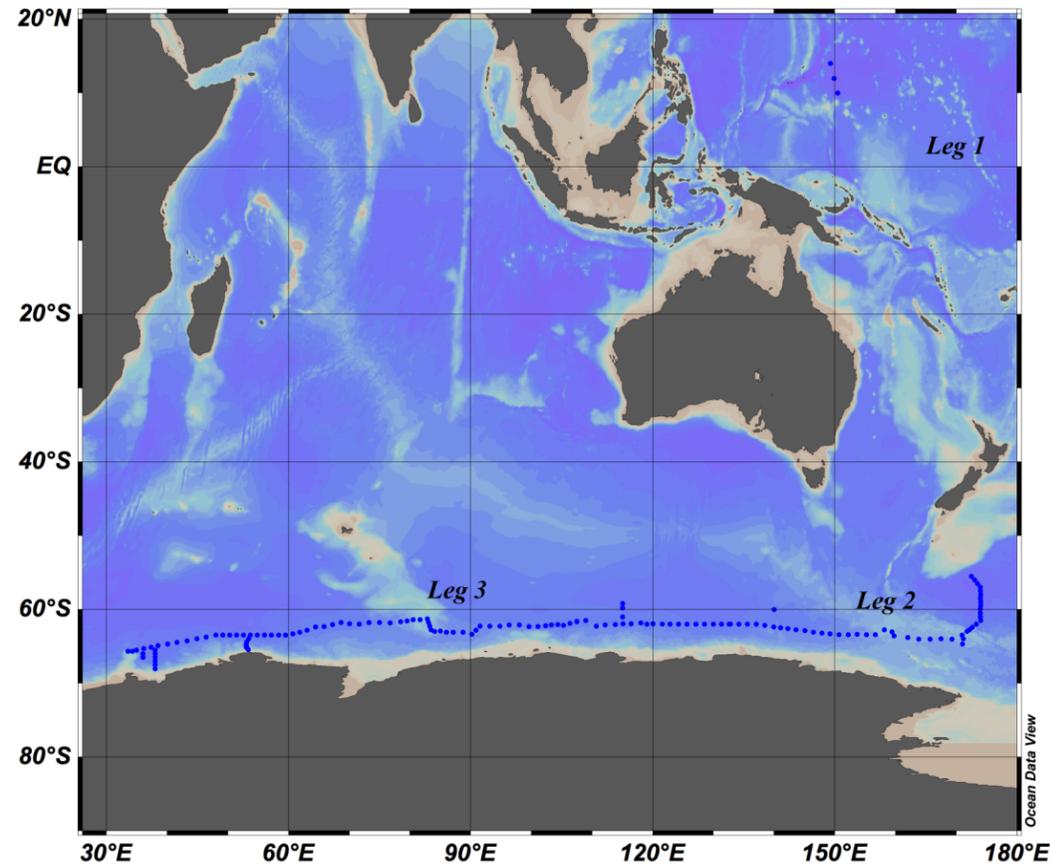


# CRUISE REPORT: P14S / S04 / S04I / I09S (MR12-05)

(Updated JUL 2015)



## Highlights

### Cruise Summary Information

Leg	Leg 1	Leg 2	Leg 3
Section Designation	N/A	P14S/S04/S04I/I09S	S04I
Expedition designation (ExpoCodes)	49NZ20121105	49NZ20121128	49NZ20130106
Chief Scientists	Katsuro Katsumata/JAMSTEC	Katsuro Katsumata/JAMSTEC	Hiroshi Uchida/JAMSTEC
Dates	2012 NOV 5 - 2012 NOV 26	2012 NOV 28 - 2013 JAN 4	2013 JAN 6 - 2013 FEB 15
Ship	R/V <i>Mirai</i>		
Ports of call	Sekinehama, JPN; Hachinohe, JPN – Auckland, NZ	Auckland, NZ - Hobart, AUS	Hobart, AUS - Fremantle, AUS
Geographic Boundaries		40° 29.82' N 33° 29.21' E	174° 2.83' E 68° 3.65' S
Stations	3	54 (Includes 6 XCTD-only)	77
Floats and drifters deployed	3 Argo floats	4 Deep NINJA floats	
Moorings deployed or recovered	2 including 1 emergency recovery of Southern Ocean Flux Buoy (Bureau of Meteorology, Australia)		

### Contact Information:

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)  
2-15 Natsushima, Yokosuka, Kanagawa, Japan 237-0061

Katsuro Katsumata: k.katsumata@jamstec.go.jp

Hiroshi Uchida: huchida@jamstec.go.jp

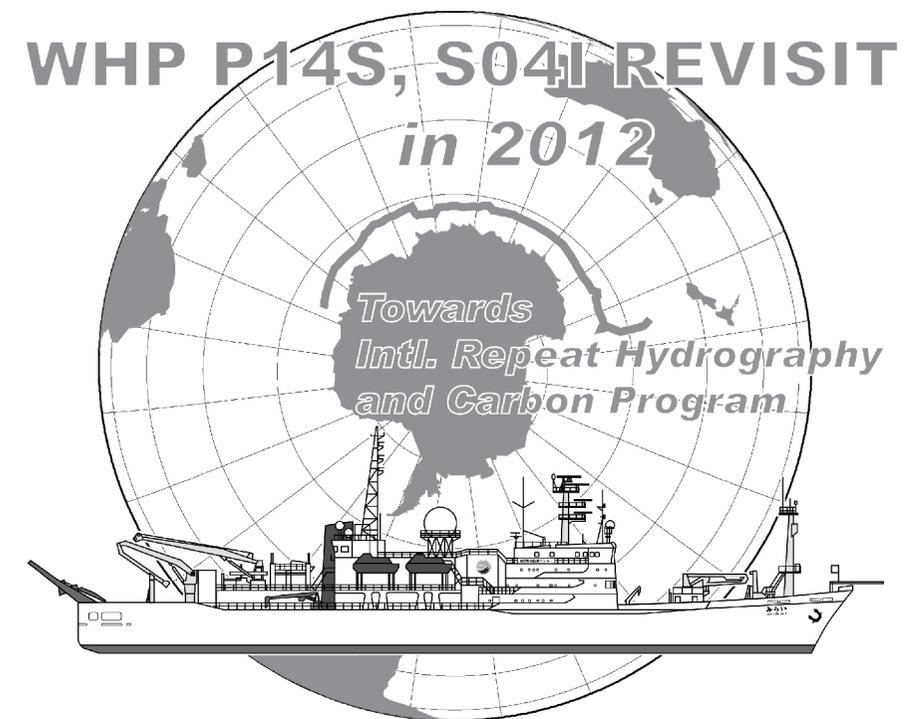
## Links To Select Topics

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): PI CCHDO	Processing
Description of Stations	Calibration (pre-cruise) Calibration (post-cruise)
Description of Parameters Sampled	Temperature Pressure Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens Salinities Oxygens
Floats and Drifters Deployed	<b>Bottle Data</b>
Moorings Deployed or Recovered	Salinity
Principal Investigators	Oxygen
Cruise Participants	Nutrients
	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	References
Navigation Bathymetry	Underway pCO2 SF6/CFCs
Acoustic Doppler Current Profiler (ADCP)	XCTD Carbon Items
Thermosalinograph	CTDO2 Measurements Chlorophyll a
XBT and/or XCTD	Bottle Salinity LADCP
Meteorological Observations	Density Expendable Microstructure Profiler
Atmospheric Chemistry Data	Oxygen
	Nutrients
Other Profiling Measurements	
LADCP	
Data Processing Notes	Acknowledgments

# WHP P14S, S04I REVISIT IN 2012 DATA BOOK

*Edited by  
Hiroshi Uchida (JAMSTEC),  
Katsuro Katsumata (JAMSTEC),  
Toshimasa Doi (JAMSTEC)*



The photograph on the front and back cover of floating ice with an iceberg was taken at the southernmost station in the cruise MR12-05 by Ms. Aiko Miura. The photograph on the inside cover of a whale was also taken by Ms. Aiko Miura.

WHP P14S, S04I REVISIT IN 2012 DATA BOOK

March 27, 2015 Published

Edited by Hiroshi Uchida (JAMSTEC), Katsuro Katsumata (JAMSTEC) and Toshimasa Doi (JAMSTEC)

Published by © JAMSTEC, Yokosuka, Kanagawa, 2015

Japan Agency for Marine-Earth Science and Technology

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

Phone +81-46-867-9474, Fax +81-46-867-9835

Printed by Aiwa Enterprise, Ltd.

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

# Contents

Contents	.....	i	3.6 Chlorofluorocarbons and Sulfur Hexafluoride	.....	87
			<i>K. Sasaki (JAMSTEC) et al.</i>		
Preface	.....	iii	3.7 Carbon Items ( $C_T$ , $A_T$ and pH)	.....	90
<i>M. Fukasawa (JAMSTEC)</i>			<i>A. Murata (JAMSTEC) et al.</i>		
Documents and station summary files			3.8 Chlorophyll <i>a</i>	.....	95
<b>1 Cruise Narrative</b>	.....	1	<i>H. Uchida (JAMSTEC) et al.</i>		
<i>K. Katsumata and H. Uchida (JAMSTEC)</i>			3.9 LADCP	.....	96
<b>2 Underway Measurements</b>			<i>S. Kouketsu (JAMSTEC) et al.</i>		
<b>2.1 Navigation</b>	.....	10	3.10 Expendable Microstructure Profiler	.....	98
<i>S. Sueyoshi (GODI) et al.</i>			<i>K. Katsumata (JAMSTEC)</i>		
<b>2.2 Swath Bathymetry</b>	.....	13	<b>Station Summary</b>		
<i>T. Matsumoto (Univ. Ryukyus), M. Nakanishi (Chiba Univ.) et al.</i>			49NZ20121105 .sum file	.....	100
<b>2.3 Surface Meteorological Observation</b>	.....	15	49NZ20121128 .sum file	.....	102
<i>S. Sueyoshi (GODI) et al.</i>			49NZ20130106 .sum file	.....	109
<b>2.4 Thermo-Salinograph and Related Measurements</b>	.....	21			
<i>H. Uchida (JAMSTEC) et al.</i>			Figures		
<b>2.5 Underway <math>pCO_2</math></b>	.....	28	<i>Figure captions</i>	.....	117
<i>A. Murata (JAMSTEC) et al.</i>			<i>Station locations</i>	.....	120
<b>2.6 Shipboard ADCP</b>	.....	30	<i>Bathymetry</i>	.....	121
<i>S. Kouketsu (JAMSTEC) et al.</i>			<i>Surface wind</i>	.....	129
<b>2.7 XCTD</b>	.....	33	<i>Sea surface temperature,</i>	.....	130
<i>H. Uchida (JAMSTEC) et al.</i>			<i>salinity,</i>	.....	131
<b>2.8 Photosynthetically Available Radiation (PAR)</b>	.....	37	<i>oxygen,</i>	.....	132
<i>H. Uchida (JAMSTEC)</i>			<i>chlorophyll a</i>	.....	133
			<i><math>\Delta pCO_2</math></i>	.....	134
<b>3 Hydrographic Measurement Techniques and Calibrations</b>			<i>Surface current</i>	.....	135
<b>3.1 CTDO<sub>2</sub> Measurements</b>	.....	38	<i>Cross-sections</i>		
<i>H. Uchida (JAMSTEC) et al.</i>			<i>Potential temperature</i>	.....	136
<b>3.2 Bottle Salinity</b>	.....	59	<i>CTD salinity</i>	.....	138
<i>H. Uchida (JAMSTEC) et al.</i>			<i>Absolute salinity</i>	.....	140
<b>3.3 Density</b>	.....	63	<i>Density (<math>\sigma_{\theta}</math> and <math>\sigma_t</math>) (EOS-80)</i>	.....	142
<i>H. Uchida (JAMSTEC)</i>			<i>Density (<math>\sigma_{\theta}</math> and <math>\sigma_t</math>) (TEOS-10)</i>	.....	144
<b>3.4 Oxygen</b>	.....	67	<i>Neutral Density (<math>\gamma^{\theta}</math>)</i>	.....	146
<i>Y. Kumamoto (JAMSTEC) et al.</i>			<i>CTD oxygen</i>	.....	148
<b>3.5 Nutrients</b>	.....	72	<i>CTD chlorophyll a</i>	.....	150
<i>M. Aoyama (MRI/JMA) et al.</i>			<i>CTD beam attenuation coefficient</i>	.....	152

<i>Bottle sampled oxygen</i>	.....	154
<i>Silicate</i>	.....	156
<i>Nitrate</i>	.....	158
<i>Nitrite</i>	.....	159
<i>Phosphate</i>	.....	162
<i>Dissolved inorganic carbon (C<sub>T</sub>)</i>	.....	164
<i>Total alkalinity (A<sub>T</sub>)</i>	.....	166
<i>pH</i>	.....	168
<i>CFC-11</i>	.....	170
<i>CFC-12</i>	.....	172
<i>CFC-113</i>	.....	174
<i>SF<sub>6</sub></i>	.....	176
<i>Current velocity</i>	.....	178
<i>Difference between previous occupations and the revisit</i>		
<i>Potential temperature</i>	.....	180
	<i>(2012/13-1995/96)</i>	
<i>CTD Salinity (2012/13-1995/96)</i>	.....	182
<i>CTD oxygen (2012/13-1995/96)</i>	.....	184
<i>Bottle oxygen (2012/13-1995/96)</i>	.....	186

.sum, .sea, .wct and other data files

*CD-ROM on the back cover*

# Preface

Please forgive me for starting the preface of this data book with the sentence “At last, we have arrived at offshore of the Adelie Coast”.

Also, one might be aware that JAMSTEC tends to select zonal lines of GO-SHIP (and WHP-revisit) plan as our target.

Concerning the revisit of WHP lines, we firstly undertook the revisit of P01 in 1999. Analysis of data from P01:1999 showed that there was a basin-wide warming of bottom layer compared to the former P01 cruise in 1985 carried out by US scientists. This finding of the bottom layer warming in the North Pacific received worldwide attention of scientists and generated quite a few studies for investigating/clarifying physical mechanisms of the warming.

As the results, several WHP-revisit cruises reported the same warming of bottom layer as found along P01 obviously along the pathway of the Lower Circumpolar Deep Water (LCDW) and/or the North Pacific Deep Water (NPDW).

On the other hand, a numerical model of bottom layer of the world ocean has suggested that such warming of bottom layer in the Pacific is likely to occur under an abrupt decrease in the formation rate of Antarctic Bottom Water (AABW) off the Adelie Coast. The model showed that the bottom layer, even in the northern most part of the Pacific, will be warmed by 0.005 °C within only 50 years after the abrupt decrease in the bottom water formation. We anticipated that our finding on P01 could be traced up to Adelie Coast and that an enormous change was occurring in the meridional overturn system in the Pacific. The most recent comprehensive analysis using ocean data assimilation including the data from WHP-revisits and/or GO-SHIP cruises concluded that the bottom layer warming in the Pacific might be traced up to the surface of Adelie Coast and to possible changes in the physical parameters of subducted water there.

Of course, JAMSTEC’s contribution to WHP-revisits and/or GO-SHIP cruises has brought various scientific advancements not only in the fields of climate research but also of biogeochemical study as have been shown in

IPCC reports and other scientific magazines. All of those results have been strong driving forces of our effort toward each cruise and data sharing. However, it is also true that we have conducted our observational efforts of WHP-revisits and/or GO-SHIP cruises in line with our genuine scientific interest. And...this is the reasons why JAMSTEC, a scientific research organization, could have contributed so positively to any international frameworks of data acquisition and sharing such as GO-SHIP.

Lastly, I would like to thank all scientists for your referring our data book as often. As mentioned before, such reference from scientists also proves the scientific importance of GO-SHIP and consequently helps JAMSTEC to continue GO-SHIP activities.

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

On National Foundation Day

Masao Fukasawa

Operating Executive Director, JAMSTEC

\*Acronym

JAMSTEC	Japan Agency for Marine-Earth Science and Technology
WHP	World Ocean Circulation Experiment Hydrographic Program
GO-SHIP	Global Ocean Ship-Based Hydrographic Investigation Program
IPCC	Inter-governmental Panel for Climate Change



# 1 Cruise Narrative

September 30, 2014

Katsuro Katsumata (JAMSTEC)

Hiroshi Uchida (JAMSTEC)

Ocean Climate Change Research Program

Research Institute for Global Change (RIGC)

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

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

Fax: +81-46-867-9835

## 1.1 Highlights

**Cruise code:** MR12-05

**Expocode:** Leg 1: 49NZ20121105

Leg 2: 49NZ20121128

Leg 3: 49NZ20130106

**WOCE section designation:** P14S, S04I

**Ship:** R/V Mirai

**Ports of call:** Leg 1: Sekinehama, Japan; Hachinohe, Japan – Auckland, New Zealand

Leg 2: Auckland, New Zealand – Hobart, Australia

Leg 3: Hobart, Australia – Fremantle, Australia

**Cruise date:** Leg 1: 5 November 2012 – 26 November 2012

Leg 2: 28 November 2012 – 4 January 2013

Leg 3: 6 January 2013 – 15 February 2013

**Chief scientists:** Legs 1 and 2: Katsuro Katsumata (k.katsumata@jamstec.go.jp)

Leg 3: Hiroshi Uchida (huchida@jamstec.go.jp)

**Number of Stations:** Leg 1: 3 stations

Leg 2: 54 stations including 6 XCTD-only stations

Leg 3: 77 stations

**Floats and drifters deployed:**

3 Argo floats (Leg 1) and 4 Deep NINJA floats (Leg 2)

**Mooring recovery:**

2 including 1 emergency recovery of Southern Ocean Flux Buoy  
(Bureau of Meteorology, Australia)

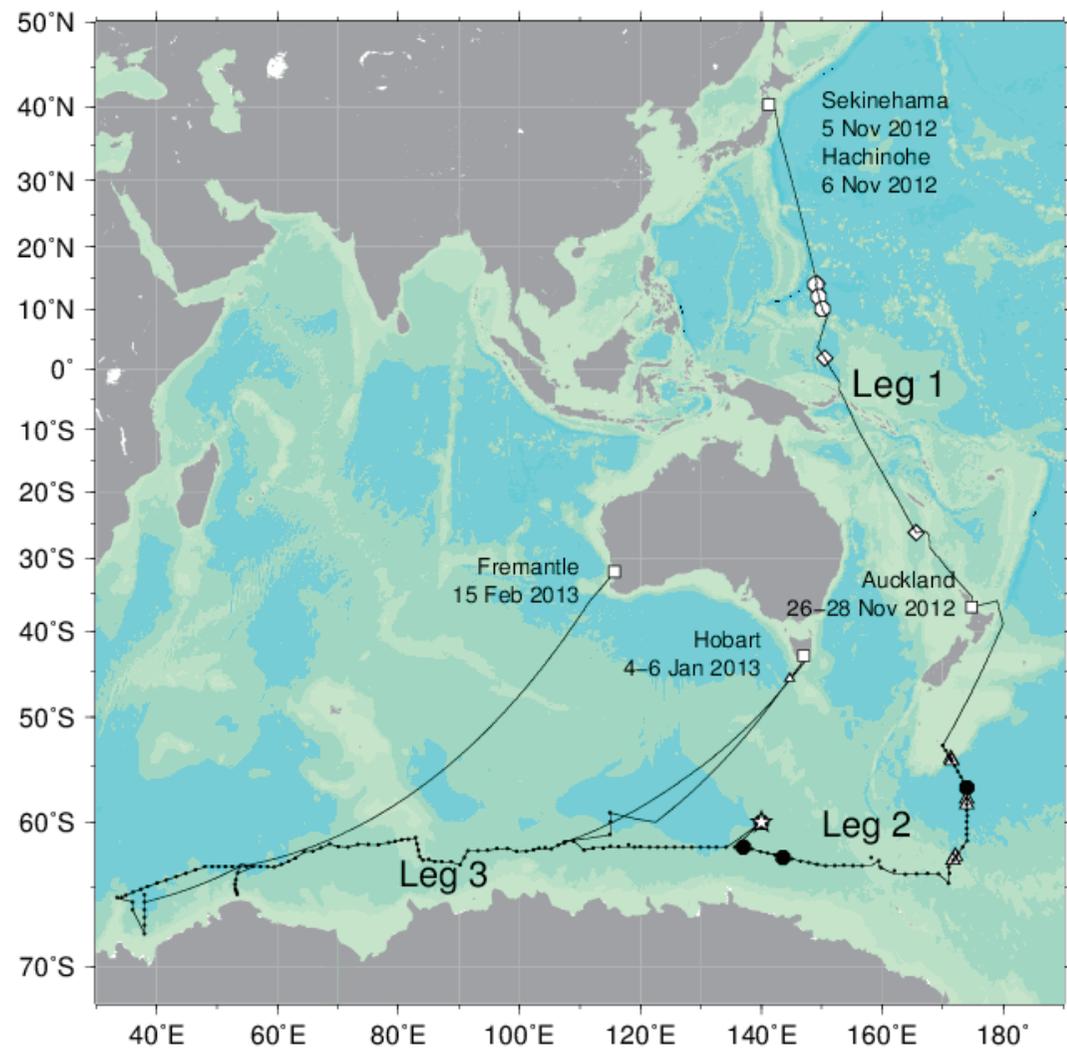


Figure 1.1.1. MR12-05 cruise track. White circles show the deployment position of Argo floats. White diamonds show neuston net sampling (the northernmost station overlaps the northern most Argo deployment). White large triangles show the XMP deployment stations. Star is the flux-buoy recovery position. Black dots show CTD/bottle sampling stations. Black circles show the Deep NINJA deployment positions (one position overlaps the flux-buoy position). Small white triangle shows Australian SOFS buoy recover position.

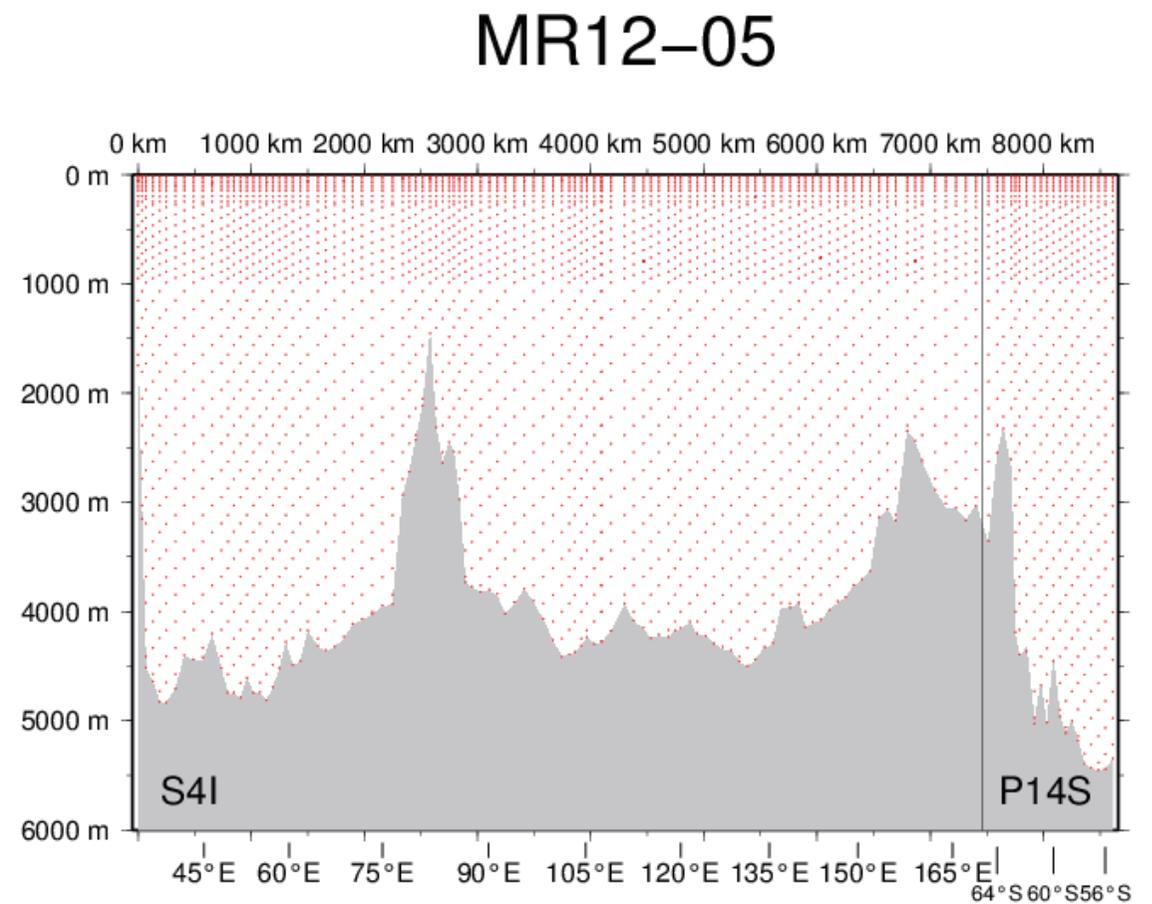


Figure 1.1.2. Water sampling positions. Meridional segments on S04I are not included.

## 1.2 Cruise Summary

### (1) Geographic boundaries

MR12-05 cruise (Fig. 1.1.1) re-occupied two WOCE hydrographic sections; P14S and S04I. The P14S is a meridional section nominally along 174°E, between 53°S and 65°S. The S04I is a zonal section nominally along 62°S between 33°E and 170°E.

### (2) Stations occupied

A total of 152 stations were occupied using a CTD/O<sub>2</sub>/LADCP package equipped with 36 Niskin bottles. The package consists of a SBE911 plus, SBE35, SBE43, RINKO, Chlorophyll fluorometer, altimeter, transmissometer, PAR and an RDI ADCP. At 5 stations, two or three casts were made to collect sufficient sample for radio-isotope analysis. A total of 7 stations were occupied using XCTD. All stations are shown on Fig.1.1.1.

### (3) Sampling and measurement

Water samples were analyzed for salinity, oxygen, nutrients, CFC11, CFC12, CFC113, SF6, total alkalinity, DIC, pH, density and chlorophyll-*a*. Staggered sampling scheme was employed (see Fig.1.1.2). Samples for radio-isotopes were also collected. Underway measurements were conducted along the cruise track for pCO<sub>2</sub>, temperature, salinity, oxygen, surface current, bathymetry and meteorological parameters.

### (4) Floats and drifters deployed

Three ARGO floats were deployed on the Leg 1. Four Deep NINJA floats were launched on the Leg 2.

### (5) Mooring deployed and recovered

One mooring at approximate location of 60°S, 140°E was recovered successfully. An emergency recovery was conducted of SOFS buoy (Bureau of Meteorology, Australia) at approximate location of 45.7°S, 144.6°E.

## 1.3 Principle investigators and personnel in charge onboard

The principal investigators (PI) and the persons responsible for major parameters are listed in Table 1.3.1.

Table 1.3.1. List of principal investigator and person in charge on the ship.

Item	Principal Investigator	Person in charge onboard
<b>Underway</b>		
Navigation	Data Management Group (CEIST/JAMSTEC) <i>dmo@jamstec.go.jp</i>	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Bathymetry	Takeshi Matsumoto (Univ. of Ryukyus) <i>tak@sci.u-ryukyu.ac.jp</i>	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Meteorology	Data Management Group (CEIST/JAMSTEC) <i>dmo@jamstec.go.jp</i>	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Thermo-salinograph	Hiroshi Uchida (JAMSTEC) <i>huchida@jamtec.go.jp</i>	Kanako Yoshida (MWJ) (legs 1, 3) Misato Kuwahara (MWJ) (leg 2)
pCO <sub>2</sub>	Akihiko Murata (JAMSTEC) <i>murataa@jamstec.go.jp</i>	Yoshiko Ishikawa (MWJ)
pCO <sub>2</sub> /pCH <sub>4</sub> by Cavity Ring-Down Spectroscopy	Sohiko Kameyama (Hokkaido Univ.) <i>skameyama@ees.hokkaido.ac.jp</i>	Sohiko Kameyama (Hokkaido Univ.)

ADCP	Shinya Kouketsu (JAMSTEC) <i>skouketsu@jamstec.go.jp</i>	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)		<i>huchida@jamstec.go.jp</i>	
Ceilometer	Data Management Group (CEIST/JAMSTEC) <i>dmo@jamstec.go.jp</i>	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)	Salinity	Hiroshi Uchida (JAMSTEC) <i>huchida@jamstec.go.jp</i>	Tatsuya Tanaka (MWJ)
Water Isotopes	Yasushi Fujiyoshi (Hokkaido Univ.) <i>fujiyo@lowtem.hokudai.ac.jp</i>	Souichiro Sueyoshi (GODI)	Density	Hiroshi Uchida (JAMSTEC) <i>huchida@jamstec.go.jp</i>	Hiroshi Uchida (JAMSTEC)
Sky Radiometer	Kazuma Aoki (Univ. of Toyama) <i>kazuma@sci.u-toyama.ac.jp</i>	None	Oxygen	Yuichiro Kumamoto (JAMSTEC) <i>kumamoto@jamstec.go.jp</i>	Misato Kuwahara (MWJ) (leg 2) Kanako Yoshida (MWJ) (leg 3)
Lidar	Nobuo Sugimoto (NIES) <i>nsugimot@nies.go.jp</i>	None	Nutrients	Michio Aoyama (Fukushima Univ.) <i>r706@ipc.fukushima-u.ac.jp</i>	Minoru Kamata (MWJ)
Gravity	Takeshi Matsumoto (Univ. of Ryukyus) <i>tak@sci.u-ryukyu.ac.jp</i>	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)	CFCs/SF <sub>6</sub>	Ken'ichi Sasaki (JAMSTEC) <i>ksasaki@jamstec.go.jp</i>	Ken'ichi Sasaki (JAMSTEC)
Magnetic Field	Takeshi Matsumoto (Univ. of Ryukyus) <i>tak@sci.u-ryukyu.ac.jp</i>	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)	DIC	Akihiko Murata (JAMSTEC) <i>murataa@jamstec.go.jp</i>	Yoshiko Ishikawa (MWJ)
Cesium magnetometer	Masao Nakanishi (Chiba Univ.) <i>nakanisi@earth.s.chiba-u.ac.jp</i>	Souichiro Sueyoshi (GODI)	Alkalinity	Akihiko Murata (JAMSTEC) <i>murataa@jamstec.go.jp</i>	Tomonori Watai (MWJ)
Photosynthetically Available Radiation	Hiroshi Uchida (JAMSTEC) <i>huchida@jamstec.go.jp</i>	Hiroshi Uchida (JAMSTEC)	pH	Akihiko Murata (JAMSTEC) <i>murataa@jamstec.go.jp</i>	Tomonori Watai (MWJ)
XCTD	Hiroshi Uchida (JAMSTEC) <i>huchida@jamstec.go.jp</i>	Souichiro Sueyoshi (GODI) (Legs 1, 3) Kazuho Yoshida (GODI) (Leg 2)	DMS and Isoprene	Sohiko Kameyama (Hokkaido Univ.) <i>skameyama@ees.hokkaido.ac.jp</i>	Sohiko Kameyama (Hokkaido Univ.)
<b>Hydrography</b>			Chlorophyll- <i>a</i>	Hiroshi Uchida (JAMSTEC) <i>huchida@jamstec.go.jp</i>	Hiroshi Uchida (JAMSTEC)
CTD/O <sub>2</sub>	Hiroshi Uchida (JAMSTEC)	Shinsuke Toyoda (MWJ)	Chlorophyll isotopes	Osamu Yoshida (Rakuno Gakuen Univ.) <i>yoshida@rakuno.ac.jp</i>	Osamu Yoshida (Rakuno Gakuen Univ.)
			Pigment/Bacterial abundance	Sohiko Kameyama (Hokkaido Univ.)	Sohiko Kameyama (Hokkaido Univ.)

