	<b>Acknowledgments</b>
Atmospheric Chemistry Data	
Data Processing Notes	



**Figure 1**  
**Station locations for WHP P03 cruise**

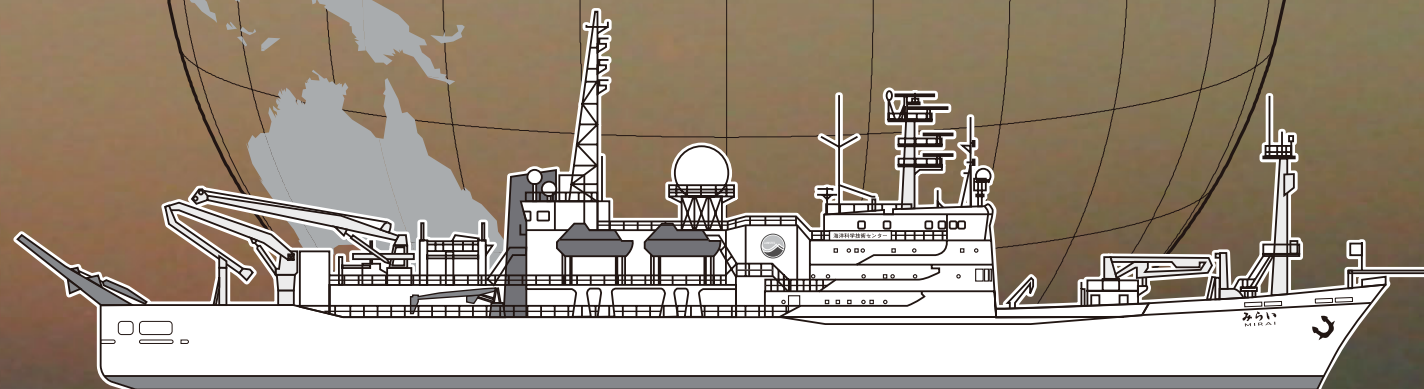


# WHP P03 REVISIT DATA BOOK

Field Activity of JAMSTEC towards International Repeat Hydrography and Carbon Program

## WHP P03 REVISIT *in 2005*

*Towards  
Intl. Repeat Hydrography  
and Carbon Program*

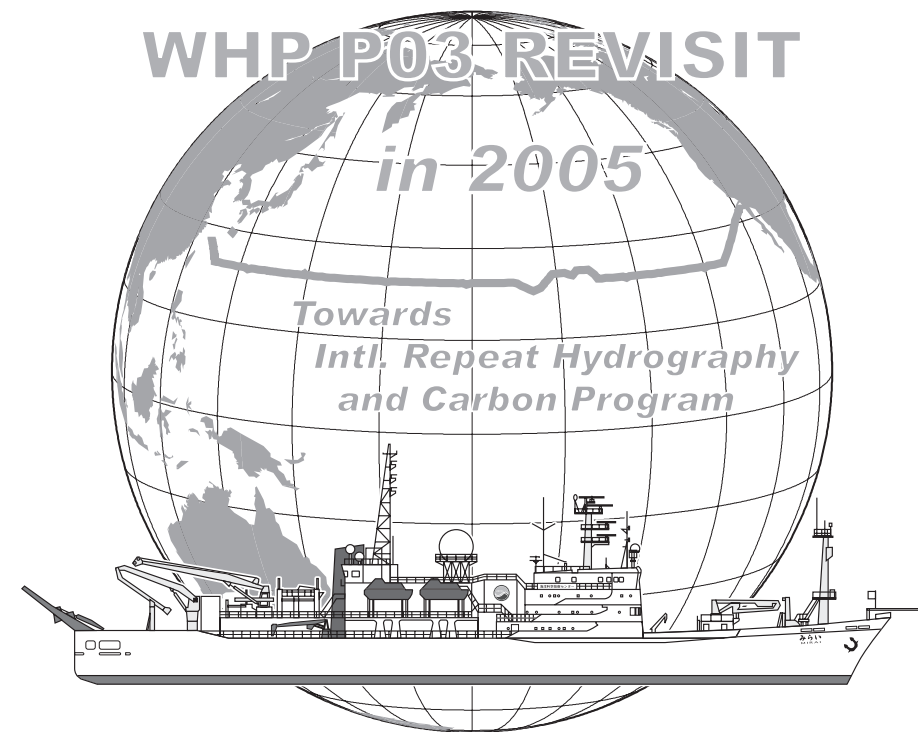






# WHP P03 REVISIT DATA BOOK

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



WHP P03 REVISIT DATA BOOK

December 27, 2007 Published

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

Published by © JAMSTEC, Yokosuka, Kanagawa, 2007

Japan Agency for Marine-Earth Science and Technology

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

Phone +81-46-867-9471, Fax +81-46-867-9455

Printed by Aiwa Printing Co., Ltd.

3-22-4 Takanawa, Minato-ku, Tokyo 108-0074, Japan

# Contents

Preface	.....	iii
<i>M. Fukasawa (JAMSTEC)</i>		
Documents and .sum files		
<b>1.Cruise Narrative</b>	.....	1
<i>T. Kawano (JAMSTEC)</i>		
<b>2.Underway Measurements</b>		
2.1 Navigation and Bathymetry	.....	12
<i>T. Matsumoto (Univ. Ryukyus) et al.</i>		
2.2 Surface Meteorological Observation	.....	18
<i>K. Yoneyama (JAMSTEC) et al.</i>		
2.3 Thermosalinograph and related measurements	.....	22
<i>Y. Kumamoto (JAMSTEC) et al.</i>		
2.4 Underway pCO <sub>2</sub>	.....	32
<i>A. Murata (JAMSTEC) et al.</i>		
2.5 Acoustic Doppler Current Profiler	.....	34
<i>Y. Yoshikawa (JAMSTEC) et al.</i>		
<b>3. Hydrographic Measurement Techniques and Calibrations</b>		
3.1 CTD/O <sub>2</sub> Measurements	.....	36
<i>H. Uchida (JAMSTEC) et al.</i>		
3.2 Salinity	.....	67
<i>T. Kawano (JAMSTEC) et al.</i>		
3.3 Oxygen	.....	73
<i>Y. Kumamoto (JAMSTEC) et al.</i>		
3.4 Nutrients	.....	82
<i>M. Aoyama (MRI) et al.</i>		
3.5 Dissolved inorganic carbon	.....	94
<i>A. Murata (JAMSTEC) et al.</i>		
3.6 Total Alkalinity	.....	98
<i>A. Murata (JAMSTEC) et al.</i>		
3.7 pH	.....	101
<i>A. Murata (JAMSTEC) et al.</i>		
3.8 CFCs	.....	104
<i>K. Sasaki (JAMSTEC) et al.</i>		
3.9 Lowered Acoustic Doppler Current Profiler	.....	107
<i>S. Kouketsu (JAMSTEC) et al.</i>		
<b>Station Summary</b>		
49MR0505_1 .sum file	.....	108
49MR0505_2 .sum file	.....	117

49MR0505_3 .sum file	.....	131
Figures		
<i>Figure captions</i>	.....	135
<i>Station locations</i>	.....	137
<i>Bathymetry</i>	.....	139
<i>Surface wind</i>	.....	157
<i>Sea surface temperature</i>	.....	159
<i>Sea surface salinity</i>	.....	161
<i>ΔpCO<sub>2</sub></i>	.....	163
<i>Surface current</i>	.....	165
Cross-sections		
<i>Potential temperature</i>	.....	167
<i>Salinity</i>	.....	169
<i>Salinity (with SSW correction)</i>	.....	171
<i>Density (σ<sub>ρ</sub>)</i>	.....	173
<i>Density (σ<sub>θ</sub>)</i>	.....	175
<i>Neutral density (γ<sup>n</sup>)</i>	.....	177
<i>Oxygen</i>	.....	179
<i>Silicate</i>	.....	181
<i>Nitrate</i>	.....	183
<i>Nitrite</i>	.....	185
<i>Phosphate</i>	.....	187
<i>Dissolved inorganic carbon</i>	.....	189
<i>Total alkalinity</i>	.....	191
<i>pH</i>	.....	193
<i>CFC-11</i>	.....	195
<i>CFC-12</i>	.....	197
<i>CFC-113</i>	.....	199
<i>Velocity</i>	.....	201
Difference between WOCE and the revisit		
<i>Potential temperature</i>	.....	203
<i>Salinity (with SSW correction)</i>	.....	205
<i>Oxygen</i>	.....	207
.sum, .sea, .wct and other data files		
<i>CD-ROM on the back cover</i>		

# Preface

Ocean General Circulation Observational Research Program of IORGC<sup>(1)</sup>/ JAMSTEC<sup>(2)</sup> selected former WHP<sup>(3)</sup> line of P3 or P3-1985 as one of four repeat long lines in accordance with the mid-term objective of the program.

P3 line was occupied by US scientists with Dr. Dean Roemmich as the chief scientist in 1985 (They also occupied P1 line on the way back to the United States from Japan after P3 line cruise with Dr. Lynne Talley as the chief scientist) and was the first land-to-land line in the North Pacific along which sets of high quality hydrographic observations were carried out. The performances of P3 cruise were outstanding from various viewpoints compared to those of other historical hydrographic observations. It should be noted here that P3-1985 was the first complete zonal section in the North Pacific with a dense station distribution and high quality CTD measurements appropriate to estimate meridional ocean fluxes. Quite a few scientific results have been published. Most of these results have focused attention on the meridonal overturn structure of sea water mass and of dissolved materials fluxes induced by the overturn of sea water mass. Those scientific results have given a new viewpoint or concept toward ocean general circulation and strongly support the scientific needs of WOCE<sup>(4)</sup>. Also data managing system in SIO<sup>(5)</sup>, one of back offices of P3 observation, was recognized as an effective support to the global hydrography network in WOCE. In fact, the framework of data assembly center (DAC) during WOCE period and ongoing IRHCP<sup>(6)</sup> inherit a concept of data management system from SIO. If it were NOT for P3-1985, we might have to make an extraordinary effort to share and utilize hydrographic data for global climate study even now.

P3 revisit was carried out during the period from October 31, 2005 to January 30, 2006 following IRHCP under CLIVAR<sup>(7)</sup> and IOCCP<sup>(8)</sup>. Therefore, the objectives of this revisit are 1) to investigate interannual and long-term variations in the ocean circulation and associated net property transports and their divergences, and 2) to quantify net changes in water mass inventories and renewal rate on seasonal to decadal time series, and to explore their relationships to estimate ocean transport divergences and air-sea exchanges. Beside these comprehensive objectives which are defined by IRHCP, one more objective was added to present revisit, that is to detect and evaluate changes in heat and material inventories of LCDW<sup>(9)</sup> together with other results from mooring observation across the Wake Island Deep Passage. This objective was the very reason why our program preferred P3 to P2.

Lastly, as noted before, we would heartily ask favors of all scientists to refer our data books of repeat hydrography including this issue as often as possible though those data sets can be accessed through web-sites of IORGC<sup>(10)</sup>, JAMSTEC<sup>(11)</sup>, IRHCP<sup>(12)</sup> and CDIAC<sup>(13),(14)</sup>. No permission is required to reproduce those data books and CDs. Such references are the only proof that our repeat hydrography activity is closely connected to science and can keep our activity sustainable.

On Canadian Thanksgiving Day at Yokosuka

*Masao Fukasawa*

Director- General of IORGC/JAMSTEC,

Program Director of Ocean General Circulation Observational Program IORGC/JAMSTEC

- (1) Institute of Observational Research for Global Change
- (2) Japan Agency for Marine-Earth Science and Technology
- (3) WOCE<sup>(4)</sup> Hydrographic Programme
- (4) World Ocean Circulation Experiment
- (5) Scripps Institution of Oceanography
- (6) International Repeat Hydrography and Carbon Project
- (7) Climate Variability and Predictability
- (8) International Ocean Carbon Coordination Project
- (9) Lower Circumpolar Deep Water
- (10) <http://www.jamstec.go.jp/iorgc/ocorp/data/post-woce.html>
- (11) [http://www.jamstec.go.jp/mirai/index\\_eng.html](http://www.jamstec.go.jp/mirai/index_eng.html)
- (12) <http://cchdo.ucsd.edu/index.html>
- (13) Carbon Dioxide Analytical Center
- (14) [http://cdiac.ornl.gov/oceans/RepeatSections/repeat\\_map.html](http://cdiac.ornl.gov/oceans/RepeatSections/repeat_map.html)



# 1 Cruise Narrative

## 1.1 Highlight

**GHPO Section Designation:** P3

**Expedition Designation:** MR05-05

**Chief Scientists and Affiliation:**

**Leg.1: Takeshi Kawano**

kawanot@jamstec.go.jp

**Leg.2: Akihiko Murata**

akihiko.murata@jamstec.go.jp

**Ikuo Kaneko**

ikuo-kaneko@jamstec.go.jp

**Leg.3: Shuichi Watanabe**

swata@jamstec.go.jp

Ocean General Circulation Observational Research Program

Institute of Observational Research for Global Change

Japan Agency for Marine-Earth Science and Technology

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

Fax: +81-46-867-9455

**Ship:** R/V MIRAI

**Ports of Call:** San Diego (U.S.A.) – Honolulu (U.S.A.) – Okinawa – Sekinehama

**Cruise Dates:** October 31, 2005 – January 30, 2006

Leg.1: October 31, 2005 – November 24, 2005

Leg.2: November 27, 2005 – January 17, 2006

Leg.3: January 20, 2006 – January 30, 2006

**Number of Stations:** 237 stations for CTD/Carousel Water Sampler

(Leg.1: 78, Leg.2: 129, Leg.3: 30)

**Geographic boundaries:** 124° 59.27' E - 117° 19.84' W

12° 43.32' N - 35°16.29' N

**Floats and drifters deployed:**

One Argo float was deployed.

**Mooring deployed or recovered mooring:**

Five mooring systems in the Wake Island Deep Channel were recovered during the period from December 14 to 16, 2005.

## 1.2 Cruise Summary

**(1) Geographic boundaries**

MR05-05 occupied stations along about 24°N, from 117°20' W to 124°59' E.

**(2) Station occupied**

A total of 237 stations (Leg.1: 78, Leg.2: 129, Leg.3: 30) 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, AANDERAA “optode” oxgen sensor and Benthos Inc. Altimeter and RDI Monitor ADCP. Cruise track and station location are shown in [Figure 1.2.1](#).

**(3) Sampling and measurements**

Water samples were analyzed for salinity, oxygen, nutrients, CFC-11, -12, -113, total alkalinity, DIC, and pH. The sampling layers in dbar were 10, 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1,000, 1,200, 1,400, 1,600, 1,800, 2,000, 2,200, 2,400, 2,600, 2,800, 3,000, 3,250, 3,500, 3,750, 4,000, 4,250, 4,500, 4,750, 5,000, 5,250, 5,500, 5,750 and bottom (minus 10 m). Samples for POM, <sup>14</sup>C, <sup>13</sup>C, <sup>15</sup>N, <sup>137</sup>Cs, N<sub>2</sub>O, CH<sub>4</sub> and Bacteria were also collected at the selected stations. The bottle depth diagram is shown in [Figure 1.2.2](#). Underway measurements of pCO<sub>2</sub>, temperature, salinity, oxygen, surface current, bathymetry and meteorological parameters were conducted along the cruise track.

**(4) Floats and Drifters deployed**

One ARGO float was 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 float.

Float S/N	ARGOS PTT ID	Date and Time of Reset (UTC)	Date and Time of Launch (UTC)	Location of Launch	CTD St. No.
2296	60094	07:32 Jan.,3	09:22 Jan, 3	24° 14.25’ N, 144° 12.65’ E	P03-291

**(5) Moorings deployed or recovered**

Five moorings for Wake Island passage Flux Experiment (WIFE) were recovered. Locations of the moorings are listed in Table 1.2.2.

Table 1.2.2. Location of the moorings determined by acoustic navigation system. Locations of WM2 and WM1 could not be determined by acoustic navigation system due to leaking of the transponder. Depth of each location is derived from multi narrow beam bathymetry data obtained in this cruise.

Station	Latitude	Longitude	Depth (m)
WM5	16° 26.18’ N	171° 33.21’ E	5,477
WM4	15° 31.19’ N	171° 14.69’ E	5,616
WM3	14° 34.14’ N	170° 55.21’ E	5,680
WM2	(13° 38.45’ N)	(170° 34.70’ E)	5,522
WM1	(12° 45.90’ N)	(170° 14.90’ E)	5,378

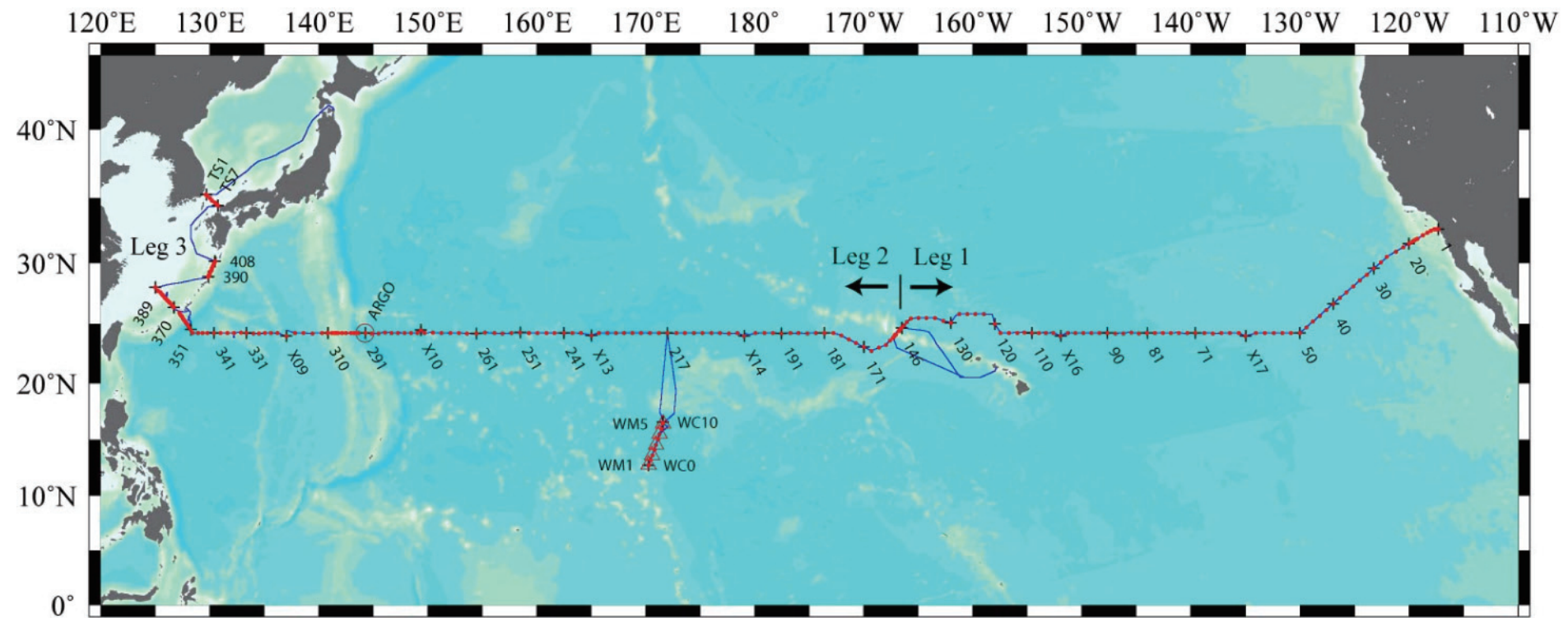


Figure 1.2.1. Cruise track.

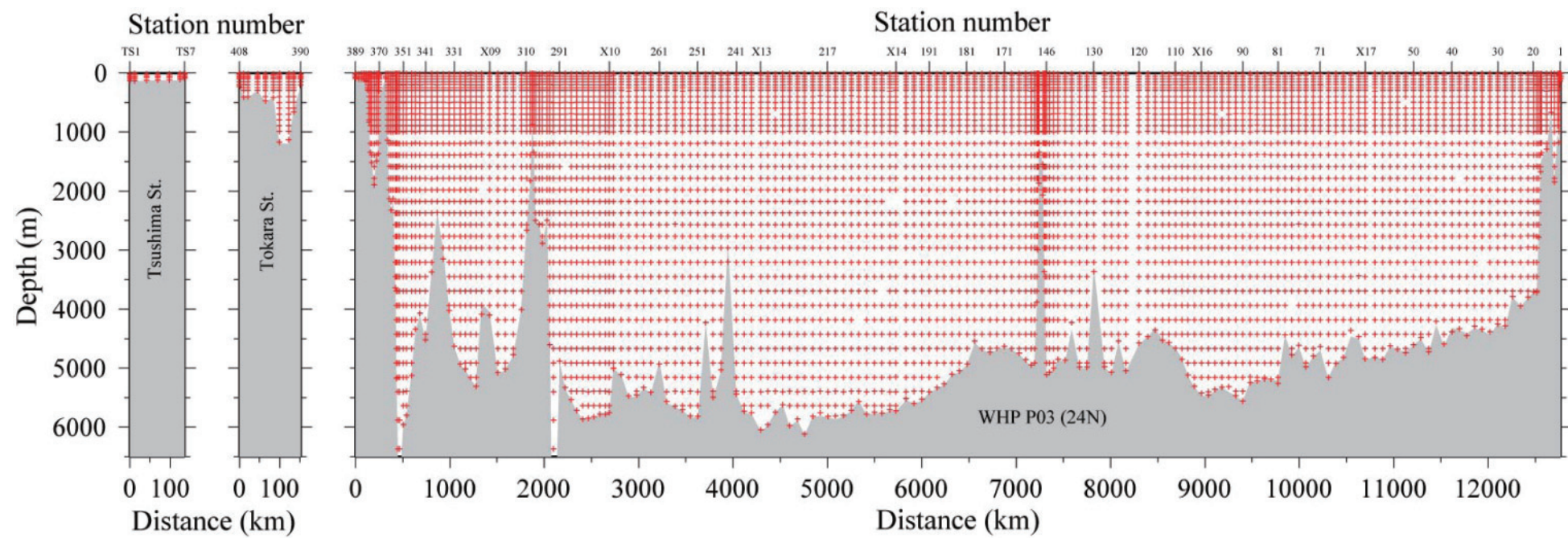


Figure 1.2.2. Bottle depth diagram.

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

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

Table 1.3.1(a). List of Principal Investigator and Person in Charge on the ship for Leg.1.		
Item	Principal Investigator	Person in Charge on the Ship
<b>Underway</b>		
ADCP	Yasushi Yoshikawa (JAMSTEC) yoshikaway@jamstec.go.jp	Soichiro Sueyoshi (GODI)
Bathymetry	Takeshi Matsumoto (Univ. Ryukyus) tak@sci.u-ryukyu.ac.jp	Soichiro Sueyoshi (GODI)
Meteorology	Kunio Yoneyama (JAMSTEC) yoneyamak@jamstec.go.jp	Soichiro Sueyoshi (GODI)
T-S	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Takuya Shiozaki (MWJ)
pCO <sub>2</sub>	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Minoru Kamata (MWJ)
<b>Hydrography</b>		
CTDO	Hiroshi Uchida (JAMSTEC) huchida@jamstec.go.jp	Kentaro Oyama (MWJ)
Salinity	Takeshi Kawano (JAMSTEC) kawanot@jamstec.go.jp	Fujio Kobayashi (MWJ)
Oxygen	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Takayoshi Seike (MWJ)
Nutrients	Michio Aoyama (MRI) maoyama@mri-jma.go.jp	Kenichiro Sato (MWJ)
DIC	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Minoru Kamata (MWJ)
Alkalinity	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Taeko Ohama (MWJ)

pH	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Taeko Ohama (MWJ)
CFCs	Kenichi Sasaki (JAMSTEC) ksasaki@jamstec.go.jp	Hideki Yamamoto (MWJ)
LADCP	Shinya Kouketsu (JAMSTEC) skouketsu@jamstec.go.jp	Shinya Kouketsu (JAMSTEC)
Δ <sup>14</sup> C & δ <sup>13</sup> C	Yuichiro Kumamoto (JAMSTEC) kumamotoy@jamstec.go.jp	Takeshi Kawano (JAMSTEC)
<sup>137</sup> Cs & Pu	Michio Aoyama (MRI) maoyama@mri-jma.go.jp	Takeshi Kawano (JAMSTEC)
CH <sub>4</sub> etc.	NaohiroYoshida (TITECH) naoyoshi@depe.titech.ac.jp	Osamu Yoshida (TITEC)

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  
TITECH: Tokyo Institute of Technology  
Univ. Ryukyus: University of the Ryukyus



Table 1.3.1(b). List of Principal Investigator and Person in Charge on the ship for Leg.2.

Item	Principal Investigator	Person in Charge on the Ship
<b>Underway</b>		
ADCP	Yasushi Yoshikawa (JAMSTEC) yoshikaway@jamstec.go.jp	Shinya Okumura (GODI)
Bathymetry	Takeshi Matsumoto (Univ. Ryukyus) tak@sci.u-ryukyu.ac.jp	Shinya Okumura (GODI)
Meteorology	Kunio Yoneyama (JAMSTEC) yoneyamak@jamstec.go.jp	Yasutaka Imai (GODI)
T-S	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Kimiko Nishijima (MWJ)
pCO <sub>2</sub>	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Mikio Kitada (MWJ)
<b>Hydrography</b>		
CTDO	Hiroshi Uchida (JAMSTEC) huchida@jamstec.go.jp	Satoshi Ozawa (MWJ)
Salinity	Takeshi Kawano (JAMSTEC) kawanot@jamstec.go.jp	Fujio Kobayashi (MWJ)
Oxygen	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Takayoshi Seike (MWJ)
Nutrients	Michio Aoyama (MRI) maoyama@mri-jma.go.jp	Junko Hamanaka (MWJ)
DIC	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Mikio Kitada (MWJ)
Alkalinity	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Fuyuki Shibata (MWJ)
pH	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Fuyuki Shibata (MWJ)
CFCs	Kenichi Sasaki (JAMSTEC) ksasaki@jamstec.go.jp	Katsunori Sagishima (MWJ)
LADCP	Shinya Kouketsu (JAMSTEC) skouketsu@jamstec.go.jp	Hiroshi Uchida (JAMSTEC)

$\Delta^{14}\text{C}$ & $\delta^{13}\text{C}$	Yuichiro Kumamoto (JAMSTEC) kumamotoy@jamstec.go.jp	Yuichiro Kumamoto (JAMSTEC)
$^{137}\text{Cs}$ & Pu	Michio Aoyama (MRI) maoyama@mri-jma.go.jp	Akihiko Murata (JAMSTEC)
CH <sub>4</sub> etc.	NaohiroYoshida (TITECH) naoyoshi@depe.titech.ac.jp	Narin Boontanon (TITECH)
<b>Floats, Drifters</b>		
Argo float	Nobuyuki Shikama (JAMSTEC) nshikama@jamstec.go.jp	Satoshi Ozawa (MWJ)
Mooring	Hiroshi Uchida (JAMSTEC) huchida@jamstec.go.jp	Satoshi Ozawa (MWJ)

GODI: Global Ocean Development Inc.

JAMSTEC: Japan Agency for Marine-Earth Science and Technology

MRI: Meteorological Research Institute, Japan Meteorological Agency

MWJ: Marine Works Japan. LTD

TITECH: Tokyo Institute of Technology

Univ. Ryukyus: University of the Ryukyus

Table 1.3.1(c). List of Principal Investigator and Person in Charge on the ship for Leg.3

Item	Principal Investigator	Person in Charge on the Ship
<b>Underway</b>		
ADCP	Yasushi Yoshikawa (JAMSTEC) yoshikaway@jamstec.go.jp	Katsuhisa Maeno (GODI)
Bathymetry	Takeshi Matsumoto (Univ. Ryukyus) tak@sci.u-ryukyu.ac.jp	Katsuhisa Maeno (GODI)
Meteorology	Kunio Yoneyama (JAMSTEC) yoneyamak@jamstec.go.jp	Katsuhisa Maeno (GODI)
T-S	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Takuhei Shiozaki (MWJ)
pCO <sub>2</sub>	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Masaki Moro (MWJ)
Bacteria	Masaaki Tamayama (JAMES) tamayamam@kuramae.ne.jp	Masaaki Tamayama (JAMES)
<b>Hydrography</b>		
CTDO	Hiroshi Uchida (JAMSTEC) huchida@jamstec.go.jp	Kentaro Oyama (MWJ)
Salinity	Takeshi Kawano (JAMSTEC) kawanot@jamstec.go.jp	Naoko Takahashi (MWJ)
Oxygen	Yuichiro Kumamoto (JAMSTEC) kumamoto@jamstec.go.jp	Kimiko Nishijima (MWJ)
Nutrients	Michio Aoyama (MRI) maoyama@mri-jma.go.jp	Junko Hamanaka (MWJ)
DIC	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Masaki Moro (MWJ)
Alkalinity	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Taeko Ohama (MWJ)
pH	Akihiko Murata (JAMSTEC) akihiko.murata@jamstec.go.jp	Taeko Ohama (MWJ)
CFCs	Kenichi Sasaki (JAMSTEC) ksasaki@jamstec.go.jp	Hideki Yamamoto (MWJ)

LADCP	Shinya Kouketsu (JAMSTEC) skouketsu@jamstec.go.jp	Shinya Kouketsu (JAMSTEC)
$\Delta^{14}\text{C}$ & $\delta^{13}\text{C}$	Yuichiro Kumamoto (JAMSTEC) kumamotoy@jamstec.go.jp	Yuichiro Kumamoto (JAMSTEC)
CH <sub>4</sub> etc.	NaohiroYoshida (TITECH) naoyoshi@depe.titech.ac.jp	Narin Boontanon (TITECH)

GODI: Global Ocean Development Inc.  
JAMES: Japan Macro-Engineers’ Society  
JAMSTEC: Japan Agency for Marine-Earth Science and Technology  
MRI: Meteorological Research Institute, Japan Meteorological Agency  
MWJ: Marine Works Japan. LTD  
TITECH: Tokyo Institute of Technology  
Univ. Ryukyus: University of the Ryukyus

1.4 Scientific Program and Methods

(1) Objectives of MR05-05 cruise project

It is well known that the oceans play a central role in determining global climate. However, heat and material transports in the oceans 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 transports of heat and materials such as carbon and nutrients in the North Pacific and to detect their long term changes and basin-scale biogeochemical changes since the 1990s.

This cruise is a reoccupation of the hydrographic section called ‘WHP-P3’, which was once observed by an ocean science group of USA in 1985 and later the observation data were included in the data set of the World



Ocean Circulation Experiment (WOCE: 1990-2002) Hydrographic Programme (WHP). We will compare physical and chemical properties along section WHP-P3 with those obtained in 1985 to detect and evaluate long term changes in the marine environment of the North Pacific.

Reoccupations of the WOCE hydrographic sections are now in progress by international cooperation among ocean science communities, in the framework of CLIVAR (Climate Variability and Predictability) as part of World Climate Research Programme (WCRP) and IOCCP (International Ocean Carbon Coordination Project). Our research is planned as a contribution to these international projects supported by WMO, ICSU/SCOR, and UNESCO/IOC.

The other objectives of this cruise are as follows:

- 1) to observe surface meteorological and hydrological parameters as a basic data of meteorology and oceanography,
- 2) to observe sea bottom topography, gravity and magnetic fields along the cruise track for understanding the dynamics of ocean plate and 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,
- 5) Calibration and recovery of mooring sensors in the Wake Island Passage.

## **(2) Cruise overview**

MR05-05 cruise was carried out during the period from October 31, 2005 to January 30, 2006. The cruise started from the coast near San Diego and sailed towards west along approximately 24°N. This line was observed in 1985 as a part of WOCE Hydrographic Programme. A total of 237 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 layers were 10, 50, 100, 150, 200, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1,000, 1,200, 1,400, 1,600, 1,800, 2,000, 2,200, 2,400, 2,600, 2,800, 3,000, 3,250, 3,500, 3,750, 4,000, 4,250, 4,500, 4,750, 5,000, 5,250, 5,500, 5,750 dbar

and approximately 10 dbar above the bottom. The scientists of JAMSTEC and Meteorological Research Institute and the 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. A scientist of Japan Macro-Engineers' Society joined Leg.3 of the cruise for the research on Colon Bacillus and General Bacteria. The scientists of Tokyo Institute of Technology joined the cruise for their research on chemical oceanography. A scientist from University of the Ryukyus was a principal investigator for geological parameters (topography, geo-magnetic field and gravity). The technicians of Global Ocean Development Inc. (GODI) had responsibility for 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. One ARGO floats prepared by JAMSTEC was launched by MWJ technicians and the ship crew.

## **(3) Cruise narrative**

R/V MIRAI departed San Diego (U.S.A) on October 31, 2005. She called for Honolulu (U.S.A.) on November 24, 2005 (Leg.1). She left Honolulu on November 27, 2005 for Okinawa (Japan) and arrived at Nakagusuku (Okinawa, Japan) on January 17, 2006 (Leg.2). For Leg.3, she departed from Nakagusuku on January 20, 2006 and arrived at Sekinehama on January 30, 2006. All watchstanders were drilled in the method of sample drawing before the first station. We observed 237 stations along approximately 24°N, namely WHP P3.

## 1.5 Major Problems and Goals not Achieved

### (1) Position Changed

#### a) Leg.1

Positions of stations 120, 122, 124, 126 and 128 were changed from (158°16.2'W, 24°15.7'N), (159°0.5'W, 24°14.5'N), (159°46.8'W, 24°28.1'N), (160°31.9'W, 24°40.2'N) and (161°15.4'W, 24°53.6'N) to (158°00'W, 25°00'N), (159°0.5'W, 25°50'N), (159°46.8'W, 25°50'N), (160°31.9'W, 24°50'N) and (161°15.4'W, 25°50'N), respectively, to avoid entering the training area of U. S. Navy.

#### b) Leg.2

The position of Station 155 was changed from (24°10.00'N, 167°06.40'W) to (24°08.82'N, 167°07.96'W). This is because the value of the water depth (2,006 m) at the original position recorded in the SUM file of WHP-P3 in 1985 was largely different from our value (800 m) at Station 155, whose position was accurately determined by modern GPS system. In addition to that, the original position of Station 155 was so unnaturally distributed against adjacent stations on the WHP-P3 section in 1985 that we could guess its position incorrect or inaccurate. Dr. Roemmich's (Chief scientist of WHP-P3 in 1985) reply to our enquiry on this matter is "It would seem that the ship was positioned correctly in between Stations 154 and 157, but the recorded position was erroneously taken from the dead reckoning Satnav computer".

The position of Station X09 (the crossover station with WHP-P09) was changed from (24°30.2'N, 136°59.1'E) to (23°59.22'N, 136°59.60'E) because a fishery boat was operating longline fishing at the planning position when R/V MIRAI reached there on January 6, 2006.

#### c) Leg.3

None of the station positions was changed. However, TS3 was shifted about 0.3 nm from its planning position because a lot of fishing boats were in operation.

### (2) Misfiring and mistrip

The carousel water sampler misfired at the following stations:

Leg.1: 33, 51 and 116

Leg.2: X14, 201, 203, 217, 231, 322 and 351\_2

Leg.3: None

Through the bottle data QC, mistrips were detected at the following stations:

Leg.1: 38

Leg.2: 185, WC2, WC5, 289, 357 and 351\_2

Leg.3: 380

### (3) CTD sensor replacement

During Leg.2, we encountered several problems (drift, shift, noise) in CTD sensors and replaced them after the following stations:

Station X14: primary and secondary conductivity sensors

Station WC8: primary oxygen sensor

Station 285: secondary oxygen sensor

### (4) Interruption of sequential occupations due to gale and bad sea condition

At Station 353 above the Ryukyu Trench, the first CTD cast was hindered due to bad weather and sea conditions. Since the prolonged gale was predicted around the area, we abandoned the original plan for sequential occupations of the P3 stations from east to west, reached the west end station (Station 369), and re-started the observation from west to east toward Station 351, where sections were connected with the second CTD cast. Station 351 was occupied twice in Leg.2.

The CTD observation in the East China Sea was suspended at Station 384 due to bad sea condition lasting for about half day. The observation was restarted at Station 382.

## 1.6 List of Participants

The members of the scientific party are listed in Table 1.6.1 to 1.6.3 along with their main tasks on the cruise.

Table 1.6.1. List of cruise participants in Leg.1.

Name	Main tasks	Affiliation
Ayako Fujii	CH <sub>4</sub> , N <sub>2</sub> O, <sup>15</sup> N	TITECH
Go Haruta	Water Sampling	MWJ
Hiroyuki Hayashi	CTD	MWJ
Akihito Hirai	Laser Ladar, Infrared Radiometer	Chiba Univ.
Tetsuya Inaba	Water Sampling	MWJ
Yoshiko Ishikawa	Carbon Items	MWJ
Minoru Kamata	Carbon Items	MWJ
Takeshi Kawano	Chief Scientist, Salinity	IORGC/JAMSTEC
Mikio Kitada	Carbon Items	MWJ
Fujio Kobayashi	Salinity	MWJ
Shinya Kouketsu	LADCP, ADCP	IORGC/JAMSTEC
Katsuhisa Maeno	Meteorology, Geology	GODI
Junji Matsushita	Nutrients	MWJ
Takami Mori	Water Sampling	MWJ
Norio Nagahama	Meteorology, Geology	GODI
Yoshifumi Noiri	Water Sampling	MWJ
Taeko Ohama	Carbon Items	MWJ
Miwa Okino	Water Sampling	MWJ
Kosuke Okudaira	Water Sampling	MWJ
Kentaro Oyama	CTD	MWJ
Satoshi Ozawa	Chief Technologist, Water Sampling	MWJ
Kenichi Sasaki	CFCs	MIO/JAMSTEC
Kenichiro Sato	Nutrients	MWJ
Takayoshi Seike	LADCP, DO	MWJ
Takuhei Siozaki	DO, Thermosalinograph	MWJ

Yuichi Sonoyama	CFCs	MWJ
Soichiro Sueyoshi	Meteorology, Geology	GODI
Nobuhiko Tahara	Water Sampling	MWJ
Tomoyuki Takamori	CTD	MWJ
Asumi Takeuchi	Water Sampling	MWJ
Ayumi Takeuchi	Nutrients	MWJ
Tatsuya Tanaka	Salinity	MWJ
Hiroshi Uchida	Water Sampling, CTD	IORGC/JAMSTEC
Hiroki Ushiromura	CTD	MWJ
Masahide Wakita	CFCs	MIO/JAMSTEC
Keisuke Wataki	DO, Thermosalinograph	MWJ
Hideki Yamamoto	CFCs	MWJ
Osamu Yoshida	CH <sub>4</sub> , N <sub>2</sub> O, <sup>15</sup> N	TITECH
Atsushi Yoshimura	Water Sampling	MWJ
Chiba Univ.:	Chiba University	
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	
TITECH:	Tokyo Institute of Technology	

Table 1.6.2. List of cruise participants in Leg.2.

Name	Main tasks	Affiliation
Eiji Abe	Laser Radar, Infrared Radiometer	Chiba Univ.
Narin Boontanon	CH <sub>4</sub> , N <sub>2</sub> O, <sup>15</sup> N	TITECH
Masanori Enoki	CFCs	MWJ
Ami Fujiwara	Water Sampling	MWJ
Junko Hamanaka	Nutrients	MWJ
Yasushi Hashimoto	Water Sampling	MWJ
Ei Hatakeyama	Carbon Items	MWJ
Miyo Ikeda	Water Sampling	MWJ
Yasutaka Imai	Meteorology, Geology, ADCP	GODI
Ikuo Kaneko	Chief Scientist, LADCP	IORGC/JAMSTEC
Mikio Kitada	Carbon Items	MWJ
Fujio Kobayashi	Salinity	MWJ
Misato Koide	Water Sampling	MWJ
Hiroshi Komura	Water Sampling	MWJ
Yuichiro Kumamoto	Water Sampling, DO	IORGC/JAMSTEC
Kohei Miura	Nutrients	MWJ
Takami Mori	Water Sampling	MWJ
Masaki Moro	Carbon Items	MWJ
Akihiko Murata	Chief Scientist, Carbon Items	IORGC/JAMSTEC
Akinori Murata	CTD, Water Sampling	MWJ
Kimiko Nishijima	DO, Thermosalinograph	MWJ
Ryo Ohyama	Meteorology, Geology, ADCP	GODI
Shinya Okumura	Meteorology, Geology, ADCP	GODI
Asako Onda	Water Sampling	MWJ
Satoshi Ozawa	CTD, Argo Float	MWJ
Katsunori Sagishima	CFCs	MWJ
Kenichi Sasaki	CFCs	MIO/JAMSTEC
Kenichiro Sato	Water Sampling	MWJ
Takayoshi Seike	DO	MWJ
Fuyuki Shibata	Chief Technologist, Carbon Items	MWJ

Naoko Takahashi	Salinity	MWJ
Tomoyuki Takamori	CTD, Water Sampling	MWJ
Ayumi Takeuchi	Nutrients	MWJ
Shinsuke Toyoda	CTD, Water Sampling	MWJ
Hiroshi Uchida	LADCP, Mooring, CTD	IORGC/JAMSTEC
Hirokatsu Uno	CTD	MWJ
Hiroki Ushiromura	CTD, Water Sampling	MWJ
Keisuke Wataki	CFCs	MWJ
Chiba Univ.:	Chiba University	
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	
TITECH:	Tokyo Institute of Technology	

Table 1.6.3. List of cruise participants in Leg.3.

Name	Main tasks	Affiliation
Yukiko Aoyagi	Water Sampling	MWJ
Narin Boontanon	CH <sub>4</sub> , N <sub>2</sub> O, <sup>15</sup> N	TITECH
Masanori Enoki	CFCs	MWJ
Ami Fujiwara	Water Sampling	MWJ
Chusei Fujiwara	Laser Radar, Infrared Radiometer	GODI
Yoko Fukuda	Water Sampling	MWJ
Junko Hamanaka	Nutrients	MWJ
Miyo Ikeda	Water Sampling	MWJ
Yoshiko Ishikawa	Carbon Items	MWJ
Minoru Kamata	Chief Technologist, Carbon Items	MWJ
Misato Koide	Water Sampling	MWJ
Shinya Koketsu	LADCP, ADCP, Bathymetry	IORGC/JAMSTEC
Yuichiro Kumamoto	Water Sampling, DO	IORGC/JAMSTEC
Hiroshi Komura	Water Sampling	MWJ
Masaaki Maekawa	Water Sampling	MWJ
Katsuhisa Maeno	Meteorology, Geology, ADCP	GODI
Junji Matsushita	Nutrients	MWJ
Hiroshi Matsunaga	CTD	MWJ
Kohei Miura	Nutrients	MWJ
Masaki Moro	Carbon Items	MWJ
Kimiko Nishijima	DO	MWJ
Tomohide Noguchi	CTD, Water Sampling	MWJ
Taeko Ohama	Carbon Items	MWJ
Asako Onda	Water Sampling	MWJ
Kentaro Oyama	CTD	MWJ
Ryo Ohyama	Meteorology, Geology, ADCP	GODI
Takuhei Shiozaki	DO	MWJ
Yuichi Sonoyama	CFCs	MWJ
Naoko Takahashi	Salinity	MWJ
Masaaki Tamayama	Bacteria	JAMES

Tatsuya Tanaka	Salinity	MWJ
Hiroshi Uchida	Water Sampling, CTD	IORGC/JAMSTEC
Masahide Wakita	CFCs	MIO/JAMSTEC
Shuichi Watanabe	Chief Scientist, LADCP, Water Sampling	MIO/JAMSTEC
Makito Yokota	CTD, Water Sampling	MWJ
Hideki Yamamoto	CFCs	MWJ
GODI:	Global Ocean Development Inc.	
MWJ:	Marine Works Japan. LTD	
JAMES:	Japan Macro-Engineers' Society	
JAMSTEC:	Japan Agency for Marine-Earth Science and Technology	
IORGC:	Institute of Observational Research for Global Change	
MIO:	Mutsu Institute for Oceanography	
TITECH:	Tokyo Institute of Technology	

## 2 Underway Measurement

### 2.1 Navigation and Bathymetry

*June 28, 2007*

#### 2.1.1 Navigation

##### (1) Personnel

<i>Souichiro Sueyoshi</i>	<i>(GODI)</i>
<i>Katsuhisa Maeno</i>	<i>(GODI)</i>
<i>Norio Nagahama</i>	<i>(GODI)</i>
<i>Yasutaka Imai</i>	<i>(GODI)</i>
<i>Shinya Okumura</i>	<i>(GODI)</i>
<i>Ryo Ohyama</i>	<i>(GODI)</i>

##### (2) 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) and two 9-channel GPS receivers (Trimble DS-4000). GPS antennas located at Navigation deck, offset to starboard and portside, respectively. We switched them to choose better state of receiving when the number of the available GPS satellites decreased or HDOP increased. 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.

##### (3) Data period

- Leg.1: 16:50, 31 October 2005 to 18:40, 24 November 2005 (UTC)
- Leg.2: 19:00, 27 November 2005 to 01:10, 17 January 2006 (UTC)
- Leg.3: 23:50, 19 January 2006 to 00:00, 30 January 2006 (UTC)

#### 2.1.2 Bathymetry

##### (1) Personnel

<i>Takeshi Matsumoto</i>	<i>(Univ. of the Ryukyus) Principal Investigator / Not on-board:</i>
<i>Souichiro Sueyoshi</i>	<i>(GODI)</i>
<i>Katsuhisa Maeno</i>	<i>(GODI)</i>
<i>Norio Nagahama</i>	<i>(GODI)</i>
<i>Yasutaka Imai</i>	<i>(GODI)</i>
<i>Shinya Okumura</i>	<i>(GODI)</i>
<i>Ryo Ohyama</i>	<i>(GODI)</i>

##### (2) Overview of the equipments

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 obtain accurate sound velocity profile of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data for the surface (6.2 m) sound velocity, and the sound velocity profile of the deeper depths was calculated using temperature and salinity profiles from the nearest CTD data by the equation in Mackenzie (1981).

System configuration and performance of SEABEAM 2112.004,

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



Beam spacing:	1 degree athwartships
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) Data Period

Bathymetric survey was carried out along the CTD observation line during the cruise

Leg.1: P03-001c on 31 Oct 2005 to P03-146 on 22 Oct. 2005

Leg.2: P03-146 on 30 Nov 2005 to P03-351 on 15 Jan 2006

Leg.3: P03-370 on 20 Jan 2006 to TS-1 on 26 Jan 2006.

### (4) Data processing

#### (4.1) Editing for the navigation data

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

#### (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

#### (4.3) Gridding

Gridding for the bathymetry data is carried out using the HIPS software version 5.4 (CARIS, Canada). Firstly, the bathymetry data during a turn, speed up or down are removed using swath editor and subset editor. A spike noise of each swath data is also removed. Then the bathymetry data are gridded by “Interpolate” function of the software with the following parameters.

Matrix size: 5 x 5

Number of nearneighbors: 16

#### Reference

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

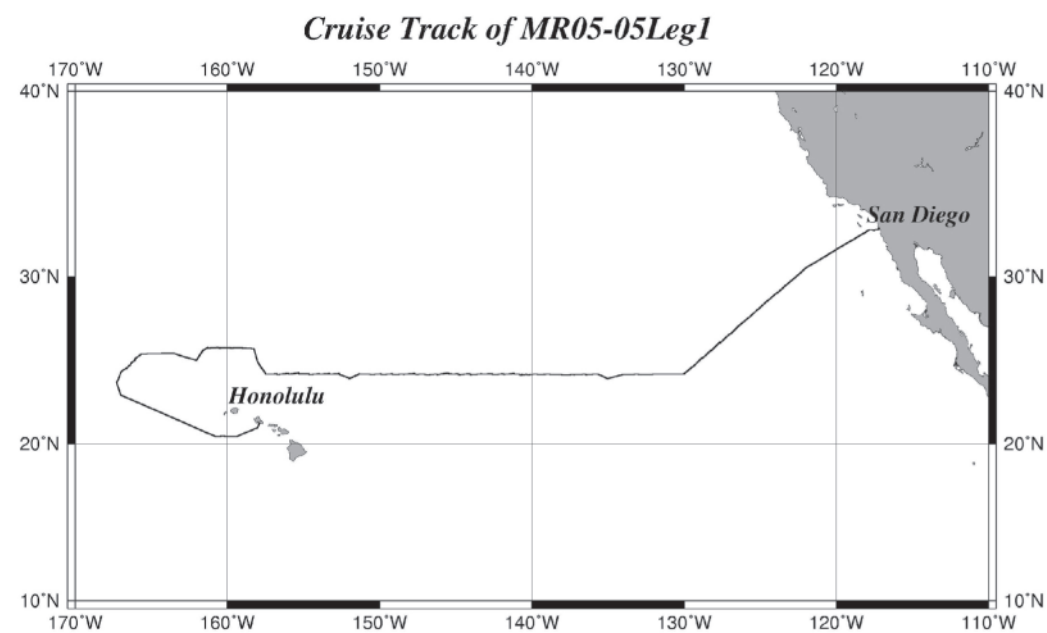


Figure 2.1.1-1. Cruise Track of MR05-05 Leg.1.

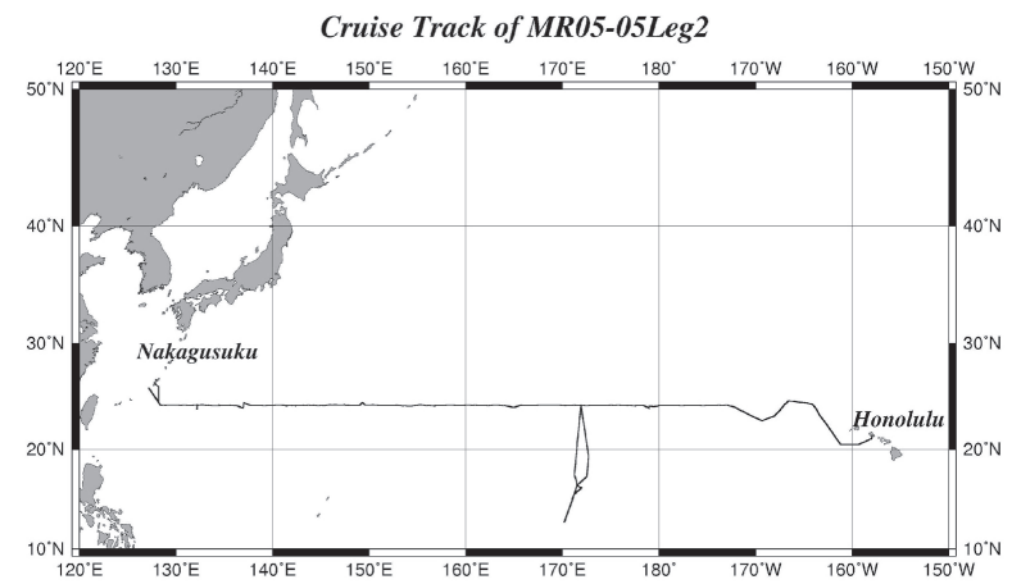


Figure 2.1.1-2. Cruise Track of MR05-05 Leg.2.

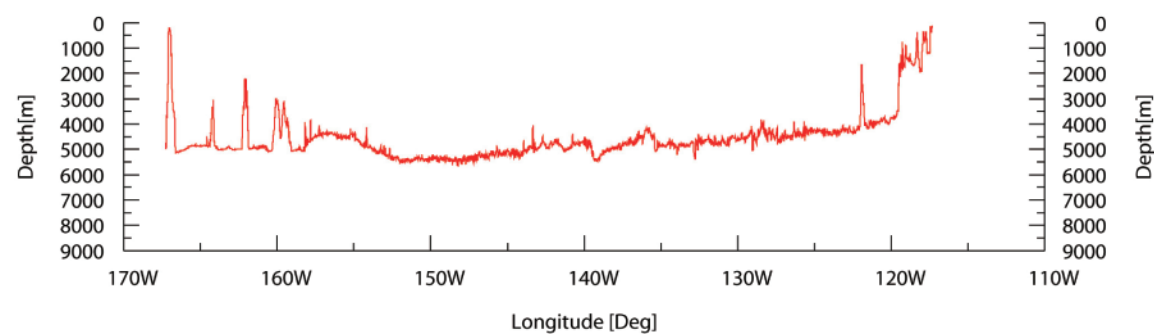


Figure 2.1.2-1. Depth profile of CTD line MR05-05 Leg.1.

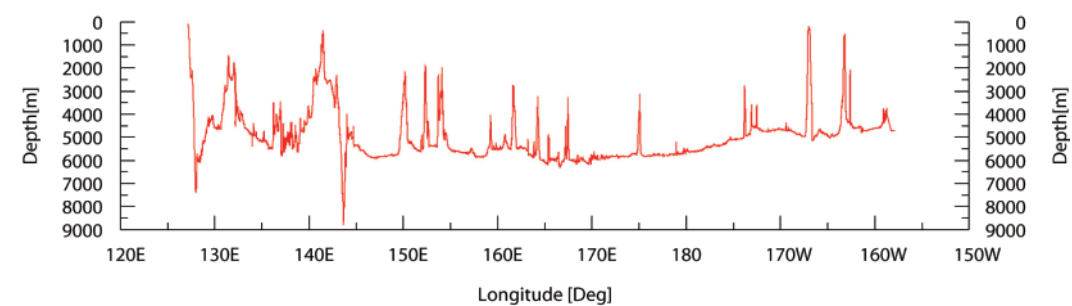


Figure 2.1.2-2. Depth profile of CTD line MR05-05 Leg.2.

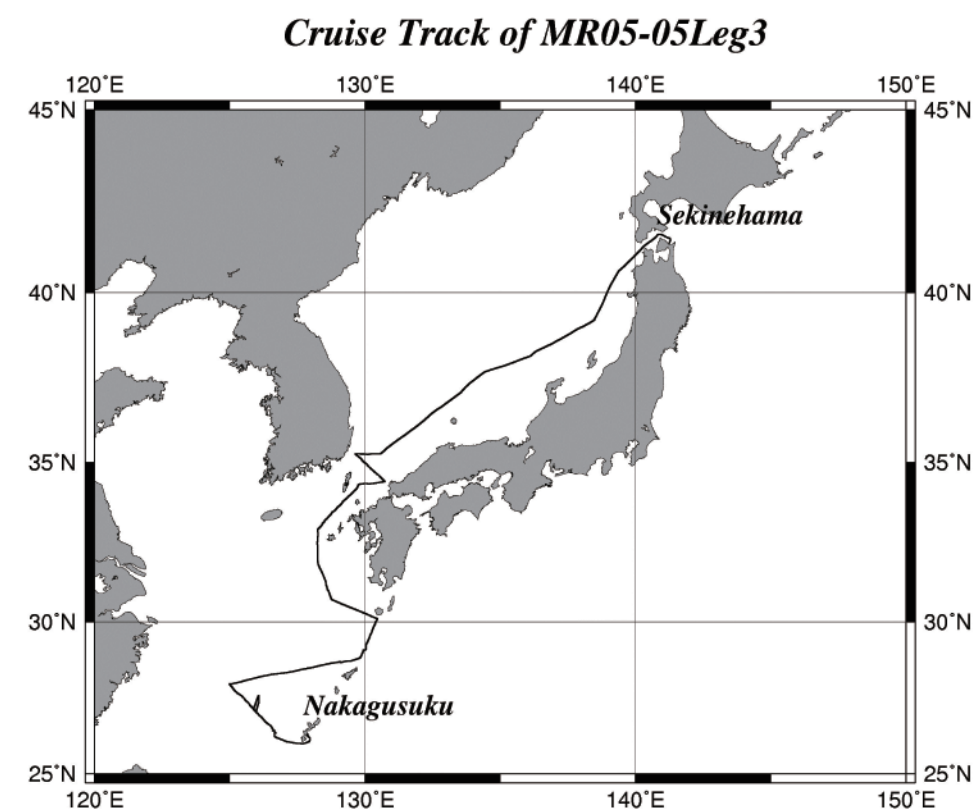


Figure 2.1.1-3. Cruise Track of MR05-05 Leg.3.

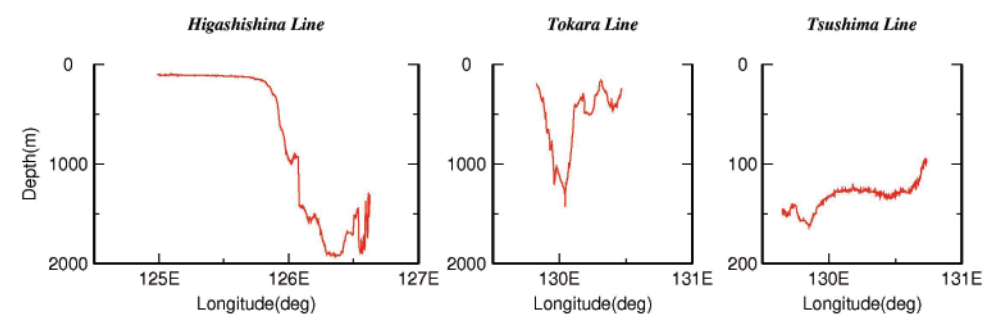


Figure 2.1.2-3. Depth profile of CTD line MR05-05 Leg.3.

### 2.1.3 Sea surface gravity

#### (1) Personnel

*Takeshi Matsumoto* (Univ. of the Ryukyus) Principal Investigator / Not on-board:

*Souichiro Sueyoshi* (GODI)

*Katsuhisa Maeno* (GODI)

*Norio Nagahama* (GODI)

*Yasutaka Imai* (GODI)

*Shinya Okumura* (GODI)

*Ryo Ohyama* (GODI)

#### (2) Introduction

Marine gravity is an important parameter in geophysics and geodesy. We collected gravity data at the sea surface during the MR05-05 Leg.1 cruise from 31 Oct. 2005 to 24 Nov. 2005, Leg.2 cruise from 27 Nov. 2005 to 17 Jan. 2006, Leg.3 cruise from 20 Jan. 2006 to 30 Jan. 2006.

#### (3) Parameters

Relative Gravity [mGal]

#### (4) Data Acquisition

We have measured relative gravity using LaCoste and Romberg air-sea gravity system II (Micro-G LaCoste, Inc.) during this cruise. To convert the relative gravity to absolute one, we measured gravity, using portable gravity meter (Scintrex gravity meter CG-3M), at Honolulu and Nakagusuku and Sekinehama as reference points.

(5) Preliminary Results

Absolute gravity is shown in Table 2.1.3.

Table 2.1.3. Absolute gravity table MR05-05 cruise.

No.	Date	UTC	Port	Absolute Gravity (mGal)	Sea Level (cm)	Draft (cm)	Gravity at Sensor* <sup>1</sup> (mGal)	L&R* <sup>2</sup> (mGal)
1	2005/Oct/31	14:23	SanDiego	-	240	636	-	11853.79
2	2005/Nov/25	21:59	Honolulu	978927.57	154	655	978928.10	11266.15
3	2006/Jan/19	02:41	Nakagusuku* <sup>3</sup>	979114.12	219	610	979114.83	11456.52
4	2006/Jan/19	23:03	Nakagusuku* <sup>3</sup>	979114.12	237	605	979114.88	11456.67
5	2006/Feb/1	00:52	Sekinehama	980371.95	286	625	980372.87	12719.15

\*1: Gravity at Sensor= Absolute Gravity + Sea Level\*0.3086/100 + (Draft-530)/100\*0.0431

\*2: LaCoste and Romberg air-sea gravity system II

\*3: It was measured at June 20, 2003.

(6) Data Archives

Gravity data obtained during this cruise will be submitted to the JAMSTEC Data Management Division, and will be archived there.

(7) Remarks

1. We did not collect data from 18 Nov. 2005 18:55UTC to 19:10UTC, due to reboot of the meter.
2. Long Accelerometer did not work properly from 31 Oct. 2005 to 18 Nov. 19:10. Therefore, Gravity, VCC and AL were not correct value.

2.1.4 On-board geomagnetic measurement

(1) Personnel

*Takeshi Matsumoto (Univ. of the Ryukyus) Principal Investigator / Not on-board:*

*Souichiro Sueyoshi (GODI)*

*Katsuhisa Maeno (GODI)*

*Norio Nagahama (GODI)*

*Yasutaka Imai (GODI)*

*Shinya Okumura (GODI)*

*Ryo Ohyama (GODI)*

(2) Introduction

Measurement of geomagnetic field on the sea is required for the interpretation of marine magnetic anomaly caused by magnetization in the upper crust. We measured geomagnetic field using a three-component magnetometer during the MR05-05 Leg.1 cruise from 31 Oct. 2005 to 24 Nov. 2005, Leg.2 cruise from 27 Nov. 2005 to 17 Jan. 2006, and Leg.3 cruise from 20 Jan. 2006 to 30 Jan. 2006.

(3) Method

A shipboard three-component magnetometer system (Tierra Tecnica SFG1214) is equipped on-board R/V MIRAI. Three-axis flux-gate sensors with ring-cored coils are fixed on the fore mast. Outputs of the sensors are digitized by a 20-bit A/D converter (1 nT/LSB), and sampled at 8 times per second. Ship's heading, pitch and roll are measured utilizing a ring-laser gyro installed for controlling attitude of a Doppler radar. Ship's position (GPS) and speed data are taken from LAN every second.

(4) Data Archives

Magnetic field data obtained during this cruise will be submitted to the JAMSTEC Data Management Division, and will be archived there.

**(5) Remarks**

We collected the data for calibration during the following period by 'figure-eight' turn.

11 Oct. 2005 00:00 – 00:23 (Leg.1)

08 Dec. 2005 05:58 – 06:22 (Leg.2)

01 Jan. 2006 03:55 – 04:21 (Leg.2)

28 Jan. 2006 08:25 – 08:50 (Leg.3)

2.2 Surface Meteorological Observation

June 15, 2007

(1) Personnel

<i>Kunio Yoneyama</i>	<i>(JAMSTEC)</i>
<i>Souichiro Sueyoshi</i>	<i>(GODI)</i>
<i>Katsuhisa Maeno</i>	<i>(GODI)</i>
<i>Norio Nagahama</i>	<i>(GODI)</i>
<i>Yasutaka Imai</i>	<i>(GODI)</i>
<i>Shinya Okumura</i>	<i>(GODI)</i>
<i>Ryo Ohyama</i>	<i>(GODI)</i>

(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 and its data used here are listed in Table 2.2.1. All SMET data were collected and processed by KOAC-7800 weather data processor manufactured 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, 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<sup>2</sup> unit, while SOAR records 1 W/m<sup>2</sup> 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 <sup>*1</sup>	air temperature	Vaisala, Finland / HMP45A	compass deck <sup>*2</sup> / 21 m
	relative humidity		
Thermometer	sea temperature	Koshin Denki, Japan / RFN1-0	4th deck / -5 m
Barometer	pressure	Setra Systems Inc., USA / 370	captain deck / 13 m

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

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

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 was less than 5 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<sup>2</sup>), and downwelling longwave radiation (W/m<sup>2</sup>).

Missing values are expressed as “9999”.

**(5) Data Quality**

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

T/RH sensor:

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

We also checked T/RH values using another calibrated portable T/RH sensor (Vaisala, HMP45A) before and

after the cruise. The results are,

Temperature (°C)

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

$0.0\pm0.6$  (°C) at port side,  $-0.3\pm0.3$  (°C) at starboard side.

Relative Humidity (%)

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

$2\pm2$  (%) at port side,  $3\pm1$  (%) at starboard side.

Pressure sensor:

Using calibrated portable barometer (Vaisala, Finland / PTB220, certificated accuracy is better than  $\pm 0.1$  hPa), pressure sensor was checked before/after the cruise. Mean difference of SMET pressure sensor and portable sensor is  $-0.1\pm0.3$  hPa.

Anemometer:

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

Pre-cruise 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  $\pm 2^{\circ}$

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

the water amount input. Expected accuracy is better than  $\pm 1$  mm corresponding to the sensor's specification. The results are as follows, and data were corrected using this relationship.

	Leg.1	Leg.2	Leg.3
minimum input water volume (cc)	0.0	0.0	0.0
minimum measured value (mm)	0.9	2.1	0.7
maximum input water volume (cc)	509.8	514.3	510.3
maximum measured value (mm)	51.6	52.7	51.5

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

- Leg.1 1200 UTC, October 31, 2005 - 1830 UTC, November 24, 2005
  - \* SST data is available from 0000 UTC, November 2, 2005.
- Leg.2 1900 UTC, November 27, 2005 - 0000 UTC, January 17, 2006
  - \* SST data is available between 0400 UTC, November 29, 2005 - 0500 UTC, January 15, 2006
- Leg.3 2350 UTC, January 19, 2006 - 2300 UTC, January 29, 2006
  - \* SST is available until 0000 UTC, January 28, 2006.

#### (7) Point of contact

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

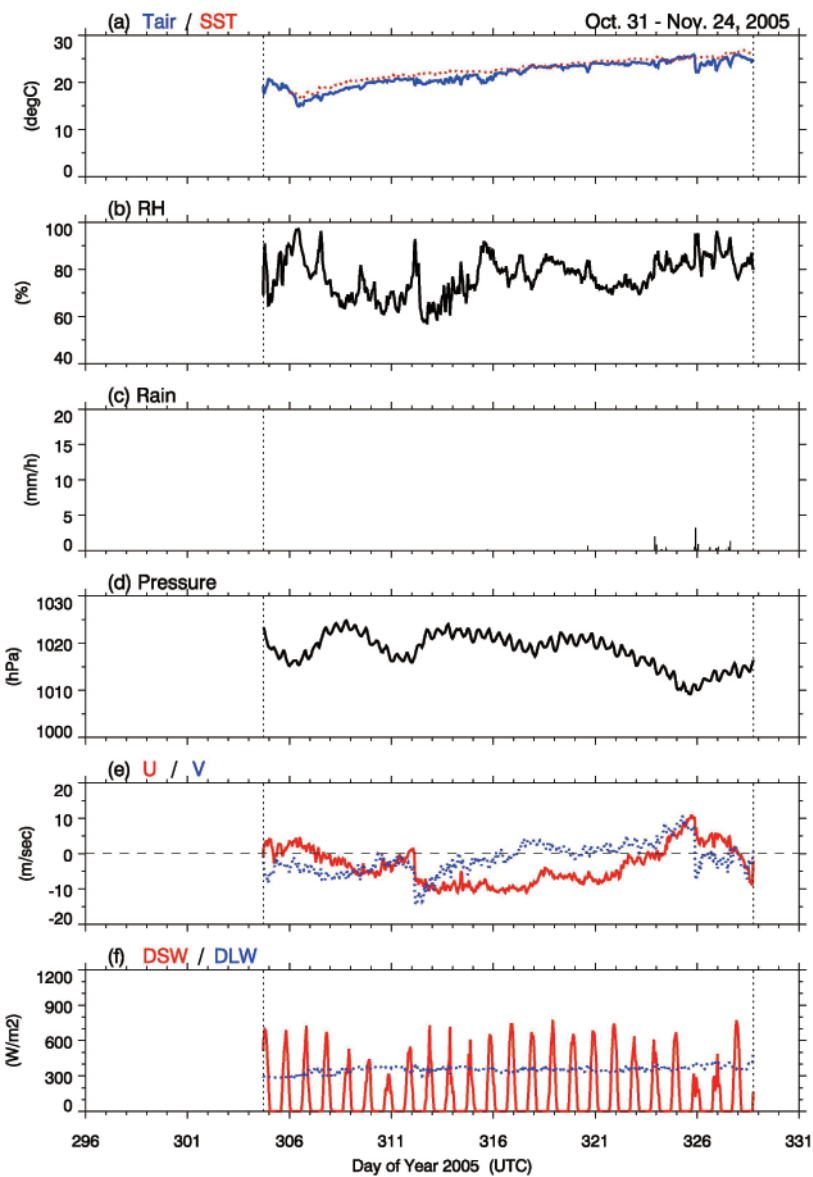


Figure 2.2.1. Time series of (a) air and sea surface temperature, (b) relative humidity, (c) precipitation, (d) pressure, (e) zonal and meridional wind components, and (e) short and long wave radiation. Day 304 corresponds to October 31, 2005.

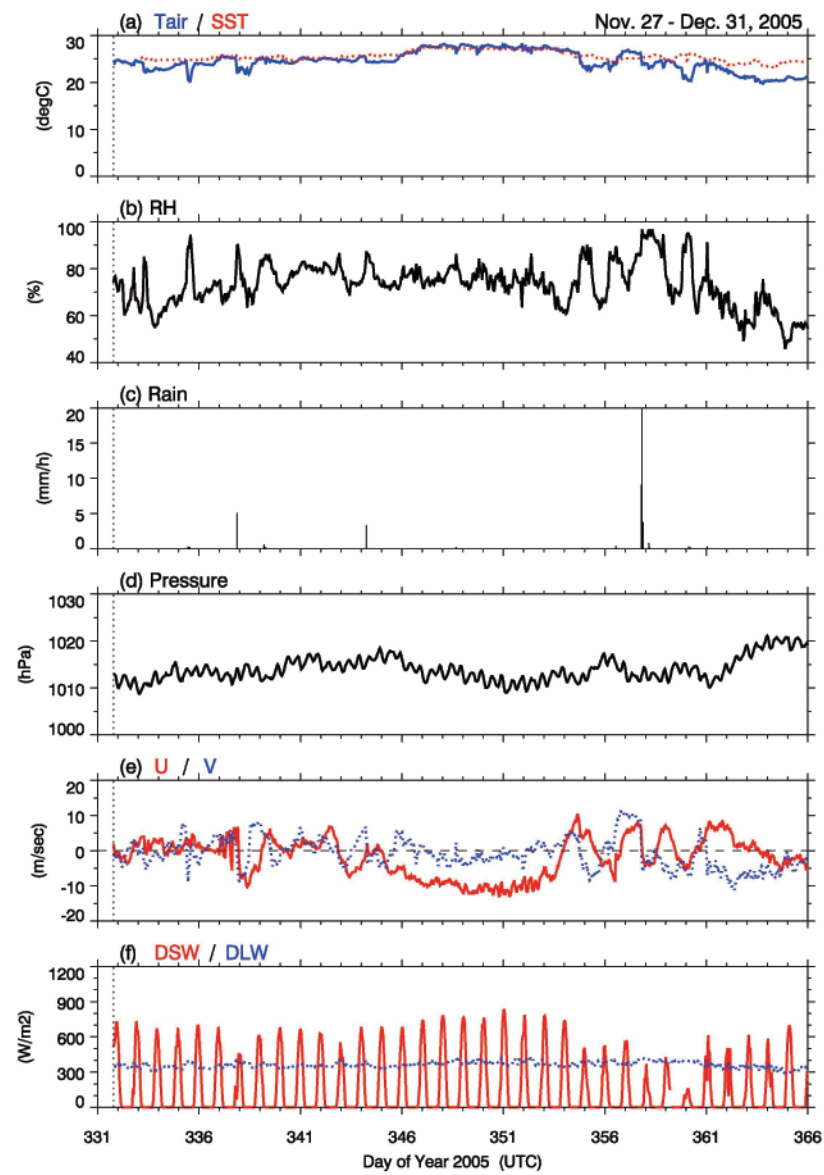


Figure 2.2.1. (continued)

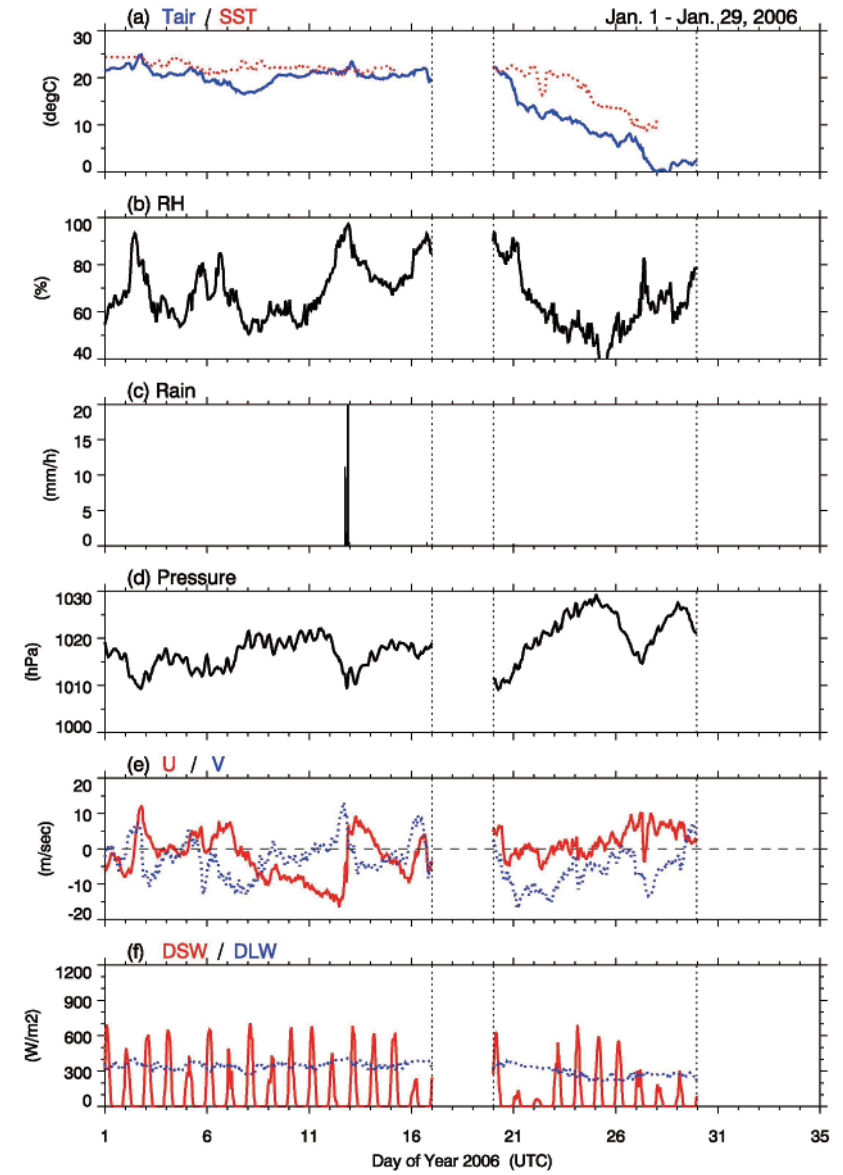


Figure 2.2.1. (continued)

## 2.3 Thermo-salinograph and related measurements

May 2, 2007

### (1) Personnel

<i>Yuichiro Kumamoto</i>	<i>(JAMSTEC)</i>
<i>Takeshi Kawano</i>	<i>(JAMSTEC)</i>
<i>Takuhei Shiozaki</i>	<i>(MWJ)</i>
<i>Keisuke Wataki</i>	<i>(MWJ)</i>
<i>Kimiko Nishijima</i>	<i>(MWJ)</i>
<i>Takayoshi Seike</i>	<i>(MWJ)</i>
<i>Osamu Yoshida</i>	<i>(Tokyo Institute of Technology)</i>

### (2) Objective

Our purpose is to measure salinity, temperature, dissolved oxygen, fluorescence, and particle size and number in near-sea surface water during MR05-05 cruise.