	<i>skameyama@ees.hokudai.ac.jp</i>	
$\Delta^{14}\text{C}/\delta^{13}\text{C}$	Yuichiro Kumamoto (JAMSTEC) <i>kumamoto@jamstec.go.jp</i>	Yuichiro Kumamoto (JAMSTEC)
$^{134}\text{Cs}/^{137}\text{Cs}$	Yuichiro Kumamoto (JAMSTEC) <i>kumamoto@jamstec.go.jp</i>	Yuichiro Kumamoto (JAMSTEC)
$\delta^{18}\text{O}$	Shigeru Aoki (Hokkaido Univ.) <i>shigeru@lowtem.hokudai.ac.jp</i>	Katsuro Katsumata (JAMSTEC) (leg 2) Kazuhiko Hayashi (JAMSTEC) (leg 3)
PFAS	Nobuyoshi Yamashita (AIST) <i>nob.yamashita@aist.go.jp</i>	Nobuyoshi Yamashita (AIST) (leg 2) Hiroshi Uchida (JAMSTEC) (leg 3)
$\text{N}_2\text{O}/\text{CH}_4$	Osamu Yoshida (Rakuno Gakuen Univ.) <i>yoshida@rakuno.ac.jp</i>	Osamu Yoshida (Rakuno Gakuen Univ.)
LADCP	Shinya Kouketsu (JAMSTEC) <i>skouketsu@jamstec.go.jp</i>	Shinya Kouketsu (JAMSTEC) (leg 2) Hiroshi Uchida (JAMSTEC) (leg 3)
XMP	Katsuro Katsumata (JAMSTEC) <i>k.katsumata@jamstec.go.jp</i>	Katsuro Katsumata (JAMSTEC)
<b>Biology</b>		
Oceanic Halobates	Tetsuo Harada (Kochi Univ.) <i>haratets@kochi-u.ac.jp</i>	Tetsuo Harada (Kochi Univ.)
<b>Floats</b>		
ARGO/Deep NINJA floats	Toshio Suga (JAMSTEC) <i>sugat@jamstec.go.jp</i>	Tetsuya Tanaka (MWJ) (leg 1) Tomoyuki Takamori (MWJ) (leg 2)

### **Mooring**

Southern Ocean Flux Mooring

Shoichiro Baba (JAMSTEC)

Shoichiro Baba (JAMSTC)

*sbaba@jamstec.go.jp*

---

CEIST	Center for Earth Information Science and Technology
GODI	Global Ocean Development Inc.
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
MWJ	Marine Works Japan, Ltd.
NIES	National Institute for Environmental Studies
AIST	National Institute of Advanced Industrial Science and Technology

## **1.4 Scientific programme and methods**

### **(1) Objectives**

It is well established that oceans play important roles in the global climate system, but quantitative description of the oceans' roles and their variabilities are still yet to be made. Given natural variabilities of the oceans, it is necessary to observe them as frequently as practicable and as accurate as possible. In this research cruise, we observed, with state-of-art precision, the Southwestern Pacific and Southern oceans, which are known to be one of the most sensitive regions in the world oceans to the global climate change, particularly as a likely source of the recently-established Pacific near-bottom warming. These oceans are also known to ventilate the intermediate-depth and deep oceans and exchange anthropogenic carbon. We also recovered a JAMSTEC southern ocean mooring, which continuously measured the air-sea flux in this region for almost a year for the first time. This expedition was conducted under the Global Ocean Ship-based Hydrographic Investigation Programme (GO-SHIP <http://www.go-ship.org>).

## **(2) Cruise narrative**

The first leg was a shift from R/V Mirai's home – Sekinehama – to the Southern Hemisphere, although some observational activities were conducted including Argo float deployments and concurrent CTD casts for salinity calibration as well as hull pump water sampling for radio-isotope analysis after the 3.11 disaster in 2011 of the Japanese nuclear powerplant.

Most of the scientists and technicians joined the cruise at Auckland. It was anticipated some days might be lost in Roaring Forties and Furious Fifties, but Mirai managed to steam through a narrow gap in the low pressure systems with 27 successful CTD and sampling casts. More serious problem was posed by sea ice. This leg of the expedition was initially planned to a much later season, but with logistic reasons we had to move up the schedule. With recent trend of ice area increase in and near the Ross Sea, the southern stations were unapproachable. We decided to skip stations in this region and to extend the S04I leg further to the west rather than spending ship-time wading through the icebergs. See the next section for detail. One of the big events in Leg 2 was a recovery of the JAMSTEC buoy which had been measuring the air-sea interaction for nearly 11 months. The window of best weather was sought on weather charts and a two-day window was found between 18<sup>th</sup> and 20<sup>th</sup> of December. The recovery was successful. After a CTD cast and a float deployment, reoccupation of S04I was resumed. The ice condition did not show much improvement and we had to cut short this leg to head to Hobart. The extra time was used to reoccupy southern 3 stations of the WOCE I09S section since its 2012 occupation did not have CFC sampling. On the way back to Hobart, a buoy was recovered that had broken loose.

Two days of resupply and six-day steaming (one way) gives almost 2 weeks between legs 2 and 3. During this period, sea ice condition was much improved and icebergs were not as much threat as were in leg 2. Weather was very kind in leg 3, although there were some casts under rough conditions (e.g., stations 112 to 115). We covered all stations as planned in this leg with successful sampling. The leg was completed after 13 days of steaming back to Australia, which gave us a plenty of time for packing and celebrating.

## **1.5 Major problems and goal not achieved**

### **(1) Stations not occupied, position changed, not close to previous occupations**

For the P14S reoccupation, data were not disclosed north of 55°S due to JAMSTEC in-house problem with cruise documentation. It was our intention to cover the P14S section to the southern most station at 66°S, but due to ice cover, southernmost 2 stations (south of 65°S) were not occupied. Our plan was to connect to the stations of WOCE S04P cruise (90KDIOFFE6\_1) and work westward on the WOCE S04/S03 stations (09AR9404\_1). To keep a safe distance to the ice edge, we had to place new stations (our station number 402, 404, 406, 408, 410) along 64°S and hastened with station distance of about 75 miles interpolated by XCTD casts in-between to re-connect to the WOCE S04 station (our station 50). After meeting the WOCE stations, however, fickle movements of the ice edge and icebergs kept us away from some of the WOCE location. Most of the stations, we managed to measure within 1 mile, but some stations (e.g. our station 70 to WOCE S04 station 28) were more than 3 miles away. Ice condition was much improved for leg 3 and all stations were located close to the WOCE stations.

### **(2) Misfiring and mistrip of water sampling**

None.

### **(3) Time lost**

At station 56, about half an hour during the cast and about 4 hours after the cast were lost due to mechanical trouble with the CTD winch. At station 139, CTD data from the first cast was noisy and the cast was repeated – approximately 45 minutes were lost. Similarly casts were re-started at station 143 and 165 and a total of approximately 40 minutes were lost. Weather condition had been kind to us. We only lost about 12 hours before the first cast of Leg 2 and about 1 hour between stations 11 and 12 due to bad weather.

## 1.6 Cruise Participants

List of Participants for leg 1

Katsuro Katsumata	Chief scientist	RIGC/JAMSTEC
Yuichiro Kumamoto	C14	RIGC/JAMSTEC
Hiroshi Uchida	Thermosalinograph/chlorophyll- <i>a</i>	RIGC/JAMSTEC
Tetsuo Harada	<i>Halobates</i>	Kochi University
Ryuta Ide	<i>Halobates</i>	Kochi University
Takero Sekimoto	<i>Halobates</i>	Kochi University
Kentaro Emi	<i>Halobates</i>	Kochi University
Tomonori Watai	Chief technician/carbon items preparation	MWJ
Tatsuya Tanaka	CTD/Float	MWJ
Makoto Takada	Carbon items preparation	MWJ
Shinsuke Toyoda	CTD	MWJ
Katsunori Sagishima	CFCs preparation	MWJ
Hironori Sato	CFCs preparation	MWJ
Kanako Yoshida	Thermosalinograph	MWJ
Emi Deguchi	Carbon items preparation	MWJ
Souichiro Sueyoshi	Chief technician/meteorology/geophysics/ADCP	GODI
Koichi Inagaki	Meteorology/geophysics/ADCP	GODI

List of Participants for leg 2

Katsuro Katsumata	Chief scientist/XMP/water sampling	RIGC/JAMSTEC
Yuichiro Kumamoto	DO/thermosalinograph / $\Delta^{14}\text{C}$	RIGC/JAMSTEC
Hiroshi Uchida	LADCP/density/chlorophyll- <i>a</i>	RIGC/JAMSTEC
Shinya Kouketsu	LADCP/ADCP/water sampling	RIGC/JAMSTEC
Kazuhiko Hayashi	Water sampling	RIGC/JAMSTEC
Ken'ichi Sasaki	CFCs	MIO/JAMSTEC
Shoichiro Baba	Mooring/water sampling	MARITEC/JAMSTEC
Takero Sekimoto	<i>Halobates</i> /water sampling	Kochi University
Nobuyoshi Yamashita	PFASs/water sampling	AIST
Eriko Yamazaki	PFASs/water sampling	AIST
Sohiko Kameyama	DMS/isoprene/water sampling	Hokkaido University
Tomohide Noguchi	Chief technician/mooring/water sampling	MWJ
Tomonori Watai	pH/total alkalinity	MWJ
Tatsuya Tanaka	Salinity/mooring	MWJ
Shinsuke Toyoda	CTD/mooring/water sampling	MWJ
Atsushi Ono	DIC	MWJ
Emi Deguchi	pH/total alkalinity	MWJ
Shungo Oshitani	CTD/mooring/water sampling	MWJ
Tomoyuki Takamori	CTD/mooring/water sampling	MWJ
Rei Ito	CTD/mooring/water sampling	MWJ
Minoru Kamata	Nutrients	MWJ
Yoshiko Ishikawa	DIC	MWJ

Yasuhiro Arie	Nutrients	MWJ
Hideki Yamamoto	CFCs	MWJ
Shoko Tatamisashi	CFCs	MWJ
Misato Kuwahara	DO/thermosalinograph	MWJ
Masahiro Orui	CFCs	MWJ
Keitaro Matsumoto	DO/mooring/water sampling	MWJ
Keisuke Tsubata	Salinity	MWJ
Takuhiro Osumi	DO	MWJ
Kohei Miura	Nutrients	MWJ
Yuki Komuro	Water sampling	MWJ
Takehiro Shibuya	Water sampling	MWJ
Saeko Kumagai	Water sampling	MWJ
Mizuho Yasui	Water sampling	MWJ
Hitomi Takahashi	Water sampling	MWJ
Ai Ozaki	Water sampling	MWJ
Kazuho Yoshida	Chief technician/meteorology/ geophysics/ADCP/XCTD	GODI
Shinya Okumura	Meteorology/geophysics/ADCP/ XCTD	GODI
Masanori Murakami	Meteorology/geophysics/ADCP/ XCTD	GODI

List of Participants for leg 3

---

Hiroshi Uchida	Chief scientist/LADCP/density/ chlorophyll- <i>a</i>	RIGC/JAMSTEC
Akihiko Murata	Carbon items/water sampling	RIGC/JAMSTEC
Toshimasa Doi	LADCP/water sampling	RIGC/JAMSTEC
Kazuhiko Hayashi	Water sampling	RIGC/JAMSTEC
Ken'ichi Sasaki	CFCs	MIO / JAMSTEC
Osamu Yoshida	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	Rakuno Gakuen University
Haruka Tamada	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	Rakuno Gakuen University
Yuko Kanayama	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	Rakuno Gakuen University
Okura Shinozaki	CH <sub>4</sub> and N <sub>2</sub> O/water sampling	Rakuno Gakuen University
Sohiko Kameyama	DMS/isoprene/water sampling	Hokkaido University
Hideki Yamamoto	Chief technician/water sampling	MWJ
Tomonori Watai	pH/total alkalinity	MWJ
Minoru Kamata	Nutrients	MWJ
Yoshiko Ishikawa	DIC	MWJ
Misato Kuwahara	DO/thermosalinograph/water sampling	MWJ
Masahiro Orui	CFCs	MWJ
Satoshi Ozawa	CTD/water sampling	MWJ
Tamami Ueno	Salinity	MWJ
Hiroshi Matsunaga	CTD/water sampling	MWJ
Naoko Miyamoto	CTD/water sampling	MWJ
Hiroki Ushiomura	Salinity	MWJ

Takami Mori	CTD/water sampling	MWJ	MIO	Mutsu Institute of Oceanography
Masanori Enoki	Nutrients	MWJ	MWJ	Marine Works Japan Ltd.
Atsushi Ono	pH/total alkalinity	MWJ	RIGC	Research Institute for Global Change
Elena Hayashi	Nutrients	MWJ		
Kanako Yoshida	DO	MWJ		
Katsunori Sagishima	CFCs	MWJ		
Hironori Sato	CFCs	MWJ		
Keisuke Tsubata	DIC	MWJ		
Takuhiro Osumi	DO/water sampling	MWJ		
Aiko Miura	Water sampling	MWJ		
Manami Kamei	Water sampling	MWJ		
Sachi Miyake	Water sampling	MWJ		
Yuta Furukawa	Water sampling	MWJ		
Iori Fujiwara	Water sampling	MWJ		
Yuki Kawabuchi	Water sampling	MWJ		
Souichiro Sueyoshi	Chief technician/meteorology/ geophysics/ADCP/XCTD	GODI		
Katsuhisa Maeno	Meteorology/geophysics/ADCP/ XCTD	GODI		
Koichi Inagaki	Meteorology/geophysics/ADCP/ XCTD	GODI		

---

AIST	National Institute of Advanced Industrial Science and Technology
GODI	Global Ocean Development Inc.
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
MARITEC	Marine Technology and Engineering Center

## 2 Underway Measurements

### 2.1 Navigation

#### (1) Personnel

Souichiro Sueyoshi	(Global Ocean Development Inc., GODI)	-leg1, leg3-
Koichi Inagaki	(GODI)	-leg1, leg3-
Kazuho Yoshida	(GODI)	-leg2-
Shinya Okumura	(GODI)	-leg2-
Masanori Murakami	(GODI)	-leg2-
Katsuhisa Maeno	(GODI)	-leg3-
Ryo Kimura	(MIRAI Crew)	-leg1, leg2-
Ryo Ohyama	(MIRAI Crew)	-leg3-

#### (2) System description

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

Sensors for navigation data are listed below;

- i) GPS system: MultiFix6 (software version 1.01), Differential GPS system.  
Receiver: Trimble SPS751, with two GPS antennas located on navigation deck, starboard side and port side, manually switched as to GPS receiving state and offset to radar-mast position, datum point.  
Decoder: Fugro STARFIX 4100LR
- ii) Doppler log: Furuno DS-30, which use three acoustic beam for current measurement

under the hull.

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

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

#### (3) Data period (Times in UTC)

Leg1: 07:00, 05 Nov. 2012 - 20:30, 25 Nov. 2012

Leg2: 21:10, 27 Nov. 2012 - 23:20, 03 Jan. 2013

Leg3: 22:50, 05 Jan. 2013 - 06:23, 15 Feb. 2013

#### (4) Remarks (Times in UTC)

i) The following periods, navigation data was invalid due to the system error.

23:25:05, 22 Nov. 2012

23:30:40, 22 Nov. 2012 - 23:36:30, 22 Nov. 2012

23:38:15, 22 Nov. 2012 - 23:38:30, 22 Nov. 2012

23:38:40, 22 Nov. 2012 - 23:38:55, 22 Nov. 2012

23:39:05, 22 Nov. 2012

18:07:50, 04 Dec. 2012

15:26:05, 05 Dec. 2012

21:32:10, 07 Dec. 2012

18:01:50, 09 Dec. 2012

15:33:50, 10 Dec. 2012

15:16:20, 15 Dec. 2012

16:07:00, 16 Dec. 2012

16:07:05, 16 Dec. 2012

20:50:55, 20 Dec. 2012

ii) The following periods, navigation data was invalid due to GPS position fix error.

12:14:15, 22 Dec. 2012

12:15:45, 22 Dec. 2012

11:47:40, 28 Dec. 2012 - 11:52:40, 28 Dec. 2012

12:39:25, 28 Dec. 2012 - 12:41:55, 28 Dec. 2012

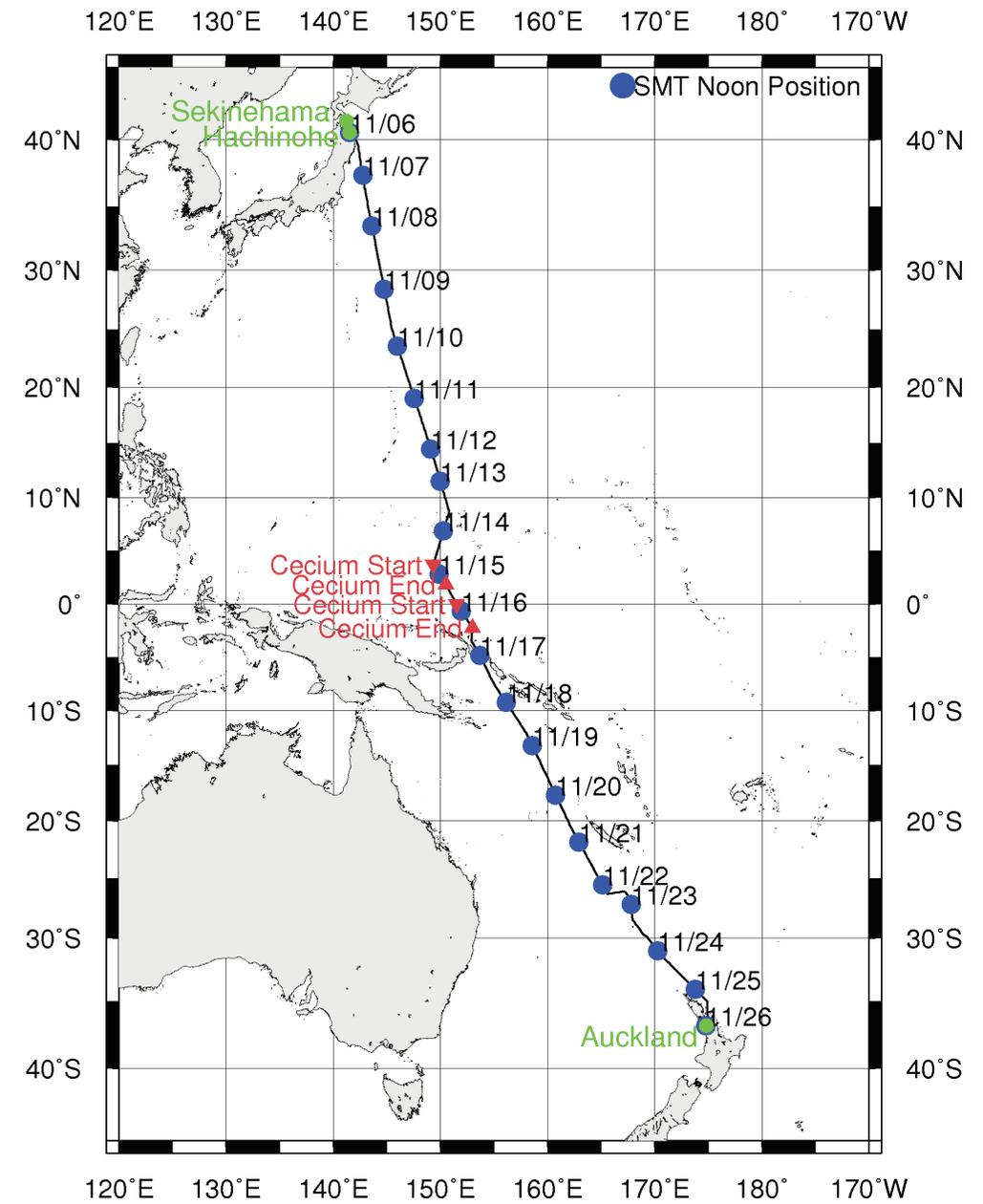


Figure 2.1.1. Cruise Track of MR12-05 Leg 1.

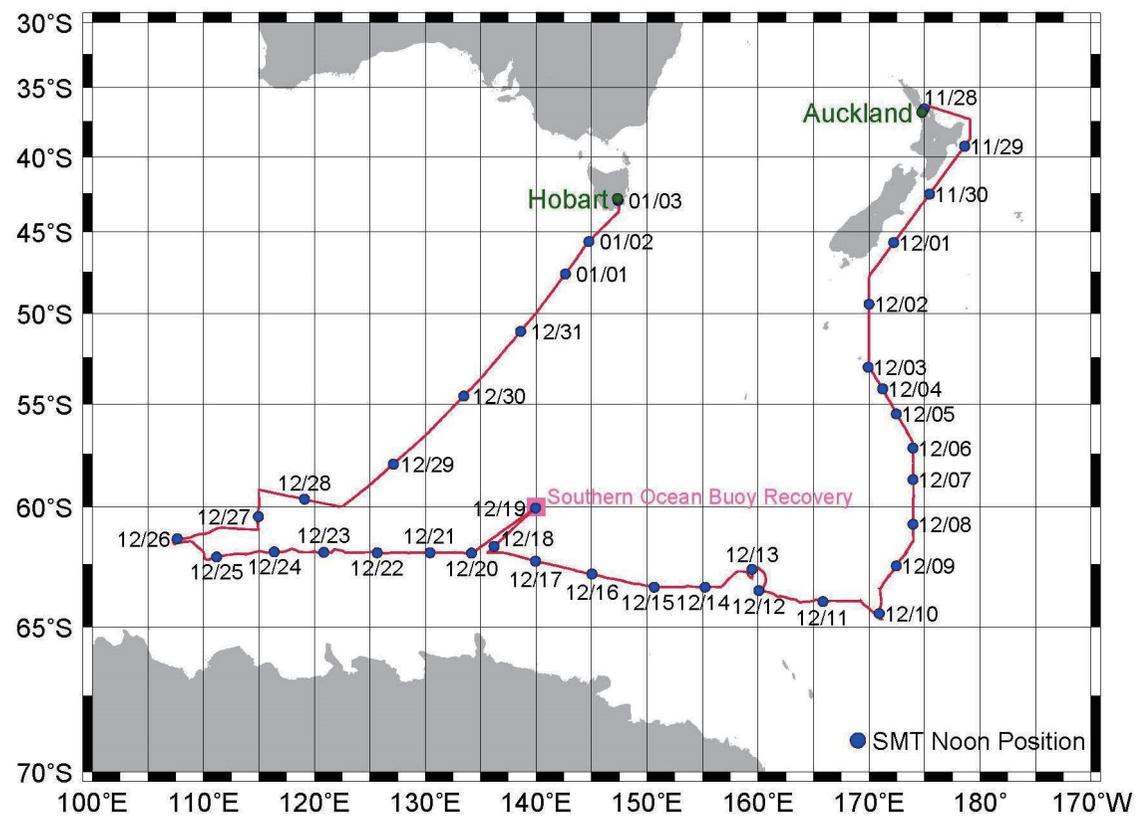


Figure 2.1.2. Cruise Track of MR12-05 Leg 2.

MR12-05 Leg3 Cruise Track

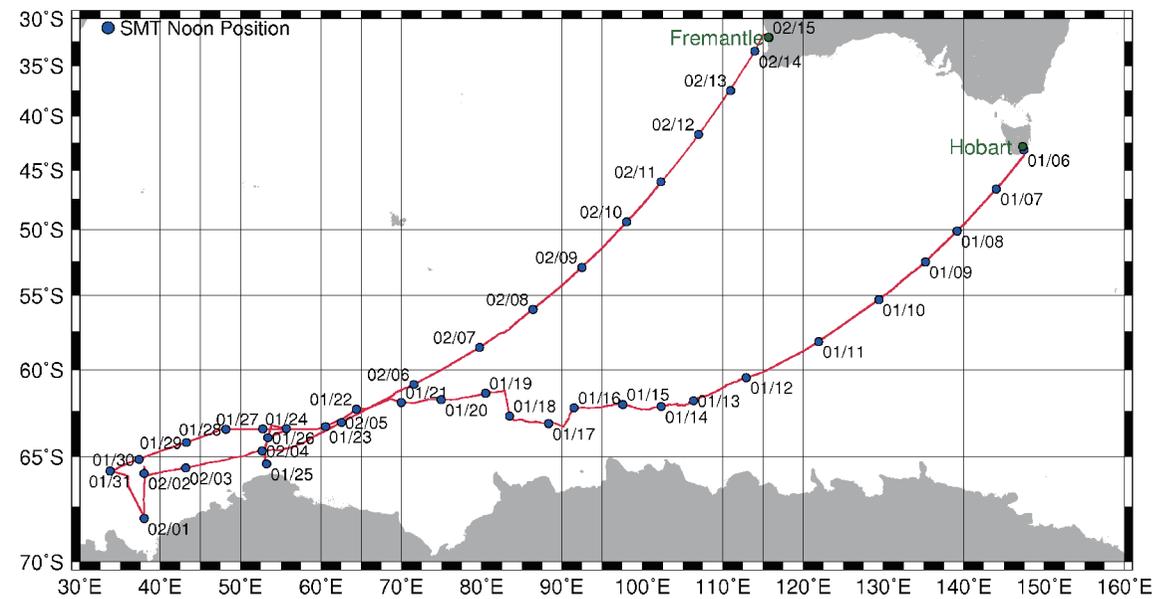


Figure 2.1.3. Cruise Track of MR12-05 Leg 3.

## 2.2 Swath Bathymetry

### (1) Personnel

Takeshi Matsumoto	(University of the Ryukyus): Principal investigator (not on-board)	
Masao Nakanishi	(Chiba University): Principal investigator (not on-board)	
Souichiro Sueyoshi	(Global Ocean Development Inc., GODI)	-leg1, leg3-
Koichi Inagaki	(GODI)	-leg1, leg3-
Kazuho Yoshida	(GODI)	-leg2-
Shinya Okumura	(GODI)	-leg2-
Masanori Murakami	(GODI)	-leg2-
Katsuhisa Maeno	(GODI)	-leg3-
Ryo Kimura	(MIRAI Crew)	-leg1, leg2-
Ryo Ohyama	(MIRAI Crew)	-leg3-

### (2) Introduction

R/V MIRAI is equipped with a Multi narrow Beam Echo Sounding system (MBES), SEABEAM 3012 Upgraded Model (L3 Communications ELAC Nautik). The objective of MBES is collecting continuous bathymetric data along ship's track to make a contribution to geological and geophysical investigations and global datasets.

### (3) Data Acquisition

The "SEABEAM 3012 Upgrade Model" on R/V MIRAI was used for bathymetry mapping during the MR12-05 cruise from 5th November 2012 to 15th February 2013.

To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data to get the sea surface sound velocity (at 6.62m), and the deeper depth sound velocity profiles were calculated by temperature and salinity profiles from CTD and XCTD data by the

equation in Del Grosso (1974) during this cruise.

Table 2.2.1 shows system configuration and performance of SEABEAM 3012Upgraded Model.

Table 2.2.1. System configuration and performance.

<i>SEABEAM 3012 (12 kHz system)</i>	
Frequency:	12 kHz
Transmit beam width:	1.6 degree
Transmit power:	20 kW
Transmit pulse length:	2 to 20 msec.
Receive beam width:	1.8 degree
Depth range:	100 to 11,000 m
Beam spacing:	0.5 degree athwart ship
Swath width:	150 degree (max)
	120 degree to 4,500 m
	100 degree to 6,000 m
	90 degree to 11,000 m
Depth accuracy:	Within < 0.5% of depth or +/-1m, whichever is greater, over the entire swath. (Nadir beam has greater accuracy; typically within < 0.2% of depth or +/-1m, whichever is greater)

#### (4) Data processing

##### i. Sound velocity correction

Each bathymetry data was corrected with a sound velocity profile calculated from the nearest CTD or XCTD data in the distance. The equation of Del Grosso (1974) was used for calculating sound velocity. The data correction was carried out using the HIPS software version 7.1 (CARIS, Canada).

##### ii. Editing and Gridding

Gridding for the bathymetry data were carried out using the HIPS. Firstly, the bathymetry data during ship's turning was basically deleted, and spike noise of each swath data was removed. Then the bathymetry data was gridded by "Interpolate" function of the software with the parameters shown as Table 2.2.2. Finally, interpolated data were exported as ASCII data, and converted to 150m grid data using "xyz2grd" utility of GMT (Generic Mapping Tool) software.

Table 2.2.2. Parameters for interpolate of bathymetry data.

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

#### (5) Data Archives

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

#### (6) Remarks (Times in UTC)

1) The following periods, the observation was carried out.

Leg1: 14:24, 06 Nov. 2012 - 13:05, 16 Nov. 2012

04:28, 17 Nov. 2012 - 07:00, 25 Nov. 2012

Leg2: 08:15, 28 Nov. 2012 - 07:00, 01 Jan. 2013

Leg3: 02:35, 6 Jan. 2013 - 12:06, 13 Feb 2013.

2) The following periods, data acquisition was suspended due to the system error and maintenance.

12:22 - 13:12, 11 Dec. 2012

07:12 - 09:02, 12 Dec. 2012

08:06 - 08:31, 23 Jan. 2013

3) The following periods, navigation data was invalid due to GPS position fix error.

23:30:30 - 23:39:05, 22 Nov. 2012 (intermittently)

11:47:37 - 11:52:42, 28 Dec. 2012

12:39:23 - 12:41:55, 28 Dec. 2012

## 2.3 Surface Meteorological Observations

### (1) Personnel

Souichiro Sueyoshi	(Global Ocean Development Inc., GODI)	-leg1, leg3-
Koichi Inagaki	(GODI)	-leg1, leg3-
Kazuho Yoshida	(GODI)	-leg2-
Shinya Okumura	(GODI)	-leg2-
Masanori Murakami	(GODI)	-leg2-
Katsuhisa Maeno	(GODI)	-leg3-
Ryo Kimura	(MIRAI Crew)	-leg1, leg2-
Ryo Ohyama	(MIRAI Crew)	-leg3-

### (2) Objectives

Surface meteorological parameters are observed as a basic dataset of the meteorology. These parameters provide the temporal variation of the meteorological condition surrounding the ship.

### (3) Methods

Surface meteorological parameters were observed during the MR12-05 cruise from 5th November 2012 to 15th February 2013. In this cruise, we used two systems for the observation.

#### i. *MIRAI Surface Meteorological observation (SMet) system*

Instruments of SMet system are listed in [Table 2.3.1](#) and measured parameters are listed in [Table 2.3.2](#). Data were collected and processed by KOAC-7800 weather data processor made by Koshin-Denki, Japan. The data set consists of 6-second averaged data.

#### ii. *Shipboard Oceanographic and Atmospheric Radiation (SOAR) measurement system*

SOAR system designed by BNL (Brookhaven National Laboratory, USA) consists of major three parts.

- a) Portable Radiation Package (PRP) designed by BNL – short and long wave downward radiation.
- b) Zeno Meteorological (Zeno/Met) system designed by BNL – wind, air temperature, relative humidity, pressure, and rainfall measurement.
- c) Scientific Computer System (SCS) developed by NOAA (National Oceanic and Atmospheric Administration, USA) – centralized data acquisition and logging of all data sets.

SCS recorded PRP data every 6 seconds, Zeno/Met data every 10 seconds. Instruments and their locations are listed in [Table 2.3.3](#) and measured parameters are listed in [Table 2.3.4](#).

For the quality control as post processing, we checked the following sensors, before and after the cruise.

#### i. *Young Rain gauge (SMet and SOAR)*

Inspect of the linearity of output value from the rain gauge sensor to change Input value by adding fixed quantity of test water.

#### ii. *Barometer (SMet and SOAR)*

Comparison with the portable barometer value, PTB220, VAISALA

#### iii. *Thermometer (air temperature and relative humidity) ( SMet and SOAR )*

Comparison with the portable thermometer value, HMP41/45, VAISALA

### (4) Preliminary results

[Figs. 2.3.1, 2.3.2, and 2.3.3](#) show the time series of the following parameters;

- Wind (SMet)
- Air temperature (SMet)
- Relative humidity (SOAR)
- Precipitation (SOAR, rain gauge)
- Short/long wave radiation (SOAR)
- Pressure (SMet)
- Sea surface temperature (SMet)
- Significant wave height (SMet)

**(5) Data archives**

These meteorological data will be submitted to the Data Management Group (DMG) of JAMSTEC just after the cruise.

22:41, 25 Dec. 2012

Leg3: 06:15, 24 Jan. 2013

01:25, 13 Feb. 2013

**(6) Remarks (Times in UTC)**

1) The following periods, observation was carried out.

Leg1: 00:00, 05 Nov. 2012 to 15:00, 16 Nov. 2012

03:00, 17 Nov. 2012 to 07:00, 25 Nov. 2012

Leg2: 06:00, 28 Nov. 2012 to 07:00, 01 Jan. 2013

Leg3: 02:00, 07 Jan. 2013 to 12:00, 13. Feb 2013

2) The following periods, navigation data of SMet data was invalid due to GPS position fix error.

Leg1: 23:30 - 23:39, 22 Nov. 2012 (intermittently)

Leg2: 2:21, 18 Dec. 2012

11:47 to 11:51, 28 Dec. 2012

12:39 to 12:41, 28 Dec. 2012

3) The following periods, FRSR data acquisition was suspended to prevent damage to the shadow-band from freezing.

Leg2: 08:01, 08 Dec. 2012 to 20:45, 28 Dec. 2012

Leg3: 19:20, 12 Jan. 2013 to 10:21, 08 Feb. 2013

4) The following time, SMet rain gauge amount values were increased because of test transmitting for MF/HF radio.

Leg1: 23:01 - 23:16, 11 Nov. 2012

Leg2: 08:54, 06 Dec. 2012

00:35, 18 Dec. 2012

Table 2.3.1. Instruments and installation locations of MIRAI Surface Meteorological observation system.

Sensors	Type	Manufacturer	Location (altitude from surface)
Anemometer	KE-500	Koshin Denki, Japan	foremast (24 m)
Tair/RH	HMP45A	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	compass deck (21 m) starboard side and port side
Thermometer: SST	RFN1-0	Koshin Denki, Japan	4th deck (-1m, inlet -5m)
Barometer	Model-370	Setra System, USA	captain deck (13 m) weather observation room
Rain gauge	50202	R. M. Young, USA	compass deck (19 m)
Optical rain gauge	ORG-815DR	Osi, USA	compass deck (19 m)
Radiometer (short wave)	MS-802	Eko Seiki, Japan	radar mast (28 m)
Radiometer (long wave)	MS-202	Eko Seiki, Japan	radar mast (28 m)
Wave height meter	WM-2	Tsurumi-seiki, Japan	bow (10 m)

Table 2.3.2. Parameters of MIRAI Surface Meteorological observation system.

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 Ship's speed	knot	Mirai log, DS-30 Furuno
4 Ship's heading	degree	Mirai gyro, TG-6000, Tokimec
5 Relative wind speed	m/s	6sec./10min. averaged
6 Relative wind direction	degree	6sec./10min. averaged
7 True wind speed	m/s	6sec./10min. averaged
8 True wind direction	degree	6sec./10min. averaged
9 Barometric pressure	hPa	adjusted to sea surface level 6sec. averaged
10 Air temperature (starboard side)	degC	6sec. averaged
11 Air temperature (port side)	degC	6sec. averaged
12 Dewpoint temperature (starboard side)	degC	6sec. averaged
13 Dewpoint temperature (port side)	degC	6sec. averaged
14 Relative humidity (starboard side)	%	6sec. averaged
15 Relative humidity (port side)	%	6sec. averaged
16 Sea surface temperature	degC	6sec. averaged
17 Rain rate (optical rain gauge)	mm/hr	hourly accumulation
18 Rain rate (capacitive rain gauge)	mm/hr	hourly accumulation
19 Down welling shortwave radiation	W/m <sup>2</sup>	6sec. averaged
20 Down welling infra-red radiation	W/m <sup>2</sup>	6sec. averaged
21 Significant wave height (bow)	m	hourly

22 Significant wave height (aft)	m	hourly
23 Significant wave period (bow)	second	hourly
24 Significant wave period (aft)	second	hourly

Table 2.3.3. Instruments and installation locations of SOAR system.

Sensors	Type	Manufacturer	Location (altitude from surface)
<i>Zeno/Met</i>			
Anemometer	05106	R.M. Young, USA	foremast (25 m)
Tair/RH	HMP45A	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	foremast (23 m)
Barometer	61302V	R.M. Young, USA	
with 61002 Gill pressure port		R.M. Young, USA	foremast (23 m)
Rain gauge	50202	R.M. Young, USA	foremast (24 m)
Optical rain gauge	ORG-815DA	Osi, USA	foremast (24 m)
<i>PRP</i>			
Radiometer (short wave)	PSP	Epply Labs, USA	foremast (25 m)
Radiometer (long wave)	PIR	Epply Labs, USA	foremast (25 m)
Fast rotating shadowband radiometer		Yankee, USA	foremast (25 m)

Table 2.3.4. Parameters of SOAR system.

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 SOG	knot	
4 COG	degree	
5 Relative wind speed	m/s	
6 Relative wind direction	degree	
7 Barometric pressure	hPa	
8 Air temperature	degC	
9 Relative humidity	%	
10 Rain rate (optical rain gauge)	mm/hr	
11 Precipitation (capacitive rain gauge)	mm	reset at 50 mm
12 Down welling shortwave radiation	$W/m^2$	
13 Down welling infra-red radiation	$W/m^2$	
14 Defuse irradiance	$W/m^2$	

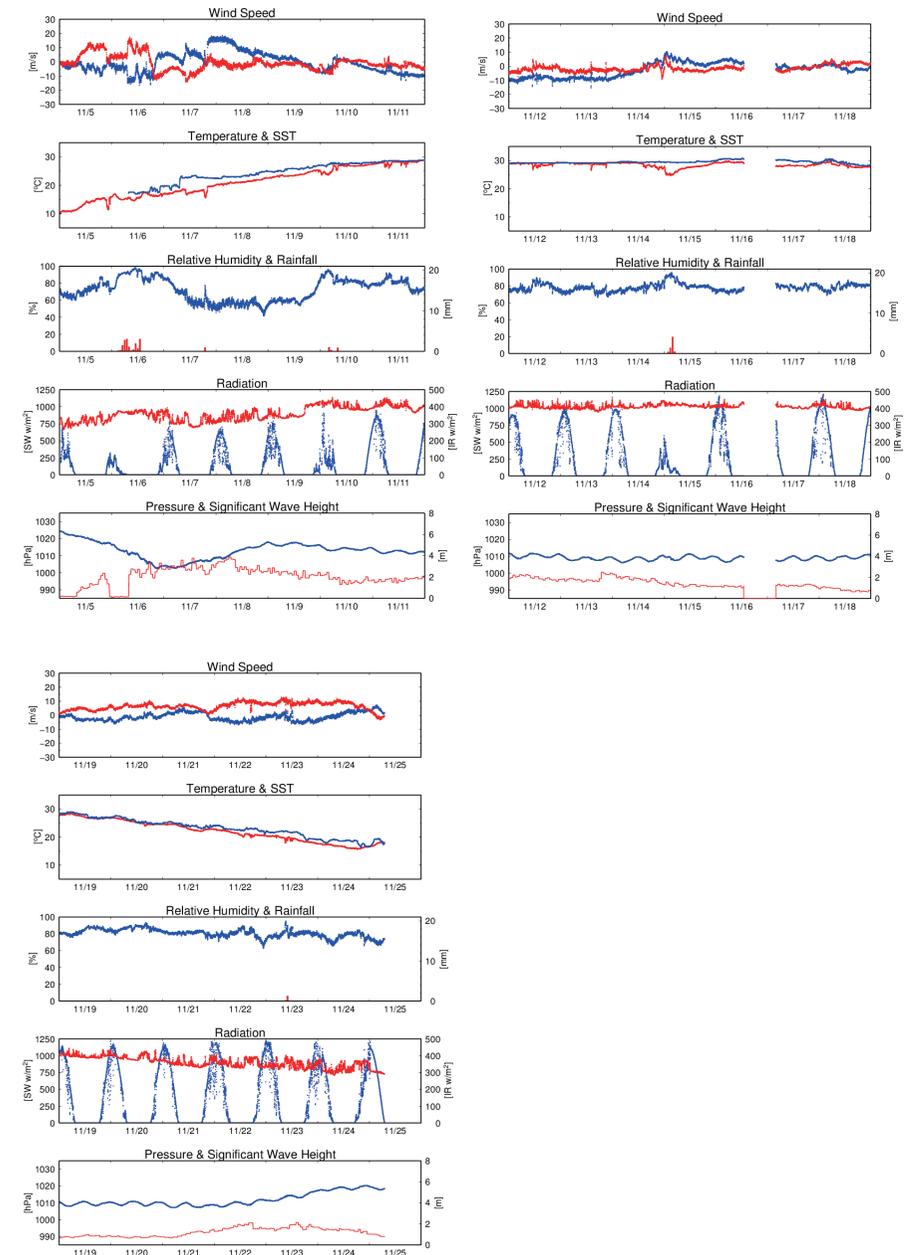


Figure 2.3.1. Time series of surface meteorological parameters during the MR12-05 leg1 cruise.

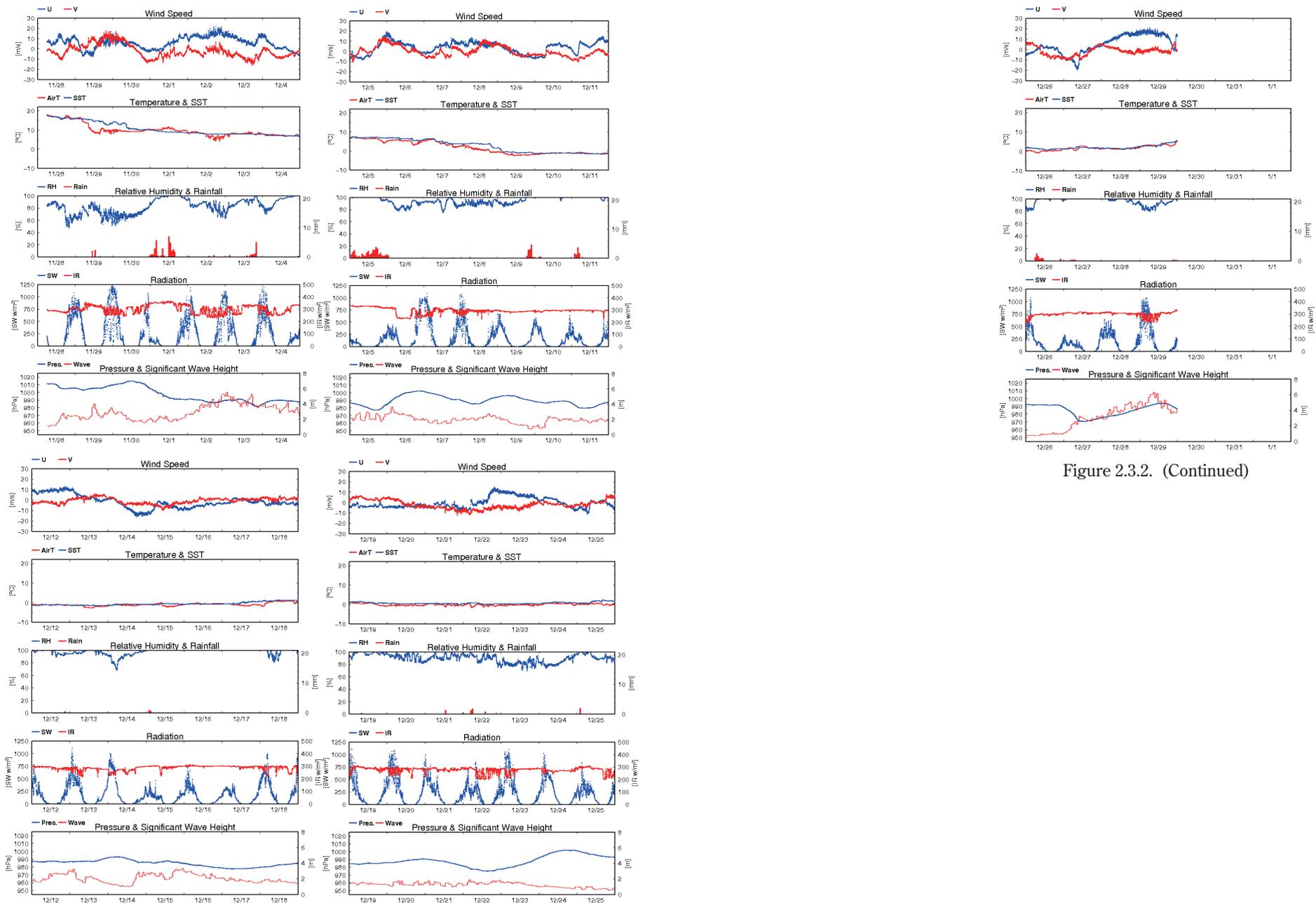


Figure 2.3.2. (Continued)

Figure 2.3.2. Time series of surface meteorological parameters during the MR12-05 leg2 cruise.

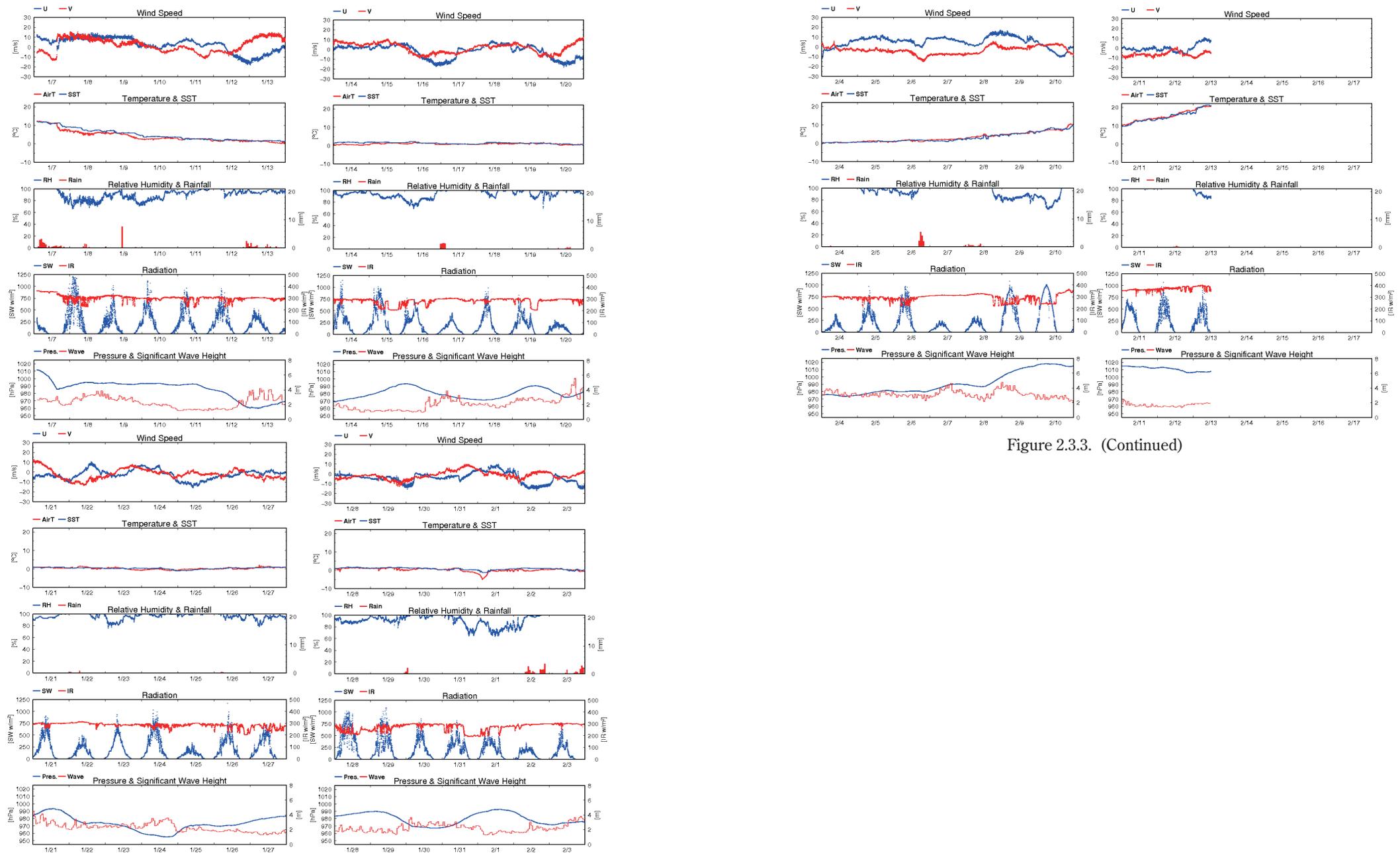


Figure 2.3.3. (Continued)

Figure 2.3.3. Time series of surface meteorological parameters during the MR12-05 leg3 cruise.

## 2.4 Thermo-Salinograph and Related Measurements

October 8, 2014

### (1) Personnel

Hiroshi Uchida (JAMSTEC)

Kanako Yoshida (MWJ) (Legs 1, 3)

Misato Kuwahara (MWJ) (Legs 2, 3)

Keitaro Matsumoto (MWJ) (Leg 2)

### (2) Objectives

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

### (3) Materials and methods

The Continuous Sea Surface Water Monitoring System (Marine Works Japan Co, Ltd.) has six sensors and automatically measures salinity, temperature, dissolved oxygen, and fluorescence in sea surface water every one minute. This system is located in the sea surface monitoring laboratory and connected to shipboard LAN system. Measured data along with time and location of the ship were displayed on a monitor and stored in a desktop computer. The sea surface water was continuously pumped up to the laboratory from about 5 m water depth and flowed into the system through a vinyl-chloride pipe. The flow rate of the surface seawater was controlled to be 1.2 L/min.

Software and sensors used in this system are listed below.

#### i. Software

Seamoni-kun Ver.1.30

#### ii. Sensors

Temperature and conductivity sensor

Model: SBE-45, SEA-BIRD ELECTRONICS, INC.

Serial number: 4563325-0362

Bottom of ship thermometer

Model: SBE 38, SEA-BIRD ELECTRONICS, INC.

Serial number: 3857820-0540

Dissolved oxygen sensors

Model: OPTODE 3835, Aanderaa Data Instruments, AS.

Serial number: 985

Model: RINKO-II, JFE Advantech Co. Ltd.

Serial number: 0013

Fluorometer

Model: C3, TURNER DESIGNS

Serial number: 2300123

#### (4) Data Processing and Quality Control

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

Salinity (S [PSU]), dissolved oxygen (O [ $\mu\text{mol/kg}$ ]) and fluorescence (F1 [RFU]) data were corrected using the water sampled data. Details of the measurement methods are described in [Sections 3.2](#), [3.4](#), and [3.8](#)

for salinity, dissolved oxygen and chlorophyll-a, respectively. Corrected salinity ( $S_{cor}$ ), dissolved oxygen ( $O_{cor}$ ), and estimated chlorophyll  $a$  (Chl-a) were calculated from following equations

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

$$O_{cor} \text{ [}\mu\text{mol/kg]} = c_0 + c_1 O + c_2 T + c_3 t$$

$$\text{Chl-a [}\mu\text{g/L]} = c_0 + c_1 \text{Fl}$$

where  $t$  is days from a reference time,  $T$  is temperature in  $^{\circ}\text{C}$ . The best fit sets of calibration coefficients ( $c_0$ - $c_3$ ) were determined by a least square technique to minimize the deviation from the water sampled data. The reference times were listed in Table 2.4.1. The calibration coefficients were listed in Table 2.4.2. Comparisons between the Continuous Sea Surface Water Monitoring System data and water sampled data are shown in from Figs. 2.4.1 to 2.4.9. For fluorometer data, water sampled data obtained at night [PAR (Photosynthetically Available Radiation)  $< 50 \mu\text{E}/(\text{m}^2 \text{ sec})$ , see Section 2.15] were used for the calibration, since sensitivity of the fluorometer to chlorophyll  $a$  is different at nighttime and daytime (Fig. 2.4.10). For leg 1, sensitivity of the fluorometer to chlorophyll  $a$  is also different at around Solomon Sea and other area. Therefore, slope ( $c_1$ ) of the calibration coefficients was changed for each area (Table 2.4.2). For latitude between  $14^{\circ}\text{S}$  and  $13^{\circ}\text{S}$ , chlorophyll  $a$  was estimated from weighted mean of the two equations as

$$\text{Chl-a} = \text{Chl-a}_1 f_1 + \text{Chl-a}_2 f_2$$

$$f_1 = 1 - (\text{latitude} + 14)$$

$$f_2 = 1 - f_1$$

where Chl-a<sub>1</sub> is chlorophyll  $a$  calculated by using the set of coefficients A, and Chl-a<sub>2</sub> is chlorophyll  $a$  calculated by using the set of coefficients B (Table 2.4.2).

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

Leg	Date	Time (UTC)
1	2012/11/06	08:09
2	2012/11/28	06:00
3	2013/01/07	02:00

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

Leg	c0	c1	c2	c3
<i>Salinity</i>				
1	-8.264243e-04	1.000025	-3.094205e-06	
2	-4.901493e-04	1.000014	-8.007142e-08	
3	4.116161e-04	0.9999879	1.490024e-07	
<i>Dissolved oxygen</i>				
1	8.682632e-03	0.9999764	-1.111354e-04	-3.665007e-05
2	9.983204e-03	0.9999737	-1.391134e-04	-3.103317e-05
3	-1.566883e-02	1.000044	2.854348e-04	8.284769e-06
<i>Chlorophyll a</i>				
1	5.352958e-02	0.1296275 (A: for latitude $\leq 14^{\circ}\text{S}$ or latitude $\geq 5^{\circ}\text{S}$ )		
	5.352958e-02	0.3467123 (B: for latitude $> 13^{\circ}\text{S}$ and latitude $< 5^{\circ}\text{S}$ )		
2	0.1141853	5.968889e-02		
3	1.445487e-02	5.716477e-02		

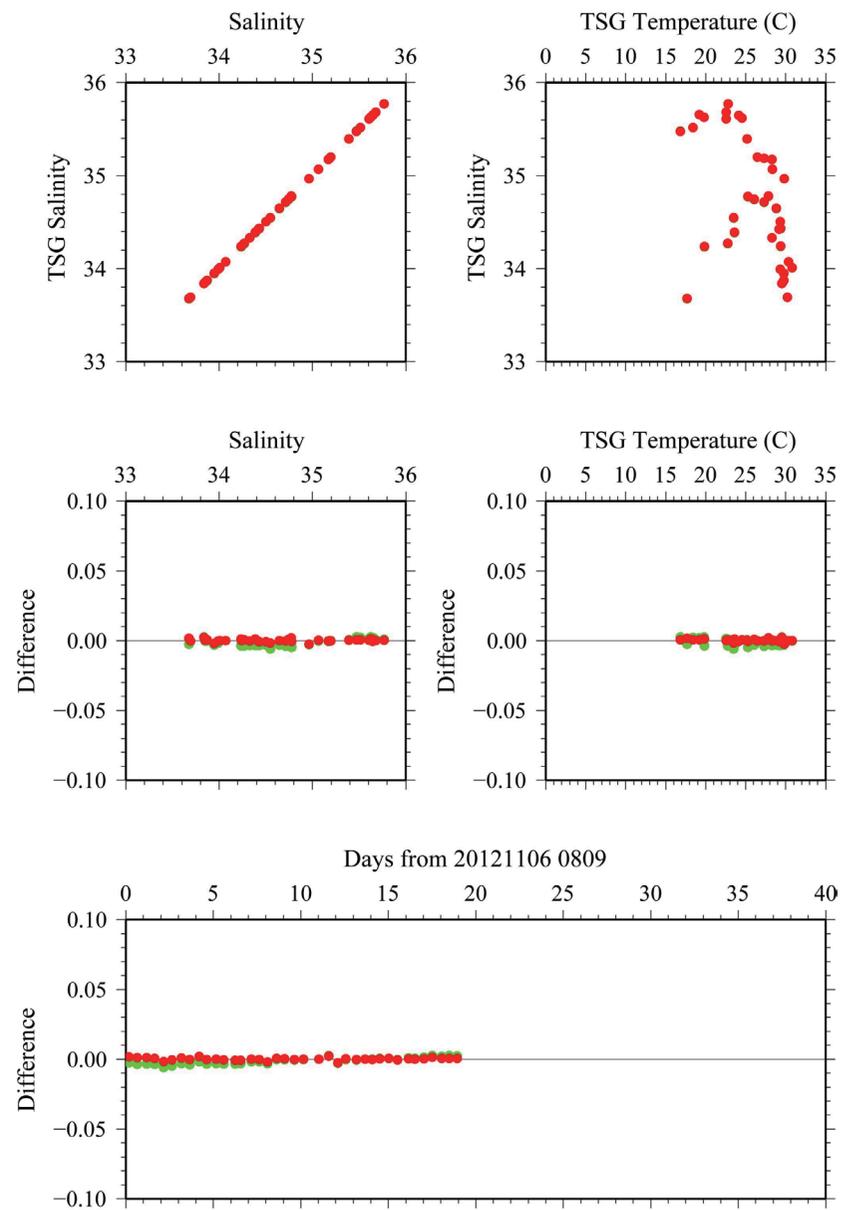


Figure 2.4.1. Comparison between TSG salinity (green: before correction, red: after correction) and sampled salinity for leg 1.

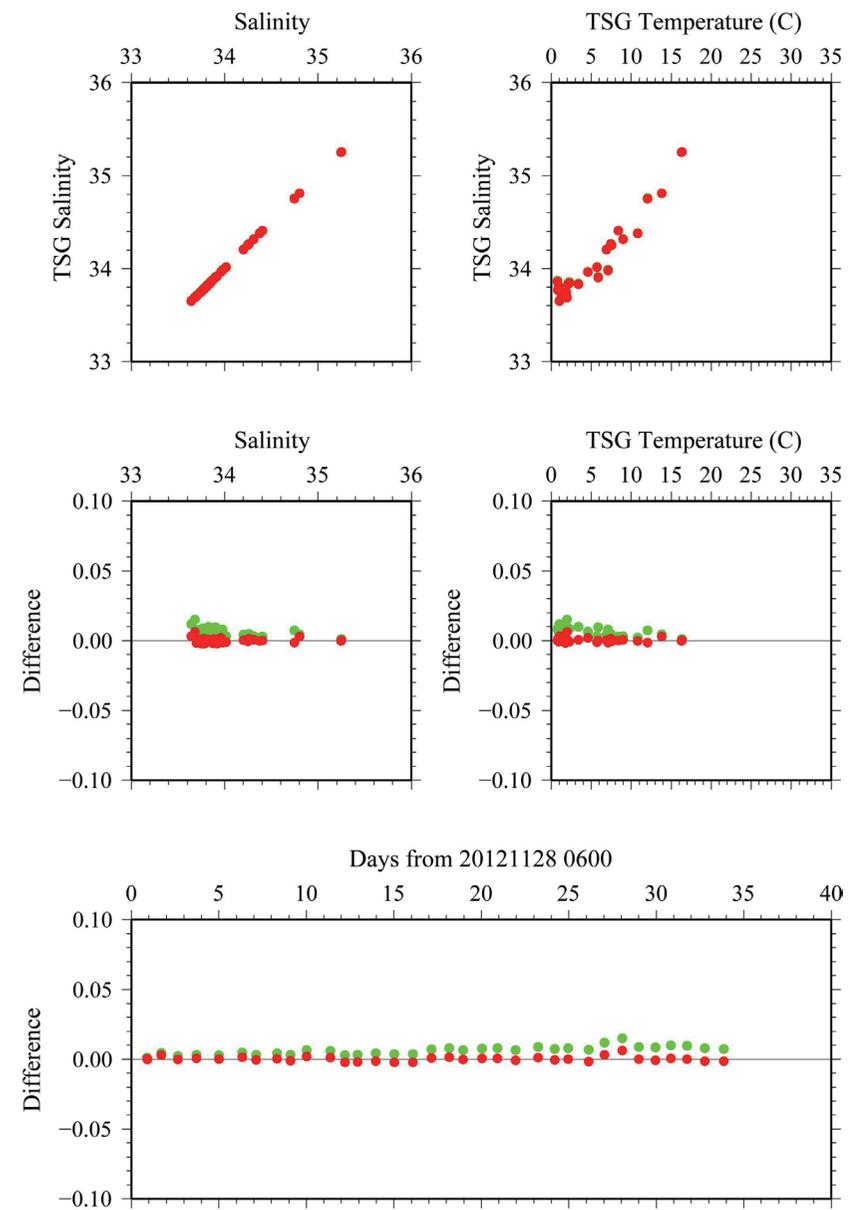


Figure 2.4.2. Same as Fig. 2.4.1, but for leg 2.

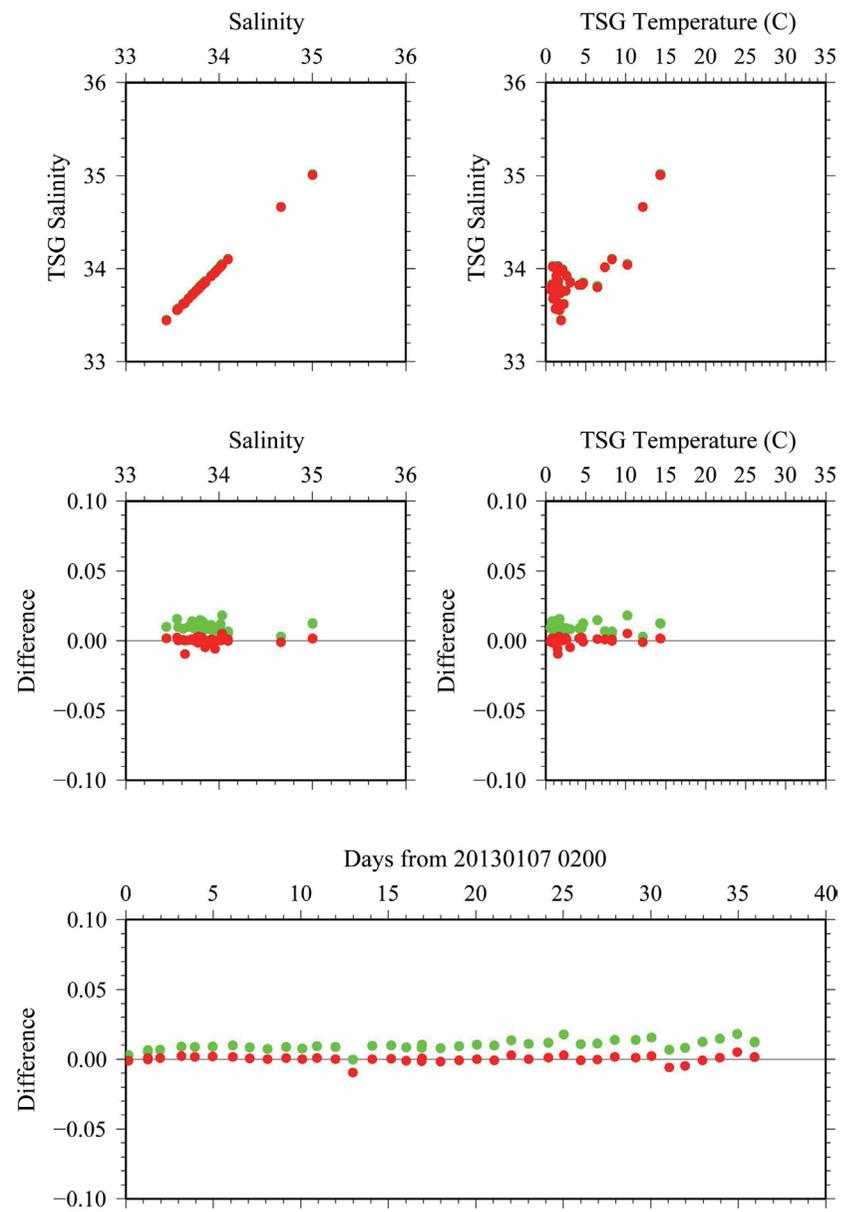


Figure 2.4.3. Same as Fig. 2.4.1, but for leg 3.