### (3) Methods

The Continuous Sea Surface Water Monitoring System (Nippon Kaiyo Co. Ltd.), including the thermo-salinograph, has six kinds of sensors and can automatically measure salinity, temperature, dissolved oxygen, fluorescence and particle size and number in near-sea surface water every one minute. This system is located in the sea surface monitoring laboratory on R/V MIRAI and connected to shipboard LAN system. Measured data, time, and location of the ship were displayed on a monitor and then stored in a data management PC (IBM NetVista 6826-CBJ).

Near-surface water was continuously pumped from a depth of about 4 m to the laboratory and flowed into the system through a vinyl-chloride pipe. The flow rate of the surface seawater was controlled by several valves

and adjusted to 12 L/min. except for a fluorometer (about 0.3 L/min.). The flow rate was measured by two flow meters.

During this cruise, the data management PC had a trouble in data acquisition of dissolved oxygen and particle counting and sizing. Thus, we connected another computer (IBM ThinkPad T41) to the system for those data storage.

Specifications of the each sensor in this system are listed below.

- a) Temperature and salinity sensors\*  
SEACAT THERMOSALINOGRAPH  
Model: SBE-21, SEA-BIRD ELECTRONICS, INC.  
Serial number: 2118859-3126  
Measurement range: Temperature -5 to +35°C, Salinity 0 to 6.5 S m<sup>-1</sup>  
Accuracy: Temperature 0.01°C 6month<sup>-1</sup>, Salinity 0.001 S m<sup>-1</sup> month<sup>-1</sup>  
Resolution: Temperatures 0.001°C, Salinity 0.0001 S m<sup>-1</sup>
- b) Bottom of ship thermometer  
Model: SBE 3S, SEA-BIRD ELECTRONICS, INC.  
Serial number: 032607  
Measurement range: -5 to +35°C  
Resolution: ±0.001°C  
Stability: 0.002°C year<sup>-1</sup>
- c) Dissolved oxygen sensor  
Model: 2127A, HACH ULTRA ANALYTICS JAPAN, INC.  
Serial number: 47477  
Measurement range: 0 to 14 ppm  
Accuracy: ±1% at 5°C of correction range  
Stability: 1% month<sup>-1</sup>
- d) Fluorometer  
Model: 10-AU-005, TURNER DESIGNS  
Serial number: 5562 FRXX  
Detection limit: 5 ppt or less for chlorophyll a  
Stability: 0.5% month-1 of full scale
- e) Particle Size sensor  
Model: P-05, Nippon Kaiyo LTD.  
Serial number: P5024

Measurement range: 0.2681 mm to 6.666 mm

Accuracy:  $\pm 10\%$  of range

Reproducibility:  $\pm 5\%$

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

f) Flow meter

Model: EMARG2W, Aichi Watch Electronics LTD.

Serial number: 8672

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

Accuracy:  $\pm 1\%$

Stability:  $\pm 1\% \text{ day}^{-1}$

\*During the past cruises, an antifoulant (antibiotic) device including TBTO (tributyltin oxide) was attached to the salinity sensor to control growth of aquatic organisms in electronic conductivity sensors. TBTO is an endocrine disrupting chemical and restricted its use in the environments by Japanese law. Consequently, we did not use the antifoulant device during this cruise. After Leg.2, we found biogenic stains on both temperature and salinity sensors that had not been found at the end of Leg.1 cruise (Photo 2.3.1). Although effectiveness of the antibiotic device is uncertain, the biogenic stains found on the sensors suggest that the device should have been attached to the sensors for longer than one month during the cruises.

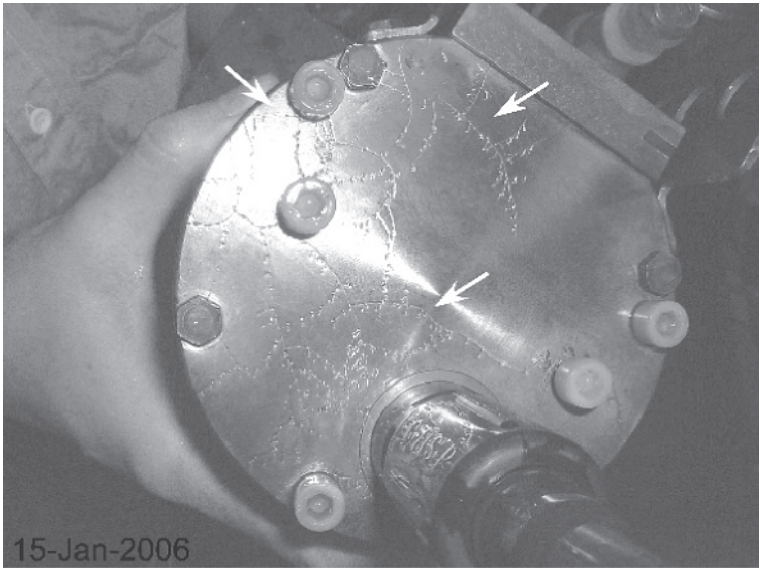


Photo 2.3.1.

(4) Measurements

Periods of measurement, maintenance, and problems during MR05-05 are listed in Table 2.3.1.

Table 2.3.1. Events list of the thermo-salinograph.

Date [UTC]	Time [UTC]	Event	Remarks
31-Oct-05	18:13	All measurements started.	Leg.1 start
11-Nov-05	02:45 ~ 03:46	The fluorescence measurement stopped for cell cleaning.	
23-Nov-05	22:57	All measurements stopped.	Leg.1 end
29-Nov-05	06:53	All measurements started.	Leg.2 start
14-Dec-05	20:23 ~ 21:50	The fluorescence measurement stopped for cell cleaning.	
15-Jan-06	05:12	All measurements stopped.	Leg.2 end
20-Jan-06	04:32	All measurements started.	Leg.3 start
25-Jan-06	05:48 ~ 07:14	Failure of data storage for T, S, Flu, location due to the PC troubles.	
26-Jan-06	07:58 ~ 09:04 09:13 ~ 09:39	Failure of data storage for T, S, Flu, location due to the PC troubles.	
26-Jan-06	09:13 ~ 09:28	Failure of data storage for oxygen and particle size due to the PC troubles.	
27-Jan-06	23:27	All measurements stopped.	Leg.3 end

(5) Calibrations

i. Comparison with bottle data

We collected the surface seawater samples approximately twice a day from the outlet equipped in the

middle of water line of the system for salinity sensor calibration. 250 ml brown glass bottle with plastic inner stopper and screw cap was used to collect the samples. The sample bottles were stored in the sea surface monitoring laboratory. The samples were measured using the Guildline 8400B at the end of each leg after all measurements of hydrocast bottle samples. The measurement technique was almost same as that for bottle salinity measurement. The results are shown in Table 2.3.2 and JAMSTEC MIRAI DATA web;

[http://www.jamstec.go.jp/mirai/2005/MR05-05\\_leg1/EPCS/MR0505\\_leg1\\_cor\\_info\\_eng.html](http://www.jamstec.go.jp/mirai/2005/MR05-05_leg1/EPCS/MR0505_leg1_cor_info_eng.html),  
[http://www.jamstec.go.jp/mirai/2005/MR05-05\\_leg2/EPCS/MR0505\\_leg2\\_cor\\_info\\_eng.html](http://www.jamstec.go.jp/mirai/2005/MR05-05_leg2/EPCS/MR0505_leg2_cor_info_eng.html),  
[http://www.jamstec.go.jp/mirai/2005/MR05-05\\_leg3/EPCS/MR0505\\_leg3\\_cor\\_info\\_eng.html](http://www.jamstec.go.jp/mirai/2005/MR05-05_leg3/EPCS/MR0505_leg3_cor_info_eng.html).

In order to calibrate the fluorescence sensor, Tokyo Institute of Technology group collected the surface seawater at the noon and about 4 hours after the sunset for measuring chlorophyll-a. 500 ml of the seawater sample was gently filtrated by low vacuum pressure (<15 cmHg) through Whatman GF/F filter (diameter 25 mm) in a dark room. The filter was immediately transferred into 7 ml of N,N-dimethylformamide (DMF) and then the bottle of DMF was stored at –20°C under dark condition to extract chlorophyll-a for more than 24 hours. Concentrations of chlorophyll-a were measured by a fluorometer (10-AU-005, TURNER DESIGNS) that was previously calibrated against a pure chlorophyll-a (Sigma chemical Co.). We carried out “Non-acidification method” (Welschmeyer, 1994) for chlorophyll-a measurements. The results of the measurements are shown in [Table 2.3.3](#).

Sensors for dissolved oxygen and particle size were not calibrated against bottle data.

**ii. Sensor calibrations**

The sensors for temperature and salinity were calibrated before and after the cruise in order to evaluated the measurement drifts during the cruise. The results of the calibrations are available through JAMSTEC MIRAI DATA Web as above.

**2.3.6 Date archive**

Quality controlled data of temperature, salinity, and dissolved oxygen can be downloaded from JAMSTEC MIRAI DATA Web;

[http://www.jamstec.go.jp/mirai/2005/MR05-05\\_leg1/EPCS/MR0505\\_1\\_qced\\_data.html](http://www.jamstec.go.jp/mirai/2005/MR05-05_leg1/EPCS/MR0505_1_qced_data.html),  
[http://www.jamstec.go.jp/mirai/2005/MR05-05\\_leg2/EPCS/MR0505\\_2\\_qced\\_data.html](http://www.jamstec.go.jp/mirai/2005/MR05-05_leg2/EPCS/MR0505_2_qced_data.html),  
[http://www.jamstec.go.jp/mirai/2005/MR05-05\\_leg3/EPCS/MR0505\\_3\\_qced\\_data.html](http://www.jamstec.go.jp/mirai/2005/MR05-05_leg3/EPCS/MR0505_3_qced_data.html).

Data of fluorescence and particle size and number are also available through the web page.

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

Date [UTC]	Time [UTC]	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Quality Flag for bottle salinity
2-Nov-05	6:50	33.5700	33.5695	2
3-Nov-05	8:22	33.1737	33.1713	2
4-Nov-05	6:13	33.6508	33.6571	3
5-Nov-05	5:17	34.2141	34.2115	2
6-Nov-05	8:26	34.5818	34.5795	2
7-Nov-05	8:00	34.8829	34.8789	2
8-Nov-05	7:46	35.0396	35.0376	2
9-Nov-05	5:59	35.2435	35.2407	2
10-Nov-05	7:10	35.1329	35.1297	2
11-Nov-05	2:40	35.1480	35.1459	2
12-Nov-05	8:16	35.1758	35.1731	2
13-Nov-05	8:21	35.2669	35.2644	2
14-Nov-05	10:58	35.3217	35.3188	2
15-Nov-05	8:14	35.3293	35.3255	2



Table 2.3.2. (continued)

Date [UTC]	Time [UTC]	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Quality Flag for bottle salinity
16-Nov-05	8:27	35.0564	35.0519	2
17-Nov-05	7:00	35.2159	35.2122	2
18-Nov-05	10:12	35.3360	35.3320	2
18-Nov-05	22:25	35.3442	35.3403	2
19-Nov-05	8:52	35.3532	35.3484	2
19-Nov-05	21:20	35.3188	35.3158	2
20-Nov-05	11:25	35.3493	35.3466	2
20-Nov-05	23:29	35.3597	35.3548	2
21-Nov-05	12:05	35.1876	35.1860	2
21-Nov-05	18:09	35.2402	35.2369	2
29-Nov-05	20:08	35.2438	35.2462	2
29-Nov-05	23:17	35.1937	35.1943	2
30-Nov-05	15:46	35.2185	35.2217	2
1-Dec-05	1:25	35.2297	35.2325	2
1-Dec-05	14:25	35.2561	35.2590	2
2-Dec-05	8:07	35.2581	35.2605	2
2-Dec-05	13:21	35.2560	35.2573	2
3-Dec-05	0:41	35.1905	35.1972	2
3-Dec-05	15:12	35.1715	35.1738	2
4-Dec-05	0:44	35.2197	35.2220	2
4-Dec-05	13:59	35.2867	35.2874	2
5-Dec-05	0:47	35.3573	35.3594	2

5-Dec-05	13:36	35.2448	35.2460	2
6-Dec-05	1:25	35.2640	35.2658	2
6-Dec-05	13:33	35.2607	35.2663	2
7-Dec-05	1:00	35.2957	35.2981	2
7-Dec-05	13:28	35.3609	35.3635	2
8-Dec-05	1:00	35.3706	35.3732	2
9-Dec-05	1:38	35.3573	35.3590	2
9-Dec-05	9:02	35.3492	35.3494	2
9-Dec-05	14:28	35.3398	35.3414	2
10-Dec-05	1:56	35.3514	35.3536	2
10-Dec-05	14:25	35.2974	35.2998	2
11-Dec-05	2:10	35.2485	35.2508	2
11-Dec-05	14:30	35.2312	35.2333	2
12-Dec-05	2:18	35.2767	35.2751	2
12-Dec-05	19:46	34.9113	34.9100	2
13-Dec-05	5:32	34.8525	34.8533	2
13-Dec-05	20:55	34.8668	34.8662	2
14-Dec-05	9:51	34.8070	34.8062	2
14-Dec-05	21:32	34.8108	34.8095	2
15-Dec-05	13:57	34.7460	34.7482	2
15-Dec-05	20:08	34.7251	34.7255	2
16-Dec-05	13:48	34.7450	34.7477	2
16-Dec-05	18:51	34.7879	34.7876	2
17-Dec-05	1:58	34.7641	34.7631	2



Table 2.3.2. (continued)

Date [UTC]	Time [UTC]	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Quality Flag for bottle salinity
17-Dec-05	14:40	34.7886	34.7886	2
18-Dec-05	11:02	34.7928	34.7894	2
18-Dec-05	14:27	34.8002	34.8000	2
19-Dec-05	8:39	34.8347	34.8312	2
19-Dec-05	21:15	35.0004	35.0000	2
20-Dec-05	2:25	34.9669	34.9672	2
21-Dec-05	10:24	35.2600	35.2600	2
21-Dec-05	15:05	35.3098	35.3092	2
22-Dec-05	10:32	35.2453	35.2428	2
22-Dec-05	15:32	35.1821	35.1809	2
23-Dec-05	5:49	35.2539	35.2529	2
23-Dec-05	15:20	35.2687	35.2681	2
24-Dec-05	4:17	35.1506	35.1516	2
24-Dec-05	15:21	35.1108	35.1093	2
25-Dec-05	3:02	35.1697	35.1665	2
25-Dec-05	15:17	35.0202	35.0187	2
26-Dec-05	3:56	34.9861	34.9841	2
26-Dec-05	15:30	35.0344	35.0326	2
27-Dec-05	3:16	35.1956	35.1938	2
27-Dec-05	15:19	35.0220	35.0204	2
28-Dec-05	3:23	35.0168	35.0160	2
28-Dec-05	15:25	35.1121	35.1052	2

29-Dec-05	3:17	35.1368	35.1358	2
29-Dec-05	15:40	34.8900	34.8895	2
30-Dec-05	4:15	34.9790	34.9782	2
30-Dec-05	15:31	35.0010	35.0015	2
31-Dec-05	4:26	34.9686	34.9685	2
01-Jan-06	5:45	34.9579	34.9565	2
01-Jan-06	15:39	34.9594	34.9580	2
02-Jan-06	6:23	34.9835	34.9818	2
02-Jan-06	15:29	34.9401	34.9392	2
02-Jan-06	17:25	34.9542	34.9542	2
03-Jan-06	13:12	34.8194	34.8195	2
03-Jan-06	17:53	34.8762	34.8715	2
04-Jan-06	5:14	34.7966	34.7961	2
04-Jan-06	17:30	34.8093	34.8091	2
05-Jan-06	6:43	34.8998	34.8989	2
05-Jan-06	17:38	34.9090	34.9085	2
06-Jan-06	6:47	34.8450	34.8434	2
06-Jan-06	17:51	34.8190	34.8180	2
07-Jan-06	7:59	34.8109	34.8101	2
07-Jan-06	17:42	34.6597	34.6584	2
08-Jan-06	8:01	34.7983	34.7971	2
08-Jan-06	18:20	34.6684	34.6674	2
09-Jan-06	20:46	34.7581	34.7569	2
10-Jan-06	13:37	34.7615	34.7667	2
10-Jan-06	17:45	34.6906	34.6897	2

Table 2.3.2. (continued)

Date [UTC]	Time [UTC]	Sensor salinity [PSS-78]	Bottle salinity [PSS-78]	Quality Flag for bottle salinity
11-Jan-06	6:11	34.8660	34.8650	2
11-Jan-06	17:47	34.7070	34.7076	2
12-Jan-06	8:57	34.7660	34.7654	2
12-Jan-06	17:34	34.7228	34.7217	2
13-Jan-06	6:46	34.7033	34.7006	2
13-Jan-06	17:37	34.7052	34.7038	2
14-Jan-06	7:31	34.6351	34.6353	2
14-Jan-06	17:44	34.6562	34.6549	2
20-Jan-06	5:50	34.7968	34.7928	2
20-Jan-06	18:35	34.6766	34.6693	2
21-Jan-06	5:36	34.6326	34.6265	2
21-Jan-06	17:57	34.5974	34.5979	2
22-Jan-06	5:46	34.5873	34.5817	2
22-Jan-06	17:20	34.6853	34.6788	2
23-Jan-06	5:42	34.7726	34.7714	2
23-Jan-06	18:06	34.6577	34.6525	2
24-Jan-06	5:44	34.6295	34.6273	2
24-Jan-06	18:07	34.6144	34.6033	2
25-Jan-06	5:46	34.5806	34.5724	2
25-Jan-06	17:52	34.5397	34.5399	2
26-Jan-06	5:41	34.5224	34.5162	2
26-Jan-06	18:14	34.2362	34.2482	2

Table 2.3.3. Comparison of sensor fluorescence and bottle chlorophyll-a.

Date [UTC]	Time [UTC]	Sensor Fluorescence	Chlorophyll-a ( $\mu\text{g/L}$ )
1-Nov-05	6:20	15.791	0.37
1-Nov-05	20:00	15.266	0.44
2-Nov-05	6:03	16.915	0.30
2-Nov-05	20:29	14.017	0.17
3-Nov-05	6:02	14.768	0.13
3-Nov-05	20:13	13.192	0.12
4-Nov-05	6:13	13.394	0.08
4-Nov-05	20:05	12.899	0.08
5-Nov-05	6:00	12.971	0.08
5-Nov-05	20:08	12.469	0.10
6-Nov-05	6:11	13.063	0.09
6-Nov-05	20:08	12.755	0.12
7-Nov-05	6:03	13.085	0.10
7-Nov-05	20:59	12.587	0.08
8-Nov-05	7:05	12.750	0.10
8-Nov-05	21:15	12.280	0.12
9-Nov-05	7:10	12.815	0.12
9-Nov-05	23:34	12.659	0.15
10-Nov-05	7:19	12.784	0.13
10-Nov-05	21:08	12.427	0.12
11-Nov-05	7:19	13.846	0.12
11-Nov-05	22:10	12.609	0.12
12-Nov-05	8:10	13.467	0.13

Table 2.3.3. (continued)

Date [UTC]	Time [UTC]	Sensor Fluorescence	Chlorophyll-a ( $\mu\text{g/L}$ )
12-Nov-05	22:08	12.914	0.11
13-Nov-05	8:33	13.169	0.10
13-Nov-05	22:10	12.733	0.11
14-Nov-05	8:12	13.103	0.10
14-Nov-05	22:00	12.639	0.12
15-Nov-05	8:12	12.977	0.11
15-Nov-05	22:03	12.357	0.08
16-Nov-05	9:22	12.768	0.09
16-Nov-05	22:00	12.361	0.09
17-Nov-05	8:07	12.623	0.11
17-Nov-05	22:35	12.353	0.11
18-Nov-05	8:25	12.652	0.12
18-Nov-05	22:15	12.260	0.11
19-Nov-05	8:52	12.803	0.08
19-Nov-05	22:10	12.305	0.08
20-Nov-05	8:06	12.589	0.08
20-Nov-05	22:15	12.542	0.09
21-Nov-05	8:10	13.062	0.12
21-Nov-05	22:15	12.828	0.13
21-Nov-05	22:15	12.828	0.13
22-Nov-05	8:11	13.125	0.16
22-Nov-05	22:10	13.035	0.15
22-Nov-05	22:10	13.035	0.18

29-Nov-05	23:27	13.936	0.14
30-Nov-05	9:00	13.722	0.14
30-Nov-05	9:00	13.722	0.15
30-Nov-05	23:22	12.934	0.13
30-Nov-05	23:22	12.934	0.13
01-Dec-05	9:01	13.479	0.12
02-Dec-05	1:45	13.153	0.13
02-Dec-05	10:08	13.229	0.08
02-Dec-05	10:08	13.229	0.08
02-Dec-05	23:50	12.193	0.10
02-Dec-05	23:50	12.193	0.10
03-Dec-05	9:01	12.679	0.08
03-Dec-05	23:29	12.356	0.14
04-Dec-05	9:00	12.600	0.12
04-Dec-05	9:00	12.600	0.12
04-Dec-05	23:28	11.957	0.10
04-Dec-05	23:28	11.957	0.10
05-Dec-05	9:39	12.214	0.10
06-Dec-05	2:01	11.869	0.09
06-Dec-05	8:56	11.974	0.08
06-Dec-05	8:56	11.974	0.08
07-Dec-05	0:22	11.713	0.09
07-Dec-05	0:22	11.713	0.09
07-Dec-05	9:01	11.932	0.07

Table 2.3.3. (continued)

Date [UTC]	Time [UTC]	Sensor Fluorescence	Chlorophyll a ( $\mu\text{g/L}$ )
07-Dec-05	23:41	11.669	0.08
08-Dec-05	8:47	11.884	0.07
08-Dec-05	8:47	11.884	0.07
09-Dec-05	1:05	11.760	0.08
09-Dec-05	1:05	11.760	0.08
09-Dec-05	10:07	12.234	0.08
10-Dec-05	0:59	11.767	0.12
10-Dec-05	10:05	12.198	0.08
10-Dec-05	10:05	12.198	0.08
11-Dec-05	1:18	11.926	0.08
11-Dec-05	1:18	11.926	0.08
11-Dec-05	10:09	12.172	0.07
21-Dec-05	2:21	11.858	0.09
21-Dec-05	12:12	12.124	0.09
21-Dec-05	12:12	12.124	0.08
22-Dec-05	1:38	12.132	0.08
22-Dec-05	1:38	12.132	0.08
22-Dec-05	11:58	12.556	0.10
23-Dec-05	1:38	12.560	0.11
23-Dec-05	12:20	12.649	0.10
23-Dec-05	12:20	12.649	0.10
24-Dec-05	1:31	13.030	0.09
24-Dec-05	1:31	13.030	0.09

24-Dec-05	12:39	13.108	0.10
25-Dec-05	2:08	13.015	0.09
25-Dec-05	11:17	13.893	0.09
26-Dec-05	1:23	13.137	0.12
26-Dec-05	1:23	13.137	0.12
26-Dec-05	10:35	13.459	0.12
27-Dec-05	1:34	13.209	0.14
27-Dec-05	11:51	13.308	0.11
27-Dec-05	11:51	13.308	0.12
28-Dec-05	1:42	13.408	0.11
28-Dec-05	1:42	13.408	0.11
28-Dec-05	10:53	14.309	0.13
29-Dec-05	1:47	13.215	0.13
29-Dec-05	11:08	13.639	0.10
29-Dec-05	11:08	13.639	0.09
30-Dec-05	1:35	13.246	0.14
30-Dec-05	1:35	13.246	0.13
30-Dec-05	11:12	14.087	0.13
31-Dec-05	1:42	12.956	0.13
31-Dec-05	10:57	13.773	0.15
31-Dec-05	10:57	13.773	0.15
02-Jan-06	2:44	12.987	0.15
02-Jan-06	2:44	12.987	0.15
02-Jan-06	13:07	13.275	0.13

Table 2.3.3. (continued)

Date [UTC]	Time [UTC]	Sensor Fluorescence	Chlorophyll a ( $\mu\text{g/L}$ )
03-Jan-06	3:29	12.960	0.10
03-Jan-06	13:46	13.116	0.10
03-Jan-06	13:46	13.116	0.10
04-Jan-06	3:20	13.127	0.12
04-Jan-06	3:20	13.127	0.12
04-Jan-06	12:22	13.009	0.12
05-Jan-06	3:37	13.136	0.10
05-Jan-06	14:03	13.950	0.13
05-Jan-06	14:03	13.950	0.13
06-Jan-06	3:40	13.146	0.22
06-Jan-06	12:25	14.240	0.25
07-Jan-06	3:40	13.948	0.25
07-Jan-06	12:30	14.208	0.27
07-Jan-06	12:30	14.208	0.26
08-Jan-06	3:40	13.427	0.27
08-Jan-06	3:40	13.427	0.27
08-Jan-06	13:02	13.625	0.25
10-Jan-06	13:10	13.954	0.25
11-Jan-06	3:40	13.387	0.23
11-Jan-06	3:40	13.387	0.23
11-Jan-06	13:34	14.446	0.45
11-Jan-06	13:34	14.446	0.44
12-Jan-06	3:20	15.650	0.74

12-Jan-06	14:34	15.012	0.48
12-Jan-06	14:34	15.012	0.49
13-Jan-06	3:18	14.052	0.54
13-Jan-06	3:18	14.052	0.55
13-Jan-06	13:22	14.403	0.35
14-Jan-06	3:43	14.164	0.44
14-Jan-06	13:53	14.134	0.36
14-Jan-06	13:53	14.134	0.37
15-Jan-06	3:40	13.333	0.24
15-Jan-06	3:40	13.333	0.25
20-Jan-06	13:27	15.864	0.18
20-Jan-06	13:27	15.864	0.18
21-Jan-06	4:56	19.848	1.57
21-Jan-06	4:56	19.848	1.62
21-Jan-06	13:10	21.013	2.40
22-Jan-06	3:47	19.055	1.54
22-Jan-06	13:18	18.849	0.49
22-Jan-06	13:18	18.849	0.48
23-Jan-06	2:43	14.727	0.33
23-Jan-06	2:43	14.727	0.32
23-Jan-06	12:34	16.606	0.47
24-Jan-06	3:42	16.021	0.63
24-Jan-06	12:36	19.706	0.83
24-Jan-06	12:36	19.706	0.88



Table 2.3.3. (continued)

Date [UTC]	Time [UTC]	Sensor Fluorescence	Chlorophyll a ( $\mu\text{g/L}$ )
25-Jan-06	3:45	20.538	2.20
25-Jan-06	3:45	20.538	2.16
25-Jan-06	13:22	25.41	3.02
26-Jan-06	6:17	21.289	1.34
26-Jan-06	14:03	23.116	0.56
26-Jan-06	14:03	23.116	0.55

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

July 4, 2007

### (1) Personnel

<i>Akihiko Murata</i>	<i>(JAMSTEC)</i>
<i>Fuyuki Shibata</i>	<i>(MWJ)</i>
<i>Mikio Kitada</i>	<i>(MWJ)</i>
<i>Minoru Kamata</i>	<i>(MWJ)</i>
<i>Taeko Ohama</i>	<i>(MWJ)</i>
<i>Yoshiko Ishikawa</i>	<i>(MWJ)</i>

### (2) Introduction

Concentrations of CO<sub>2</sub> in the atmosphere are currently increasing at a rate of 1.5 ppmv y<sup>-1</sup> 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 increasing atmospheric CO<sub>2</sub>, as well as to clarify the mechanism of the CO<sub>2</sub> absorption, because the magnitude of the predicted global warming depends on the levels of CO<sub>2</sub> in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In the P3 revist cruise, we aimed to quantify how much anthropogenic CO<sub>2</sub> is absorbed in the surface ocean of the North Pacific. For the purpose, we measured pCO<sub>2</sub> (partial pressures of CO<sub>2</sub>) in the atmosphere and in the surface seawater.

### (3) Apparatus and shipboard measurement

Continuous underway measurements of atmospheric and surface seawater pCO<sub>2</sub> were made with the CO<sub>2</sub> measuring system (Nippon ANS, Ltd) installed in the R/V MIRAI of JAMSTEC. The system comprises of a non-

dispersive infrared gas analyzer (NDIR; BINOS<sup>®</sup> model 4.1, Fisher-Rosemount), an air-circulation module and a showerhead-type equilibrator. To measure concentrations (mole fraction) of CO<sub>2</sub> in dry air (xCO<sub>2a</sub>), air sampled from the bow of the ship (approx. 30 m above the sea level) was introduced into the NDIR through a dehydrating route with an electric dehumidifier (kept at ~2°C), a Perma Pure dryer (GL Sciences Inc.), and a chemical desiccant (Mg(ClO<sub>4</sub>)<sub>2</sub>). The flow rate of the air was 500 ml min<sup>-1</sup>. To measure surface seawater concentrations of CO<sub>2</sub> in dry air (xCO<sub>2s</sub>), the air equilibrated with seawater within the equilibrator was introduced into the NDIR through the same flow route as the dehydrated air used in measuring xCO<sub>2a</sub>. The flow rate of the equilibrated air was 600 – 800 ml min<sup>-1</sup>. The seawater was taken by a pump from the intake placed at the approximately 4.5 m below the sea surface. The flow rate of seawater in the equilibrator was 500 – 800 ml min<sup>-1</sup>.

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

### (4) Quality control

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

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

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

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

We checked values of xCO<sub>2a</sub> and xCO<sub>2s</sub> by examining the signals of the NDIR on recorder charts, and by

plotting the  $x\text{CO}_2\text{a}$  and  $x\text{CO}_2\text{s}$  as a function of sequential day, longitude, sea surface temperature and sea surface salinity.

### Reference

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

Table 2.4.1. Concentrations of  $\text{CO}_2$  standard gases used in the P3 revisit cruise.

Cylinder no.	Concentrations (ppmv)
CQB17639	262.94
CQB17638	320.42
CQB17637	381.04
CQB17636	420.76

## 2.5 Acoustic Doppler Current Profiler

*September 3, 2007*

### (1) Personnel

<i>Shinya Kouketsu</i>	<i>(JAMSTEC)</i>
<i>Yasushi Yoshikawa</i>	<i>(JAMSTEC)</i>
<i>Souichiro Sueyoshi</i>	<i>(GODI)</i>
<i>Shinya Okumura</i>	<i>(GODI)</i>
<i>Katsuhisa Maeno</i>	<i>(GODI)</i>
<i>Norio Nagahama</i>	<i>(GODI)</i>

### (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 x 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 (1609038 pings of all 2656345 pings). 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.

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 from 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.

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 P3\_revisit cruise. The misalignment angle calculated was 0.15 degree and the scale factor was 0.975. 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. Time series of upper 200 m average flow for about 3 hours are calculated using the 3 minutes sub set. The continuity of the series on streaming between the CTD sites is examined. The standard deviation on the CTD sites is 56 mm/s. and that on streaming between the CTD sites is 47 mm/s. The qualities of data on CTD sites and on streaming is not so different. 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. To avoid the effect of the acceleration, we process the data only when standard deviation of ship velocity for three minutes is less than 10 cm/s. In the next step, we averaged the subset at each CTD station. Each mean profile is calculated with depth correction using the CTD data. Vertical grids are put on every 10 m.

(5) Data Structure

The record structure of the data set A, where file name is ‘ADCP\_A’, is described below. The file consists of 239 profiles in the CTD sites. Each profile consists of header and data. The header has three lines representing analyzed site, date and time, and position. The data has 67 layers in which depth, zonal velocity, meridional velocity, and vetical velocity 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. The ‘99.999’ in the data represents no available data stored.

[ data structure of the data set A ]

- Line 1: header 1
  - Column 1: cruise code
  - Column 2: analyzed site
- Line 2: header 2
  - date
- Line 3: header 3
  - Column 1: longitude (degree E)
  - Column 2: latitude (degree N)
- Line 4-70: flow data in each depth level
  - Column 1: depth (m)

- Column 2: zonal velocity (m/s)
- Column 3: meridional velocity (m/s)
- Column 4: vertical velocity (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.

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

- Line 1: header 1
  - Column 1: cruise code
  - Column 2: sequatial record number
- Line 2: header 2
  - date
- Line 3: header 3
  - Column 1: longitude (degree E)
  - Column 2: latitude (degree N)
- Line 4-38: flow data in each depth level
  - Column 1: depth (m)
  - Column 2: zonal velocity (m/s)
  - Column 3: meridional velocity (m/s)
  - Column 4: vertical velocity (m/s)



### 3 Hydrographic Measurement Techniques and Calibrations

#### 3.1 CTD/O<sub>2</sub> Measurements

*May 2, 2007*

**(1) Personnel**

<i>Hiroshi Uchida</i>	<i>(JAMSTEC)</i>
<i>Masao Fukasawa</i>	<i>(JAMSTEC)</i>
<i>Satoshi Ozawa</i>	<i>(MWJ)</i>
<i>Tomoyuki Takamori</i>	<i>(MWJ)</i>
<i>Kentaro Oyama</i>	<i>(MWJ)</i>
<i>Hiroki Ushiromura</i>	<i>(MWJ)</i>
<i>Hiroyuki Hayashi</i>	<i>(MWJ)</i>
<i>Hirokatsu Uno</i>	<i>(MWJ)</i>
<i>Akinori Murata</i>	<i>(MWJ)</i>
<i>Shinsuke Toyoda</i>	<i>(MWJ)</i>
<i>Hiroshi Matsunaga</i>	<i>(MWJ)</i>
<i>Tomohide Noguchi</i>	<i>(MWJ)</i>
<i>Makito Yokota</i>	<i>(MWJ)</i>

**(2) Winch arrangements**

The CTD package was deployed by using 4.5 Ton Traction Winch System (Dynacon, Inc., Bryan, Texas, USA), which was installed on the R/V MIRAI in April 2001. The CTD Traction Winch System with the Heave Compensation Systems (Dynacon, Inc.) is designed to reduce cable stress resulting from load variation caused by wave or vessel motion. The system was 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 Communications Co., Yokohama,

Kanagawa, Japan), 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., Bellevue, Washington, 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., Miami, Florida, 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 (PSA-916T; Teledyne Benthos, Inc., North Falmous, Massachusetts, USA) and oxygen optode (Oxygen Optode 3830; Aanderaa Data Instruments AS, Bergen, Norway) 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 11plus, S/N 0344

Under water unit:

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

Temperature sensor:

SBE 3, S/N 1464 (Leg.1: primary)

SBE 3plus, S/N 4216 (Leg.1: secondary, Leg.2, 3: primary)

SBE 3, S/N 1525 (Leg.2, 3: secondary)

Conductivity sensor:

SBE 4, S/N 1203 (Leg.1: primary)

SBE 4, S/N 2854 (Leg.1: secondary)

SBE 4, S/N 3124 (Leg.2: primary from 146\_2 to 197\_1)

SBE 4, S/N 3036 (Leg.2: secondary from 146\_2 to 197\_1)

SBE 4, S/N 2854 (Leg.2, 3: primary from X14\_1 to TS\_1)

SBE 4, S/N 3116 (Leg.2, 3: secondary from X14\_1 to TS\_1)

Oxygen sensor:

SBE 43, S/N 0391 (Leg.1: primary, Leg.2: primary from 146\_2 to WC7)

SBE 43, S/N 0488 (Leg.1: secondary)

SBE 43, S/N 0390 (Leg.2, 3: primary from WC8 to TS1)

SBE 43, S/N 0394 (Leg.2: secondary from 146\_2 to 283\_1, Leg.3: secondary)

SBE 43, S/N 0205 (Leg.2: secondary from 285\_1 to 351\_2)

Oxygen Optode 3830, S/N 612 (Leg.1, 2, 3: pilot)

Pump:

SBE 5T, S/N 3293 (Leg.1: primary)

SBE 5T, S/N 3118 (Leg.1: secondary)

SBE 5T, S/N 0984 (Leg.2, 3: primary)

SBE 5T, S/N 2627 (Leg.2, 3: secondary)

Altimeter:

PSA-916T, S/N 1100 (Leg.1)

PSA-916T, S/N 1157 (Leg.2, 3)

Deep Ocean Standards Thermometer:

SBE 35, S/N 0022 (Leg.1, 2)

SBE 35, S/N 0045 (Leg.3)

Carousel Water Sampler:

SBE 32, S/N 0391 (Leg.1, 2, 3)

Water sample bottle:

12-litre Niskin-X (no TEFLON coating)

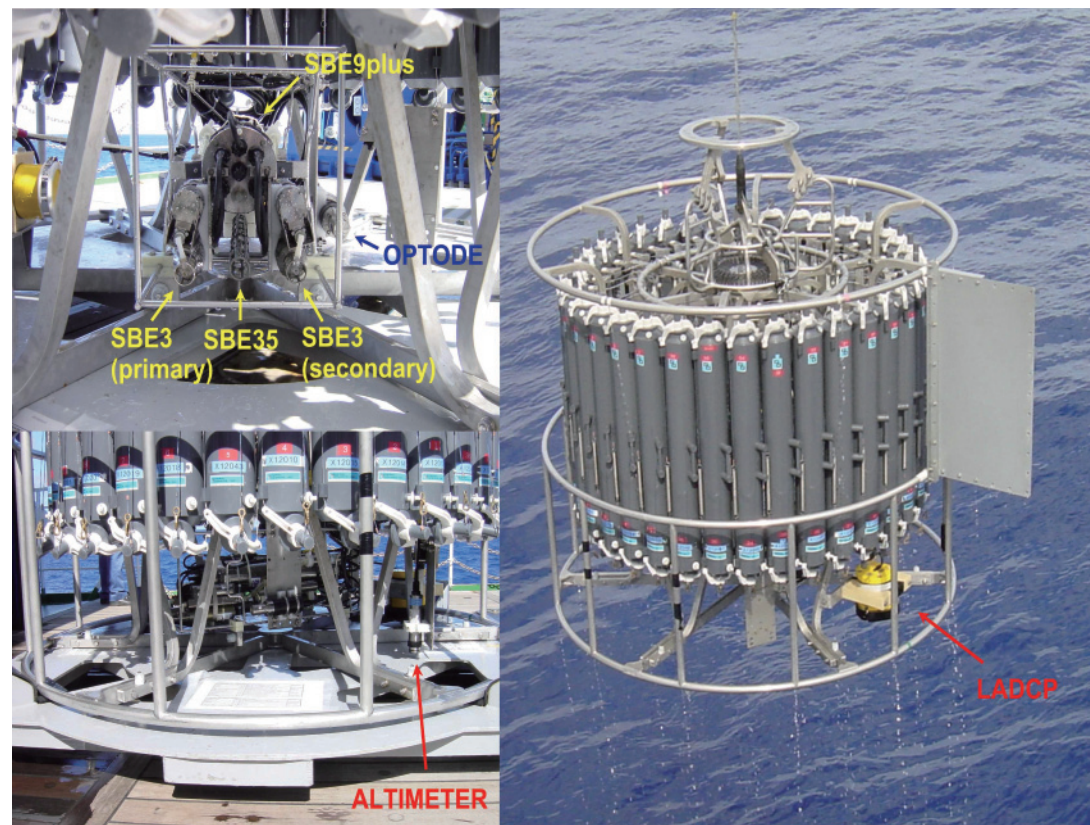


Figure 3.1.1. The CTD package (right) and the SBE 35 position in regard to the SBE 3 temperature sensors (left).

#### (4) Pre-cruise calibration

##### (4.1) Pressure

The Paroscientific series 4000 Digiquartz high pressure transducer (Paroscientific, Inc., Redmond, Washington, USA) uses a quartz crystal resonator whose frequency of oscillation varies with pressure induced stress with 0.01 per million of resolution over the absolute pressure range of 0 to 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. 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

$$c = c_1 + c_2 \times U + c_3 \times U^2$$

$$d = d_1 + d_2 \times U$$

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

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

$$U (^{\circ}\text{C}) = M \times (12 \text{ bit pressure temperature compensation word}) - B$$

The following coefficients were used in SEASOFT:

*S/N 0677*

$$M = 0.0128041$$

$$B = -9.324136$$

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

Finally, pressure is computed as

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

where t is pressure period ( $\mu\text{sec}$ ). 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 (Model 480DA, S/N 23906; Bundenberg Gauge Co. Ltd., Irlam, Manchester, UK) are performed at JAMSTEC, Yokosuka, Kanagawa, Japan by Marine Works Japan. LTD (MWJ), Yokohama, Kanagawa, Japan, usually once in a year in order to monitor sensor time drift and linearity. 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 hysteresis is typically 0.2 dbar. The following coefficients for the sensor drift correction were also used in SEASOFT:

*S/N 0677, 8 September 2005*

$$\text{slope} = 0.9998495$$

$$\text{offset} = -0.49595$$

The drift-corrected pressure is computed as

$$\text{Drift-corrected pressure (dbar)} = \text{slope} \times (\text{computed pressure in dbar}) + \text{offset}$$

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.

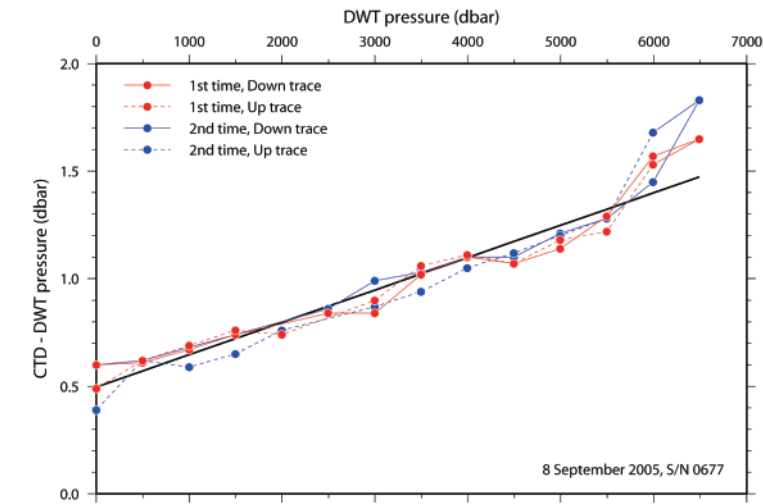


Figure 3.1.2. The residual pressures between the dead-weight piston gauge and the CTD pressure. The calibration line (black line) is also shown.

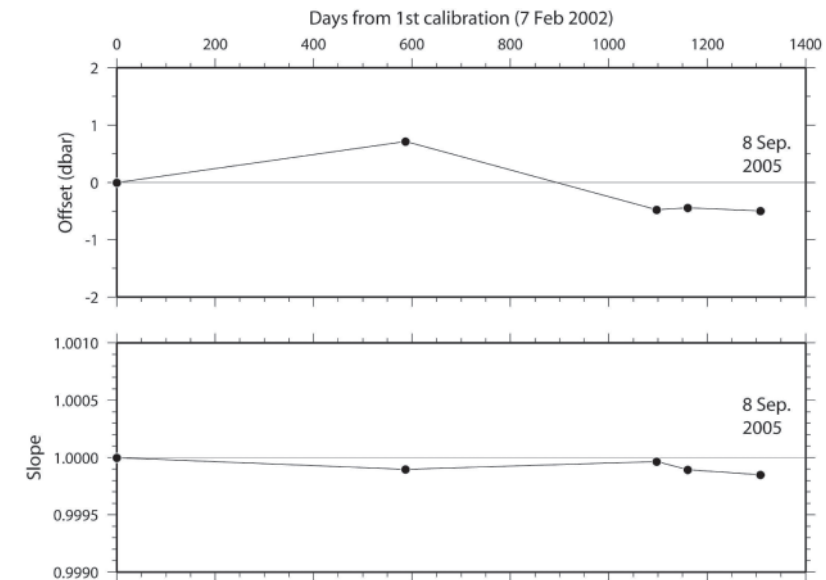


Figure 3.1.3. Pressure sensor time drift of offset (upper panel) and slope (lower panel) based on laboratory calibrations.

#### (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 1 mK, typical stability of 0.2 mK/month, and resolution of 0.2 mK at 24 samples per second. The premium temperature sensor, SBE 3plus, is a more rigorously tested and calibrated version of standard temperature sensor (SBE 3). A sensor is designated as an SBE 3plus only after demonstrating drift of less than 1 mK during a six-month screening period. In addition, the time response is carefully measured and verified to be  $0.065 \pm 0.010$  seconds.

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

*S/N 1464 (Leg.1: primary), 14 September 2005*

$$g = 4.84384166\text{e-}03$$

$$h = 6.80721378\text{e-}04$$

$$i = 2.69562893\text{e-}05$$

$$j = 2.12657768\text{e-}06$$

$$f_0 = 1000.000$$

*S/N 4216 (Leg.1: secondary, Leg.2 and 3: primary), 20 September 2005*

$$g = 4.35983643\text{e-}03$$

$$h = 6.46128037\text{e-}04$$

$$i = 2.28907910\text{e-}05$$

$$j = 1.94862297\text{e-}06$$

$$f_0 = 1000.000$$

*S/N 1525 (Leg.2 and 3: secondary), 14 September 2005*

$$g = 4.84604175\text{e-}03$$

$$h = 6.75287460\text{e-}04$$

$$i = 2.65140918\text{e-}05$$

$$j = 2.12921574\text{e-}06$$

$$f_0 = 1000.000$$

Temperature (ITS-90) is computed according to

Temperature (ITS-90) =

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

where  $f$  is the instrument frequency (kHz).

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

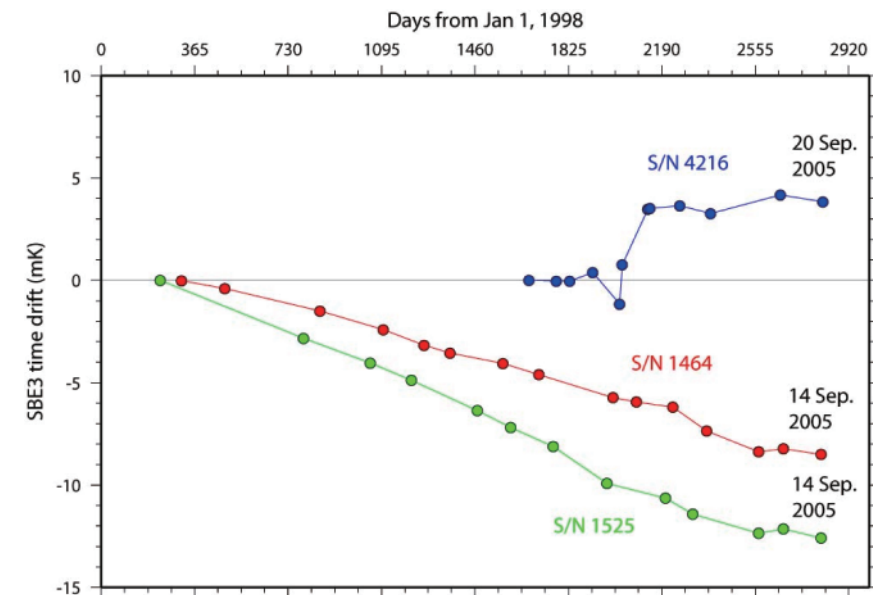


Figure 3.1.4. Time drift of SBE 3 temperature sensors based on laboratory calibrations.



#### (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. The following coefficients were used in SEASOFT:

*S/N 1203 (Leg.1: primary), 15 September 2005*

g = -4.05182265e+00  
h = 4.93483365e-01  
i = 9.77451923e-05  
j = 2.18599851e-05  
CPcor = -9.57e-08 (nominal)  
CTcor = 3.25e-06 (nominal)

*S/N 2854 (Leg.1: secondary, Leg.2: primary from X14\_1 to 351\_2, Leg.3: primary),*

*15 September 2005*

g = -1.02631821e+01  
h = 1.41526600e+00  
i = -9.49444425e-06  
j = 5.73270605e-05  
CPcor = -9.57e-08 (nominal)  
CTcor = 3.25e-06 (nominal)

*S/N 3124 (Leg.2: primary from 146\_2 to 197\_1), 8 November 2005*

g = -1.02907974e+01  
h = 1.38692851e+00  
i = -8.89254353e-05  
j = 8.59164344e-05  
CPcor = -9.57e-08 (nominal)  
CTcor = 3.25e-06 (nominal)

*S/N 3036 (Leg.2: secondary from 146\_2 to 197\_1), 23 September 2005*

g = -1.03246469e+01  
h = 1.42860596e+00  
i = 3.40735271e-04  
j = 4.76172694e-05  
CPcor = -9.57e-08 (nominal)  
CTcor = 3.25e-06 (nominal)

*S/N 3116 (Leg.2: secondary from X14\_1 to 351\_2, Leg.3: secondary), 8 November 2005*

g = -1.04289250e+01  
h = 1.43335621e+00  
i = 4.35984135e-04  
j = 3.98255096e-05  
CPcor = -9.57e-08 (nominal)  
CTcor = 3.25e-06 (nominal)

Conductivity of a fluid in the cell is expressed as:

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

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 hysteresis 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, and typical stability is 2% per 1,000 hours.

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

*S/N 0391 (Leg.1: primary, Leg.2: primary from 146\_2 to WC7), 18 October 2005*

$$\text{Soc} = 0.35440$$

$$\text{Offset} = -0.4919$$

$$\text{TCor} = 0.0013$$

$$\text{PCor} = 1.350\text{e-}04$$

*S/N 0488 (Leg.1: secondary), 11 October 2005*

$$\text{Soc} = 0.58120$$

$$\text{Offset} = -0.6959$$

$$\text{TCor} = -0.0004$$

$$\text{PCor} = 1.350\text{e-}04$$

*S/N 0390 (Leg.2: primary from WC8 to 351\_2, Leg.3: primary), 18 October 2005*

$$\text{Soc} = 0.3877$$

$$\text{Offset} = -0.5151$$

$$\text{TCor} = 0.0012$$

$$\text{PCor} = 1.350\text{e-}04$$

*S/N 0394 (Leg.2: secondary from 146\_2 to 283\_1, Leg.3: secondary), 1 July 2005*

$$\text{Soc} = 0.3629$$

$$\text{Offset} = -0.5220$$

$$\text{TCor} = 0.0020$$

$$\text{PCor} = 1.350\text{e-}04$$

*S/N 0205 (Leg.2: secondary from 285\_1 to 351\_2), 10 May 2005*

$$\text{Soc} = 0.4131$$

$$\text{Offset} = -0.4688$$

$$\text{TCor} = -0.0009$$

$$\text{PCor} = 1.350\text{e-}04$$

Oxygen (ml/l) is computed as

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

$$\begin{aligned} \text{Oxsat}(t, s) = & \exp[A_1 + A_2 \times (100 / t) + A_3 \times \ln(t / 100) + A_4 \times (t / 100) \\ & + s \times \{B_1 + B_2 \times (t / 100) + B_3 \times (t / 100) \times (t / 100)\}] \end{aligned}$$

$$A_1 = -173.4292$$

$$A_2 = 249.6339$$

$$A_3 = 143.3483$$

$$A_4 = -21.8482$$

$$B_1 = -0.033096$$

$$B_2 = -0.00170$$

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.

Serial number 0488 is used in SBE’s research for oxygen sensor membranes. This sensor has a membrane that is thicker than production SBE 43s. This thicker membrane will cause the sensor to respond more slowly than standard SBE 43s but it may be more stable. The field performance of this sensor is examined in the leg.1.

#### (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 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, the 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. The following coefficients were stored in EEPROM:

*S/N 0022 (Leg.1 and 2), 12 October 1999 (1st step: linearization)*

$$\begin{aligned} a_0 &= 4.320725498\text{e-}3 \\ a_1 &= -1.189839279\text{e-}3 \\ a_2 &= 1.836299593\text{e-}3 \\ a_3 &= -1.032916769\text{e-}5 \\ a_4 &= 2.225491125\text{e-}7 \end{aligned}$$

*S/N 0045 (Leg.3), 27 October 2002 (1st step: linearization)*

$$\begin{aligned} a_0 &= 5.84093815\text{e-}03 \\ a_1 &= -1.65529280\text{e-}03 \\ a_2 &= 2.37944937\text{e-}04 \\ a_3 &= -1.32611385\text{e-}05 \\ a_4 &= 2.83355203\text{e-}07 \end{aligned}$$

Linearized temperature (ITS-90) is computed according to

Linearized temperature (ITS-90) =

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

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). The slow time drift of the SBE 35 is adjusted by periodic recertification corrections.

*S/N 0022 (Leg.1 and 2), 30 September 2005 (2nd step: fixed point calibration)*

Slope = 1.000036

Offset = 0.000151

*S/N 0045 (Leg.3), 3 October 2005 (2nd step: fixed point calibration)*

Slope = 1.000013

Offset = -0.001084

Temperature (ITS-90) is calibrated according to

Temperature (ITS-90) = Slope  $\times$  Linearized temperature + Offset

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

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

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

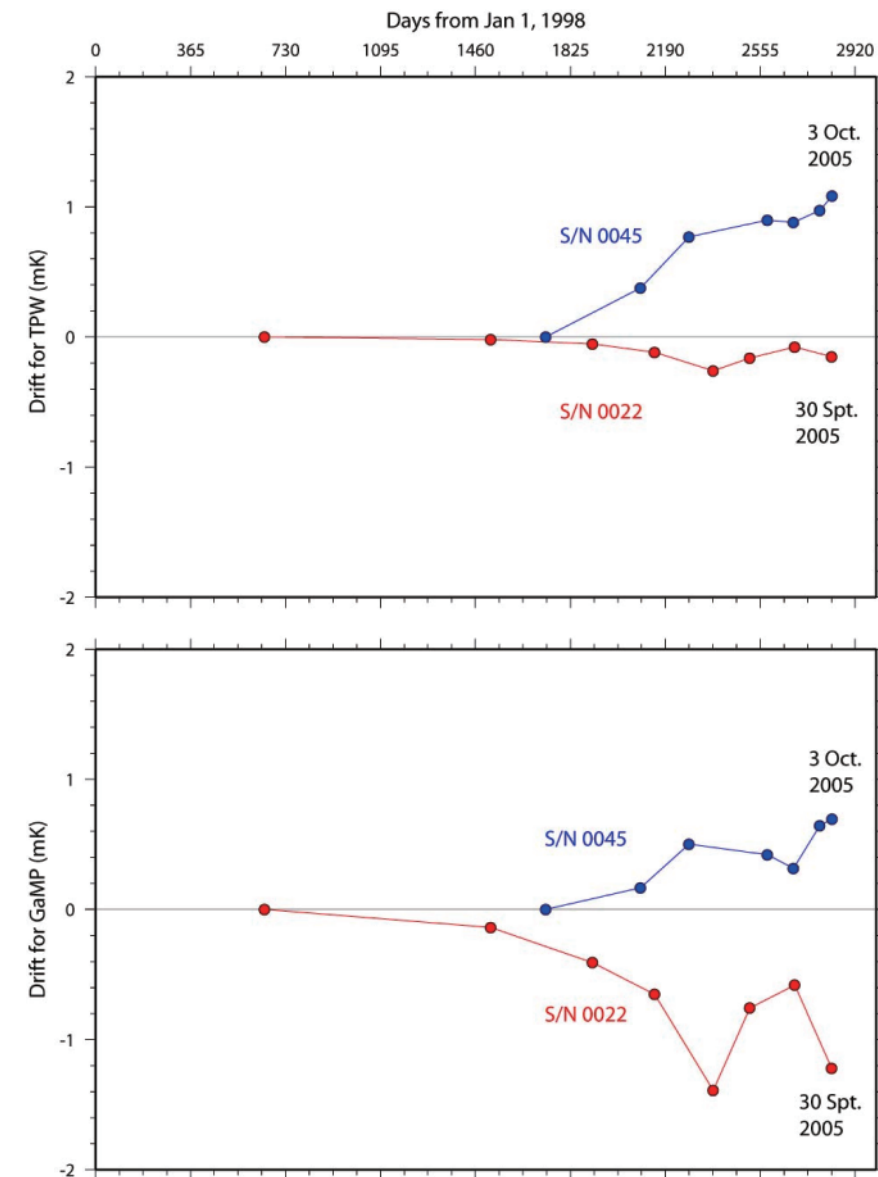


Figure 3.1.5. SBE35 time drift based on laboratory fixed point calibrations (triple point of water, TPW and gallium melt point, GaMP) performed by SBE, Inc.

#### (4.6) Altimeter

Benthos PSA-916T Sonar Altimeter (Teledyne Benthos, Inc.) determines the distance of the target from the unit by generating a narrow beam acoustic pulse and measuring the travel time for the pulse to bounce back from the target surface. The PSA-916T is the same as the standard PSA-916 Sonar Altimeter except 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  $\pm 0.4$  cm total distance. Since the total travel time is divided by two, the jitter error is  $\pm 0.2$  cm.

The following scale factors were used in SEASOFT:

*S/N 1100, S/N 1157*

$$\text{FSVolt} \times 300 / \text{FSRange} = 15$$

$$\text{Offset} = 0.0$$

#### (4.7) Oxygen Optode

Oxygen Optode 3830 (Aanderaa Instruments AS) is based on the ability of selected substances to act as dynamic fluorescence quenchers. The fluorescent indicator is a special platinum porphyrine complex embedded in a gas permeable foil that is exposed to the surrounding water. A black optical isolation coating protects the complex from sunlight and fluorescent particles in the water. This sensing foil is attached to a sapphire window providing optical access for the measuring system from inside watertight titanium housing. The foil is excited by modulated blue light, and the phase of a returned red light is measured. By linearizing and temperature compensating, with an incorporated temperature sensor, the absolute  $\text{O}_2$  concentration can be determined.

In order to use with the SBE 911plus CTD system, an analog adaptor (3966) is connected to the oxygen optode (3830). The analog adaptor is packed into titanium housing made by Alec Electronics Co. Ltd., Kobe,

Hyogo, Japan (Figure 3.1.6). The sensor is designed to operate down to 6,000 meters and the titanium housing for the analog adaptor is designed to operate down to 7,000 meters. The range for dissolved oxygen is 120% of surface saturation in all natural waters, nominal accuracy is less than 5% of saturation, and setting time (68%) is shorter than 25 seconds.

The following scale factors were used in SEASOFT:

*S/N 612*

$$\text{Phase shift (degrees)} = V_p \times 12 + 10$$

$$\text{Temperature (}^\circ\text{C)} = V_t \times 9 - 5$$

where  $V_p$  and  $V_t$  are voltage output (V) of phase shift and temperature, respectively.

Each batch of sensing foils is delivered with calibration data describing the behavior with respect to oxygen concentration and temperature.

*Foil batch No. 4104 (S/N 612), 13 November 2004*

$$\text{C0Coef}_0 = 3.199840\text{e}+3$$

$$\text{C0Coef}_1 = -1.119634\text{e}+2$$

$$\text{C0Coef}_2 = 2.408296$$

$$\text{C0Coef}_3 = -2.248740\text{e}-2$$

$$\text{C1Coef}_0 = -1.744936\text{e}+2$$

$$\text{C1Coef}_1 = 5.462500$$

$$\text{C1Coef}_2 = -1.244084\text{e}-1$$

$$\text{C1Coef}_3 = 1.239153\text{e}-3$$

$$\text{C2Coef}_0 = 3.941711$$

$$\text{C2Coef}_1 = -1.086677\text{e}-1$$

$$\text{C2Coef}_2 = 2.719394\text{e}-3$$

$$\text{C2Coef}_3 = -2.906343\text{e}-5$$

$$\text{C3Coef}_0 = -4.220910\text{e}-2$$

$$\text{C3Coef}_1 = 1.018155\text{e}-3$$

$$C3Coef_2 = -2.905609e-5$$

$$C3Coef_3 = 3.306610e-7$$

$$C4Coef_0 = 1.738870e-4$$

$$C4Coef_1 = -3.637668e-6$$

$$C4Coef_2 = 1.227403e-7$$

$$C4Coef_3 = -1.468399e-9$$

Temperature dependent coefficients are calculated as follows.

$$C0Coef = C0Coef_0 + C0Coef_1 \times t + C0Coef_2 \times t^2 + C0Coef_3 \times t^3$$

$$C1Coef = C1Coef_0 + C1Coef_1 \times t + C1Coef_2 \times t^2 + C1Coef_3 \times t^3$$

$$C2Coef = C2Coef_0 + C2Coef_1 \times t + C2Coef_2 \times t^2 + C2Coef_3 \times t^3$$

$$C3Coef = C3Coef_0 + C3Coef_1 \times t + C3Coef_2 \times t^2 + C3Coef_3 \times t^3$$

$$C4Coef = C4Coef_0 + C4Coef_1 \times t + C4Coef_2 \times t^2 + C4Coef_3 \times t^3$$

where  $t$  is temperature ( $^{\circ}\text{C}$ ). The oxygen concentration can be calculated by use of the following formula.

$$O_2 (\mu\text{mol/l}) = C0Coef + C1Coef \times P + C2Coef \times P^2 + C3Coef \times P^3 + C4Coef \times P^4$$

where  $P$  is phase shift (degrees) measured by the Optode. In addition to the above mentioned coefficient, phase measurement is calibrated for individual sensor and foil variations by a two point calibration (one in air saturated water and one in a zero-oxygen solution).

$$P = A + B \times P_b$$

where  $P$  is a calibrated phase shift (degrees) and  $P_b$  is a raw phase measurement. The coefficients  $A$  and  $B$  can be calculated by ordinary linear curve fitting and is delivered.

*S/N 612, 20 September 2005*

$$A = -3.00536$$

$$B = 1.11847$$

Outputs from the sensor are the raw phase shift ( $P_b$ ) and temperature. The raw phase data was calibrated using above coefficients after data acquisition. The oxygen concentration was calculated using temperature data

from the first responding CTD temperature sensor instead of temperature data from slow responding optode temperature sensor.

Since the sensing foil is only permeable to gas and not water, the optode can not sense the effect of salt dissolved in the water, hence the optode always measures as if immersed in fresh water. Therefore the oxygen concentration,  $\mu\text{mol/l}$ , was multiplied by the following factor.

$$\exp\{S(B_0 + B_1 \times T_s + B_2 \times T_s^2 + B_3 \times T_s^3) + C_0 \times S^2\}$$

where  $S$  is salinity,  $T_s$  is scaled temperature ( $= \ln\{(298.15 - t)/(273.15 + t)\}$ ),  $t$  is temperature ( $^{\circ}\text{C}$ ),

$$B_0 = -6.24097e-3$$

$$B_1 = -6.93498e-3$$

$$B_2 = -6.90358e-3$$

$$B_3 = -4.29155e-3$$

$$C_0 = -3.11680e-7$$

The response of the sensing foil decreases to some extent with the ambient water pressure. Therefore the oxygen concentration was multiplied by the following factor.

$$(1 + 0.03 \times P_r / 1000)$$

where  $P_r$  is pressure in dbar. This factor (0.03) is empirically determined and different from that in the user's manual. (The factor was changed as 0.032 after analyzing the data obtained in this cruise.)



Figure 3.1.6. Oxygen Optode (3830) with analog adaptor (3966). The analog adaptor is packed into titanium housing made by Alec Electronics Co., Ltd.



## **(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 primary conductivity sensor module and the pump. Auxiliary sensors included Deep Ocean Standards Thermometer, altimeter and oxygen optode. The SBE 9plus was mounted horizontally in a 36-position carousel frame.

CTD system was powered on at least 30 minutes in advance of the data acquisition and was powered off at least two minutes after the operation in order to acquire pressure data on the ship's deck.

The package was lowered into the water from the starboard side and held 10 m beneath the surface 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 (or 300 m when significant wave height is high) 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 1.1 m/s except for bottle firing stops. At each bottle firing stops, the bottle was fired after waiting from the stop for 30 seconds and the package was stayed at least 5 seconds for measurement of the Deep Ocean Standards Thermometer. At 200 m (or 300 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 Niskin-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*

SEASAVE-Win32, version 5.27b

### **(5.2) Data collection problems**

#### *Leg.1:*

At following stations, trigger of the bottle was not released. Therefore the latch assembly was replaced after the cast.

33\_1 (#12), 51\_1 (#28), 116\_1 (#36)

At station 38\_1, bottle #19 did not trip correctly. It was found by temperature reading at dissolved oxygen sampling. Therefore the latch assembly was replaced after the cast.

At station 51\_1, bottle #26 was not fired by missed operation.

After station 51\_1, bottle #15 was changed from S/N X12006 to S/N X12009 due to frequent leak.

At following stations, output from the sensor showed abnormal values.

94\_1, secondary sensors, 32-96 dbar (down cast)

114\_1, secondary conductivity, 1,192-2,546 dbar (down cast)

118\_1, primary conductivity, 1,391-1,438 dbar (down cast)

#### *Leg.2:*

At following stations, trigger of the bottle was not released. Therefore the latch assembly was replaced after the cast.

X14\_1 (#17), 201\_1 (#17), 203\_1 (#10), 217\_2 (#28), 231\_1 (#26), 322\_1 (#18), 351\_2 (#14)

At following stations, bottle did not trip correctly. It was found by temperature reading at dissolved oxygen sampling. Therefore the latch assembly was replaced after the cast.

WC5\_1 (#8), 291\_1 (#20), 351\_2 (21)

At following stations, bottle did not trip correctly. It was found by sampled water analysis.

185\_1 (#17): The latch assembly was replaced after station 195\_1.

WC2\_1 (#1): The latch assembly was replaced after station WC5\_1.

357\_1 (#17): The bottle tripped before firing the bottle.

At station 217\_2, bottle #36 was not fired by missed operation.

After station 267\_1, bottle #23 was changed from S/N X12043 to S/N X12005.

At following stations, output from the sensor showed abnormal values.

146\_2, secondary sensors

148\_1, secondary sensors

WC7\_1, primary sensors

328\_1, primary sensors, 0-1,106 dbar (up cast), Jellyfish in primary TC duct

At station 299\_1, the deck unit fused at 2,790 dbar of up cast. The system was re-started at the depth.

At station 347\_1, system error occurred at 2,743-2,744 dbar of up cast by unknown reason.

For primary oxygen sensor S/N 0391, noise became large near surface (0-400 dbar) compared to the data obtained from the same sensor in leg 1. The sensor was bleached after stations 171\_1, 209\_1 and WC6\_1. Noise became large again although it was improved after bleaching.

After station 197\_1, the primary conductivity sensor was changed from S/N 3124 to S/N 2854, and the secondary conductivity sensor was also changed from S/N 3036 to S/N 3116, due to large time drift.

After station WC7\_1, the primary oxygen sensor was changed from S/N 0391 to S/N 0390 due to shift and noise.

After station 283\_1, the secondary oxygen sensor was changed from S/N 0394 to S/N 0205 due to small noise. But the noise was found in the secondary oxygen data after the sensor change as well. So the connecting cable for the secondary oxygen sensor after station 285\_1. But the noise was found as well. At station 333\_1, the connecting port was changed from AUX3 to AUX2 and the noise disappeared after that.

*Leg.3:*

At station 380\_1, bottle #23 was not trip correctly. It was found by temperature reading at dissolved oxygen sampling. Therefore the latch assembly 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 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 following are the SEASOFT data processing module sequence and specifications used in the reduction of CTD data in this cruise.

#### *Data processing software*

SEASOFT-Win32, version 5.27b

DATCNV converted the raw data to scan number, pressure, depth, temperatures, conductivities, oxygen voltage, descent rate, altitude, and optode phase shift. 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, and time were output as the first two columns. Scan number, pressure, depth, temperatures, conductivities, oxygen voltage, descent rate, altitude

and optode phase shift were averaged over 4.4 seconds. And salinity, potential temperature, density ( $\sigma_\theta$ ) 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, the typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit was set to advance the primary and the secondary conductivity for 1.73 scans ( $1.75/24 = 0.073$  seconds). Oxygen data are also systematically delayed with respect to depth mainly because of the long time constant of the oxygen sensor and of an additional delay from the transit time of water in the pumped plumbing line. This delay was compensated by 6 seconds advancing oxygen sensor output (oxygen voltage) relative to the temperature. For the serial number 0488 that have thicker membrane than standard SBE 43s, the delay was compensated by 14 seconds. Oxygen optode data are also delayed by relatively slow response time of the sensor. The delay was compensated by 8 seconds advancing optode sensor output (phase shift and optode temperature) relative to the CTD 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 1,000 scans. Data greater than 10 standard deviations were flagged. The second pass computed a standard deviation over the same 1,000 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.

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 exist every dbar.

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

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

For stations from 146\_2 to 331\_1 in Leg.2, small noise was found in the secondary oxygen data because the sensor connected to the port of AUX3. Therefore the sensor output (voltage) was low-pass filtered with a time constant of 1 second at the same time of the low-pass filtering for the pressure data mentioned above. At following stations, the noise could not be removed completely from down cast profile data.

X14\_1: 5,650-5,800 dbar

201\_1: 5,600-5,760 dbar

203\_1: 5,710-5,850 dbar

205\_1: 5,760-5,820 dbar

207\_1: 5,660-5,860 dbar

213\_1: 5,840-5,880 dbar

215\_1: 5,750-5,920 dbar

217\_1: 5,730-5,880 dbar

Remaining spikes in salinity or oxygen data were manually eliminated from the raw data or the 1-dbar-averaged data. When number of data in the 1-dbar-pressure bin was less than 10, the data of the bin was not used. The data gap over 1-dbar was linearly interpolated with a quality flag of 6.

For the oxygen optode data, the delay due to the long time constant was compensated by 8 seconds using the software module ALIGNCTD mentioned above. However it was found that the delay was dependent on temperature. So the delay was compensated advancing optode sensor output relative to the CTD temperature as a following function of temperature.

$$\text{align (sec)} = 25 \times \exp(-0.13 \times t) \text{ (for } 0 \leq t \leq 16.3 \text{ }^{\circ}\text{C)}$$

$$\text{align (sec)} = 25 \text{ (for } t < 0 \text{ }^{\circ}\text{C)}$$

$$\text{align (sec)} = 3 \text{ (for } t > 16.3 \text{ }^{\circ}\text{C)}$$

where t is CTD temperature (°C).

**(6) Post-cruise calibration**

Post-cruise calibration is basically performed for each leg. However the cruise period of Leg.2 is longer than usual (53 days). So the data of Leg.2 is divided into two periods for the post-cruise calibration. In this section the two periods are called as Leg.2a (from station 146\_2 to WC10\_1) and Leg. 2b (from station 217\_2 to 351\_2).

**(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. Therefore CTD system was powered on for 30 minutes in advance of the data acquisition (from 55\_1, Leg.1). 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 one minute, 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 from [Figure 3.1.7](#) to [Figure 3.1.10](#).

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. Estimated offset of the pressure data is summarized in Table 3.1.1. 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 deviation are calculated from time series of the average of the pre- and the post-cast deck pressures.

Leg	S/N	Mean deck Pressure (dbar)	Standard deviation (dbar)	Residual pressure (dbar)	Estimated offset (dbar)
Leg.1	0677	−0.53	0.03	0.03	−0.56
Leg.2a	0677	−0.54	0.03	0.03	−0.57
Leg.2b	0677	−0.53	0.02	0.03	−0.56
Leg.3	0677	−0.49	0.02	0.03	−0.52

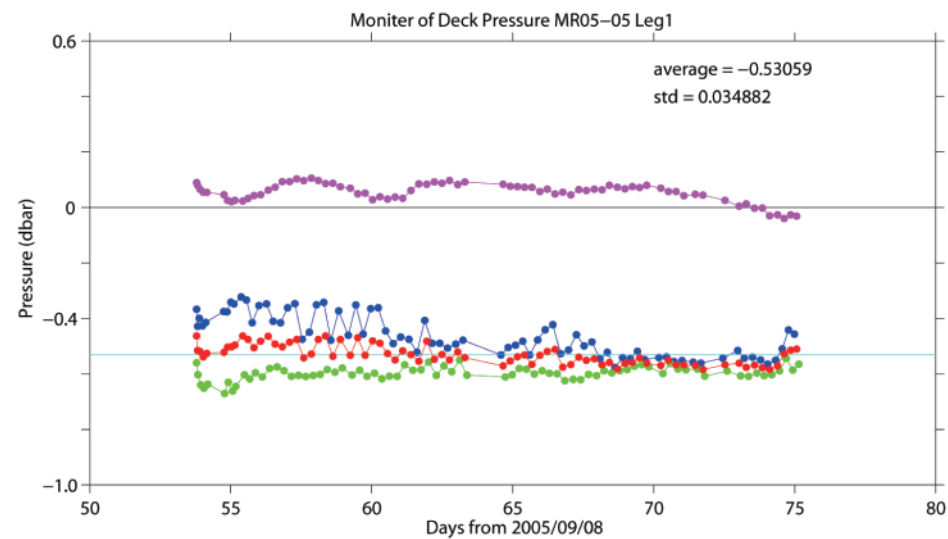


Figure 3.1.7. Time series of the CTD deck pressure for Leg.1. Pink dot indicates atmospheric pressure anomaly. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dot indicates an average of the pre- and the post-cast deck pressures.

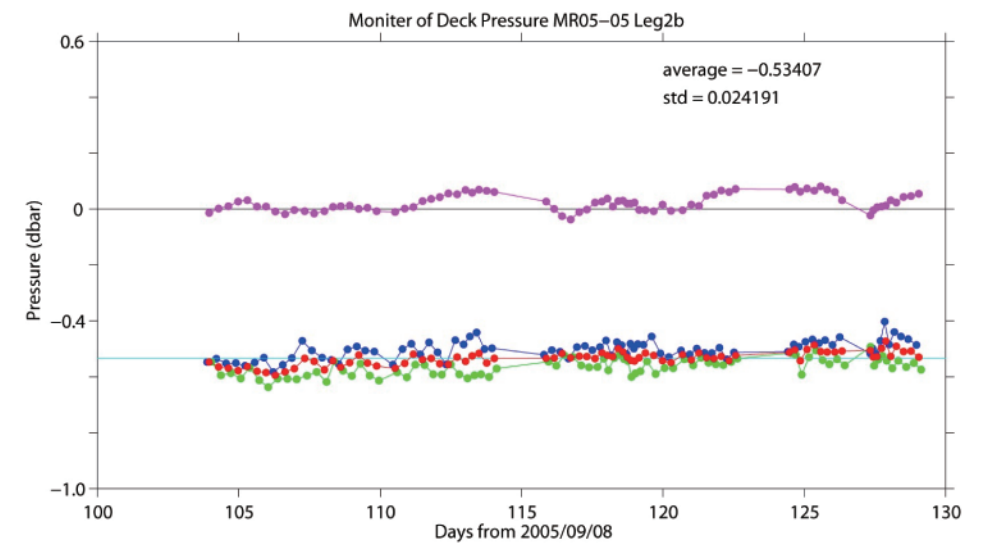


Figure 3.1.9. Same as Figure 3.1.7, but for Leg.2b.

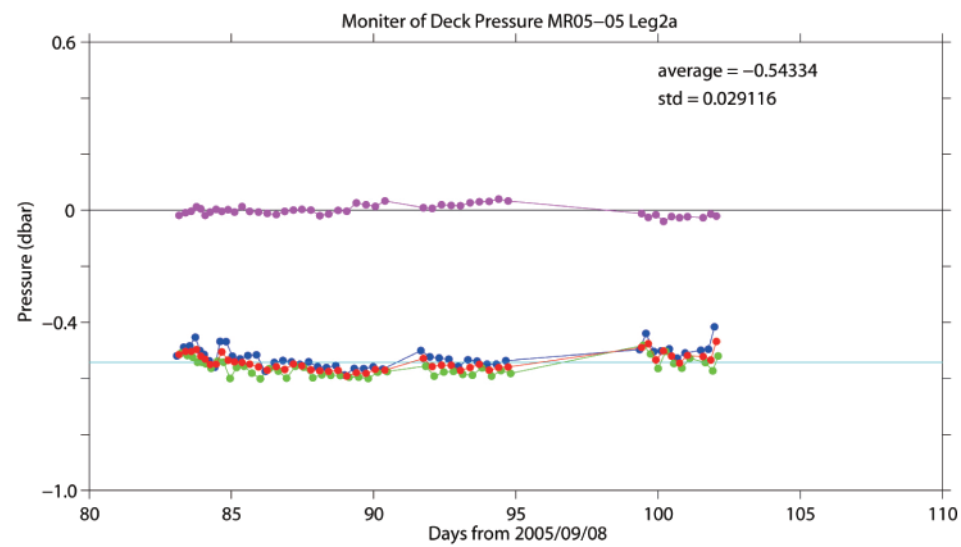


Figure 3.1.8. Same as Figure 3.1.7, but for Leg.2a.

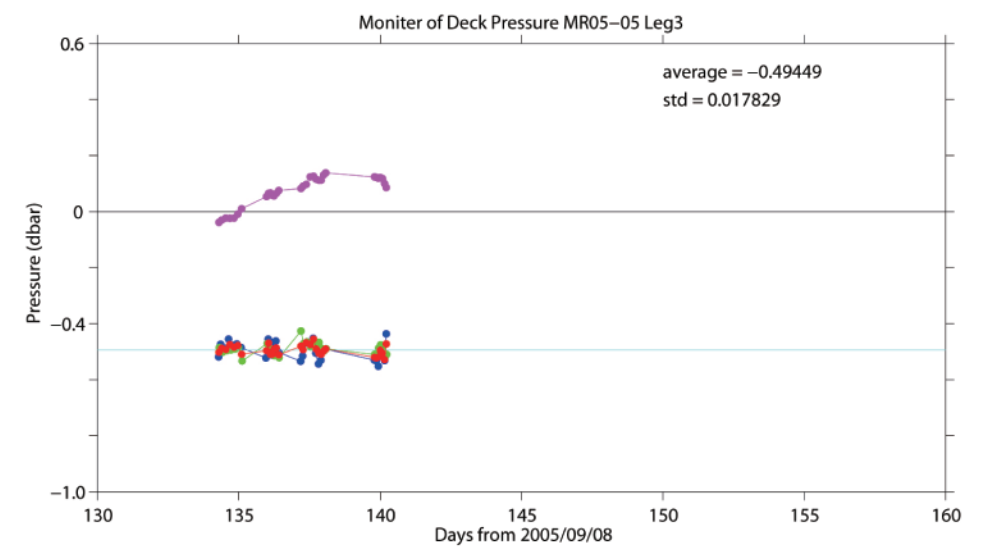


Figure 3.1.10. Same as Figure 3.1.7, but for Leg.3.

(6.2) Temperature

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

Post-cruise sensor calibrations for the SBE 35 were performed at SBE, Inc.

*S/N 0022, 1 February 2006 (2nd step: fixed point calibration)*

Slope = 1.000034

Offset = 0.000038

*S/N 0045, 21 February 2006 (2nd step: fixed point calibration)*

Slope = 1.000009

Offset = -0.001109

Offset of the SBE 35 (S/N 0022) data from the pre-cruise calibration is estimated to be 0.1 mK 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 CTD temperature is calibrated as

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

where T is CTD temperature in °C, P is pressure in dbar, t is time in days from pre-cruise calibration date of 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 calibration is performed for the CTD data created by the software module ROSSUM. 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. For Leg.3 the calibration coefficients determined for Leg.2b are used for the calibration because the maximum pressure of the CTD casts

is shallower than 2,000 dbar in Leg.3.

Finally following temperature data are used for the data set in consideration for the data quality.

Leg.1: secondary (S/N 4216) except for 94\_1 and 114\_1

primary (S/N 1464) for 94\_1 and 114\_1

Leg.2: primary (S/N 4216) except for WC7\_1 and 328\_1

secondary (S/N 1525) for WC7\_1 and 328\_1

Leg.3: primary (S/N 4216)

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 from Figure 3.1.11 to Figure 3.1.17.

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.

Leg	S/N	Number of data	ADEV (mK)	Note
Leg.1	1464	976	0.10	for 94_1, 114_1
	4216	976	0.10	
Leg.2a	4216	672	0.12	for WC7_1
	1525	661	0.10	
Leg.2b	4216	1070	0.14	for 328_1
	1525	1070	0.11	



Table 3.1.3. Calibration coefficients for the CTD temperature sensors.

Leg	S/N	$c_0$ (°C/dbar)	$c_1$ (°C/day)	$c_2$ (°C)
Leg.1	1464	$-1.090\text{e-}7$	$1.3833\text{e-}5$	$-0.34\text{e-}3$
	4216	$1.8917\text{e-}8$	$-4.1245\text{e-}6$	$0.55\text{e-}3$
Leg.2a	4216	$-3.9923\text{e-}9$	$-1.1221\text{e-}6$	$0.70\text{e-}3$
	1525	$1.0202\text{e-}9$	$-5.4892\text{e-}6$	$0.84\text{e-}3$
Leg.2b	4216	$-7.2153\text{e-}9$	$1.0834\text{e-}5$	$-0.65\text{e-}3$
	1525	$2.7008\text{e-}9$	$1.8342\text{e-}6$	$-0.07\text{e-}3$
Leg.3	4216	Same as Leg.2b	Same as Leg.2b	Same as Leg.2b

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 (Num) is also shown.

Leg	S/N	Pressure $\geq$ 1,950 dbar			Pressure < 1,950 dbar		
		Num	Mean (mK)	Sdev (mK)	Num	Mean (mK)	Sdev (mK)
Leg.1	1464	976	-0.01	0.14	1392	-0.57	4.3
	4216	976	-0.01	0.14	1392	-0.13	4.0
Leg.2a	4216	672	0.02	0.17	888	-0.04	4.6
	1525	661	-0.00	0.17	872	0.16	5.5
Leg.2b	4216	1070	-0.00	0.18	1407	-0.11	4.3
	1525	1070	-0.01	0.15	1421	-0.21	4.4
Leg.3	4216	—	—	—	332	-0.59	5.5

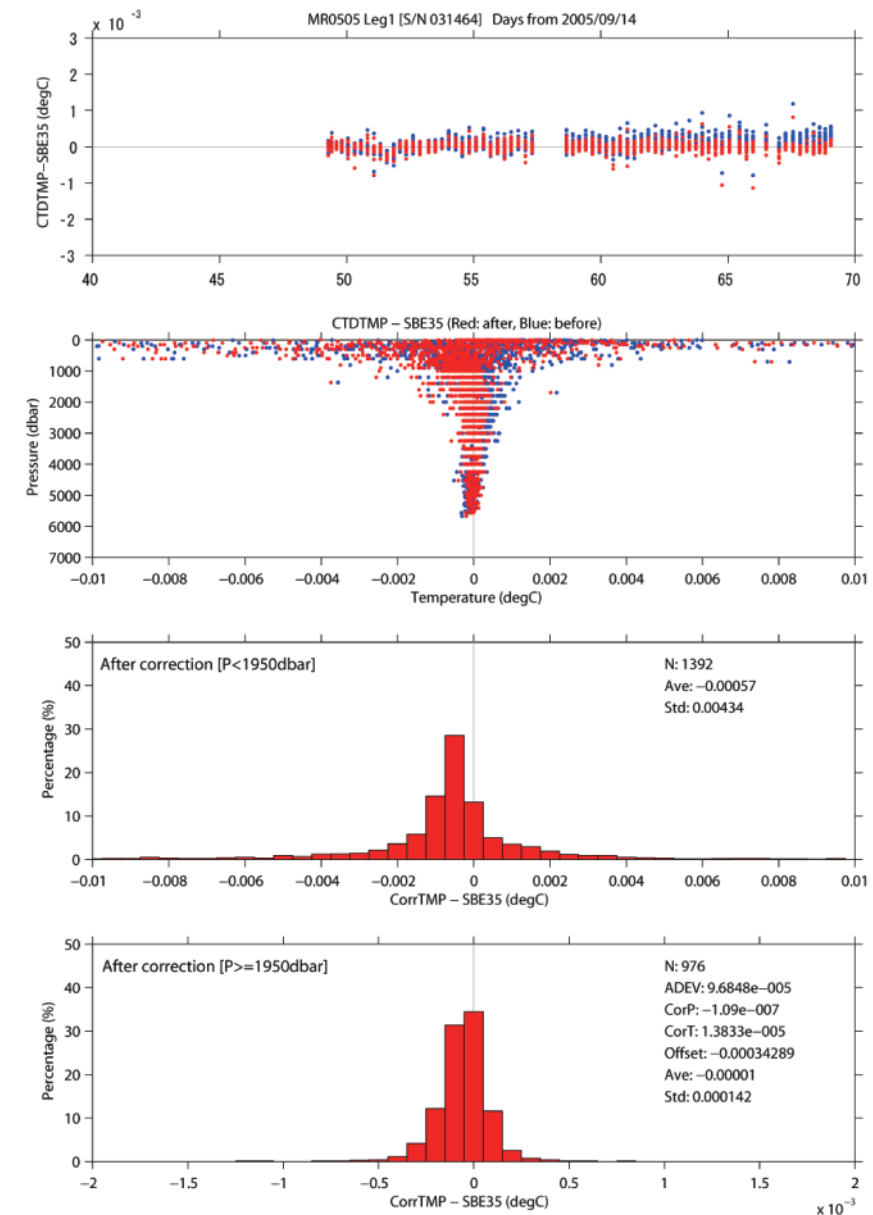


Figure 3.1.11. Difference between the CTD temperature (primary) and the SBE 35 for Leg.1. Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Top panel shows for  $P \geq 1950$  dbar. Lower two panels show histogram of the difference after the calibration.

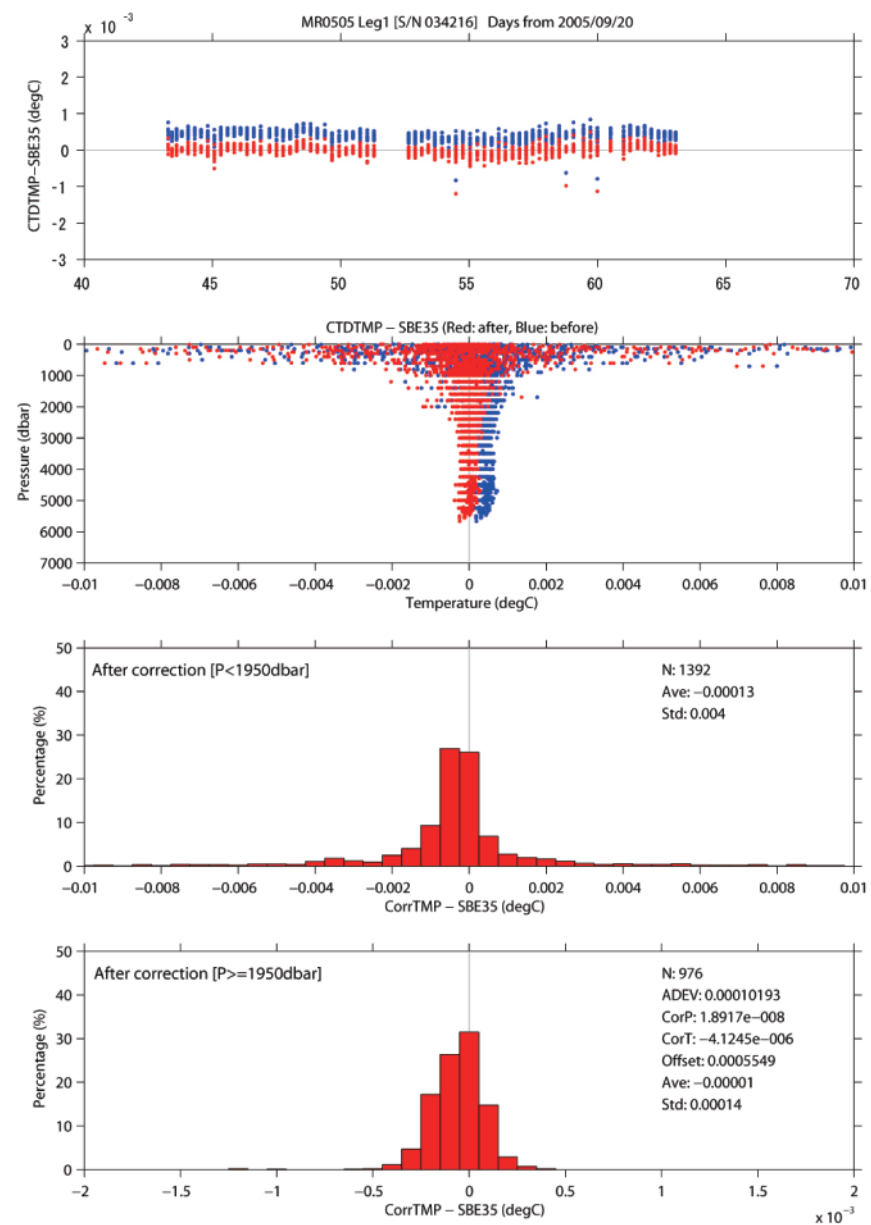


Figure 3.1.12. Same as Figure 3.1.11, but for the secondary CTD temperature for Leg.1.

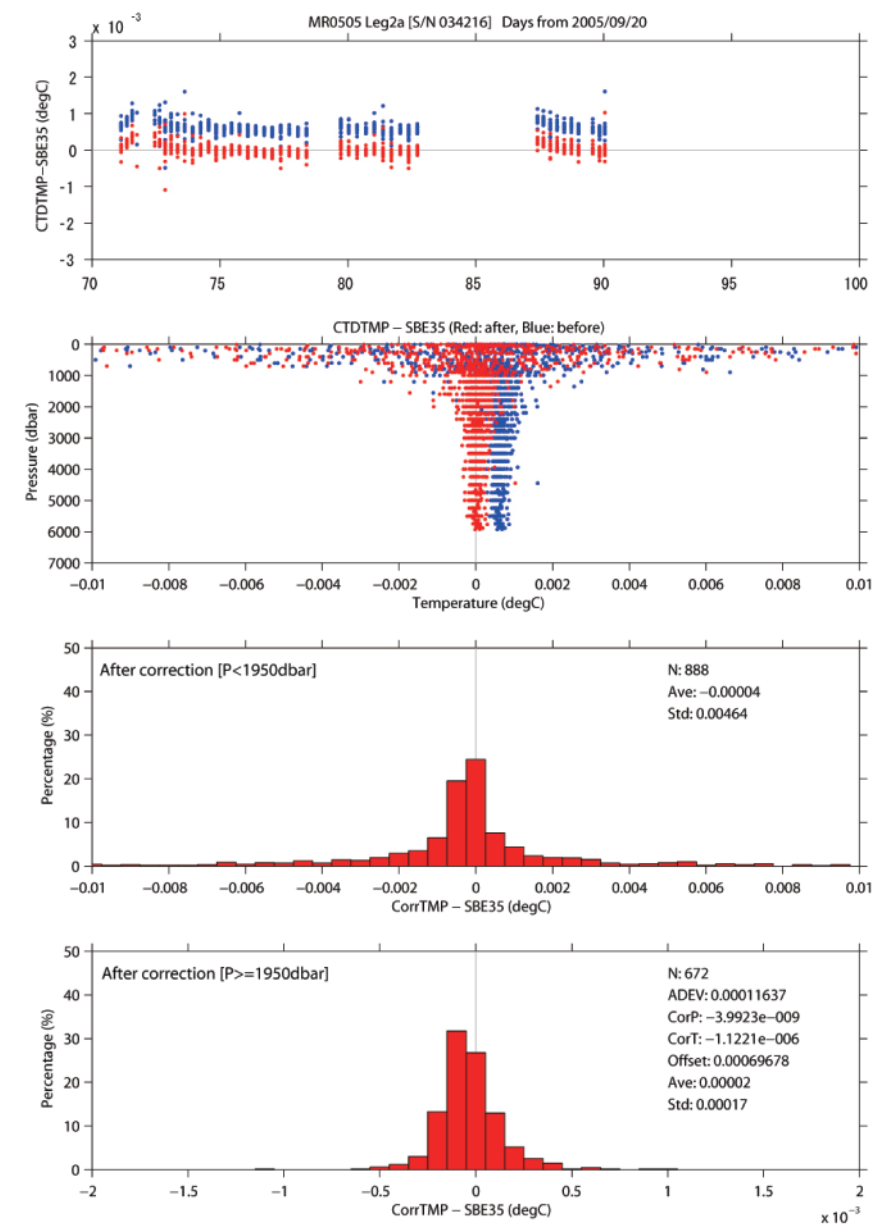


Figure 3.1.13. Same as Figure 3.1.11, but for the primary CTD temperature for Leg.2a.

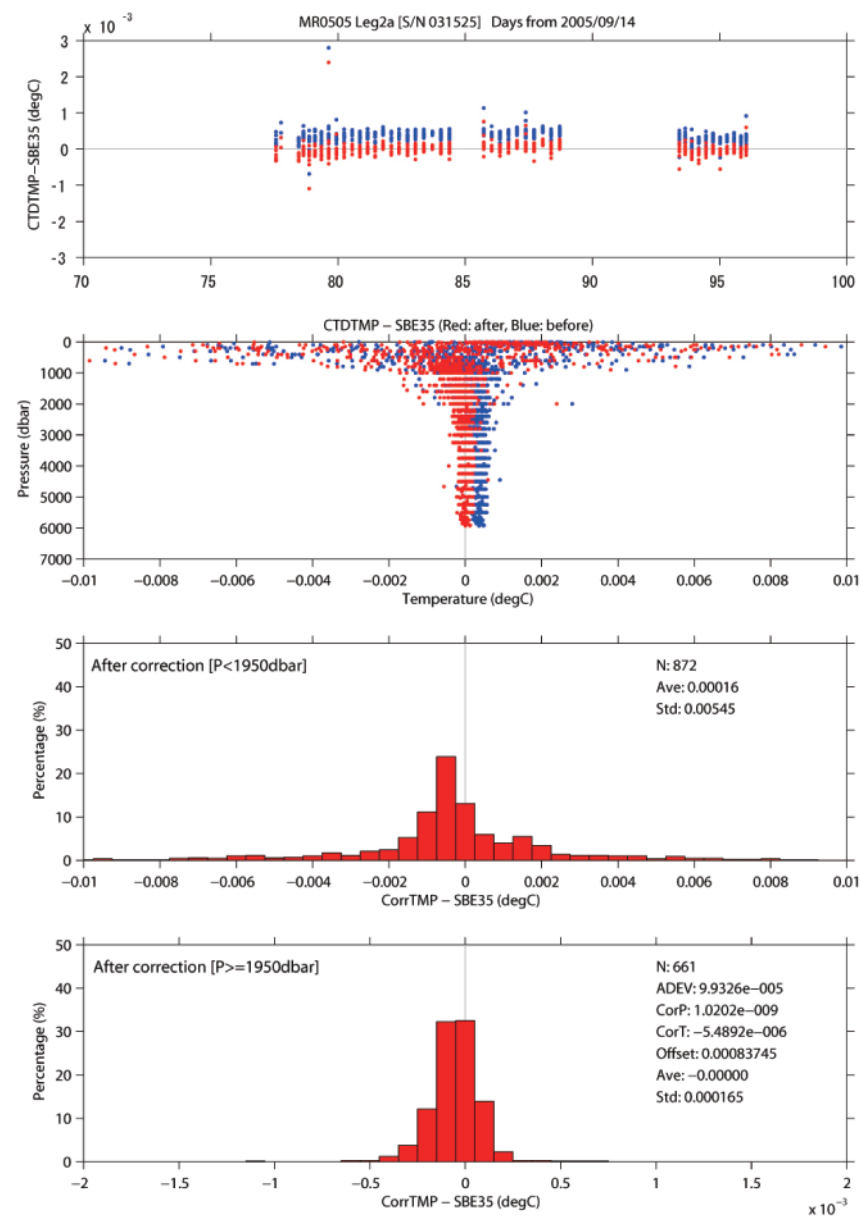


Figure 3.1.14. Same as Figure 3.1.11, but for the secondary CTD temperature for Leg.2a.

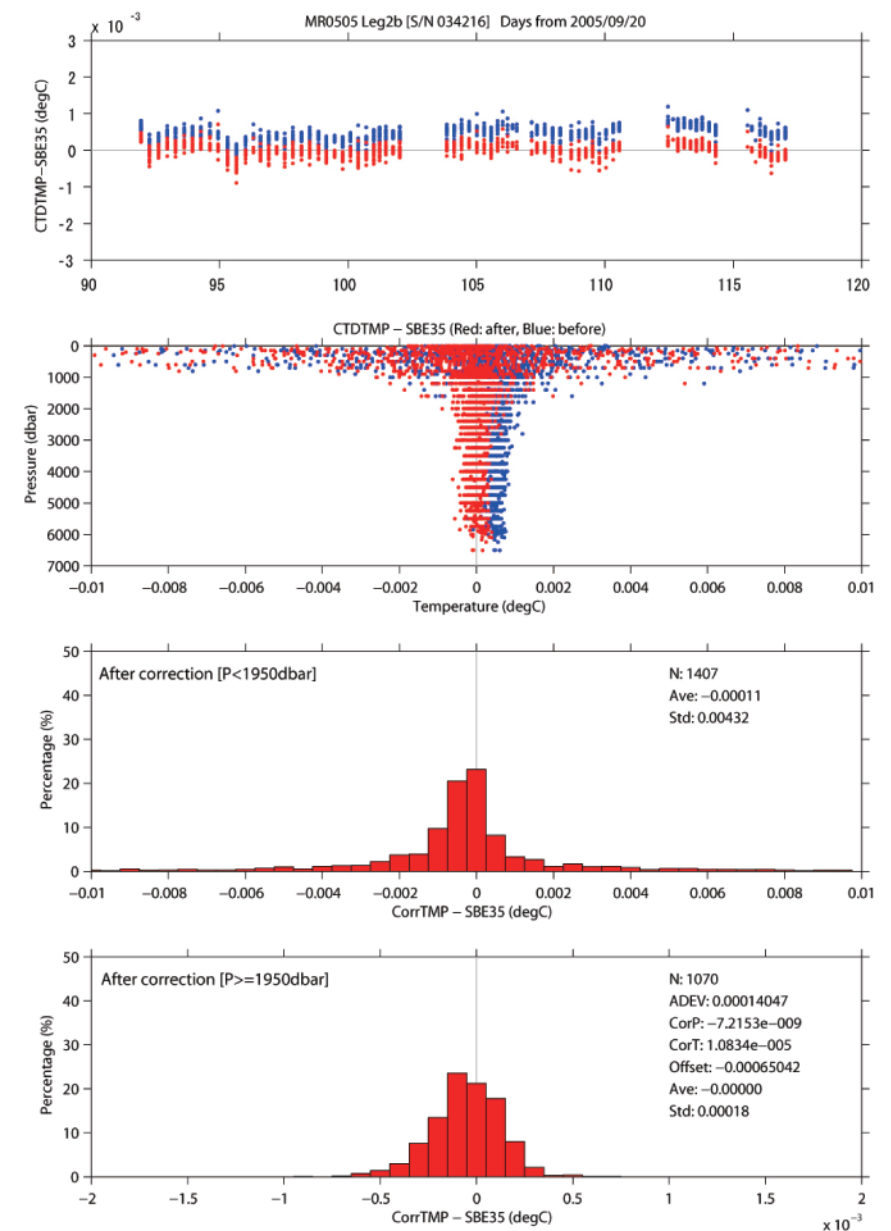


Figure 3.1.15. Same as Figure 3.1.11, but for the primary CTD temperature for Leg.2b.

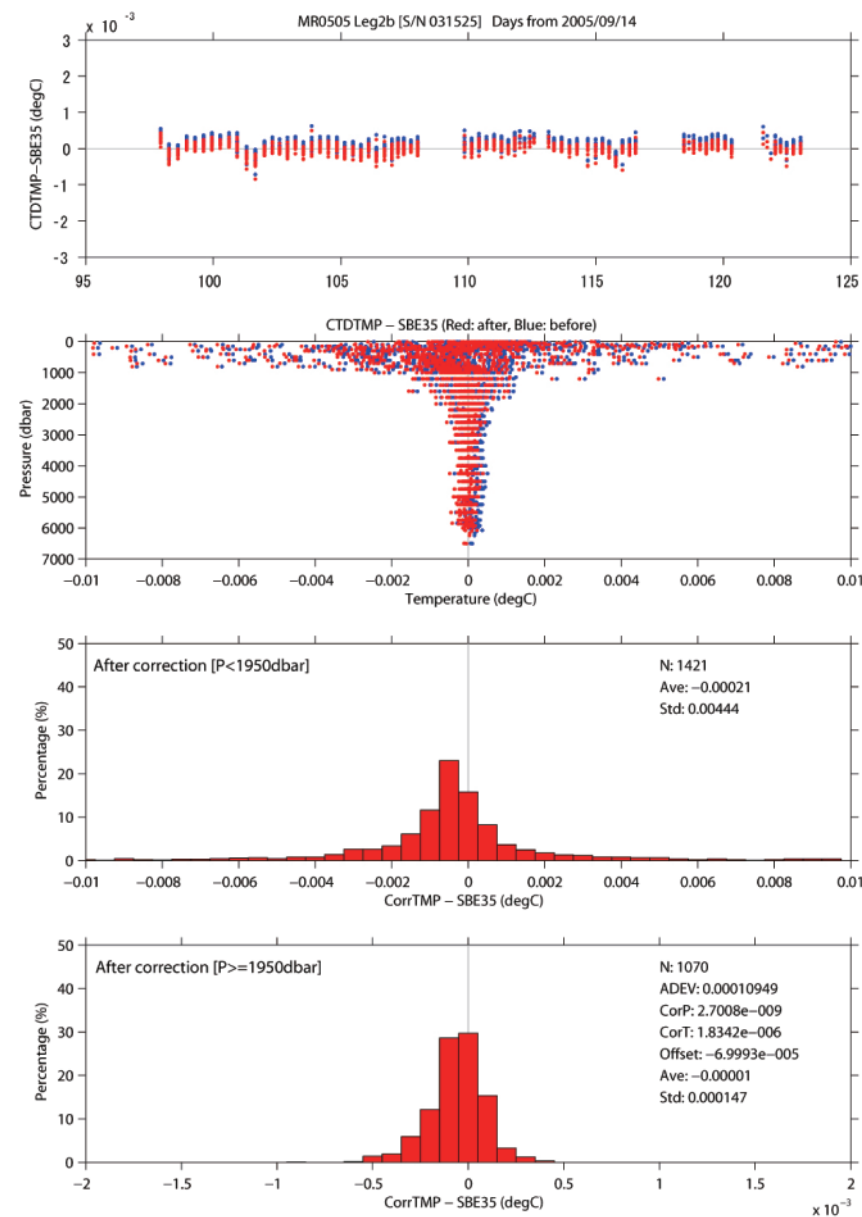


Figure 3.1.16. Same as Figure 3.1.11, but for the secondary CTD temperature for Leg.2b.

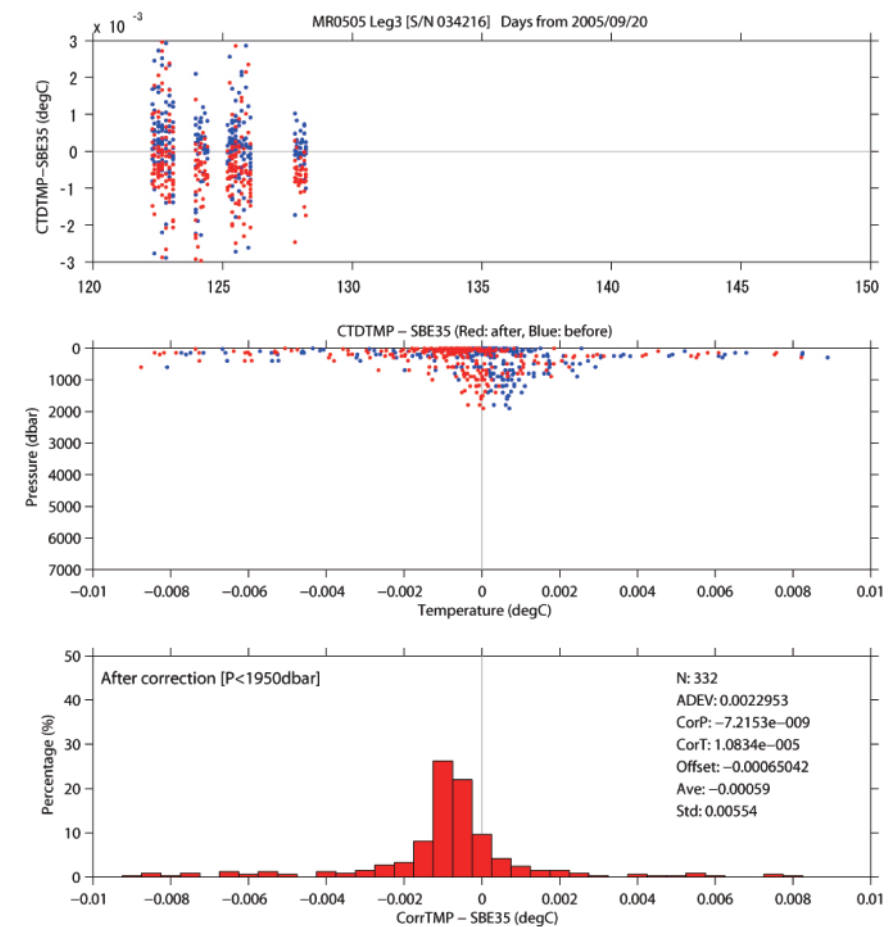


Figure 3.1.17. Same as Figure 3.1.11, but for the primary CTD temperature for Leg.3. Top and bottom panels show for full pressure range.

### (6.3) Salinity

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

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

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

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

where Grad is vertical salinity gradient in PSU dbar<sup>-1</sup>, and P is pressure in dbar. Gr and PR are threshold of the salinity gradient (0.5 mPSU dbar<sup>-1</sup>) 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.

Finally salinity data derived from following conductivity sensor are used for the data set in consideration for the data quality.

Leg.1: secondary (S/N 2854) except for 94\_1 and 114\_1

primary (S/N 1203) for 94\_1 and 114\_1

Leg.2: primary (S/N 3124 and S/N 2854) except for WC7\_1 and 328\_1

secondary (S/N 3116) for WC7\_1 and 328\_1

Leg.3: primary (S/N 2854)

The CTD data created by the software module ROSSUM are used after the post-cruise calibration for the CTD temperature.

The coefficients are determined for some groups of the CTD stations. The results of the post-cruise calibration for the CTD salinity are summarized in Table 3.1.5 and shown in from [Figure 3.1.18](#) to [Figure 3.1.21](#).

And the calibration coefficients and the number of the data 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 950 dbar. Number of data used (Num) is also shown.

Leg	Pressure ≥ 950 dbar			Pressure < 950 dbar		
	Num	Mean (mPSU)	Sdev (mPSU)	Num	Mean (mPSU)	Sdev (mPSU)
Leg.1	1320	0.01	0.32	1002	0.06	6.36
Leg.2a	920	-0.02	0.34	656	0.72	5.89
Leg.2b	1422	-0.02	0.36	1025	0.67	3.16
Leg.3	25	-0.04	0.41	296	-0.17	1.86

Table 3.1.6. Calibration coefficients for the CTD salinity. Number of data used (Num) is also shown.

Stations	(Num)	C0	C1	C2	C3
Leg 1:					
1_1-26_1	(275)	-6.9332569403e-6	-1.7406138415e-3	2.1616864848e-6	7.4450762843e-3
28_1-44_1	(298)	-1.2804422689e-6	-9.1223600910e-4	3.6879791066e-7	5.1074521112e-3
46_1-73_1	(512)	3.6529672450e-7	-2.3847830676e-4	-1.4495159805e-7	3.1629438129e-3
94_1,114_1	(65)	2.7703624740e-6	6.1243709126e-5	-8.2572575661e-7	4.0659912660e-3
74_1-104_1	(543)	1.8730171701e-6	-1.4227773847e-4	-6.2019187422e-7	3.2067999773e-3
106_1-146_1	(629)	-6.1266343657e-7	-3.3024724989e-4	1.6374587979e-7	3.8794661715e-3
Leg 2a:					
146_2	(32)	-1.3534051256e-6	2.6822634099e-4	4.8090447234e-7	-1.7023616632e-3
148_1	(30)	2.8648089621e-6	7.9162918294e-4	-8.5229000985e-7	-4.1877005940e-3
150_1	(27)	-6.3263920182e-6	5.6172052014e-4	2.1176194280e-6	-4.0658193232e-3
152_1-157_1	(96)	-1.3932496449e-6	5.0002444812e-4	4.6572414581e-7	-4.3072082193e-3
159_1,161_1	(62)	2.6431715417e-6	6.2244409716e-4	-8.1258089784e-7	-4.1441691258e-3
163_1-171_1	(161)	8.2248815256e-7	5.4513664671e-4	-2.1423403281e-7	-5.1979263905e-3
173_1-197_1	(437)	4.6490157041e-6	7.1901447939e-4	-1.4095235922e-6	-6.4071128225e-3
X14_1-217_1	(355)	4.5636737732e-6	-2.0954365226e-4	-1.4886356365e-6	3.3521757553e-3
WC7_1	(36)	2.3388948512e-6	-2.5405823909e-4	-6.8264841424e-7	2.6121348754e-3
WC0_1-WC10_1	(345)	4.4734717282e-6	-1.0524927421e-4	-1.4726908749e-6	3.5284312593e-3
Leg 2b:					
217_2-223_1	(141)	8.1232759178e-6	-4.1703838739e-4	-2.5464247645e-6	3.8110914876e-3
225_1-241_1	(318)	3.1775413340e-6	-2.7641170222e-4	-9.9523713450e-7	3.5148018313e-3
243_1	(25)	-5.5463302053e-6	-6.6347509786e-4	1.7271918177e-6	4.5585473787e-3
245_1-279_1	(660)	2.8847022900e-6	-3.3899298844e-4	-9.2783398683e-7	3.7937826601e-3
281_1-295_1	(271)	3.0443912104e-6	-1.5733314930e-4	-9.6264878196e-7	3.1990129886e-3
297_1-312_1	(184)	-9.3159288381e-6	-4.9418235747e-4	2.9682608422e-6	3.7280395807e-3
328_1	(33)	-1.5232103653e-6	-6.0491327964e-4	5.1646883670e-7	2.9111918302e-3
314_1-333_1	(315)	1.2037381315e-6	-2.1752035380e-4	-3.8674041433e-7	3.2959858445e-3
335_1-343_1	(130)	-2.0392893584e-7	-1.8946836643e-4	6.4501351565e-8	2.7992069617e-3
345_1-351_1	(134)	2.7238042547e-6	-2.3311048294e-5	-8.6986291755e-7	2.5838371732e-3
369_1-357_1	(136)	8.7957026329e-7	1.1423193230e-4	-2.8274598494e-7	1.8615333187e-3
355_1-351_2	(105)	3.6018768105e-6	-1.6276726098e-4	-1.1078997582e-6	2.8866166830e-3
Leg 3:					
370_1-TS1_1	(321)	3.6800065006e-6	-6.9694450581e-5	-1.1545267726e-6	2.4027579868e-3



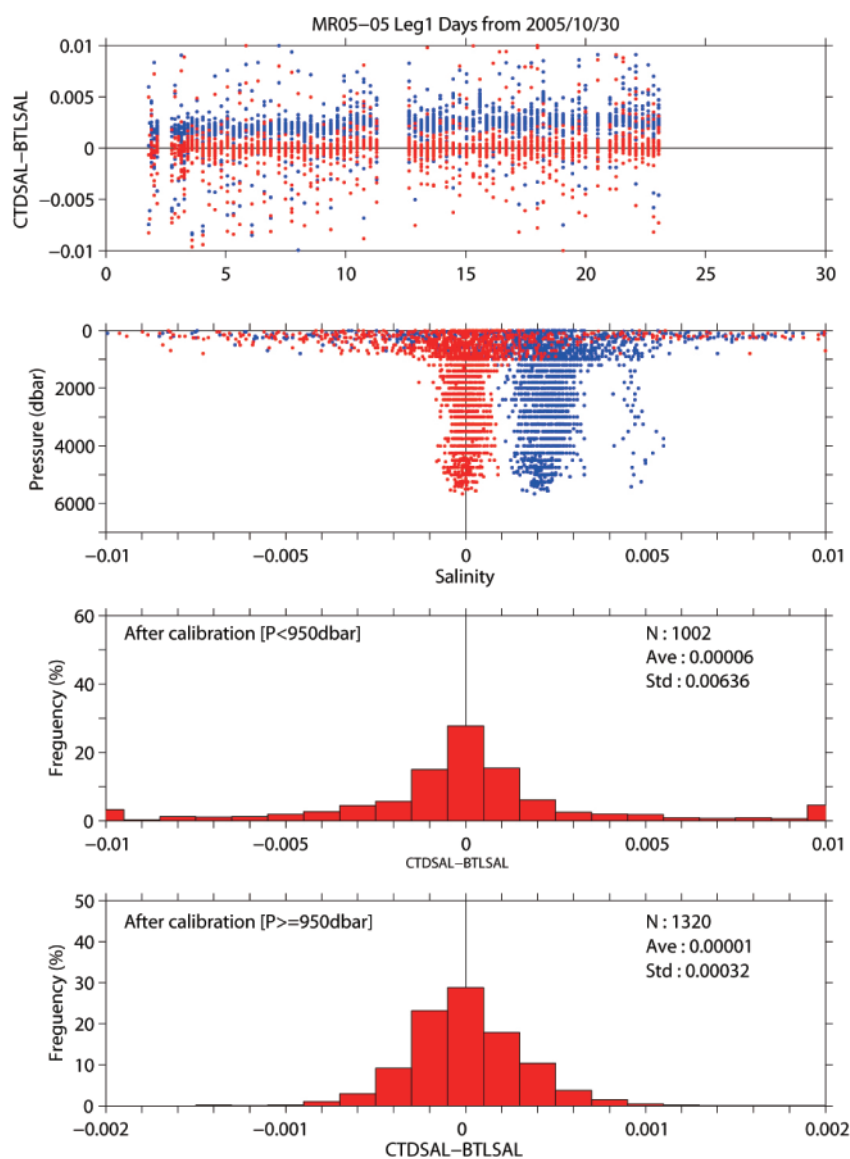


Figure 3.1.18. Difference between the CTD salinity and the bottle salinity for Leg.1. Blue and red dots indicate before and after the post-cruise calibration using the bottle salinity data, respectively. Top panel shows for  $P \geq 950$  dbar. Lower two panels show histogram of the difference after the calibration.

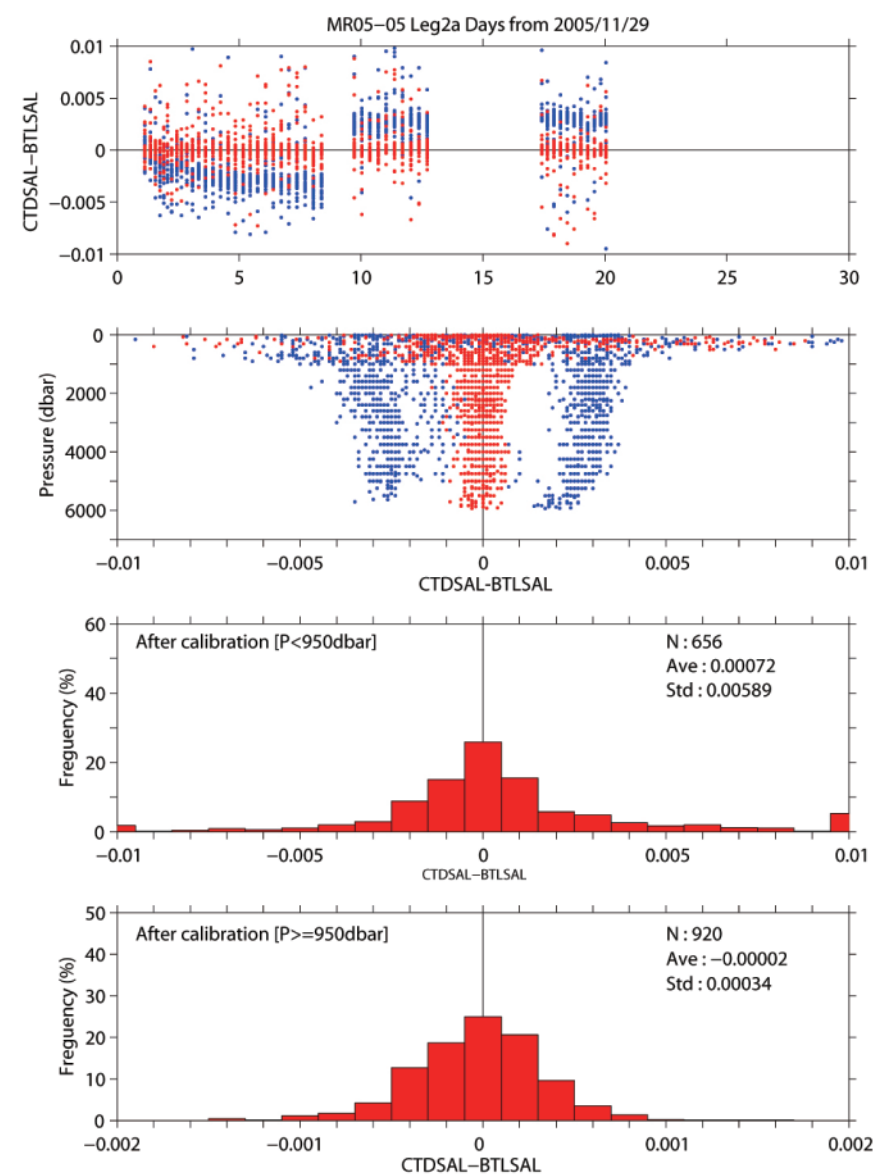


Figure 3.1.19. Same as Figure 3.1.18, but for Leg.2a.



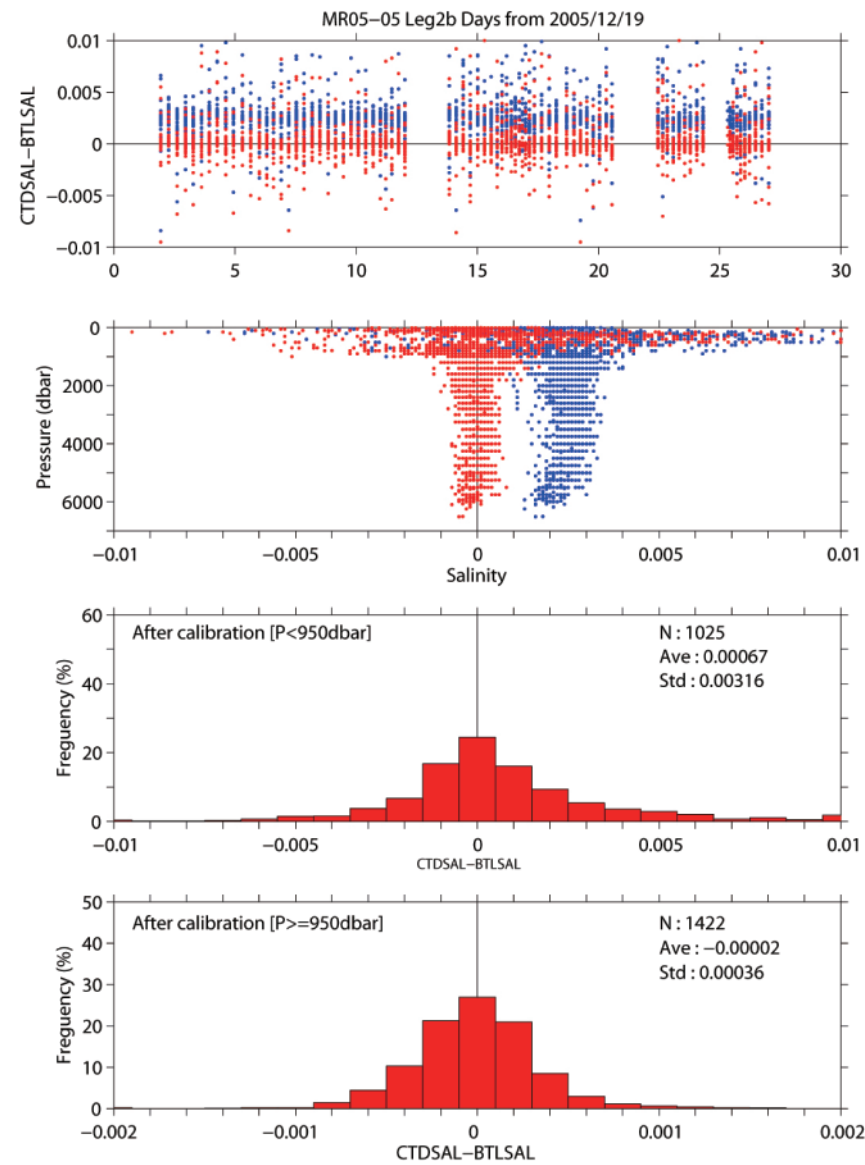


Figure 3.1.20. Same as Figure 3.1.18, but for Leg.2b.

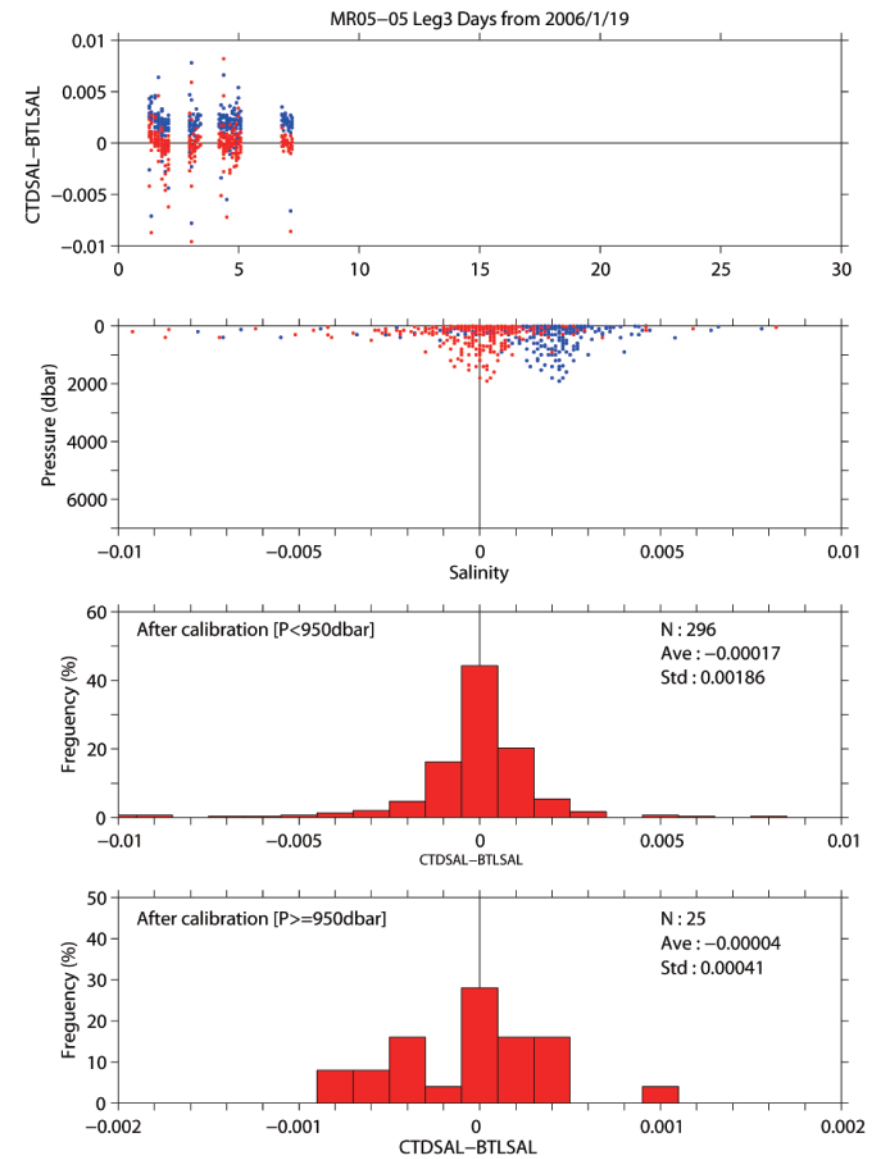


Figure 3.1.21. Same as Figure 3.1.18, but for Leg.3. Top panel shows for full pressure range.

#### (6.4) Oxygen (SBE 43)

The CTD oxygen is calibrated using the oxygen model as

$$\begin{aligned} & \text{Calibrated oxygen (ml/l)} \\ &= \{(\text{Soc} + \text{dSoc}) \times \{v + \text{offset} + \text{doffset}\} \times \exp\{(\text{TCor} + \text{dTCor}) \times t + (\text{PCor} + \text{dPCor}) \times p\}\} \\ & \times \text{Oxsat}(t, s) \end{aligned}$$

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. Soc, offset, TCor and PCor are the pre-cruise calibration coefficients 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

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

where Grad is vertical oxygen gradient in  $\mu\text{mol kg}^{-1} \text{ dbar}^{-1}$ , and  $P$  is pressure in dbar. Gr and PR are threshold of the oxygen gradient ( $0.3 \mu\text{mol kg}^{-1} \text{ dbar}^{-1}$ ) 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 down-cast CTD oxygen data. The down-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.

Finally oxygen data derived from following oxygen sensor are used for the data set in consideration for the data quality.

Leg.1: primary (S/N 0391)

Leg.2: primary (S/N 0391) for 146\_2 and 148\_1

secondary (S/N 0394) from 150\_1 to WC8\_1

primary (S/N 0390) from WC9\_1 to 351\_2

Leg.3: primary (S/N 0390)

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 for each station. Some stations, especially for 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 from Figure 3.1.22 to Figure 3.1.5.19. 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 950 dbar. Number of data used (Num) is also shown.

Leg	Pressure $\geq$ 950 dbar			Pressure $<$ 950 dbar		
	Num	Mean ( $\mu\text{mol/kg}$ )	Sdev ( $\mu\text{mol/kg}$ )	Num	Mean ( $\mu\text{mol/kg}$ )	Sdev ( $\mu\text{mol/kg}$ )
Leg.1	1325	−0.04	0.65	1006	0.05	3.58
Leg.2a	925	0.04	0.66	643	0.08	2.94
Leg.2b	1419	−0.03	0.91	1012	0.07	2.54
Leg.3	25	−0.10	0.33	295	−0.03	2.23

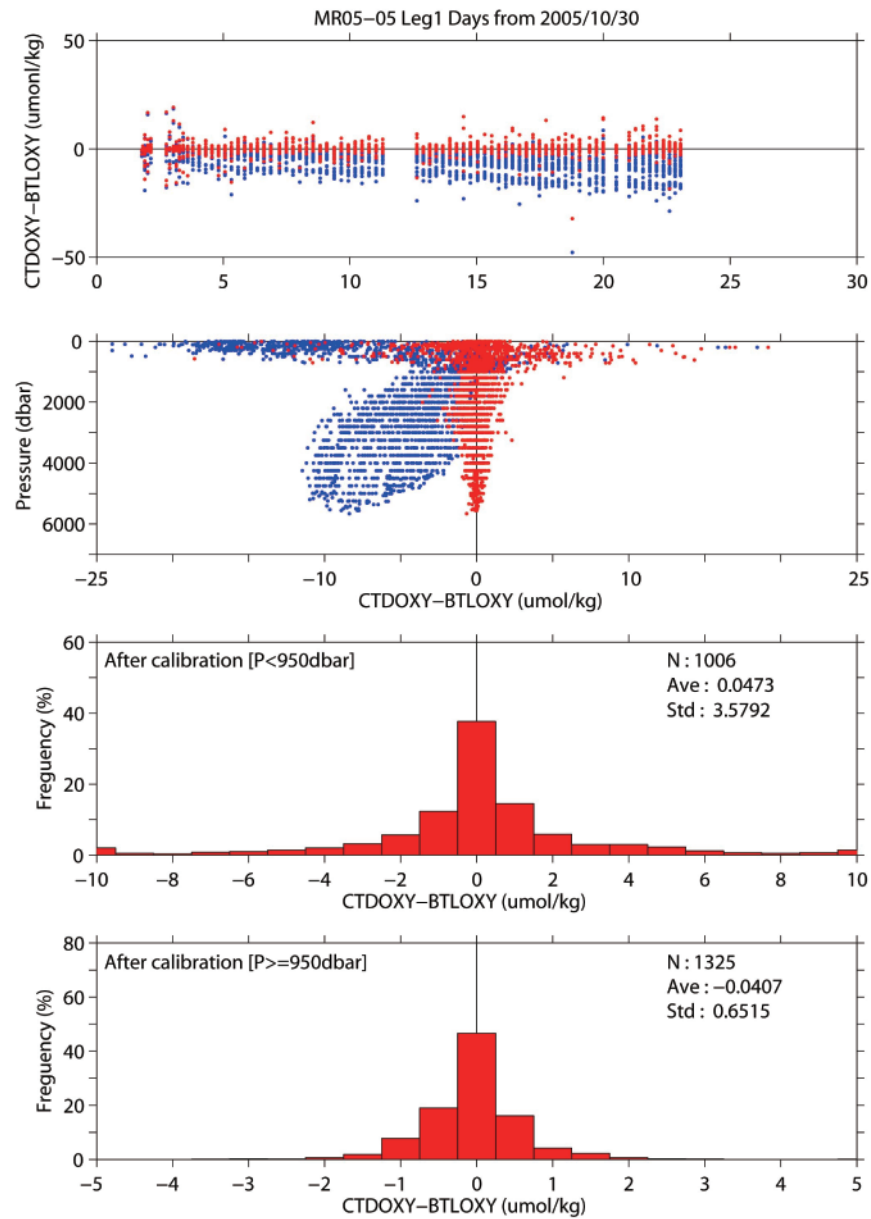


Figure 3.1.22. Difference between the CTD oxygen and the bottle oxygen for Leg.1. Blue and red dots indicate before and after the post-cruise calibration using the bottle oxygen data, respectively. Top panel shows for  $P \geq 950$  dbar. Lower two panels show histogram of the difference after the calibration.

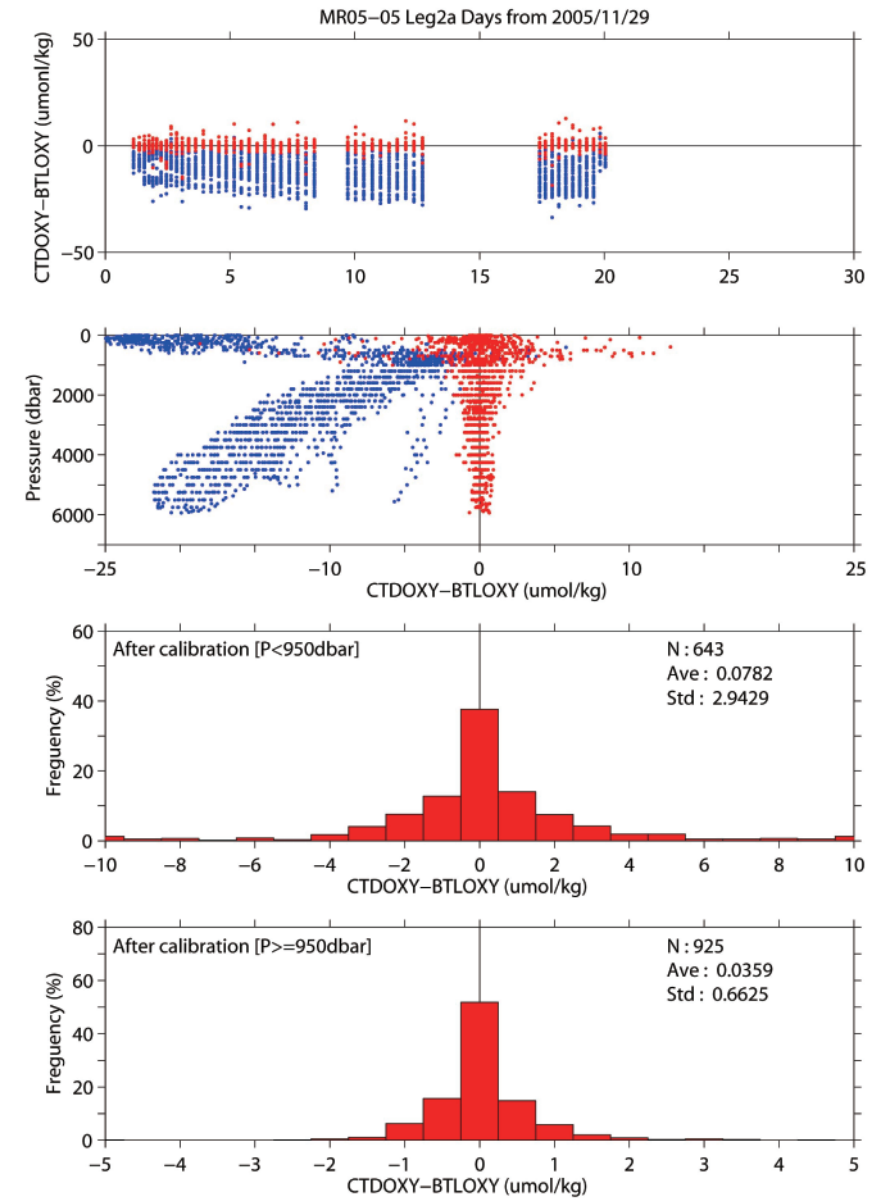


Figure 3.1.23. Same as Figure 3.1.22, but for Leg.2a.

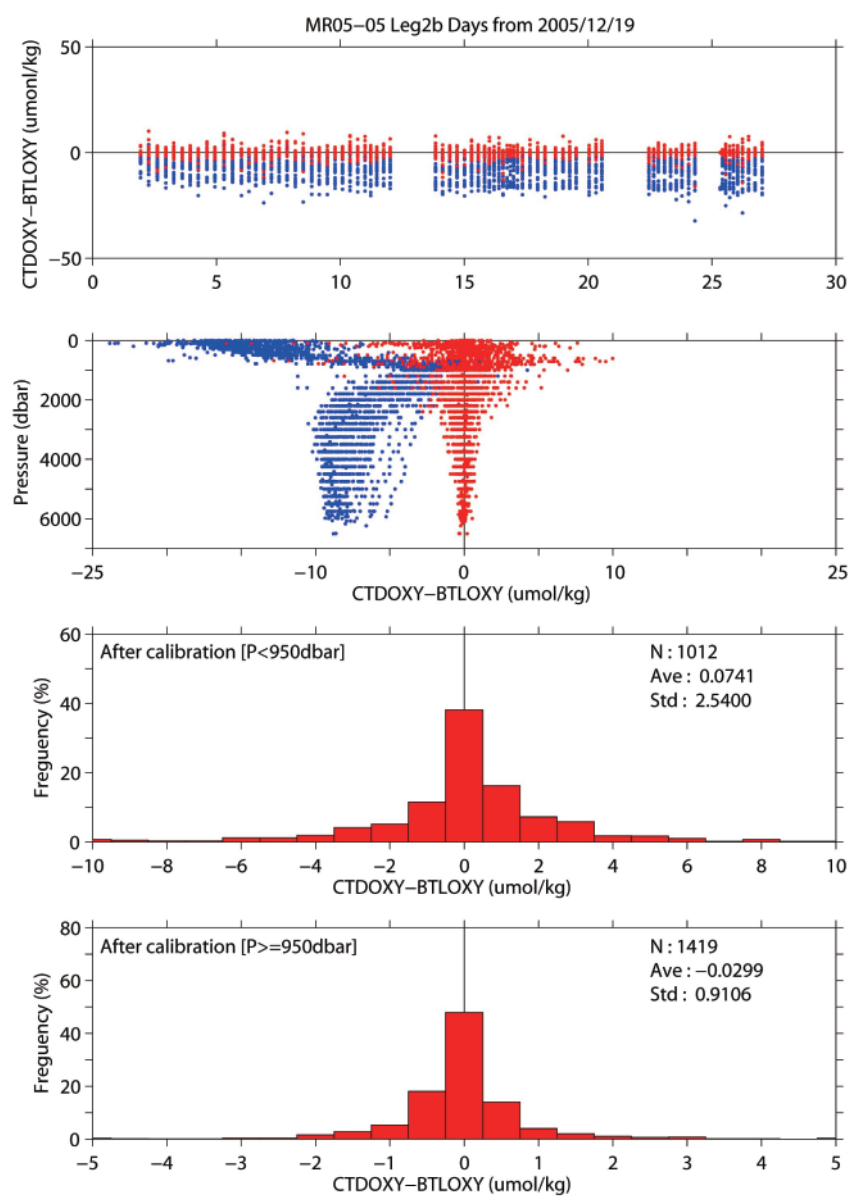


Figure 3.1.24. Same as Figure 3.1.22, but for Leg.2b.

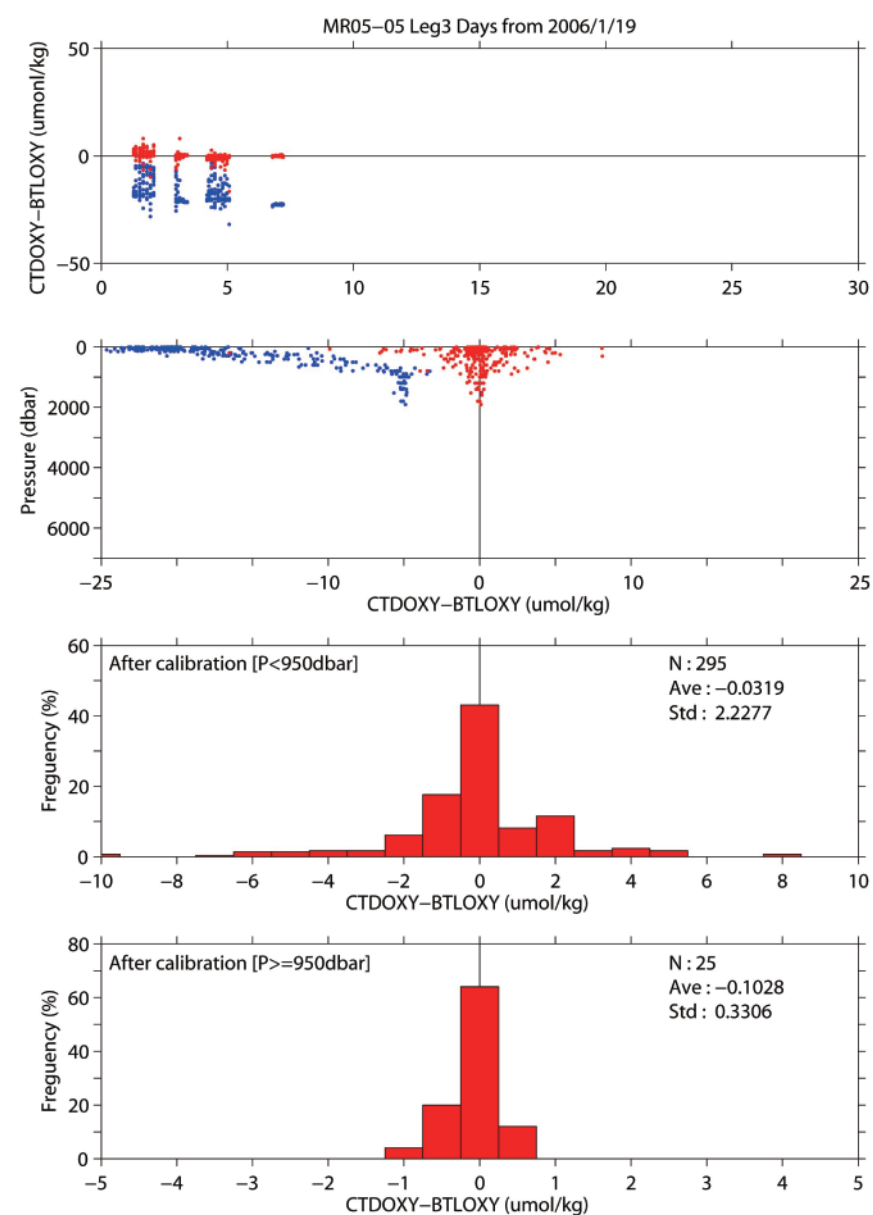


Figure 3.1.25. Same as Figure 3.1.22, but for Leg.3. Top panel shows for full pressure range.

Table 3.1.8. Calibration coefficients for the CTD oxygen. Number of data used (Num) is also shown.