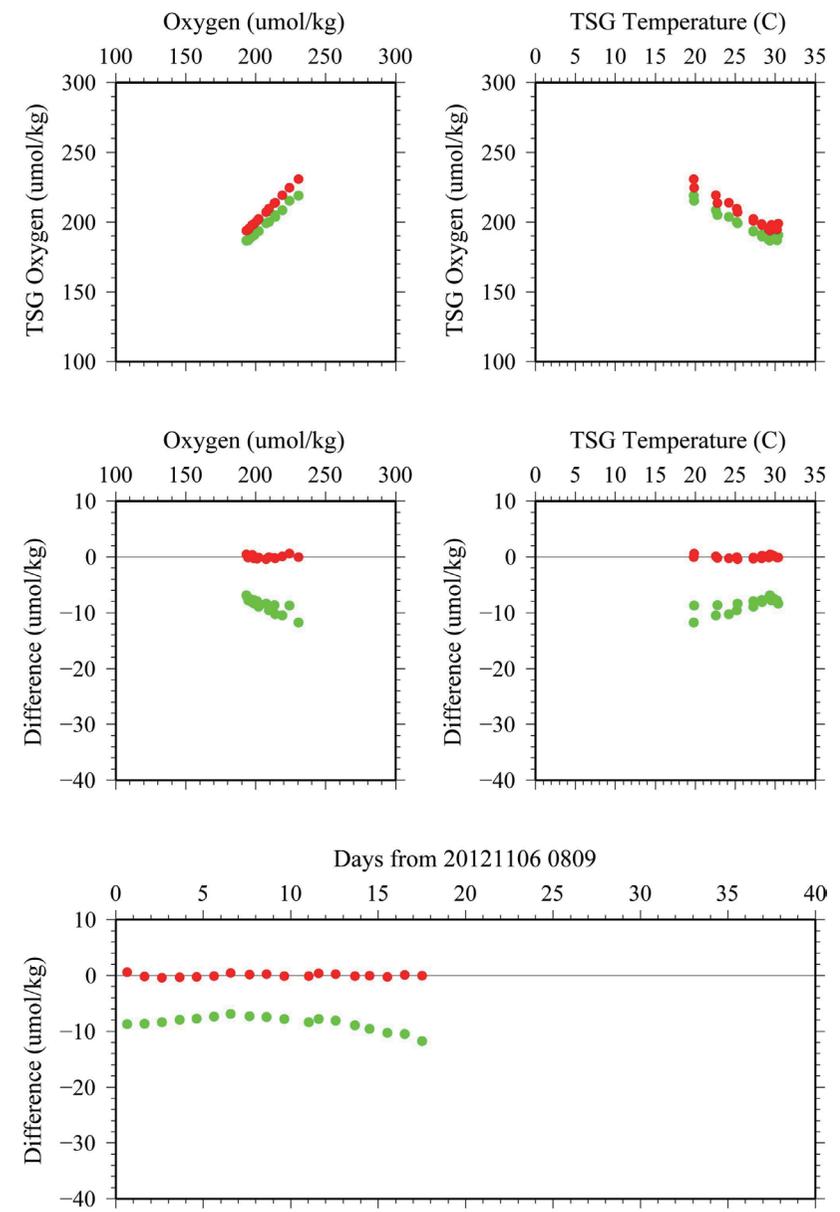


Figure 2.4.4. Comparison between TSG oxygen (green: before correction, red: after correction) and sampled oxygen for leg 1.

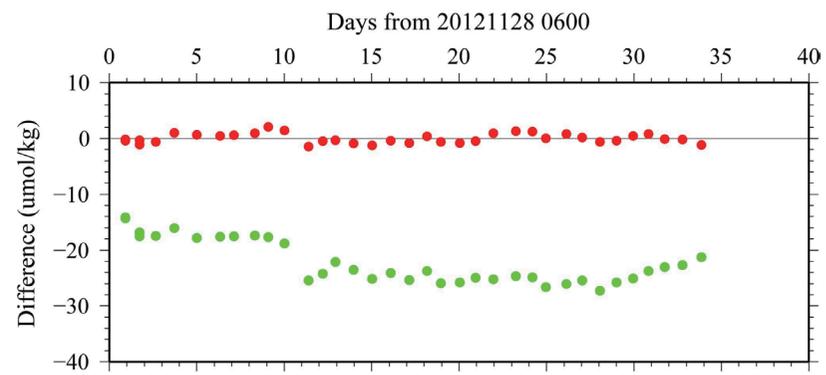
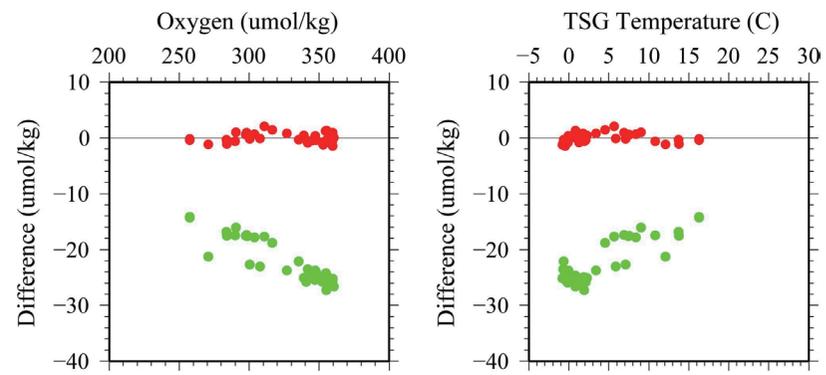
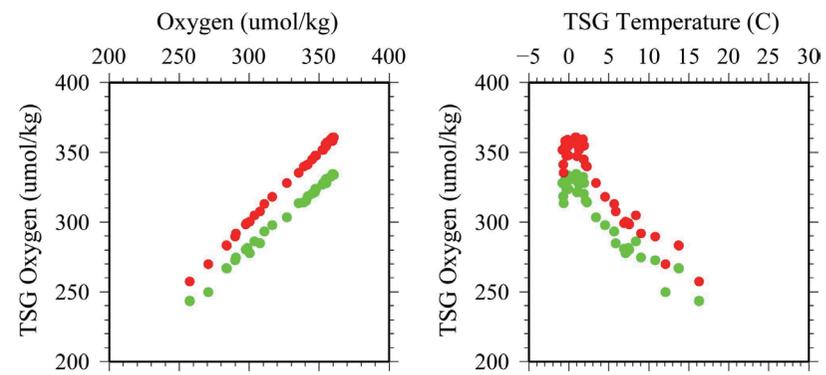


Figure 2.4.5. Same as Fig. 2.4.4, but for leg 2.

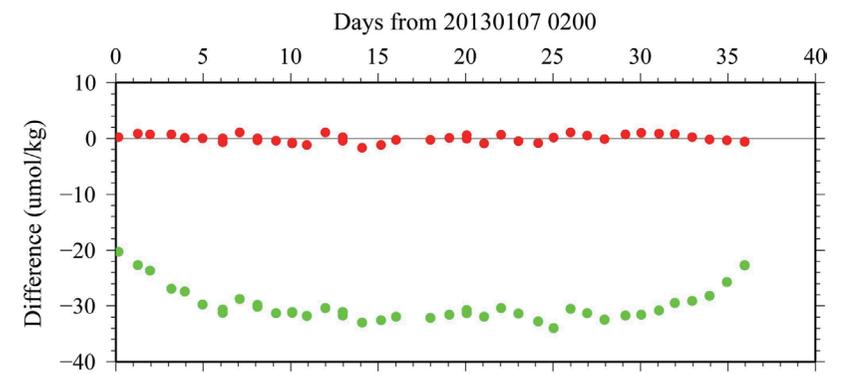
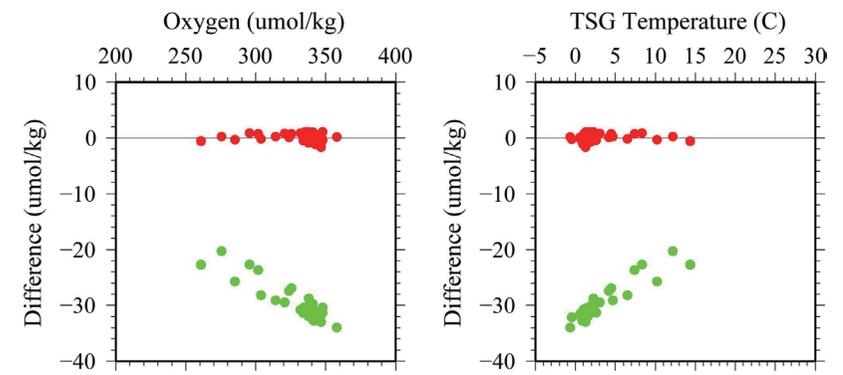
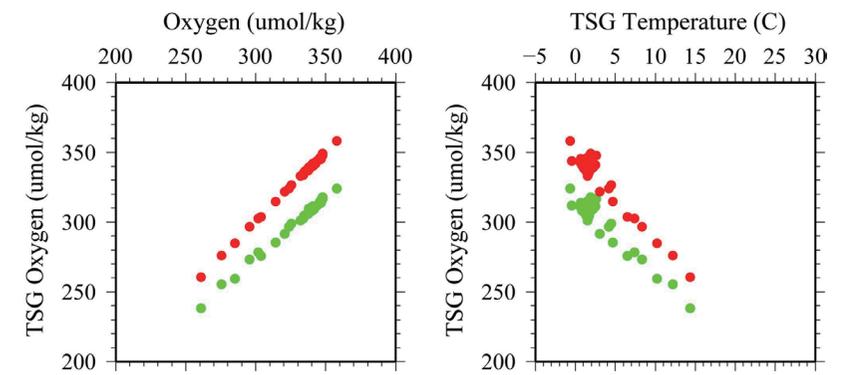


Figure 2.4.6. Same as Fig. 2.4.4, but for leg 3.

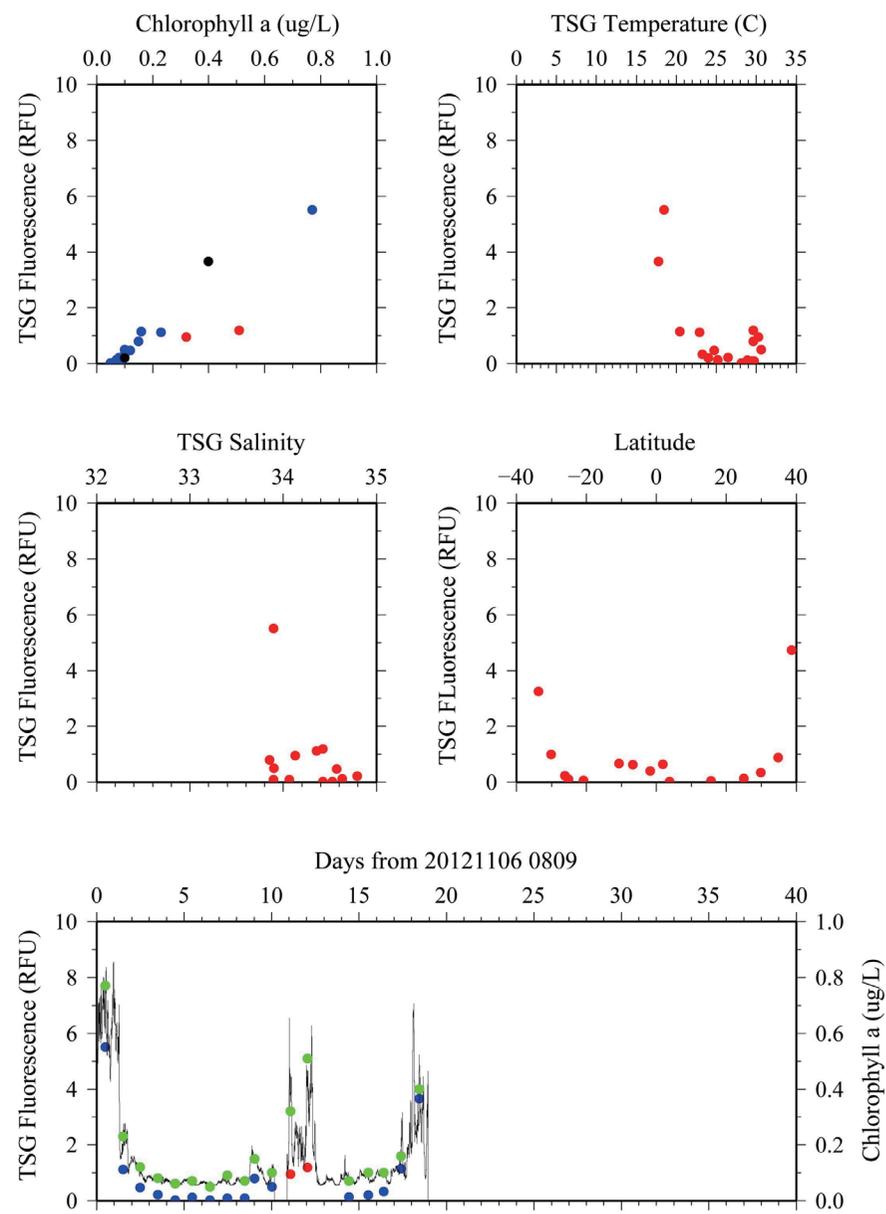


Figure 2.4.7. Comparison between TSG fluorescence and sampled chlorophyll *a* for leg 1. Black dots indicate the daytime data. For bottom panel, blue or red dots indicate fluorescence and green dots indicate water sampled chlorophyll *a*. Line indicates chlorophyll *a* estimated from fluoremeter.

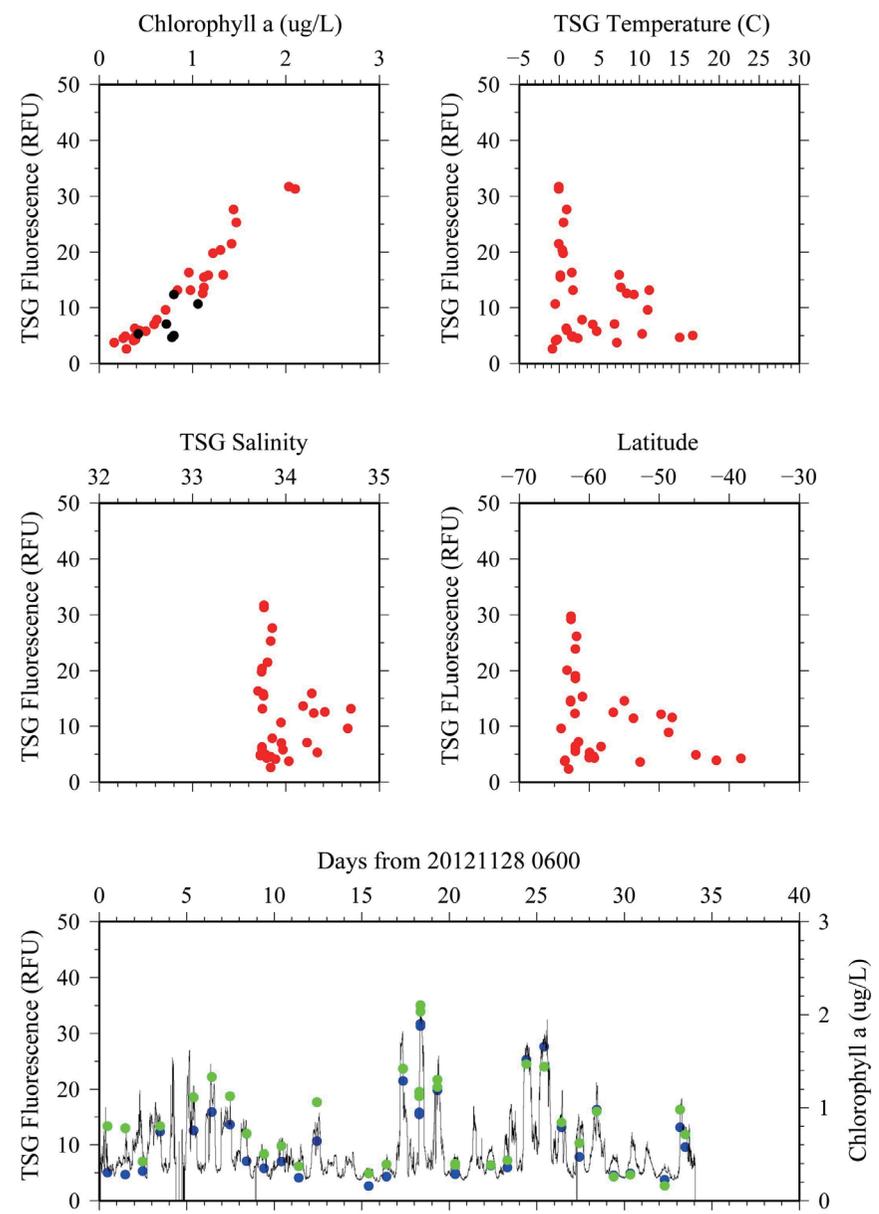


Figure 2.4.8. Same as Fig. 2.4.7, but for leg 2.

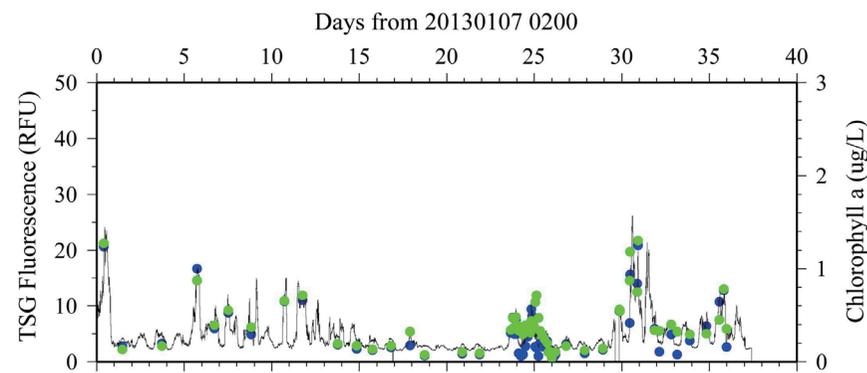
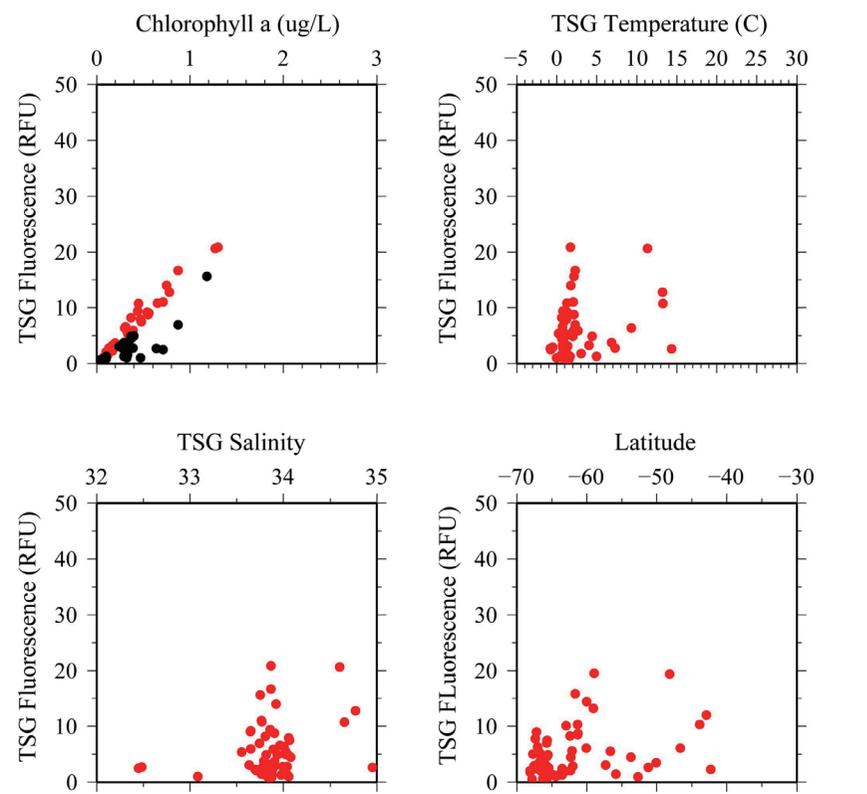


Figure 2.4.9. Same as Fig. 2.4.7, but for leg 3.

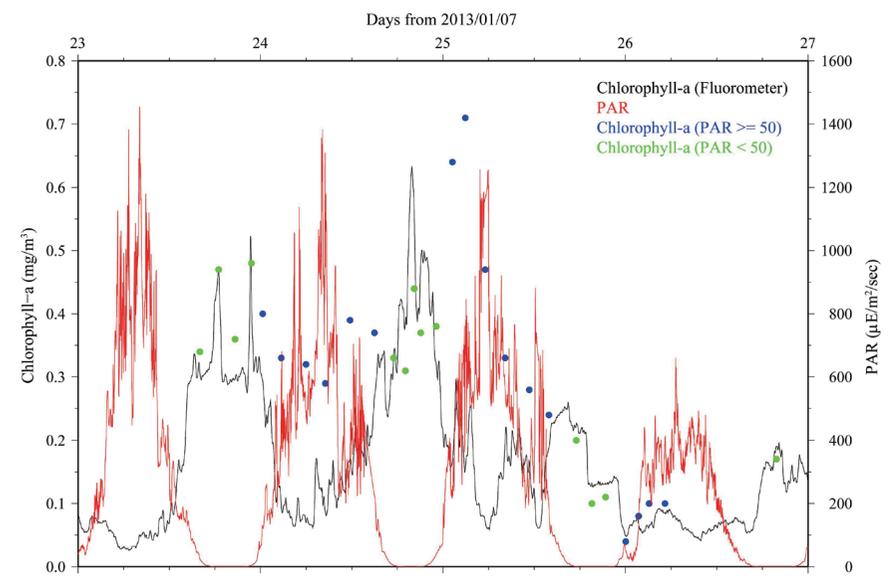


Figure 2.4.10. Diurnal variation of the chlorophyll a estimated from the fluorometer. Water sampled chlorophyll a (blue and green dots) does not show such diurnal variation.

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

October 2, 2014

### (1) Personnel

Akihiko Murata	(JAMSTEC)
Yoshiko Ishikawa	(MWJ)
Tomonori Watai	(MWJ)
Emi Deguchi	(MWJ)
Atsushi Ono	(MWJ)
Keisuke Tsubata	(MWJ)

### (2) Introduction

According to the latest report from Intergovernmental Panel on Climate Change, concentrations of CO<sub>2</sub> in the atmosphere have increased by 40% since pre-industrial times owing to human activities such as burning of fossil fuels, deforestation, and cement production. It is evaluated that the ocean has absorbed about 30% of the emitted anthropogenic CO<sub>2</sub>. It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric CO<sub>2</sub>, and to clarify the mechanism of the CO<sub>2</sub> absorption, because the magnitude of future global warming depends on the levels of CO<sub>2</sub> in the atmosphere.

The Southern Ocean is one of the regions where uncertainty of uptake of anthropogenic CO<sub>2</sub> is large. In this cruise, therefore, we were aimed at quantifying how much anthropogenic CO<sub>2</sub> is absorbed in the ocean interior of the Southern Ocean. For the purpose, we measured atmospheric and surface seawater partial pressures of CO<sub>2</sub> (pCO<sub>2</sub>) along the WHP P14S and S04I lines at ~170°E and ~60°S, respectively, in the Southern Ocean.

### 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 (Li-COR LI-7000), an air-circulation module and a showerhead-type equilibrator. To measure concentrations (mole fraction) of CO<sub>2</sub> in dry air (xCO<sub>2</sub>a), 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>2</sub>s), 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>2</sub>a. The flow rate of the equilibrated air was 700 – 800 ml min<sup>-1</sup>. The seawater was taken by a pump from the intake placed at the approx. 4.5 m below the sea surface. The flow rate of seawater in the equilibrator was 400 – 500 ml min<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 2.5.1), xCO<sub>2</sub>a (twice), xCO<sub>2</sub>s (7 times). This measuring system was run automatically throughout the cruise by a PC control.

### Quality control

Concentrations of CO<sub>2</sub> of the standard gases are listed in Table 2.5.1, which were calibrated after cruise by the JAMSTEC primary standard gases. The CO<sub>2</sub> concentrations of the primary standard gases were calibrated by the Scripps Institution of Oceanography, La Jolla, CA, USA.

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

Effects of water temperature increased between the inlet of surface seawater and the equilibrator on xCO<sub>2</sub>s were adjusted based on Takahashi *et al.* (1993), although the temperature increases were slight, being ~0.3 °C.

We checked values of xCO<sub>2</sub>a and xCO<sub>2</sub>s by examining signals of the NDIR by plotting the xCO<sub>2</sub>a and

xCO<sub>2</sub>s as a function of sequential day, longitude, sea surface temperature and sea surface salinity.

### Reference

Takahashi, T., J. Olafsson, J. G. Goddard, D. W. Chipman, and S. C. Southerland (1993) Seasonal variation of CO<sub>2</sub> and nutrients in the high-latitude surface oceans: a comparative study, *Global Biogeochem. Cycles*, 7, 843 – 878.

Table 2.5.1. Concentrations of CO<sub>2</sub> standard gases used during the Southern Ocean cruise.

Cylinder no.	Concentrations (ppmv)
CRC00049	270.14
CRC00046	330.29
CRC00047	360.31
CRC00048	420.22

## 2.6 Shipboard ADCP

September 30, 2014

### (1) Personnel

Shinya Kouketsu	(JAMSTEC)	: Principal Investigator
Souichiro Sueyoshi	(Global Ocean Development Inc., GODI)	-leg1, leg3-
Koichi Inagaki	(GODI)	-leg1, leg3-
Kazuho Yoshida	(GODI)	-leg2-
Shinya Okumura	(GODI)	-leg2-
Masanori Murakami	(GODI)	-leg2-
Katsuhisa Maeno	(GODI)	-leg3-
Ryo Kimura	(MIRAI Crew)	-leg1, leg2-
Ryo Ohyama	(MIRAI Crew)	-leg3-

### (2) Objective

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

### (3) Methods

Upper ocean current measurements were made in the MR12-05 cruise, using the hull-mounted Acoustic Doppler Current Profiler (ADCP) system. For most of its operation the instrument was configured for water-tracking mode. Bottom-tracking mode, interleaved bottom-ping with water-ping, was made to get the calibration data for evaluating transducer misalignment angle in the shallow water. The system consists of following components;

- 1) R/V MIRAI has installed vessel-mount ADCP (75 kHz "Ocean Surveyor", Teledyne RD Instruments). It has a phased-array transducer with single assembly and creates 4 acoustic beams electronically.

- 2) For heading source, we use ship's gyro compass (Tokimec, Japan), continuously providing heading to the ADCP system directory. Also we have Inertial Navigation System (PHINS, iXSEA) which provide high-precision heading and attitude information are stored in ".N2R" data files.
- 3) DGPS system (Trimble SPS751 & StarFixXP) providing position fixes.
- 4) We used VmDas version 1.46.5 (TRDI) for data acquisition.
- 5) To synchronize time stamp of pinging with GPS time, the clock of the logging computer is adjusted to GPS time every 8 minutes.
- 6) The sound speed at the transducer does affect the vertical bin mapping and vertical velocity measurement, is calculated from temperature, salinity (constant value; 35.0 psu) and depth (6.5 m; transducer depth) by equation in Medwin (1975).

Data was configured for 8-m intervals starting 23-m below the surface. Every ping was recorded as raw ensemble data (.ENR). Also, 60 seconds and 300 seconds averaged data were recorded as short term average (.STA) and long term average (.LTA) data, respectively. Major parameters for the measurement (Direct Command) are shown in [Table 2.6.1](#).

### (4) Processed data

We corrected the misalignment of ADCP with the bottom track measurements and provided 9 sminutes averaged velocity profiles.

### (5) Data archive

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

**(6) Remarks (Times in UTC)**

1) The observation was carried out within following periods

Leg1: 07:00, 05 Nov. 2012 - 15:00, 16 Nov. 2012

03:00, 17 Nov. 2012 - 07:00, 25 Nov. 2012

Leg2: 06:00, 28 Nov. 2012 - 07:00, 01 Jan. 2013

Leg3: 02:00, 07 Jan. 2013 - 12:00, 13 Feb 2013

2) RSSI (Echo Intensity) became weak deeper layers than 300m around southern part of P14S line as shown in Fig 2.6-1. The following periods, we changed temporally some of parameters (Depth cell size (WS), number of cells (WN) and blanking distance (WF)) due to trying to improve of the state.

01:30 - 01:44, 10 Dec. 2012 : WS;400[cm], WN;128, WF; 400[cm]

01:45 - 02:51, 10 Dec. 2012 : WS;400[cm], WN;128, WF; 800[cm]

3) The following periods, navigation data was invalid due to GPS position fix error.

Leg1: 23:25:06 - 23:39:07, 22 Nov. 2012 (intermittently)

Leg2: 11:47:39 - 13:41:46, 28 Dec. 2012

Table 2.6.1. Major parameters.

---

***Bottom-Track Commands***

BP = 000

Pings per Ensemble (almost over 1300m depth)

Leg1: 01:19UTC 07 Nov. 2012 – 15:00UTC 16 Nov. 2012

03:00UTC 17 Nov. 2012 – 04:39UTC 17 Nov. 2012

06:48UTC 17 Nov. 2012 – 09:43UTC 18 Nov. 2012

10:59UTC 18 Nov. 2012 – 18:41UTC 22 Nov. 2012

20:56UTC 22 Nov. 2012 – 08:09UTC 23 Nov. 2012

09:16UTC 23 Nov. 2012 – 02:32UTC 23 Nov. 2012

Leg2: 06:00UTC 28 Nov. 2012 – 02:31UTC 30 Nov. 2012

17:30UTC 30 Nov. 2012 – 20:54UTC 01 Dec. 2012

16:17UTC 03 Dec. 2012 – 07:00UTC 01 Jan. 2013

Leg3: 17:43UTC 06 Jan. 2013 – 14:35UTC 06 Feb. 2013

05:15UTC 07 Feb. 2013 – 12:00UTC 13 Feb. 2013

BP = 001

Pings per Ensemble (almost less than 1300m depth)

Leg1: 04:16UTC 05 Nov. 2012 – 01:19UTC 07 Nov. 2012

04:39UTC 17 Nov. 2012 – 06:47UTC 17 Nov. 2012

09:43UTC 18 Nov. 2012 – 10:59UTC 18 Nov. 2012

18:41UTC 22 Nov. 2012 – 20:56UTC 22 Nov. 2012

08:09UTC 23 Nov. 2012 – 09:16UTC 23 Nov. 2012

02:32UTC 23 Nov. 2012 – 07:00UTC 25 Nov. 2012

Leg2: 02:32UTC 30 Nov. 2012 – 17:30UTC 30 Nov. 2012

20:54UTC 01 Dec. 2012 – 16:17UTC 03 Dec. 2012

Leg3: 06:18UTC 05 Jan. 2013 – 17:43UTC 06 Jan. 2013

14:35UTC 06 Feb. 2013 – 05:15UTC 07 Feb. 2013

**Environmental Sensor Commands**

EA = +04500	Heading Alignment (1/100 deg)
EB = +00000	Heading Bias (1/100 deg)
ED = 00065	Transducer Depth (0 - 65535 dm)
EF = +001	Pitch/Roll Divisor/Multiplier (pos/neg) [1/99 - 99]
EH = 00000	Heading (1/100 deg)
ES = 35	Salinity (0-40 pp thousand)
EX = 00000	Coord Transform (Xform:Type; Tilts; 3Bm; Map)
EZ = 10200010	Sensor Source (C; D; H; P; R; S; T; U)
	C (1): Sound velocity calculates using ED, ES, ET (temp.)
	D (0): Manual ED
	H (2): External synchro
	P (0), R (0): Manual EP, ER (0 degree)
	S (0): Manual ES
	T (1): Internal transducer sensor
	U (0): Manual EU

**Timing Commands**

TE = 00:00:02.00	Time per Ensemble (hrs:min:sec.sec/100)
TP = 00:02.00	Time per Ping (min:sec.sec/100)

**Water-Track Commands**

WA = 255	False Target Threshold (Max) (0-255 count)
WB = 1	Mode 1 Bandwidth Control (0=Wid, 1=Med, 2=Nar)
WC = 120	Low Correlation Threshold (0-255)
WD = 111 100 000	Data Out (V; C; A; PG; St; Vsum; Vsum^2;#G;P0)
WE = 1000	Error Velocity Threshold (0-5000 mm/s)
WF = 0800	Blank After Transmit (cm)

WG = 001	Percent Good Minimum (0-100%)
WI = 0	Clip Data Past Bottom (0 = OFF, 1 = ON)
WJ = 1	Rcvr Gain Select (0 = Low, 1 = High)
WM = 1	Profiling Mode (1-8)
WN = 100	Number of depth cells (1-128)
WP = 00001	Pings per Ensemble (0-16384)
WS= 0800	Depth Cell Size (cm)
WT = 000	Transmit Length (cm) [0 = Bin Length]
WV = 0390	Mode 1 Ambiguity Velocity (cm/s radial)

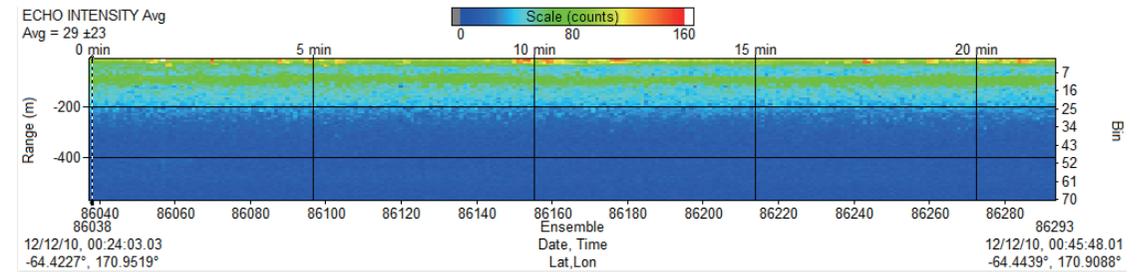


Figure 2.6.1. Time series of Echo Intensity profile between P14S-26 and P14S-27.