Stations	(Num)	dSoc	dTCor	dPCor	doffset
Leg1:					
1_1-16_1	(136)	2.8411653261e-4	1.1157544479e-3	2.7913096082e-6	-1.2818258956e-3
18_1	(28)	4.2389172171e-3	6.5527402402e-4	-2.9529810502e-6	2.0664010586e-3
20_1	(27)	5.9072097463e-3	5.9612891352e-4	-3.1353113762e-8	-4.4323898789e-3
22_1	(28)	1.4921406865e-2	-6.5325808935e-4	-4.4711358817e-6	-7.6317176255e-3
24_1	(28)	1.9502900984e-2	-1.2552442883e-3	-7.9727251405e-6	-6.3244004082e-3
26_1	(28)	6.6080225258e-3	1.3348273077e-3	2.0108004441e-6	-6.9442801869e-3
28_1	(31)	2.3907902710e-3	1.3980340097e-3	2.0147433243e-6	-9.6097019240e-4
30_1	(30)	3.8642832072e-3	1.1394308990e-3	1.2625937853e-6	4.5201954492e-4
31_1,33_1	(58)	1.6612524428e-2	-2.9661153407e-4	-2.3286171688e-6	-1.1730133444e-2
34_1	(30)	1.1671470168e-2	6.0064381700e-4	-2.9265249203e-6	2.3737334951e-4
36_1	(30)	1.4742805723e-2	3.5139798210e-4	-3.8078312299e-6	-3.4660381192e-3
38_1	(29)	1.7756937413e-2	-2.8662753525e-4	-2.0696816014e-6	-1.0350116601e-2
40_1	(31)	1.3605434044e-2	2.6150325230e-4	-2.2558010990e-6	-2.7140487884e-3
42_1	(32)	1.3966404403e-2	3.5366741890e-4	4.1330466301e-7	-1.1009394537e-2
44_1	(30)	1.3481142712e-2	6.4280517854e-4	1.4713187709e-6	-1.21034442471e-2
46_1	(32)	4.4694794291e-3	1.4883454168e-3	2.3644833952e-6	1.5721113166e-3
48_1	(32)	1.1130737563e-2	4.8450882920e-4	-1.6510862104e-6	1.4630265016e-3
50_1	(31)	8.4763091288e-3	1.0883086434e-3	9.1712758329e-7	-5.5864118041e-4
51_1	(32)	1.4944199059e-2	2.4506097776e-4	-2.8283437473e-6	1.4945106511e-4
53_1	(32)	1.3910303466e-2	3.4172740013e-4	-1.3691189313e-6	-2.1255254705e-3
55_1	(32)	6.8014008640e-3	1.1531861650e-3	-2.0020125795e-6	1.1410714798e-2
56_1	(33)	1.2517626809e-2	8.1108907052e-4	3.7872190066e-7	-4.5176222009e-3
58_1	(33)	1.6319792743e-2	3.8367617062e-4	-9.3400247948e-7	-6.9070472175e-3
X17_1	(33)	1.7087246890e-2	2.5018727097e-4	-7.9854470212e-7	-7.8186395031e-3
62_1	(31)	1.8545518133e-2	8.4758872479e-5	-5.9882240024e-7	-1.0094825871e-2
64_1	(30)	2.1132916026e-2	-8.4524534367e-5	-1.8460928672e-7	-1.2676220107e-2
66_1	(32)	1.1354464188e-2	8.7840649983e-4	-5.3989278862e-8	1.5023212549e-3
67_1	(33)	1.5723980896e-2	5.5818159188e-4	4.8707807680e-7	-7.7589769151e-3
69_1	(34)	1.4101372227e-2	6.0844509702e-4	-1.1537381873e-6	1.0971585001e-3
71_1	(31)	1.7080867016e-2	3.8066764603e-4	-2.7093763518e-6	4.3505332228e-4
73_1	(33)	1.9235850708e-2	1.8928766136e-4	-7.9818206862e-7	-8.6271606204e-3
74_1	(34)	2.4033941887e-2	-5.3761784646e-4	-3.0412762966e-6	-8.5162384097e-3
76_1	(32)	1.9596836070e-2	1.6094611647e-4	-1.2564144578e-6	-6.0789348597e-3
77_1	(32)	2.5097320053e-2	-4.4172670651e-4	-4.2140610212e-6	-7.5211666372e-3
79_1	(31)	1.8944841633e-2	2.2474686044e-4	-9.4559433507e-7	-6.4465271345e-3
81_1	(33)	1.0772193579e-2	1.0211573501e-3	3.5729065791e-6	-6.4587950227e-3
83_1	(34)	9.2558005344e-3	1.3835520827e-3	-5.3320326791e-7	1.2209320453e-2
84_1	(35)	1.3741033402e-2	1.0442928833e-3	9.8949469261e-7	-5.0156732118e-4
86_1	(35)	3.4387864975e-2	-1.1317622023e-3	-4.2790121263e-6	-1.5226899965e-2
88_1	(34)	1.7501150773e-2	9.6128641172e-4	6.1250499331e-7	-5.5100209139e-3
90_1	(35)	2.4016156189e-2	1.1568638088e-4	-1.9997467064e-6	-4.6192746234e-3
92_1	(36)	2.2801594002e-2	1.4456793205e-4	-7.9206640035e-7	-6.7082483172e-3
94_1	(34)	2.1276396902e-2	4.0236259781e-4	1.6423691110e-7	-5.0113968514e-3
96_1	(34)	1.7586577193e-2	9.5413105512e-4	5.3115223152e-7	1.9169914386e-4
98_1	(34)	2.3281206887e-2	3.6280206888e-4	-7.5538796215e-7	-4.6148055082e-3
100_1	(35)	1.9607360482e-2	8.1086209461e-4	1.0114462418e-6	-4.0591264022e-3
X16_1	(34)	2.4020184788e-2	2.4077815879e-4	-1.6624202265e-6	6.1994742333e-4
104_1	(34)	1.9301698049e-2	9.9716273877e-4	1.1292321372e-6	4.4486781074e-4
106_1	(33)	3.7074454439e-2	-7.0415113930e-4	-2.2511412520e-6	-1.7511769248e-2
108_1	(32)	3.1381730648e-2	-2.6022098343e-4	-3.3289196375e-6	-4.4506707340e-3
110_1	(31)	3.8740835013e-2	-6.7171847217e-4	-1.7338020698e-6	-2.0947323198e-2
112_1	(31)	2.9851343344e-2	1.3176980732e-4	2.3429241248e-6	-1.7478888940e-2
114_1	(31)	2.5236481375e-2	4.2515474628e-4	-2.8443737934e-7	-3.3852598730e-3
116_1	(29)	2.8182488833e-2	4.1209091055e-4	-1.1734305445e-6	-6.1207321567e-3
118_1	(33)	3.0966553786e-2	-1.8365152495e-4	-4.6695530525e-6	8.7521737225e-4
120_1	(21)	3.6079776583e-2	-4.4129565615e-4	-1.3587444647e-6	-1.5705749328e-2
122_1	(33)	2.4804654687e-2	5.5864425693e-4	-1.5070773420e-7	-1.8434122298e-3
124_1	(31)	3.0218657690e-2	-6.6105450515e-5	-3.8921825260e-6	1.5124071439e-3
126_1	(33)	1.9627777203e-2	1.0747655389e-3	-1.1455309895e-7	8.8614333372e-3
128_1	(33)	3.1751674249e-2	2.6634525634e-4	1.5207706274e-6	-1.8176807649e-2
130_1,132_1	(59)	2.5135138070e-2	4.6264106890e-4	-1.3233400851e-6	3.2419344331e-4
134_1	(33)	3.6848282221e-2	-6.9629658189e-4	-5.0952357091e-6	-4.3672708315e-3
136_1	(29)	2.0365730703e-2	1.2968294124e-3	1.1796185243e-6	6.2962100557e-3
138_1	(32)	2.5925077770e-2	4.0679558181e-4	-2.2823266346e-6	4.8879748734e-3
140_1	(32)	3.1645148674e-2	1.7573498412e-4	-5.4619663287e-7	-8.6145005433e-3
142_1	(33)	3.8874259815e-2	-5.9068769855e-4	-5.1241960385e-6	-6.1837227227e-3
144_1	(33)	3.6412320564e-2	-3.4000701047e-4	-3.9279452812e-6	-4.9847908143e-3
146_1	(33)	2.2070939078e-2	9.4495827134e-4	-1.4157172415e-6	1.1513223600e-2
Leg 2a:					
146_2	(25)	3.4314628587e-2	-9.3087500529e-4	-5.1774381094e-6	-1.5863348468e-3
148_1	(22)	3.2787911160e-2	-1.8951084925e-3	-3.3737557039e-6	-2.9190789136e-3
150_1-153_1	(64)	2.5939275226e-2	5.8341281881e-4	2.4271007242e-6	4.8524650166e-4
154_1-157_1	(58)	2.8993026397e-2	4.1358222390e-4	4.6262134422e-7	-3.8917174759e-3
Leg 2b:					
217_2	(34)	1.3859683202e-2	8.7865744863e-4	2.1575656745e-6	-1.2261575788e-2
219_1	(36)	1.3074798332e-2	8.0970975722e-4	1.5084212045e-6	-5.4274390121e-3
221_1	(36)	2.3184695947e-2	-5.9719556684e-5	9.6208770650e-8	-1.4418283950e-2
223_1	(36)	2.4106582742e-2	-4.4805055833e-5	-2.2718214043e-6	-5.7829858128e-3
225_1	(36)	2.1266719121e-2	2.7658412180e-4	-2.3675746915e-6	-1.2249768897e-4
227_1	(36)	3.1227181589e-2	-6.0691044587e-4	-2.6756225964e-6	-1.1247862730e-2
229_1-231_1	(70)	2.4632852068e-2	2.0144398223e-4	-2.8192616115e-7	-9.3271646280e-3
233_1	(36)	2.5698457819e-2	4.4026259921e-5	-2.1031541932e-6	-4.2830342568e-3
X13_1	(36)	2.3670576933e-2	3.2769060768e-4	6.9031178357e-7	-1.0698361026e-2
237_1	(36)	1.8880629571e-2	2.3204631835e-4	-3.2461564835e-6	1.1038409710e-2
239_1	(36)	1.8186891316e-2	6.0112097624e-4	-1.4100636286e-6	5.1951553512e-3
241_1	(34)	1.9306988158e-2	7.1495272321e-4	-6.1293787337e-7	2.1737786791e-3
243_1	(25)	2.7452283092e-2	-1.1306367268e-5	-2.0174062086e-6	-7.2829365708e-3
245_1	(33)	2.8607681486e-2	-1.5693228943e-4	-1.6035097568e-6	-9.9751279706e-3
247_1	(35)	2.3406903498e-2	2.2634888584e-4	-1.2428838346e-6	-2.8028712675e-3
249_1	(30)	2.4379344567e-2	1.7624386839e-4	-6.0417727965e-7	-4.7733548727e-3
251_1	(36)	3.5037057890e-2	-4.4864770263e-4	1.0101907361e-6	-2.4883695670e-2
253_1	(36)	2.4737209429e-2	6.5386249491e-5	-3.6891334773e-6	3.8676579842e-3
255_1	(36)	2.5204948867e-2	2.1148221671e-4	-1.6627604637e-6	-2.8852759960e-3
257_1	(35)	2.8147353031e-2	2.4518110139e-4	7.2327710002e-7	-1.4255861726e-2
259_1	(35)	2.5991896341e-2	2.6037276039e-4	-1.0456864393e-6	-5.5426444388e-3
261_1	(32)	2.2628837230e-2	7.5988075820e-4	-4.1655542103e-7	-2.7188889288e-3
263_1	(34)	1.9820650775e-2	5.3416060580e-4	-3.7524950179e-6	1.2251561256e-2
265_1	(35)	2.7649119002e-2	9.6611670814e-5	-3.3745623692e-6	1.8094666686e-4
267_1	(36)	2.5889555278e-2	2.3810926839e-4	-1.4902513772e-6	-3.1345608292e-3
269_1	(35)	2.1537855427e-2	5.7684341816e-4	-5.3150780999e-7	1.2250063549e-3
271_1	(34)	3.4828346976e-2	-5.6474346490e-4	-5.330785639e-6	-3.1062764225e-3
273_1	(33)	2.6291484155e-2	5.7527391628e-4	8.1295727807e-7	-9.2704985927e-3
X10_1	(36)	3.5553664861e-2	-3.0585410534e-5	-2.8516682561e-7	-1.8883963792e-2
275_1	(36)	2.9512580596e-2	2.7084784103e-4	-2.7468918385e-7	-1.3176498089e-2
277_1	(36)	3.2869124611e-2	-1.5631215638e-4	-3.0053837187e-6	-5.8748364848e-3
279_1	(36)	2.8614311784e-2	3.2363073786e-4	-1.2661986058e-6	-6.1863453418e-3
281_1	(36)	2.8390077921e-2	2.0887458832e-4	-3.4246497985e-6	1.0895303144e-4
283_1	(36)	3.3715138680e-2	-2.5486483162e-5	-1.3087010034e-6	-1.1668278730e-2
285_1	(35)	4.4223880210e-2	-9.6428011720e-4	-2.6560586416e-6	-2.1032712908e-2



```

287_1      (35)  2.6985592235e-2  3.9370057732e-4  -2.1485456457e-6  -1.2372384187e-4
289_1      (33)  3.1648346109e-2  1.0209081769e-4  -2.9449735995e-6  -5.1844643144e-3
291_1      (32)  2.1071386983e-2  9.6682327066e-4  8.6254878867e-7  4.0345079093e-4
293_1      (36)  2.8015344500e-2  4.3547755860e-4  -2.0634560709e-7  -8.0107976193e-3
295_1      (31)  2.1827713280e-2  8.3899007041e-4  -3.9382326997e-6  1.3688594235e-2
297_1-305_1 (105) 2.7773001546e-2  5.3712710561e-4  1.5328461785e-6  -6.4399478014e-3
306_1-312_1 (82)  2.8855216555e-2  4.0256345493e-4  -1.5020063602e-6  -2.9411348970e-3
314_1      (32)  2.8381615612e-2  5.1649089138e-4  -1.0137338402e-6  -4.7646204413e-3
316_1      (33)  2.7050171946e-2  1.1394910474e-3  1.8692788304e-6  -1.2415273138e-2
318_1      (33)  3.2008771738e-2  7.7384707595e-5  4.6814092805e-6  2.0662254975e-4
X09_1      (29)  3.7365751198e-2  -3.6171414553e-4  -2.5538770211e-6  -1.1621187407e-2
322_1      (28)  3.1994634299e-2  3.4390392314e-4  -4.5403354019e-7  -1.0745791088e-2
324_1      (34)  3.3294243001e-2  4.4030381498e-5  -3.3439134505e-6  -5.4361571929e-3
326_1      (32)  3.5898295823e-2  -1.4000676176e-4  -3.2516563294e-6  -9.0008117504e-3
328_1      (33)  3.5788937582e-2  -2.3402600597e-5  -2.6823510232e-6  -9.3382310020e-3
329_1      (32)  4.2977005787e-2  -7.4179814417e-4  -3.9768295833e-6  -1.6326476855e-2
331_1      (31)  4.6514831613e-2  -1.0118166177e-3  -2.1244413320e-6  -2.4699312293e-2
333_1      (29)  3.1668688954e-2  3.1526164252e-4  -2.1655040828e-6  -5.4802508657e-3
335_1-339_1 (72)  2.8426491060e-2  7.0598619161e-4  -1.0388347171e-8  -3.9515056753e-3
341_1      (31)  2.9990461926e-2  5.1622503234e-4  -7.3588786235e-7  -6.3253881314e-3
343_1      (29)  3.0898134526e-2  4.8361719865e-4  -3.4659105792e-7  -7.8545493062e-3
345_1      (30)  4.0806999958e-2  -5.2565812016e-4  -5.8795417378e-6  -8.8450313289e-3
347_1      (33)  3.6806813506e-2  -4.5030400280e-4  -2.9333374736e-6  -1.0612626829e-2
349_1      (36)  3.2713863609e-2  6.1559624613e-4  -3.2628342407e-6  -3.8115855611e-3
351_1      (36)  4.3360572024e-2  -6.0097470278e-4  -3.6958898061e-6  -1.5120605017e-2
369_1-359_1 (105) 3.0037218808e-2  4.5359665354e-4  -1.2846640466e-6  -4.3799960663e-3
357_1      (32)  3.4594812288e-2  -4.3505352461e-4  -3.3943737245e-6  -5.7232208372e-3
355_1      (36)  3.4943624686e-2  5.0034863107e-5  -1.2519124546e-6  -1.0984065650e-2
353_1, 351_2 (69)  3.7404467500e-2  1.0345046957e-5  -1.3470606487e-6  -1.2981773806e-2

Leg 3:
370_1-TS1_1 (320)  3.8115006786e-2  4.4123814357e-4  2.1389358081e-7  -1.1949938654e-2
-----

```

### (6.5) Oxygen optode

The optode oxygen is calibrated by the Stern-Volmer equation, according to a method by Uchida et al. (submitted manuscript):

$$O_2 (\mu\text{mol/l}) = (\tau_0 / \tau - 1) / K_{sv}$$

where  $\tau$  is decay time,  $\tau_0$  is decay time in the absence of oxygen and  $K_{sv}$  is Stern-Volmer constant. The  $\tau_0$  and the  $K_{sv}$  are assumed to be functions of temperature as follows.

$$K_{sv} = C_{11} + C_{12} \times t + C_{13} \times t^2$$

$$\tau_0 = C_{21} + C_{22} \times t$$

$$\tau = C_{31} + C_{32} \times P_b$$

where  $t$  is CTD temperature ( $^{\circ}\text{C}$ ) and  $P_b$  is raw phase measurement (deg). The calibration coefficients ( $C_{11}$ ,  $C_{12}$ ,  $C_{13}$ ,  $C_{21}$ ,  $C_{22}$ ,  $C_{31}$  and  $C_{32}$ ) are determined for post-cruise calibration. The best fit sets of coefficients are determined by minimizing the sum of absolute deviation from the bottle oxygen data. The FORTRAN subroutine

DMINF1 of the Scientific Subroutine Library II (Fujitsu Ltd., Kanagawa, Japan) is used to determine the sets.

For compensation of the pressure response of the sensing foil, the oxygen concentration is multiplied by the following factor  $1 + 0.032 \times P_r / 1000$ , where  $P_r$  is pressure in dbar.

The calibration is performed for the up-cast phase data created by the software module ROSSUM after the post-cruise calibration for the CTD temperature and salinity.

The calibration coefficients are determined for Leg.1 and Leg.2 to 3. The results of the post-cruise calibration for the optode oxygen are summarized in Table 3.1.9 and shown in from [Figure 3.1.26](#) and Figure 3.1.5.21. And the calibration coefficients and number of the data used for the calibration are listed in [Table 3.1.10](#).

Table 3.1.9. Difference between the optode oxygen and the bottle oxygen after the post-cruise calibration. Mean and standard deviation (Sdev) are calculated for the data below and above 950 dbar. Number of data (Num) used is also shown.

Leg	Pressure $\geq$ 950 dbar			Pressure < 950 dbar		
	Num	Mean ( $\mu\text{mol/kg}$ )	Sdev ( $\mu\text{mol/kg}$ )	Num	Mean ( $\mu\text{mol/kg}$ )	Sdev ( $\mu\text{mol/kg}$ )
Leg.1	1319	-0.11	0.38	1013	0.04	0.86
Leg.2/3	2365	-0.01	0.35	2004	-0.01	0.90



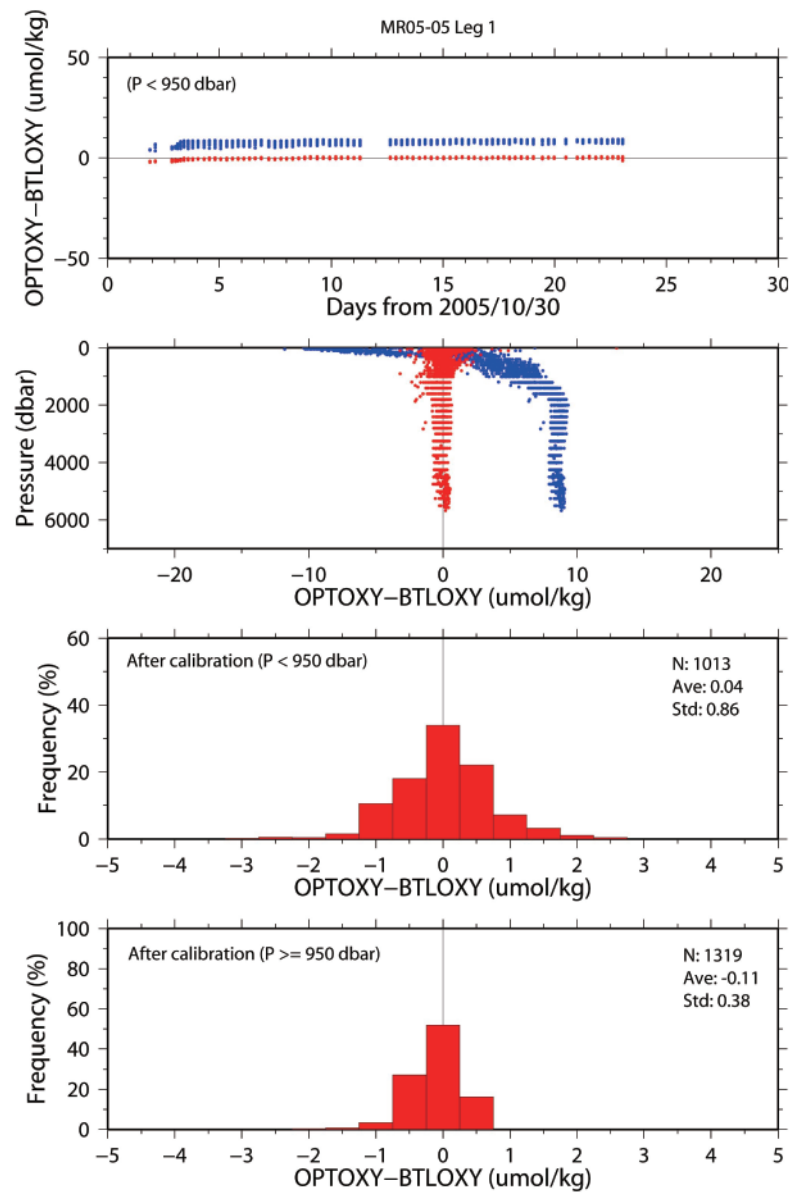


Figure 3.1.26. Difference between the optode oxygen and the bottle oxygen for Leg.1. Blue and red dots indicate before and after the post-cruise calibration using the bottle oxygen data, respectively. Top panel shows for  $P \geq 950$  dbar. Lower two panels show histogram of the difference after the calibration.

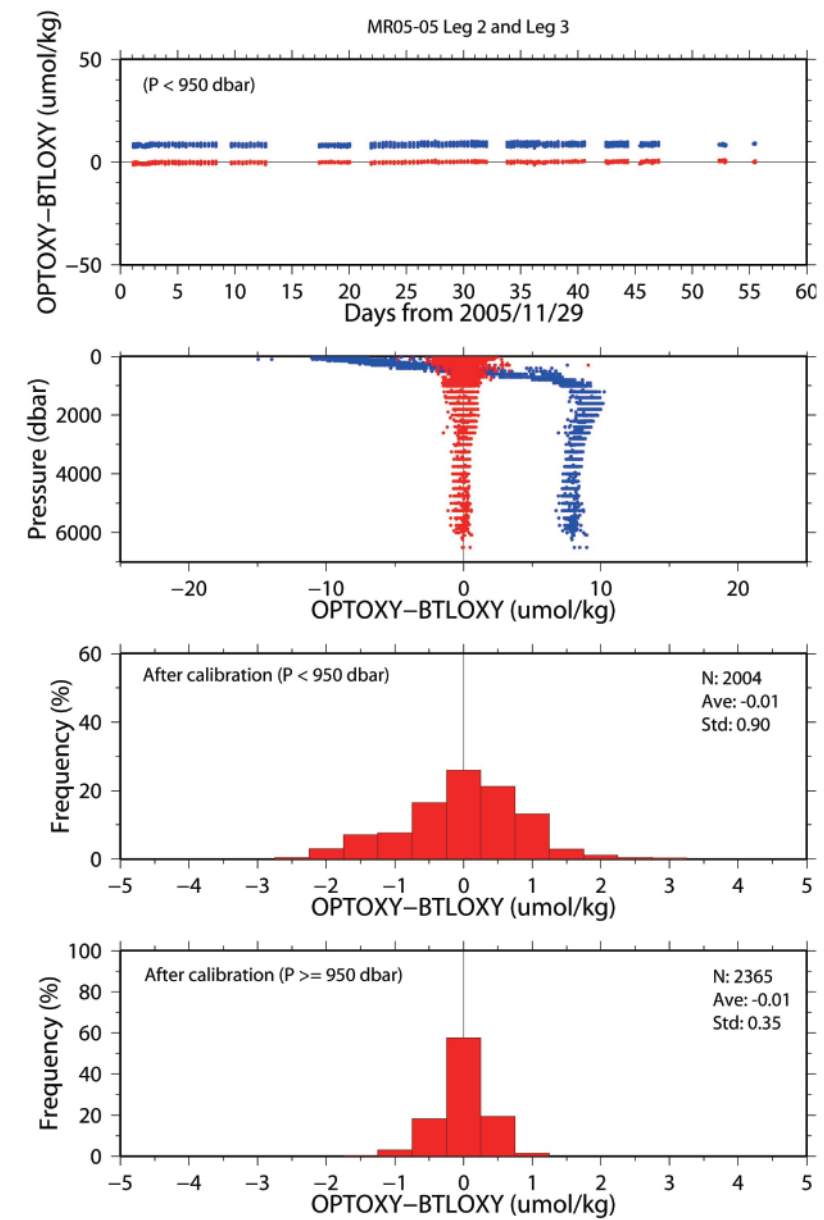


Figure 3.1.27. Same as Figure 3.1.26, but for Leg.2 and Leg.3.

Table 3.1.10. Calibration coefficients for the optode oxygen. Number of data used (Num) for the calibration and mean absolute deviation (ADEV) between the optode oxygen and the bottle oxygen are also shown.

Leg.1	Num	= 2332,	ADEV	= 0.41 $\mu$ mol/kg
	C <sub>11</sub>	= 3.05627e-3		
	C <sub>12</sub>	= 1.40559e-4		
	C <sub>13</sub>	= 2.14264e-6		
	C <sub>21</sub>	= 61.1209		
	C <sub>22</sub>	= 9.86981e-2		
	C <sub>31</sub>	= -8.48263		
	C <sub>32</sub>	= 1.10631		
Leg.2/3	Num	= 4369,	ADEV	= 0.45 $\mu$ mol/kg
	C <sub>11</sub>	= 2.85451e-3		
	C <sub>12</sub>	= 1.30281e-4		
	C <sub>13</sub>	= 2.00579e-6		
	C <sub>21</sub>	= 61.6282		
	C <sub>22</sub>	= 0.101157		
	C <sub>31</sub>	= -7.42425		
	C <sub>32</sub>	= 1.11110		

References

Uchida, H., K. Ohyama, S. Ozawa, and M. Fukasawa (2007): In-situ calibration of the Sea-Bird 9plus CTD thermometer,*J. Atmos. Oceanic Technol.* (in press)

Uchida, H., T. Kawano, I. Kaneko, and M. Fukasawa: In-situ calibration of optode-based oxygen sensors, submitted to *J. Atmos. Oceanic Technol.* (*accepted*)

3.2 Bottle Salinity

September 7, 2007

(1) Personnel

<i>Takeshi Kawano</i>	<i>(JAMSTEC)</i>
<i>Fujio Kobayashi</i>	<i>(MWJ)</i>
<i>Naoko Takahashi</i>	<i>(MWJ)</i>
<i>Tatsuya Tanaka</i>	<i>(MWJ)</i>

(2) Objectives

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

(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 more than 12 hours in the same laboratory as where the salinity measurement was made.

(3.2) Instruments and Method

The salinity analysis was carried out on Guildline Autosol salinometer model 8400B (S/N 62556), which was modified by attaching 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 degrees C. The measurement

system was almost same as Aoyama et al (2003). The salinometer was operated in an air-conditioned laboratory of the ship at a bath temperature of 24 degrees C.

An ambient temperature varied from approximately 19 degrees C to 24 degrees C, while a bath temperature was very stable and varied within +/- 0.002 degrees C on rare occasion. A measure of a double conductivity ratio of a sample is taken as a median of thirty-one reading. 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 seventh filling of the cell for Leg.1 and the eighth and ninth filling for Leg.2 and Leg.3. In the case where the difference between the double conductivity ratio of this two fillings is smaller than 0.00002, the average value of the two double conductivity ratios is used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981). If the difference is greater than or equal to 0.00003, we measure another additional filling of the cell. In the case where the double conductivity ratio of the additional filling does not satisfy the criteria above, we measure two other fillings of the cell and the median of the double conductivity ratios of five fillings are used to calculate the bottle salinity.

The measurement was conducted for about 10 to 18 hours per day (typically from 3:00 to 17:00) and the cell was cleaned with ethanol or soap or both after the measurement of the day. We measured more than 8,000 samples in total.

(4) Preliminary Result

(4.1) Stand Seawater

Leg.1

Standardization control was set to 501 and all measurements were done by this setting. STNBY was 5517 ±0001 and ZERO was 0.00001 ±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 117 bottles of P145 during routine measurement. There were 5 bad bottles which conductivities are extremely high. Data of these 5 bottles are not taken into consideration hereafter.

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

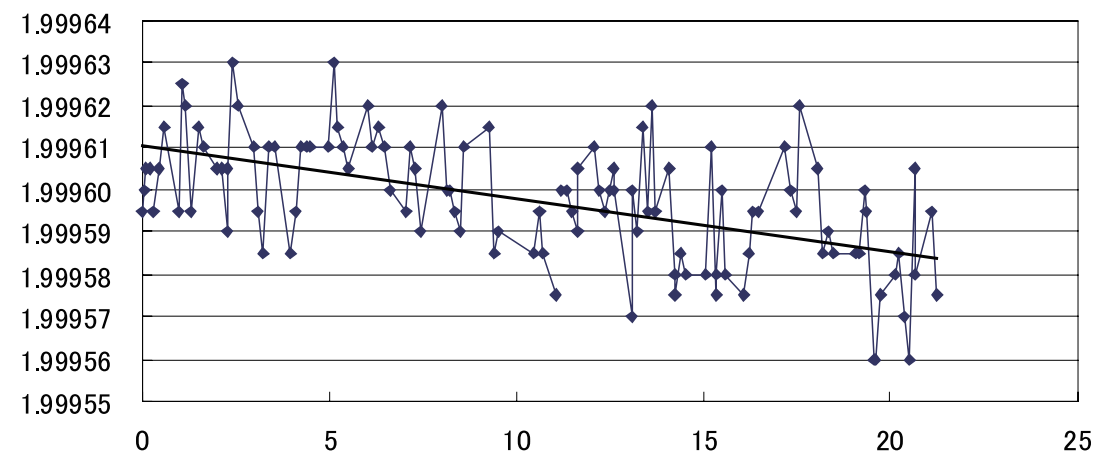


Figure 3.2.1. History of Double conductivity ratio of P145 during Leg.1. X and Y axes represent time (Julian day) and double conductivity ratio, respectively.

Drifts were calculated by fitting data from P145 to the equation obtained by the least square method (solid lines). Correction for the double conductivity ratio of the sample was made to compensate for the drift (Figure 3.2.2). After correction, the average of double conductivity ratio became 1.99961 and the standard deviation was 0.00012, which is equivalent to 0.0002 in salinity. We added 0.00001 to the corrected measured double conductivity ratio.

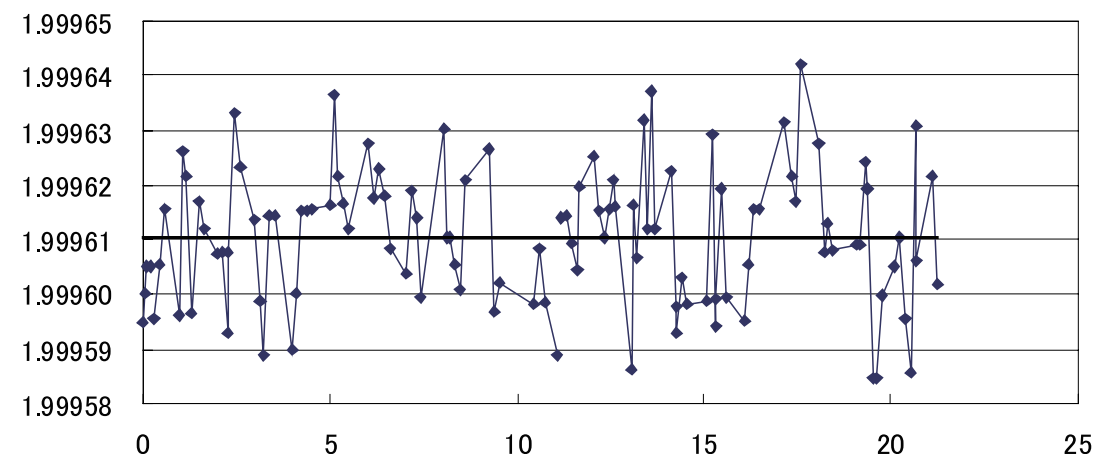


Figure 3.2.2. History of Double conductivity ratio of P145 during Leg.1. X and Y axes represent time (Julian day) and double conductivity ratio, respectively. (after correction)

## Leg.2

Standardization control was set to 474 before WIPE (Wake Islands passage Flux Experiment). STNBY was  $5498 \pm 0001$  and ZERO was  $0.00001 \pm 0.00001$ . We removed the conductivity cell and washed it thoroughly with soap. Then, standardization control was changed to 479. STNBY became  $5501 \pm 0001$  and ZERO was  $0.00001 \pm 0.00001$ .

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 54 bottles of P145 during routine measurement before WIPE and 109 bottles after WIPE. There were 2 bad bottles whose conductivities were extremely high. Data of these 2 bottles are not taken into consideration hereafter.

Figure 3.2.3 shows the history of double conductivity ratio of the Standard Seawater batch P145. Drifts were calculated by fitting data from P145 to the equation obtained by the least square method (solid lines). Correction for the double conductivity ratio of the sample was made to compensate for the drift (Figure 3.2.4). After

correction, the average of double conductivity ratio became 1.99962 and the standard deviation was 0.00012 before WIPE and 0.00011 after WIPE, those are equivalent to 0.0002 in salinity. We added 0.000021 before WIPE and 0.000012 after WIPE to the corrected measured double conductivity ratio.

### Leg.3

Standardization control was set to 484 and all the measurements were done by this setting. STNBY was  $5505 \pm 0001$  and ZERO was  $0.00001 \pm 0.00001$ . 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 25 bottles of P145 during routine measurement.

Figure 3.2.5 shows the history of double conductivity ratio of the Standard Seawater batch P145. Drifts were calculated by fitting data from P145 to the equation obtained by the least square method (solid lines). Correction for the double conductivity ratio of the sample was made to compensate for the drift (Figure 3.2.6). After correction, the average of double conductivity ratio became 1.99962 and the standard deviation was 0.00014, which is equivalent to 0.0003 in salinity. We added 0.000004 to the corrected measured double conductivity ratio.

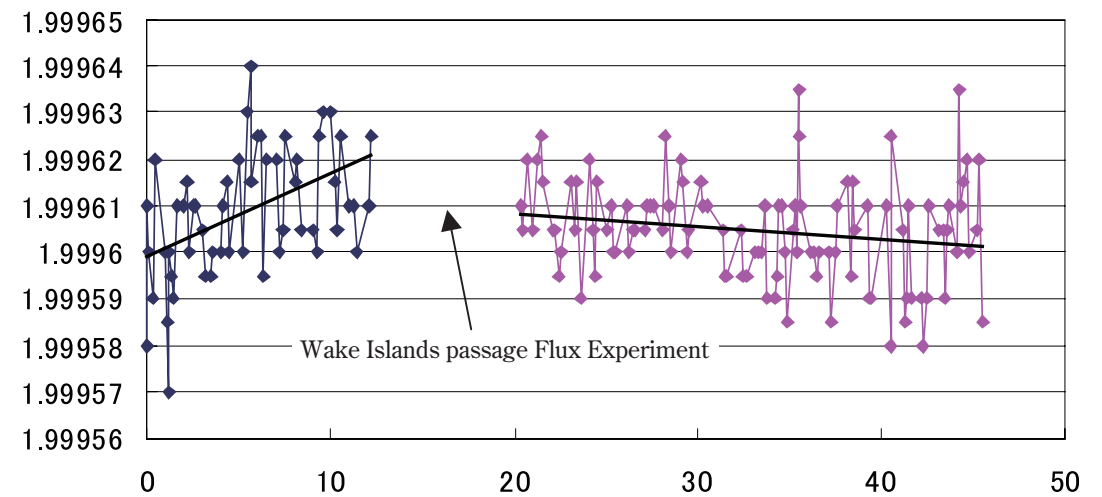


Figure 3.2.3. History of Double conductivity ratio of P145 during Leg.2. X and Y axes represent time (Julian day) and double conductivity ratio, respectively.

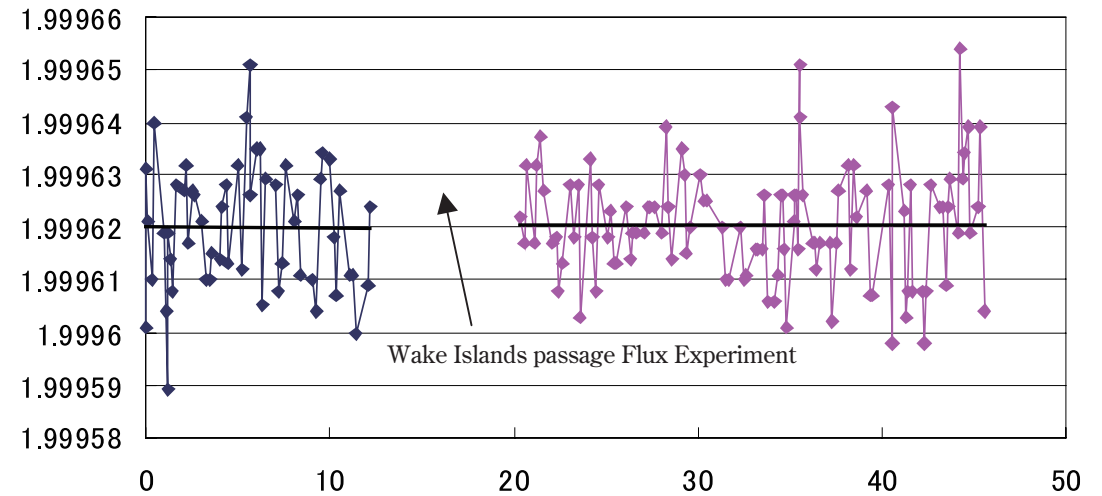


Figure 3.2.4. History of Double conductivity ratio of P145 during Leg.2. X and Y axes represent time (Julian day) and double conductivity ratio, respectively. (after correction)

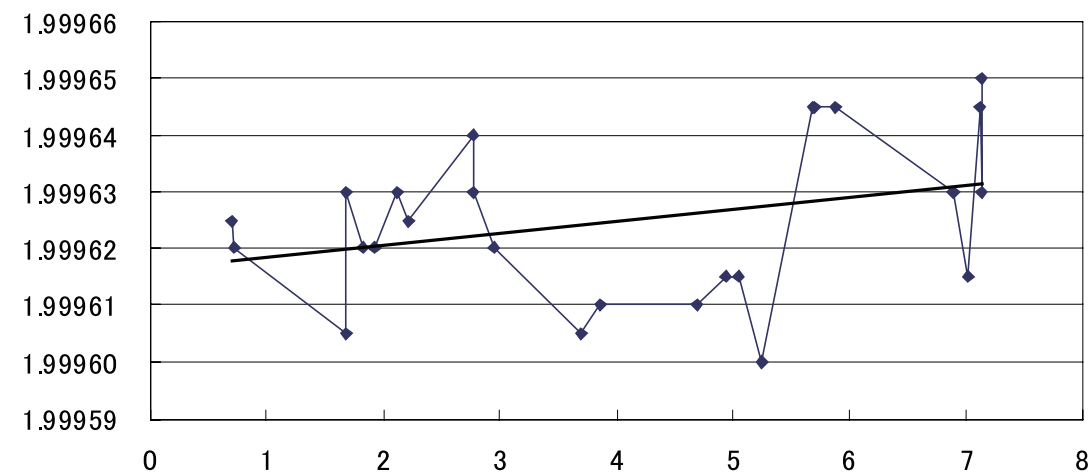


Figure 3.2.5. History of Double conductivity ratio of P145 during Leg.3. X and Y axes represent time (Julian day) and double conductivity ratio, respectively.

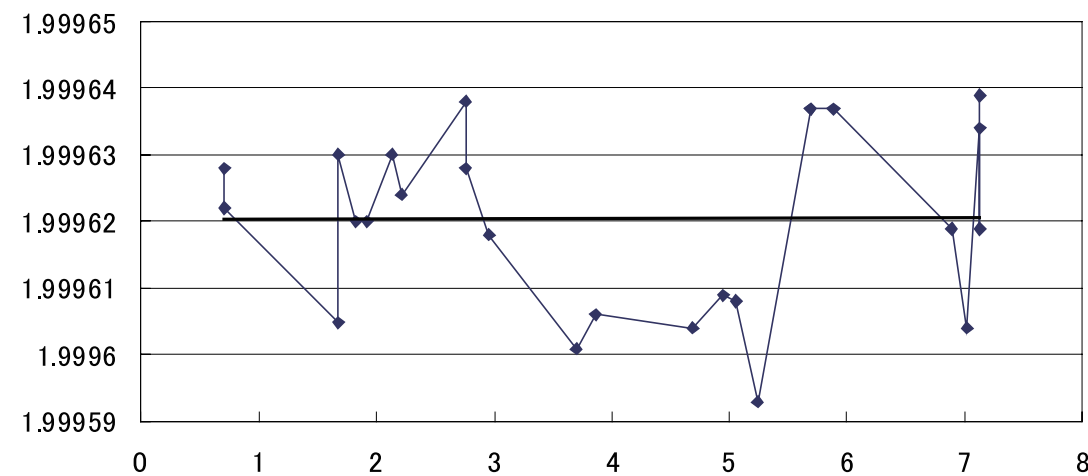


Figure 3.2.6. History of Double conductivity ratio of P145 during Leg.3. X and Y axes represent time (Julian day) and double conductivity ratio, respectively. (after correction)

#### (4.2) Sub-Standard Seawater

We also used sub-standard seawater which was a deep-sea water filtered by pore size of 0.45 micrometer and was 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.

#### (4.3) Replicate and Duplicate Samples

##### Leg.1

We took 435 pairs of replicate and 27 pairs of duplicate samples. Figure 3.2.7 (a) and (b) shows the histogram of the absolute difference between each pair the replicate samples and that of the duplicate samples, respectively. There were 2 bad measurements in the replicate samples. Particularly, one of the pair was extremely high (more than 0.01in salinity). Excluding these bad measurements, the standard deviation of the absolute difference in 433 pairs of the replicate samples was 0.00017 in salinity and that in 27 pairs of the duplicate samples was 0.00032 in salinity.

##### Leg.2

We took 668 pairs of replicate and 20 pairs of duplicate samples. Figure 3.2.8 (a) and (b) shows the histogram of the absolute difference between each pair of the replicate samples and that of the duplicate samples, respectively. There were 3 questionable measurements in the replicate samples. Excluding these questionable measurements, the standard deviation of the absolute difference in 665 pairs of the replicate samples was 0.00017 in salinity and that in 20 pairs of the duplicate samples was 0.00025 in salinity.

##### Leg.3

We took 48 pairs of replicate and 3 pairs of duplicate samples. Figure 3.2.9 shows the histogram of the absolute difference between each pair of the replicate samples. There was one bad (miss-trip) sample for



duplicates. The standard deviation of the absolute difference of 48 pairs of the replicate samples was 0.00011 in salinity. The absolute differences in salinity between 2 duplicate samples were 0.0002 and 0.0007.

The results of replicate samples were averaged and flagged as 6 in the seafile.

### Reference

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

UNESCO : Tenth report of the Joint Panel on Oceanographic Tables and Standards. *UNESCO Tech. Papers in Mar. Sci.*, 36, 25 pp., 198

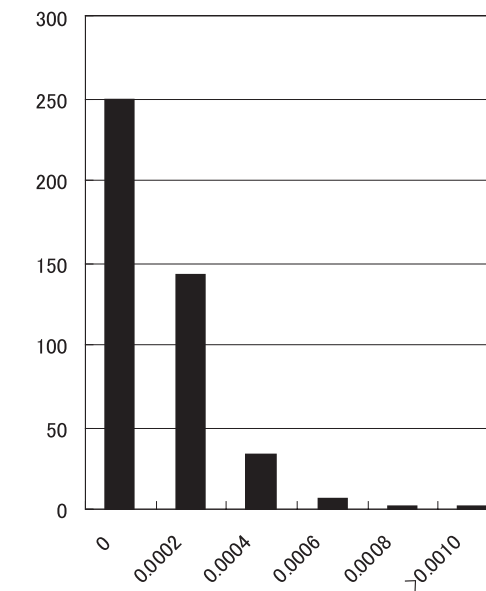


Figure 3.2.7 (a). The histogram of the absolute difference between replicate samples in Leg.1.

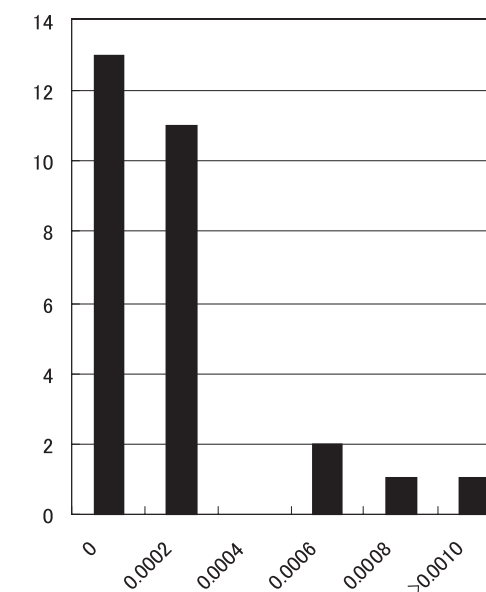


Figure 3.2.7 (b). The histogram of the absolute samples between duplicate samples in Leg.1.

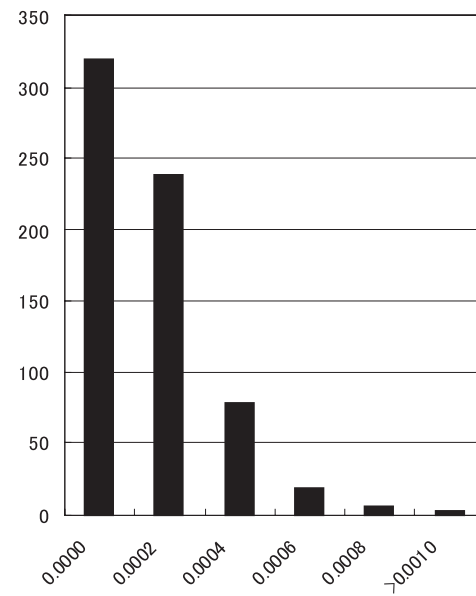


Figure 3.2.8 (a). The histogram of the absolute difference between replicate samples in Leg.2

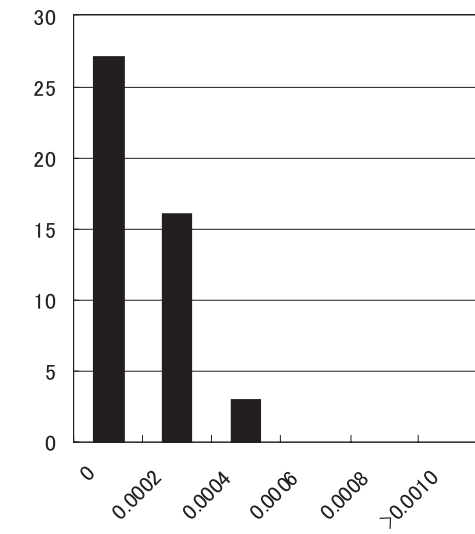


Figure 3.2.9. The histogram of the absolute difference between replicate samples in Leg.3.

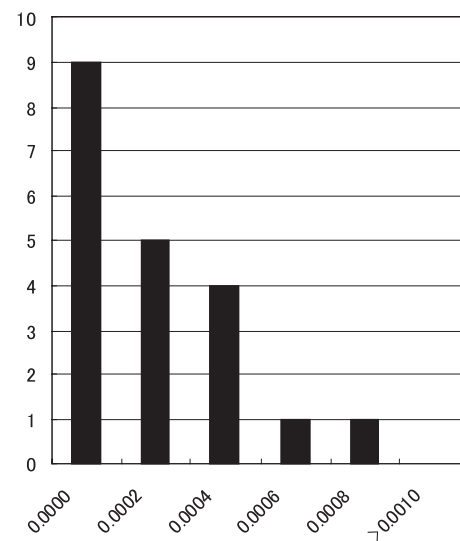


Figure 3.2.8 (b). The histogram of the absolute samples between duplicate samples in Leg.2.

3.3 Bottle Oxygen

May 1, 2007

(1) Personnel

<i>Yuichiro Kumamoto</i>	<i>(JAMSTEC)</i>
<i>Ikuo Kaneko</i>	<i>(JAMSTEC)</i>
<i>Takayoshi Seike</i>	<i>(MWJ)</i>
<i>Keisuke Wataki</i>	<i>(MWJ)</i>
<i>Kimiko Nishijima</i>	<i>(MWJ)</i>
<i>Takuhei Shiozaki</i>	<i>(MWJ)</i>

(2) Objectives

Dissolved oxygen is one of significant tracers for ocean circulation study. Recent studies on the subarctic 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 MR05-05 Leg.1 (from 31-Oct-05 to 24-Nov-05), Leg.2 (from 27-Nov-05 to 17-Jan-06), and Leg.3 (from 20-Jan-06 to 30-Jan-06), we measured dissolved oxygen concentration from surface to bottom layers at all the hydrocast stations along around 24°N. These stations were the reoccupation of the WHP-P03 stations in 1985. Our purpose is to evaluate change of dissolved oxygen in the subtropical North Pacific between 1985 and 2005/2006.

(3) Reagents

- Pickling Reagent I: Manganous chloride solution (3 M)
- Pickling Reagent II: Sodium hydroxide (8 M) / sodium iodide solution (4 M)
- Sulfuric acid solution (5 M)
- Sodium thiosulfate (0.025 M)

- Potassium iodate (0.001667 M)
- CSK standard of potassium iodate: Lot ASE8281, Wako Pure Chemical Industries Ltd., 0.0100 N

(4) Instruments

- Burette for sodium thiosulfate;
  - APB-510 manufactured by Kyoto Electronic Co. Ltd. / 10 cm<sup>3</sup> of titration vessel
- Burette for potassium iodate;
  - APB-410 manufactured by Kyoto Electronic Co. Ltd. / 20 cm<sup>3</sup> of titration vessel
- Detector; Automatic photometric titrator manufactured, Kimoto Electronic Co. Ltd.

(5) Seawater sampling

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

(6) Sample measurement

At least two hours after the re-shaking, the pickled samples were measured on board. A magnetic stirrer bar and 1 cm<sup>3</sup> sulfuric acid solution were added into the sample flask and stirring began. Samples were titrated by sodium thiosulfate solution whose molarity was determined by potassium iodate solution ([section 3.3.7](#)).

Temperature of sodium thiosulfate during titration was recorded by a thermometer. We measured dissolved oxygen concentration using two sets of the titration apparatus, named DOT-1 and DOT-3. Dissolved oxygen concentration ( $\mu\text{mol kg}^{-1}$ ) was calculated by the 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. 0.025 M) was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130°C. 1.7835 g potassium iodate accurately weighed out was dissolved in deionized water and diluted to final volume of 5 dm<sup>3</sup> in a calibrated volumetric flask (0.001667 M). 10 cm<sup>3</sup> of the standard potassium iodate solution was added to a flask using a volume-calibrated dispenser. Then, 90 cm<sup>3</sup> of deionized water, 1 cm<sup>3</sup> of sulfuric acid solution, and 0.5 cm<sup>3</sup> of pickling reagent solution II and I were added into the flask in order. Amount of titrated volume of sodium thiosulfate (usually 5 times measurements average) gave the molarity of the sodium thiosulfate titrant. Table 3.3.1 shows the result of the standardization during this cruise. Error (C.V.) of the standardization was  $0.02 \pm 0.01\%$ , c.a.  $0.05 \mu\text{mol kg}^{-1}$ .

### (8) Determination of the blank

The oxygen in the pickling reagents I (0.5 cm<sup>3</sup>) and II (0.5 cm<sup>3</sup>) was assumed to be  $3.8 \times 10^{-8}$  mol (Murray *et al.*, 1968). The blank from the presence of redox species apart from oxygen in the reagents (the pickling reagents I, II, and the sulfuric acid solution) was determined as follows. 1 cm<sup>3</sup> and 2 cm<sup>3</sup> of the standard potassium iodate solution were added to two flasks, respectively. Then 100 cm<sup>3</sup> of deionized water, 1 cm<sup>3</sup> of sulfuric acid solution, and 0.5 cm<sup>3</sup> of pickling reagent solution II and I each were added into the two flasks in order. The blank was determined by difference between the two times of the first (1 cm<sup>3</sup> of KIO<sub>3</sub>) titrated volume of the sodium thiosulfate and the second (2 cm<sup>3</sup> of KIO<sub>3</sub>) one. The results of 3 times blank determinations were averaged (Table 3.3.1). The averaged blank of DOT-1 and DOT-3 during the whole legs were -0.009 and -0.005 cm<sup>3</sup>, respectively.

Table 3.3.1. Results of the standardization and the blank determinations during MR05-05.

Date (UTC)	KIO <sub>3</sub>		DOT-1 (cm <sup>3</sup> )			DOT-3 (cm <sup>3</sup> )			Samples (Stations)
	#	bottle	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	E.P.	blank	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	E.P.	blank	
2005/10/30	1	20050829-25	20051028-3	3.960	-0.010	20051028-4	3.961	-0.005	1-16
2005/11/02		20050829-26	20051028-3	3.961	-0.010	20051028-4	3.959	-0.004	18-26
2005/11/03		20050829-27	20051031-1	3.960	-0.011	20051031-2	3.961	-0.005	28-34
2005/11/04		20050829-28	20051031-1	3.960	-0.009	20051031-2	3.959	0.000	36-44
2005/11/06		20050829-29	20051031-3	3.960	-0.011	20051031-4	3.960	-0.008	46-53
2005/11/07		20050829-30	20051031-3	3.958	-0.008	20051031-4	3.958	-0.004	55-58,X17,62
2005/11/09		20050829-31	20051105-1	3.960	-0.012	20051105-2	3.960	-0.006	64-73
2005/11/11		20050829-37	20051105-3	3.960	-0.011	20051105-4	3.963	-0.004	74-81
2005/11/12		20050829-38	20051105-3	3.960	-0.010	20051105-4	3.960	-0.008	83-90
2005/11/14		20050829-39	20051112-1	3.962	-0.009	20051112-2	3.964	-0.005	92-100
2005/11/15	2	20050829-40	20051112-1	3.960	-0.010	20051112-2	3.963	-0.004	X16,104-110
2005/11/17		20050829-41	20051112-3	3.963	-0.010	20051112-4	3.963	-0.006	112-120
2005/11/18		20050829-42	20051112-3	3.963	-0.009	20051112-4	3.964	-0.004	122-130
2005/11/20		20050829-43	20051116-1	3.957	-0.010	20051116-2	3.958	-0.007	132-140
2005/11/21		20050829-44	20051116-1	3.957	-0.009	20051116-2	3.959	-0.005	142-146
2005/11/30		20050830-49	20051128-1	3.960	-0.011	20051128-2	3.961	-0.005	146(2)-153
2005/12/01	3	20050829-50	20051128-1	3.959	-0.010	20051128-2	3.958	-0.005	154-163
2005/12/02		20050829-51	20051128-3	3.961	-0.009	20051128-4	3.961	-0.006	165-173
2005/12/03		20050829-52	20051128-3	3.959	-0.010	20051128-4	3.959	-0.005	175-183
2005/12/05		20050829-53	20051203-1	3.960	-0.010	20051203-2	3.960	-0.008	185-193
2005/12/07		20050829-54	20051203-1	3.960	-0.009	20051203-2	3.960	-0.006	195,197,X14, 201,203
2005/12/09		20050829-55	20051203-3	3.959	-0.010	20051203-4	3.960	-0.005	205-213
2005/12/11		20050829-56	20051203-3	3.961	-0.010	20051203-4	3.960	-0.004	215,217

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

Table 3.3.1. (continued)

Date (UTC)	KIO <sub>3</sub>		DOT-1 (cm <sup>3</sup> )			DOT-3 (cm <sup>3</sup> )			Samples (Stations)
	#	bottle	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	E.P.	blank	Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	E.P.	blank	
2005/12/16	4	20050829-61	20051211-1	3.963	-0.009	20051211-2	3.966	-0.005	WC0-WC4
2005/12/17		20050829-62	20051211-1	3.962	-0.008	20051211-2	3.960	-0.007	WC5-WC10
2005/12/20		20050829-63	20051211-3	3.961	-0.010	20051211-4	3.962	-0.003	217(2)-225
2005/12/22		20050829-64	20051211-3	3.964	-0.010	20051211-4	3.964	-0.006	227-233,X13
2005/12/24		20050829-65	20051223-1	3.964	-0.008	20051223-2	3.963	-0.005	237-245
2005/12/25		20050829-66	20051223-1	3.964	-0.009	20051223-2	3.963	-0.004	247-253
2005/12/27		20050829-67	20051223-3	3.965	-0.011	20051223-4	3.965	-0.005	255-263
2005/12/28		20050829-68	20051223-3	3.963	-0.007	20051223-4	3.964	-0.003	265-273
2005/12/30	5	20050829-73	20051229-1	3.964	-0.010	20051229-2	3.964	-0.006	X10,275-279
2006/01/01		20050829-74	20051229-1	3.964	-0.007	20051229-2	3.965	-0.005	281-289
2006/01/03		20050829-75	20051229-3	3.965	-0.010	20051229-4	3.963	-0.007	291-299
2006/01/04		20050829-76	20051229-3	3.966	-0.010	20051229-4	3.966	-0.006	301-312
2006/01/05		20050829-77	20060105-1	3.961	-0.007	20060105-2	3.961	-0.004	314-318,X09,322
2006/01/07		20050829-78	20060105-1	3.961	-0.009	20060105-2	3.961	-0.002	324-333
2006/01/10		20050829-79	20060105-3	3.959	-0.008	20060105-4	3.960	-0.005	335-343
2006/01/11		20050829-80	20060105-3	3.962	-0.009	20060105-4	3.962	-0.005	345-351
2006/01/12	6	20050829-85	20060112-1	3.965	-0.011	20060112-2	3.966	-0.005	369-355
2006/01/14		20050829-86	20060112-1	3.963	-0.009	20060112-2	3.966	-0.004	353,351(2)
2006/01/20	6	20050829-88	20060112-3	3.968	-0.009	20060112-4	3.970	-0.004	370-389
2006/01/23		20050829-89	20060112-3	3.967	-0.006	20060112-4	3.967	-0.006	390-408
2006/01/25		20050829-90	20060120-1	3.964	-0.008	20060120-2	3.969	-0.001	TS7- TS1

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

### (9) Reagent blank

The blank determined in section 3.3.8, pure water blank ( $V_{\text{blk, dw}}$ ) can be represented by equation 1,

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

where

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

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

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

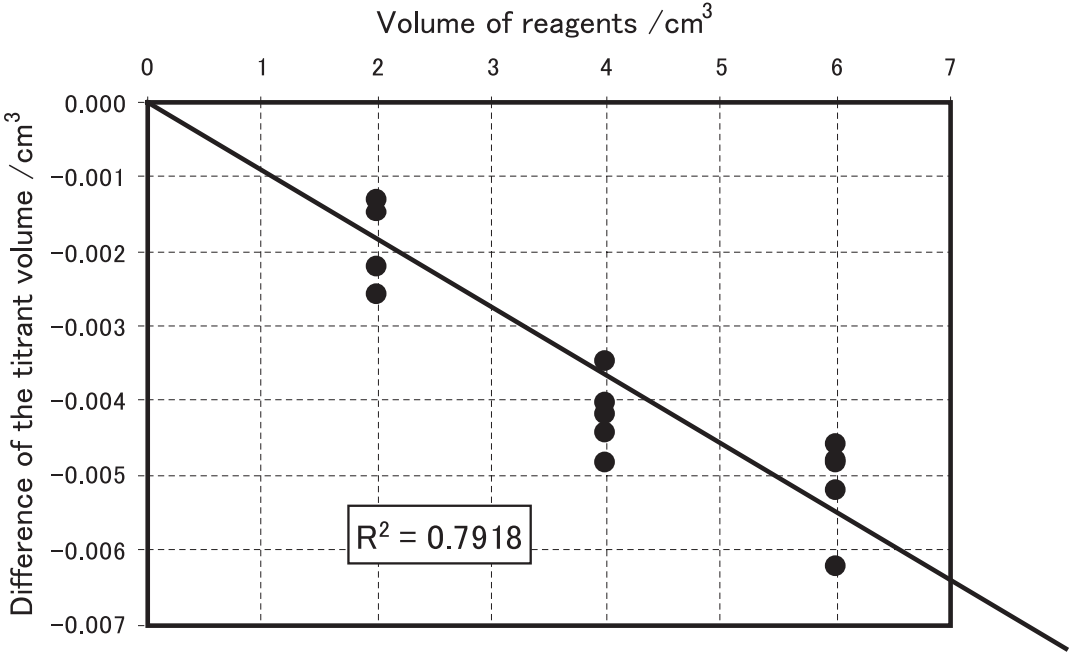


Figure 3.3.1. Blank (cm<sup>3</sup>) due to redox species apart from oxygen in the reagents.

The relation between difference of the titrant (Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>) volume and the volume of the reagents added

( $V_{\text{reagent}}$ ) is expressed by equation 2,

$$\text{Difference of the titrant volume} = -0.0009 V_{\text{reagent}} \quad (2)$$

There was no significant difference between the results of DOT-1 and DOT-3.  $V_{\text{blk, reg}}$  was estimated to be about  $-0.002 \text{ cm}^3$ , suggesting that about  $0.01 \mu\text{mol}$  of reductants was contained in every  $2 \text{ cm}^3$  of the reagents added. In other words, the difference of the pure water blank ( $V_{\text{blk, dw}}$ ) between DOT-1 and DOT-3, determined in the section 3.3.8, was due to the difference of the end-point blank ( $V_{\text{blk, ep}}$ ) between the two titration apparatus ( $-0.007$  and  $-0.003 \text{ cm}^3$  for DOT-1 and DOT-3, respectively).

#### (10) Sample blank

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

$$V_{\text{blk, sw}} = V_{\text{blk, spl}} + V_{\text{blk, dw}} \quad (3)$$

If the pure water blank ( $V_{\text{blk, dw}}$ ) that is determined in section 3.3.8 is identical both in pure water and in seawater, the difference between the seawater blank and the pure water one gives the sample blank ( $V_{\text{blk, spl}}$ ).

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

We measured vertical profiles of the sample blank at four stations (Table 3.3.2) using DOT-1 system. The sample blank ranged from  $0.4$  to  $0.8 \mu\text{mol kg}^{-1}$  and its vertical and horizontal variations are small. Our results agree to reported values ranged from  $0.4$  to  $0.8 \mu\text{mol kg}^{-1}$  (Culberson *et al.*, 1991) and our previous results obtained in the western North Pacific, reoccupation of WHP-P10 in 2005. Ignorant of the sample blank will cause systematic errors in the oxygen calculations, but these errors are expected to be the same to all investigators and not to affect the comparison of results from different investigators (Culberson, 1994).

Table 3.3.2. Results of the sample blank determinations during MR05-05.

Station: P03-006 32.5°N / 118.0°W		Station: P03-031 29.1°N / 123.9°W		Station: P03-136 25.5°N / 164.3°W		Station: P03-215 24.2°N / 172.8°E	
CTD Pres. dbar	Sample blank $\mu\text{mol kg}^{-1}$	CTD Pres. dbar	Sample blank $\mu\text{mol kg}^{-1}$	CTD Pres. dbar	Sample blank $\mu\text{mol kg}^{-1}$	CTD Pres. dbar	Sample blank $\mu\text{mol kg}^{-1}$
9	0.48	10	0.45	9	0.38	10	0.39
149	0.71	51	0.50	48	0.38	50	0.40
249	0.68	101	0.56	100	0.51	100	0.48
400	0.63	152	0.56	150	0.57	150	0.53
600	0.74	501	0.63	200	0.64	200	0.63
800	0.70	1001	0.70	600	0.59	502	0.76
1003	0.76	2003	0.66	1201	0.52	1003	0.66
1403	0.69	3001	0.68	2201	0.60	2000	0.69
1801	0.70	4249	0.73	3251	0.60	3500	0.71
1867	0.78	4459	0.72	3751	0.62	5002	0.72

#### (11) Replicate sample measurement

Replicate samples were taken from every CTD cast. Total amount of the replicate sample pairs in good measurement (flag=2) was 837. The standard deviation of the replicate measurement was  $0.08 \mu\text{mol kg}^{-1}$  and there was no significant difference between DOT-1 and DOT-3 measurements. The standard deviation was calculated by a procedure (SOP23) in DOE (1994). The difference between the replicate sample pairs did not depend on sampling pressure (Figure 3.3.2) and measurement date (Figure 3.3.3). The standard deviations during



Leg.1, Leg.2, and Leg.3 were  $0.083$  ( $n=299$ ) and  $0.083$  ( $n=493$ ), and  $0.085 \mu\text{mol kg}^{-1}$  ( $n=45$ ), respectively. In the hydrographic data sheet, a mean of replicate sample pairs is shown with the flag 2.

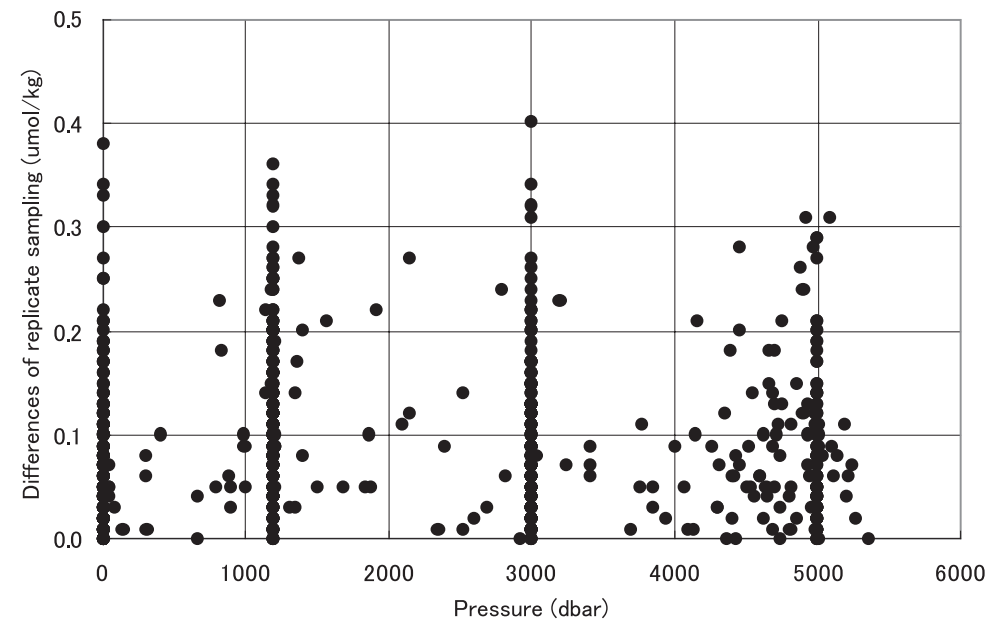


Figure 3.3.2. Differences in the replicate measurements against sampling pressure.

#### (12) Duplicate sample measurement

We also collected seawater samples from two Niskin samplers that were collected at same depth (duplicate sampling). Total 50 pairs of the duplicate samples were taken in deep layers below 800 dbar during all the legs. The standard deviation of the total duplicate measurement was  $0.10 \mu\text{mol kg}^{-1}$ . We concluded that total measurement error of bottle oxygen was less than  $0.10 \mu\text{mol kg}^{-1}$  during MR05-05 cruise.

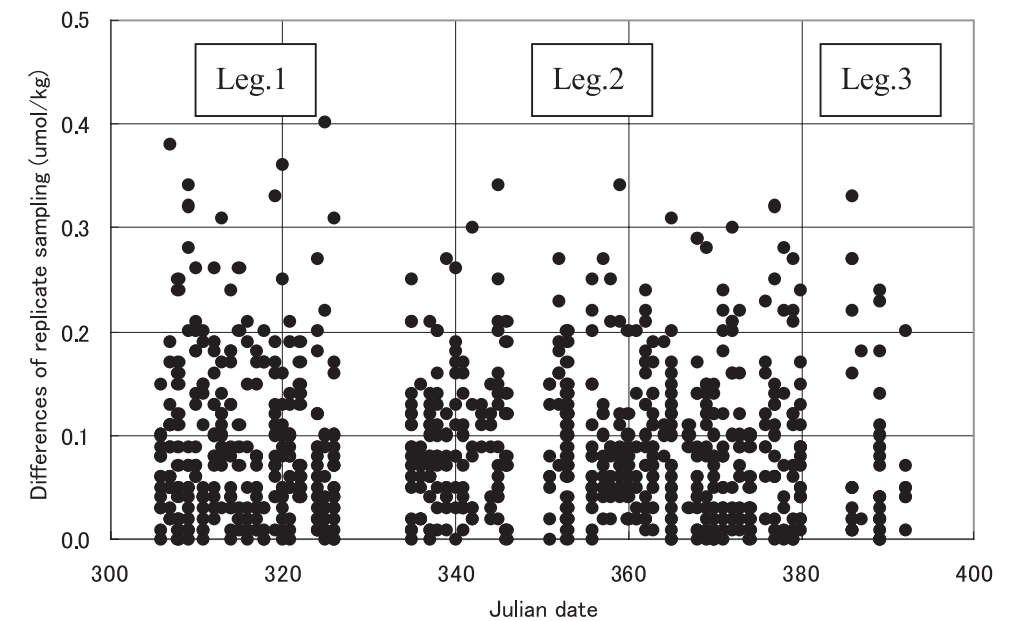


Figure 3.3.3. Differences in the replicate measurements against measurement date (Julian date).

#### (13) CSK standard measurements

The CSK standard solution is commercial potassium iodate solution ( $0.0100 \text{ N}$ ) for analysis of oxygen in seawater. During the cruises, we measured concentration of the CSK standard solution (Lot ASE8281) against our  $\text{KIO}_3$  standard in order to confirm the accuracy of our oxygen measurement on board (Table 3.3.3). Error weighted means of DOT-1 and DOT-3 results were  $0.009999 \pm 0.000005$  and  $0.010002 \pm 0.000006$  normal (N) respectively, which indicates that there was no systematic difference between DOT-1 and DOT-3 measurements. The averaged value of the CSK standard solution was so close to the certified value ( $0.0100 \text{ N}$ ) that we did not correct sample measurements results using the CSK standard results. Additionally, we also measured the same lot (ASE8281) of the CSK standard solution during our previous cruise in 2005 (MR05-02). Results of the CSK measurements in the both cruises agreed well within the errors (less than 0.1%), suggesting that there was no systematic difference in the oxygen measurements between MR05-02 and MR05-05.

Table 3.3.3. Results of the CSK standard measurements.

Date (UTC)	KIO <sub>3</sub> batch#	DOT-1		DOT-3	
		Conc. (N)	error (N)	Conc. (N)	error (N)
2005/11/07	ASE8281-1	0.010005	0.000005	0.010006	0.000003
2005/11/18	ASE8281-2	0.009998	0.000003	0.009993	0.000017
2005/12/07	ASE8281-3	0.010004	0.000007	0.010001	0.000007
2005/12/25	ASE8281-4	0.010001	0.000004	0.010005	0.000007
2006/01/11	ASE8281-5	0.009997	0.000006	0.009998	0.000011
2006/01/14	ASE8281-6	0.009998	0.000008	0.009997	0.000009
2006/01/26	ASE8281-7	0.009989	0.000006	0.009990	0.000005
Weighted mean		0.009999	0.000005	0.010002	0.000006
Date (UTC)	KIO <sub>3</sub> batch#	DOT-1		DOT-2	
		Conc. (N)	error (N)	Conc. (N)	error (N)
2005/6/21	ASE8281-0	0.010005	0.000010	0.010002	0.000006

(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 (good), 3 (questionable), 4 (bad), and 5 (missing) have been assigned (Table 3.3.4). The replicate data (section 3.3-11) were averaged and flagged 2 if both of them were flagged 2. If either of them was flagged 3 or 4, a datum with "younger" flag was selected. Thus, we did not use flag of 6 (replicate measurements). For the choice between 2, 3, or 4, we basically followed a flagging procedure as listed below:

- a. Bottle oxygen concentration and difference between bottle oxygen and CTD oxygen at the 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 or sigma-theta. If a datum deviated from a group of plots, it was flagged 3.
- c. Vertical sections against pressure and potential density were drawn. If a datum was anomalous on the section plots, datum flag was degraded from 2 to 3, or from 3 to 4.
- d. If the bottle flag was 4 (did not trip correctly), a datum was flagged 4 (bad). In the case of the bottle flag

3 (leaking) or 5 (unknown problem), a datum was flagged based on steps a, b, and c.

Table 3.3.4. Summary of assigned quality control flags.

Flag	Definition	
2	Good	6,698
3	Questionable	5
4	Bad (Faulty)	10
5	Not reported (missing)	4
Total		6,717

(15) Results

(15.1) Comparison at cross-stations during MR05-05

At stations of P03-146, 217, and 351, hydrocast sampling for dissolved oxygen was conducted two times at interval of about a week. Dissolved oxygen profiles of the two hydrocasts at the three cross-stations agreed well (Figure 3.3.4). In the layers deeper than 4,000 dbar, difference of dissolved oxygen between the two hydrocasts was calculated to be 0.20  $\mu\text{mol kg}^{-1}$  (standard deviation, n=24).

(15.2) Comparison at cross-stations of MR05-05 and MR05-02

During June of 2006, we also conducted another repeat cruise of WHP-P10, named MR05-02 cruise, along about 149°E in the western North Pacific. At the cross point of MR05-05 and MR05-02, we carried out two cross-stations at 24.5°N/149.4°E (MR05-02\_P10-067 and MR05-05\_P03-X10) and 24.2°N/149.0°E (MR05-02\_P10-X03 and MR05-05\_P03-275). Repeat measurements of dissolved oxygen at interval of about six months showed that dissolved oxygen decreased by 20  $\mu\text{mol kg}^{-1}$  in deep layers ranged from about 1,500 to 2,500 dbar (Figure 3.3.5). It should also be noted that oxygen concentration also decreased slightly (about 2  $\mu\text{mol kg}^{-1}$ ) in bottom water below 5,000 dbar at the both two cross-stations. As mentioned in section 3.3.15.1, the results at the cross-stations during MR05-05 cruise showed that the repeat measurements of dissolved oxygen in bottom water agreed within 0.2  $\mu\text{mol kg}^{-1}$ . Additionally, using the CSK standard solution we ensured traceability of dissolved

oxygen analyses during MR05-02 and MR05-05 cruises within about 0.1% correspondent to about  $0.2 \mu\text{mol kg}^{-1}$  (section 3.3.13). These results indicate that total reproducibility of our oxygen measurement is about  $0.2 \mu\text{mol kg}^{-1}$ , suggesting that observed oxygen decreases of about  $2 \mu\text{mol kg}^{-1}$  in the bottom water at the cross-stations are significant. The variability of oxygen concentration within six months in the deep and bottom waters implies that apparent decadal change of dissolved oxygen derived from repeat hydrography should be discussed carefully.

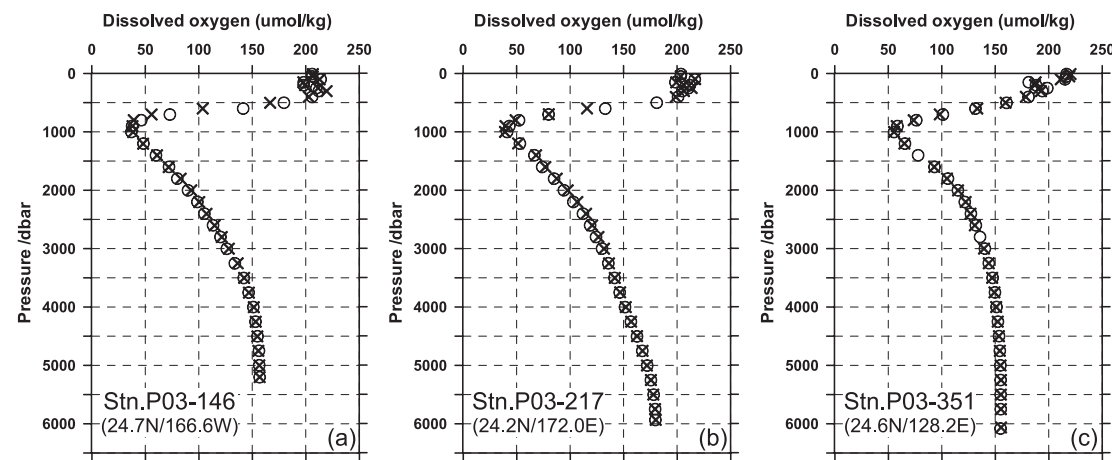


Figure 3.3.4. Comparison of dissolved oxygen profiles between the first hydrocast (circles) and the second one (crosses) at the cross-stations of Stn. P03-146 (a), -217 (b), and -351 (c) during MR05-05 cruise.

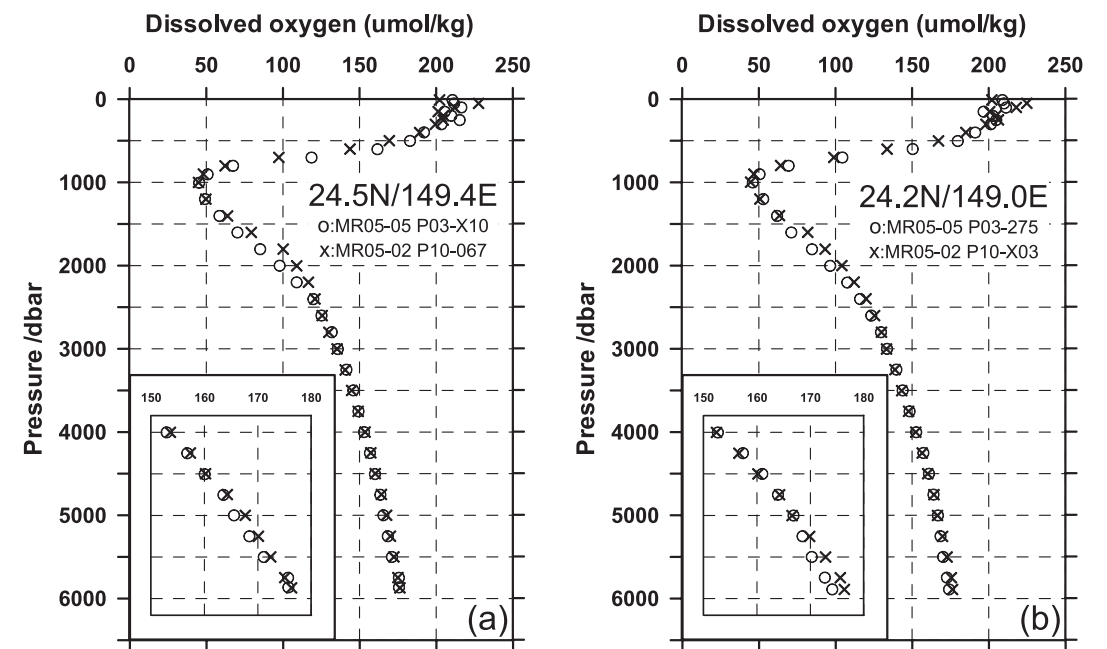


Figure 3.3.5. Comparison of dissolved oxygen profiles during MR05-02 and MR05-05 cruises at the cross-stations located at  $24.5^\circ\text{N}/149.4^\circ\text{E}$  (a) and  $24.2^\circ\text{N}/149.0^\circ\text{E}$  (b). Circles show data obtained at Stn. P03-X10 (a) and P03-275 (b) of MR05-05 cruise on December/12/2005. Crosses indicate data obtained at Stn. P10-067 (a) and P10-X03 (b) of MR05-02 cruise on June/10/2005.

### (15.3) Comparison with WHP-P03 oxygen data in 1985

We compared our oxygen data and gridded data of WHP-P03 in 1985 and found that our oxygen data were slightly lower than those of WHP-P03. Below 2,000 m depth the difference in average is calculated in  $-2.2 \pm 1.7 \mu\text{mol kg}^{-1}$  (Figure 3.3.6). This "offset" value is closed to reported adjustments, about minus  $3 \mu\text{mol kg}^{-1}$  for dissolved oxygen data of WHP-P03 (Johnson *et al.*, 2001; Gouretski and Jancke, 2001). We here corrected oxygen data of WHP-P03 by the averaged offset value,  $2.2 \mu\text{mol kg}^{-1}$ .

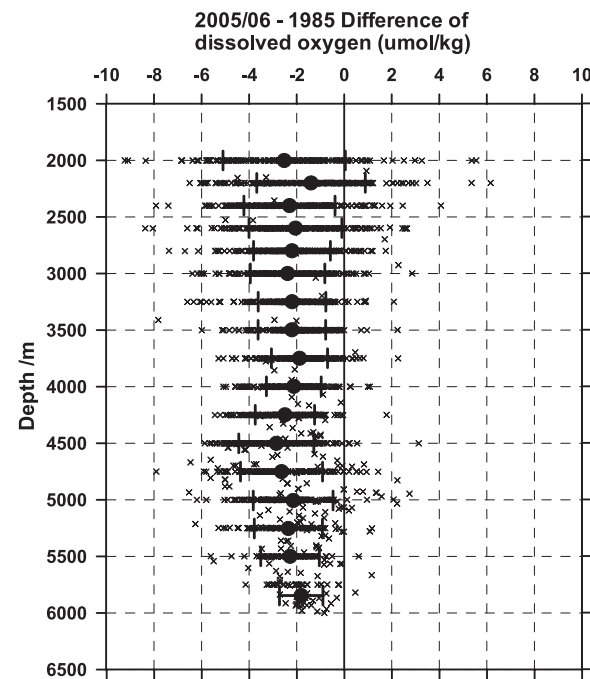


Figure 3.3.6. Oxygen difference (2005/2006 data minus 1985 data,  $\mu\text{mol kg}^{-1}$ ) against water depth. Closed circles denote mean of the differences with 1 sigma error at sampling layers.

Figure 3.3.7(a) shows distribution of oxygen difference (2005/2006 data minus 1985 data) against water depth. Below 1,000 m depth, there were not differences more than  $5 \mu\text{mol kg}^{-1}$ . The dispersion of the difference in the deep/bottom water ( $\pm 1.7 \mu\text{mol kg}^{-1}$  for 1 sigma) was also independent from the sampling depths, suggesting that the dispersion was derived from analytical errors and the data gridding. The dispersion of 2 sigma ( $\pm 3.4 \mu\text{mol}$ ) and the offset correction of  $2.2 \mu\text{mol kg}^{-1}$  imply that oxygen differences less than  $5 \mu\text{mol kg}^{-1}$  between 1985 and 2005/06 is not significant. In the layers shallower than 1,000 m depth, we found some increases and decreases of dissolved oxygen. In order to focus on the shallow variations, the differences were plotted against water density (sigma theta) from 24.5 to 27.5 (approximately correspondent to layers from 200 to 1,200 m depth) in Figure 3.3.7(b).

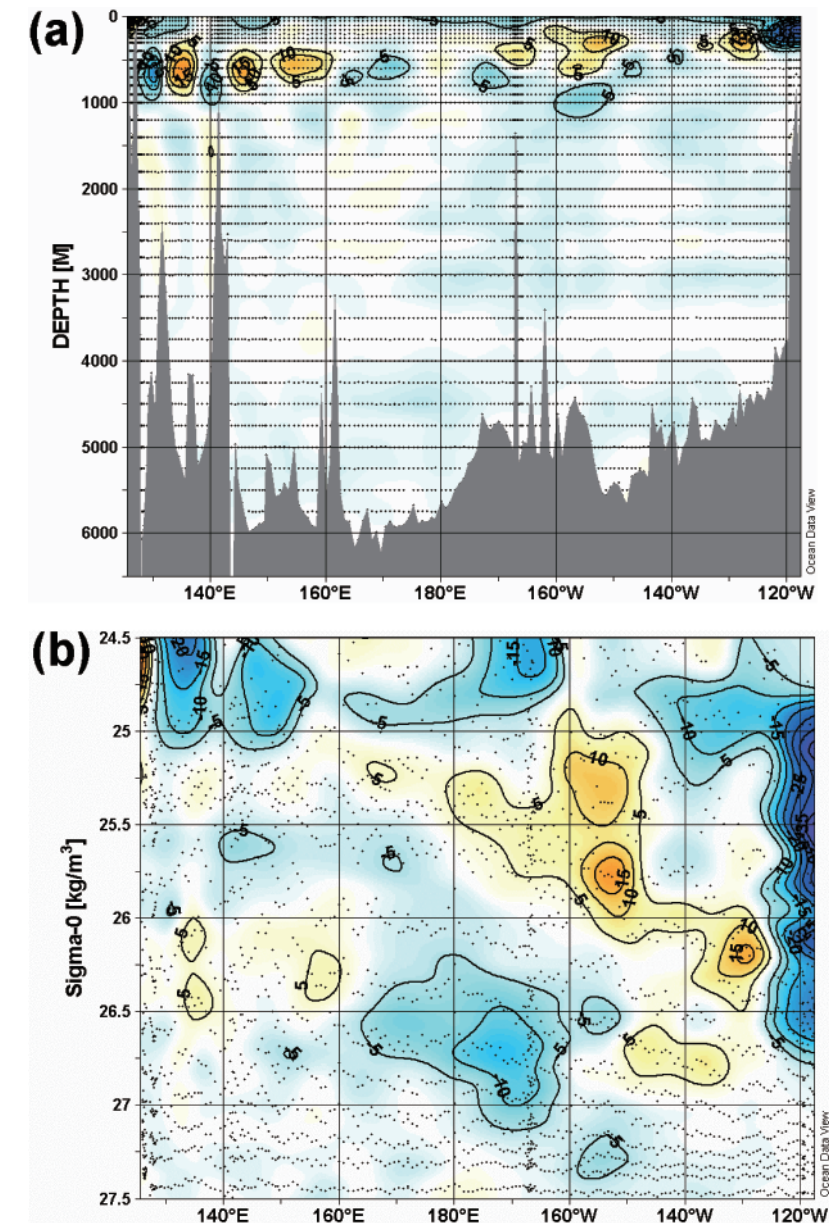


Figure 3.3.7. Differences of dissolved oxygen ( $\mu\text{mol kg}^{-1}$ ) between 2005/06 and 1985 (2005/2006 data minus 1985 data) against water depth (a) and water density, sigma-theta (b). Data of WHP-P03 in 1985 were corrected by the deep/bottom offset. Contour intervals are  $5 \mu\text{mol kg}^{-1}$ . Small dots indicate sampling layers of dissolved oxygen during MR05-05 in 2005/06.

We found a significant decrease of dissolved oxygen at the eastern end where oxygen concentration was relatively low. This decrease may be due to variability of local upwelling. Oxygen increase around 130°W to the International Date Line ranged from 25.0 to 26.2 sigma theta implies variation of mesoscale eddies. From 160°W to 160°E, around 26.8 sigma theta dissolved oxygen decreased, which is similar to the intermediate oxygen decrease in the subarctic regions in the North Pacific (Emerson *et al.*, 2001; Watanabe *et al.*, 2001). The decadal change along around 24°N, however, was smaller than that found in the subarctic North Pacific.

## References

- Culberson, A.H. (1994) Dissolved oxygen, in *WHPO Pub. 91-1 Rev. 1*, November 1994, Woods Hole, Mass., USA.
- Culberson, A.H., G. Knapp, M.C. Stalcup, R.T. Williams, and F. Zemlyak (1991) A comparison of methods for the determination of dissolved oxygen in seawater, *WHPO Pub. 91-2*, August 1991, Woods Hole, Mass., USA.
- Dickson, A. (1996) Determination of dissolved oxygen in sea water by Winkler titration, in *WHPO Pub. 91-1 Rev. 1*, November 1994, Woods Hole, Mass., USA.
- DOE (1994) Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74.
- Emerson, S, S. Mecking and J.Abell (2001) The biological pump in the subtropical North Pacific Ocean: nutrient sources, redfield ratios, and recent changes. *Global Biogeochem. Cycles*, **15**, 535-554.
- Gouretski, V.V. and K. Jancke (2001) Systematic errors as the causes for an apparent deep water property variability: global analysis of the WOCE and historical hydrographic data, *Prog. Oceanogr.*, **48**, 337-402.
- Johnson, G.C., P.E. Robbins, and G.E. Hufford (2001) Systematic adjustments of hydrographic sections for internal consistency, *J. Atmos. Oceanic Technol.*, **18**, 1234-1244.
- 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.
- Murray, C.N., J.P. Riley, and T.R.S. Wilson (1968) The solubility of oxygen in Winkler reagents used for determination of dissolved oxygen, *Deep-Sea Res.*, **15**, 237-238.
- Watanabe, Y.W., T. Ono, A. Shimamoto, T. Sugimoto, M. Wakita and S. Watanabe (2001) Probability of a reduction in the formation rate of subsurface water in the North Pacific during the 1980s and 1990s. *Geophys. Res. Letts.*, **28**, 3298-3292.



3.4 Nutrients

July 19, 2007

(1) Personnel

Michio Aoyama (MRI / Japan Meteorological Agency, Principal Investigator)

Leg.1

Kenichiro Sato (MWJ)

Ayumi Takeuchi (MWJ)

Junji Matsushita (MWJ)

Leg.2

Junko Hamanaka (MWJ)

Ayumi Takeuchi (MWJ)

Kohei Miura (MWJ)

Leg.3

Junko Hamanaka (MWJ)

Junji Matsushita (MWJ)

Kohei Miura (MWJ)

(2) Objectives

The objectives of nutrients analyses during the R/V MIRAI MR0505 cruise along 24N line in the Western North Pacific are as follows;

Describe the present status of nutrients concentration with excellent comparability.

The determinants 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 the temporal and spatial variation of nutrients based on the previous high quality experiments data of

WOCE, GOSECS, IGY and so on.

Study 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

(3.1) 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 the seawater sample to form phosphomolybdic acid which is in turn reduced to phosphomolybdous acid using L-ascorbic acid as the reductant.

Nitrate + nitrite and nitrite are analyzed by 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 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 that of Grasshoff et al. (1983), wherein 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 reagents for each parameter are shown in [Figures 3.4.1-3.4.4](#).





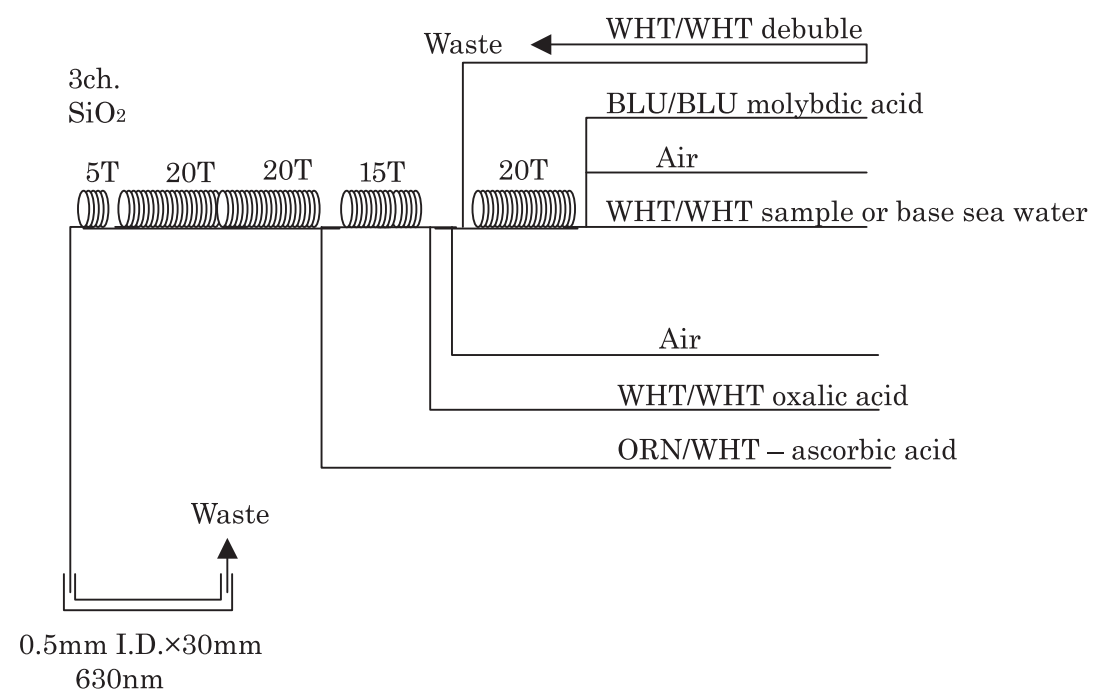


Figure 3.4.3. 3ch. (SiO<sub>2</sub>) Flow diagram.

## Silicic Acid Reagents

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

up to 1,000 ml. After mixing, 5 ml sodium dodecyl sulphate (15% solution in water) is added.

### **(3.2) 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 bath at 25  $\pm$  1deg. C for 10 minutes before used to stabilize the temperature of samples.

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

### **(3.3) Data processing**

Raw data from TRAACS800 were treated as follows:

Check baseline shift.

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

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

Baseline correction and sensitivity correction were done basically by 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**

### **(4.1) 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 that are 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 were 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 were done by using the coefficient of linear expansion of borosilicate crown glass.

Because of their larger temperature coefficients of cubical expansion and lack of tables constructed for these materials, the plastic volumetric flasks were gravimetrically calibrated over the temperature range of intended use and used at the temperature of calibration within 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. In addition, assay of nitrite was determined according as 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 1,000 mg L<sup>-1</sup>. Since this solution is alkaline solution of 0.5 M KOH, an aliquot of 40ml solution were diluted to 500 ml as B standard together with an aliquot of 20 ml of 1 M HCl. Then the pH of B standard for silicate prepared to be 6.9.

#### Ultra pure water

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

#### Low-Nutrient Seawater (LNSW)

Surface water 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 measured carefully 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 by according as recipes, as shown in Table 3.4.2. All volumetric laboratory tools were calibrated prior to 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	B'	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8
NO <sub>3</sub> (µM)	45000	900	900	0	BA	AY	AX	AV	BC	55.0	55.0
NO <sub>2</sub> (µM)	4000	20	20	0	BA	AY	AX	AV	BC	1.2	1.2
SiO <sub>2</sub> (µM)	36000	2880	3240	0	BA	AY	AX	AV	BC	172.8	194.4
PO <sub>4</sub> (µM)	3000	60	60	0	BA	AY	AX	AV	BC	3.6	3.6

Table 3.4.2. Working calibration standard recipes.			
C-STD	B-1 STD	B-1' STD	B-2 STD
C-7	30 ml	0 ml	30 ml
C-8	0 ml	30 ml	30 ml

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

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](#).

#### (4.2) Reference material of nutrients in seawater

To obtain more accurate and high quality nutrients data to achieve the objectives stated above, huge numbers of the bottles of the reference material of nutrients in seawater (hereafter RMNS) are prepared (Aoyama et al., 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 was of unprecedented quality and coverage due to much care in sampling and measurements, the differences of nutrients concentration at crossover points are still found among the expeditions (Aoyama and Joyce, 1996, Mordy et al., 2000, Gouretski and Jancke, 2001).

Table 3.4.3. Timing of renewal of in-house standards.	
NO <sub>3</sub> , NO <sub>2</sub> , SiO <sub>2</sub> , PO <sub>4</sub>	Renewal
A-1 Std. (NO <sub>3</sub> )	maximum 1 month
A-2 Std. (NO <sub>2</sub> )	maximum 1 month
A-3 Std. (SiO <sub>2</sub> )	commercial prepared solution
A-4 Std. (PO <sub>4</sub> )	maximum 1 month
B-1 Std. and B-1' Std. (mixture of NO <sub>3</sub> , SiO <sub>2</sub> , PO <sub>4</sub> )	8 days
B-2 Std. (NO <sub>2</sub> )	8 days
C Std	Renewal
C-7~C-8 Std ( mixture of B1 (B1') and B2 Std.)	24 hours
Reduction estimation	Renewal
D-1 Std.	when A-1 renewed
43μM NO <sub>3</sub>	when C-std renewed
47μM NO <sub>2</sub>	when C-std renewed

For instance, the mean offset of nitrate concentration at deep waters was 0.5 μmol kg<sup>-1</sup> for 345 crossovers at the world oceans, though the maximum was 1.7 μmol kg<sup>-1</sup> (Gouretski and Jancke, 2001). At the 31 crossover

points in the Pacific WHP one-time lines, the WOCE standard of reproducibility for nitrate of 1% was fulfilled at about half of the crossover points and the maximum difference was 7% at deeper layers below 1.6 deg. 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 intercompariosn 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<sup>-1</sup>) and 0.8% (range 0.5-5 μmol l<sup>-1</sup>), respectively. For phosphate, slight increase by 0.02-0.07 μmol l<sup>-1</sup> per year was observed due to the 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 an around the world cruise along ca. 30 deg. S and conducted in 2003 and 2004, RMNS was analyzed at about 500 stations. The results of BEAGLE2003 cruise will be available soon. (Databook of BEAGLE2003)

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 the depths of 1,500-2,000 meters where the nutrients concentrations reach its 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 deg. C, for 2 hours, 2 times in two days. The filling procedure of autoclaved seawater basically remained the same throughout our study. After cooled at room

temperature in two days, polypropylene bottles of 100 ml capacity were filled with the autoclaved seawater of 90 ml through a membrane filter with a pore size of 0.2  $\mu\text{m}$  (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 each bottle was attached on all of 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 were prepared as packages. These packages were renewed daily and analyzed every 2 runs on the same day. 250 bottles of RMNS lot AZ were 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 around 24-26 deg. C.

**Assigned concentration for RMNSs**

We assigned nutrients concentrations for RMNS lots BC, AV, AX, AY and BA as shown in Table 3.4.4.

**(ii) The homogeneity of RMNSs**

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, which were used during the cruise. As shown in Table 3.4.5, the homogeneity of RMNS lot BC for nitrate and silicate are the same magnitude of analytical precision derived from fresh raw seawater. The homogeneity for phosphate, however, exceeds the analytical precision at some extent.

Table 3.4.4. Assigned concentration of RMNSs

	Nitrate	Phosphate	Silicate
RMNS-BA	0.1 $\pm$ 0.0	0.06 $\pm$ 0.01	1.6 $\pm$ 0.1
RMNS-AY	5.6 $\pm$ 0.0	0.52 $\pm$ 0.01	30.1 $\pm$ 0.1
RMNS-AX	21.4 $\pm$ 0.1	1.61 $\pm$ 0.01	59.5 $\pm$ 0.1
RMNS-AV	33.4 $\pm$ 0.1	2.52 $\pm$ 0.01	157.9 $\pm$ 0.2
RMNS-BC	40.7 $\pm$ 0.1	2.78 $\pm$ 0.01	160.0 $\pm$ 0.2
RMNS-AZ	42.3 $\pm$ 0.1	3.02 $\pm$ 0.01	137.2 $\pm$ 0.2

Table 3.4.5. Homogeneity of lot BC and previous lots derived from simultaneous 30 samples measurements and analytical precision onboard R/V Mirai in May 2005.

	Nitrate CV%	Phosphate CV%	Silicate 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 x 2

**(5) Quality control**

**(5.1) Precision of nutrients analyses during the cruise**

Precision of nutrients analyses during the cruise was evaluated based on the 12 measurements, which are measured every 12 samples, during a run at the concentration evaluated n of C-7. We also the reproducibility based on the replicate analyses of five samples in each run. Summary of the precisions are shown in Table



3.4.6. As shown in Table 3.4.6 and Figures 3.4.5-3.4.7, the precisions for each parameter are generally good considering analytical precisions estimated from the simultaneous analyses of 60 samples in May 2005. The 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 0.08% for phosphate, 0.07% for nitrate and 0.08% for silicate in terms of median of precision, respectively. Therefore we can conclude that the analytical precisions for phosphate, nitrate and silicate throughout this cruise were maintained or better than those compared to the pre-cruise evaluations. The time series of precision are shown in Figures 3.4.5-3.4.7.

Table 3.4.6. Summary of precision based on the replicate analyses of 12 samples in each run through out cruise.

	Nitrate	Phosphate	Silicate
	CV%	CV%	CV%
Median	0.070	0.070	0.090
Mean	0.076	0.072	0.087
Maximum	0.170	0.190	0.170
Minimum	0.030	0.030	0.020
N	277	277	277

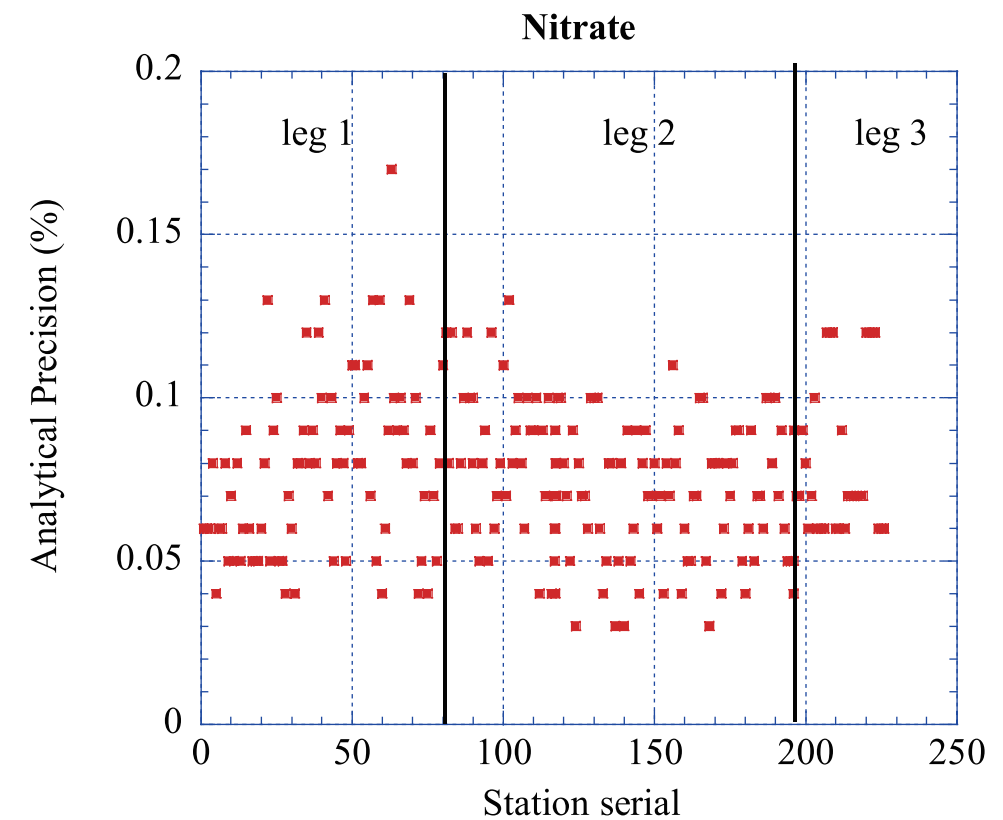


Figure 3.4.5. Time series of precision of nitrate.

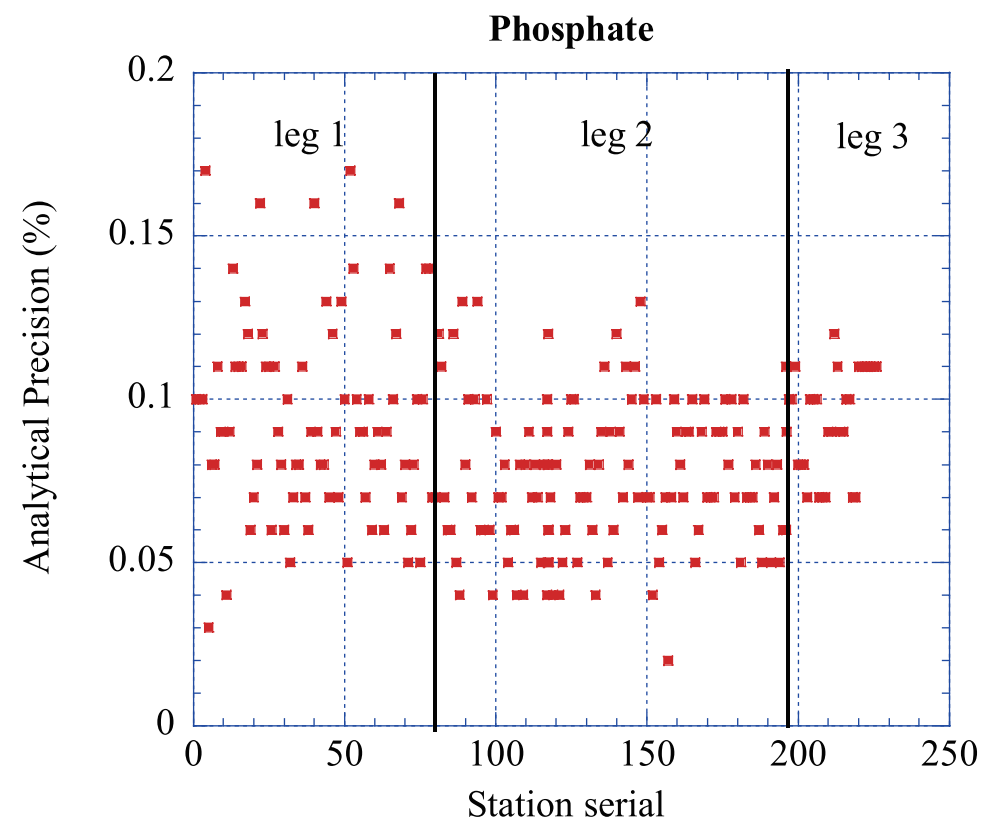


Figure 3.4.6. Time series of precision of phosphate.

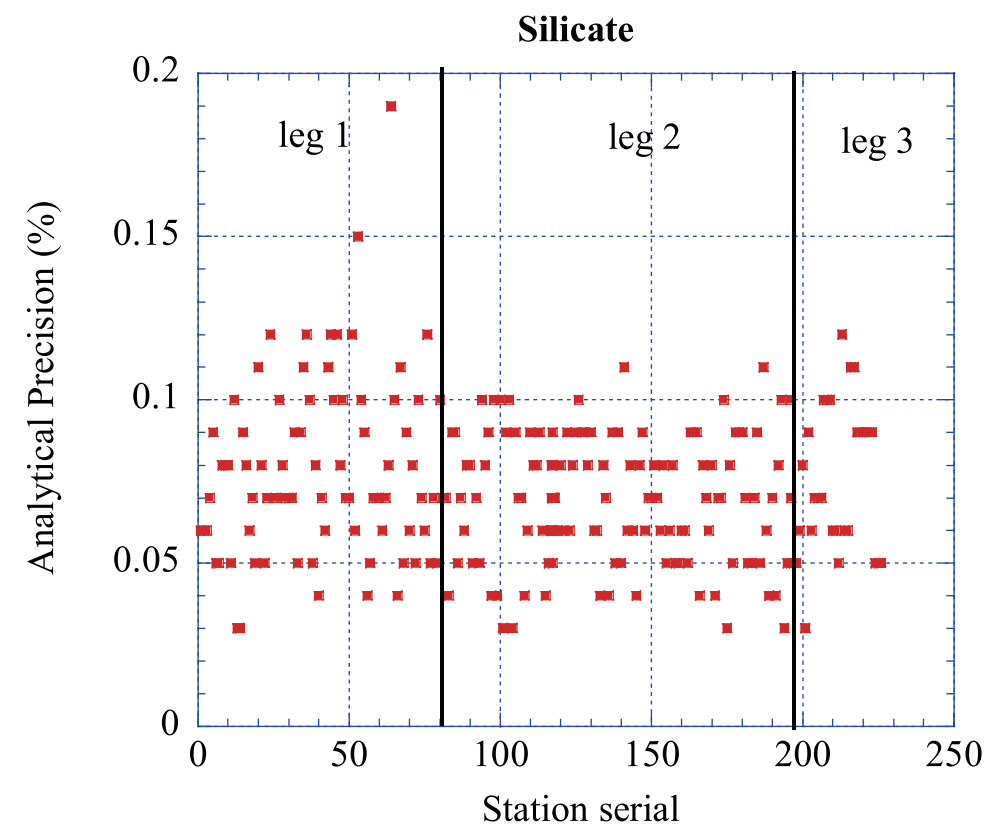


Figure 3.4.7. Time series of precision of silicate.

**(5.2) Carry-over**

We can also summarize the magnitudes of carry-over throughout the cruise. These are small enough within acceptable levels as shown in Table 3.4.7.

Table 3.4.7. Summary of carry-over through out cruise.

	Nitrate	Phosphate	Silicate
	%	%	%
Median	0.21	0.20	0.24
Mean	0.21	0.20	0.23
Maximum	0.40	0.40	0.43
Minimum	0.01	0.00	0.05
N	277	277	277

**(6) Evaluation of Z-scores of RMNSs**

Since we used RMNSs throughout the cruise, we can evaluate the trueness of our analysis in terms of Z-score of RMNSs.

Z-score for each analysis of RMNS is defined as follows:

$$Z_{par} = \text{ABS}((C_{par} - C_{nominal})/P_{par}) \quad (1)$$

Where

$Z_{par}$  is Z-score for an analysis

$C_{par}$  is obtained concentration of a RMNS for interested parameter, nitrate, phosphate or silicate.

$C_{nominal}$  is assigned concentration of RMNS for interested parameter, nitrate, phosphate or silicate.

$P_{par}$  is analytical precision at the concentration of RMNS for interested parameter, nitrate, phosphate or silicate.

Averages of these Z-scores were obtained for three parameters, nitrate, phosphate and silicate based on Z-scores for 7 RMNSs used at each run and shown in [Figure 3.4.8](#). Means of Z-score based on the Z-score of three parameters were also obtained and shown in [Figure 3.4.9](#).

These Z-scores were less than 0.5 in general and indicating that our analyses were in excellent tracerbility throughout the cruise.

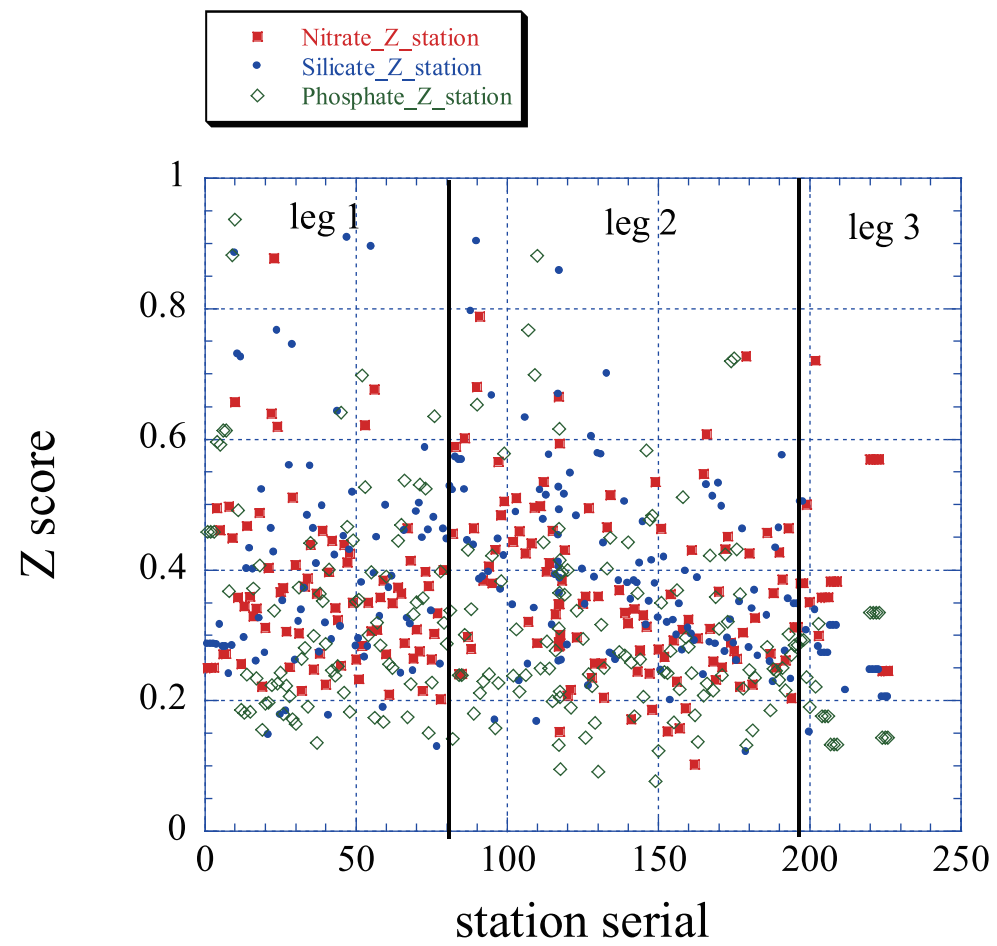


Figure 3.4.8. Z-score of nitrate, silicate and phosphate.

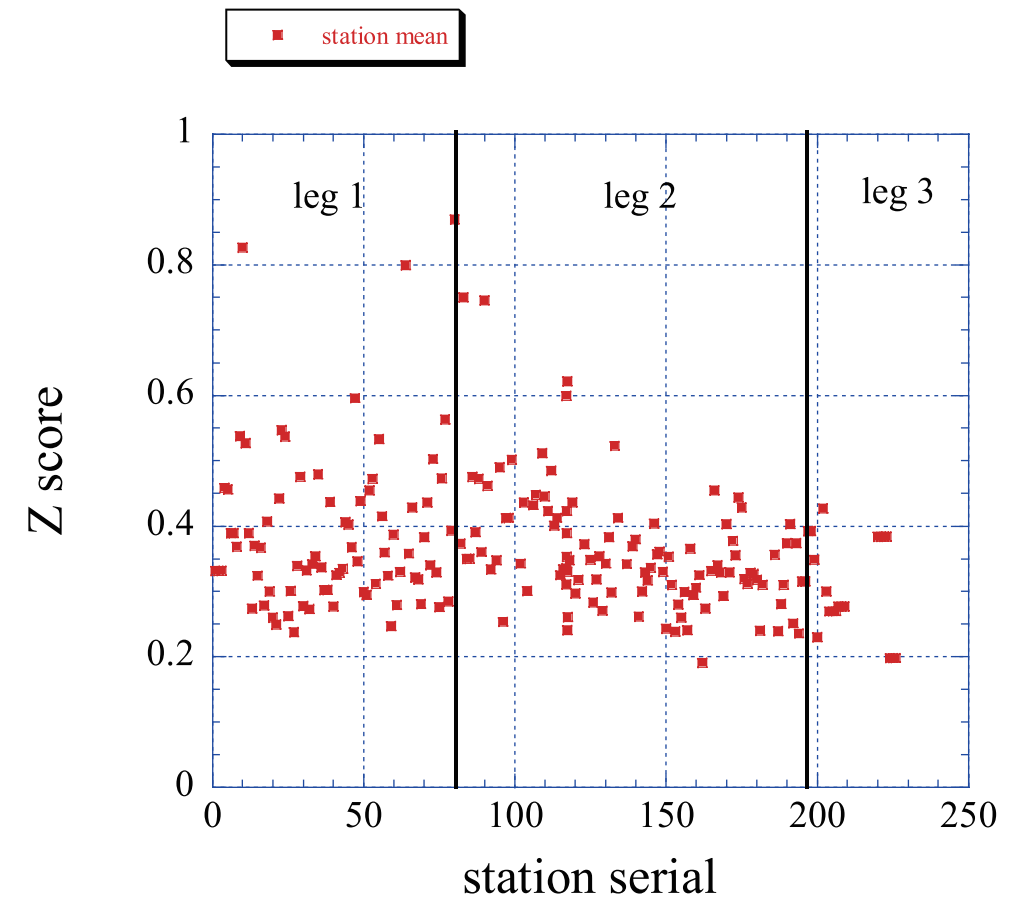


Figure 3.4.9. Means of Z-score at the stations.

**(7) Problems/improvements occurred and solutions**

Nothing occurred during the cruise.

**Reference**

- Aminot, A. and Kerouel, R. 1991. Autoclaved seawater as a reference material for the determination of nitrate and phosphate in seawater. *Anal. Chim. Acta*, **248**, 277-283.
- Aminot, A. and Kirkwood, D.S. 1995. Report on the results of the fifth ICES intercomparison exercise for nutrients in sea water, *ICES coop. Res. Rep. Ser.*, **213**.
- Aminot, A. and Kerouel, R. 1995. Reference material for nutrients in seawater: stability of nitrate, nitrite, ammonia and phosphate in autoclaved samples. *Mar. Chem.*, **49**, 221-232.
- Aoyama M., and Joyce T.M. 1996, WHP property comparisons from crossing lines in North Pacific. *In Abstracts, 1996 WOCE Pacific Workshop*, Newport Beach, California.
- Aoyama, M., Ota, H., Iwano, S., Kamiya, H., Kimura, M., Masuda, S., Nagai, N., Saito, K., Tubota, H. 2004. Reference material for nutrients in seawater in a seawater matrix, *Mar. Chem.*, submitted.
- Grasshoff, K., Ehrhardt, M., Kremling K. et al. 1983. *Methods of seawater anylysis*. 2nd rev. Weinheim: Verlag Chemie, Germany, West.
- JAMSTEC, BEAGLE2003 DATA BOOK, 2005,
- Joyce, T. and Corry, C. 1994. Requirements for WOCE hydrographic programmed data reporting. WHPO Publication, 90-1, Revision 2, WOCE Report No. 67/91.
- Kirkwood, D.S. 1992. Stability of solutions of nutrient salts during storage. *Mar. Chem.*, **38**, 151-164.
- Kirkwood, D.S. Aminot, A. and Perttila, M. 1991. Report on the results of the ICES fourth intercomparison exercise for nutrients in sea water. *ICES coop. Res. Rep. Ser.*, **174**.
- Mordy, C.W., Aoyama, M., Gordon, L.I., Johnson, G.C., Key, R.M., Ross, A.A., Jennings, J.C. and Wilson. J. 2000. Deep water comparison studies of the Pacific WOCE nutrient data set. *Eos Trans-American Geophysical Union*. **80** (supplement), OS43.

Murphy, J., and Riley, J.P. 1962. *Analytica chim. Acta* **27**, 31-36.

Gouretski, V.V. and Jancke, K. 2001. Systematic errors as the cause for an apparent deep water property variability: global analysis of the WOCE and historical hydrographic data · REVIEW ARTICLE, *Progress In Oceanography*, **48**: Issue 4, 337-402.

### 3.5 Dissolved inorganic carbon (C<sub>T</sub>)

July 18, 2007

#### (1) Personnel

<i>Akihiko Murata</i>	<i>(JAMSTEC)</i>
<i>Minoru Kamata</i>	<i>(MWJ)</i>
<i>Masaki Moro</i>	<i>(MWJ)</i>
<i>Yoshiko Ishikawa</i>	<i>(MWJ)</i>

#### (2) Introduction

Concentrations of CO<sub>2</sub> in the atmosphere are currently increasing at a rate of 1.5 ppmv y<sup>-1</sup>, 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 increasing atmospheric CO<sub>2</sub>, as well as to clarify the mechanism of the CO<sub>2</sub> absorption, because the magnitude of the predicted global warming depends on the levels of CO<sub>2</sub> in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In this cruise (MR05-05, revisit of WOCE P3 line) using the R/V MIRAI, we aimed to quantify how much anthropogenic CO<sub>2</sub> is absorbed in North Pacific Intermediate Water, which is one of the characteristic waters in the North Pacific. For the purpose, we measured CO<sub>2</sub>-system properties such as dissolved inorganic carbon (C<sub>T</sub>), total alkalinity (A<sub>T</sub>), pH and underway pCO<sub>2</sub>.

In this section, we describe data on C<sub>T</sub> obtained in the cruise in detail.

#### (3) Apparatus

Measurements of C<sub>T</sub> were made with two total CO<sub>2</sub> 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<sub>2</sub>

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 26 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<sub>2</sub> dissolved in a seawater sample is extracted in a stripping chamber of a CO<sub>2</sub> extraction system by adding phosphoric acid (10% v/v). The stripping chamber is approximately 25 cm in length and has a fine frit at the bottom. In order to degas CO<sub>2</sub> as quickly as possible, a heating wire kept at 40°C is rolled from the bottom to a 1/3 height of the stripping chamber. 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 an exact 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 acid. The seawater reacted with phosphoric acid is stripped of CO<sub>2</sub> by bubbling the nitrogen gas through a fine frit at the bottom of the stripping chamber. The CO<sub>2</sub> stripped in the stripping chamber is carried by the nitrogen gas (140 ml min<sup>-1</sup> for the systems-A and -B) to the coulometer through a dehydrating module. For the system-A, the module consists of two electric dehumidifiers (kept at 1 - 2°C) and a chemical desiccant (Mg(ClO<sub>4</sub>)<sub>2</sub>). For the system-B, it consists of three electric dehumidifiers with a chemical desiccant.

#### (4) Shipboard measurement

##### *Sampling*

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

At a chemical laboratory on the ship, a headspace of approximately 1% of the bottle volume was made by



removing seawater with a plastic pipette. A saturated mercuric chloride of 100  $\mu$ l was added to poison seawater samples. The glass bottles were sealed with a greased (Apiezon M, M&I Materials Ltd) ground glass stopper and the clips were secured. The seawater samples were kept at 4°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

There were 3 legs in the P3 revisit cruise. At the start of each leg, we calibrated the measuring systems by blank and 5 kinds of Na<sub>2</sub>CO<sub>3</sub> solutions (nominally 500, 1,000, 1,500, 2,000, 2,500  $\mu$ mol/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 repeatedly measured 2% CO<sub>2</sub> gas until the measurements became stable. Then we started the calibration.

The measurement sequence such as system blank (phosphoric acid blank), 2% CO<sub>2</sub> gas in a nitrogen base, seawater samples (6) was programmed to repeat. The measurement of 2% CO<sub>2</sub> gas was made to monitor response of coulometer solutions (from UIC, Inc.). For every renewal of coulometer solutions, certified reference materials (CRMs, batch 72 and a small number of 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<sub>T</sub> based on raw data for each station helped us check performances of the measuring systems.

In the cruise, we finished all the analyses for C<sub>T</sub> on board the ship. As we used two systems, we did not encounter such a situation as that we had to abandon the measurement due to time limitation. During Leg.2, we replaced the pipette of a volume of 26 ml for the system-B to that of 22 ml after Stn. 251. Furthermore, a ramp of light source of the coulometer for the system-B was replaced. During Leg.3, only the system-A was used.

### (5) Quality control

We conducted quality control of the data after returning to a laboratory on land. With calibration factors, which had been determined on board based on blank and 5 kinds of Na<sub>2</sub>CO<sub>3</sub> solutions (see *analysis*), we calculated C<sub>T</sub> of CRM (batches 69 and 72), and plotted the values as a function of sequential day, separating legs and the systems used. There were no statistically-significant trends of CRM measurements, except for the measurements with the system-A during Leg.3. As shown in [Table 3.5.1](#), averages of C<sub>T</sub> of CRM shows a variation, probably implying instability of a coulometer.

Based on the averages of C<sub>T</sub> of CRM, we re-calculated the calibration factors so that measurements of seawater samples could become comparable to the certified value of batches 72 or 69.

Temporal variations of RM measurements for one coulomer solution are shown in [Figure 3.5.1](#). This figure clearly shows that RM measurements had a linear trend of  $\sim 3$  to  $\sim 6$   $\mu$ mol kg<sup>-1</sup> day<sup>-1</sup>, implying that measurements of seawater samples also have the trend. The trend was also found in temporal changes of 2% CO<sub>2</sub> gas measurements. The trend seems to be due to “cell age” change (Johnson *et al.*, 1998) of a coulometer solution.

Considering these trends, we adjusted measurements of seawater samples to be comparable to the certified value of batches 72 or 69.

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

The average and standard deviation of absolute values of differences of C<sub>T</sub> analyzed consecutively were 1.2 and 1.1  $\mu$ mol kg<sup>-1</sup> (n=129), 1.0 and 0.7  $\mu$ mol kg<sup>-1</sup> (n=197), and 0.5 and 0.5  $\mu$ mol kg<sup>-1</sup> (n=21), for Leg.1, 2 and 3, respectively.

To evaluate accuracy of measured C<sub>T</sub>, we compared vertical profiles of C<sub>T</sub> measured in MR05-05, C<sub>T</sub> calculated from A<sub>T</sub> and pH measured in MR05-05, and C<sub>T</sub> measured at a station of other WOCE lines crossing the P3 line. Results for cross station with WOCE P17 line along 135°W are shown in [Figure 3.5.2](#). From this

figure, it is found that  $C_T$  measured in this cruise were sufficiently accurate. Together with other comparisons, we estimated the accuracy to be  $\sim \pm 2.0 \mu\text{mol kg}^{-1}$ .

Reference

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

Table 3.5.1. Measurements of  $C_T$  of CRM (batch 72 or 69) during the MR05-05 (WOCE P3 revisit) cruise.

Leg	System	Num	Ave ( $\mu\text{mol kg}^{-1}$ )	Std ( $\mu\text{mol kg}^{-1}$ )	Batch number
1	A	8	1906.2	0.7	69
	A	72	2091.7	1.3	72
	B	24	2088.6	1.5	72
2	A	40	2093.9	1.9	72
	B	9	2095.2	1.0	72
	B	18	2093.4	1.8	72
3	A	2	2090.9		72
	A	2	2088.8		72
	A	2	2088.8		72

The certified values of  $C_T$  for batches 69 and 72 are 1907.63 and 2091.61  $\mu\text{mol kg}^{-1}$ , respectively. During the Leg. 2, the pipette of system-B was replaced.

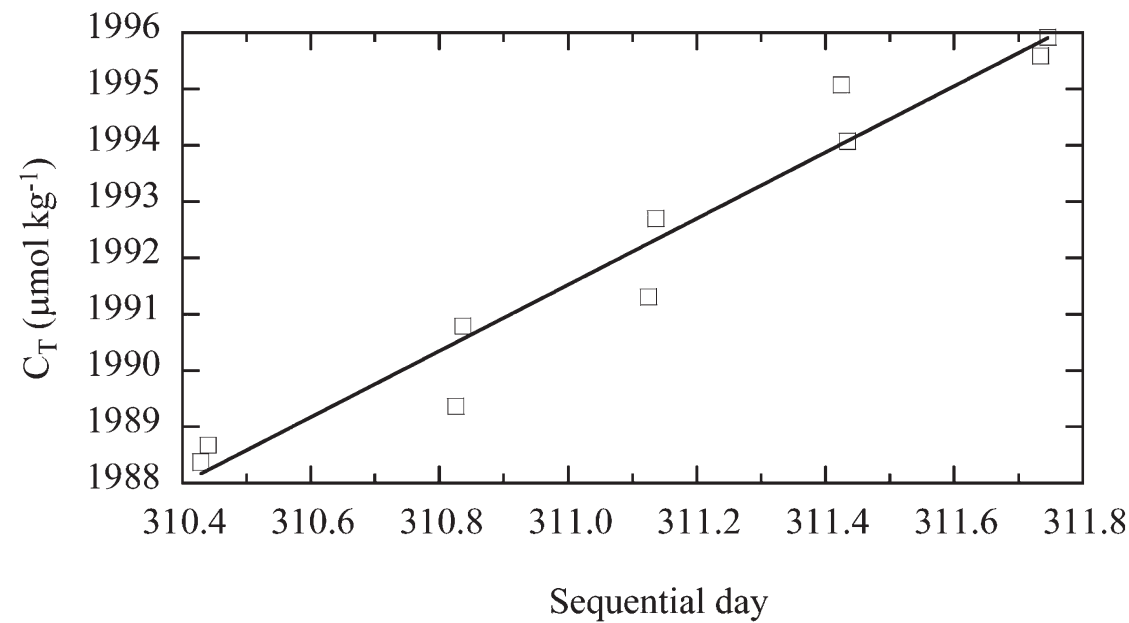


Figure 3.5.1. An example of RM measurements at Stns. 051 and 056, which show an increasing trend (5.9  $\mu\text{mol kg}^{-1} \text{ day}^{-1}$ ).

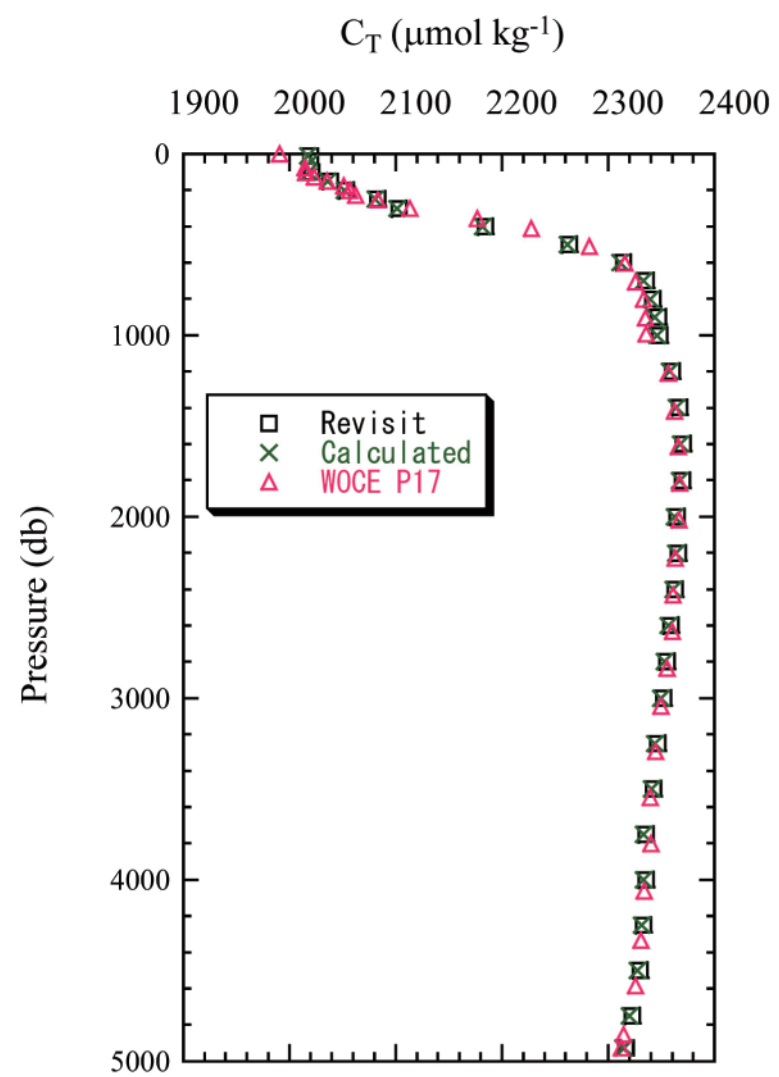


Figure 3.5.2. Comparison of vertical profiles of  $C_T$  measured in MR05-05 with  $C_T$  calculated from  $A_T$  and pH measured also in MR05-05 and  $C_T$  measured in WOCE P17C cruise conducted in 1997.

### 3.6 Total alkalinity ( $A_T$ )

July 18, 2007

#### (1) Personnel

<i>Akihiko Murata</i>	<i>(JAMSTEC)</i>
<i>Fuyuki Shibata</i>	<i>(MWJ)</i>
<i>Mikio Kitada</i>	<i>(MWJ)</i>
<i>Minoru Kamata</i>	<i>(MWJ)</i>
<i>Taeko Ohama</i>	<i>(MWJ)</i>

#### (2) Introduction

Concentrations of  $CO_2$  in the atmosphere are currently increasing at a rate of  $1.5 \text{ ppmv y}^{-1}$  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 increasing atmospheric  $CO_2$ , as well as to clarify the mechanism of the  $CO_2$  absorption, because the magnitude of the predicted global warming depends on the levels of  $CO_2$  in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In this cruise (MR05-05, revisit of WOCE P3 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.

#### (3) 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 an 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.

Seawater of approximately 40 ml is transferred from a sample bottle (borosilicate glass bottle; 130 ml) into a water-jacketed ( $25^\circ C$ ) pressurized by  $N_2$  gas and is introduced into a water-jacketed ( $25^\circ C$ ) titration cell. Next, a given volume of the 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 with a stirring chip. Then a small volume of titrant ( $\sim 0.1 \text{ ml}$ ) 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 based on a modified Gran approach.

#### (4) Shipboard measurement

##### *Sampling*

All seawater samples were collected from depths 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 rinsed with seawater of a half or a full bottle volume. A few hours before analysis, the seawater samples were kept at  $25^\circ C$  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  $A_T$ s were approximately 0, 100, 1,000, 2,000 and  $2,500 \mu\text{mol kg}^{-1}$ . 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  $\sim 3 \mu\text{mol kg}^{-1}$ , we started measurement of seawater samples. We analyzed reference materials (RM), which were produced for  $C_T$  measurement by JAMSTEC and were also efficient for monitoring  $A_T$  measurement. In addition, certified reference materials (CRM, batches 69 and 72, certified value = 2114.42 and 2312.79  $\mu\text{mol kg}^{-1}$ , respectively) were 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 the performance of the measuring system.

We finished all  $A_T$  analyses on board the ship. Although we did not encounter such a serious problem that we had to give up the analyses, we experienced some malfunctions of the system during the cruise, which are summarized as follows:

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

##### (5) Quality control

Temporal changes of  $A_T$ , which originate from analytical problems (drifts and sudden changes of responses of electrodes used, etc), were monitored by measuring  $A_T$  of CRM. For example, discontinuous changes of  $A_T$  are illustrated in [Figure. 3.6.1](#). Based on averaged and certified values of  $A_T$  of CRM, we re-calculated normality of HCl. Using the re-calibrated normality, we re-calculated  $A_T$  of seawater samples. By this procedure, we could

obtain  $A_T$  values, which are comparable to CRM.

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

The average and standard deviation of absolute values of differences in  $A_T$  analyzed consecutively were 2.1 and 1.9  $\mu\text{mol kg}^{-1}$  ( $n = 123$ ), 1.9 and 1.5  $\mu\text{mol kg}^{-1}$  ( $n = 203$ ) and 2.2 and 1.9  $\mu\text{mol kg}^{-1}$  ( $n = 20$ ) for Leg.1, 2 and 3, respectively.

To evaluate the accuracy of measured  $A_T$ , we compared vertical profiles of  $A_T$  measured in MR05-05 with  $A_T$  calculated from  $C_T$  and pH measured in MR05-05, and with  $A_T$  measured at a station of other WOCE lines crossing the P3 line. Results for cross station with the WOCE P16 line along 153°W are shown in [Figure. 3.6.2](#). From this figure, it is found that  $A_T$  measured in this cruise were sufficiently accurate. Together with other comparisons, we estimated the accuracy to be  $3 - 2 \mu\text{mol kg}^{-1}$ .

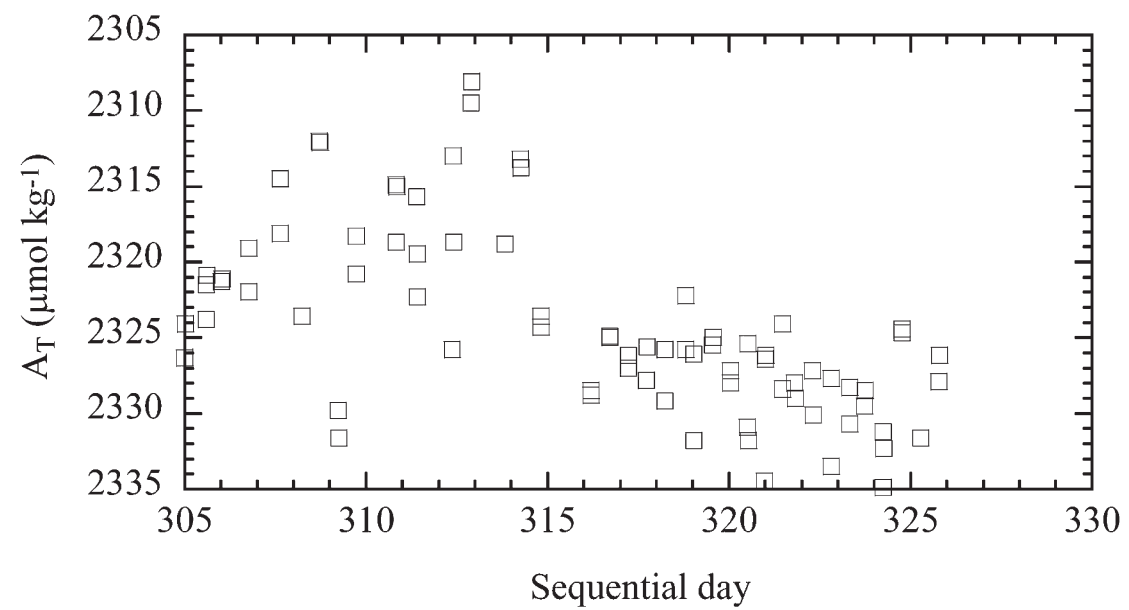


Figure 3.6.1. RM measurements during Leg.1, which illustrate discontinuous changes at about 315 sequential day.

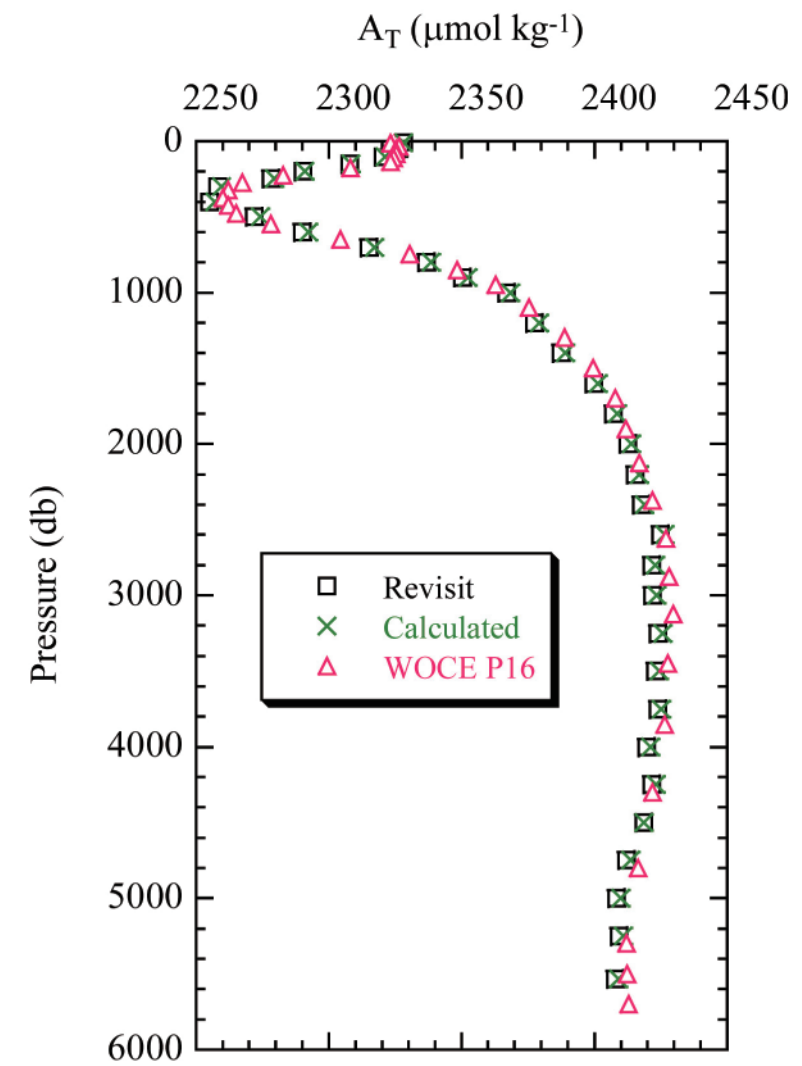


Figure 3.6.2. Comparison of vertical profiles of  $A_T$  measured in MR05-05 with  $A_T$  calculated from  $C_T$  and pH measured also in MR05-05 and with  $A_T$  measured in WOCE P16 revisit cruise conducted in 2006.



## 3.7 pH

*July 19, 2007*

### (1) Personnel

*Akihiko Murata* (JAMSTEC)

*Fuyuki Shibata* (MWJ)

*Taeko Ohama* (MWJ)

### (2) Introduction

Concentrations of CO<sub>2</sub> in the atmosphere are currently increasing at a rate of 1.5 ppmv y<sup>-1</sup> 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 increasing atmospheric CO<sub>2</sub>, as well as to clarify the mechanism of the CO<sub>2</sub> absorption, because the magnitude of the anticipated global warming depends on the levels of CO<sub>2</sub> in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In this cruise (MR05-05, revisit of WOCE P3 line), we aimed to quantify how much anthropogenic CO<sub>2</sub> absorbed in North Pacific Intermediate Water, which is one of the characteristic waters in the North Pacific. For the purpose, we measured CO<sub>2</sub>-system properties such as dissolved inorganic carbon (C<sub>T</sub>), total alkalinity (A<sub>T</sub>), pH and underway pCO<sub>2</sub>.

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

### (3) Apparatus

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

Seawater is transferred from borosilicate glass bottle (300 ml) to a sample cell in the spectrophotometer. The length and volume of the cell are 8 cm and 13 ml, respectively, and the sample cell was kept at 25.00 ± 0.05° C in a thermostated compartment. First, absorbance of seawater only is measured at three wavelengths (730, 578 and 434 nm). Then an indicator is injected and circulated for about 4 minutes to mix with seawater sufficiently. After the pump is stopped, the absorbance of seawater + indicator is measured at the same wavelengths.

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

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

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

### (4) Shipboard measurement

#### *Sampling*

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

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

#### *Analysis*

For indicator solution, *m*-cresol purple (2 mM) was used. The indicator solution was produced on board the

ship, and retained in a 1,000 ml DURAN® laboratory bottle. We renewed 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 indicator solution sufficiently under no headspace condition. However, by circulating the mixed solution with a peristaltic pump, a well-mixed condition came to be obtained rather shortly, leading to a rapid stabilization of absorbance. We renewed a TYGON® tube of a peristaltic pump periodically, when a tube deteriorated.

Absorbance of seawater only and that of seawater + indicator solutions were measured 15 times for each, and the averages computed from the last five values of the absorbance were used for pH calculation (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 absorbance of seawater only and that of seawater + indicator solution were infrequently greater than  $\pm 0.001$ . This implies dirt of the cell. In this case, we cleaned or replaced the cell.

## (5) Quality control

Correction for pH change resulting from addition of indicator solutions is recommended (DOE, 1994). To check the perturbation of pH due to the addition, we measured absorbance ratios by doubling the volume of indicator solutions added to a same seawater sample. We corrected absorbance ratios based on an empirical method (DOE, 1994). [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 pH value.

The average and standard deviation of absolute values of differences of pH analyzed consecutively were 0.0007 and 0.0012 pH unit (n = 163), 0.0007 and 0.0006 pH unit (n = 255), and 0.0009 and 0.0009 (n = 36) for Leg.1, 2 and 3, respectively.

All values are reported in total pH scale.

## References

- Clayton T.D. & 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).

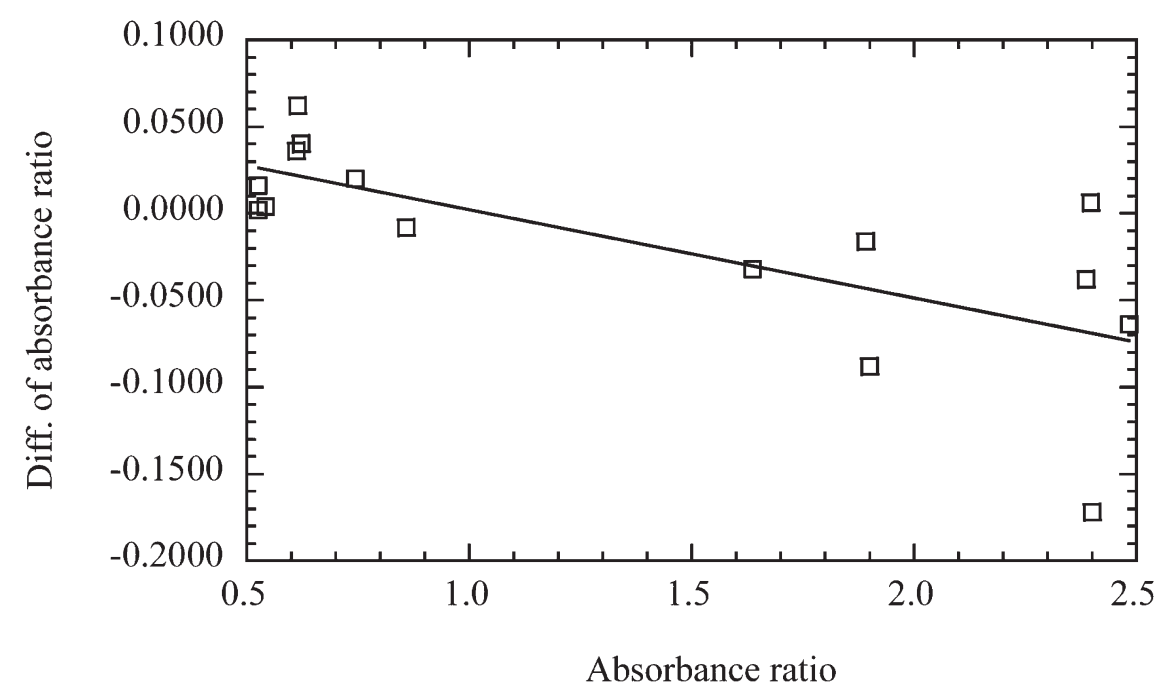


Figure 3.7.1. Perturbation of absorbance ratios by adding indicator solutions. The line ( $y = -0.0509x + 0.0529$ ,  $R^2 = 0.510$ ) was determined by the method of least squares.

### 3.8 Chlorofluorocarbons (CFCs)

October 3, 2007

#### (1) Personnel

<i>Ken'ichi Sasaki</i>	<i>(JAMSTEC)</i>
<i>Masahide Wakita</i>	<i>(JAMSTEC)</i>
<i>Shuichi Watanabe</i>	<i>(JAMSTEC)</i>
<i>Katsunori Sagishima</i>	<i>(MWJ)</i>
<i>Yuichi Sonoyama</i>	<i>(MWJ)</i>
<i>Hideki Yamamoto</i>	<i>(MWJ)</i>
<i>Keisuke Wataki</i>	<i>(MWJ)</i>
<i>Masanori Enoki</i>	<i>(MWJ)</i>

#### (2) Introduction

Chlorofluorocarbons (CFCs) are completely man-made compounds that are chemically and biologically stable gasses in the environment. The CFCs have been accumulated in the atmosphere since 1930's (Walker et al., 2000). The atmospheric CFCs can slightly dissolve in sea surface water and then penetrated into the ocean interior by water circulation. The dissolved CFC concentrations in sea water have been used as transient tracers for the ocean circulation with times scale on the order of decades.