## 2.7 XCTD

May 6, 2013

### (1) Personnel

Hiroshi Uchida (JAMSTEC)  
 Souichiro Sueyoshi (GODI) (Legs 1 and 3)  
 Koichi Inagaki (GODI) (Legs 1 and 3)  
 Kazuho Yoshida (GODI) (Leg 2)  
 Shinya Okumura (GODI) (Leg 2)  
 Masanori Murakami (GODI) (Leg 2)  
 Katsuhisa Maeno (GODI) (Leg 3)

### (2) Objectives

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

### (3) Instrument and Method

The XCTDs used were XCTD-1, XCTD-2 and XCTD-4 (Tsurumi-Seiki Co., Ltd., Yokohama, Kanagawa, Japan) with an MK-150N deck unit (Tsurumi-Seiki Co., Ltd.). The manufacturer's specifications are listed in Table 2.7.1. In this cruise, the XCTD probes were deployed by using 8-loading automatic launcher or hand launcher (Tsurumi-Seiki Co., Ltd.). For comparison with CTD, XCTD was deployed at about 10 minutes after the beginning of the down cast of the CTD (999\_C02, 999\_C03, P14S\_25, S04\_402, S04I\_166, and S04I\_167).

The fall-rate equation provided by the manufacturer was used to infer depth  $Z$  (m),  $Z = at - bt^2$ , where  $t$  is the elapsed time in seconds from probe entry into the water, and  $a$  (terminal velocity) and  $b$  (acceleration) are the empirical coefficients (Table 2.7.2).

Table 2.7.1. Manufacturer's specifications of XCTD-1, XCTD-2 and XCTD-4.

Parameter	Range	Accuracy
Conductivity	0 ~ 60 mS cm <sup>-1</sup>	±0.03 mS cm <sup>-1</sup>
Temperature	-2 ~ 35 °C	±0.02 °C
Depth	0 ~ 1000 m (for XCTD-1) 0 ~ 1850 m (for XCTD-2 and XCTD-4)	5 m or 2%, whichever is greater *

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

Table 2.7.2. Manufacturer's coefficients for the fall-rate equation.

Model	$a$ (terminal velocity, m/s)	$b$ (acceleration, m/s <sup>2</sup> )	$e$ (terminal velocity error, m/s)
XCTD-1	3.42543	0.00047	not estimated
XCTD-2	3.43898	0.00031	-0.0239
XCTD-4	3.68081	0.00047	-0.0075

#### (4) Data Processing and Quality Control

The XCTD data were processed and quality controlled based on a method by Uchida et al. (2011). Differences between XCTD and CTD depths were shown in Fig. 2.7.1. The terminal velocity error was estimated for the XCTD-2 and for the XCTD-4 (Table 2.7.2). Difference of temperature on pressure surfaces were examined by using side-by-side XCTD and CTD data (Fig. 2.7.2). The XCTD data were corrected for the depth error by using the estimated terminal velocities. Average thermal bias below 400 dbar was 0.009 °C. Mean of the thermal biases of XCTD data estimated from four cruises was  $0.015 \pm 0.004$  °C (Table 2.7.3). The mean thermal bias (0.015 °C) was corrected for the XCTD data obtained in this cruise. Difference of salinity on reference temperature surfaces were examined by using neighboring CTD data (Table 2.7.4). The estimated salinity biases were corrected for the XCTD data (Fig. 2.7.3) except for the XCTD data obtained at 999\_326 and 999\_329, because neighboring CTD data was not available in this cruise.

Table 2.7.3. Thermal biases of the XCTD temperature data.

Cruise	Average thermal bias (°C)	Depth range	Source
MR09-01	0.016	>= 1100 dbar	Uchida et al. (2011)
KH-02-3	0.019	>= 1100 dbar	Uchida et al. (2011)
MR11-08	0.014	>= 1100 dbar	Uchida et al. (2013)
MR12-05	0.009	>= 400 dbar	This report
<i>Mean</i>	$0.015 \pm 0.004$		

Table 2.7.4. Salinity biases of the XCTD data.

XCTD station	Salinity bias	Reference temperature (°C)	Reference salinity	Reference CTD stations
999_C02	0.007	2.3	34.6251	999_C02
999_C03	0.018	2.3	34.6293	999_C03
P14S_25	0.001	0.9	34.7122	*1
S04_401	0.001	0.9	34.7122	*1
S04_402	0.001	0.9	34.7122	*1
S04_403	-0.006	0.9	34.7122	*1
S04_405	-0.009	0.9	34.7122	*1
S04_407	-0.009	0.9	34.7122	*1
S04_409	0.004	0.9	34.7122	*1
S04_411	-0.003	0.9	34.7122	*1
999_C04	0.017	1.2	34.7279	999_C04
S04I_166	-0.015	0.9	34.7065	S04I_166, S04I_167
S04I_167	-0.021	0.9	34.7065	S04I_166, S04I_167

\*1: P14S\_25, P14S\_27, S04\_50, S04\_402, S04\_404, S04\_406, S04\_408, S04\_410

#### References

- Kizu, S., H. Onishi, T. Suga, K. Hanawa, T. Watanabe, and H. Iwamiya (2008): Evaluation of the fall rates of the present and developmental XCTDs. *Deep-Sea Res I*, **55**, 571–586.
- Uchida, H., K. Shimada, and T. Kawano (2011): A method for data processing to obtain high-quality XCTD data. *J. Atmos. Oceanic Technol.*, **28**, 816–826.

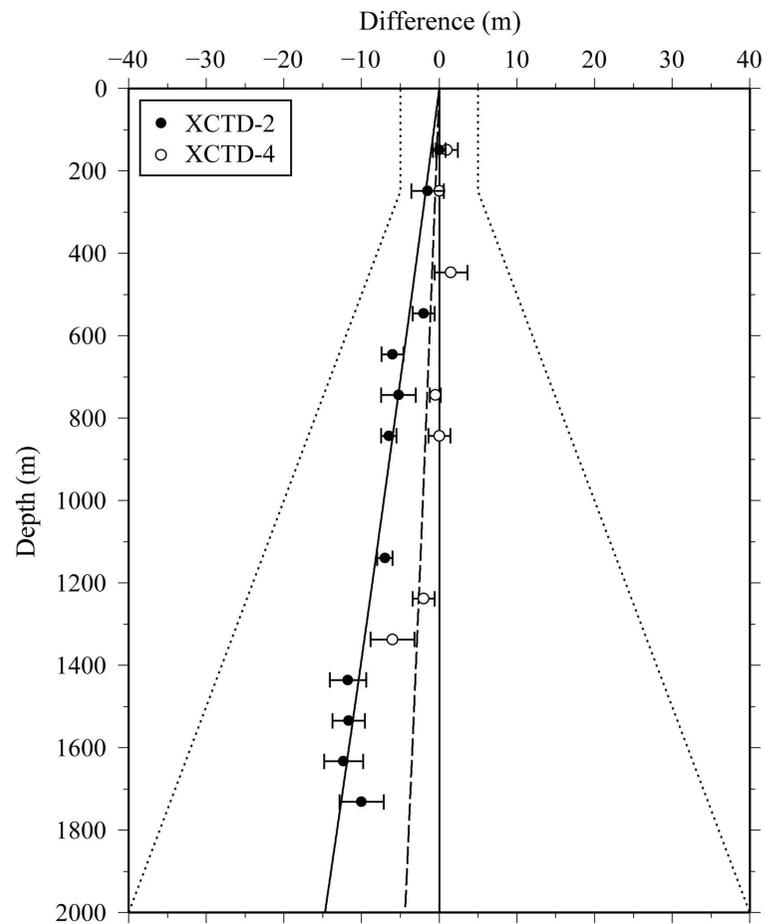


Figure 2.7.1. Differences between XCTD and CTD depths for XTD-2 and XCTD-4. Differences were estimated with the same method as Uchida et al. (2011). Standard deviation of the estimates (horizontal bars) and the manufacturer's specification for XCTD depth error (dotted lines) are shown. The regressions for the XCTD-2 data (solid line) and for the XCTD-4 data (broken line) are also shown.

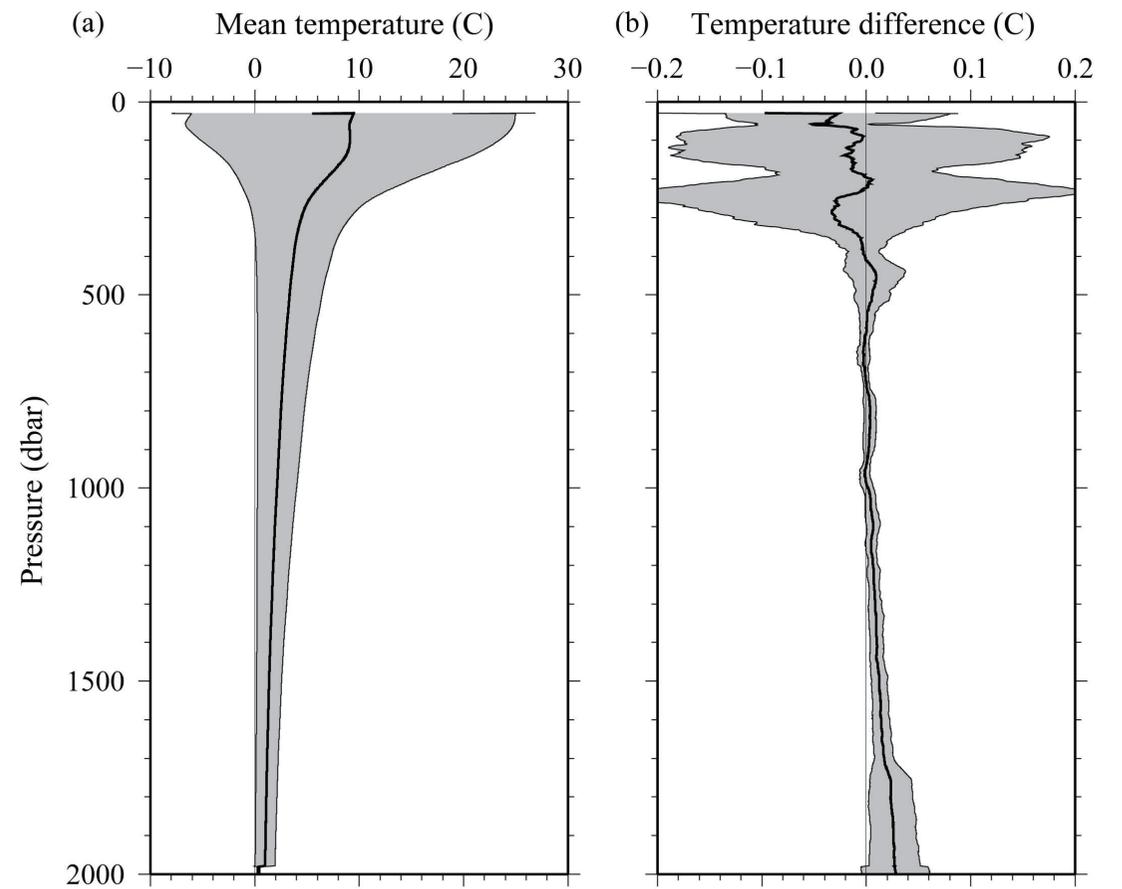


Figure 2.7.2. Comparison between XCTD and CTD temperature profiles. (a) Mean temperature files of CTD profiles with standard deviation (shade) and (b) mean temperature difference with standard deviation (shade) between the XCTD and CTD. Mean profiles were low-pass filtered by a running mean with a window of 51 dbar.

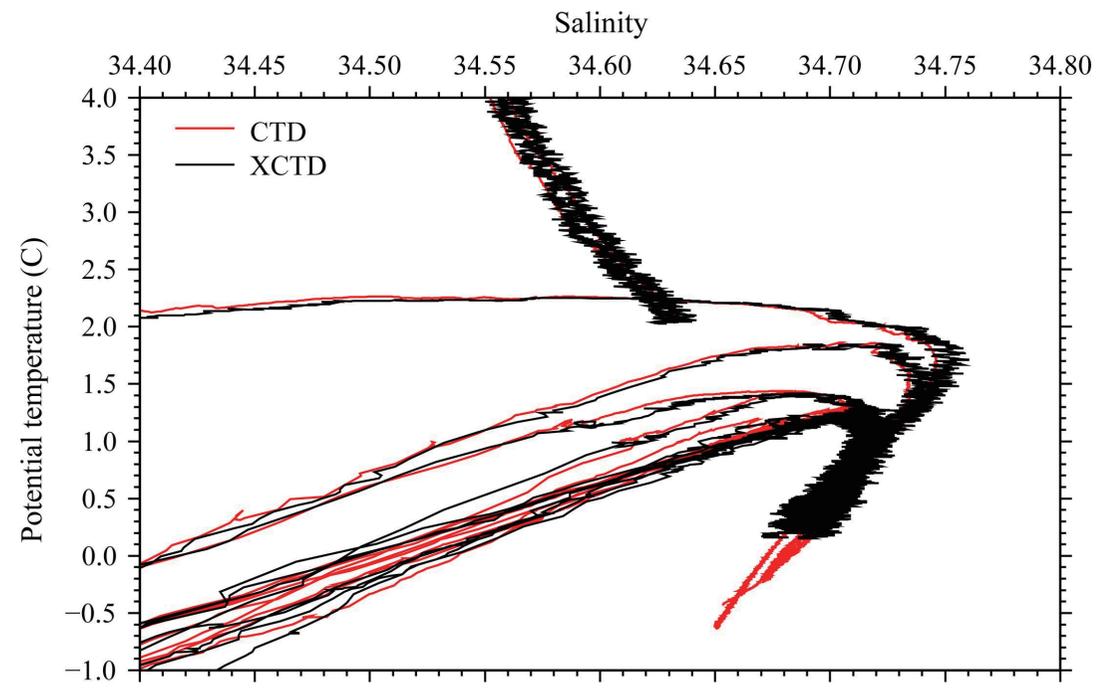


Figure 2.7.3. Comparison of temperature-salinity profiles of CTD (red lines) data used for the XCTD salinity bias estimation and salinity bias-corrected XCTD (black lines) data.

## 2.8 Photosynthetically Available Radiation (PAR)

May 6, 2013

### (1) Personnel

Hiroshi Uchida (JAMSTEC)

### (2) Objectives

The PAR sensor is used to measure surface Photosynthetically Available Radiation (PAR) continuously along the cruise track for a study of primary production.

### (3) Instrument and method

The PAR is measured by a PUV-510B (Biospherical Instruments Inc., San Diego, CA, USA) at one minute intervals. The PAR sensor was installed on the roof top of the anti-rolling system by looking upward. The PAR sensor was calibrated before the cruise by the K-Engineering Co., Ltd., Japan.

Serial no.: 19209

Date of calibration: September 28, 2012

Slope: -6.220

Offset: 0.000109  $\mu\text{E}/(\text{cm}^2 \text{ sec})$

### (4) Comparison with another PAR sensor

Data measured by a PUV-510B were compared with the data measured by another PAR sensor (Serial no.: 049, Satlantic LP, Halifax, NS, Canada) used in the CTD profiler measurement. The Satlantic's PAR sensor was attached to the body of the surface PAR (PUV-510B) sensor and the PAR data were compared for four hours of daytime (2:54-6:53 [UTC], February 9, 2013) (Figure 2.8.1).

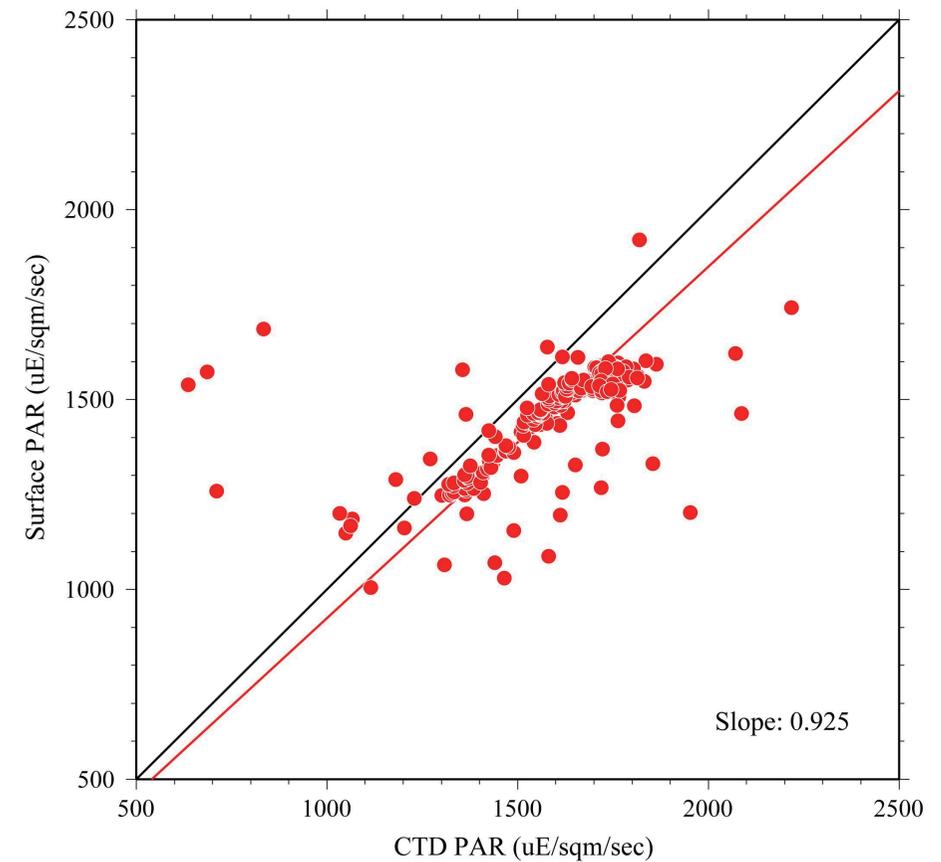


Figure 2.8.1. Comparison of two PAR sensors used for the surface PAR measurement and the CTD profiler measurement.

## 3 Hydrographic Measurement Techniques and Calibrations

### 3.1 CTDO<sub>2</sub> Measurements

*October 22, 2014*

#### (1) Personnel

Hiroshi Uchida (JAMSTEC)  
Shinsuke Toyoda (MWJ) (legs 1, 2)  
Satoshi Ozawa (MWJ) (leg 3)  
Tomohide Noguchi (MWJ) (leg 2)  
Tomoyuki Takamori (MWJ) (leg 2)  
Shungo Oshitani (MWJ) (leg 2)  
Naoko Miyamoto (MWJ) (leg 3)  
Hiroshi Matsunaga (MWJ) (leg 3)  
Takami Mori (MWJ) (leg 3)

#### (2) Winch arrangements

The CTD package was deployed by using 4.5 Ton Traction Winch System (Dynacon, Inc., Bryan, Texas, USA), which was installed on the R/V Mirai in April 2001 (Fukasawa et al., 2004). Primary system components include a complete CTD Traction Winch System with up to 8000 m of 9.53 mm armored cable (Ocean Cable and Communications Co., Yokohama, Kanagawa, Japan).

#### (3) Overview of the equipment

The CTD system was SBE 911plus system (Sea-Bird Electronics, Inc., Bellevue, Washington, USA). The SBE 911plus system controls 36-position SBE 32 Carousel Water Sampler. The Carousel accepts 12-litre Niskin-X water sample bottles (General Oceanics, Inc., Miami, Florida, USA). The SBE 9plus was mounted horizontally in a 36-position carousel frame. SBE's temperature (SBE 3) and conductivity (SBE 4) sensor modules were used with the SBE 9plus underwater unit. The pressure sensor is mounted in the main housing

of the underwater unit and is ported to outside through the oil-filled plastic capillary tube. A modular unit of underwater housing pump (SBE 5T) flushes water through sensor tubing at a constant rate independent of the CTD's motion, and pumping rate (3000 rpm) remain nearly constant over the entire input voltage range of 12-18 volts DC. Flow speed of pumped water in standard TC duct is about 2.4 m/s. Two sets of temperature and conductivity modules were used. An SBE's dissolved oxygen sensor (SBE 43) was placed between the primary conductivity sensor and the pump module. Auxiliary sensors, a Deep Ocean Standards Thermometer (SBE 35), an altimeter (PSA-916T; Teledyne Benthos, Inc., North Falmous, Massachusetts, USA), two oxygen optodes (RINKO-III; JFE Alec Co., Ltd, Kobe Hyogo, Japan), two fluorometers (Seapoint sensors, Inc., Kingston, New Hampshire, USA), a transmissometer (C-Star Transmissometer; WET Labs, Inc., Philomath, Oregon, USA), and a Photosynthetically Active Radiation (PAR) sensor (Satlantic, LP, Halifax, Nova Scotia, Canada) were also used with the SBE 9plus underwater unit. To minimize rotation of the CTD package, a heavy stainless frame (total weight of the CTD package without sea water in the bottles is about 1000 kg) was used with an aluminum plate (54 × 90 cm).

#### Summary of the system used in this cruise

Deck unit:

SBE 11plus, S/N 0272 (leg 1, leg 2 stations from 001\_1 to 076\_1)

SBE 11plus, S/N 0344 (leg 2 stations from 076\_2 to 503\_1, leg 3)

Under water unit:

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

Temperature sensor:

SBE 3plus, S/N 4815 (primary)

SBE 3plus, S/N 1464 (secondary)

Conductivity sensor:

SBE 4, S/N 2854 (leg 1 primary, legs 2 and 3 secondary)

SBE 4, S/N 2435 (leg 1 secondary, legs 2 and 3 primary)

Oxygen sensor:

SBE 43, S/N 2211 (legs 2 and 3)

SBE 43, S/N 0949 (leg 3)

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

JFE Advantech RINKO-III, S/N 0079 (foil batch no. 160002A) (secondary: legs 1 and 2)

JFE Advantech RINKO-III, S/N 0037 (foil batch no. 160005A) (secondary: leg 3)

Pump:

SBE 5T, S/N 4598 (primary)

SBE 5T, S/N 4595 (secondary)

Altimeter:

PSA-916T, S/N 1100

Deep Ocean Standards Thermometer:

SBE 35, S/N 0022

Fluorometer:

Seapoint Sensors, Inc., S/N 3054 (measurement range: 0-5 ug/L)

Seapoint Sensors, Inc., S/N 3497 (measurement range: 0-15 ug/L)

Transmissometer:

C-Star, S/N CST-1363DR

PAR:

Satlantic LP, S/N 0049

Carousel Water Sampler:

SBE 32, S/N 0278

Water sample bottle:

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

**(4) Pre-cruise calibration**

**i. Pressure**

The Paroscientific series 4000 Digiquartz high pressure transducer (Model 415K: Paroscientific, Inc., Redmond, Washington, USA) uses a quartz crystal resonator whose frequency of oscillation varies with pressure induced stress with 0.01 per million of resolution over the absolute pressure range of 0 to 15000 psia (0 to 10332 dbar). Also, a quartz crystal temperature signal is used to compensate for a wide range of temperature changes at the time of an observation. The pressure sensor has a nominal accuracy of 0.015 % FS (1.5 dbar), typical stability of 0.0015 % FS/month (0.15 dbar/month), and resolution of 0.001 % FS (0.1 dbar). Since the pressure sensor measures the absolute value, it inherently includes atmospheric pressure (about 14.7 psi). SEASOFT subtracts 14.7 psi from computed pressure automatically.

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

S/N 1027, 4 February 2011

The time drift of the pressure sensor is adjusted by periodic recertification corrections against a dead-weight piston gauge (Model 480DA, S/N 23906; Piston unit, S/N 079K; Weight set, S/N 3070; Bundenberg Gauge Co. Ltd., Irlam, Manchester, UK). The corrections are performed at JAMSTEC, Yokosuka, Kanagawa, Japan by Marine Works Japan Ltd. (MWJ), Yokohama, Kanagawa, Japan, usually once in a year in order to monitor sensor time drift and linearity.

S/N 1027, 23 August 2012

slope = 1.00003946

offset = -0.42611

## ii. Temperature (SBE 3)

The temperature sensing element is a glass-coated thermistor bead in a stainless steel tube, providing a pressure-free measurement at depths up to 10500 (6800) m by titanium (aluminum) housing. The SBE 3 thermometer has a nominal accuracy of 1 mK, typical stability of 0.2 mK/month, and resolution of 0.2 mK at 24 samples per second. The premium temperature sensor, SBE 3plus, is a more rigorously tested and calibrated version of standard temperature sensor (SBE 3).

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

S/N 4815, 1 March 2012

S/N 1464, 20 September 2012

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

S/N 4815,  $-3.45974716e-7$  [ $^{\circ}\text{C}/\text{dbar}$ ]

S/N 1464,  $-7.75293156e-9$  [ $^{\circ}\text{C}/\text{dbar}$ ]

## iii. Conductivity (SBE 4)

The flow-through conductivity sensing element is a glass tube (cell) with three platinum electrodes to provide in-situ measurements at depths up to 10500 (6800) m by titanium (aluminum) housing. The SBE 4 has a nominal accuracy of 0.0003 S/m, typical stability of 0.0003 S/m/month, and resolution of 0.00004 S/m at 24 samples per second. The conductivity cells have been replaced to newer style cells for deep ocean measurements.

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

S/N 2854, 21 September 2012

S/N 2435, 21 September 2012

The value of conductivity at salinity of 35, temperature of 15  $^{\circ}\text{C}$  (IPTS-68) and pressure of 0 dbar is 4.2914 S/m.

## iv. Oxygen (SBE 43)

The SBE 43 oxygen sensor uses a Clark polarographic element to provide in-situ measurements at depths up to 7000 m. The range for dissolved oxygen is 120 % of surface saturation in all natural waters, nominal accuracy is 2 % of saturation, and typical stability is 2 % per 1000 hours.

Pre-cruise sensor calibration was performed at SBE, Inc.

S/N 2211, 19 October 2012

S/N 0949, 18 September 2012

## v. Deep Ocean Standards Thermometer

Deep Ocean Standards Thermometer (SBE 35) is an accurate, ocean-range temperature sensor that can be standardized against Triple Point of Water and Gallium Melt Point cells and is also capable of measuring temperature in the ocean to depths of 6800 m. The SBE 35 was used to calibrate the SBE 3 temperature sensors in situ (Uchida et al., 2007).

Pre-cruise sensor linearization was performed at SBE, Inc.

S/N 0022, 4 March 2009

Then the SBE 35 is certified by measurements in thermodynamic fixed-point cells of the TPW (0.01  $^{\circ}\text{C}$ ) and GaMP (29.7646  $^{\circ}\text{C}$ ). The slow time drift of the SBE 35 is adjusted by periodic recertification corrections. Pre-cruise sensor calibration was performed at SBE, Inc. From the end of 2011, the SBE has been applying a NIST correction to the fixed-point cells used for the calibration.

S/N 0022, 6 March 2012 (slope and offset correction)

Slope = 1.000012

Offset = -0.000023

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 and was set to 4. The 2.7 seconds is required for converting the measured values to temperature and storing average in EEPROM.

#### vi. Altimeter

Benthos PSA-916T Sonar Altimeter (Teledyne Benthos, Inc.) determines the distance of the target from the unit by generating a narrow beam acoustic pulse and measuring the travel time for the pulse to bounce back from the target surface. It is rated for operation in water depths up to 10000 m. The PSA-916T uses the nominal speed of sound of 1500 m/s.

#### vii. Oxygen optode (RINKO)

RINKO (JFE Alec Co., Ltd.) is based on the ability of selected substances to act as dynamic fluorescence quenchers. RINKO model III is designed to use with a CTD system which accept an auxiliary analog sensor, and is designed to operate down to 7000 m.

Data from the RINKO can be corrected for the time-dependent, pressure-induced effect by means of the same method as that developed for the SBE 43 (Edwards et al., 2010). The calibration coefficients, H1 (amplitude of hysteresis correction), H2 (curvature function for hysteresis), and H3 (time constant for hysteresis) were determined empirically as follows.

$$H1 = 0.007 \text{ (for S/N 0024)}$$

$$H1 = 0.008 \text{ (for S/N 0079 and 0037)}$$

$$H2 = 5000 \text{ dbar}$$

$$H3 = 2000 \text{ seconds}$$

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

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

where V is voltage,  $V_0$  is voltage in the absence of oxygen and  $K_{sv}$  is Stern-Volmer constant. The  $V_0$  and the  $K_{sv}$  are assumed to be functions of temperature as follows.

$$K_{sv} = C_0 + C_1 \times T + C_2 \times T^2$$

$$V_0 = 1 + C_3 \times T$$

$$V = C_4 + C_5 \times V_b$$

where T is CTD temperature ( $^{\circ}\text{C}$ ) and  $V_b$  is raw output (volts).  $V_0$  and V are normalized by the output in the absence of oxygen at  $0^{\circ}\text{C}$ . The oxygen concentration is calculated using accurate temperature data from the CTD temperature sensor instead of temperature data from the RINKO. The pressure-compensated oxygen concentration  $O_{2c}$  can be calculated as follows.

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

where p is CTD pressure (dbar) and  $C_p$  (0.013 for S/N0024) is the compensation coefficient.

Since the sensing foil of the optode is permeable only to gas and not to water, the optode oxygen must be corrected for salinity. The salinity-compensated oxygen can be calculated by multiplying the factor of the effect of salt on the oxygen solubility. The coefficients of the equation by Garcia and Gordon (1992) were modified based on the laboratory experiment (Uchida et al., in prep.) and used for the compensation ( $B0 = -6.33568e-3$ ,  $B1 = -6.84389e-3$ ,  $B2 = -1.18326e-2$ ,  $B3 = -5.51960e-2$ ,  $C0 = 3.40543e-6$ ).

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

S/N 0024, 21 May 2012

S/N 0079, 21 May 2012

S/N 0037, 18 September 2012

#### viii. Fluorometer

The Seapoint Chlorophyll Fluorometer (Seapoint Sensors, Inc., Kingston, New Hampshire, USA) provides in-situ measurements of chlorophyll-a at depths up to 6000 m. The instrument uses modulated blue LED lamps and a blue excitation filter to excite chlorophyll-a. The fluorescent light emitted by the chlorophyll-a passes through a red emission filter and is detected by a silicon photodiode. The low level signal is then processed using synchronous demodulation circuitry, which generates an output voltage proportional to chlorophyll-a concentration.

## ix. Transmissometer

The C-Star Transmissometer (WET Labs, Inc., Philomath, Oregon, USA) measures light transmittance at a single wavelength (650 nm) over a known path (25 cm). In general, losses of light propagating through water can be attributed to two primary causes: scattering and absorption. By projecting a collimated beam of light through the water and placing a focused receiver at a known distance away, one can quantify these losses. The ratio of light gathered by the receiver to the amount originating at the source is known as the beam transmittance. Suspended particles, phytoplankton, bacteria and dissolved organic matter contribute to the losses sensed by the instrument. Thus, the instrument provides information both for an indication of the total concentrations of matter in the water as well as for a value of the water clarity.

Light transmission  $T_r$  (in %) and beam attenuation coefficient  $c_p$  are calculated from the sensor output (V in volt) as follows.

$$T_r = c_0 + c_1 V$$

$$c_p = - (1 / 0.25) \ln(T_r / 100)$$

The pre-cruise calibration coefficients were determined by using the data obtained in the R/V Mirai MR12-02 cruise.