In this cruise, we determined the concentrations of three CFC species, CFC-11 ( $\text{CCl}_3\text{F}$ ), CFC-12 ( $\text{CCl}_2\text{F}_2$ ) and CFC-113 ( $\text{C}_2\text{Cl}_3\text{F}_3$ ).

#### (3) Apparatus

Dissolved CFCs were measured by a method modified from the original design of Bullister and Weiss (1988). Two analytical systems were used in this cruise. A custom made purging and trapping system was attached to

gas chromatograph (GC-14B: Shimadzu Ltd). Stainless steel packed column ("1/8 OD tubing, 100-120 mesh Porapak T® packed 5cm) was used as a cold trap. Silica Plot capillary column [i.d.: 0.53 mm, length: 4 m, tick: 0.25  $\mu\text{m}$ ] and a tandem capillary column (Pola Bond-Q [i.d.: 0.53 mm, length: 7 m, tick: 6.0  $\mu\text{m}$ ] followed by Silica Plot [i.d.: 0.53 mm, length: 22 m, tick: 0.25  $\mu\text{m}$ ]) was used as a pre-column and main column, respectively. Each CFC was detected by an electron capture detector (ECD-14: Shimadzu Ltd).

#### (4) Shipboard measurement

##### *Sampling*

Seawater sub-samples for CFC measurements were collected from 12 liter Niskin bottles to 300 ml sub-sampling glass bottles which were developed for CFC analyses in JAMSTEC. The sub-sampling bottles have stainless steel union altered from original design of Swagelok® on the end of the bottle. A 6 mm OD glass tube goes through the union into the bottle interior and reaches to near the bottom of bottle. A small plastic stop valve was on the upper end of glass tube. The bottles were filled by nitrogen gas before sampling. The stop valve was connected to Niskin bottle. The sub-sample was introduced from the bottom. Two times of the bottle volumes of seawater sample were overflowed from vent valve put on side of the union and then the all valves closed from downstream. The bottles filled by seawater sample were kept in water bathes roughly controlled on sample temperature. The CFC concentrations were determined as soon as possible after sampling. These procedures were needed in order to minimize contamination from atmospheric CFCs.

##### *Analysis*

The CFCs analytical system is modified from the original design of Bullister and Weiss (1988). Analytical conditions are listed in [Table 3.8.1](#). Constant volume of sample water (50 ml) is taken into the purging & trapping system. Dissolved CFCs are de-gassed by  $\text{N}_2$  gas purge and concentrated in a cold trap column. The CFCs are desorbed by electrically heating the trap column, and lead into the pre-column. CFCs and other compounds are roughly separated in the pre-column. The pre-column is switched to cleaning line and flushed back by counter

flow of pure nitrogen gas when CFCs completely go through pre-column. The back flush system is prevent to enter any compounds that have higher retention time than CFC-113 into main analytical column and permits short time analysis. CFCs which are sent into main column are separated further and detected by an electron capture detector (ECD).

Gas loops that the 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 CPB28620, CPB30532 and CPB30528 for working gases and CPB30524 for reference gas were used for calibration. Mixing ratios of the standard gasses were calculated by gravimetric data (Table 3.8.2). 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 after calibrations of the standard gasses.

Table 3.8.1. Analytical conditions of dissolved CFCs in seawater.

Temperature	
Column oven:	95 °C (Constant)
Detector (ECD):	240 °C
Trap column:	-45 °C (at adsorbing) & 140 °C (at desorbing)
Mass flow rate of nitrogen gas	
Carrier gas:	15 ml/min
Detector make-up gas:	22 ml/min
Back flush gas:	>15 ml/min
Sample purge gas:	150 ml/min

Table 3.8.2. CFC mixing ratios of standard gasses.

Cylinder	CFC-11	CFC-12	CFC-113	Application
	pptv			
CPB28620	301	169	50.3	Working gas for Leg.2 & 3
CPB30524	300	159	30.2	Reference gas for all Legs
CPB30528	300	158	29.9	Working gas for Leg.2
CPB30532	300	158	29.9	Working gas for Leg.1 & 2

(5) 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. CFC concentrations in deep water which was one of oldest water masses of the ocean were low but not zero for CFC-11 and -12. Average concentrations of CFC-11, 12 in denser water than 27.6 sigma-0 were 0.022 ± 0.008 (n = 1430), 0.009 ± 0.004 (n = 1379). These values were assumed as sampling blanks which was contaminations from Niskin bottle and/or during sub-sampling and were subtracted from all data.

Concentration of CFC-113 in deep water mass is less than detection limit at about half of stations but significant blank had been found in other stations(0.006 ± 0.003 pmol kg<sup>-1</sup> in average (n = 773)). Cause of the blank was unknown. In this case, mean value in deep water samples at each station was considered to be blank for analysis at the station and was subtracted from measurements.

*Interfering compound for CFC-113 analysis*

A large and broad peak was interfered determining CFC-113 peak area for samples collected from surface layer. 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. The precisions were estimated by two methods. One (A) is estimated by following equation,  $s = (S(DC^2)/(2n-1))^{0.5}$ , where DC is difference between replicate analyses. Another (B) is average difference of replicate analyses (with standard deviation, SD). Precisions estimated from former equation were 0.006 (n = 377), 0.004 (n = 376) and 0.004 (n = 298) pmol kg<sup>-1</sup> for CFC-11, -12 and -113 determinations. These from latter were 0.006 (SD=0.007), 0.004 (0.004) and 0.004 (0.005) pmol kg<sup>-1</sup> for CFC-11, -12 and -113 determinations.

### **References**

- 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<sub>3</sub>F and CCl<sub>2</sub>F<sub>2</sub> in seawater and air. *Deep Sea Research*, **35**, 839-853 (1988).

### 3.9 LADCP(Lowered Acoustic Doppler Current Profiler)

September 3, 2007

#### (1) Personnel

<i>Shinya Kouketsu</i>	<i>(JAMSTEC)</i>
<i>Ikuo Kaneko</i>	<i>(JAMSTEC)</i>
<i>Shuichi Watanabe</i>	<i>(JAMSTEC)</i>
<i>Hiroshi Uchida</i>	<i>(JAMSTEC)</i>
<i>Takayoshi Seike</i>	<i>(MWJ)</i>

#### (2) Instrument and method

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

One ping raw data were recorded. From Sta. 1 to St. 48, a bin length was set to 16 m. The bin length of 8m was used from Sta. 50. A total of 79, 126 and 31 operations were made with CTD observations in Leg.1 from San Diego to Honolulu, in Leg.2 from Honolulu to Nakagusuku, and in Leg.3 from Nakagusuku to Sekinehama, respectively. Since the pressure resistance of the instrument is 6,500 dbar, the instrument was detached on the CTD/RMS frame at Stas. 223, 293, 353 and 357 where the depth was deeper than about 6,000 dbar. The performance of the LADCP instrument was not good from Sta. 1 to Sta. 110 in Leg.1. The data near the bottom were often missed. We replaced the Serial Number (SN) 2553 of the instruments with the SN 1512 of it from Sta. 112. The performance was improved. Profiles of the area over 100 m distance from LADCP in shallow depths and of the area to almost 60 m in deeper depths were obtained. Echo intensity was weak between stations 351 and 367. Backscatters might be especially too few in this section.

#### (3) Data process and result

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

Error velocities estimated by the inversion are small values of 0.05 – 0.2 m/s, but the typical value of the surface currents is about 0.2 m/s in this section. It may be difficult to describe the detailed structure of currents by using these values. In Leg.3 (Okinawa trough, Tokara strait, and Tsushima strait cross sections), small error velocities (less than 10 cm/s) were estimated.

Velocities using bottom tracks were 5 – 10 cm/s. The large bottom flow of about 15 cm/s was observed near the shore of the United States. The errors of 0.5 - 2 cm/s were quite small. It is sufficient to detect the bottom current. The velocities near the bottom are not shown in Leg.3, since the depths were shallow and the inversion errors were sufficient small all through the water columns.

#### 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.



49MR0505\_1.sum file

P03 REV R/V MIRAI CRUISE MR0505 LEG 1																		
SHIP/CRS	WOCE	CAST		UTC		EVENT		POSITION			UNC	COR	HT	ABOVE	WIRE	MAX	NO. OF	COMMENTS
EXPCODE	SECT	STNNBR	CASTNO	TYPE	DATE	TIME	CODE	LATITUDE	LONGITUDE	NAV	DEPTH	DEPTH	BOTTOM	OUT	PRESS	BOTTLES	PARAMETERS	
49MR0505_1	P03	1	1	ROS	103105	1856	BE 32	39.14 N	117 19.93 W	GPS	110	110						
49MR0505_1	P03	1	1	BUC	103105	1859	UN 32	39.11 N	117 19.88 W	GPS	108	108					1,33	16.1C
49MR0505_1	P03	1	1	UNK	103105	1859	UN 32	39.11 N	117 19.88 W	GPS	108	108						AIR N2O SMPL
49MR0505_1	P03	1	1	ROS	103105	1902	BO 32	39.08 N	117 19.85 W	GPS	107	108		9	92	95	3 1-8,27	
49MR0505_1	P03	1	1	ROS	103105	1909	EN 32	39.02 N	117 19.84 W	GPS	108	108						
49MR0505_1	P03	2	1	ROS	103105	1947	BE 32	38.38 N	117 25.88 W	GPS	150	151						
49MR0505_1	P03	2	1	BUC	103105	1948	UN 32	38.38 N	117 25.89 W	GPS	150	151					1	17.5C
49MR0505_1	P03	2	1	ROS	103105	1954	BO 32	38.32 N	117 25.95 W	GPS	150	151		7	138	140	4 1-8,27	
49MR0505_1	P03	2	1	ROS	103105	2006	EN 32	38.19 N	117 25.97 W	GPS	151	151						
49MR0505_1	P03	3	1	ROS	103105	2114	BE 32	37.02 N	117 30.16 W	GPS	1192	1191						
49MR0505_1	P03	3	1	BUC	103105	2121	UN 32	36.94 N	117 30.19 W	GPS	1192	1191					1,31,33	18.2C
49MR0505_1	P03	3	1	UNK	103105	2121	UN 32	36.94 N	117 30.19 W	GPS	1192	1191						AIR N2O SMPL
49MR0505_1	P03	3	1	ROS	103105	2139	BO 32	36.80 N	117 30.27 W	GPS	1193	1192		10	1189	1189	22 1-8,23,24,26,27,31,33,64,81	#2 AT OXYCLINE
49MR0505_1	P03	3	1	ROS	103105	2235	EN 32	36.31 N	117 30.55 W	GPS	1206	1204						
49MR0505_1		501	1	UNK	103105	2255	UN 32	36.41 N	117 32.06 W	GPS	1203	1204						AEROSOL SMPL
49MR0505_1	P03	4	1	ROS	110105	0002	BE 32	38.39 N	117 40.54 W	GPS	1048	1047						
49MR0505_1	P03	4	1	BUC	110105	0010	UN 32	38.31 N	117 40.60 W	GPS	1023	1031					1	18.4C
49MR0505_1	P03	4	1	ROS	110105	0027	BO 32	38.25 N	117 40.76 W	GPS	973	971		8	984	994	14 1-8,27	
49MR0505_1	P03	4	1	ROS	110105	0116	EN 32	37.86 N	117 41.01 W	GPS	968	970						
49MR0505_1	P03	6	1	ROS	110105	0246	BE 32	31.70 N	118 1.83 W	GPS	1895	1888						
49MR0505_1	P03	6	1	BUC	110105	0254	UN 32	31.61 N	118 1.75 W	GPS	1909	1906					1,33	17.9C
49MR0505_1	P03	6	1	UNK	110105	0254	UN 32	31.61 N	118 1.75 W	GPS	1909	1906						AIR N2O SMPL
49MR0505_1	P03	6	1	ROS	110105	0322	BO 32	31.33 N	118 1.61 W	GPS	1877	1883		9	1883	1866	19 1-8,23,24,26,27	
49MR0505_1	P03	6	1	ROS	110105	0436	EN 32	30.58 N	118 1.66 W	GPS	1880	1877						
49MR0505_1	P03	8	1	ROS	110105	1758	BE 32	21.83 N	118 20.31 W	GPS	637	639						
49MR0505_1	P03	8	1	BUC	110105	1800	UN 32	21.85 N	118 20.30 W	GPS	638	638					1,33	17.9C
49MR0505_1	P03	8	1	UNK	110105	1800	UN 32	21.85 N	118 20.30 W	GPS	638	638						AIR N2O SMPL
49MR0505_1	P03	8	1	ROS	110105	1814	BO 32	21.94 N	118 20.17 W	GPS	677	677		12	664	669	11 1-8,23,24,26,27	
49MR0505_1	P03	8	1	ROS	110105	1847	EN 32	22.08 N	118 19.87 W	GPS	718	715						
49MR0505_1	P03	10	1	ROS	110105	2044	BE 32	9.19 N	118 45.83 W	GPS	1314	1314						
49MR0505_1	P03	10	1	BUC	110105	2053	UN 32	9.14 N	118 45.71 W	GPS	1304	1303					1,33	18.4C
49MR0505_1	P03	10	1	UNK	110105	2053	UN 32	9.14 N	118 45.71 W	GPS	1304	1303						AIR N2O SMPL
49MR0505_1	P03	10	1	ROS	110105	2110	BO 32	8.97 N	118 45.65 W	GPS	1288	1300		10	1314	1303	16 1-8,27	
49MR0505_1	P03	10	1	ROS	110105	2203	EN 32	8.39 N	118 45.48 W	GPS	1276	1270						
49MR0505_1		502	1	UNK	110105	2217	UN 32	7.50 N	118 47.20 W	GPS	1251	1269						AEROSOL SMPL
49MR0505_1	P03	12	1	ROS	110205	0011	BE 31	54.62 N	119 15.44 W	GPS	1460	1459						
49MR0505_1	P03	12	1	BUC	110205	0018	UN 31	54.55 N	119 15.48 W	GPS	1414	1413					1,33	18.4C
49MR0505_1	P03	12	1	UNK	110205	0018	UN 31	54.55 N	119 15.48 W	GPS	1414	1413						AIR N2O SMPL
49MR0505_1	P03	12	1	ROS	110205	0041	BO 31	54.34 N	119 15.49 W	GPS	1293	1287		11	1364	1365	16 1-8,23,24,26,27	
49MR0505_1	P03	12	1	ROS	110205	0132	EN 31	53.92 N	119 15.53 W	GPS	1108	1106						
49MR0505_1	P03	14	1	ROS	110205	0250	BE 31	51.16 N	119 21.53 W	GPS	1575	1580						
49MR0505_1	P03	14	1	BUC	110205	0258	UN 31	51.09 N	119 21.56 W	GPS	1639	1633					1	17.9C
49MR0505_1	P03	14	1	ROS	110205	0323	BO 31	50.89 N	119 21.60 W	GPS	1736	1741		14	1691	1694	18 1-8,23,24,26,27	#5-6 FILTRATED SEAWATER SAMPLE

109

49MR0505_1	P03	33	1	BUC	110405	0649	UN	28	35.15	N	124	30.68	W	GPS	4351	4354				1			19.8C
49MR0505_1	P03	33	1	ROS	110405	0751	BO	28	35.07	N	124	31.33	W	GPS	4334	4333	9	4403	4413	29	1-8,27		#12 MISS FIRE
49MR0505_1	P03	33	1	ROS	110405	0941	EN	28	35.28	N	124	32.35	W	GPS	4318	4321							
49MR0505_1	P03	34	1	ROS	110405	1246	BE	28	6.15	N	125	7.49	W	GPS	4318	4319							
49MR0505_1	P03	34	1	BUC	110405	1254	UN	28	6.14	N	125	7.58	W	GPS	4310	4316				1,33			20.7C
49MR0505_1	P03	34	1	UNK	110405	1300	UN	28	6.15	N	125	7.65	W	GPS	4300	4303							AIR N2O SMPL
49MR0505_1	P03	34	1	ROS	110405	1356	BO	28	6.13	N	125	8.28	W	GPS	4289	4295	9	4359	4363	30	1-8,23,24,26,27		
49MR0505_1	P03	34	1	ROS	110405	1555	EN	28	6.25	N	125	9.20	W	GPS	4154	4154							
49MR0505_1	P03	36	1	ROS	110405	1904	BE	27	35.94	N	125	45.65	W	GPS	4409	4414							
49MR0505_1	P03	36	1	BUC	110405	1911	UN	27	35.95	N	125	45.70	W	GPS	4418	4423				1,33			20.1C
49MR0505_1	P03	36	1	UNK	110405	1919	UN	27	35.95	N	125	45.75	W	GPS	4418	4437							AIR N2O SMPL
49MR0505_1	P03	36	1	UNK	110405	2011	BE	27	35.88	N	125	46.16	W	GPS	4493	4489							80L THROUGH HULL PUMP FOR R.N.
49MR0505_1	P03	36	1	ROS	110405	2016	BO	27	35.88	N	125	46.16	W	GPS	4493	4494	9	4481	4521	33	1-8,22,27		
49MR0505_1	P03	36	1	UNK	110405	2022	EN	27	35.87	N	125	46.20	W	GPS	4493	4494							
49MR0505_1	P03	36	1	ROS	110405	2211	EN	27	35.59	N	125	46.95	W	GPS	4488	4484							
49MR0505_1		505	1	UNK	110405	2229	UN	27	34.09	N	125	49.21	W	GPS	4511	4521							AEROSOL SMPL
49MR0505_1	P03	38	1	ROS	110505	0106	BE	27	9.13	N	126	22.65	W	GPS	4353	4356							
49MR0505_1	P03	38	1	BUC	110505	0114	UN	27	9.07	N	126	22.68	W	GPS	4346	4348				1,33			20.9C
49MR0505_1	P03	38	1	UNK	110505	0121	UN	27	9.05	N	126	22.71	W	GPS	4348	4348							AIR N2O SMPL
49MR0505_1	P03	38	1	ROS	110505	0215	BO	27	8.88	N	126	22.93	W	GPS	4383	4385	11	4355	4402	30	1-8,12,13,23,24,26,27		#19 MISS TRIP
49MR0505_1	P03	38	1	ROS	110505	0411	EN	27	8.60	N	126	23.90	W	GPS	4437	4432							
49MR0505_1	P03	40	1	ROS	110505	0709	BE	26	39.58	N	126	57.24	W	GPS	4317	4324							
49MR0505_1	P03	40	1	BUC	110505	0715	UN	26	39.61	N	126	57.35	W	GPS	4322	4329				1			20.6C
49MR0505_1	P03	40	1	ROS	110505	0819	BO	26	40.00	N	126	58.08	W	GPS	4524	4522	9	4504	4459	31	1-8,27		#1=#2 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	40	1	ROS	110505	1012	EN	26	40.65	N	126	58.68	W	GPS	4684	4684							
49MR0505_1	P03	42	1	ROS	110505	1322	BE	26	10.69	N	127	34.52	W	GPS	4629	4628							
49MR0505_1	P03	42	1	BUC	110505	1331	UN	26	10.72	N	127	34.67	W	GPS	4628	4627				1,31,33			20.4C
49MR0505_1	P03	42	1	UNK	110505	1351	UN	26	10.78	N	127	34.97	W	GPS	4611	4597							AIR N2O SMPL
49MR0505_1	P03	42	1	ROS	110505	1438	BO	26	10.97	N	127	35.56	W	GPS	4545	4554	8	4721	4668	36	1-8,23,24,26,27,31,33,64,81		#2 AT OXYCLINE
49MR0505_1	P03	42	1	ROS	110505	1646	EN	26	11.01	N	127	37.21	W	GPS	4555	4549							
49MR0505_1	P03	42	2	UNK	110505	1646	UN	26	11.01	N	127	37.21	W	GPS	4555	4549							AIR CH4 SMPL
49MR0505_1	P03	44	1	ROS	110505	1955	BE	25	40.98	N	128	11.85	W	GPS	4280	4276							
49MR0505_1	P03	44	1	BUC	110505	2002	UN	25	41.01	N	128	11.90	W	GPS	4292	4278				1,33			21.0C
49MR0505_1	P03	44	1	UNK	110505	2008	UN	25	41.06	N	128	11.94	W	GPS	4267	4266							AIR N2O SMPL
49MR0505_1	P03	44	1	ROS	110505	2106	BO	25	41.23	N	128	12.48	W	GPS	4208	4206	9	4264	4277	30	1-8,27		#1=#3 (B-10) DUPLICATE SMPLS
49MR0505_1		506	1	UNK	110505	2156	UN	25	41.36	N	128	12.75	W	GPS	4347	4335							AEROSOL SMPL
49MR0505_1	P03	44	1	ROS	110505	2301	EN	25	41.56	N	128	13.38	W	GPS	4466	4464							
49MR0505_1	P03	46	1	ROS	110605	0400	BE	25	12.87	N	128	48.79	W	GPS	4744	4743							
49MR0505_1	P03	46	1	BUC	110605	0407	UN	25	12.86	N	128	48.88	W	GPS	4741	4704				1,33			21.0C
49MR0505_1	P03	46	1	UNK	110605	0420	UN	25	12.82	N	128	49.02	W	GPS	4741	4743							AIR N2O SMPL
49MR0505_1	P03	46	1	ROS	110605	0515	BO	25	12.86	N	128	49.47	W	GPS	4669	4675	8	4775	4804	32	1-8,23,24,26,27		
49MR0505_1	P03	46	1	ROS	110605	0720	EN	25	13.49	N	128	50.32	W	GPS	4547	4546							
49MR0505_1	P03	48	1	ROS	110605	1032	BE	24	42.70	N	129	24.94	W	GPS	4500	4500							
49MR0505_1	P03	48	1	BUC	110605	1040	UN	24	42.75	N	129	25.00	W	GPS	4501	4500				1			21.4C
49MR0505_1	P03	48	1	ROS	110605	1143	BO	24	43.05	N	129	25.41	W	GPS	4478	4484	9	4523	4556	32	1-8,27		#1=#4 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	48	1	ROS	110605	1347	EN	24	43.01	N	129	26.16	W	GPS	4491	4486							
49MR0505_1	P03	50	1	ROS	110605	1648	BE	24	15.44	N	130	1.79	W	GPS	4613	4614							
49MR0505_1	P03	50	1	BUC	110605	1656	UN	24	15.47	N	130	1.85	W	GPS	4616	4619				1,33			21.1C
49MR0505_1	P03	50	1	UNK	110605	1659	UN	24	15.47	N	130	1.88	W	GPS	4626	4626							AIR N2O SMPL

49MR0505_1	P03	50	1	ROS	110605	1800	BO	24	15.51	N	130	2.31	W	GPS	4614	4614	9	4635	4684	35	1-8,22,27	#1=#5 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	50	1	UNK	110605	1806	BE	24	15.51	N	130	2.31	W	GPS	4614	4624						80L THROUGH HULL PUMP FOR R.N.
49MR0505_1	P03	50	1	UNK	110605	1824	EN	24	15.51	N	130	2.31	W	GPS	4614	4611						
49MR0505_1	P03	50	1	ROS	110605	2008	EN	24	15.58	N	130	3.17	W	GPS	4644	4640						
49MR0505_1		507	1	UNK	110605	2212	UN	24	15.32	N	130	35.75	W	GPS	4872	4873						AEROSOL SMPL
49MR0505_1	P03	51	1	ROS	110605	2310	BE	24	15.62	N	130	49.99	W	GPS	4725	4726						
49MR0505_1	P03	51	1	BUC	110605	2317	UN	24	15.59	N	130	50.06	W	GPS	4742	4742				1,33		21.9C
49MR0505_1	P03	51	1	UNK	110605	2322	UN	24	15.59	N	130	50.11	W	GPS	4754	4744						AIR N2O SMPL
49MR0505_1	P03	51	1	ROS	110705	0024	BO	24	15.55	N	130	50.83	W	GPS	4747	4758	10	4826	4821	32	1-8,12,13,23,24,26,27	#1=#6 (B-10) DUPLICATE SMPLS, #28 MISS FIRE
49MR0505_1	P03	51	1	ROS	110705	0228	EN	24	15.71	N	130	51.90	W	GPS	4758	4756						
49MR0505_1	P03	53	1	ROS	110705	0532	BE	24	16.29	N	131	39.16	W	GPS	4692	4694						
49MR0505_1	P03	53	1	BUC	110705	0539	UN	24	16.31	N	131	39.17	W	GPS	4696	4694				1,33		21.6C
49MR0505_1	P03	53	1	UNK	110705	0547	UN	24	16.30	N	131	39.20	W	GPS	4696	4693						AIR N2O SMPL
49MR0505_1	P03	53	1	ROS	110705	0643	BO	24	16.31	N	131	39.38	W	GPS	4695	4694	9	4693	4761	32	1-8,27	#1=#7 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	53	1	ROS	110705	0845	EN	24	16.14	N	131	39.95	W	GPS	4681	4677						
49MR0505_1	P03	55	1	ROS	110705	1149	BE	24	14.79	N	132	25.84	W	GPS	4625	4625						
49MR0505_1	P03	55	1	BUC	110705	1157	UN	24	14.81	N	132	25.86	W	GPS	4642	4626				1		21.5C
49MR0505_1	P03	55	1	ROS	110705	1304	BO	24	14.71	N	132	26.11	W	GPS	4626	4625	10	4646	4701	32	1-8,27	#1=#8 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	55	1	ROS	110705	1515	EN	24	14.46	N	132	26.73	W	GPS	4642	4670						
49MR0505_1	P03	56	1	ROS	110705	1820	BE	24	15.42	N	133	14.25	W	GPS	4874	4866						
49MR0505_1	P03	56	1	BUC	110705	1827	UN	24	15.37	N	133	14.28	W	GPS	4863	4865				1,31,33,82		21.4C
49MR0505_1	P03	56	1	UNK	110705	1832	UN	24	15.36	N	133	14.31	W	GPS	4873	4864						AIR N2O SMPL
49MR0505_1	P03	56	1	ROS	110705	1935	BO	24	15.22	N	133	14.66	W	GPS	4860	4857	9	4881	4938	33	1-8,23,24,26,27,31,33,82	#1=#9 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	56	1	ROS	110705	2139	EN	24	14.91	N	133	15.38	W	GPS	4841	4840						
49MR0505_1		508	1	UNK	110705	2225	UN	24	14.75	N	133	25.90	W	GPS	4882	4872						AEROSOL SMPL
49MR0505_1	P03	58	1	ROS	110805	0045	BE	24	15.06	N	134	2.78	W	GPS	4796	4804						
49MR0505_1	P03	58	1	BUC	110805	0052	UN	24	15.00	N	134	2.80	W	GPS	4808	4798				1,33		21.8C
49MR0505_1	P03	58	1	UNK	110805	0058	UN	24	14.95	N	134	2.83	W	GPS	4815	4809						AIR N2O SMPL
49MR0505_1	P03	58	1	ROS	110805	0159	BO	24	14.60	N	134	3.16	W	GPS	4842	4831	10	4866	4907	33	1-8,27	#1=#10 (B-10) DUPLICATE SMPLS
49MR0505_1		509	1	UNK	110805	0300	UN	24	14.18	N	134	3.43	W	GPS	4842	4845						RAIN SMPL (0.3MM/HR)
49MR0505_1	P03	58	1	ROS	110805	0407	EN	24	13.60	N	134	4.21	W	GPS	4843	4843						
49MR0505_1	P03	X17	1	ROS	110805	0748	BE	23	59.89	N	135	0.10	W	GPS	4858	4867						
49MR0505_1	P03	X17	1	BUC	110805	0756	UN	23	59.80	N	135	0.20	W	GPS	4875	4868				1		22.0C
49MR0505_1	P03	X17	1	ROS	110805	0904	BO	23	59.80	N	135	0.63	W	GPS	4841	4842	9	4865	4926	33	1-8,12,13,23,24,26,27	#1=#11 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	X17	1	ROS	110805	1107	EN	23	59.85	N	135	1.68	W	GPS	4824	4824						
49MR0505_1	P03	62	1	ROS	110805	1433	BE	24	15.15	N	135	37.46	W	GPS	4491	4500						
49MR0505_1	P03	62	1	BUC	110805	1444	UN	24	15.24	N	135	37.57	W	GPS	4497	4492				1,33		21.7C
49MR0505_1	P03	62	1	UNK	110805	1449	UN	24	15.26	N	135	37.64	W	GPS	4478	4474						AIR N2O SMPL
49MR0505_1	P03	62	1	ROS	110805	1550	BO	24	15.47	N	135	37.98	W	GPS	4462	4472	10	4487	4537	31	1-8,27	#1=#12 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	62	1	ROS	110805	1758	EN	24	15.96	N	135	39.74	W	GPS	4442	4438						
49MR0505_1	P03	64	1	ROS	110805	2110	BE	24	14.13	N	136	26.57	W	GPS	4450	4461						
49MR0505_1	P03	64	1	BUC	110805	2120	UN	24	14.25	N	136	26.64	W	GPS	4459	4462				1,33		22.1C
49MR0505_1	P03	64	1	UNK	110805	2133	UN	24	14.38	N	136	26.74	W	GPS	4417	4425						AIR N2O SMPL
49MR0505_1	P03	64	1	ROS	110805	2229	BO	24	14.74	N	136	27.37	W	GPS	4272	4293	10	4492	4459	31	1-8,23,24,26,27	#1=#13 (B-10) DUPLICATE SMPLS
49MR0505_1		510	1	UNK	110805	2237	UN	24	14.81	N	136	27.46	W	GPS	4287	4287						AEROSOL SMPL
49MR0505_1	P03	64	1	ROS	110905	0037	EN	24	15.28	N	136	28.65	W	GPS	4593	4589						
49MR0505_1	P03	66	1	ROS	110905	0336	BE	24	14.14	N	137	13.14	W	GPS	4841	4840						
49MR0505_1	P03	66	1	BUC	110905	0346	UN	24	14.10	N	137	13.19	W	GPS	4840	4835				1,33		22.0C
49MR0505_1	P03	66	1	UNK	110905	0353	UN	24	14.07	N	137	13.22	W	GPS	4840	4830						AIR N2O SMPL

49MR0505_1	P03	66	1	ROS	110905	0454	BO	24	14.08	N	137	13.84	W	GPS	4838	4828	9	4909	4900	33	1-8,27	#1=#14 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	66	1	ROS	110905	0702	EN	24	14.44	N	137	15.01	W	GPS	4827	4832						
49MR0505_1	P03	67	1	ROS	110905	0958	BE	24	13.86	N	137	59.86	W	GPS	4894	4894						
49MR0505_1	P03	67	1	BUC	110905	1006	UN	24	13.86	N	137	59.97	W	GPS	4914	4904				1		22.5C
49MR0505_1	P03	67	1	ROS	110905	1117	BO	24	14.17	N	138	0.53	W	GPS	4942	4944	10	4990	5012	33	1-8,27	#1=#15 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	67	1	ROS	110905	1333	EN	24	14.68	N	138	1.32	W	GPS	4958	4957						
49MR0505_1	P03	69	1	ROS	110905	1634	BE	24	14.60	N	138	47.98	W	GPS	5169	5171						
49MR0505_1	P03	69	1	BUC	110905	1644	UN	24	14.66	N	138	48.13	W	GPS	5172	5173				1,31,33		22.4C
49MR0505_1	P03	69	1	UNK	110905	1650	UN	24	14.71	N	138	48.19	W	GPS	5168	5174						AIR N2O SMPL
49MR0505_1	P03	69	1	ROS	110905	1756	BO	24	14.94	N	138	48.19	W	GPS	5174	5180	10	5178	5255	34	1-8,23,24,26,27,31,33	#1=#16 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	69	1	ROS	110905	2014	EN	24	15.49	N	138	48.77	W	GPS	5187	5190						
49MR0505_1	P03	69	2	UNK	110905	2014	UN	24	15.49	N	138	48.77	W	GPS	5187	5190						AIR CH4 SMPL
49MR0505_1	P03	71	1	ROS	110905	2332	BE	24	14.67	N	139	37.38	W	GPS	4691	4696						
49MR0505_1		511	1	UNK	110905	2338	UN	24	14.72	N	139	37.41	W	GPS	4687	4687						AEROSOL SMPL
49MR0505_1	P03	71	1	BUC	110905	2340	UN	24	14.73	N	139	37.42	W	GPS	4706	4701				1,33		22.6C
49MR0505_1	P03	71	1	UNK	110905	2344	UN	24	14.77	N	139	37.45	W	GPS	4678	4709						AIR N2O SMPL
49MR0505_1	P03	71	1	ROS	111005	0045	BO	24	15.37	N	139	37.70	W	GPS	4719	4723	10	4718	4719	35	1-8,27,64,81	
49MR0505_1	P03	71	1	ROS	111005	0253	EN	24	15.99	N	139	38.91	W	GPS	4817	4821						
49MR0505_1	P03	73	1	ROS	111005	0542	BE	24	14.16	N	140	21.37	W	GPS	4810	4807						
49MR0505_1	P03	73	1	BUC	111005	0551	UN	24	14.15	N	140	21.53	W	GPS	4816	4813				1		22.5C
49MR0505_1	P03	73	1	ROS	111005	0657	BO	24	14.58	N	140	21.99	W	GPS	4809	4812	10	4887	4882	36	1-8,22,27	#1=#17 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	73	1	UNK	111005	0700	BE	24	14.62	N	140	22.01	W	GPS	4810	4811						80L THROUGH HULL PUMP FOR R.N.
49MR0505_1	P03	73	1	UNK	111005	0713	EN	24	14.70	N	140	22.06	W	GPS	4810	4811						
49MR0505_1	P03	73	1	ROS	111005	0902	EN	24	15.34	N	140	22.70	W	GPS	4810	4810						
49MR0505_1		512	1	UNK	111005	2306	UN	24	12.88	N	140	44.16	W	GPS	4777	4775						AEROSOL SMPL
49MR0505_1		513	1	UNK	111105	0000	BE	24	13.58	N	140	45.13	W	GPS	4439	4446						FIGURE-OF-EIGHT SAILING FOR MAGNETOMETER
49MR0505_1		513	1	UNK	111105	0023	EN	24	13.91	N	140	45.26	W	GPS	4418	4453						
49MR0505_1	P03	74	1	ROS	111105	1403	BE	24	16.37	N	141	8.47	W	GPS	4989	4990						
49MR0505_1	P03	74	1	BUC	111105	1410	UN	24	16.41	N	141	8.51	W	GPS	4990	4990				1,33		22.2C
49MR0505_1	P03	74	1	UNK	111105	1420	UN	24	16.46	N	141	8.59	W	GPS	4989	4992						AIR N2O SMPL
49MR0505_1	P03	74	1	ROS	111105	1523	BO	24	16.94	N	141	8.96	W	GPS	4992	4991	9	5043	5066	34	1-8,12,13,23,24,26,27	#1=#18 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	74	1	ROS	111105	1735	EN	24	18.01	N	141	9.59	W	GPS	5014	5015						
49MR0505_1	P03	76	1	ROS	111105	2016	BE	24	15.06	N	141	50.83	W	GPS	4645	4642						
49MR0505_1	P03	76	1	BUC	111105	2024	UN	24	15.13	N	141	50.89	W	GPS	4629	4632				1,33		22.5C
49MR0505_1	P03	76	1	UNK	111105	2030	UN	24	15.17	N	141	50.95	W	GPS	4632	4629						AIR N2O SMPL
49MR0505_1		514	1	UNK	111105	2106	UN	24	15.50	N	141	51.17	W	GPS	4594	4600						RAIN SMPL (0.6MM/HR)
49MR0505_1	P03	76	1	ROS	111105	2133	BO	24	15.64	N	141	51.34	W	GPS	4612	4613	9	4697	4698	32	1-8,27	#1=#19 (B-10) DUPLICATE SMPLS
49MR0505_1		515	1	UNK	111105	2309	UN	24	16.41	N	141	52.04	W	GPS	4628	4619						AEROSOL SMPL
49MR0505_1	P03	76	1	ROS	111105	2337	EN	24	16.67	N	141	52.41	W	GPS	4600	4600						
49MR0505_1	P03	77	1	ROS	111205	0222	BE	24	14.70	N	142	34.96	W	GPS	4800	4798						
49MR0505_1	P03	77	1	BUC	111205	0228	UN	24	14.77	N	142	35.01	W	GPS	4801	4800				1,31,33,82		23.1C
49MR0505_1	P03	77	1	UNK	111205	0240	UN	24	14.90	N	142	35.12	W	GPS	4796	4784						AIR N2O SMPL
49MR0505_1	P03	77	1	ROS	111205	0335	BO	24	15.46	N	142	35.32	W	GPS	4794	4794	9	4861	4854	33	1-8,23,24,26,27,31,33,82	#1=#20 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	77	1	ROS	111205	0538	EN	24	16.60	N	142	35.93	W	GPS	4762	4762						
49MR0505_1	P03	77	2	UNK	111205	0540	UN	24	16.61	N	142	35.97	W	GPS	4744	4744						AIR N2O SMPL
49MR0505_1	P03	79	1	ROS	111205	0831	BE	24	15.43	N	143	19.04	W	GPS	4464	4458						
49MR0505_1	P03	79	1	BUC	111205	0840	UN	24	15.55	N	143	19.02	W	GPS	4452	4452				1		23.2C
49MR0505_1	P03	79	1	ROS	111205	0942	BO	24	15.92	N	143	18.92	W	GPS	4417	4418	9	4468	4506	31	1-8,27	#1=#21 (B-10) DUPLICATE SMPLS
49MR0505_1	P03	79	1	ROS	111205	1137	EN	24	16.29	N	143	18.75	W	GPS	4460	4463						

113

114



49MR0505_1	P03	116	1	BUC	111705	1103	UN	24	15.07	N	156	43.68	W	GPS	4354	4350				1				24.9C
49MR0505_1	P03	116	1	ROS	111705	1205	BO	24	15.64	N	156	43.54	W	GPS	4409	4405	10	4414	4421	29	1-8,27			#36 MISS FIRE
49MR0505_1	P03	116	1	ROS	111705	1407	EN	24	16.60	N	156	43.27	W	GPS	4453	4453								
49MR0505_1	P03	118	1	ROS	111705	1719	BE	24	15.81	N	157	29.66	W	GPS	4423	4466								
49MR0505_1	P03	118	1	BUC	111705	1726	UN	24	15.89	N	157	29.65	W	GPS	4459	4471					1,31,33			24.8C
49MR0505_1	P03	118	1	UNK	111705	1740	UN	24	16.08	N	157	29.62	W	GPS	4510	4482								AIR N2O SMPL
49MR0505_1	P03	118	1	ROS	111705	1832	BO	24	16.60	N	157	29.53	W	GPS	4488	4484	10	4543	4539	30	1-8,23,24,26,27,31,33			
49MR0505_1	P03	118	1	ROS	111705	2036	EN	24	17.60	N	157	28.95	W	GPS	4511	4489								
49MR0505_1	P03	118	2	UNK	111705	2036	UN	24	17.60	N	157	28.95	W	GPS	4511	4489								AIR CH4 SMPL
49MR0505_1		522	1	UNK	111705	2216	UN	24	36.40	N	157	43.41	W	GPS	4633	4635								AEROSOL SMPL
49MR0505_1	P03	120	1	ROS	111805	0013	BE	25	0.05	N	157	59.97	W	GPS	4597	4599								STATION POSITION WAS SHIFTED NORTH
49MR0505_1	P03	120	1	BUC	111805	0020	UN	25	0.11	N	158	0.01	W	GPS	4582	4589					1,33			25.2C
49MR0505_1	P03	120	1	UNK	111805	0032	UN	25	0.18	N	158	0.12	W	GPS	4607	4604								AIR N2O SMPL
49MR0505_1	P03	120	1	ROS	111805	0124	BO	25	0.32	N	158	0.15	W	GPS	4648	4630	10	4596	4653	35	1-8,27,64,81			
49MR0505_1	P03	120	1	ROS	111805	0325	EN	25	0.84	N	158	0.40	W	GPS	4731	4743								
49MR0505_1	P03	122	1	ROS	111805	0940	BE	25	49.98	N	159	0.45	W	GPS	5054	5060								STATION POSITION WAS SHIFTED NORTH
49MR0505_1	P03	122	1	BUC	111805	0947	UN	25	49.96	N	159	0.47	W	GPS	5058	5060					1			25.1C
49MR0505_1	P03	122	1	ROS	111805	1100	BO	25	50.19	N	159	0.84	W	GPS	5058	5061	10	5095	5137	33	1-8,23,24,26,27			
49MR0505_1	P03	122	1	ROS	111805	1312	EN	25	50.86	N	159	1.82	W	GPS	5057	5062								
49MR0505_1	P03	124	1	ROS	111805	1612	BE	25	50.14	N	159	46.69	W	GPS	4563	4564								STATION POSITION WAS SHIFTED NORTH
49MR0505_1	P03	124	1	BUC	111805	1619	UN	25	50.20	N	159	46.72	W	GPS	4556	4558					1,33			25.2C
49MR0505_1	P03	124	1	UNK	111805	1624	UN	25	50.21	N	159	46.76	W	GPS	4549	4554								AIR N2O SMPL
49MR0505_1	P03	124	1	ROS	111805	1724	BO	25	50.38	N	159	47.24	W	GPS	4534	4535	8	4582	4620	34	1-8,22,27			
49MR0505_1	P03	124	1	UNK	111805	1724	BE	25	50.39	N	159	47.27	W	GPS	4535	4535								80L THROUGH HULL PUMP FOR R.N.
49MR0505_1	P03	124	1	UNK	111805	1724	EN	25	50.51	N	159	47.41	W	GPS	4507	4535								
49MR0505_1	P03	124	1	ROS	111805	1933	EN	25	50.96	N	159	48.30	W	GPS	4376	4376								
49MR0505_1		523	1	UNK	111805	2152	UN	25	50.11	N	160	25.67	W	GPS	5076	5073								AEROSOL SMPL
49MR0505_1	P03	126	1	ROS	111805	2221	BE	25	50.12	N	160	31.78	W	GPS	5089	5083								
49MR0505_1	P03	126	1	BUC	111805	2228	UN	25	50.17	N	160	31.85	W	GPS	5077	5080					1,33			25.5C
49MR0505_1	P03	126	1	UNK	111805	2233	UN	25	50.22	N	160	31.90	W	GPS	5078	5088								AIR N2O SMPL
49MR0505_1	P03	126	1	ROS	111805	2345	BO	25	50.73	N	160	32.69	W	GPS	5079	5077	10	5213	5160	33	1-8,12,13,23,24,26,27			
49MR0505_1	P03	126	1	ROS	111905	0157	EN	25	51.24	N	160	34.32	W	GPS	5074	5075								
49MR0505_1	P03	128	1	ROS	111905	1057	BE	25	50.13	N	161	15.26	W	GPS	4994	4992								
49MR0505_1	P03	128	1	BUC	111905	1104	UN	25	50.18	N	161	15.31	W	GPS	4992	4991					1			25.2C
49MR0505_1	P03	128	1	ROS	111905	1215	BO	25	50.71	N	161	15.36	W	GPS	4994	4996	10	5021	5068	33	1-8,23,24,26,27			
49MR0505_1	P03	128	1	ROS	111905	1428	EN	25	51.70	N	161	15.40	W	GPS	4997	5002								
49MR0505_1		524	1	UNK	111905	2232	UN	25	9.84	N	161	58.56	W	GPS	3029	3016								RAIN SMPL (1.5MM/HR)
49MR0505_1		525	1	UNK	111905	2246	UN	25	8.57	N	161	59.78	W	GPS	2227	2227								AEROSOL SMPL
49MR0505_1	P03	130	1	ROS	111905	2328	BE	25	5.70	N	162	1.94	W	GPS	3314	3309								
49MR0505_1	P03	130	1	BUC	111905	2335	UN	25	5.68	N	162	1.82	W	GPS	3348	3356					1,33			25.7C
49MR0505_1	P03	130	1	UNK	111905	2335	UN	25	5.68	N	162	1.82	W	GPS	3350	3356								AIR N2O SMPL
49MR0505_1	P03	130	1	ROS	112005	0023	BO	25	5.78	N	162	1.66	W	GPS	3350	3335	10	3377	3410	26	1-8,23,24,26,27			
49MR0505_1		526	1	UNK	112005	0110	UN	25	6.06	N	162	1.74	W	GPS	3145	3138								RAIN SMPL (1.3MM/HR)
49MR0505_1	P03	130	1	ROS	112005	0202	EN	25	6.21	N	162	1.67	W	GPS	3010	3012								
49MR0505_1	P03	132	1	ROS	112005	0508	BE	25	16.72	N	162	44.30	W	GPS	5006	5006								
49MR0505_1	P03	132	1	BUC	112005	0515	UN	25	16.72	N	162	44.20	W	GPS	5005	5006					1,33			25.5C
49MR0505_1	P03	132	1	UNK	112005	0518	UN	25	16.71	N	162	44.18	W	GPS	5007	5006								AIR N2O SMPL
49MR0505_1	P03	132	1	ROS	112005	0626	BO	25	16.43	N	162	43.44	W	GPS	5005	5006	10	5104	5078	33	1-8,27			
49MR0505_1	P03	132	1	ROS	112005	0845	EN	25	16.17	N	162	42.32	W	GPS	5008	5006								

Parameter  
1=Salinity, 2=Oxygen, 3=Silicate, 4=Nitrate, 5=Nitrite, 6=PHOSPHATE, 7=CFC-11, 8=CFC-12, 12= $\Delta^{14}\text{C}$ , 13= $\delta^{13}\text{C}$ , 22= $^{137}\text{CS}$ , 23= Total carbon, 24=Alkalinity, 26=PH, 27=CFC-113, 31=  $\text{CH}_4$ , 33= $\text{N}_2\text{O}$ , 42= Abundance of bacteria  
64= Incubation, 81= Particulate organic matter, 82= $^{15}\text{NO}_2$

49MR0505\_2.sum file

P03 REV R/V MIRAI CRUISE MR0505 LEG 2																		
SHIP/CRS	WOCE	CAST		UTC EVENT		POSITION			UNC	COR	HT ABOVE	WIRE	MAX	NO. OF				
EXPCODE	SECT	STNNBR	CASTNO	TYPE	DATE	TIME	CODE	LATITUDE	LONGITUDE	NAV	DEPTH	DEPTH	BOTTOM	OUT	PRESS	BOTTLES	PARAMETERS	COMMENTS
49MR0505_2		536	1	UNK	113005	0019	UN 24	39.48 N	166 19.81 W	GPS	4927	4925						AEROSOL SMPL
49MR0505_2	P03	146	2	ROS	113005	0154	BE 24	40.60 N	166 33.54 W	GPS	5125	5125						
49MR0505_2	P03	146	2	BUC	113005	0203	UN 24	40.50 N	166 33.50 W	GPS	5125	5125					1,33	25.2C
49MR0505_2	P03	146	2	UNK	113005	0217	UN 24	40.40 N	166 33.41 W	GPS	5126	5127						AIR N2O SMPL
49MR0505_2	P03	146	2	ROS	113005	0318	BO 24	39.98 N	166 33.05 W	GPS	5110	5110	9	5143	5198	33	1-8,23,24,26,27	#4 FOR CHLORA FILTRATION (3000DB)
49MR0505_2	P03	146	2	ROS	113005	0540	EN 24	39.40 N	166 32.35 W	GPS	5109	5109						
49MR0505_2	P03	148	1	ROS	113005	0741	BE 24	36.02 N	166 39.77 W	GPS	4176	4177						
49MR0505_2	P03	148	1	BUC	113005	0749	UN 24	36.03 N	166 39.78 W	GPS	4177	4180					1,33	25.1C
49MR0505_2	P03	148	1	UNK	113005	0801	UN 24	36.05 N	166 39.74 W	GPS	4194	4195						AIR N2O SMPL
49MR0505_2	P03	148	1	ROS	113005	0848	BO 24	36.03 N	166 39.64 W	GPS	4209	4213	9	4202	4260	30	1-8,27	#2=#1 DUPL SMPLS (B-10DB)
49MR0505_2	P03	148	1	ROS	113005	1044	EN 24	36.23 N	166 39.28 W	GPS	4414	4416						
49MR0505_2	P03	150	1	ROS	113005	1241	BE 24	30.29 N	166 43.81 W	GPS	3368	3377						
49MR0505_2	P03	150	1	BUC	113005	1249	UN 24	30.29 N	166 43.81 W	GPS	3395	3394					1	25.2C
49MR0505_2	P03	150	1	ROS	113005	1339	BO 24	30.31 N	166 43.89 W	GPS	3371	3370	5	3369	3409	27	1-8,23,24,26,27	#3=#13 DUPL SMPLS (3000DB)
49MR0505_2	P03	150	1	ROS	113005	1518	EN 24	30.11 N	166 44.19 W	GPS	3189	3187						
49MR0505_2	P03	152	1	ROS	113005	1729	BE 24	26.25 N	166 48.75 W	GPS	2036	2037						
49MR0505_2	P03	152	1	BUC	113005	1736	UN 24	26.35 N	166 48.76 W	GPS	2055	2054					1	25.1C
49MR0505_2	P03	152	1	ROS	113005	1807	BO 24	26.42 N	166 48.74 W	GPS	2079	2076	11	2073	2091	20	1-8,23,24,26,27	
49MR0505_2	P03	152	1	ROS	113005	1921	EN 24	26.67 N	166 48.64 W	GPS	2174	2174						
49MR0505_2	P03	153	1	ROS	113005	2123	BE 24	25.27 N	166 49.20 W	GPS	1549	1550						
49MR0505_2	P03	153	1	BUC	113005	2132	UN 24	25.26 N	166 49.16 W	GPS	1545	1549					1,33	25.4C
49MR0505_2	P03	153	1	UNK	113005	2142	UN 24	25.23 N	166 49.18 W	GPS	1532	1532						AIR N2O SMPL
49MR0505_2	P03	153	1	ROS	113005	2153	BO 24	25.20 N	166 49.20 W	GPS	1492	1491	5	1551	1560	17	1-8,23,24,26,27	
49MR0505_2	P03	153	1	ROS	113005	2255	EN 24	24.98 N	166 49.31 W	GPS	1513	1499						
49MR0505_2		537	1	UNK	120105	0012	UN 24	16.06 N	167 1.80 W	GPS	228	228						AEROSOL SMPL
49MR0505_2	P03	154	1	ROS	120105	0101	BE 24	8.71 N	167 5.70 W	GPS	1221	1222						
49MR0505_2	P03	154	1	BUC	120105	0110	UN 24	8.64 N	167 5.79 W	GPS	1309	1308					1	25.5C
49MR0505_2	P03	154	1	ROS	120105	0131	BO 24	8.62 N	167 5.94 W	GPS	1416	1417	26	1351	1352	16	1-8,23,24,26,27	
49MR0505_2	P03	154	1	ROS	120105	0228	EN 24	8.63 N	167 6.42 W	GPS	1658	1659						
49MR0505_2	P03	155	1	ROS	120105	0514	BE 24	8.82 N	167 7.96 W	GPS	2006	1993						CHANGE LOCATION
49MR0505_2	P03	155	1	BUC	120105	0521	UN 24	8.94 N	167 7.93 W	GPS	1946	1946					1,33	25.2C
49MR0505_2	P03	155	1	UNK	120105	0531	UN 24	9.00 N	167 7.80 W	GPS	1914	1913						AIR N2O SMPL
49MR0505_2	P03	155	1	ROS	120105	0548	BO 24	9.00 N	167 7.62 W	GPS	1882	1870	20	1889	1885	19	1-8,27	
49MR0505_2	P03	155	1	ROS	120105	0658	EN 24	9.18 N	167 6.73 W	GPS	1495	1493						
49MR0505_2	P03	157	1	ROS	120105	0958	BE 24	6.08 N	167 10.06 W	GPS	2856	2856						
49MR0505_2	P03	157	1	BUC	120105	1005	UN 24	6.00 N	167 9.96 W	GPS	2895	2896					1,33	25.2C
49MR0505_2	P03	157	1	UNK	120105	1016	UN 24	5.90 N	167 9.92 W	GPS	2970	2970						AIR N2O SMPL
49MR0505_2	P03	157	1	ROS	120105	1050	BO 24	5.59 N	167 9.92 W	GPS	3011	3039	12	3033	3036	24	1-8,23,24,26,27	
49MR0505_2	P03	157	1	ROS	120105	1220	EN 24	4.58 N	167 10.22 W	GPS	3082	3094						
49MR0505_2	P03	159	1	ROS	120105	1426	BE 24	1.44 N	167 14.27 W	GPS	3914	3907						
49MR0505_2	P03	159	1	BUC	120105	1434	UN 24	1.37 N	167 14.30 W	GPS	3904	3904					1	25.2C
49MR0505_2		538	1	UNK	120105	1510	UN 24	1.27 N	167 14.52 W	GPS	3923	3921						RAIN SMPL (0.9MM/HR)
49MR0505_2	P03	159	1	ROS	120105	1530	BO 24	1.25 N	167 14.62 W	GPS	3922	3925	11	3912	3941	29	1-8,27	#4=#10 DUPL SMPLS (3750DB)
49MR0505_2	P03	159	1	ROS	120105	1720	EN 24	1.28 N	167 15.44 W	GPS	4190	4191						
49MR0505_2	P03	161	1	ROS	120105	1925	BE 23	51.03 N	167 22.55 W	GPS	4926	4926						

118

119

49MR0505_2	P03	197	1	UNK	120705	0801	UN	24	13.95	N	179	59.39	W	GPS	5533	5535						AIR N2O SMPL
49MR0505_2	P03	197	1	ROS	120705	0908	BO	24	13.63	N	179	59.28	W	GPS	5538	5540	10	5545	5629	36	1-8,22,27	#2 FOR R.N.
49MR0505_2	P03	197	2	UNK	120705	0917	BE	24	13.58	N	179	59.29	W	GPS	5539	5541						80L THROUGH HULL PUMP FOR R.N.
49MR0505_2	P03	197	2	UNK	120705	1005	EN	24	13.34	N	179	59.12	W	GPS	5537	5541						
49MR0505_2	P03	197	1	ROS	120705	1127	EN	24	12.77	N	179	58.88	W	GPS	5546	5546						
49MR0505_2		547	1	UNK	120805	0019	UN	24	7.77	N	179	27.00	E	GPS	5711	5712						AEROSOL SMPL
49MR0505_2		548	1	UNK	120805	0558	BE	24	10.90	N	179	10.50	E	GPS	5737	5736						MAGNETOMETER CALIBRATION
49MR0505_2		548	1	UNK	120805	0623	EN	24	10.63	N	179	9.52	E	GPS	5738	5740						
49MR0505_2	P03	X14	1	ROS	120805	1600	BE	23	59.90	N	178	59.87	E	GPS	5739	5740						PRI AND SEC CND SENSORS REPLACED
49MR0505_2	P03	X14	1	BUC	120805	1609	UN	23	59.90	N	178	59.86	E	GPS	5743	5744				1,33		25.6C
49MR0505_2	P03	X14	1	UNK	120805	1620	UN	23	59.87	N	178	59.82	E	GPS	5741	5740						AIR N2O SMPL
49MR0505_2	P03	X14	1	ROS	120805	1729	BO	23	59.67	N	178	59.77	E	GPS	5748	5748	10	5739	5835	35	1-8,12,13,23,24,26,27	#17 MISS FIRE
49MR0505_2	P03	X14	1	ROS	120805	1957	EN	23	59.23	N	178	59.85	E	GPS	5742	5743						
49MR0505_2		549	1	UNK	120805	2250	UN	24	13.63	N	178	27.18	E	GPS	5733	5725						RAIN SMPL (0.7MM/HR)
49MR0505_2	P03	201	1	ROS	120805	2324	BE	24	15.23	N	178	23.31	E	GPS	5723	5723						
49MR0505_2	P03	201	1	BUC	120805	2332	UN	24	15.18	N	178	23.33	E	GPS	5726	5727				1,33		26.1C
49MR0505_2	P03	201	1	UNK	120805	2340	UN	24	15.14	N	178	23.30	E	GPS	5724	5724						AIR N2O SMPL
49MR0505_2	P03	201	1	ROS	120905	0050	BO	24	14.73	N	178	23.24	E	GPS	5725	5724	10	5744	5819	35	1-8,27	#17 MISS FIRE
49MR0505_2		550	1	UNK	120905	0057	UN	24	14.71	N	178	23.22	E	GPS	5727	5725						AEROSOL SMPL
49MR0505_2	P03	201	1	ROS	120905	0312	EN	24	13.81	N	178	22.93	E	GPS	5731	5730						
49MR0505_2	P03	203	1	ROS	120905	0717	BE	24	13.65	N	177	36.26	E	GPS	5781	5780						
49MR0505_2	P03	203	1	BUC	120905	0724	UN	24	13.58	N	177	36.24	E	GPS	5776	5775				1,33		25.8C
49MR0505_2	P03	203	1	UNK	120905	0732	UN	24	13.51	N	177	36.26	E	GPS	5774	5773						AIR N2O SMPL
49MR0505_2	P03	203	1	ROS	120905	0845	BO	24	12.89	N	177	36.15	E	GPS	5772	5772	8	5812	5872	35	1-8,27	#10 MISS FIRE
49MR0505_2	P03	203	1	ROS	120905	1111	EN	24	11.81	N	177	36.08	E	GPS	5787	5762						
49MR0505_2	P03	205	1	ROS	120905	1524	BE	24	14.94	N	176	47.27	E	GPS	5762	5762						
49MR0505_2	P03	205	1	BUC	120905	1530	UN	24	14.91	N	176	47.23	E	GPS	5755	5756				1,31,33,82		26.1C
49MR0505_2	P03	205	1	UNK	120905	1542	UN	24	14.84	N	176	47.19	E	GPS	5760	5760						AIR CH4 & N2O SMPL
49MR0505_2	P03	205	1	ROS	120905	1651	BO	24	14.42	N	176	46.83	E	GPS	5756	5756	9	5825	5857	36	1-8,23,24,26,27,31,33,64,82	
49MR0505_2	P03	205	1	ROS	120905	1924	EN	24	13.65	N	176	45.93	E	GPS	5761	5760						
49MR0505_2	P03	207	1	ROS	120905	2323	BE	24	14.76	N	175	59.57	E	GPS	5798	5800						
49MR0505_2	P03	207	1	BUC	120905	2331	UN	24	14.80	N	175	59.53	E	GPS	5792	5792				1,33		26.2C
49MR0505_2	P03	207	1	UNK	120905	2341	UN	24	14.85	N	175	59.53	E	GPS	5795	5796						AIR N2O SMPL
49MR0505_2	P03	207	1	ROS	121005	0051	BO	24	15.22	N	175	59.61	E	GPS	5792	5790	9	5808	5889	36	1-8,27	
49MR0505_2		551	1	UNK	121005	0102	UN	24	15.28	N	175	59.64	E	GPS	5801	5802						AEROSOL SMPL
49MR0505_2	P03	207	1	ROS	121005	0312	EN	24	16.28	N	175	59.98	E	GPS	5821	5796						
49MR0505_2	P03	209	1	ROS	121005	0736	BE	24	15.09	N	175	9.99	E	GPS	5557	5551						
49MR0505_2	P03	209	1	BUC	121005	0743	UN	24	15.12	N	175	10.00	E	GPS	5571	5580				1,33		26.4C
49MR0505_2		552	1	UNK	121005	0751	UN	24	15.17	N	175	10.05	E	GPS	5584	5581						RAIN SMPL (1.8MM/HR)
49MR0505_2	P03	209	1	UNK	121005	0753	UN	24	15.17	N	175	10.04	E	GPS	5587	5588						AIR N2O SMPL
49MR0505_2	P03	209	1	ROS	121005	0901	BO	24	15.44	N	175	10.16	E	GPS	5589	5588	10	5587	5676	36	1-8,22,27	#2 FOR R.N.
49MR0505_2	P03	209	2	UNK	121005	0923	BE	24	15.44	N	175	10.22	E	GPS	5605	5604						80L THROUGH HULL PUMP FOR R.N.
49MR0505_2	P03	209	2	UNK	121005	0934	EN	24	15.47	N	175	10.24	E	GPS	5593	5593						
49MR0505_2	P03	209	1	ROS	121005	1120	EN	24	15.79	N	175	10.43	E	GPS	5603	5603						
49MR0505_2	P03	211	1	ROS	121005	1525	BE	24	15.05	N	174	23.04	E	GPS	5728	5728						
49MR0505_2	P03	211	1	BUC	121005	1535	UN	24	15.00	N	174	23.05	E	GPS	5735	5735				1,33		26.2C
49MR0505_2	P03	211	1	UNK	121005	1543	UN	24	14.96	N	174	23.07	E	GPS	5728	5729						AIR N2O SMPL
49MR0505_2	P03	211	1	ROS	121005	1652	BO	24	14.60	N	174	23.09	E	GPS	5727	5728	10	5747	5828	36	1-8,12,13,23,24,26,27	
49MR0505_2	P03	211	1	ROS	121005	1922	EN	24	14.06	N	174	23.16	E	GPS	5728	5729						
49MR0505_2	P03	213	1	ROS	121005	2339	BE	24	15.28	N	173	34.11	E	GPS	5820	5819						
49MR0505_2	P03	213	1	BUC	121005	2346	UN	24	15.22	N	173	34.09	E	GPS	5829	5818				1,33		26.2C

121



122

WITHOUT LADCP  
25.8C  
AIR N2O SMPL

25.2C  
AIR N2O SMPL

25.0C  
AIR CH4 & N2O SMPL

25.8C  
AIR N2O SMPL  
#18=#6 DUPL SMPLS (4750DB)

26.0C  
AIR N2O SMPL  
#2 FOR R.N., #26 MISS FIRE  
80L THROUGH HULL PUMP FOR R.N.

25.9C  
AIR N2O SMPL

HEAVY RAIN WHEN BEGINNING THE CAST  
RAIN SMPL (38.0MM/HR)  
25.9C  
AIR N2O SMPL

RAIN SMPL (2.4MM/HR)

26.4C  
AIR N2O SMPL

26.4C  
AIR CH4 & N2O SMPL

124

125

126

80L THROUGH HULL PUMP FOR R.N.