## x. PAR

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

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

S/N 0049, 22 January 2009

## (5) Data collection and processing

### i. Data collection

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

The package was lowered into the water from the starboard side and held 10 m beneath the surface in order to activate the pump. After the pump was activated, the package was lifted to the surface and lowered at a rate of 1.0 m/s to 200 m (or 300 m when significant wave height was high) then the package was stopped to operate the heave compensator of the crane. The package was lowered again at a rate of 1.2 m/s to the bottom. For the up cast, the package was lifted at a rate of 1.1 m/s except for bottle firing stops. As a rule, 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 SBE 35 at each bottle firing stops. For depths where vertical gradient of water properties were expected to be large, the bottle was exceptionally fired after waiting from the stop for 60 seconds to enhance exchanging the water between inside and outside of the bottle (depths  $\leq$  500 dbar for station from C01\_1 to C03\_1, depths  $\leq$  100 dbar for station from 063\_1 to 068\_1, depths  $\leq$  200 dbar for station from C04\_1 to 073\_1, depths  $\leq$  250 dbar for station from 074\_1 to 166\_1). At 200 m (or 300 m) from the surface, the package was stopped to stop the heave compensator of the crane.

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

### *Data acquisition software*

SEASAVE-Win32, version 7.22

## ii. Data collection problems

### (a) Miss trip and miss fire

Niskin bottles did not trip correctly at the following stations.

Miss trip	Miss fire
None	None

### (b) Noise of the primary temperature and conductivity sensors

Data quality for the primary temperature and conductivity sensors were bad at the following stations, so that data from the secondary temperature and conductivity sensors were used.

Down cast profile data: 015\_1, 123\_1, 126\_1

Up cast bottle data: 064\_1, 123\_1, 124\_1, 134\_1

### (c) Noise of the transmissometer

Data quality of the down cast of the transmissometer was bad at the following stations, so that data from the up cast was used.

135\_1: from surface to bottom

145\_1: pressure deeper than 1000 dbar

148\_1: pressure deeper than 3600 dbar

### (d) Over range of the fluorometer

Over range of the primary fluorometer (measurement range: 0-5 ug/L) were frequently occurred. Therefore, the secondary fluorometer (measurement range: 0-15 ug/L) was basically used for the dataset. However, the primary fluorometer was used for stations from 149\_1, because the secondary fluorometer was drifted in time from station 149\_1.

### (e) Winch trouble

The CTD package was stopped relatively for a long time due to a mechanical problem of the winch system at 502 dbar of up cast for station 004\_1 (50 minutes) and at 2780 dbar of up cast for station 056\_1 (25 minutes).

### (f) RS-232C communications timeout

Communications timeout of RS-232C was occurred at following stations. The fuse of the CTD deck unit blew due to unknown reason.

076\_1: 2888 dbar of up cast: Deck unit was replaced after the cast.

088\_2: 3125 dbar of up cast: The end connection to the armored cable was reprocessed.

130\_1: 4085 dbar of down cast: The cast was aborted

## iii. Data processing

SEASOFT consists of modular menu driven routines for acquisition, display, processing, and archiving of oceanographic data acquired with SBE equipment. Raw data are acquired from instruments and are stored as unmodified data. The conversion module DATCNV uses instrument configuration and calibration coefficients to create a converted engineering unit data file that is operated on by all SEASOFT post processing modules. The following are the SEASOFT and original software data processing module sequence and specifications used in the reduction of CTD data in this cruise.

### *Data processing software*

SBEDataProcessing-Win32, version 7.22

DATCNV converted the raw data to engineering unit data. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition. The duration was set to 4.4 seconds, and the offset was set to 0.0 second. The hysteresis correction for the SBE 43 data (voltage) was applied for both profile and bottle information data.

TCORP (original module, version 1.1) corrected the pressure sensitivity of the SBE 3 for both profile and

bottle information data.

RINKOCOR (original module, version 1.0) corrected the time-dependent, pressure-induced effect (hysteresis) of the RINKO for both profile data.

RINKOCORROS (original module, version 1.0) corrected the time-dependent, pressure-induced effect (hysteresis) of the RINKO for bottle information data by using the hysteresis-corrected profile data.

BOTTLESUM created a summary of the bottle data. The data were averaged over 4.4 seconds (or 1 second for the bottle fired without stop).

ALIGNCTD converted the time-sequence of sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9plus CTD with the ducted temperature and conductivity sensors and a 3000-rpm pump, the typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit was set to advance the primary and the secondary conductivity for 1.73 scans ( $1.75/24 = 0.073$  seconds). Oxygen data are also systematically delayed with respect to depth mainly because of the long time constant of the oxygen sensor and of an additional delay from the transit time of water in the pumped plumbing line. This delay was compensated by 6 seconds advancing the SBE 43 oxygen sensor output (voltage) relative to the temperature data. Delay of the RINKO data was also compensated by 1 second advancing sensor output (voltage) relative to the temperature data. Delay of the transmissometer data was also compensated by 2 seconds advancing sensor output (voltage) relative to the temperature data.

WILDEDIT marked extreme outliers in the data files. The first pass of WILDEDIT obtained an accurate estimate of the true standard deviation of the data. The data were read in blocks of 1000 scans. Data greater than 10 standard deviations were flagged. The second pass computed a standard deviation over the same 1000 scans excluding the flagged values. Values greater than 20 standard deviations were marked bad. This process was applied to pressure, temperature, conductivity, SBE 43, and RINKO output.

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

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

WFILTER performed as a median filter to remove spikes in fluorometer and transmissometer data. A median value was determined by 49 scans of the window.

SECTIONU (original module, version 1.1) selected a time span of data based on scan number in order to reduce a file size. The minimum number was set to be the start time when the CTD package was beneath the sea-surface after activation of the pump. The maximum number was set to be the end time when the depth of the package was 1 dbar below the surface. The minimum and maximum numbers were automatically calculated in the module.

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

DESPIKE (original module, version 1.0) removed spikes of the data. A median and mean absolute deviation was calculated in 1-dbar pressure bins for both down- and up-cast, excluding the flagged values. Values greater than 4 mean absolute deviations from the median were marked bad for each bin. This process was performed 2 times for temperature, conductivity, SBE 43, and RINKO output.

DERIVE was used to compute oxygen (SBE 43).

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

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

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

Remaining spikes in the CTD data were manually eliminated from the 1-dbar-averaged data. The data gaps resulting from the elimination were linearly interpolated with a quality flag of 6. Especially for the transmissometer data, relatively large data gaps were linearly interpolated for depth range of 257-563 dbar of station 135\_1, 177-182 dbar of station 141\_1, and 1794-1849 dbar of station 145\_1.

## (6) Post-cruise calibration

### i. Pressure

The CTD pressure sensor offset in the period of the cruise was estimated from the pressure readings on the ship deck. For best results the Paroscientific sensor was powered on for at least 20 minutes before the operation. In order to get the calibration data for the pre- and post-cast pressure sensor drift, the CTD deck pressure was averaged over first and last one minute, respectively. Then the atmospheric pressure deviation from a standard atmospheric pressure (14.7 psi) was subtracted from the CTD deck pressure to check the pressure sensor time drift. The atmospheric pressure was measured at the captain deck (20 m high from the base line) and sub-sampled one-minute interval as a meteorological data. Time series of the CTD deck pressure is shown in Fig. 3.1.1. The CTD pressure sensor offset was estimated from the deck pressure. Mean of the pre- and the post-casts data over the whole period gave an estimation of the pressure sensor offset (-0.01 dbar) from the pre-cruise calibration. The post-cruise correction of the pressure data is not deemed necessary for the pressure sensor.

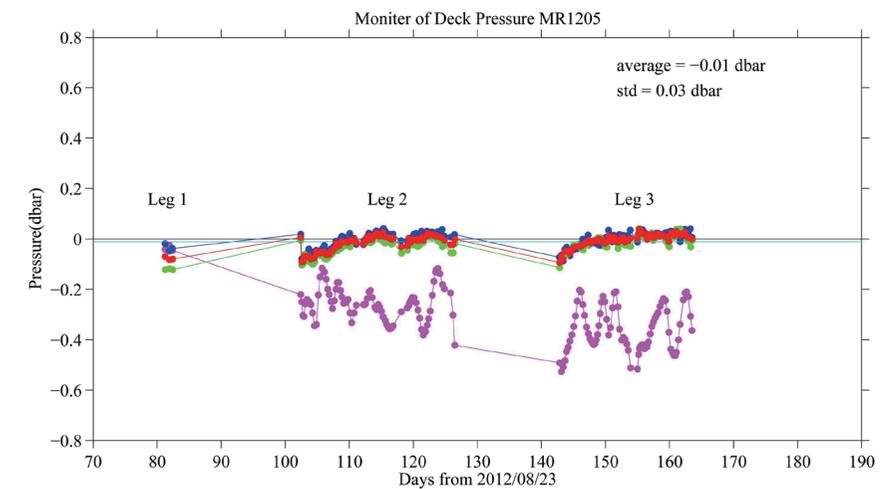


Figure 3.1.1. Time series of the CTD deck pressure. Atmospheric pressure deviation (magenta dots) from a standard atmospheric pressure was subtracted from the CTD deck pressure. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dots indicate averages of the pre- and the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

### ii. Temperature

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

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

*S/N 0022, 3 September 2013 (2nd step: fixed point calibration)*

Slope = 1.000006

Offset = 0.000187

Offset of the SBE 35 data from the pre-cruise calibration was estimated to be smaller than 0.2 mK. So the post-cruise correction of the SBE 35 temperature data was not deemed necessary for the SBE 35.

The CTD temperature was preliminary calibrated as

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

where T is CTD temperature in °C, P is pressure in dbar, t is time in days from pre-cruise calibration date of the CTD temperature and  $c_0$ ,  $c_1$ , and  $c_2$  are calibration coefficients. The coefficients were determined using the data for the depths deeper than 950 dbar.

The primary temperature data were basically used for the post-cruise calibration. The secondary temperature sensor was also calibrated and used instead of the primary temperature data when the data quality of the primary temperature data was bad. The calibration coefficients are listed in Table 3.1.1. The results of the post-cruise calibration for the CTD temperature are summarized in Table 3.1.2 and shown in from Fig. 3.1.2 to Fig. 3.1.6.

Table 3.1.1. Calibration coefficients for the CTD temperature sensors.

Leg	Serial number	$c_0$ (°C/dbar)	$c_1$ (°C/day)	$c_2$ (°C)	Station
1	4815	-	-	0.0009	
2	4815	-1.54321e-8	2.87072e-5	-0.0071	~025
		1.72901e-8	-8.25355e-6	0.0035	026~
2	1464	9.52754e-8	7.92269e-5	-0.0057	~025
		1.09093e-7	-3.12326e-6	0.0011	026~
3	4815	-4.63955e-9	3.34095e-6	0.0001	
3	1464	7.28496e-8	1.32368e-5	-0.0006	

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

Leg	Serial number	Pressure ≥ 950 dbar			Pressure < 950 dbar		
		Number	Mean (mK)	Sdev (mK)	Number	Mean (mK)	Sdev (mK)
1	4815	18	0.0	0.5	45	1.2	6.9
2	4815	1056	0.0	0.2	1295	0.4	5.3
2	1464	1054	0.0	0.2	1306	-0.0	4.8
3	4815	1010	-0.0	0.2	1246	0.3	4.7
3	1525	1002	0.0	0.3	1251	-0.6	4.4

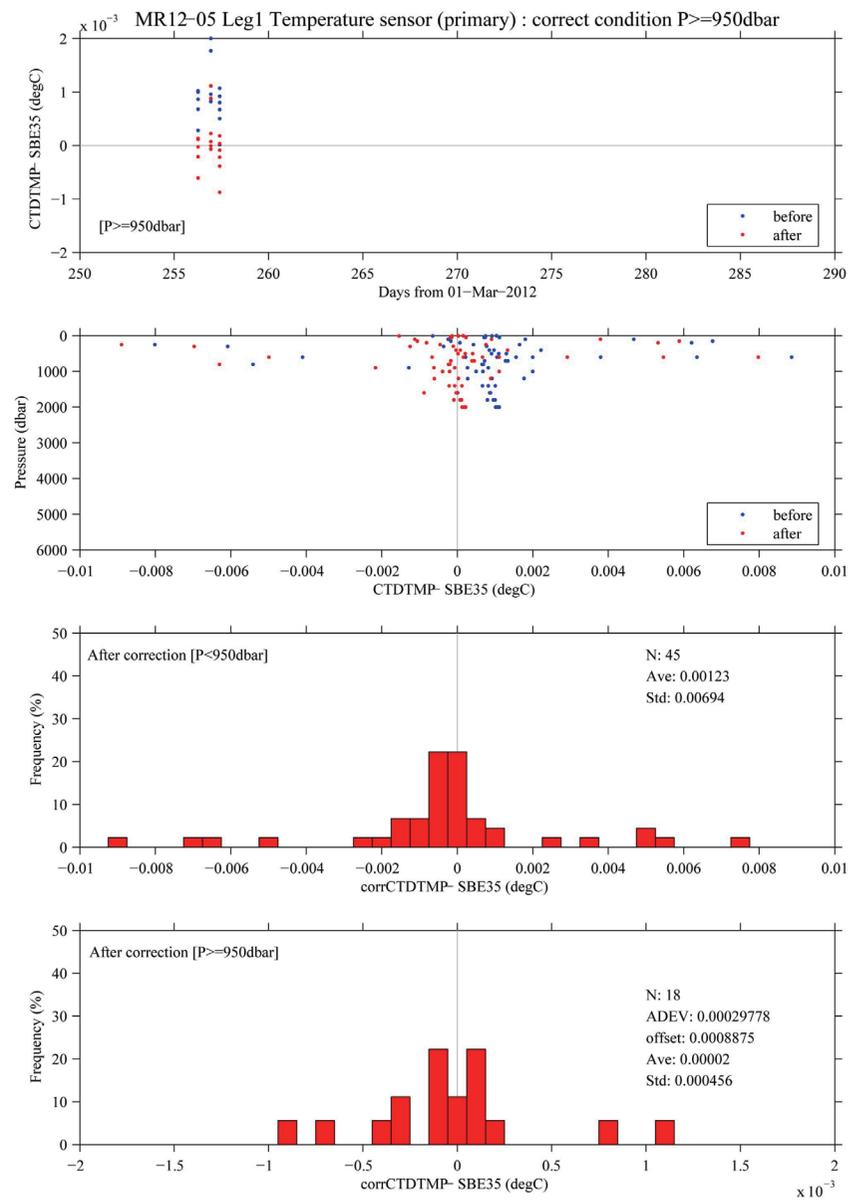


Figure 3.1.2. Difference between the CTD temperature (primary) and the SBE 35 for leg 1. Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Lower two panels show histogram of the difference after the calibration.

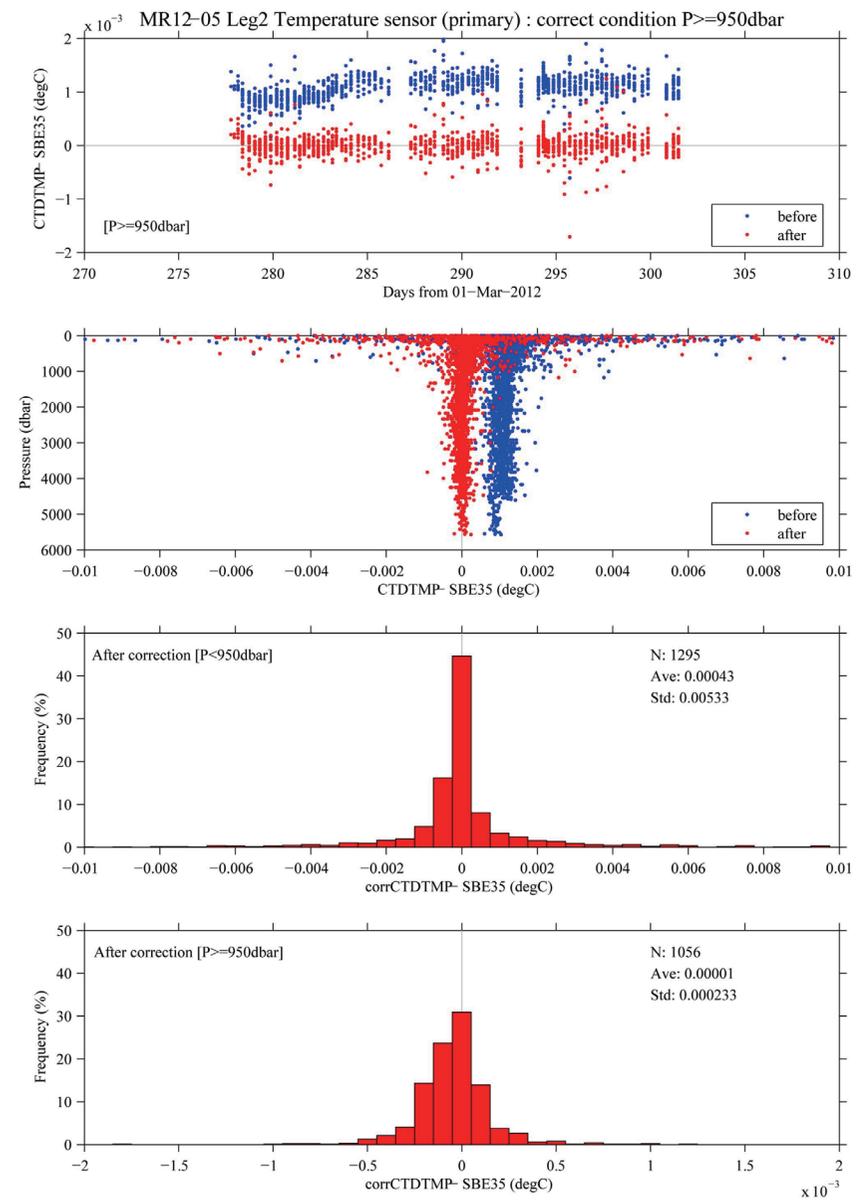


Figure 3.1.3. Same as Fig. 3.1.2, but for leg2.

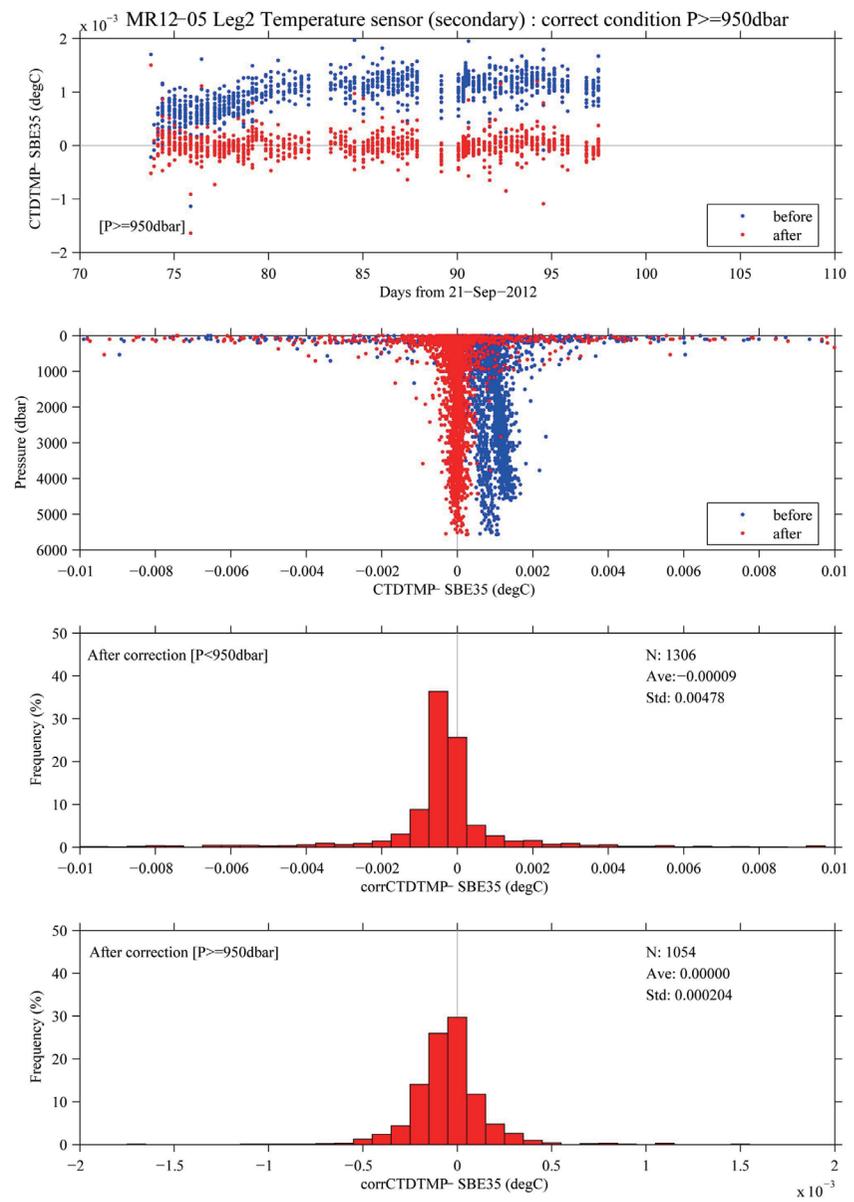


Figure 3.1.4. Same as Fig. 3.1.2, but for secondary temperature sensor for leg 2.

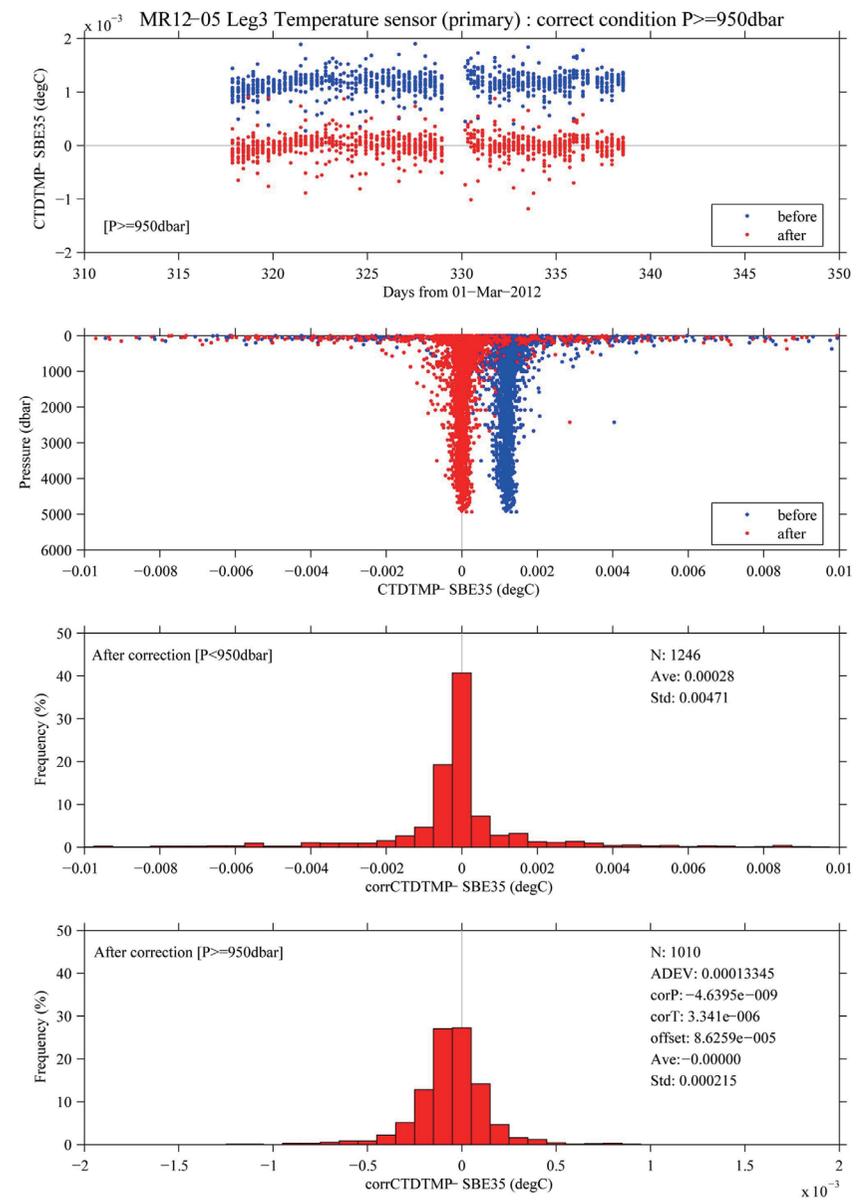


Figure 3.1.5. Same as Fig. 3.1.2, but for leg 3.

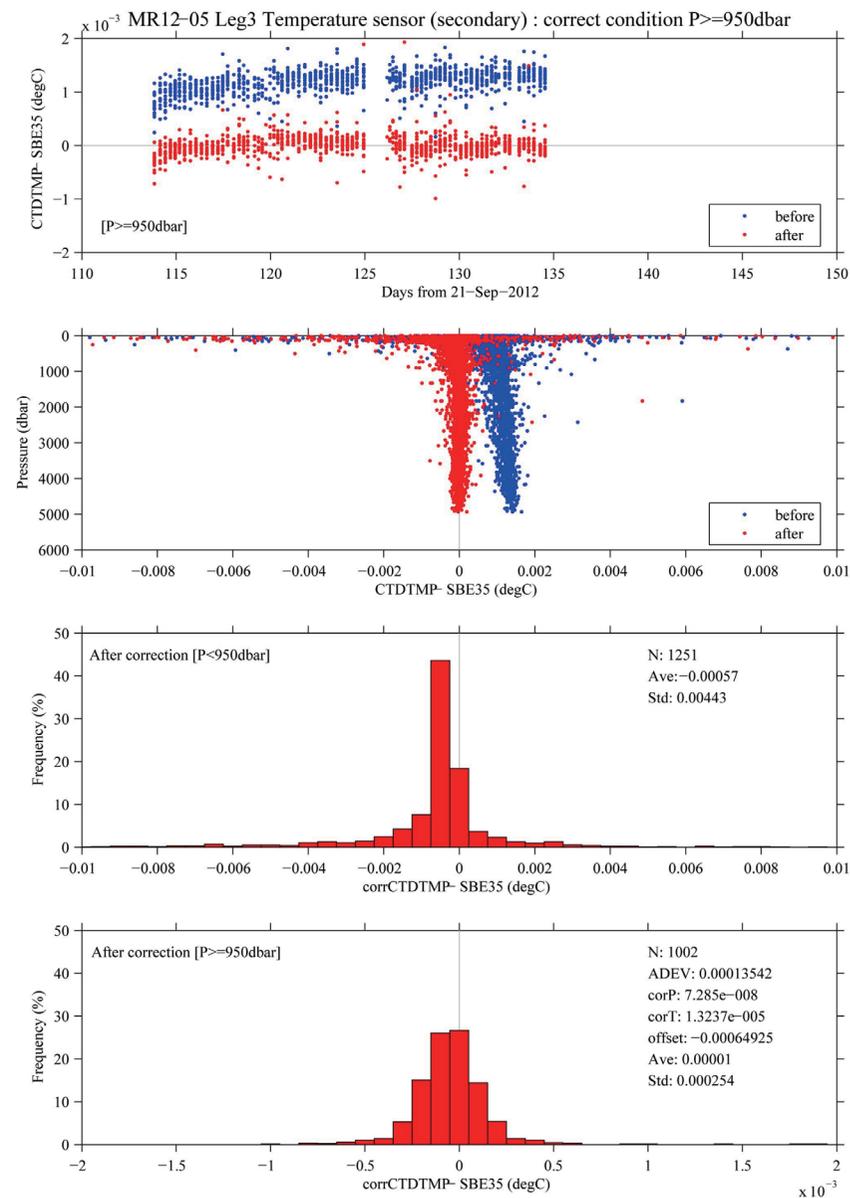


Figure 3.1.6. Same as Fig. 3.1.2, but for secondary temperature sensor for leg 3.

### iii. Salinity

The discrepancy between the CTD conductivity and the conductivity calculated from the bottle salinity data with the CTD temperature and pressure data is considered to be a function of conductivity, pressure and time. The CTD conductivity was calibrated as

$$\text{Calibrated conductivity} = c_0 \times C + c_1 \times P + c_2 \times C \times P + c_3 \times t + c_4$$

where C is CTD conductivity in S/m, P is pressure in dbar, t is time in days from 14 April 2009 and  $c_0$ ,  $c_1$ ,  $c_2$ ,  $c_3$  and  $c_4$  are calibration coefficients. The best fit sets of coefficients were determined by a least square technique to minimize the deviation from the conductivity calculated from the bottle salinity data.

The primary conductivity data created by the software module ROSSUM were basically used after the post-cruise calibration for the temperature data. The secondary conductivity sensor was also calibrated and used instead of the primary conductivity data when the data quality of the primary temperature or conductivity data was bad. The coefficients were determined for each leg. The calibration coefficients are listed in Table 3.1.3. The results of the post-cruise calibration for the CTD salinity are summarized in Table 3.1.4 and shown in from Fig. 3.1.7 to Fig. 3.1.11.

Table 3.1.3. Calibration coefficients for the CTD conductivity sensors.

Leg	Serial Number	$c_0$ [S/(m dbar)]	$c_1$ (1/dbar)	$c_2$ [S/(m day)]	$c_3$ (S/m)	$c_4$	Station
1	2854	-7.70527e-5	1.39303e-6	-4.83208e-7	-4.97522e-5	5.04388e-4	
2	2435	1.31818e-4	4.00954e-7	-1.14786e-7	-6.09242e-6	-5.06603e-4	
2	2854	1.02000e-4	1.61048e-7	-4.41938e-8	-4.80557e-6	-4.38375e-4	
3	2435	3.18511e-4	1.06019e-6	-3.37484e-7	-2.48779e-5	-1.11175e-3	~110
		2.04845e-4	5.84160e-7	-1.79325e-7	-4.40484e-6	-8.93388e-4	111~
3	2854	1.96052e-4	8.09425e-7	-2.62172e-7	-3.45533e-5	-6.80743e-4	
		8.92585e-5	-9.12391e-8	3.75737e-8	-7.47841e-7	-5.49522e-4	

Table 3.1.4. Difference between the CTD salinity and the bottle salinity after the post-cruise calibration. Mean and standard deviation (Sdev) (in 10<sup>-3</sup>) are calculated for the data below and above 950 dbar. Number of data used is also shown.

Leg	Serial number	Pressure ≥ 950 dbar			Pressure < 950 dbar		
		Number	Mean	Sdev	Number	Mean	Sdev
1	2854	18	0.1	0.3	39	1.3	7.5
2	2435	989	0.0	0.4	1156	-0.5	3.6
2	2854	987	-0.0	0.4	1167	-0.2	3.6
3	2435	1006	-0.0	0.4	1225	-0.0	5.5
3	2854	996	-0.0	0.4	1230	0.1	5.8

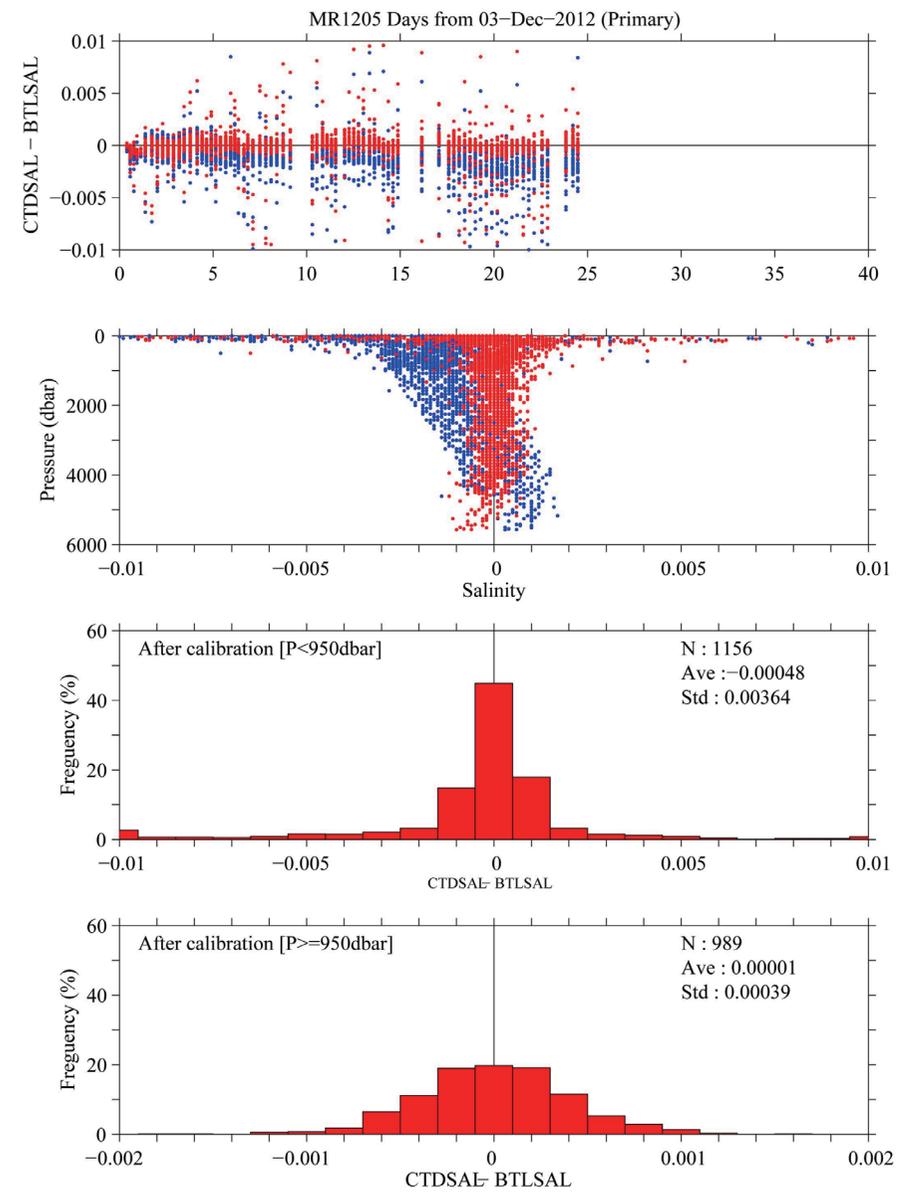
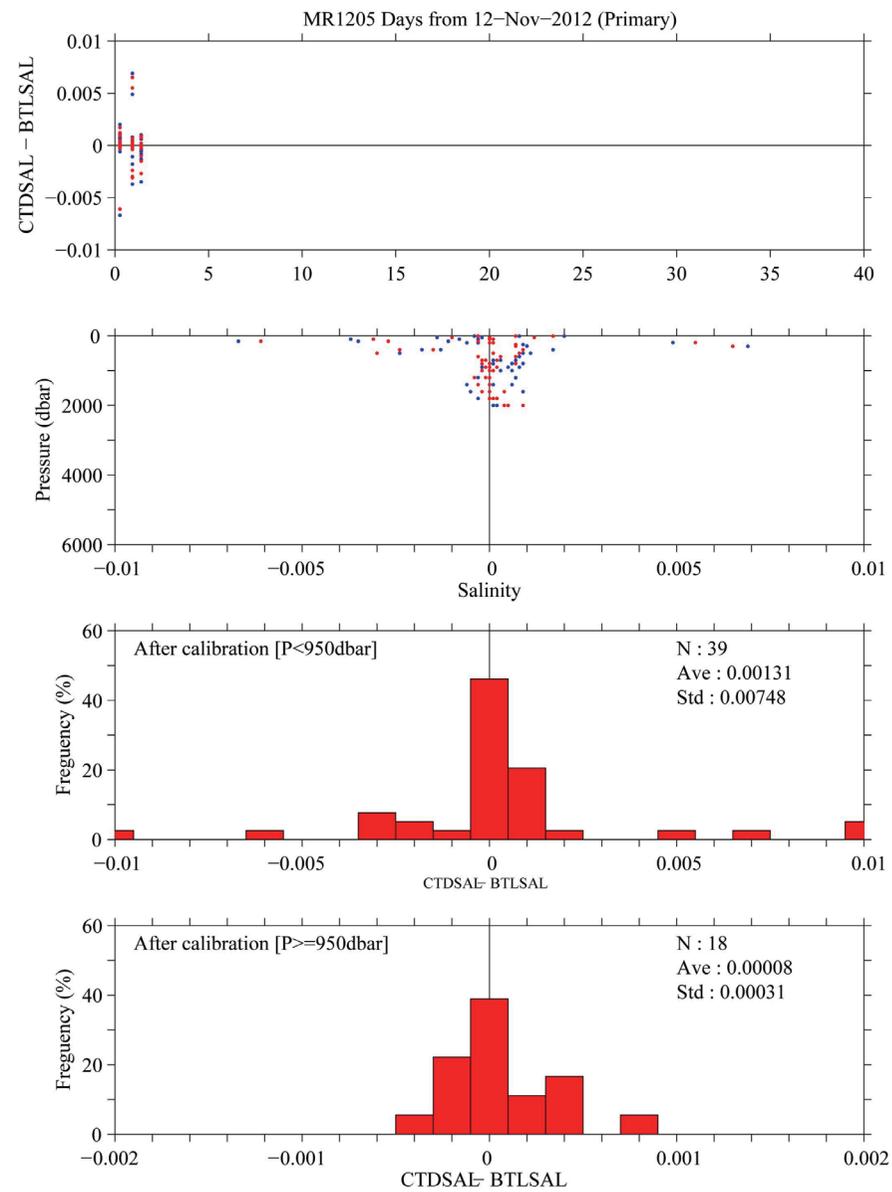


Figure 3.1.7. Difference between the CTD salinity (primary) and the bottle salinity for leg 1. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration.

Figure 3.1.8. Same as Fig. 3.1.7, but for leg 2.

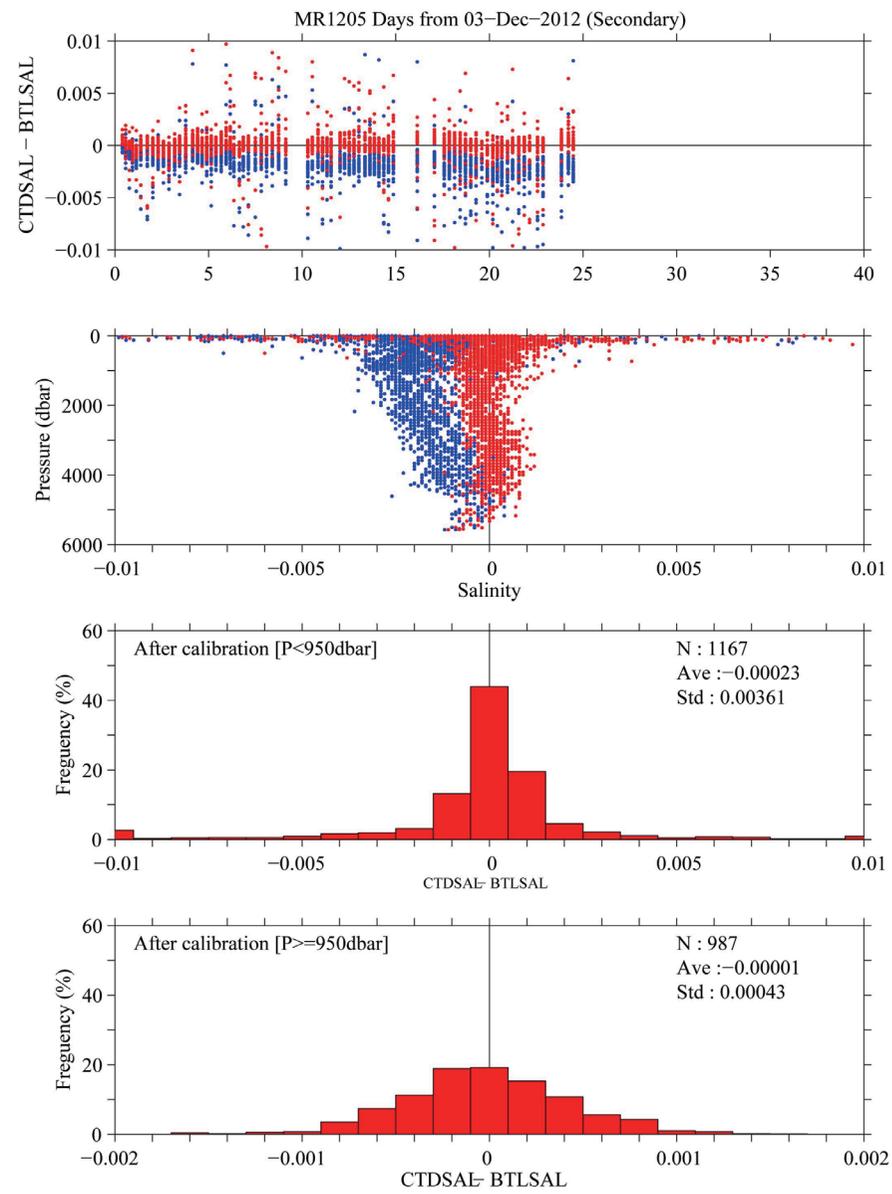


Figure 3.1.9. Same as Fig. 3.1.7, but for secondary salinity data for leg 2.

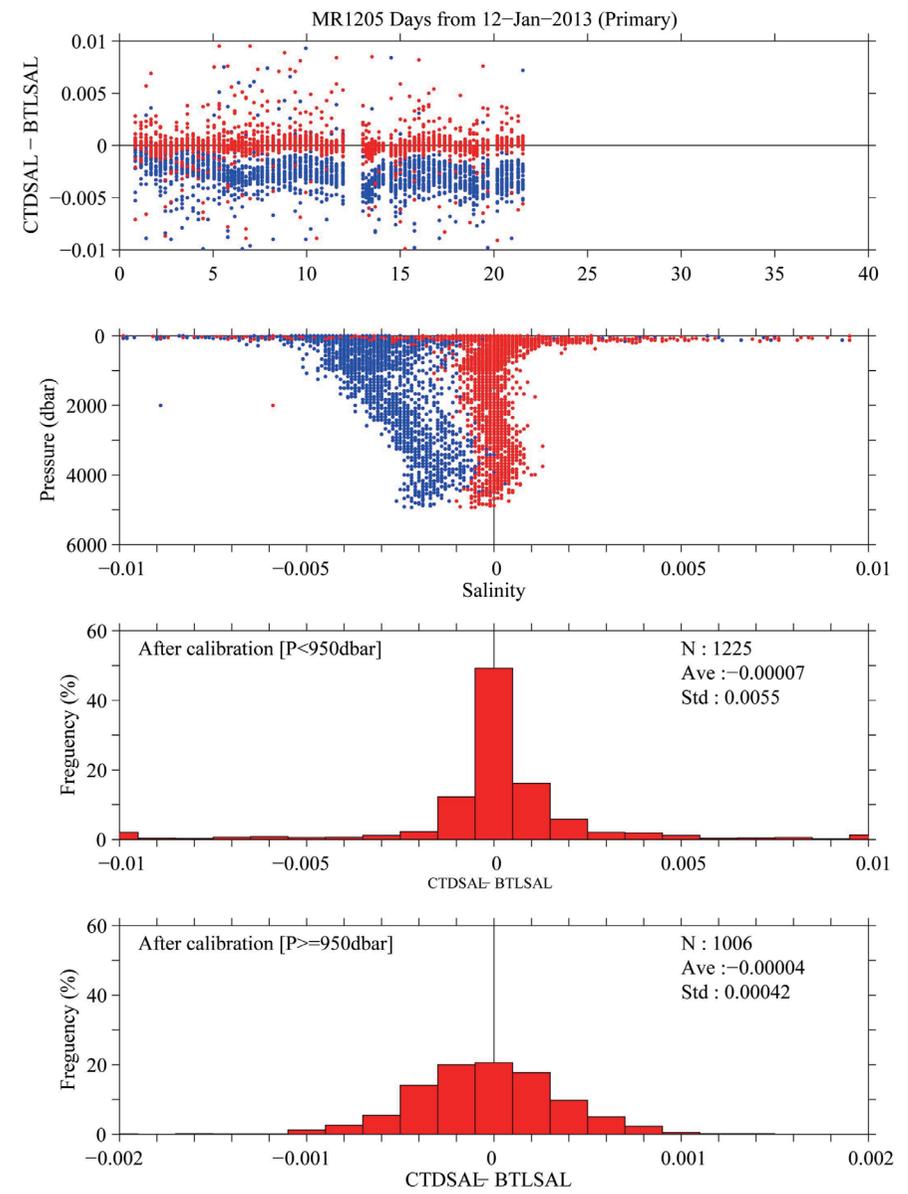


Figure 3.1.10. Same as Fig. 3.1.7, but for leg 3.

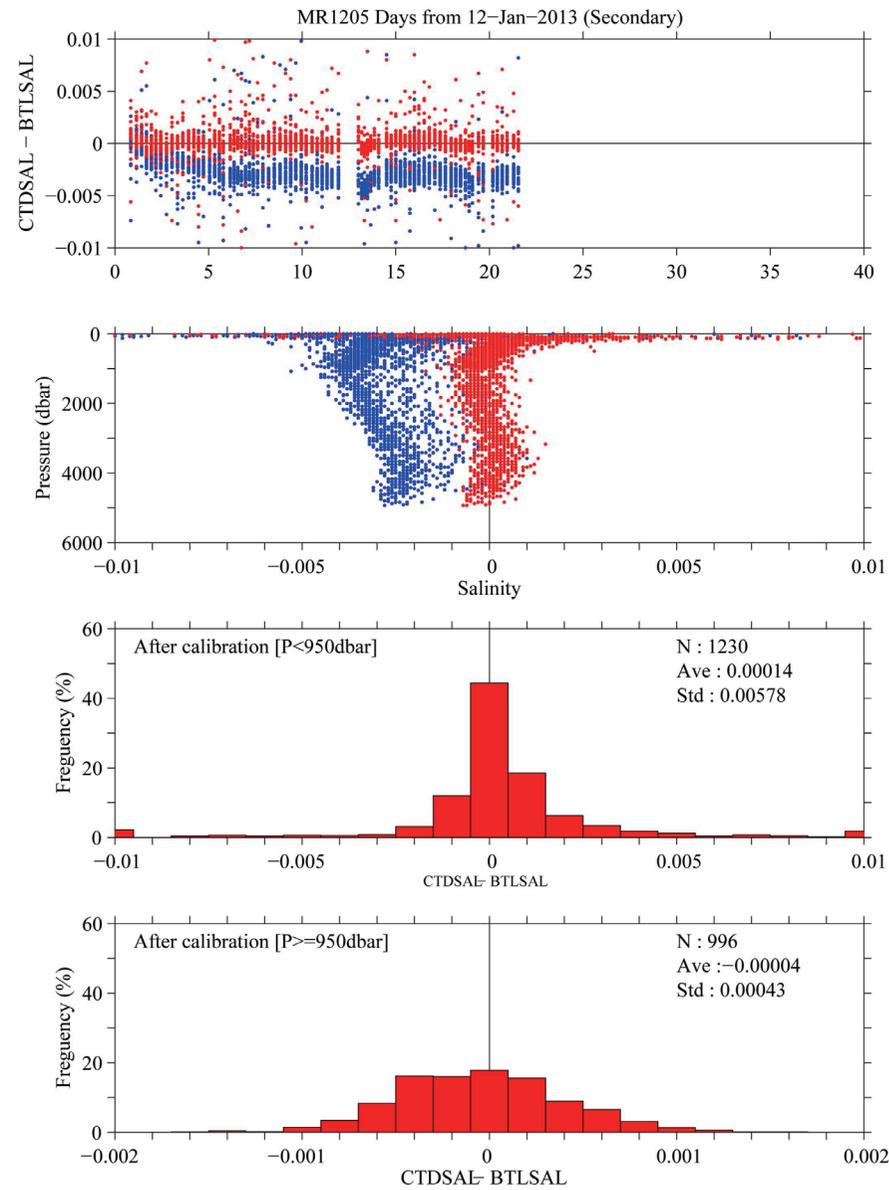


Figure 3.1.11. Same as Fig. 3.1.7, but for secondary salinity data for leg 3.

#### iv. Oxygen

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

$$[O_2] \text{ (}\mu\text{mol/l)} = [(V_0 / V)^{1.2} - 1] / K_{sv}$$

$$K_{sv} = C_0 + C_1 \times T + C_2 \times T^2$$

$$V_0 = 1 + C_3 \times T$$

$$V = C_4 + C_5 \times V_b + C_6 \times t + C_7 \times t \times V_b$$

where  $V_b$  is the RINKO output (voltage),  $V_0$  is voltage in the absence of oxygen,  $T$  is temperature in  $^{\circ}\text{C}$ , and  $t$  is exciting time (days) integrated from the first CTD cast for each leg. Time drift of the RINKO output was corrected. The calibration coefficients were determined by minimizing the sum of absolute deviation with a weight from the bottle oxygen data. The revised quasi-Newton method (DMINF1) was used to determine the sets.

The post-cruise calibrated temperature and salinity data were used for the calibration. The calibration coefficients are listed in Table 3.1.5. The results of the post-cruise calibration for the RINKO oxygen are summarized in Table 3.1.6 and shown in from Fig. 3.1.12 to Fig. 3.1.14.

Table 3.1.5 Calibration coefficients for the RINKO oxygen sensors.

Leg	$c_0$	$c_1$	$c_2$	$c_3$	$c_4$	$c_5$
1	4.733362e-3	1.729522e-4	2.164708e-6	-1.431144e-3	-7.402308e-2	3.205825e-1
2	5.644516e-3	2.046661e-4	2.784686e-6	-3.090264e-3	-0.1119851	0.3162570
3	4.729148e-3	2.002866e-4	3.871103e-6	8.659935e-4	-9.234123e-2	0.3306834

Table 3.1.5 Continue.

Leg	c <sub>6</sub>	c <sub>7</sub>
1	-	-
2	-1.036494e-4	2.598641e-4
3	-2.497366e-4	2.824747e-4

Table 3.1.6 Difference between the RINKO 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 is also shown.

Leg	Serial number	Pressure ≥ 950 dbar			Pressure < 950 dbar		
		Number	Mean [μmol/kg]	Sdev	Number	Mean [μmol/kg]	Sdev
1	0024	52	0.00	0.11	40	0.02	0.45
2	0024	987	-0.01	0.29	1157	0.09	1.00
3	0024	1009	-0.04	0.29	1245	-0.02	0.90

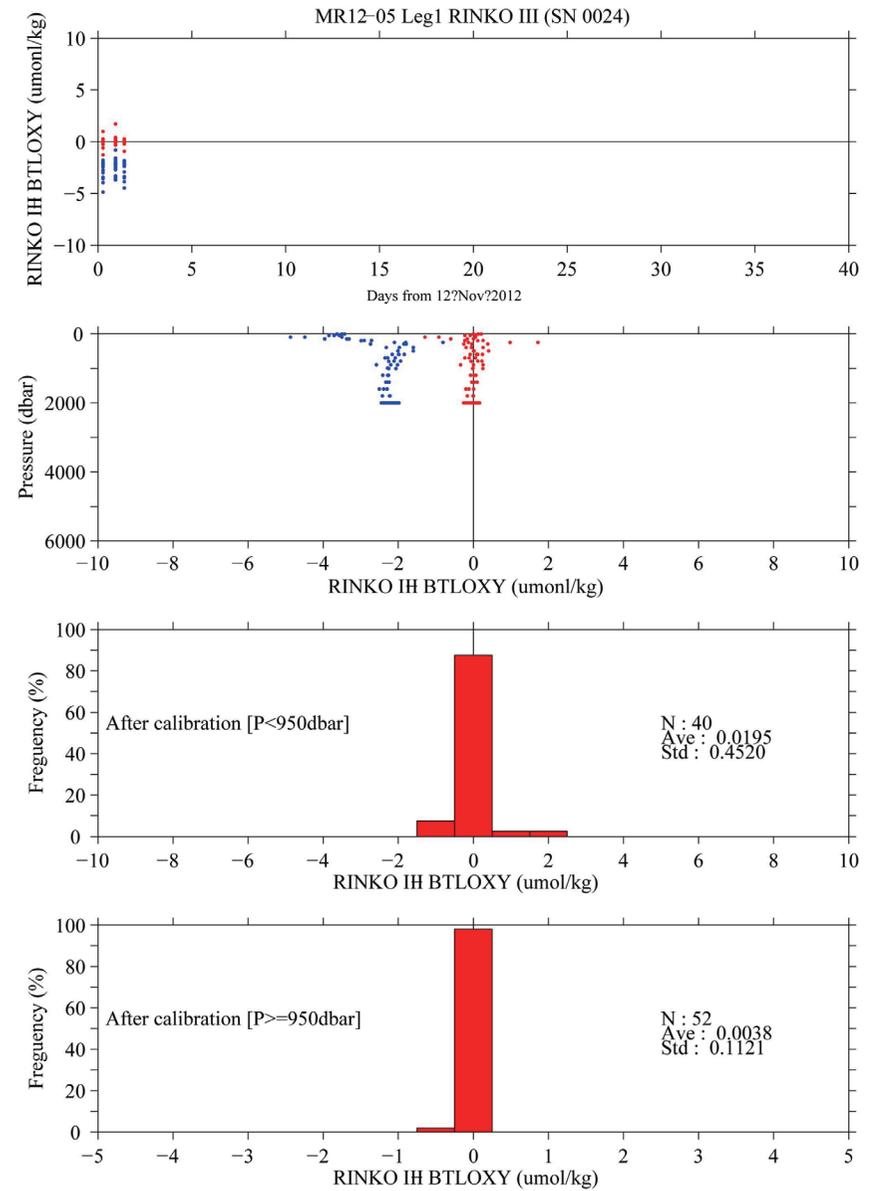


Figure 3.1.12. Difference between the CTD oxygen and the bottle oxygen for leg 1. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration.

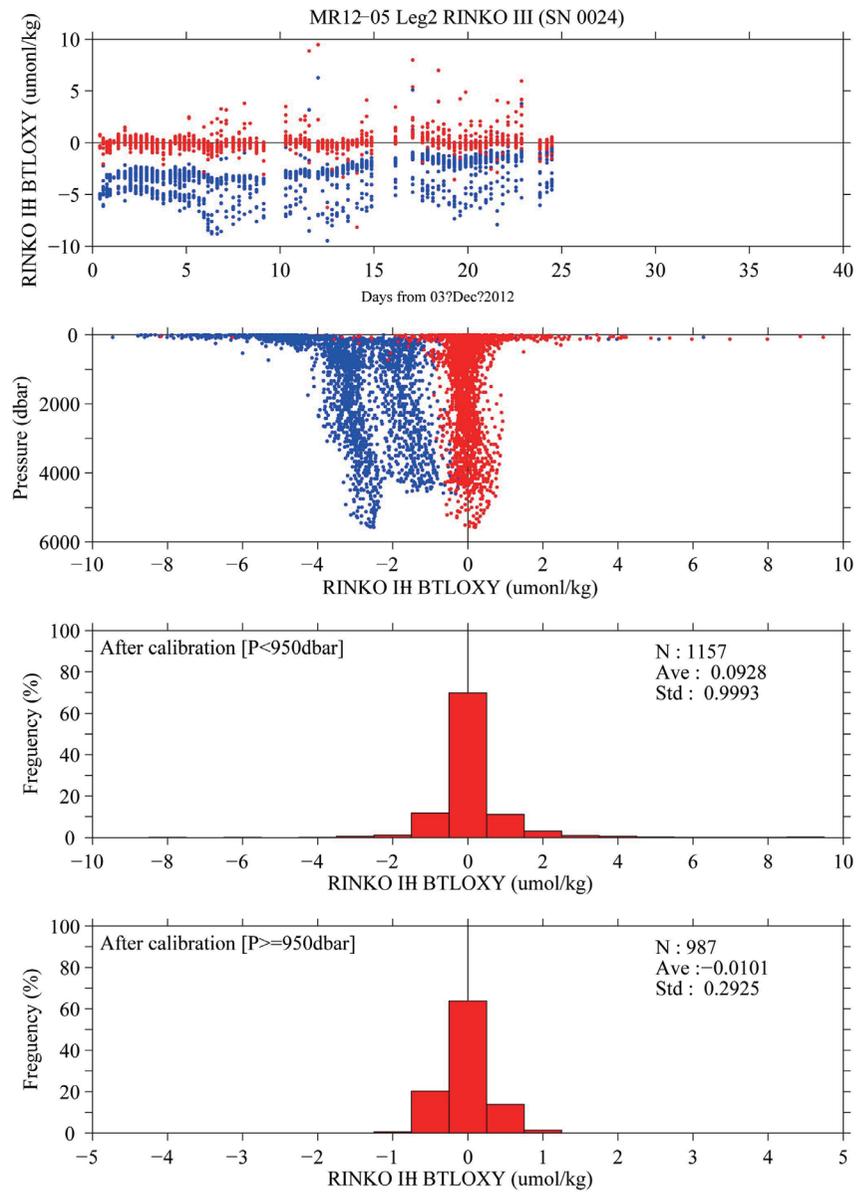


Figure 3.1.13. Same as Fig. 3.1.12, but for leg 2.

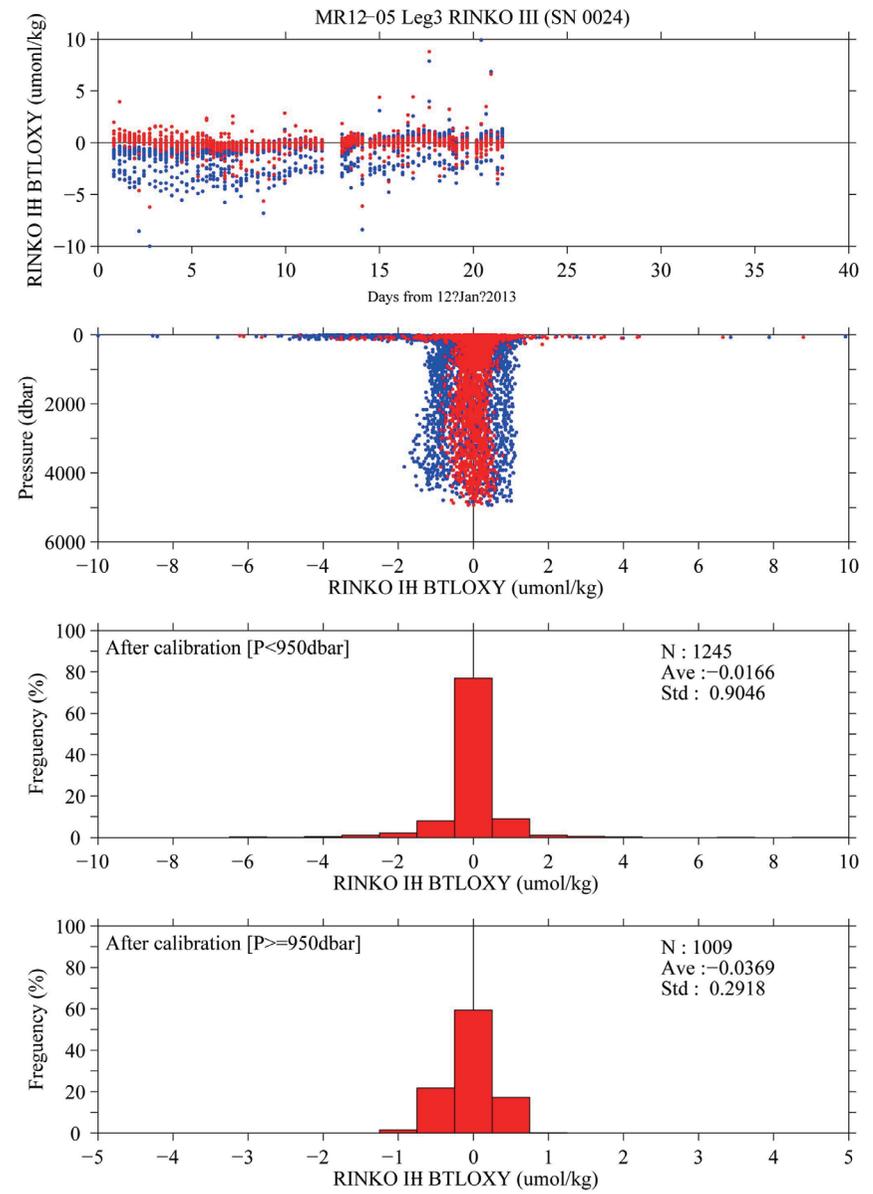


Figure 3.1.14. Same as Fig. 3.1.12, but for leg 3.

## v. Fluorometer

The CTD fluorometer (FLUOR in  $\mu\text{g/L}$ ) was calibrated by comparing with the bottle sampled chlorophyll-a as

$$\text{FLUOR}_c = c_0 + c_1 \times \text{FLUOR} + c_2 \times \ln(c_3 \times \text{FLUOR} + 1)$$

where  $c_0$ ,  $c_1$ ,  $c_2$  and  $c_3$  are calibration coefficients (Fig. 3.1.15). The CTD fluorometer data is slightly noisy so that the up cast profile data which was averaged over one decibar agree with the bottle sampled data better than the discrete CTD fluorometer data obtained at bottle-firing stop. Therefore, the CTD fluorometer data at water sampling depths extracted from the up cast profile data were compared with the bottle sampled chlorophyll-a data. The bottle sampled data obtained at dark condition [PAR (Photosynthetically Available Radiation)  $< 50 \mu\text{E}/(\text{m}^2 \text{ sec})$ ] were used for the calibration, since sensitivity of the fluorometer to chlorophyll a is different at nighttime and daytime (see Section 2.4). The calibration coefficients are listed in Table 3.1.7. The results of the post-cruise calibration for the fluorometer are summarized in Table 3.1.8.

Table 3.1.7. Calibration coefficients for the CTD fluorometer.

Sensor	$c_0$	$c_1$	$c_2$	$c_3$
Secondary (leg 1)	-0.0245343	0.953320	0.0	0.0
Secondary (legs 2 and 3 [for stations 88_2 ~ 148_1])	-7.51097e-2	0.234395	5.43321e-2	107.923
Primary (leg 3 [for stations 149_1 ~ 166_1])	-0.127043	0.246599	8.41309e-2	61.0197

Table 3.1.8. Difference between the CTD fluorometer and the bottle chlorophyll-a after the post-cruise calibration. Mean, standard deviation (Sdev), and number of data used are shown. Data obtained at daytime are also used in this calculation.

Number	Mean	Sdev
178	0.03 $\mu\text{g/L}$	0.10 $\mu\text{g/L}$

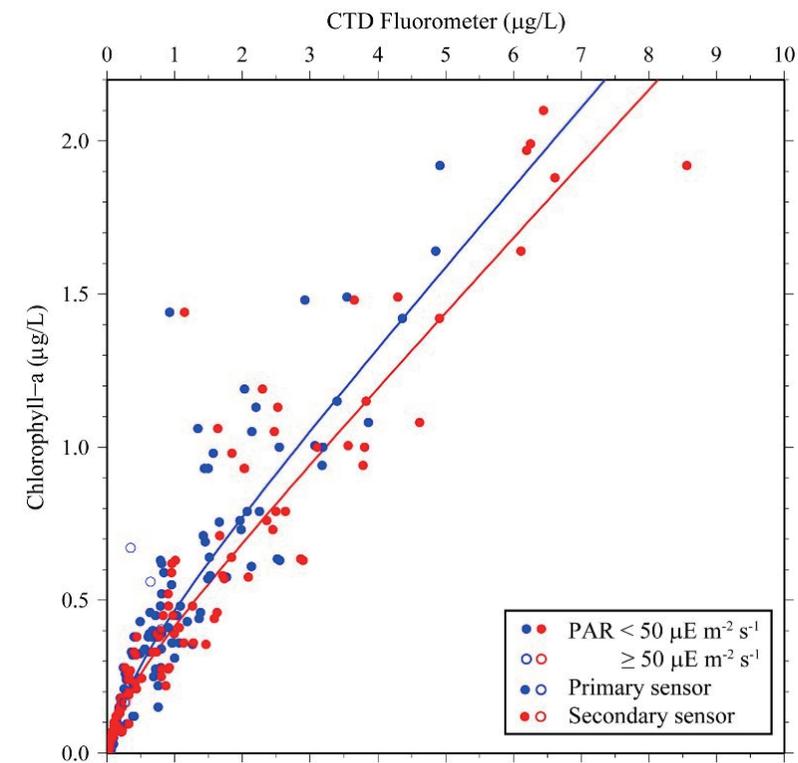


Figure 3.1.15. Comparison of the CTD fluorometer and the bottle sampled chlorophyll-a. The regression lines are also shown.