49MR0505_2	P03	316	1	ROS	010506	2307	BO	24	15.27	N	138	33.80	E	GPS	5027	5028	9	5061	5103	33	1-8,27	
49MR0505_2	P03	316	1	ROS	010606	0116	EN	24	15.17	N	138	33.37	E	GPS	5028	5028						
49MR0505_2	P03	318	1	ROS	010606	0501	BE	24	14.69	N	137	48.26	E	GPS	5124	5125						
49MR0505_2	P03	318	1	BUC	010606	0508	UN	24	14.60	N	137	48.23	E	GPS	5122	5122				1,33		21.9C
49MR0505_2	P03	318	1	UNK	010606	0517	UN	24	14.47	N	137	48.18	E	GPS	5100	5106						AIR N2O SMPL
49MR0505_2	P03	318	1	ROS	010606	0621	BO	24	14.07	N	137	47.83	E	GPS	5027	5031	9	5153	5173	36	1-8,22,27	#2-4 FOR R.N.
49MR0505_2	P03	318	2	UNK	010606	0628	BE	24	14.04	N	137	47.79	E	GPS	5029	5021						80L THROUGH HULL PUMP FOR R.N.
49MR0505_2	P03	318	2	UNK	010606	0644	EN	24	13.99	N	137	47.69	E	GPS	5007	5007						
49MR0505_2	P03	318	1	ROS	010606	0836	EN	24	13.47	N	137	47.40	E	GPS	5060	5065						
49MR0505_2	P03	X09	1	ROS	010606	1514	BE	23	59.82	N	136	59.77	E	GPS	4045	4046						
49MR0505_2	P03	X09	1	BUC	010606	1522	UN	23	59.77	N	136	59.78	E	GPS	4045	4040				1,33		22.1C
49MR0505_2	P03	X09	1	UNK	010606	1531	UN	23	59.64	N	136	59.79	E	GPS	4071	4072						AIR N2O SMPL
49MR0505_2	P03	X09	1	ROS	010606	1622	BO	23	59.22	N	136	59.60	E	GPS	4091	4100	10	4163	4166	30	1-8,12,13,23,24,26,27	#2 DUPL FOR SALNTY
49MR0505_2	P03	X09	1	ROS	010606	1808	EN	23	58.37	N	136	59.05	E	GPS	4128	4128						
49MR0505_2	P03	322	1	ROS	010606	2241	BE	24	14.84	N	136	12.03	E	GPS	3925	3925						
49MR0505_2	P03	322	1	BUC	010606	2249	UN	24	14.65	N	136	11.97	E	GPS	3948	3969				1,33		21.9C
49MR0505_2	P03	322	1	UNK	010606	2258	UN	24	14.51	N	136	11.89	E	GPS	3987	3988						AIR N2O SMPL
49MR0505_2	P03	322	1	ROS	010606	2347	BO	24	14.15	N	136	11.41	E	GPS	4368	4363	10	4181	4154	29	1-8,23,24,26,27	#2 DUPL FOR SALNTY, #18 MISS FIRE
49MR0505_2		566	1	UNK	010706	0030	UN	24	13.93	N	136	11.10	E	GPS	4539	4539						RAIN SMPL (1.5MM/HR)
49MR0505_2	P03	322	1	ROS	010706	0136	EN	24	13.55	N	136	10.77	E	GPS	4748	4765						
49MR0505_2	P03	324	1	ROS	010706	0444	BE	24	15.56	N	135	36.84	E	GPS	5309	5309						
49MR0505_2	P03	324	1	BUC	010706	0453	UN	24	15.42	N	135	36.73	E	GPS	5314	5316				1,33		22.3C
49MR0505_2	P03	324	1	UNK	010706	0503	UN	24	15.27	N	135	36.58	E	GPS	5322	5320						AIR N2O SMPL
49MR0505_2	P03	324	1	ROS	010706	0607	BO	24	14.98	N	135	36.17	E	GPS	5326	5326	9	5367	5403	34	1-8,23,24,26,27	
49MR0505_2	P03	324	1	ROS	010706	0820	EN	24	14.33	N	135	34.96	E	GPS	5329	5330						
49MR0505_2	P03	326	1	ROS	010706	1116	BE	24	14.17	N	135	2.04	E	GPS	5174	5175						
49MR0505_2	P03	326	1	BUC	010706	1124	UN	24	14.19	N	135	1.88	E	GPS	5167	5167				1,33		22.2C
49MR0505_2	P03	326	1	UNK	010706	1134	UN	24	14.25	N	135	1.79	E	GPS	5172	5176						AIR N2O SMPL
49MR0505_2	P03	326	1	ROS	010706	1234	BO	24	14.30	N	135	1.37	E	GPS	5171	5172	9	5200	5250	33	1-8,27	
49MR0505_2	P03	326	1	ROS	010706	1443	EN	24	14.35	N	135	0.61	E	GPS	5169	5174						
49MR0505_2	P03	328	1	ROS	010706	1728	BE	24	13.89	N	134	30.70	E	GPS	5034	5038						
49MR0505_2	P03	328	1	BUC	010706	1738	UN	24	13.91	N	134	30.68	E	GPS	5040	5041				1		23.7C
49MR0505_2	P03	328	1	ROS	010706	1848	BO	24	13.42	N	134	30.90	E	GPS	5021	5022	8	5076	5108	33	1-8,23,24,26,27	JELLYFISH IN PRI TC DUCT(UP CAST ABOVE 1200M)
49MR0505_2	P03	328	1	ROS	010706	2055	EN	24	12.34	N	134	30.22	E	GPS	5032	5030						
49MR0505_2	P03	329	1	ROS	010706	2347	BE	24	12.60	N	133	59.39	E	GPS	4952	4951						
49MR0505_2	P03	329	1	BUC	010706	2357	UN	24	12.53	N	133	59.37	E	GPS	4949	4949				1,33		22.3C
49MR0505_2	P03	329	1	UNK	010806	0007	UN	24	12.54	N	133	59.35	E	GPS	4951	4949						AIR N2O SMPL
49MR0505_2	P03	329	1	ROS	010806	0102	BO	24	12.42	N	133	59.12	E	GPS	4948	4948	8	4957	5017	32	1-8,27	
49MR0505_2	P03	329	1	ROS	010806	0306	EN	24	12.13	N	133	58.38	E	GPS	4947	4947						
49MR0505_2	P03	331	1	ROS	010806	0628	BE	24	15.81	N	133	21.58	E	GPS	4645	4646						
49MR0505_2	P03	331	1	BUC	010806	0636	UN	24	15.66	N	133	21.53	E	GPS	4641	4642				1,33		21.9C
49MR0505_2	P03	331	1	UNK	010806	0646	UN	24	15.58	N	133	21.45	E	GPS	4640	4637						AIR N2O SMPL
49MR0505_2	P03	331	1	ROS	010806	0742	BO	24	15.33	N	133	21.01	E	GPS	4642	4642	9	4700	4707	31	1-8,27	
49MR0505_2	P03	331	1	ROS	010806	0941	EN	24	14.60	N	133	20.52	E	GPS	4640	4641						
49MR0505_2	P03	333	1	ROS	010806	1219	BE	24	16.93	N	132	49.97	E	GPS	4037	4038						
49MR0505_2	P03	333	1	BUC	010806	1226	UN	24	16.99	N	132	49.80	E	GPS	4042	4043				1,31,33		23.7C
49MR0505_2	P03	333	1	UNK	010806	1242	UN	24	17.17	N	132	49.61	E	GPS	4042	4040						AIR N2O SMPL
49MR0505_2	P03	333	1	ROS	010806	1322	BO	24	17.38	N	132	49.35	E	GPS	4047	4048	10	4097	4091	33	1-8,23,24,26,27,31,33,81	#2-5 FOR POM
49MR0505_2	P03	333	1	ROS	010806	1510	EN	24	18.18	N	132	48.54	E	GPS	4001	4001						
49MR0505_2	P03	335	1	ROS	011006	0958	BE	24	15.32	N	132	12.50	E	GPS	3015	3013						
49MR0505_2	P03	335	1	BUC	011006	1005	UN	24	15.56	N	132	12.36	E	GPS	3073	3074				1,33		23.4C



129

49MR0505_2	P03	367	1	ROS	011306	1021	BO	25	45.65	N	127	17.45	E	GPS	1191	1187	10	1158	1145	15	1-8,27	
49MR0505_2	P03	367	1	ROS	011306	1110	EN	25	45.25	N	127	16.88	E	GPS	1281	1290						
49MR0505_2	P03	365	1	ROS	011306	1245	BE	25	37.37	N	127	24.79	E	GPS	2155	2153						
49MR0505_2	P03	365	1	BUC	011306	1256	UN	25	37.32	N	127	24.66	E	GPS	2149	2150				1,31,33	22.1C	
49MR0505_2	P03	365	1	UNK	011306	1307	UN	25	37.30	N	127	24.57	E	GPS	2139	2138					AIR N2O SMPL	
49MR0505_2	P03	365	1	ROS	011306	1325	BO	25	37.20	N	127	24.46	E	GPS	2138	2140	9	2151	2150	20	1-8,23,24,26,27,31,33	
49MR0505_2	P03	365	1	ROS	011306	1438	EN	25	37.10	N	127	24.25	E	GPS	2132	2134						
49MR0505_2	P03	363	1	ROS	011306	1638	BE	25	27.96	N	127	30.96	E	GPS	2344	2343						
49MR0505_2	P03	363	1	BUC	011306	1648	UN	25	27.99	N	127	30.78	E	GPS	2343	2343				1	22.1C	
49MR0505_2	P03	363	1	ROS	011306	1720	BO	25	27.93	N	127	30.72	E	GPS	2343	2344	10	2340	2356	21	1-8,27	
49MR0505_2	P03	363	1	ROS	011306	1834	EN	25	27.95	N	127	30.22	E	GPS	2470	2472						
49MR0505_2	P03	361	1	ROS	011306	2009	BE	25	19.87	N	127	37.84	E	GPS	2187	2184						
49MR0505_2	P03	361	1	BUC	011306	2016	UN	25	19.96	N	127	37.71	E	GPS	2171	2169				1,33	22.2C	
49MR0505_2	P03	361	1	UNK	011306	2025	UN	25	20.02	N	127	37.57	E	GPS	2139	2142					AIR N2O SMPL	
49MR0505_2	P03	361	1	ROS	011306	2044	BO	25	20.09	N	127	37.44	E	GPS	2176	2175	10	2143	2154	20	1-8,23,24,26,27	
49MR0505_2	P03	361	1	ROS	011306	2156	EN	25	20.32	N	127	36.83	E	GPS	2186	2177						
49MR0505_2	P03	359	1	ROS	011306	2357	BE	25	10.03	N	127	45.47	E	GPS	3655	3647						
49MR0505_2	P03	359	1	BUC	011406	0006	UN	25	10.16	N	127	45.36	E	GPS	3632	3632				1	22.0C	
49MR0505_2	P03	359	1	ROS	011406	0057	BO	25	10.50	N	127	45.34	E	GPS	3643	3652	9	3674	3698	27	1-8,27	
49MR0505_2	P03	359	1	ROS	011406	0241	EN	25	10.98	N	127	45.51	E	GPS	3645	3651						
49MR0505_2	P03	357	1	ROS	011406	0417	BE	25	3.90	N	127	49.19	E	GPS	5184	5182						
49MR0505_2	P03	357	1	BUC	011406	0424	UN	25	3.85	N	127	49.20	E	GPS	5189	5189				1,33	22.4C	
49MR0505_2	P03	357	1	UNK	011406	0434	UN	25	3.82	N	127	49.15	E	GPS	5193	5191					AIR N2O SMPL	
49MR0505_2	P03	357	1	ROS	011406	0538	BO	25	3.50	N	127	48.98	E	GPS	5228	5225	11	5214	5269	33	1-8,23,24,26,27	#17 MISS TRIP
49MR0505_2	P03	357	1	ROS	011406	0751	EN	25	2.37	N	127	48.35	E	GPS	5245	5243						
49MR0505_2	P03	355	1	ROS	011406	0958	BE	24	58.38	N	127	55.03	E	GPS	6708	6713						
49MR0505_2	P03	355	1	BUC	011406	1005	UN	24	58.35	N	127	54.99	E	GPS	6703	6703				1,33	22.8C	
49MR0505_2	P03	355	1	UNK	011406	1015	UN	24	58.33	N	127	54.94	E	GPS	6677	6674					AIR N2O SMPL	
49MR0505_2	P03	355	1	ROS	011406	1136	BO	24	58.10	N	127	54.14	E	GPS	6571	6558	-9	6489	6502	36	1-8,27	
49MR0505_2	P03	355	1	ROS	011406	1433	EN	24	58.29	N	127	52.45	E	GPS	6283	6293						
49MR0505_2	P03	353	1	ROS	011406	1609	BE	24	49.00	N	128	1.25	E	GPS	6996	7006						
49MR0505_2	P03	353	1	BUC	011406	1617	UN	24	49.11	N	128	1.13	E	GPS	7053	7052				1,33	23.2C	
49MR0505_2	P03	353	1	UNK	011406	1626	UN	24	49.20	N	128	1.07	E	GPS	7111	7094					AIR N2O SMPL	
49MR0505_2	P03	353	1	ROS	011406	1751	BO	24	49.87	N	128	0.92	E	GPS	7412	7411	-9	6438	6501	36	1-8,23,24,26,27	
49MR0505_2	P03	353	1	ROS	011406	2054	EN	24	51.54	N	128	0.68	E	GPS	7303	7303						
49MR0505_2	P03	351	2	ROS	011406	2309	BE	24	33.00	N	128	13.49	E	GPS	5968	5969						
49MR0505_2	P03	351	2	BUC	011406	2316	UN	24	33.05	N	128	13.52	E	GPS	5948	5949				1,33	22.7C	
49MR0505_2	P03	351	2	UNK	011406	2325	UN	24	33.08	N	128	13.51	E	GPS	5972	5961					AIR N2O SMPL	
49MR0505_2	P03	351	2	ROS	011506	0038	BO	24	33.35	N	128	13.63	E	GPS	5972	5972	11	5975	6062	35	1,2	#14 MISS FIRE, #21 MISS TRIP
49MR0505_2	P03	351	2	ROS	011506	0311	EN	24	33.88	N	128	13.88	E	GPS	6031	6020						

Parameter

1=Salinity, 2=Oxygen, 3=Silicate, 4=Nitrate, 5=Nitrite, 6=PHOSPHATE, 7=CFC-11, 8=CFC-12, 12= $\Delta^{14}\text{C}$ , 13= $\delta^{13}\text{C}$ , 22= $^{137}\text{CS}$ , 23= Total carbon, 24=Alkalinity, 26=PH, 27=CFC-113, 31=  $\text{CH}_4$ , 33= $\text{N}_2\text{O}$ , 42= Abundance of bacteria, 64= Incubation, 81= Particulate organic matter, 82= $^{15}\text{NO}_3$

49MR0505\_3.sum file

P03 REV R/V MIRAI CRUISE MR0505 LEG 3																		
SHIP/CRS	WOCE	CAST		UTC		EVENT		POSITION			UNC	COR	HT	ABOVE	WIRE	MAX	NO. OF	
EXPCODE	SECT	STNNBR	CASTNO	TYPE	DATE	TIME	CODE	LATITUDE	LONGITUDE	NAV	DEPTH	DEPTH	BOTTOM	OUT	PRESS	BOTTLES	PARAMETERS	COMMENTS
49MR0505_3	P03	370	1	ROS	012006	0650	BE 26	23.41 N	126 42.26 E	GPS	406	406						
49MR0505_3	P03	370	1	BUC	012006	0651	UN 26	23.40 N	126 42.26 E	GPS	397	398					1,33,42	22.3C
49MR0505_3	P03	370	1	ROS	012006	0659	BO 26	23.31 N	126 42.22 E	GPS	328	328	16	304	308		9 1-8,27,42	
49MR0505_3	P03	370	1	UNK	012006	0703	UN 26	23.27 N	126 42.20 E	GPS	311	311						AIR N2O SMPL
49MR0505_3	P03	370	1	ROS	012006	0725	EN 26	23.03 N	126 42.10 E	GPS	194	194						
49MR0505_3	P03	372	1	ROS	012006	0831	BE 26	27.07 N	126 37.50 E	GPS	1400	1402						
49MR0505_3	P03	372	1	BUC	012006	0839	UN 26	27.04 N	126 37.53 E	GPS	1387	1387					1,31,33,42	22.3C
49MR0505_3	P03	372	1	UNK	012006	0852	UN 26	27.03 N	126 37.55 E	GPS	1371	1370						AIR N2O SMPL
49MR0505_3	P03	372	1	ROS	012006	0858	BO 26	27.02 N	126 37.54 E	GPS	1366	1365	13	1369	1376		18 1-8,23,24,26,27,31,33,42,81	
49MR0505_3	P03	372	1	ROS	012006	1006	EN 26	26.81 N	126 37.58 E	GPS	1324	1325						
49MR0505_3	P03	374	1	ROS	012006	1205	BE 26	36.26 N	126 31.57 E	GPS	1488	1489						
49MR0505_3	P03	374	1	BUC	012006	1213	UN 26	36.21 N	126 31.53 E	GPS	1488	1489					1,33,42	22.2C
49MR0505_3	P03	374	1	UNK	012006	1223	UN 26	36.17 N	126 31.47 E	GPS	1491	1491						AIR N2O SMPL
49MR0505_3	P03	374	1	ROS	012006	1234	BO 26	36.29 N	126 31.34 E	GPS	1516	1516	14	1509	1489		19 1-8,27,42	
49MR0505_3	P03	374	1	ROS	012006	1342	EN 26	36.73 N	126 30.46 E	GPS	1513	1516						
49MR0505_3	P03	376	1	ROS	012006	1519	BE 26	44.02 N	126 20.27 E	GPS	1900	1903						
49MR0505_3	P03	376	1	BUC	012006	1528	UN 26	44.07 N	126 20.13 E	GPS	1912	1913					1,42	22.5C
49MR0505_3	P03	376	1	ROS	012006	1557	BO 26	44.38 N	126 19.77 E	GPS	1910	1913	14	1946	1891		22 1-8,12,13,23,24,26,27,42	#17=#19 DUPL SMPLS (1800DB)
49MR0505_3	P03	376	1	ROS	012006	1718	EN 26	45.27 N	126 18.91 E	GPS	1897	1897						
49MR0505_3	P03	378	1	ROS	012006	1906	BE 26	53.17 N	126 11.44 E	GPS	1536	1536						
49MR0505_3	P03	378	1	BUC	012006	1914	UN 26	53.25 N	126 11.36 E	GPS	1532	1533					1,33,42	22.7C
49MR0505_3	P03	378	1	UNK	012006	1927	UN 26	53.42 N	126 11.24 E	GPS	1532	1532						AIR N2O SMPL
49MR0505_3	P03	378	1	ROS	012006	1935	BO 26	53.48 N	126 11.18 E	GPS	1535	1535	10	1540	1530		19 1-8,27,42	
49MR0505_3	P03	378	1	ROS	012006	2044	EN 26	54.11 N	126 10.73 E	GPS	1554	1553						
49MR0505_3	P03	380	1	ROS	012006	2220	BE 26	57.86 N	126 5.07 E	GPS	1417	1417						
49MR0505_3	P03	380	1	BUC	012006	2229	UN 26	57.99 N	126 5.03 E	GPS	1417	1417					1,42	23.2C
49MR0505_3	P03	380	1	ROS	012006	2248	BO 26	58.19 N	126 4.94 E	GPS	1357	1356	10	1349	1353		19 1-8,23,24,26,27,42	#23 MISS TRIP, SEAWATER SAMPLE (#23) COLLECTED FROM #5
49MR0505_3	P03	380	1	ROS	012006	2356	EN 26	58.84 N	126 4.54 E	GPS	977	977						
49MR0505_3	P03	382	1	ROS	012106	0147	BE 27	4.27 N	125 58.71 E	GPS	863	863						
49MR0505_3	P03	382	1	BUC	012106	0156	UN 27	4.38 N	125 58.66 E	GPS	853	853					1,31,33,42	22.6C
49MR0505_3	P03	382	1	ROS	012106	0206	BO 27	4.44 N	125 58.56 E	GPS	837	836	11	835	838		18 1-8,23,24,26,27,31,33,42,81	#23=#25 DUPL SMPLS (800DB)
49MR0505_3	P03	382	1	UNK	012106	0211	UN 27	4.45 N	125 58.53 E	GPS	829	830						AIR CH4 & N2O SMPL
49MR0505_3	P03	382	1	ROS	012106	0251	EN 27	4.91 N	125 58.36 E	GPS	780	780						
49MR0505_3	P03	382	2	ROS	012106	2254	BE 27	4.34 N	125 58.63 E	GPS	851	851						
49MR0505_3	P03	382	2	BUC	012106	2303	UN 27	4.45 N	125 58.56 E	GPS	838	838					1,33	23.2C
49MR0505_3	P03	382	2	UNK	012106	2312	UN 27	4.46 N	125 58.54 E	GPS	829	829						AIR N2O SMPL
49MR0505_3	P03	382	2	ROS	012106	2315	BO 27	4.46 N	125 58.53 E	GPS	829	829	12	819	826		15 1,2	
49MR0505_3	P03	382	2	ROS	012206	0002	EN 27	4.68 N	125 58.27 E	GPS	790	790						
49MR0505_3	P03	384	1	ROS	012206	0052	BE 27	9.92 N	125 52.99 E	GPS	307	307						
49MR0505_3	P03	384	1	BUC	012206	0054	UN 27	9.91 N	125 52.98 E	GPS	301	301					1,42	22.5C
49MR0505_3	P03	384	1	ROS	012206	0100	BO 27	9.90 N	125 52.96 E	GPS	303	304	12	282	288		9 1-8,23,24,26,27,42	
49MR0505_3	P03	384	1	ROS	012206	0124	EN 27	9.86 N	125 52.89 E	GPS	296	296						

132

AIR N2O SMPL



## Figure captions

- Figure 1: Station locations for WHP P03 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). Temperature data is averaged over 1-hour.
- Figure 5: Sea surface salinity (SSS). Salinity data is averaged over 1-hour.
- Figure 6: Difference in the partial pressure of CO<sub>2</sub> between the ocean and the atmosphere,  $\Delta p\text{CO}_2$ .
- Figure 7: Surface current at 100 m depth measured by shipboard acoustic Doppler current profiler (ADCP).
- Figure 8: Potential temperature (°C) cross section calculated by using CTD temperature and salinity data calibrated by bottle salinity measurements. Vertical exaggeration of the 0-6, 500 m section is 1,000:1. Expanded section of the upper 1,000 m is made with a vertical exaggeration of 2,500:1.
- Figure 9: CTD salinity (psu) cross section calibrated by bottle salinity measurements. Vertical exaggeration is same as Figure 8.
- Figure 10: Same as Figure 9 but with SSW batch correction.
- Figure 11: Density ( $\sigma_0$ ) (kg/m<sup>3</sup>) cross section calculated using CTD temperature and calibrated salinity data with SSW batch correction. Vertical exaggeration is same as Figure 8.
- Figure 12: Same as Figure 11 but for  $\sigma_4$  (kg/m<sup>3</sup>).
- Figure 13: Neutral density ( $\gamma^n$ ) (kg/m<sup>3</sup>) cross section calculated using CTD temperature and calibrated salinity data with SSW batch correction. Vertical exaggeration is same as Figure 8.
- Figure 14: Cross section of bottle sampled dissolved oxygen (μmol/kg). Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 15: Silicate (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 16: Nitrate (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration of the upper 1,000 m section is same as Figure 8.
- Figure 17: Nitrite (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 18: Phosphate (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 19: Dissolved inorganic carbon (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 20: Total alkalinity (μmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 21: pH cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.



- Figure 22: CFC-II (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 23: CFC-12 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 24: CFC-113 (pmol/kg) cross section. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Figure 8.
- Figure 25: Cross section of current velocity (cm/s) normal to the cruise track measured by LADep (northward is positive).
- Figure 26: 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 the revisit cruise, respectively. On white areas differences in temperature do not exceed the detection limit of 0.002°C. Vertical exaggeration is same as Figure 8.
- Figure 27: 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 are used. On white areas differences in salinity do not exceed the detection limit of 0.002 psu. Vertical exaggeration is same as Figure 8.
- Figure 28: Difference in dissolved oxygen (µmol/kg) 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 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 8.

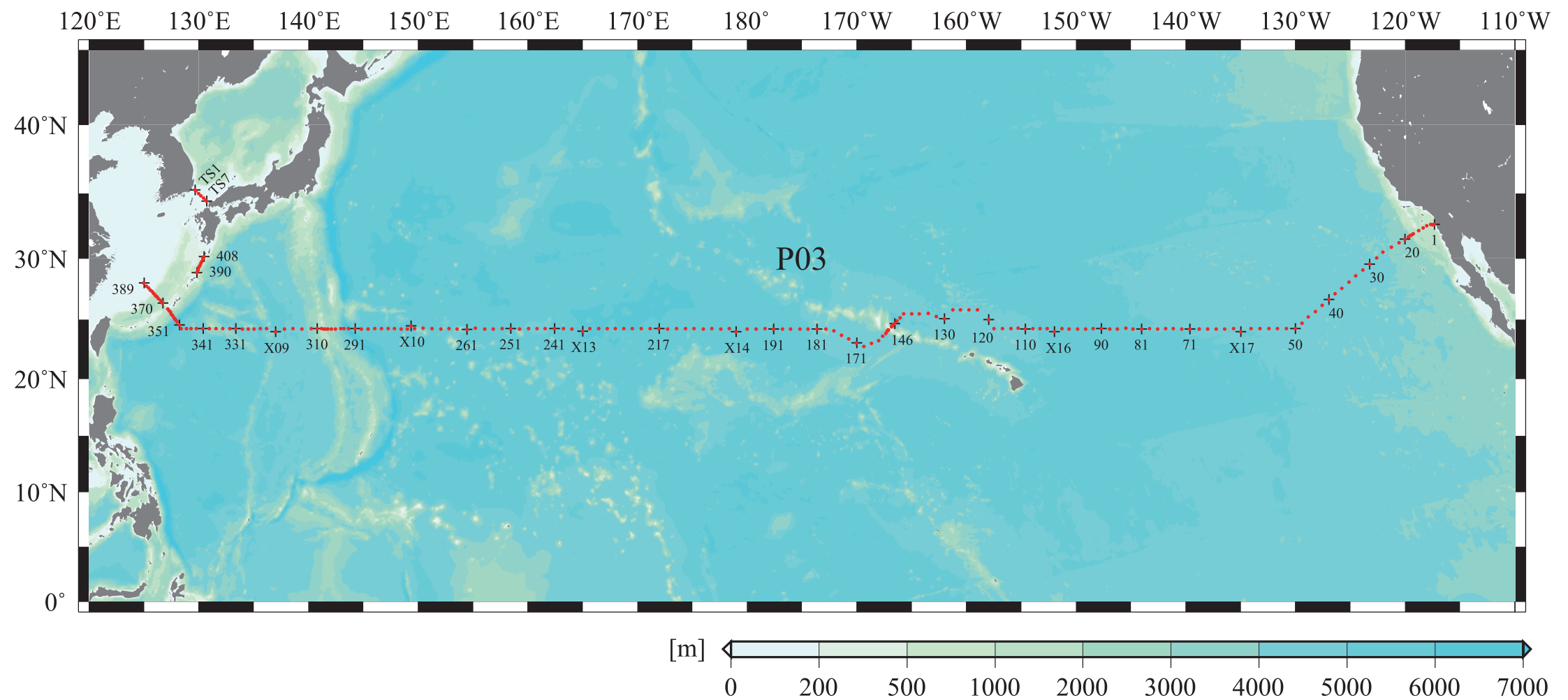
#### Note

1. As for the traceability of SSW to Mantyla's value, the offset for the batches P96 (WOCE P03), and P145 (Revisit) is +0.0013 and -0.0021, respectively (The newest values, Kawano et al., in preparation).

#### References

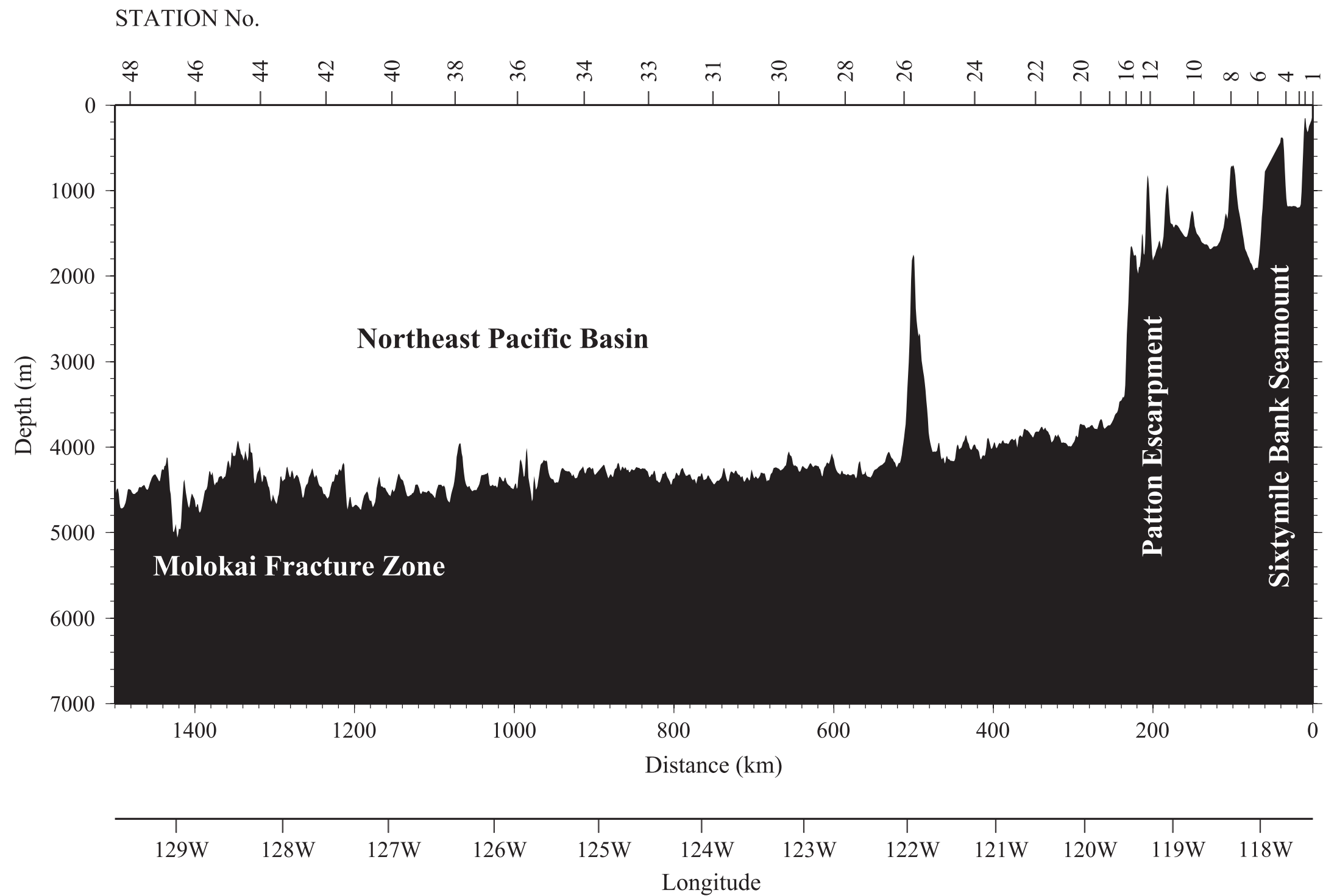
- Jackett, D. R. and R. J. McDougall (1997): A neutral density variable for the world's oceans, *Journal of Physical Oceanography*, **27**, 237-263.
- Smith, W H. F. and D. T. Sandwell (1997): Global seafloor topography from satellite altimetry and ship depth soundings, *Science*, **277**, 1956-1962.

**Figure 1**  
**Station locations for WHP P03 cruise**

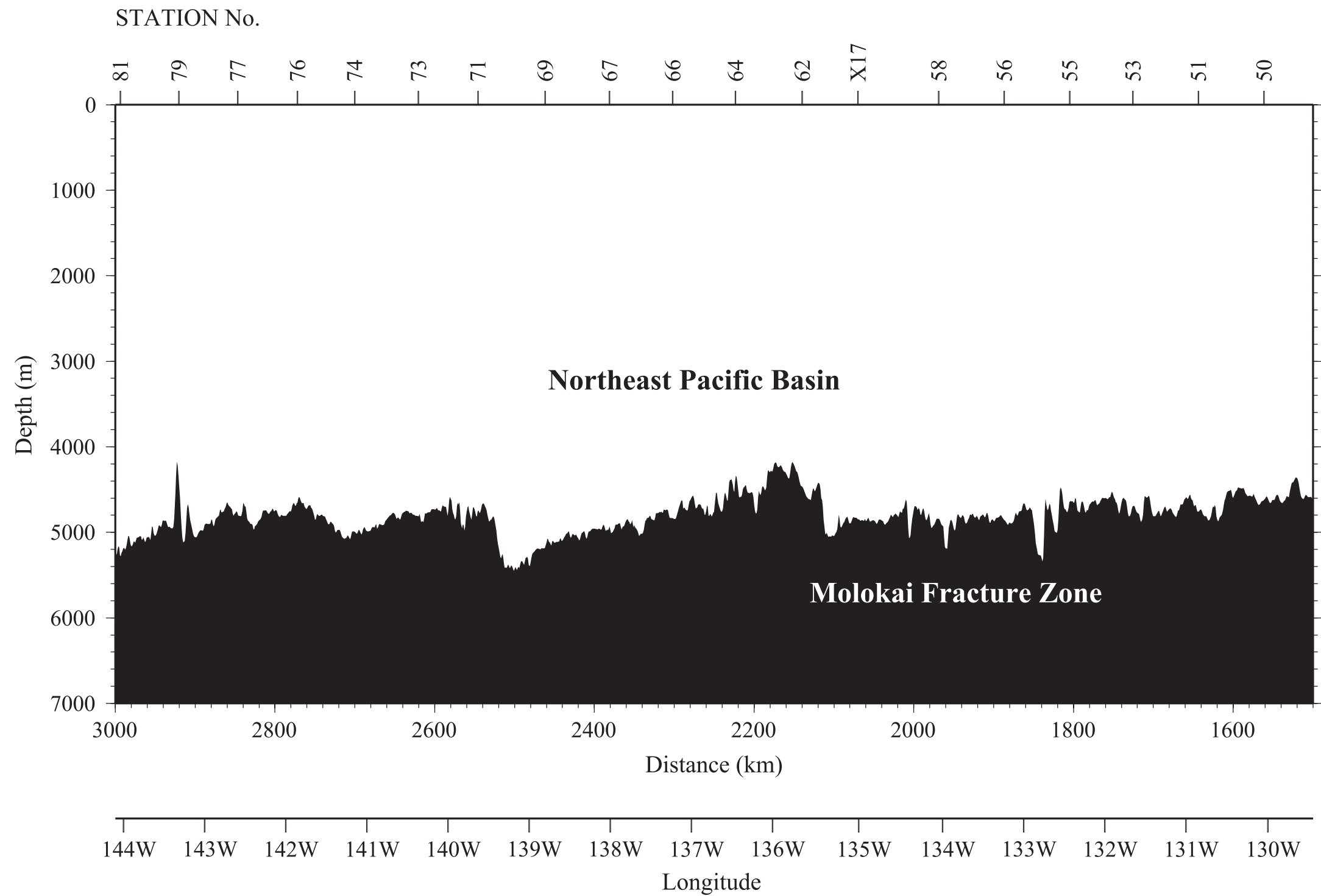


**Figure 2**

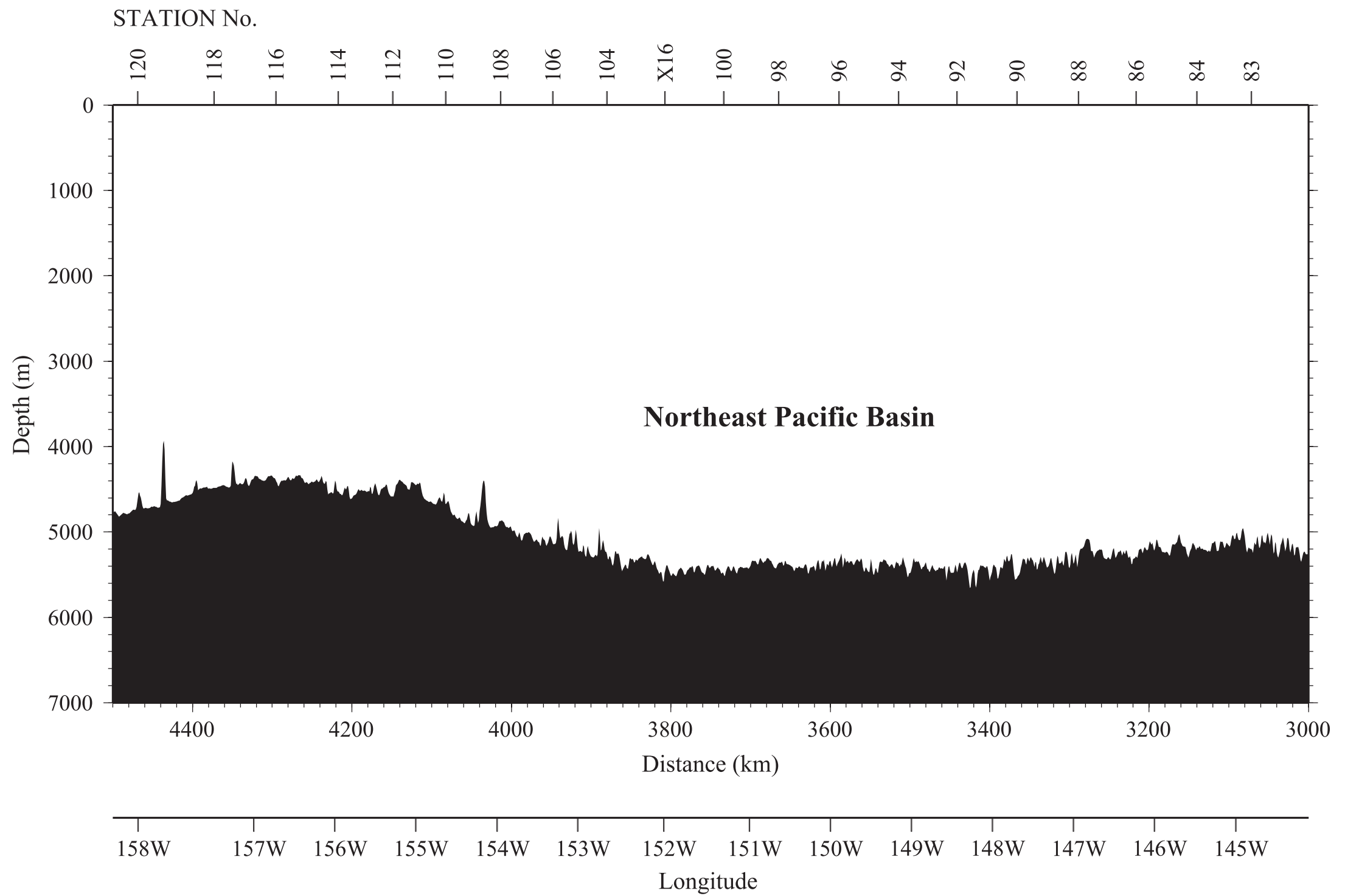
**Bathymetry measured by Multi Narrow Beam Echo Sounding System**



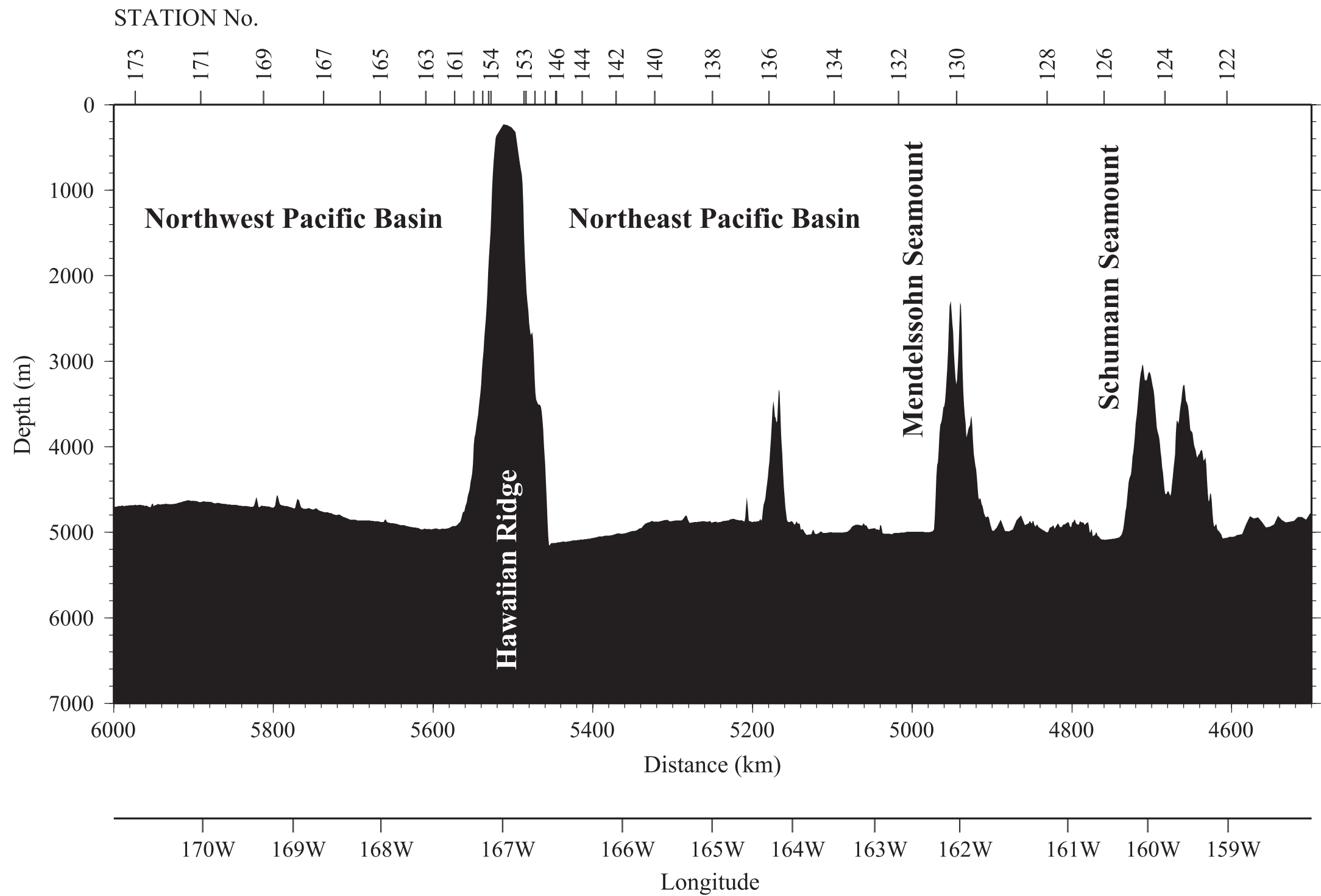
**Figure 2**  
**Continued**



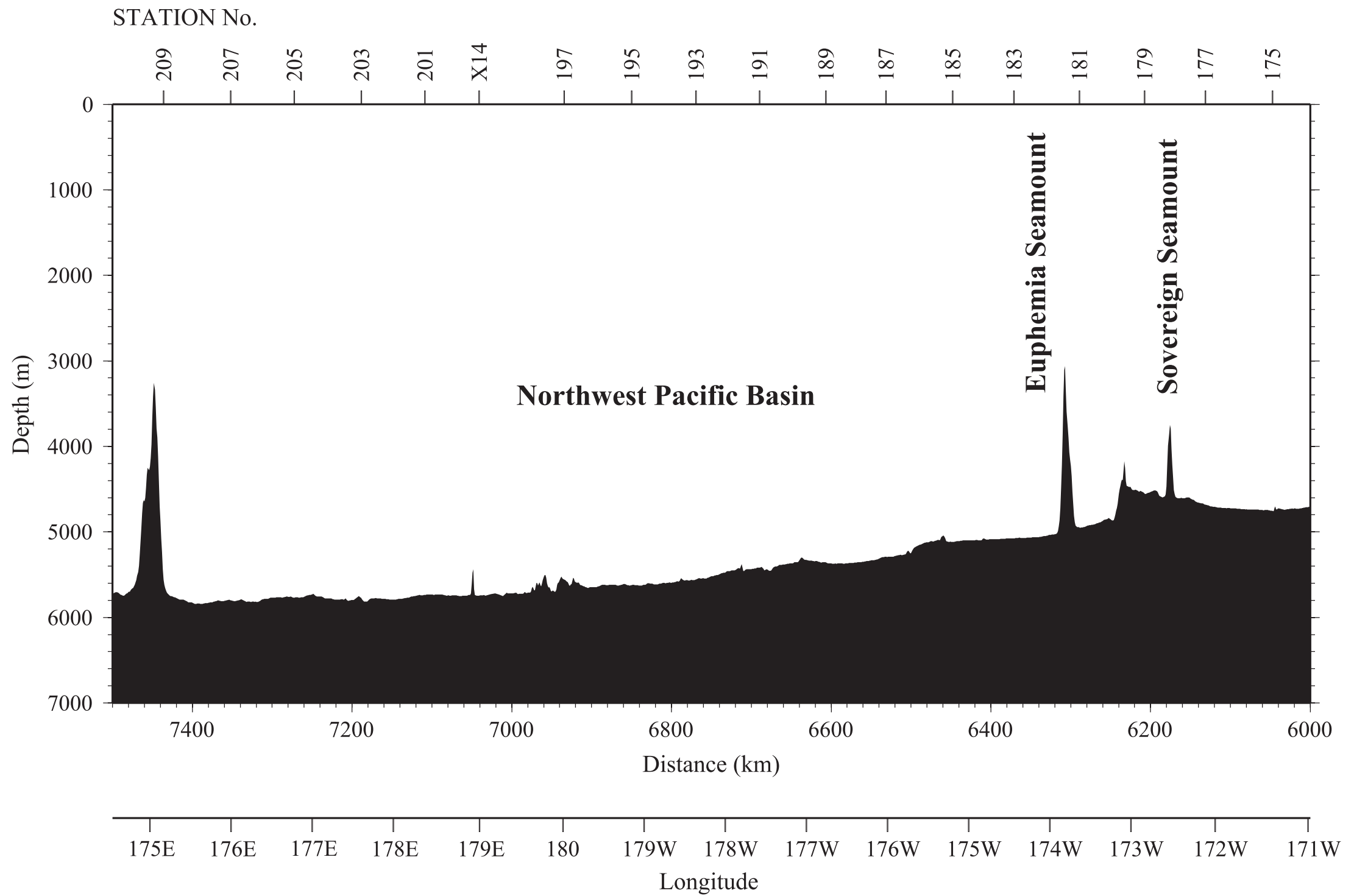
**Figure 2**  
**Continued**



**Figure 2**  
**Continued**

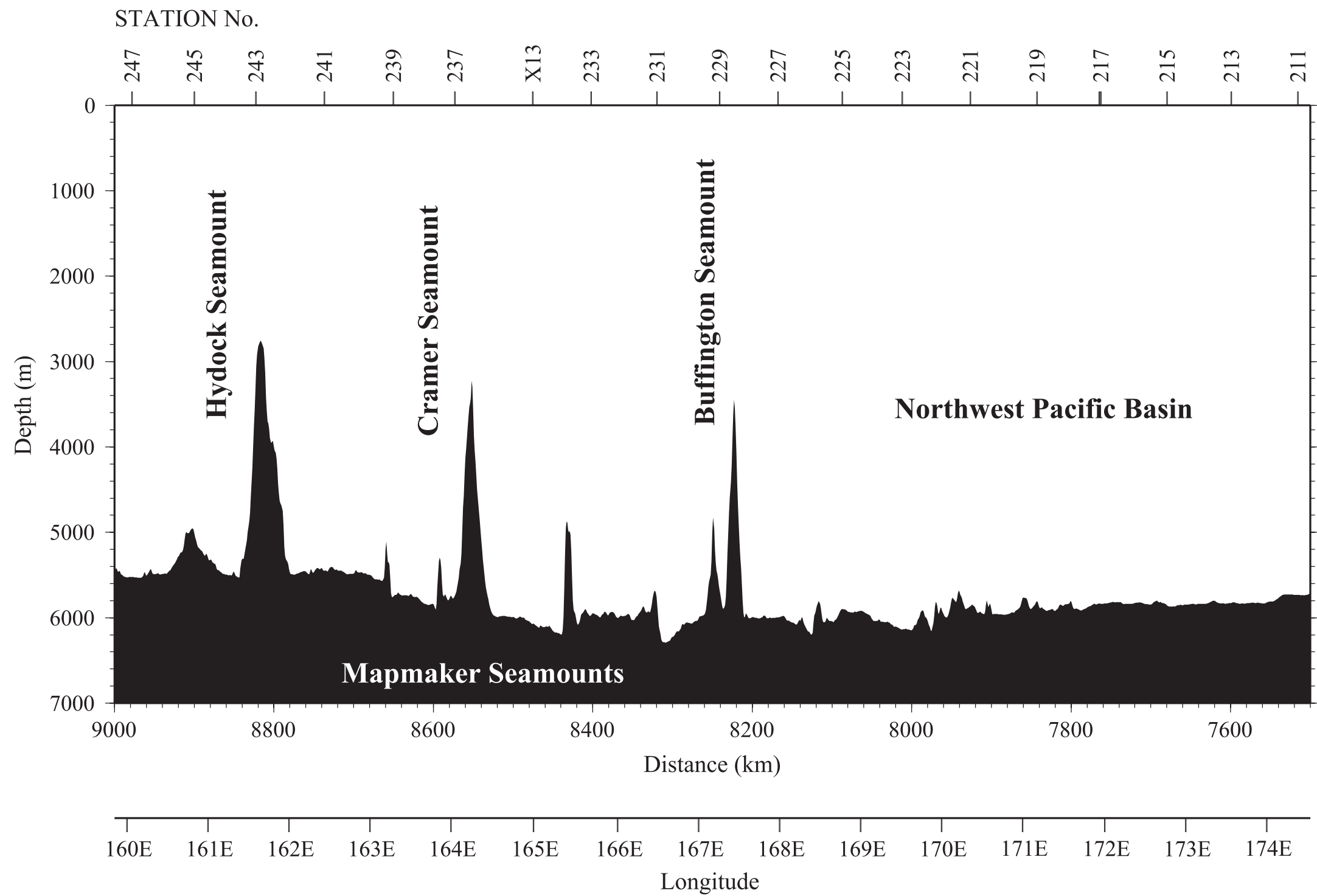


**Figure 2**  
**Continued**





**Figure 2**  
**Continued**



**Figure 2**  
**Continued**

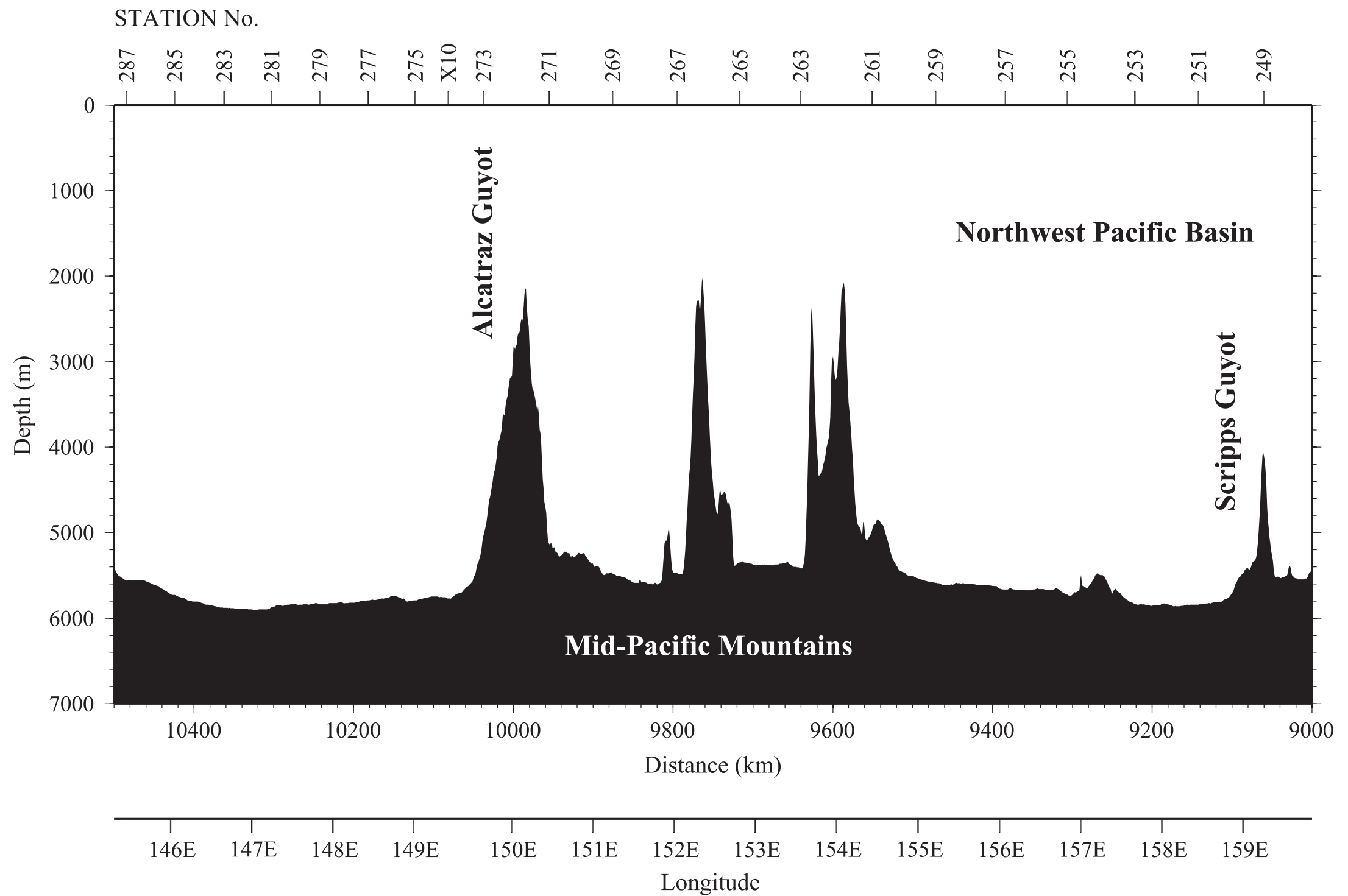
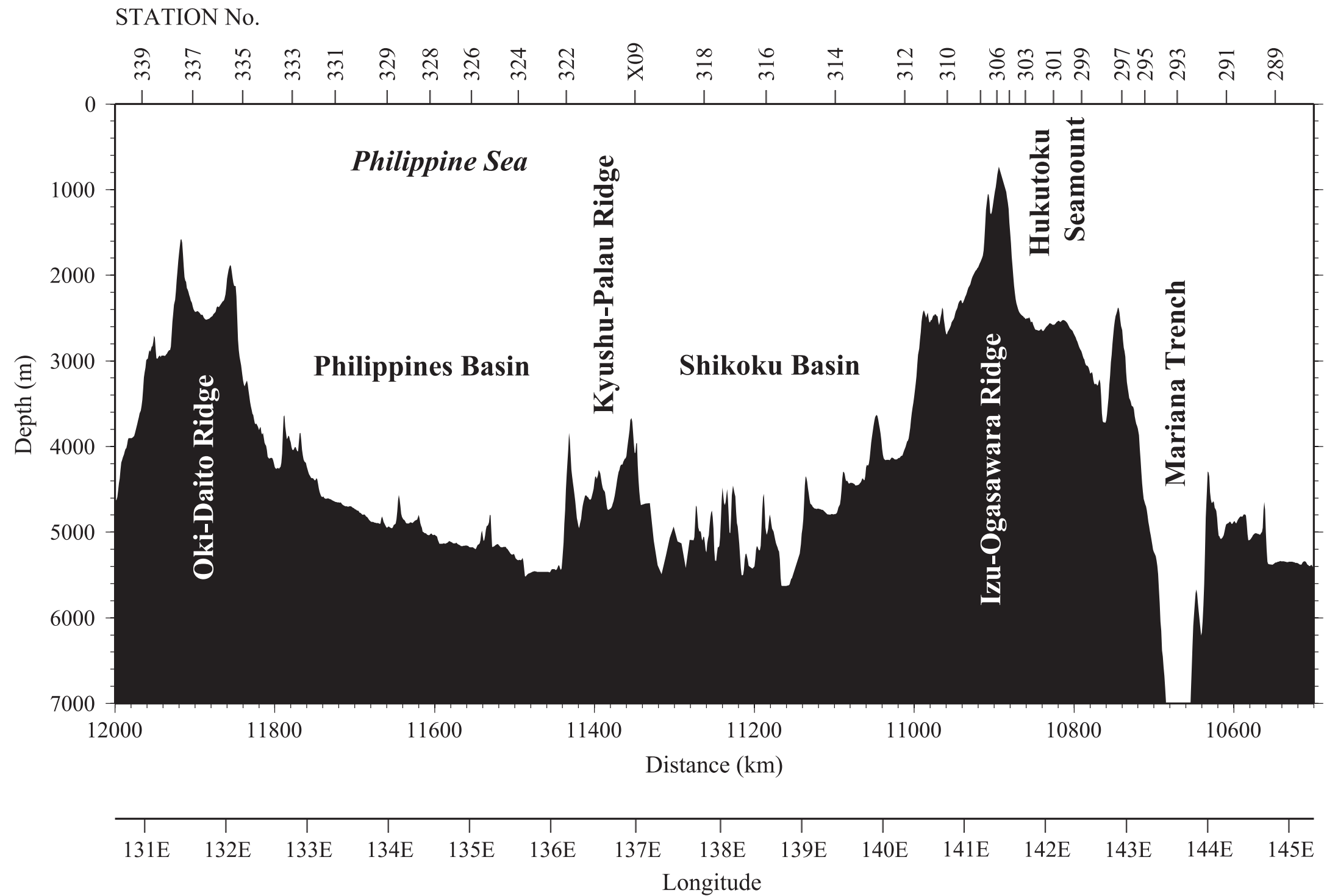
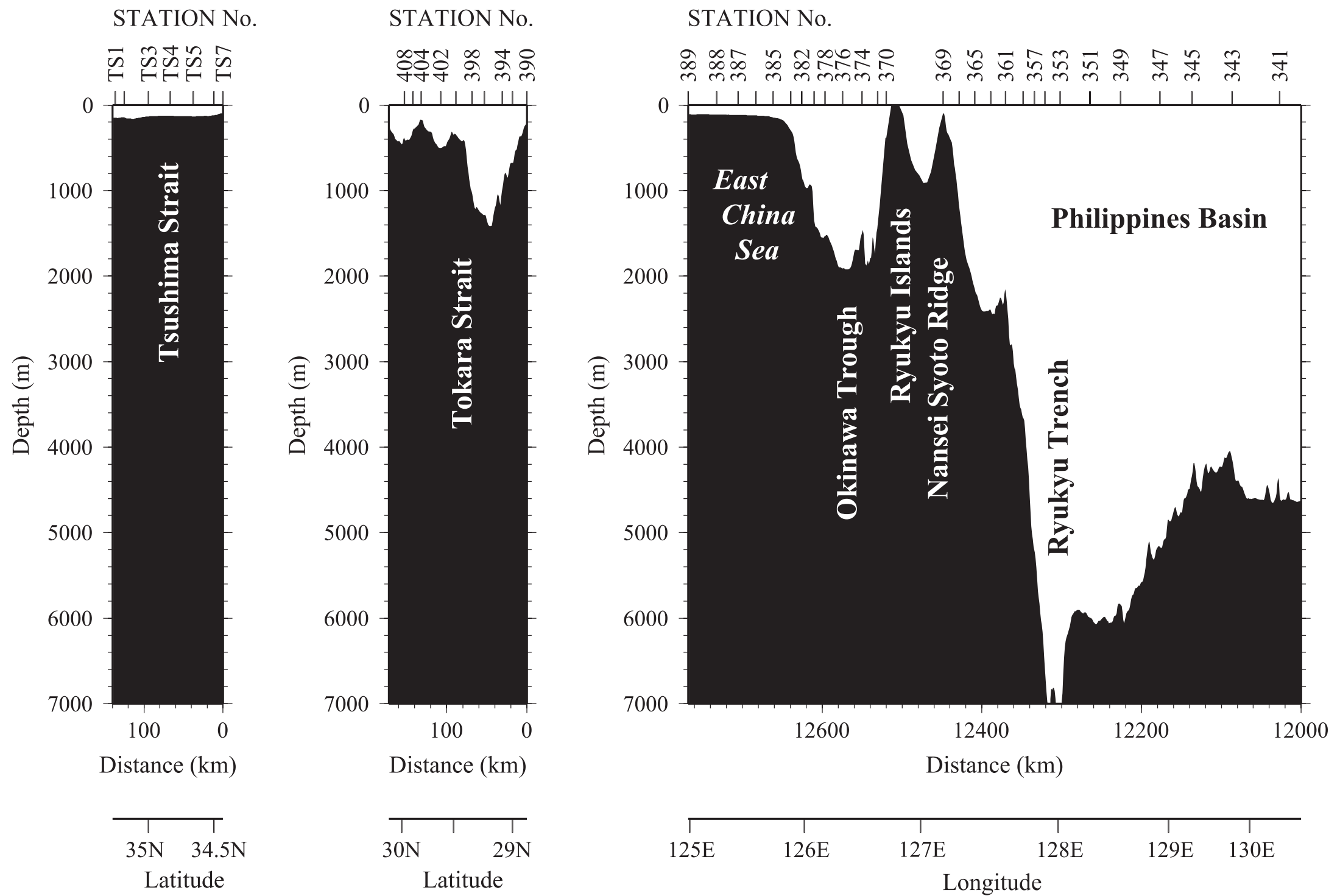


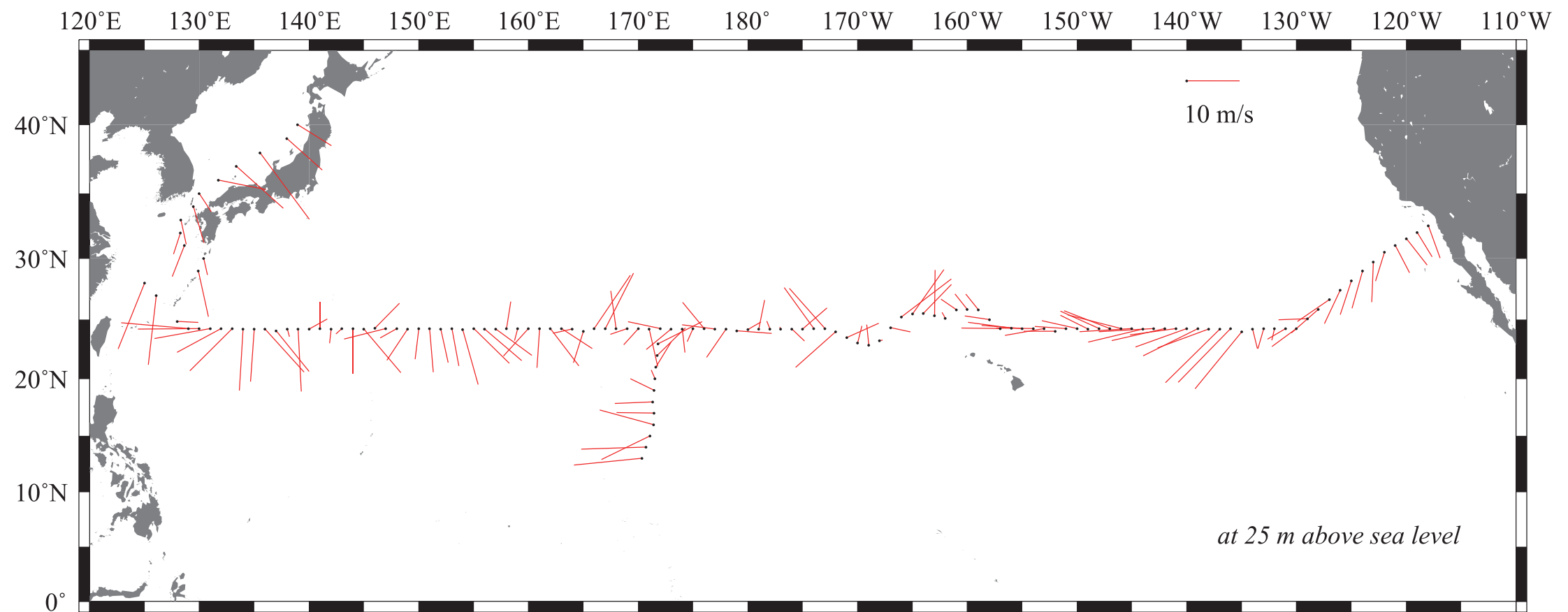
Figure 2  
Continued



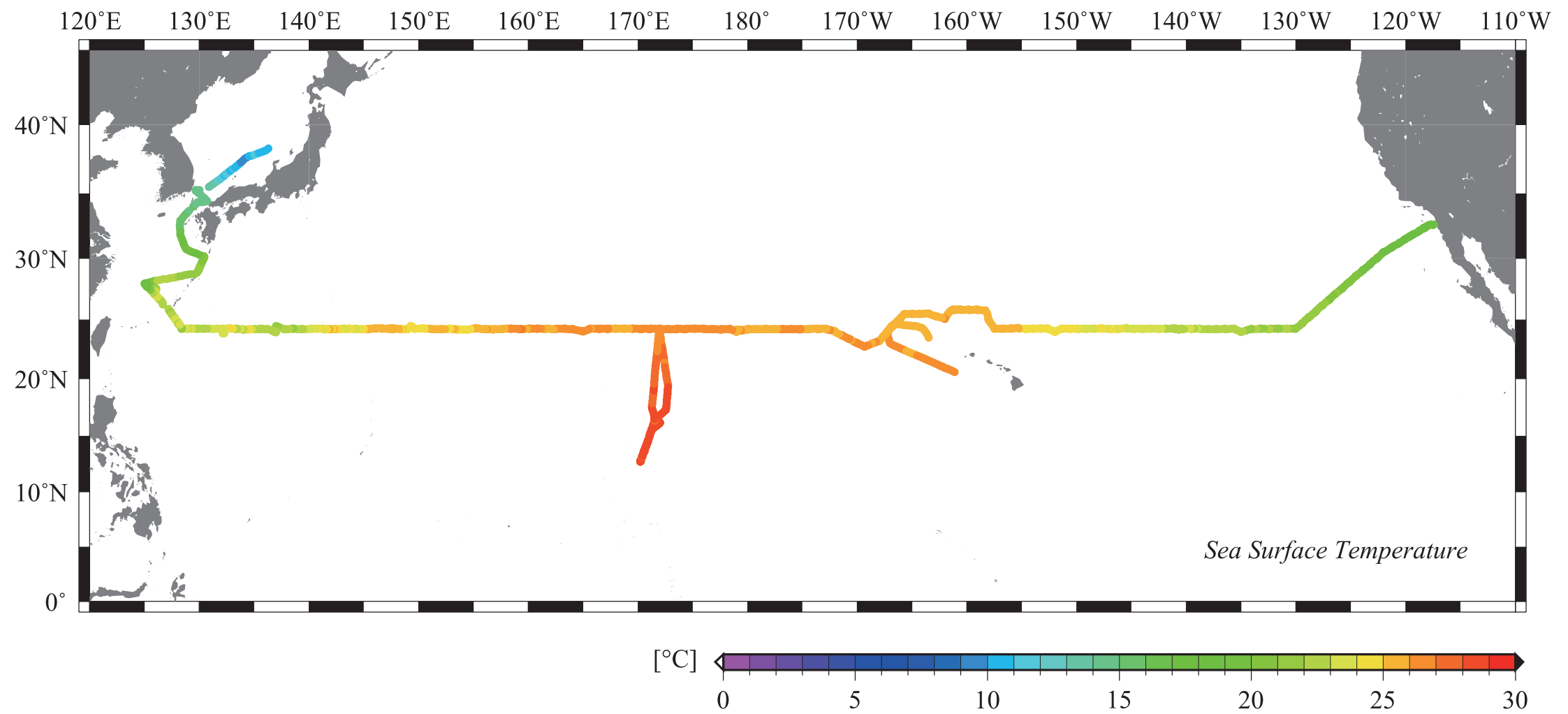
**Figure 2**  
**Continued**



**Figure 3**  
**Surface wind measured at 25 m above sea level**



**Figure 4**  
**Sea surface temperature (SST)**



**Figure 5**  
**Sea surface salinity (SSS)**

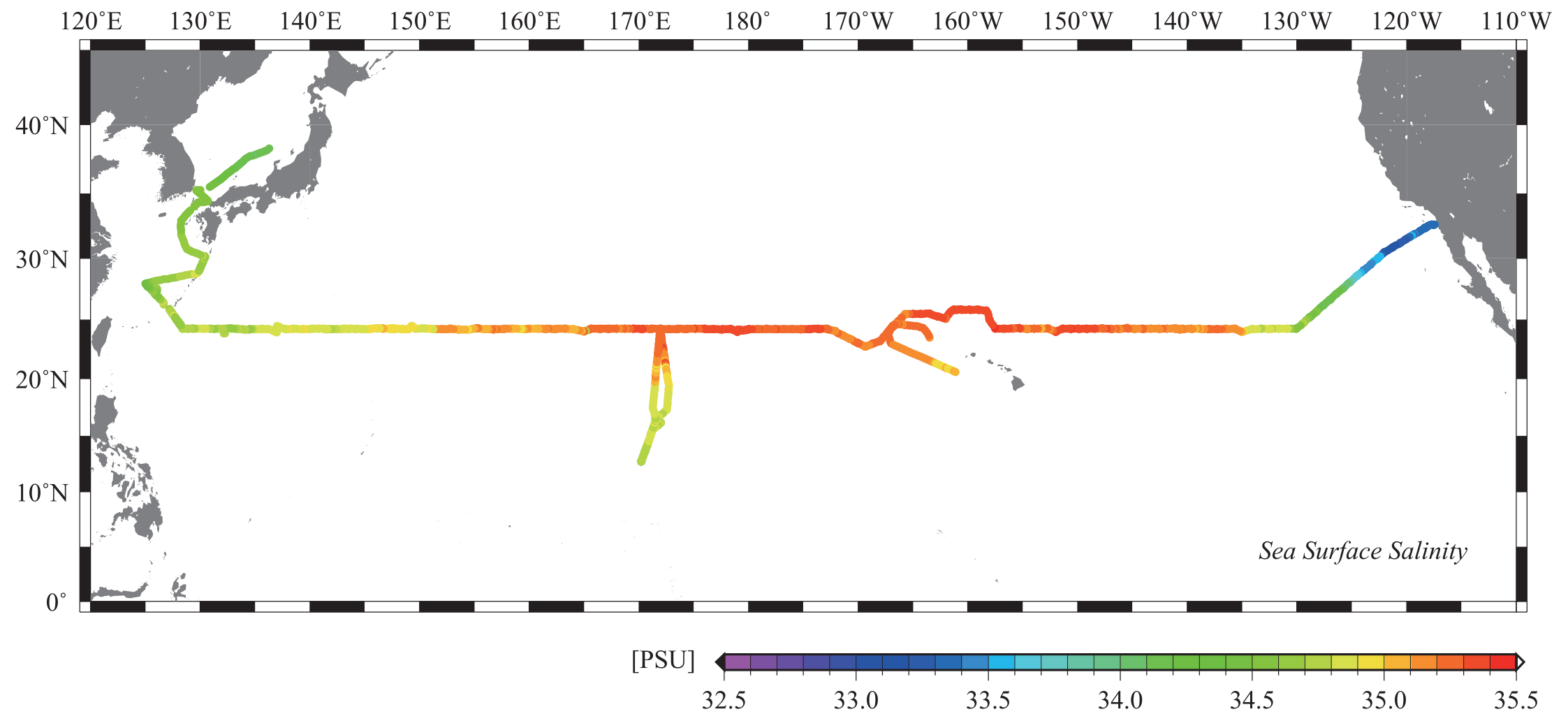
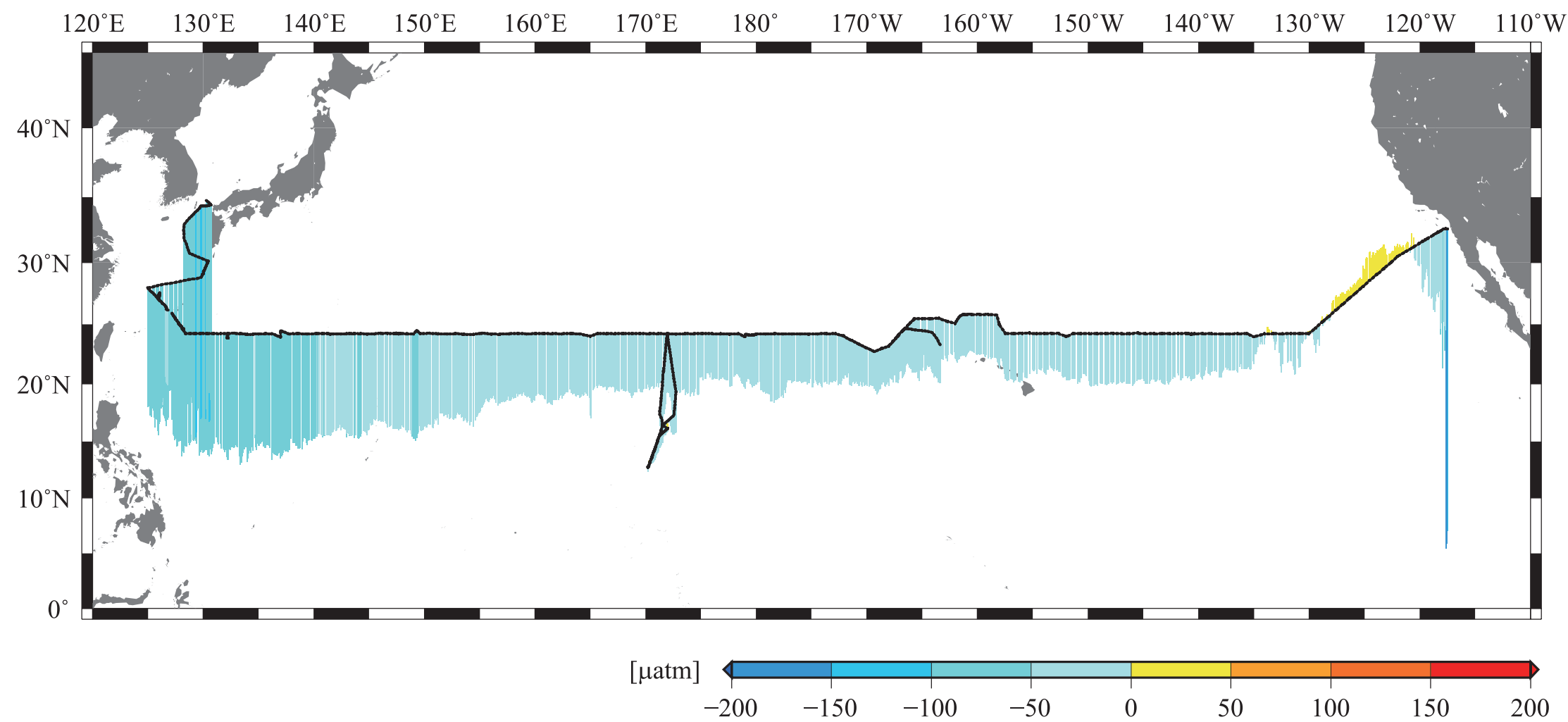


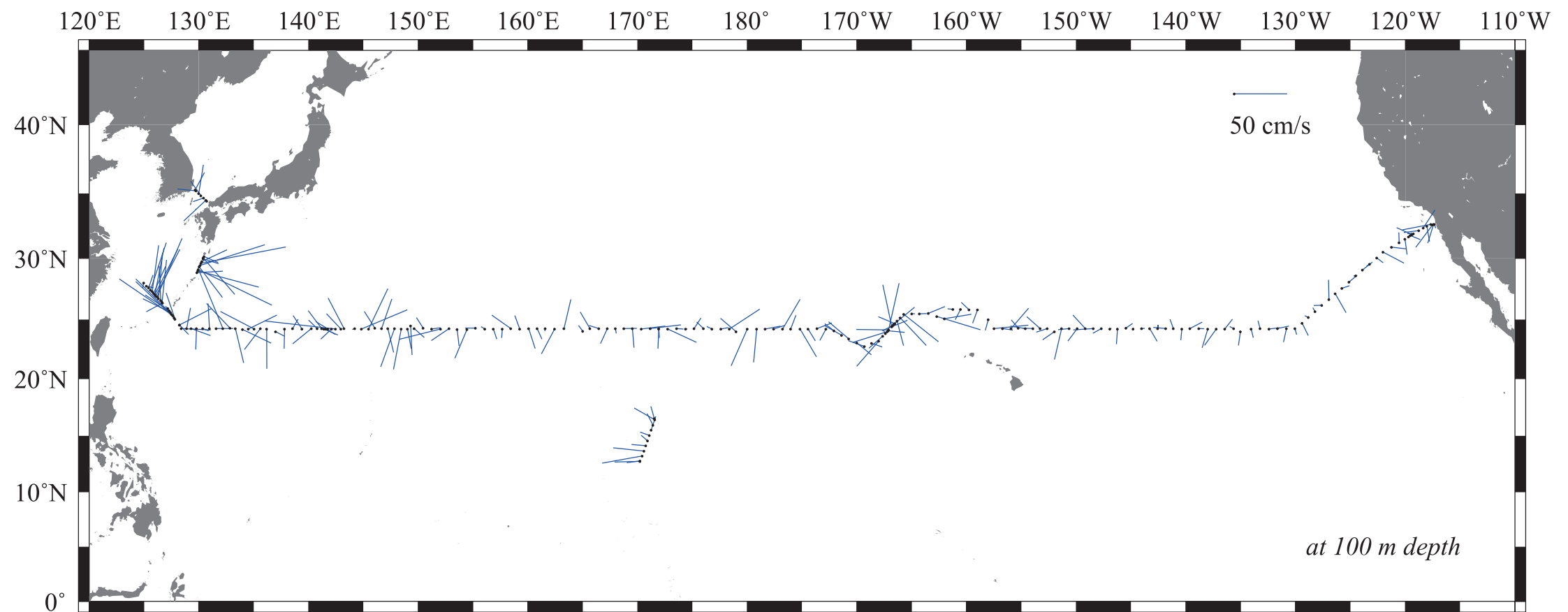


Figure 6

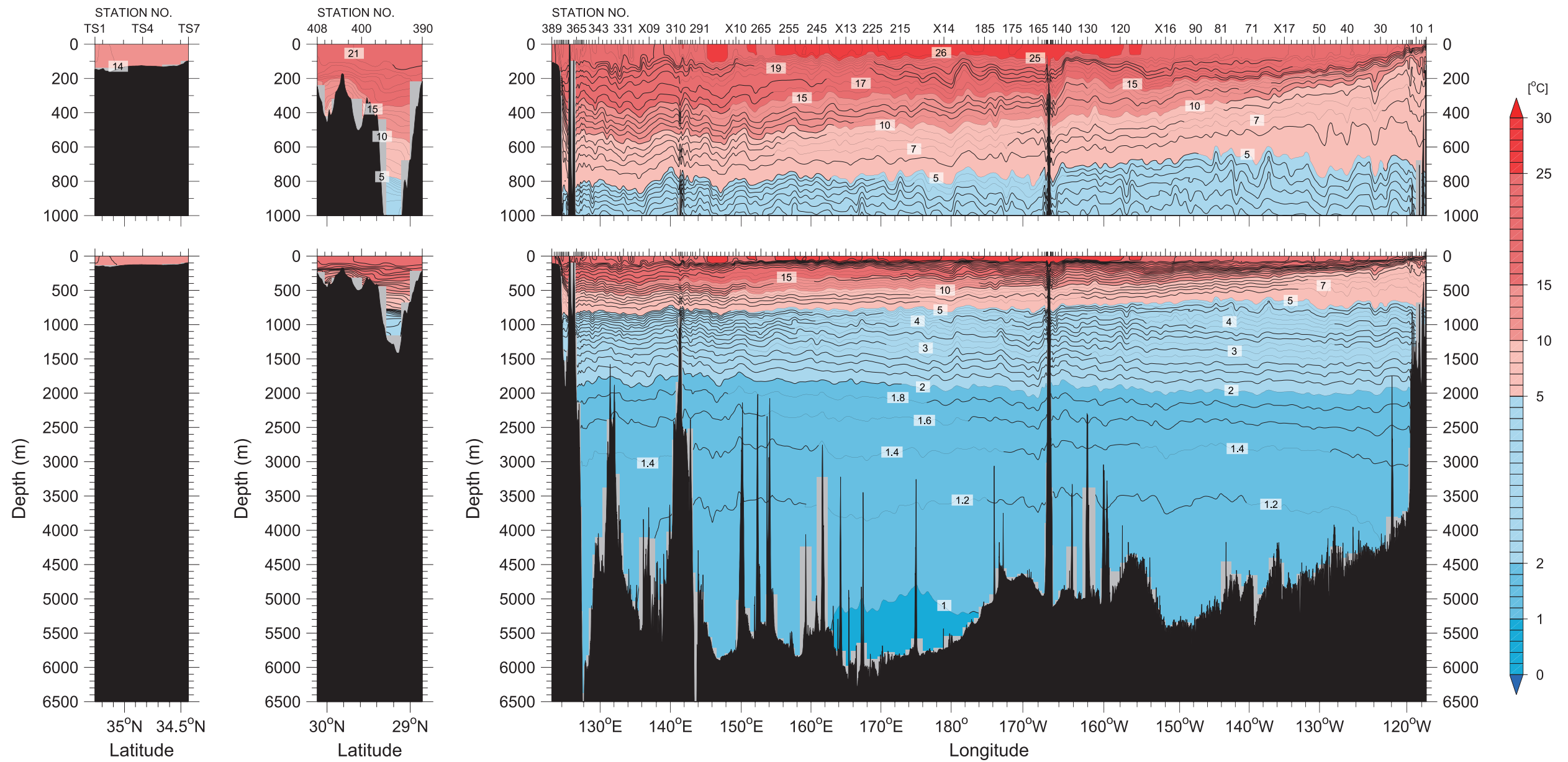
$\Delta p\text{CO}_2$



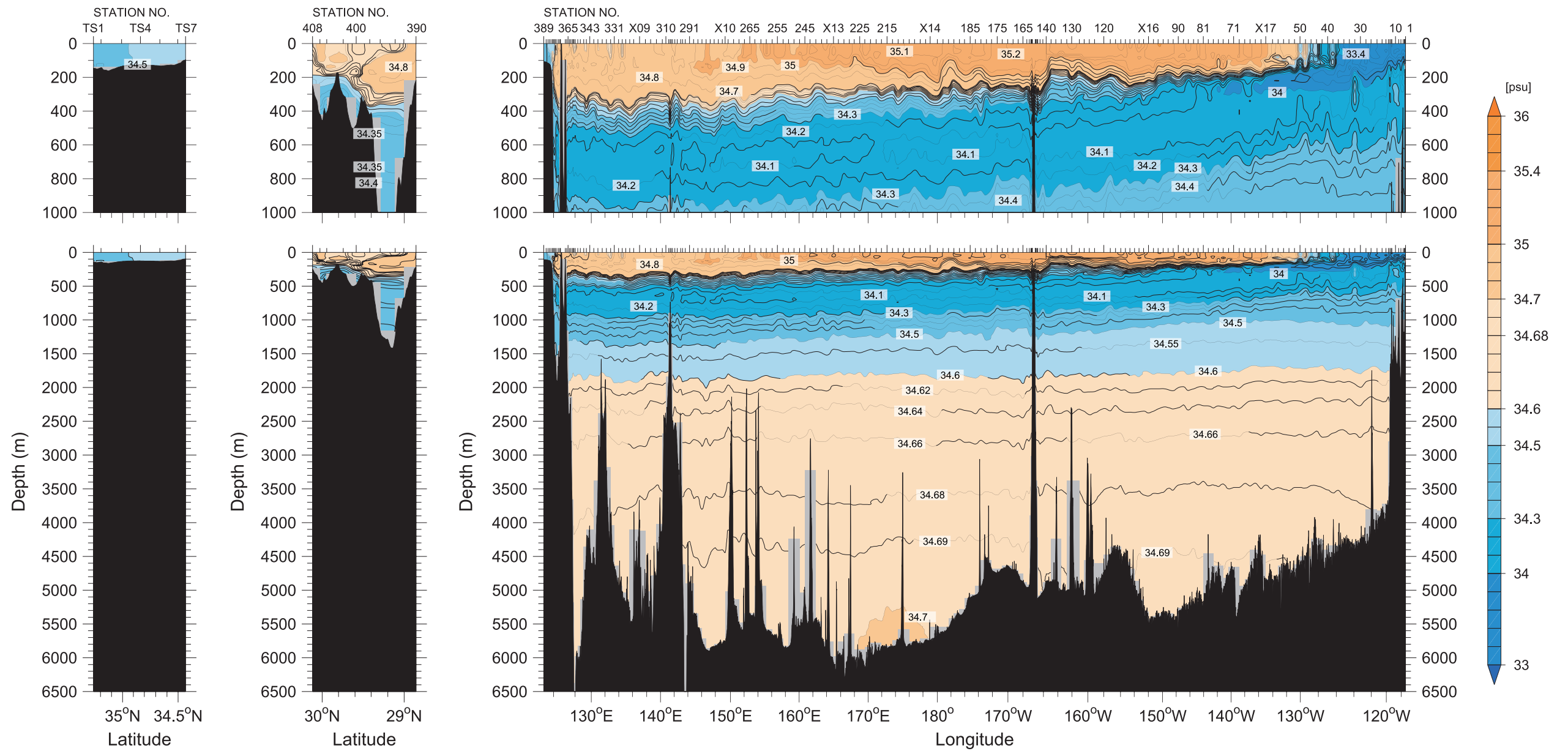
**Figure 7**  
**Surface current measured by shipboard ADCP**



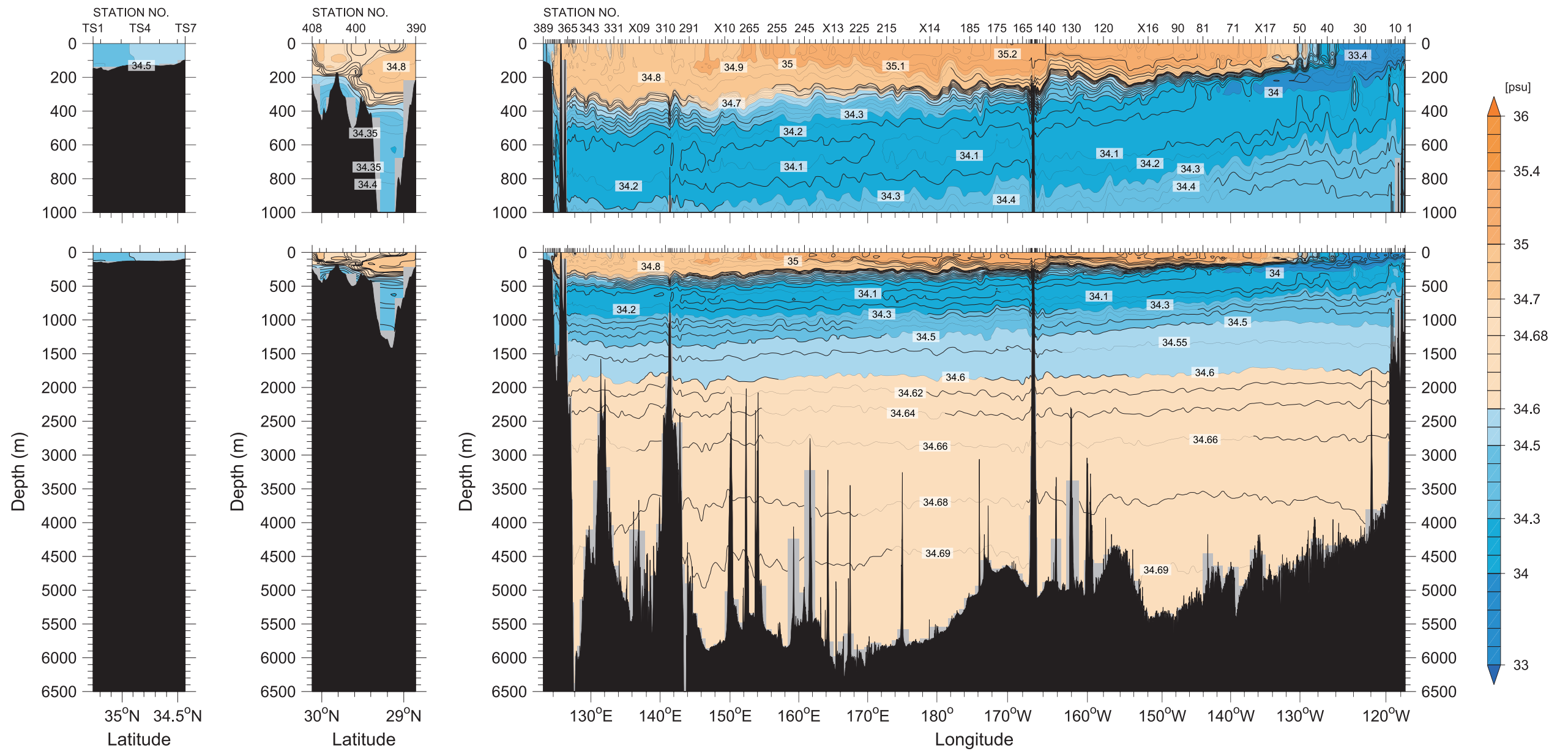
**Figure 8**  
**Potential temperature (°C)**



**Figure 9**  
**CTD salinity (psu)**

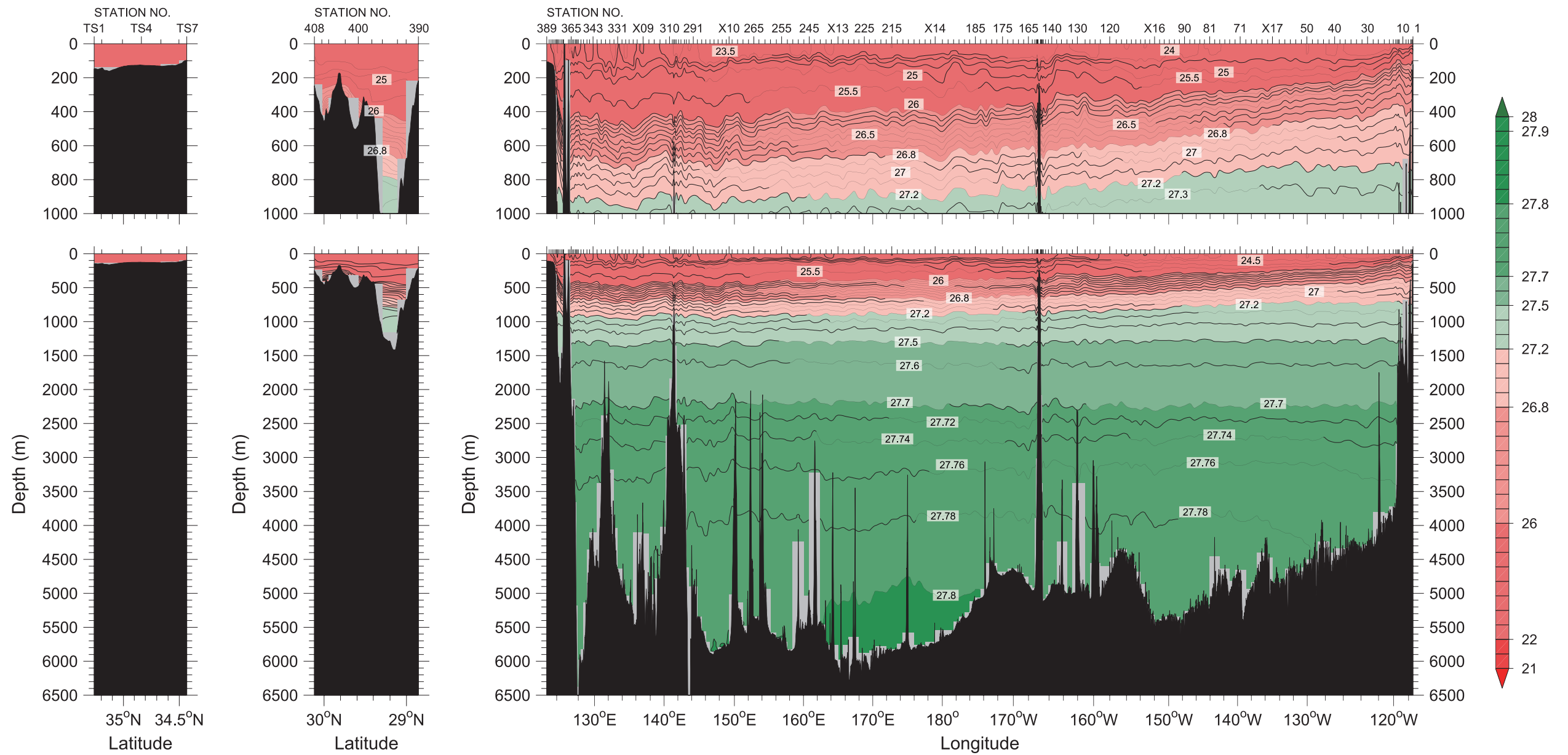


**Figure 10**  
**CTD salinity (psu) with SSW batch correction**

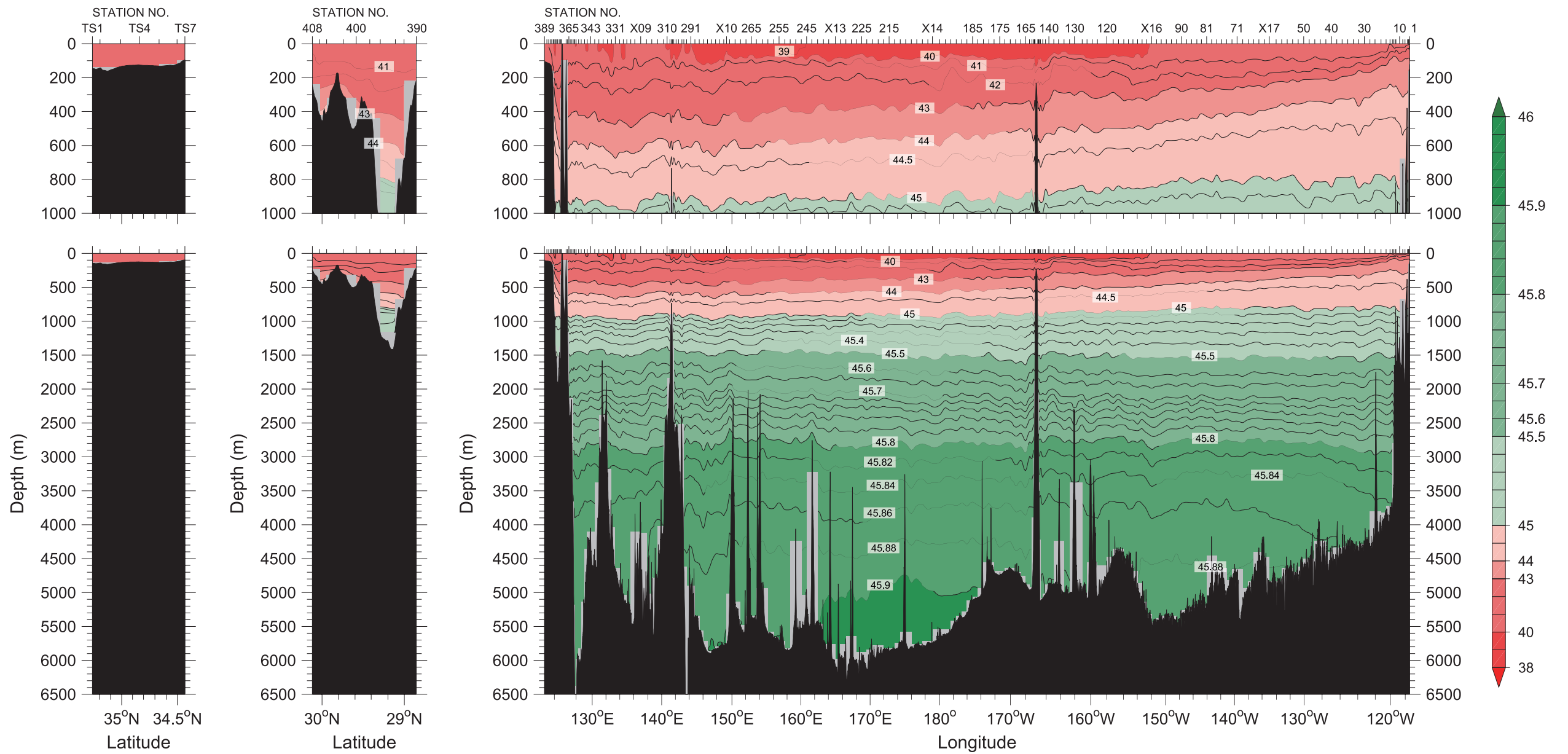




**Figure 11**  
**Density ( $\sigma_0$ ) ( $\text{kg/m}^3$ )**



**Figure 12**  
**Density ( $\sigma_4$ ) ( $\text{kg/m}^3$ )**





**Figure 13**  
**Density ( $\gamma^n$ ) ( $\text{kg/m}^3$ )**

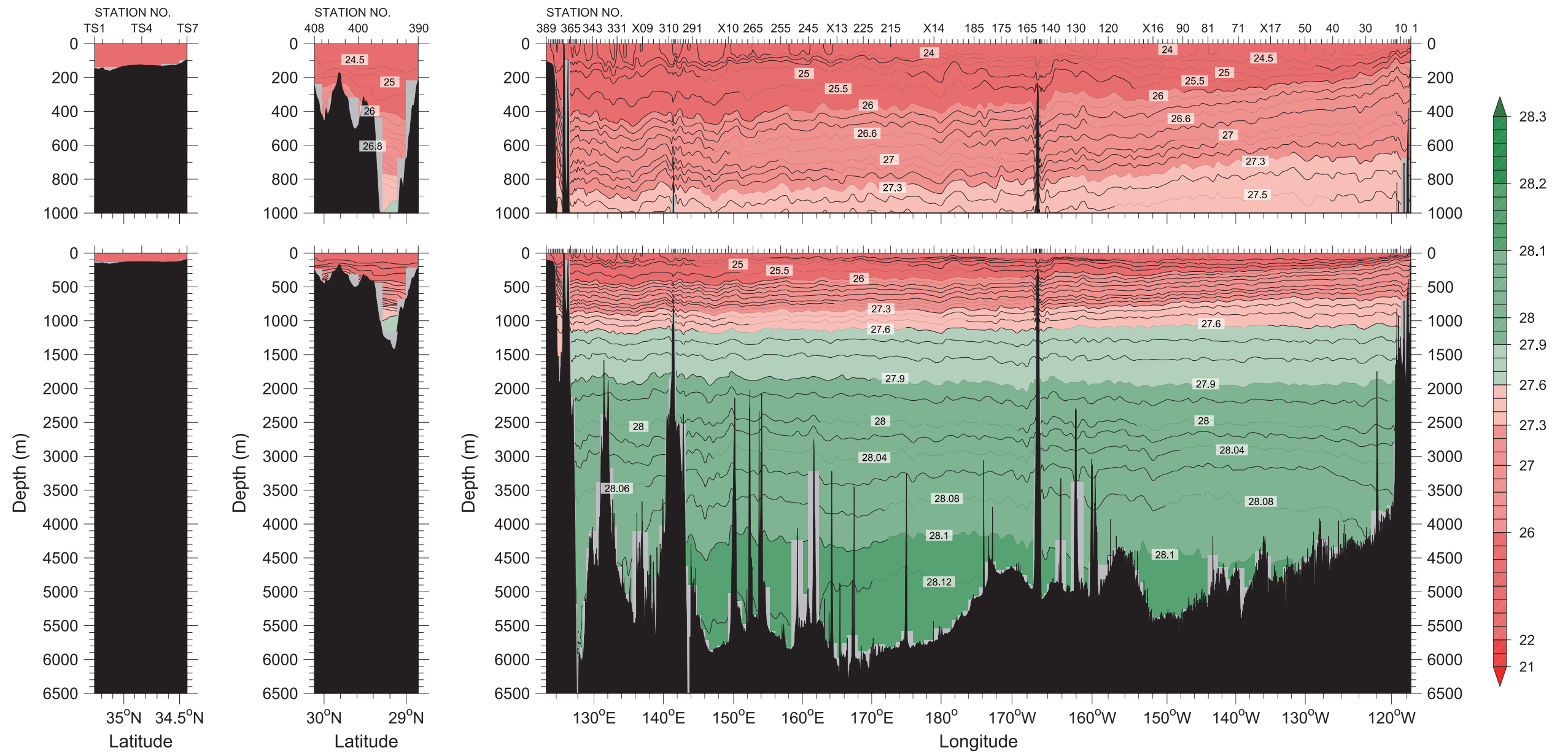
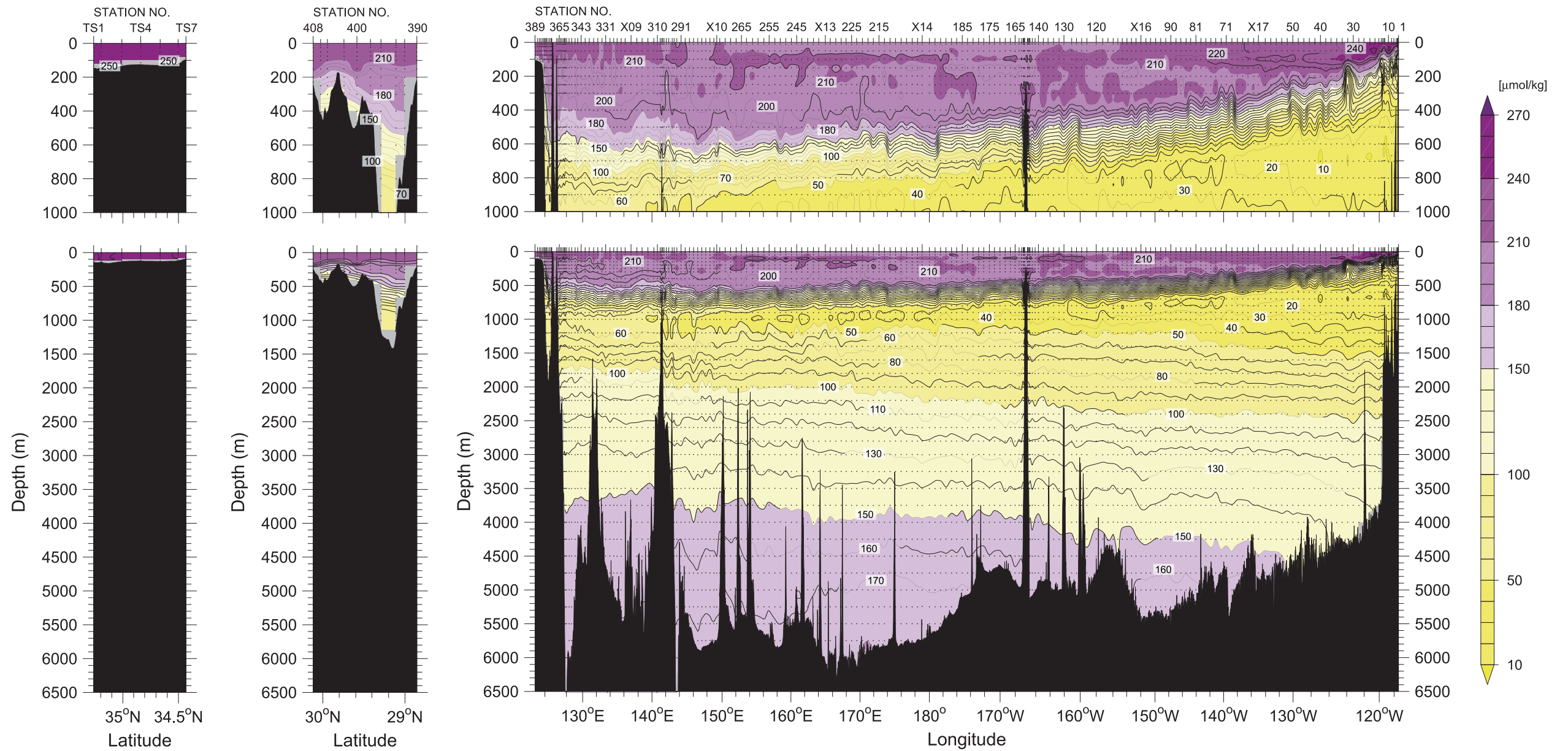
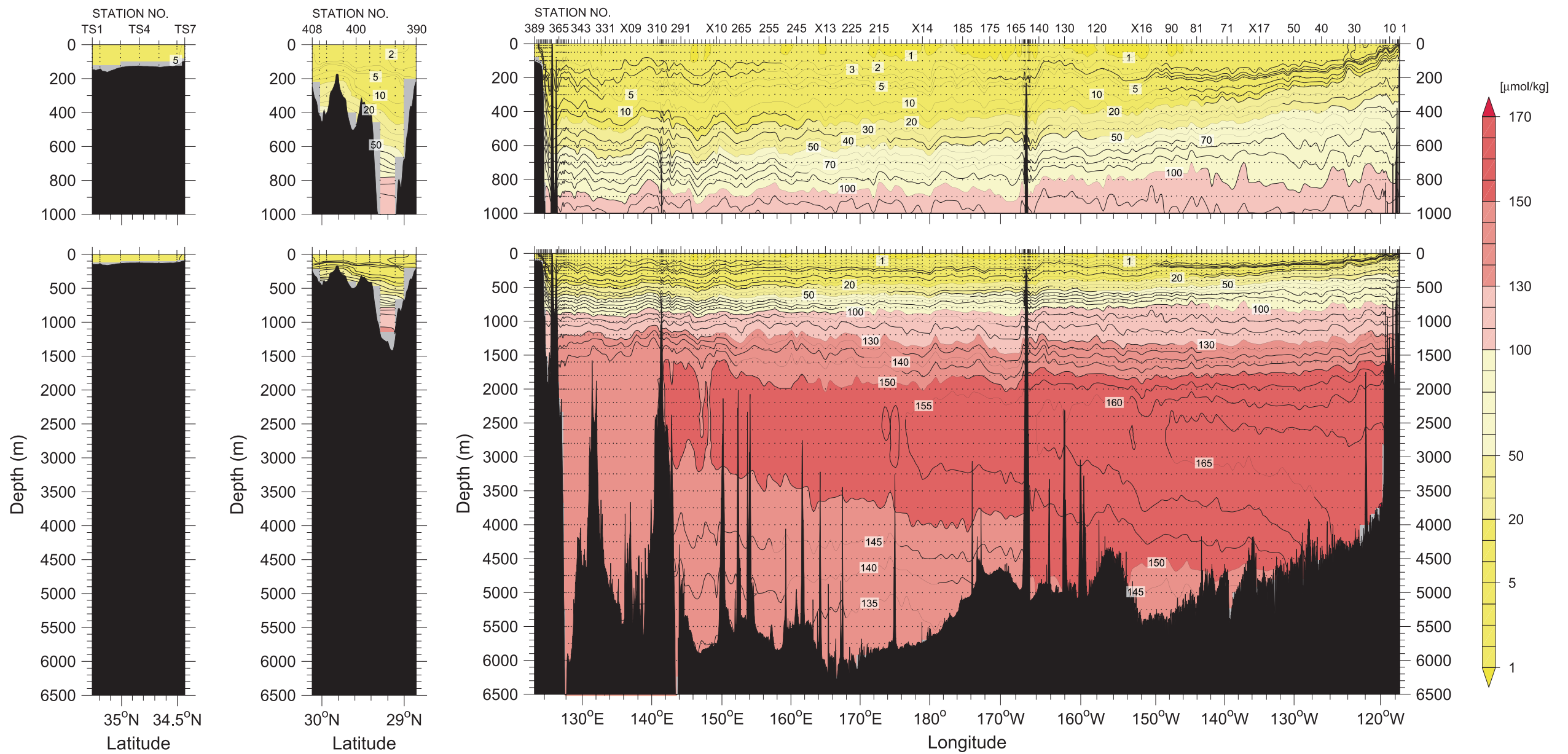


Figure 14

Bottle sampled dissolved oxygen ( $\mu\text{mol/kg}$ )



**Figure 15**  
**Silicate ( $\mu\text{mol/kg}$ )**





**Figure 16**  
**Nitrate ( $\mu\text{mol/kg}$ )**

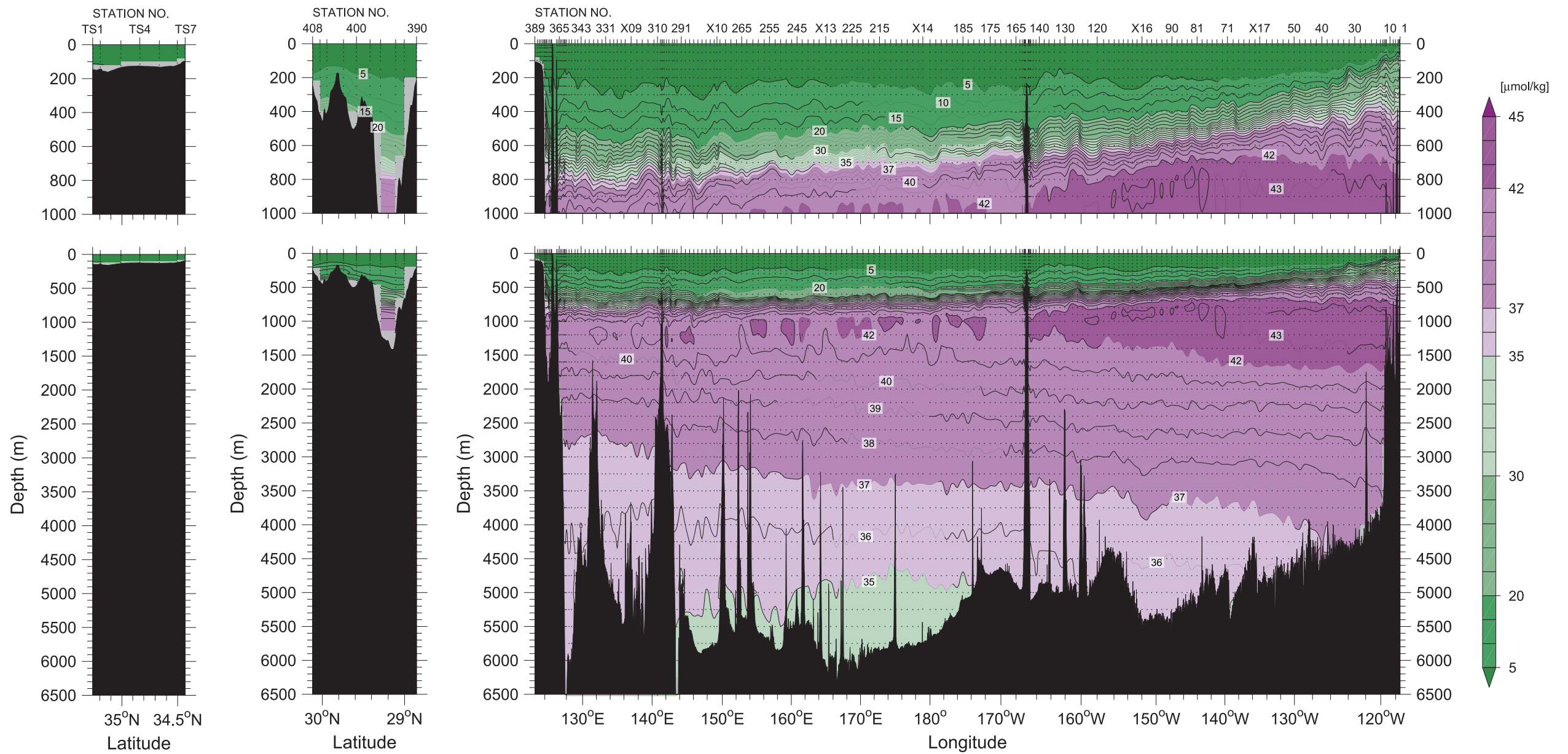
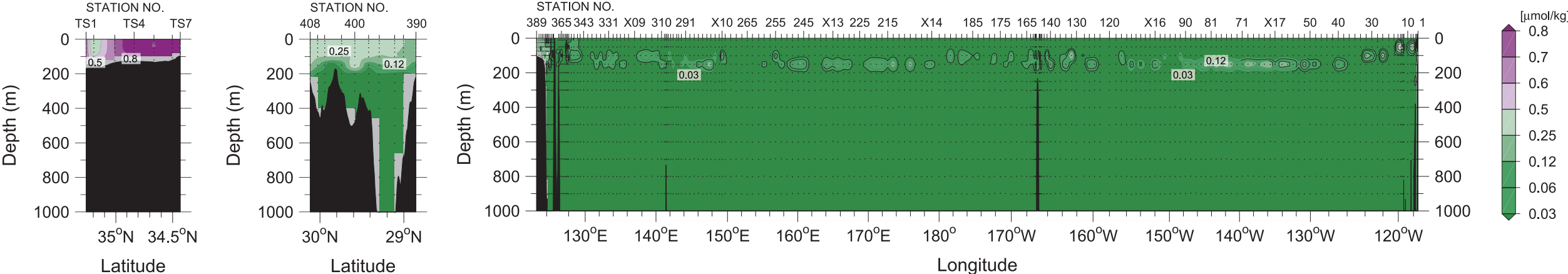
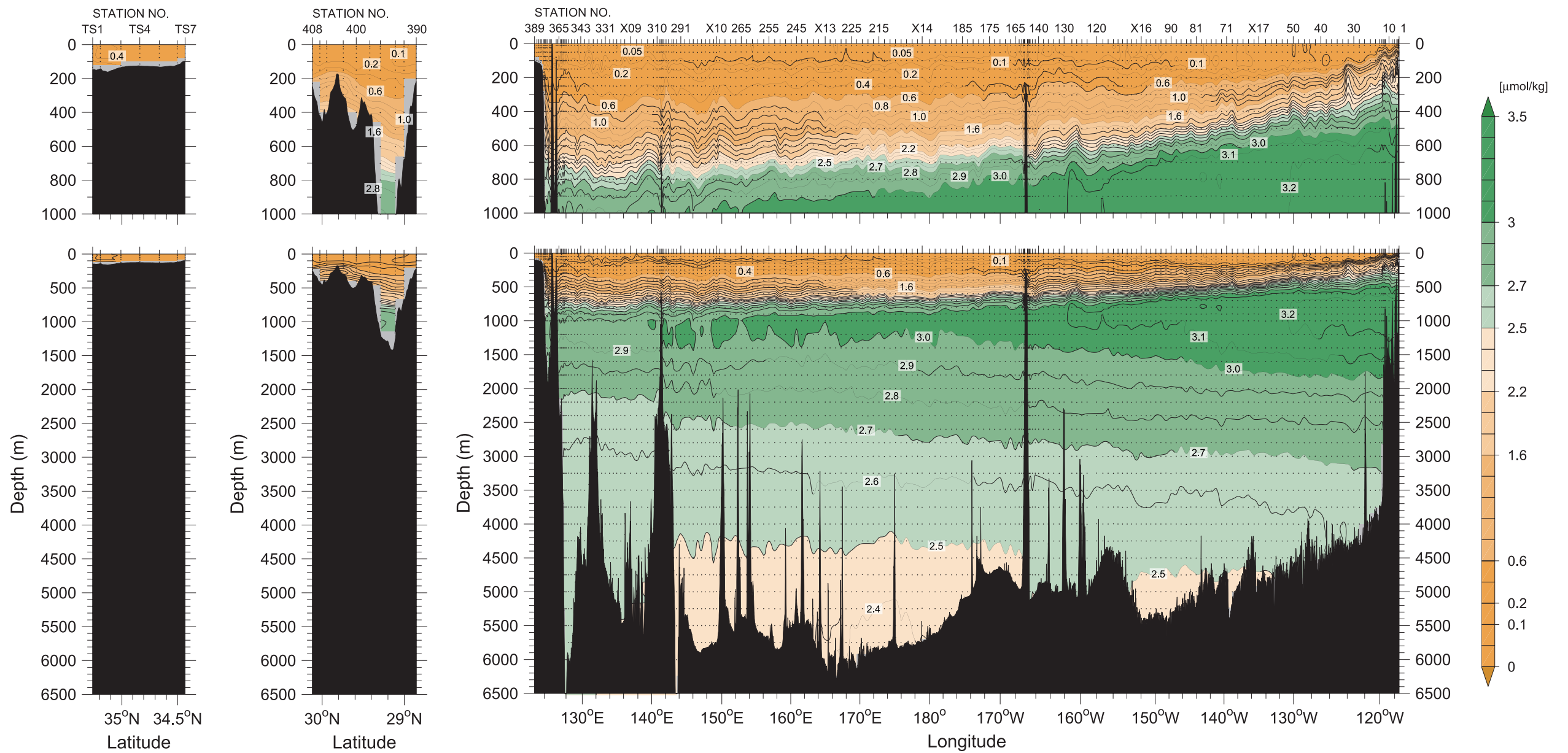


Figure 17

Nitrate ( $\mu\text{mol/kg}$ )



**Figure 18**  
**Phosphate ( $\mu\text{mol/kg}$ )**



**Figure 19**  
**Dissolved inorganic carbon ( $\mu\text{mol/kg}$ )**

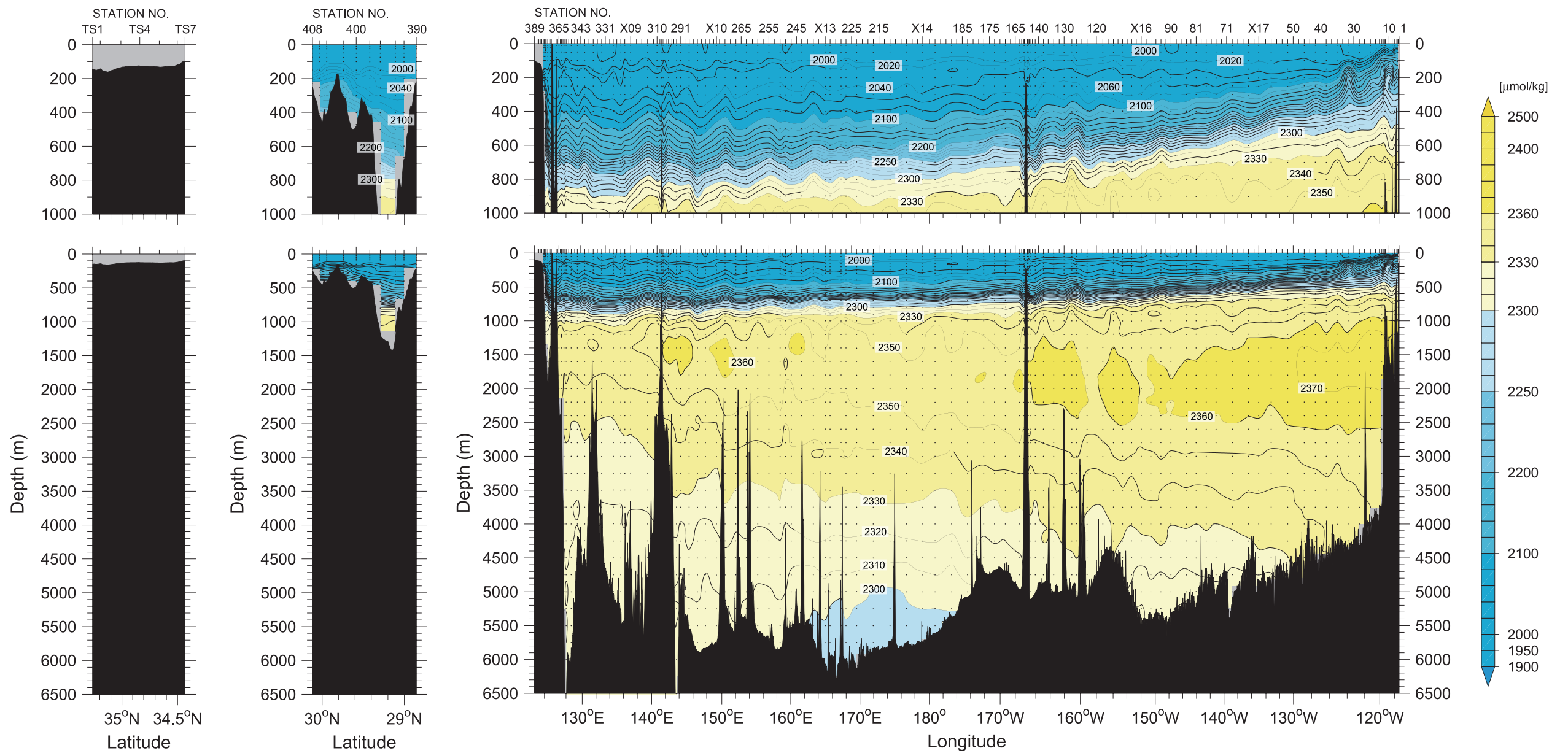




Figure 20

Total alkalinity ( $\mu\text{mol/kg}$ )

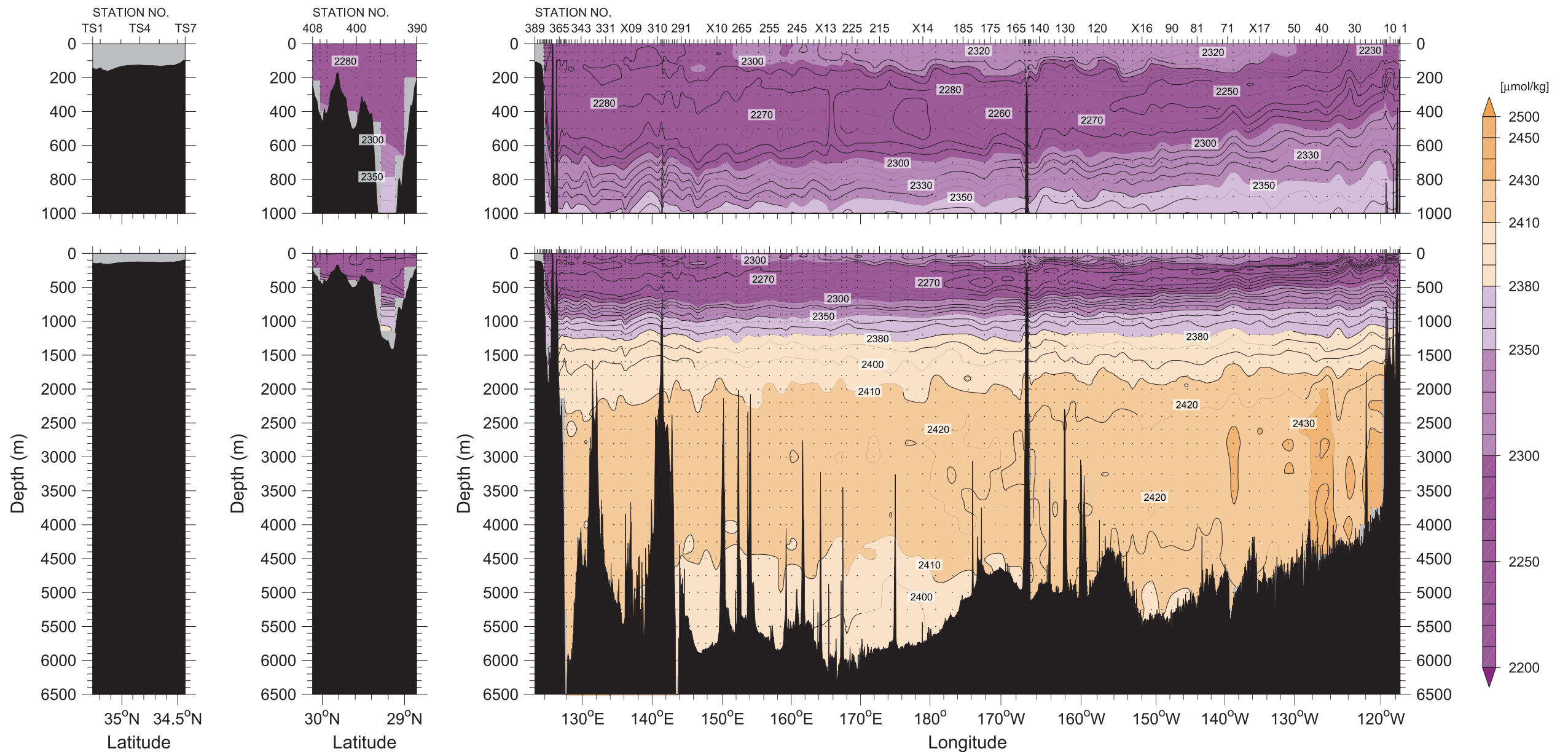
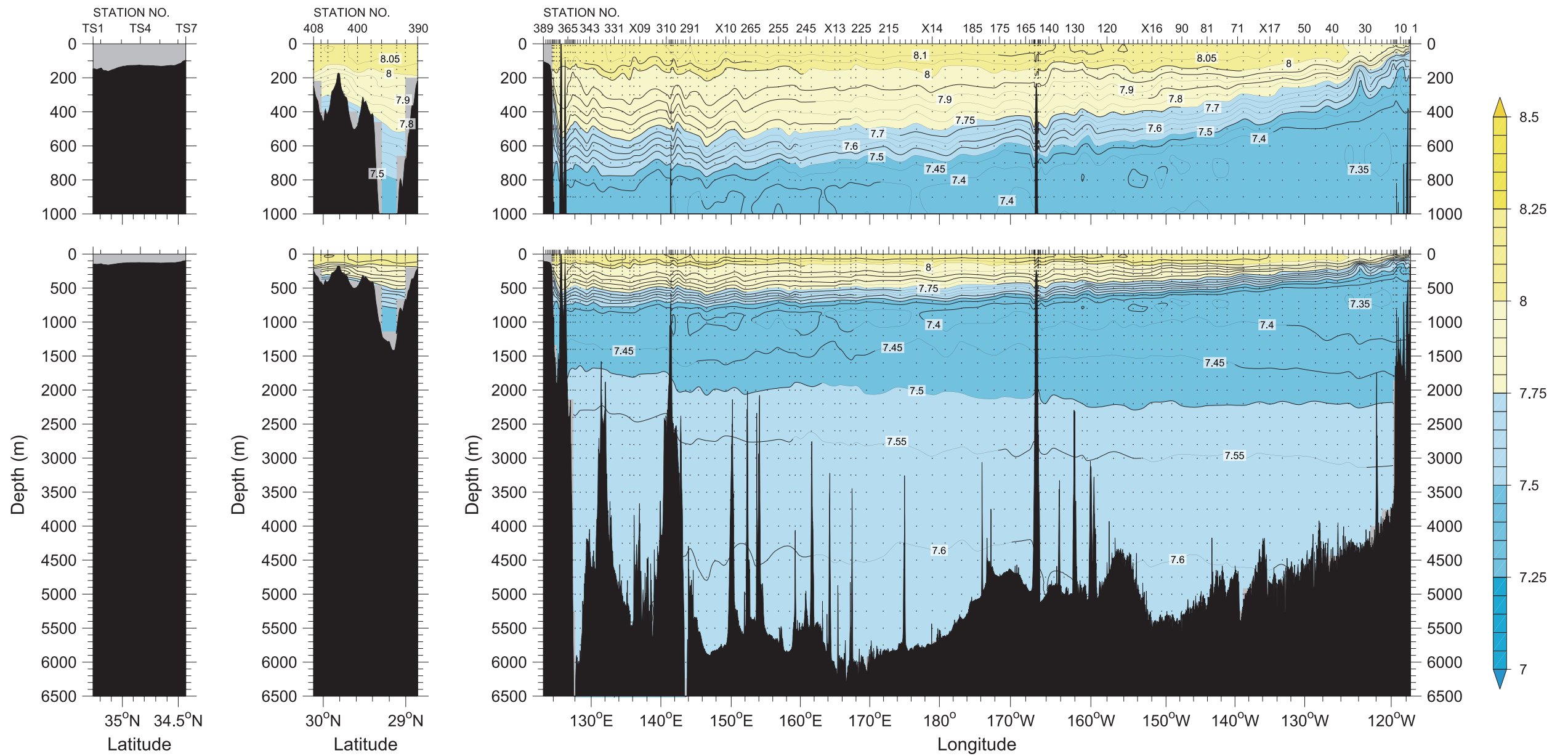
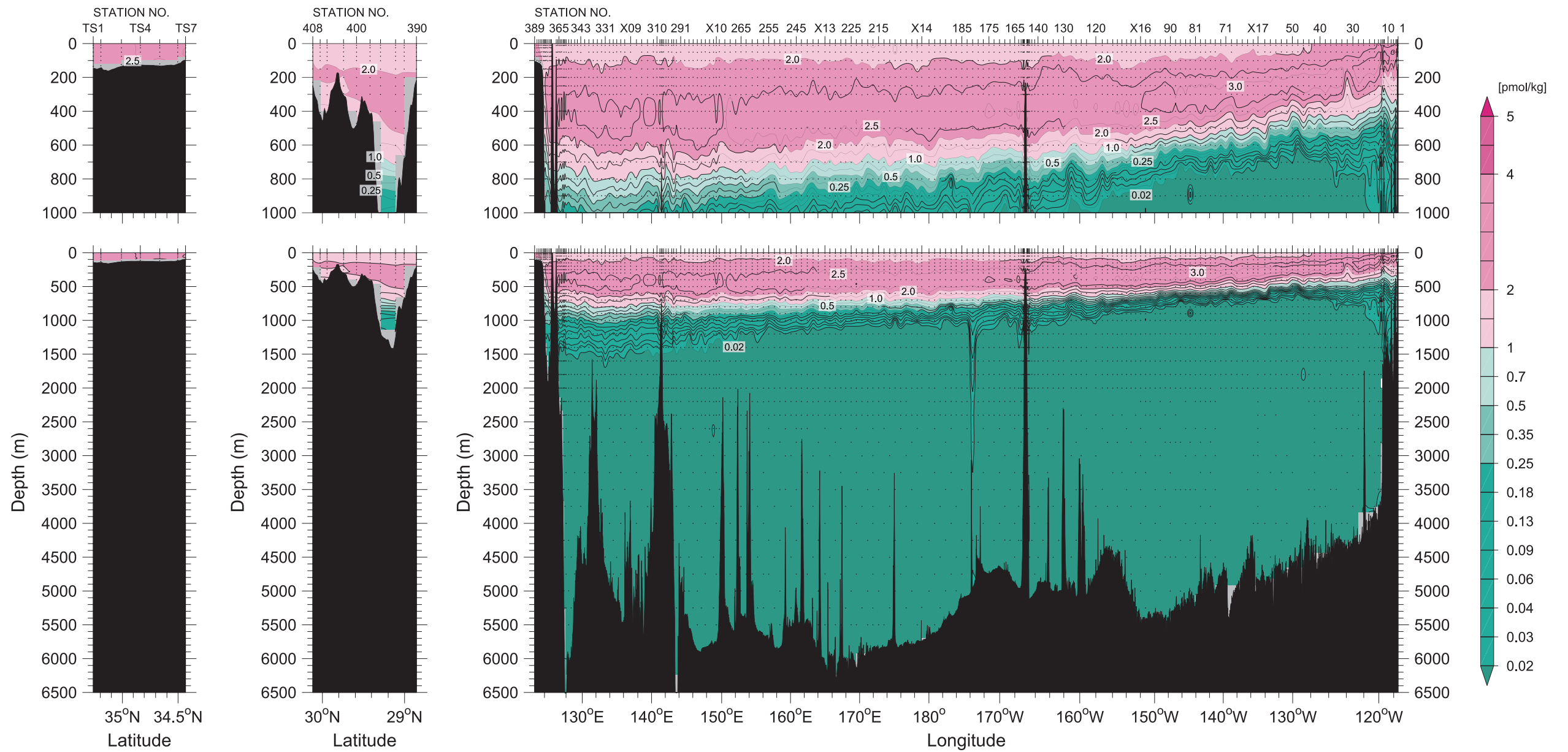


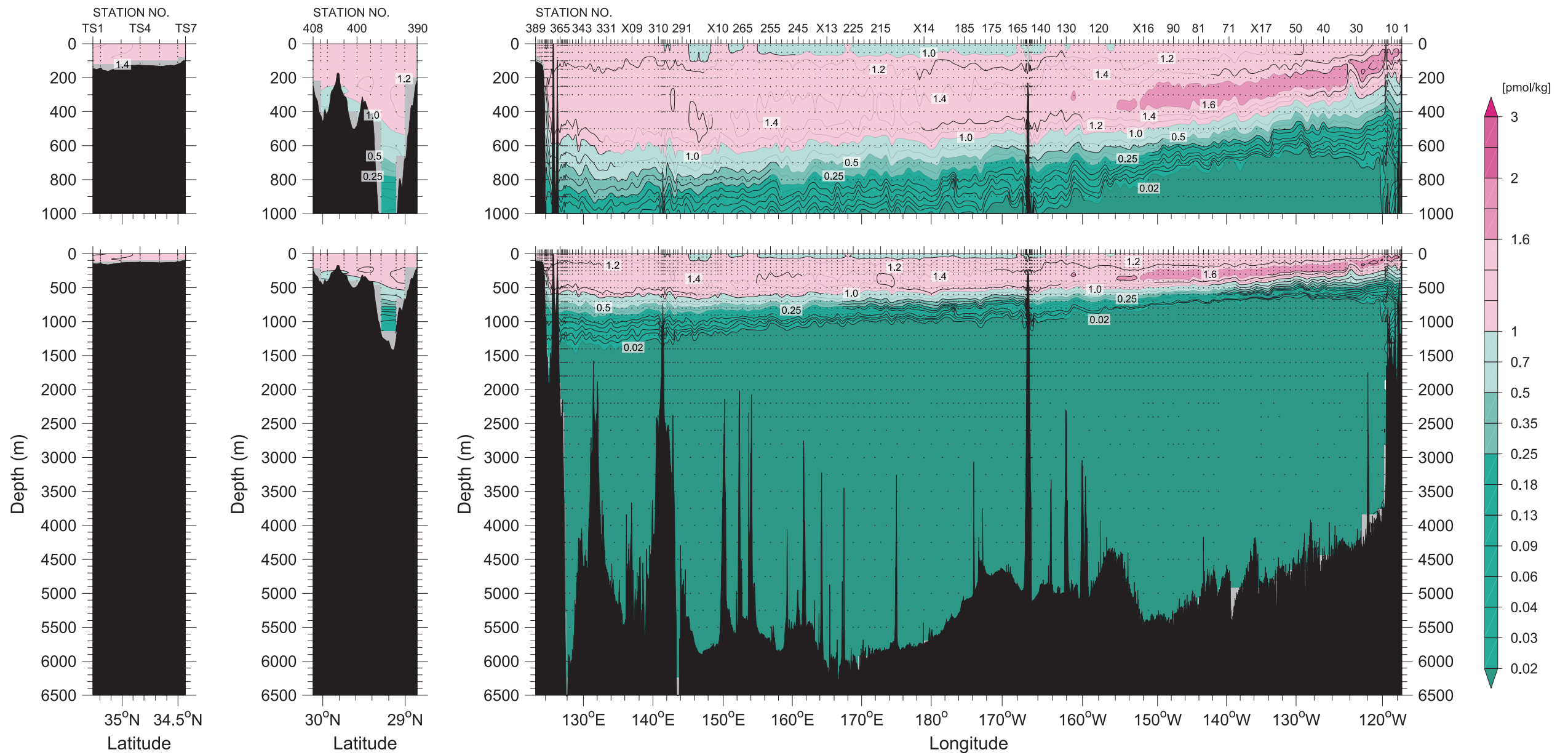
Figure 21  
pH



**Figure 22**  
**CFC-11 (pmol/kg)**

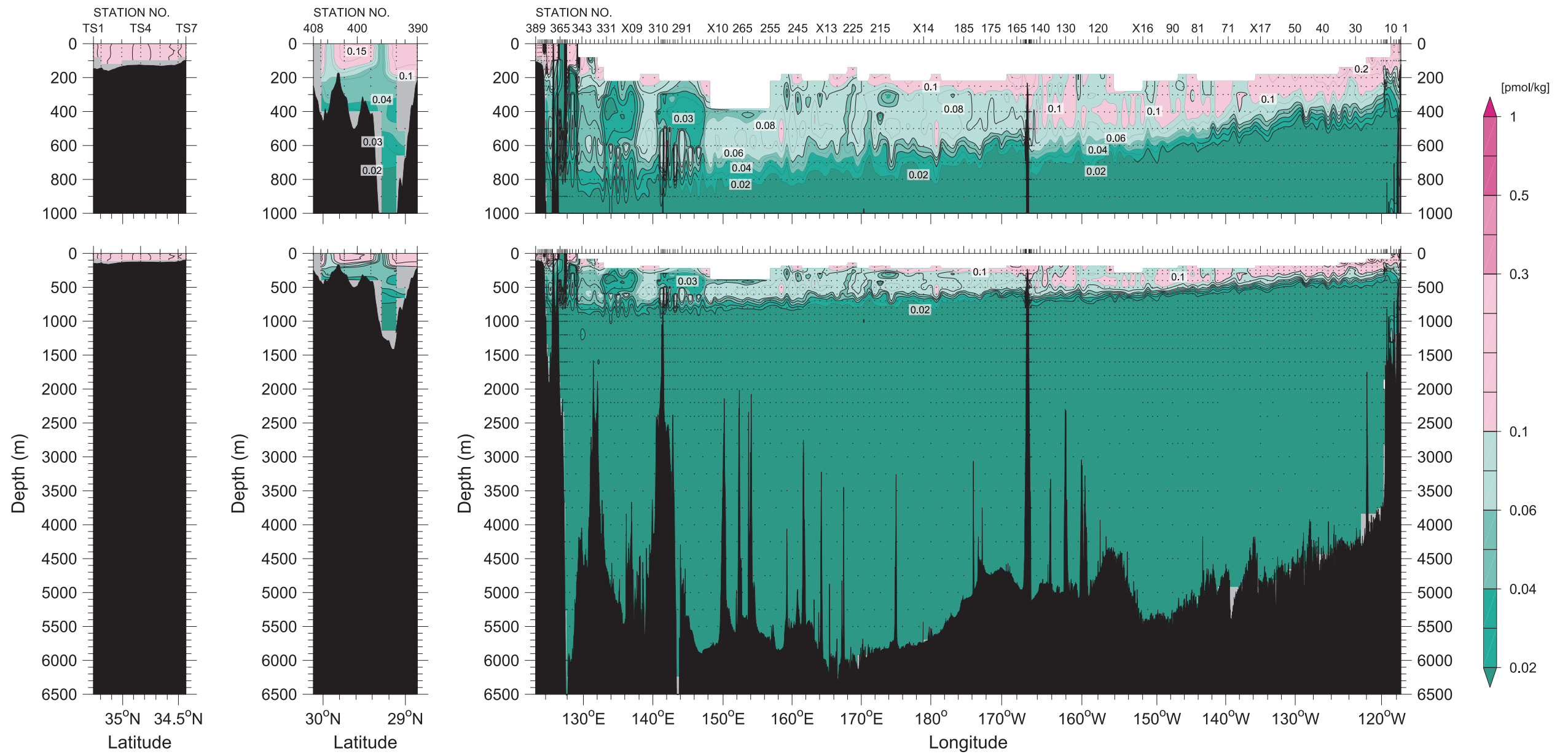


**Figure 23**  
**CFC-12 (pmol/kg)**



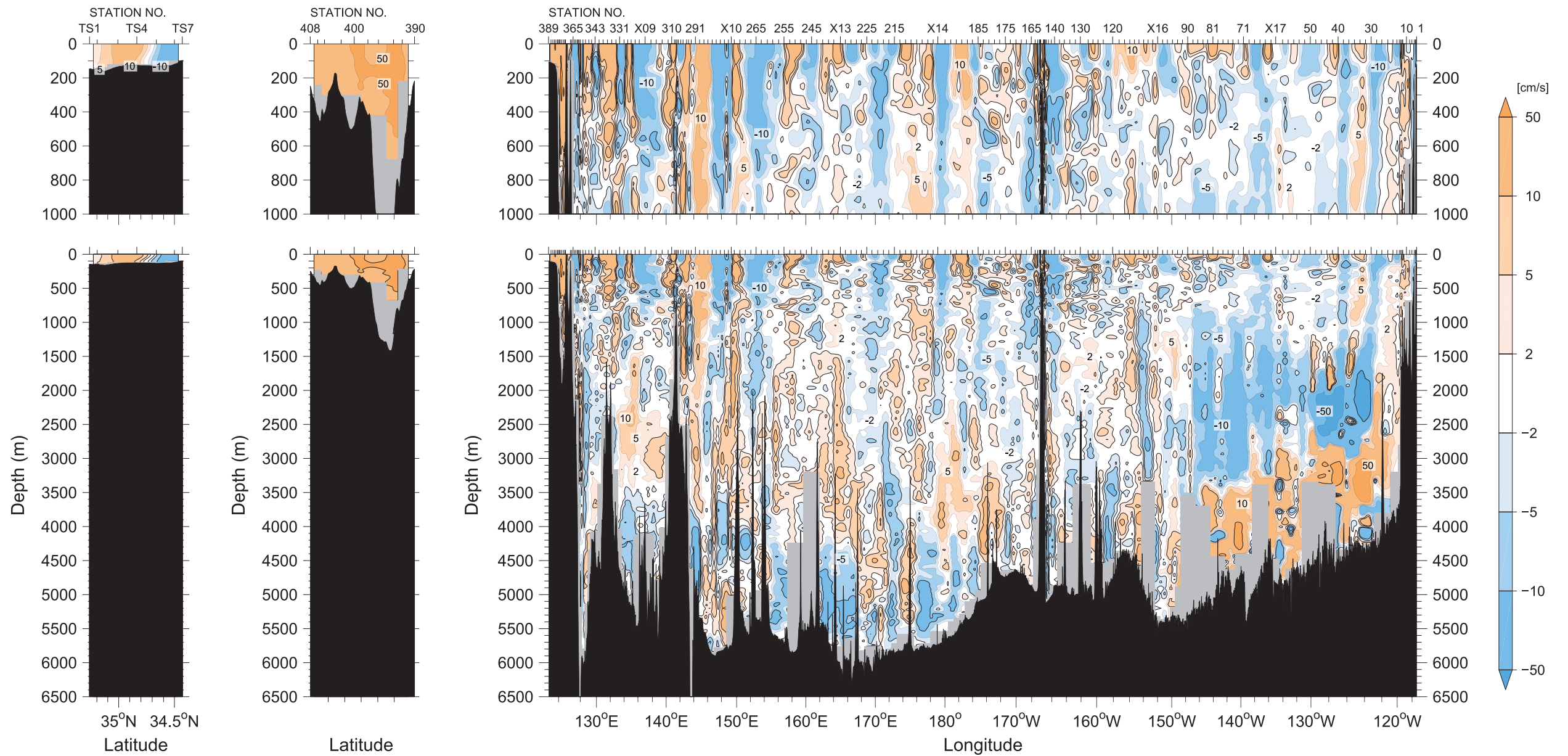


**Figure 24**  
**CFC-113 (pmol/kg)**



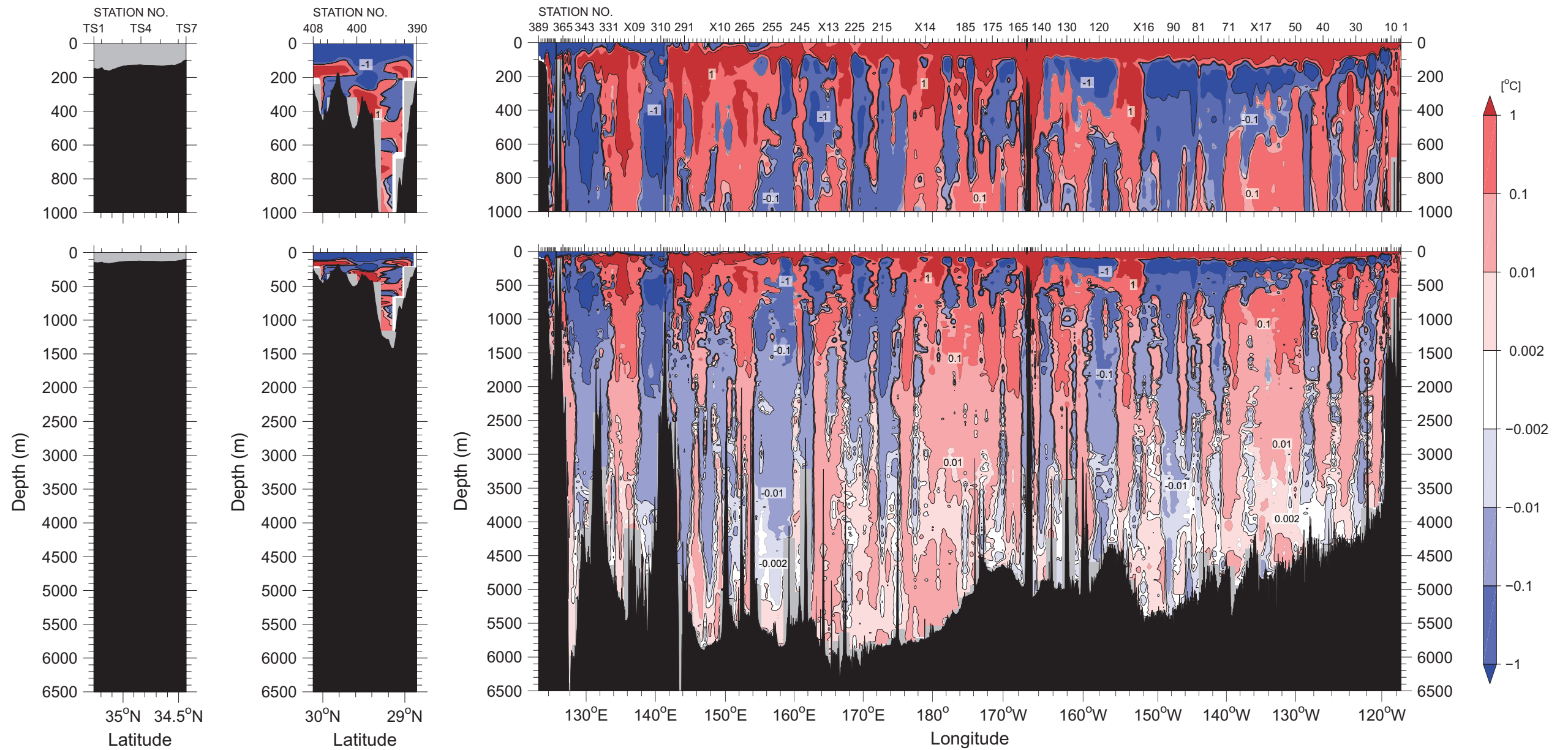
**Figure 25**

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



**Figure 26**

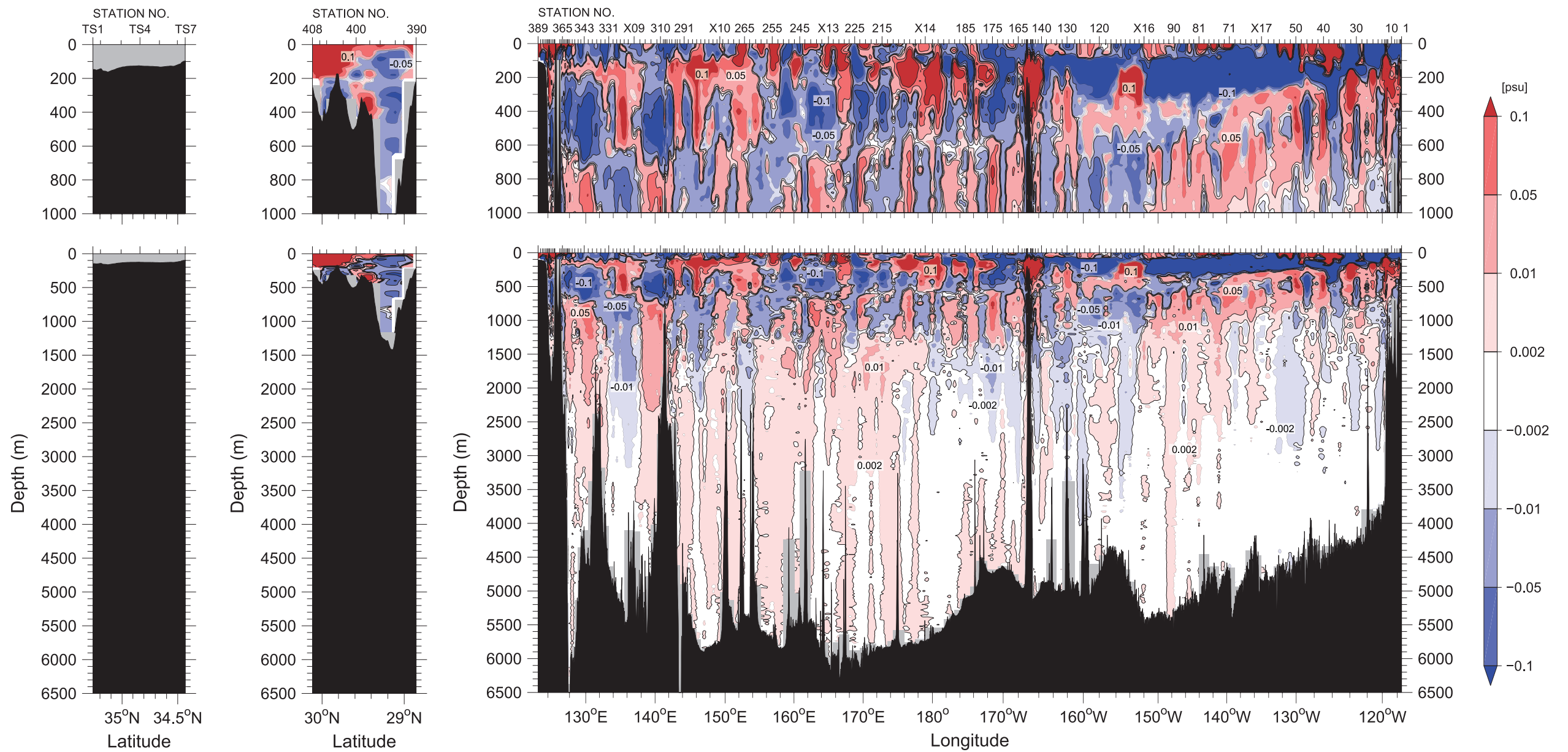
**Difference in potential temperature (°C) between results from WOCE and the revisit cruise**





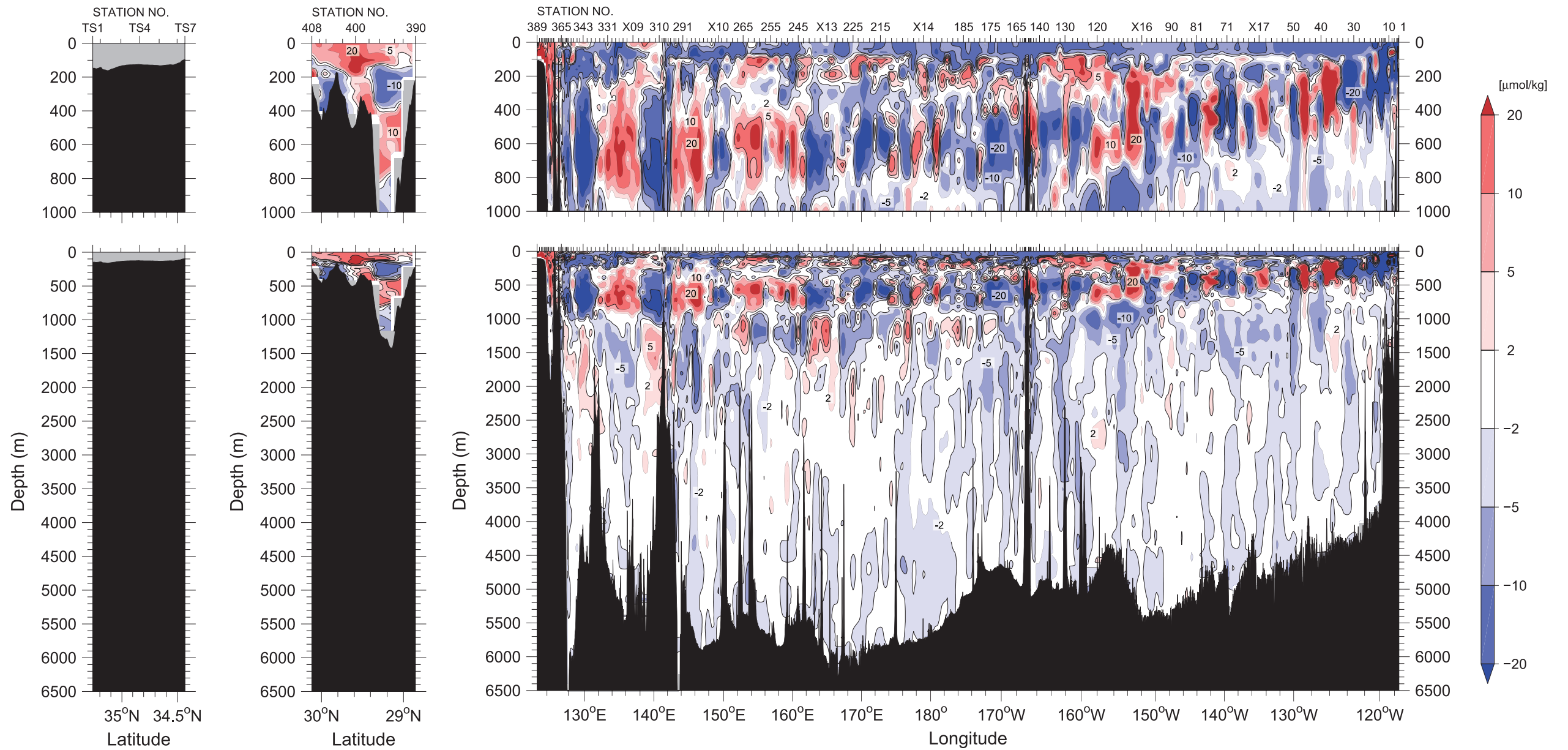
**Figure 27**

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



**Figure 28**

**Difference in dissolved oxygen ( $\mu\text{mol/kg}$ ) between results from WOCE and the revisit cruise**







## CCHDO Data Processing Notes

Date	Contact	Data Type	Action
01/16/08	Kappa	CTD/BTL/SUM	woce & exchange format
			I downloaded all the ctd, btl & sum files in woce and exchange format from the CDIAC site and burned them to a CD, which I just put on your desk. LADCP data, which I didn't download, are also available