## vi. Transmissometer

The transmissometer ( $T_r$  in %) is calibrated as

$$T_r = (V - V_d) / (V_r - V_d) \times 100$$

where  $V$  is the measured signal (voltage),  $V_d$  is the dark offset for the instrument, and  $V_r$  is the signal for clear water.  $V_d$  can be obtained by blocking the light path.  $V_d$  and  $V_{air}$ , which is the signal for air, were measured on deck before each cast after wiping the optical windows with ethanol.  $V_d$  was constant (0.0012) during the cruise.  $V_r$  is estimated from the measured maximum signal in the deep ocean at each cast. Since the transmissometer drifted in time (Fig. 3.1.16),  $V_r$  is expressed as

$$V_r = c_0 + c_1 \times t$$

where  $t$  is time (in days) from the first cast for each leg, and  $c_0$ ,  $c_1$ , and  $c_2$  are calibration coefficients.

The calibration coefficients are listed in Table 3.1.9.

Table 3.1.9. Calibration coefficients for the CTD transmissometer.

Leg	$c_0$	$c_1$	$V_d$	Note
1	4.79000	–	0.0012	estimated from station C01
2	4.78998	$-1.05177e-3$	0.0012	for stations 001-068
	4.77840	$-1.05177e-3$	0.0012	for stations C04-074
	4.75812	$-1.05177e-3$	0.0012	for stations 075-503
3	4.72956	$-1.66124e-3$	0.0012	

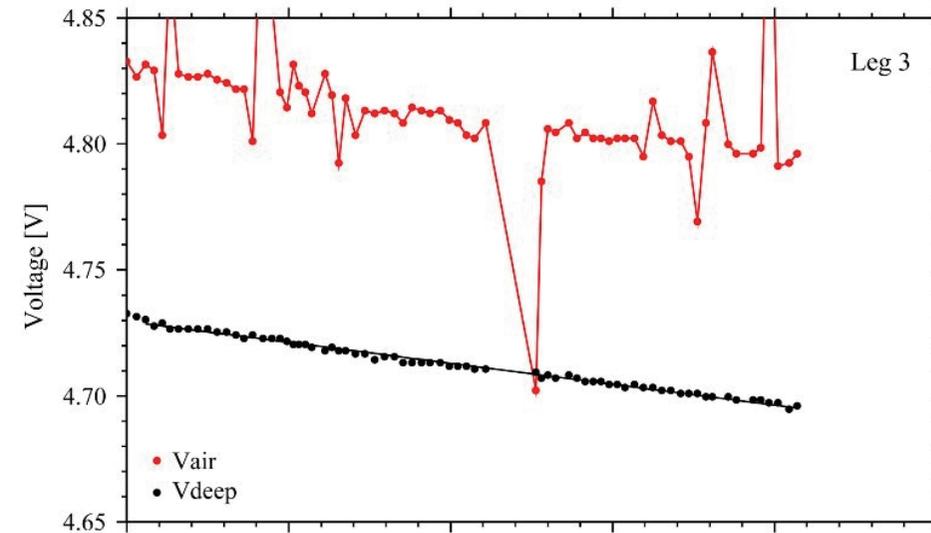
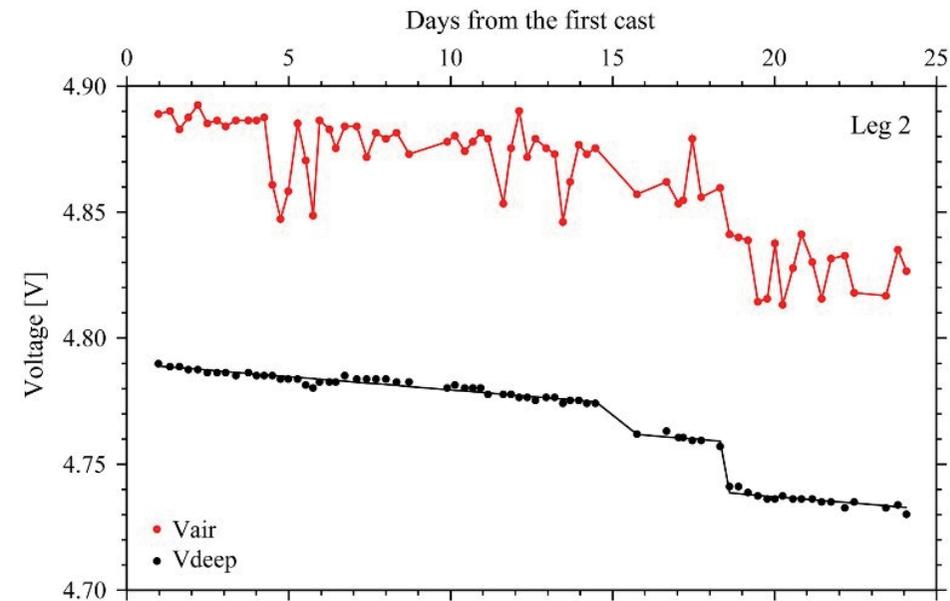


Figure 3.1.16. Time series of an output signal (voltage) from transmissometer at on deck before CTD casts ( $V_{air}$ ) and deep ocean ( $V_{deep}$ ) for leg 2 (upper panel) and leg 3 (lower panel). The black solid line indicates the modeled signal in the deep clear ocean.

## vii. PAR

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

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

## References

- Edwards, B., D. Murphy, C. Janzen and N. Larson (2010): Calibration, response, and hysteresis in deep-sea dissolved oxygen measurements, *J. Atmos. Oceanic Technol.*, 27, 920–931.
- Fukasawa, M., T. Kawano and H. Uchida (2004): Blue Earth Global Expedition collects CTD data aboard Mirai, BEAGLE 2003 conducted using a Dynacon CTD traction winch and motion-compensated crane, *Sea Technology*, 45, 14–18.
- García, H. E. and L. I. Gordon (1992): Oxygen solubility in seawater: Better fitting equations. *Limnol. Oceanogr.*, 37 (6), 1307–1312.
- Uchida, H., G. C. Johnson, and K. E. McTaggart (2010): CTD oxygen sensor calibration procedures, The GO-SHIP Repeat Hydrography Manual: A collection of expert reports and guidelines, IOCCP Rep., No. 14, ICPO Pub. Ser. No. 134.
- Uchida, H., K. Ohyama, S. Ozawa, and M. Fukasawa (2007): In situ calibration of the Sea-Bird 9plus CTD thermometer, *J. Atmos. Oceanic Technol.*, 24, 1961–1967.

## 3.2 Bottle Salinity

October 2, 2014

### (1) Personnel

Hiroshi Uchida (JAMSTEC)

Tatsuya Tanaka (MWJ) (Legs 1 and 2)

Hiroki Ushiomura (MWJ) (Leg 3)

Tamami Ueno (MWJ) (Leg 3)

Keisuke Tsubata (MWJ) (Leg 2)

### (2) Objectives

Bottle salinities were measured to calibrate CTD salinity data.

### (3) Instrument and Method

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

#### i. Salinity Sample Collection

The bottles in which the salinity samples were collected and stored were 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 24 hours in the same laboratory as the salinity measurement was made.

#### ii. Instruments and Methods

Salinity of water samples was measured with two salinometers (Autosal model 8400B; Guildline Instruments Ltd., Ontario, Canada; S/N 62556 for leg 1 and S/N 62827 for legs 2 and 3), which was modified by adding an peristaltic-type intake pump (Ocean Scientific International Ltd., Hampshire, UK) and two

platinum thermometers (Guildline Instruments Ltd., model 9450). One thermometer monitored an ambient temperature and the other monitored a salinometer's bath temperature. The resolution of the thermometers was 0.001 °C. The measurement system was almost same as Aoyama et al. (2002). The salinometer was operated in the air-conditioned laboratory of the ship at a bath temperature of 24 °C.

The ambient temperature varied from approximately 20 to 24 °C, while the bath temperature was stable and varied within  $\pm 0.002$  °C. A measure of a double conductivity ratio of a sample was taken as a median of 31 readings. Data collection was started after 10 seconds and it took about 10 seconds to collect 31 readings by a personal computer. Data were sampled for the sixth and seventh filling of the cell. In case where the difference between the double conductivity ratio of this two fillings was smaller than 0.00002, the average value of the two double conductivity ratios was used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981). When the difference was greater than or equal to the 0.00003, we measured another additional filling of the cell. In case where the double conductivity ratio of the additional filling did not satisfy the criteria above, we measured other additional fillings of the cell within 10 fillings in total. In case where the number of fillings was 10 and those fillings did not satisfy the criteria above, the median of the double conductivity ratios of five fillings were used to calculate the bottle salinity.

The measurement was conducted about from 6 to 23 hours per day and the cell was cleaned with soap after the measurement for each day. A total of about 5700 water samples were measured during the cruise.

### (4) Results

#### i. Standard Seawater

Standardization control was set to 688 (leg 1), 509 (leg 2), and 514 (leg 3). The value of STANDBY was  $5197 \pm 0001$  (leg 1),  $5432 \pm 0002$  (leg 2), and  $5438 \pm 0002$  (leg 3), and that of ZERO was 0.00000 or -0.00001 for all legs. We used IAPSO Standard Seawater batch P154 whose conductivity ratio is 0.99990 (double conductivity ratio is 1.99980) as the standard for salinity measurement. We measured 8 (leg 1), 98 (leg 2), and 115 (leg 3) bottles of the Standard Seawater during the cruise. Histories of double conductivity ratio measurement of the Standard Seawater are shown in [Figs. 3.2.1](#) (leg 1), [3.2.2](#) (leg 2), and [3.2.3](#) (leg 3).

Time drift of the salinometer was corrected by using the Standard Seawater measurements. For leg 1, offset of the salinometer was estimated from the average of the Standard Seawater measurement for each day because number of data was small. For legs 2 and 3, linear time drift of the salinometer was estimated from the Standard Seawater measurement by using the least square method (thin black lines in Figs. 3.2.2 and 3.2.3). For leg 2, linear time drift was calculated for two periods before and after December 15, 2013, because tendency of the time drift was changed during the cruise. The average of double conductivity ratio was 1.99980 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity after the time drift correction.



Figure 3.2.1. History of double conductivity ratio measurement of the Standard Seawater (P154) during leg 1. Horizontal and vertical axes represents date and double conductivity ratio, respectively. Blue dots indicate raw data and red dots indicate corrected data.

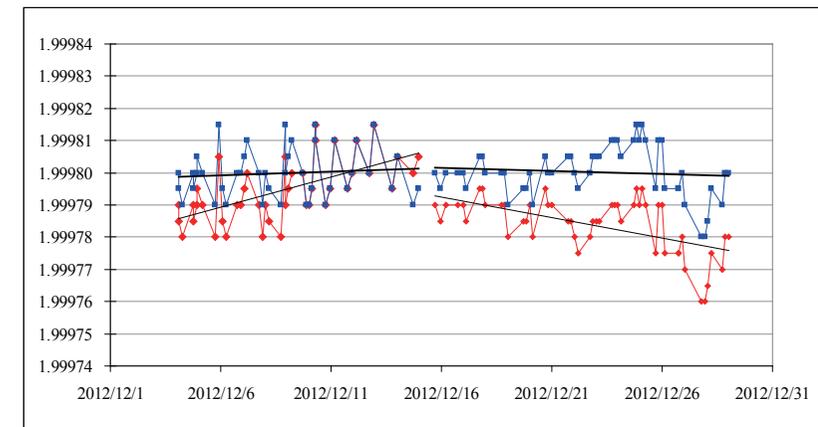


Figure 3.2.2. Same as Fig. 3.2.1, but for leg 2.

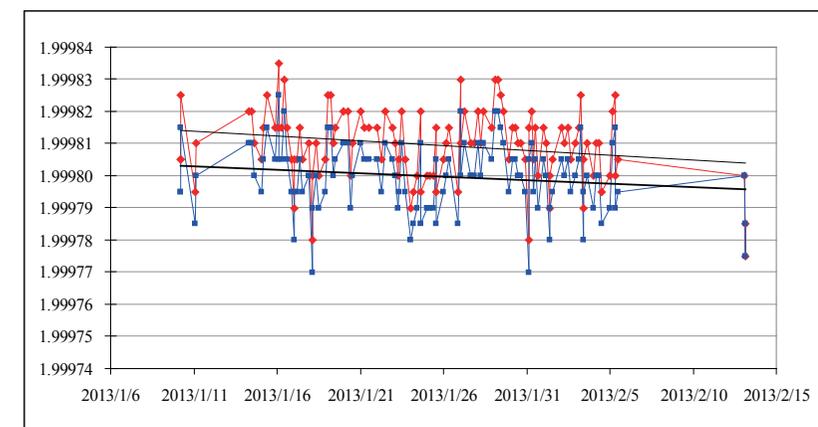


Figure 3.2.3. Same as Fig. 3.2.1, but for leg 3.

## ii. Sub-Standard Seawater

We also used sub-standard seawater which was deep-sea water filtered by pore size of 0.45  $\mu\text{m}$  and stored in a 20 liter cubitainer made of polyethylene and stirred for at least 24 hours before measuring. It was measured every 6 samples in order to check the possible sudden drift of the salinometer. During the whole measurements, there was no detectable sudden drift of the salinometer.

### iii. Replicate Samples

We took 12 (leg 1), 419 (leg 2), and 437 (leg 3) pairs of replicate samples during the cruise. Histograms of the absolute difference between replicate samples are shown in Figs. 3.2.4 (leg 1), 3.2.5 (leg 2), and 3.2.6 (leg 3). The root-mean-squares of the absolute difference were 0.00015 (leg 1), 0.00018 (leg 2), and 0.00020 (leg 3).

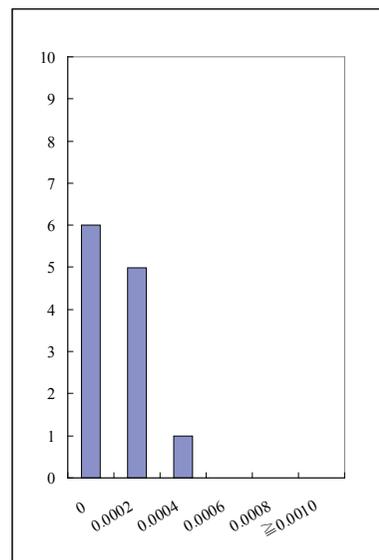


Figure 3.2.4. Histogram of the absolute difference between replicate samples for leg 1. Horizontal axis is absolute difference in salinity and vertical axis is frequency.

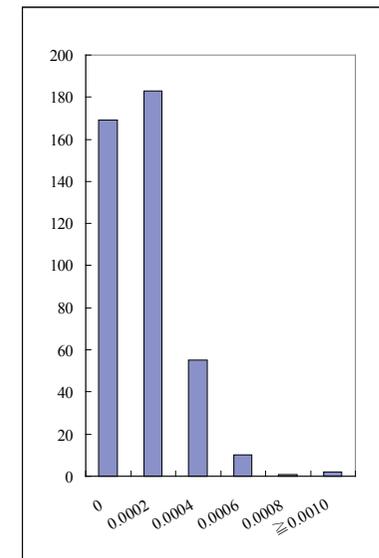


Figure 3.2.5. Same as Fig. 3.2.4, but for leg 2.

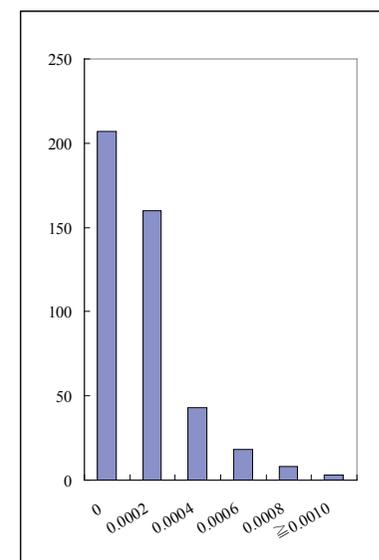


Figure 3.2.6. Same as Fig. 3.2.4, but for leg 3.

## References

- Aoyama, M., T. Joyce, T. Kawano and Y. Takatsuki (2002): Standard seawater comparison up to P129. Deep-Sea Research, I, Vol. 49, 1103-1114.
- Kawano (2010): Salinity. The GO-SHIP Repeat Hydrography Manual: A collection of Expert Reports and Guidelines, IOCCP Report No. 14, ICPO Publication Series No. 134, Version 1.
- UNESCO (1981): Tenth report of the Joint Panel on Oceanographic Tables and Standards. UNESCO Tech. Papers in Mar. Sci., 36, 25 pp.

### 3.3 Density

September 30, 2014

#### (1) Personnel

Hiroshi Uchida (JAMSTEC)

#### (2) Objectives

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

#### (3) Materials and methods

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

The water samples were collected in 100-mL aluminum bottles (Mini Bottle Can, Daiwa Can Company, Japan). The bottles were stored at room temperature (~23 °C) upside down. The bottles were warmed up in a water bath (~30 °C) for about one hour before measurement. The water sample was filled in a 12-mL glass vial and the glass vial was sealed with Parafilm M (Pechiney Plastic Packaging, Inc., Menasha, Wisconsin, USA) immediately after filling. Densities of the samples were measured at 20 °C by the density meter two times for each bottle and averaged to estimate the density. When the difference between the two measurements was greater than 0.002, additional measurements were conducted until two samples satisfying the above criteria were obtained.

Time drift of the density meter was monitored by periodically measuring the density of ultra-pure water

(Milli-Q water, Millipore, Billerica, Massachusetts, USA) prepared from Yokosuka (Japan) tap water in October 2012. The true density at 20 °C of the Milli-Q water was estimated to be 998.2042 kg m<sup>-3</sup> from the isotopic composition ( $\delta D = -8.76 \text{ ‰}$ ,  $\delta^{18}O = -56.86 \text{ ‰}$ ) and International Association for the Properties of Water and Steam (IAPWS)-95 standard. An offset correction was applied to the measured density by using the Milli-Q water measurements ( $\rho_{\text{Milli-Q}}$ ) with a slight modification of the density dependency (Uchida et al., 2011). The offset ( $\rho_{\text{offset}}$ ) of the measured density ( $\rho$ ) was estimated from the following equation:

$$\rho_{\text{offset}} = (\rho_{\text{Milli-Q}} - 998.2042) - (\rho - 998.2042) \times 0.000241 \text{ [kg m}^{-3}\text{]}.$$

The offset correction was verified by measuring Reference Material for Density in Seawater (prototypes Dn-RM1 [100 ml PFA bottle sealed with double aluminum bags], Reference Material for Nutrients in Seawater (RMNS) lot BF (Kanso Technos Co., Ltd.), and International Association of the Physical Sciences of the Ocean (IAPSO) Standard Seawater (SSW) (Ocean Scientific International Ltd., Havant, UK) batch P154 along with the Milli-Q water.

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

#### (4) Results

Results of density measurements of the Reference Material for Density in Seawater (Dn-RM1, RMNS, and IAPSO SSW) were shown in [Table 3.3.1](#) and [Table 3.3.2](#). Mean densities of the Dn-RM1 were similar for legs 2 and 3, except for the results on January 15 and February 2, 2013 ([Table 3.3.2](#)). Density of Dn-RM1 measured at first, middle and last of the series of the measurement of sea water samples drifted in time (-0.0004 kg/m<sup>3</sup>/hour) for the results on January 15 and biased (about +0.0196 kg/m<sup>3</sup>) for the results on February 2. Therefore, densities measured on these days were corrected by a time drift correction for January 15 and offset correction for February 2 to match the mean density of the Dn-RM1 with the average (1024.2605 kg/m<sup>3</sup>) for leg 3.

A total of 26 pairs of replicate samples were measured. The root-mean square of the absolute difference of replicate samples was 0.0016 g/kg.

The measured density salinity anomalies ( $\delta S_A$ ) are shown in [Fig. 3.3.1](#). The measured  $\delta S_A$  well agree

with calculated  $\delta S_A$  from Pawlowicz et al. (2011) which exploits the correlation between  $\delta S_A$  and nutrient concentrations and carbonate system parameters based on mathematical investigation using a model relating composition, conductivity and density of arbitrary seawaters.

Table 3.3.1. Result of density measurements of the Reference Material for Density in Seawater (prototype Dn-RM1).

Date	Stations (sample no.)	Mean density of Dn-RM1 (kg/m <sup>3</sup> )	Note
<i>Leg 2</i>			
2012/12/04	(001,004)	1024.2608	
2012/12/06	011	1024.2626	
2012/12/08	018	1024.2618	
2012/12/10	023,027	1024.2624	
2012/12/11	404	1024.2603	
2012/12/15	053	1024.2605	
2012/12/17	059	1024.2604	
2012/12/19	064	1024.2634	
2012/12/23	071	1024.2632	
2012/12/25	078	1024.2618	
2012/12/27	085	1024.2631	
2012/12/28	081,083,087,501	1024.2621	bottles #7,9-36 for station 501
2012/12/30	501,503	1024.2611	bottles #1,8 for station 501
Average: 1024.2618 ± 0.0011 (n = 13)			

*Leg 3*

2013/01/15	090	1024.2566*	1024.2600 after drift correction
2013/01/16	094	1024.2593	
2013/01/18	100	1024.2604	
2013/01/19	104	1024.2610	
2013/01/21	111,116	1024.2618	
2013/01/23	123	1024.2607	
2013/01/25	128	1024.2631	
2013/01/28	133	1024.2597	
2013/01/30	none	1024.2598	
2013/01/31	146,151	1024.2606	
2013/02/02	156	1024.2801*	1024.2601 after bias correction bottles #1,17-30,32,33,35,36
2013/02/03	162,156,166	1024.2589	bottles #31,34 for station 156
Average: 1024.2605 ± 0.0012 (n = 10: exclude data labeled by asterisk)			

Table 3.3.2. Comparison of density measurement of the Reference Material for Nutrients in Seawater (lot BF) and IAPSO SSW (batch 154).

Date	Reference	Density [kg/m <sup>3</sup> ]	Note
<i>Leg 2</i>			
2012/12/04	RMNS BF	1024.4815	
2012/12/06	RMNS BF	1024.4832	
2012/12/08	RMNS BF	1024.4824	
2012/12/30	RMNS BF	1024.4838	
		Average: 1024.4827 ± 0.0010	
2012/12/08	SSW P154	1024.7631	
2012/12/08	SSW P154	1024.7640	
2012/12/10	SSW P154	1024.7642	
2012/12/15	SSW P154	1024.7618	
2012/12/23	SSW P154	1024.7631	
2012/12/28	SSW P154	1024.7640	
		Average: 1024.7634 ± 0.0009	
<i>Leg 3</i>			
2013/01/16	SSW P154	1024.7626	
2013/01/21	SSW P154	1024.7645	
2013/01/31	SSW P154	1024.7622	
		Average: 1024.7631 ± 0.0012	

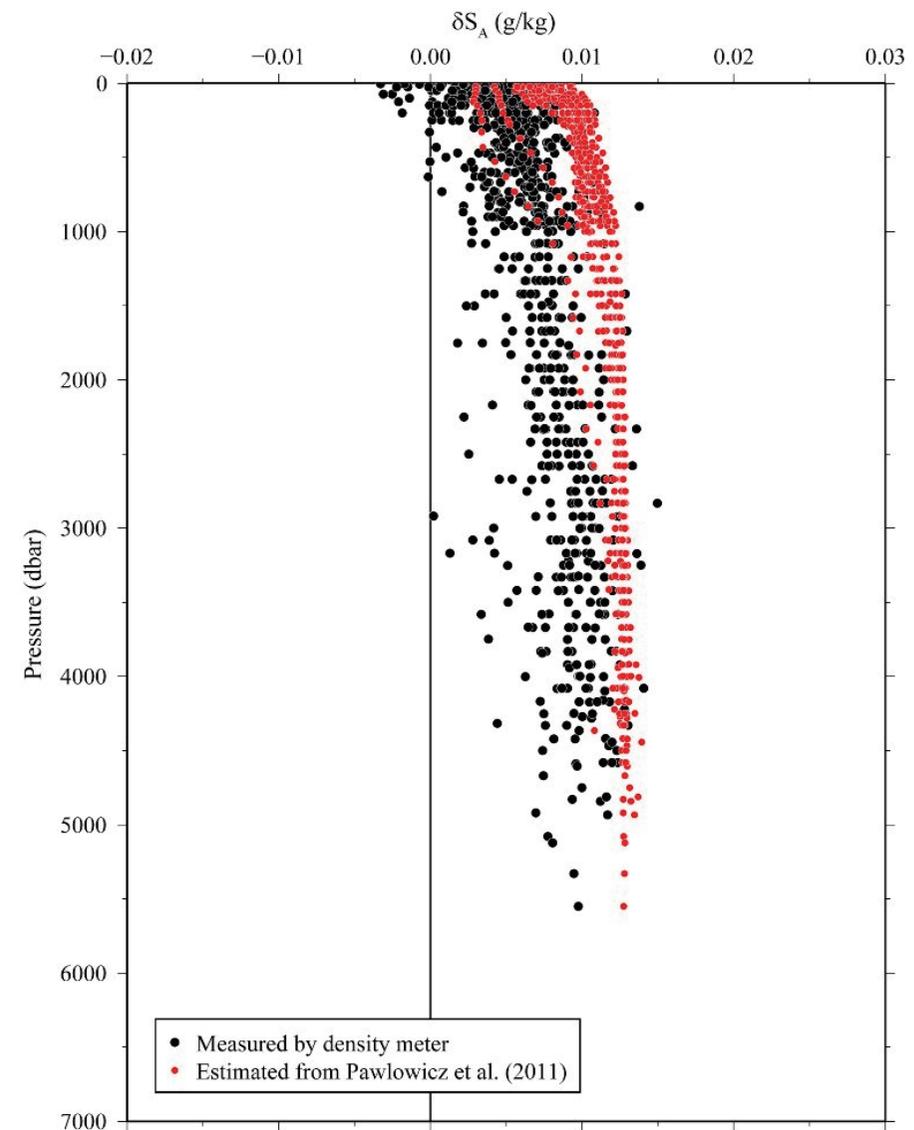


Figure 3.3.1. Vertical distribution of density salinity anomaly measured by the density meter. Absolute Salinity anomaly estimated from nutrients and carbonate parameters (Pawlowicz et al., 2011) are also shown for comparison.

## References

- IOC, SCOR and IAPSO (2010): The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, United Nations Educational, Scientific and Cultural Organization (English), 196 pp.
- Pawlowicz, R., D. G. Wright and F. J. Millero (2011): The effects of biogeochemical processes on ocean conductivity/salinity/density relationships and the characterization of real seawater. *Ocean Science*, 7, 363–387.
- Uchida, H., T. Kawano, M. Aoyama and A. Murata (2011): Absolute salinity measurements of standard seawaters for conductivity and nutrients. *La mer*, 49, 237–244.

## 3.4 Oxygen

September 29, 2014

### (1) Personnel

Yuichiro Kumamoto (Japan Agency for Marine-Earth Science and Technology)

Misato Kuwahara (Marine Works Japan Co. Ltd)

Kanako Yoshida (Marine Works Japan Co. Ltd)

Keitaro Matsumoto (Marine Works Japan Co. Ltd)

Takuhiro Osumi (Marine Works Japan Co. Ltd)

### (2) Objectives

Dissolved oxygen is one of good tracers for the ocean circulation. Climate models predict a decline in oceanic dissolved oxygen concentration and a consequent expansion of the oxygen minimum layers under global warming conditions, which results mainly from decreased interior advection and ongoing oxygen consumption by remineralization. The mechanism of the decrease, however, is still unknown. During MR12-05 cruise, we measured dissolved oxygen concentration from surface to bottom layers at all the hydrocast stations in the western Pacific and Southern Oceans. Most of the stations reoccupied the WOCE Hydrographic Program P14S and S4 stations in the 1990s. Our purpose is to evaluate temporal change in dissolved oxygen concentration in the western Pacific and Southern Oceans between the 1990s and 2012/13.

### (3) Reagents

Pickling Reagent I: Manganous chloride solution (3M)

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

Sulfuric acid solution (5M)

Sodium thiosulfate (0.025M)

Potassium iodate (0.001667M): Wako Pure Chemical Industries, Ltd., volumetric standard, reference

material for iodometry, Lot No.EPR3227, Purity: 99.96±0.01%

CSK standard of potassium iodate: Lot DCE2131, Wako Pure Chemical Industries Ltd., 0.0100N

### (4) Instruments

Burette for sodium thiosulfate and potassium iodate;

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

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

### (5) Seawater sampling

Following procedure is based on a determination method in the WHP Operations Manual (Dickson, 1996). Seawater samples were collected from 12-liters Niskin sampler bottles attached to 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 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. Temperature of sodium thiosulfate during titration was recorded by a thermometer. We measured dissolved oxygen concentration using two sets of the titration apparatus, named DOT-7 and DOT-8. Dissolved oxygen

concentration ( $\mu\text{mol kg}^{-1}$ ) was calculated by the sample temperature during the sampling, bottle salinity, flask volume, and titrated volume of the sodium thiosulfate solution. When the bottle salinity data is flagged to be 3 (questionable), 4 (bad), or 5 (missing), CTD salinity (primary) data is referred in the calculation alternatively.

#### (7) Standardization

Concentration of sodium thiosulfate titrant (ca. 0.025M) was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130°C. 1.7835 g potassium iodate weighed out accurately was dissolved in deionized water and diluted to final volume of 5 dm<sup>3</sup> in a calibrated volumetric flask (0.001667M). 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 3.4.1 shows result of the standardization during this cruise. Coefficient of variation (C.V.) for the standardizations was 0.02±0.01 % (n = 67), 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 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 3.4.1). The averaged blank values for DOT-7 and DOT-8 were 0.003±0.001 (standard deviation, S.D., n=34) and 0.001±0.001 (S.D., n=33) cm<sup>3</sup>, respectively.

#### (9) Replicate sample measurement

From a routine CTD cast at all the stations, a pair of replicate samples was collected at four layers of 25, 400, 1500, and 3500 dbars. In order to estimate uncertainty including instrumental error, one and the other of the replicate sample pair were measured using DOT-7 and DOT-8, respectively. The total number of the replicate sample pairs in good measurement (flagged 2) was 550 (Fig. 3.4.1). The standard deviation of the replicate measurement was 0.09  $\mu\text{mol kg}^{-1}$  calculated by a procedure (SOP23) in DOE (1994). The results of the replicate measurements are not included in the data sheet.

#### (10) Duplicate sample measurement

During the leg-1 duplicate samples were taken from 36 Niskin bottles at stations C01 and C02 (Table 3.4.2). One and the other of the duplicate sample pair were measured using DOT-7 and DOT-8, respectively, in order to estimate uncertainty depends on the apparatus. The standard deviation of the duplicate measurements at the stations C01 and C02 were calculated to be 0.12 and 0.07  $\mu\text{mol kg}^{-1}$ , respectively, which were equivalent with that of the replicate measurements (see section 9).

#### (11) CSK standard measurements

The CSK standard is a commercial potassium iodate solution (0.0100 N) for analysis of dissolved oxygen. We titrated the CSK standard solutions (Lot DCE2131) against our KIO<sub>3</sub> standards as samples before and during the cruise (Table 3.4.3). A good agreement among them confirms that concentration of the KIO<sub>3</sub> standards did not change between preparation of the standards onshore and the sample measurements on board.

**(12) Quality control flag assignment**

Quality flag values were assigned to oxygen measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev.2 section 4.5.2 (Joyce *et al.*, 1994). Measurement flags of 2 (good), 3 (questionable), 4 (bad), and 5 (missing) have been assigned (Table 3.4.4). For the choice between 2, 3, or 4, we basically followed a flagging procedure as listed below:

- a. Bottle oxygen concentration at the sampling layer was plotted against sampling pressure. Any points not lying on a generally smooth trend were noted.
- b. Difference between bottle oxygen and CTD oxygen was then plotted against sampling pressure. If a datum deviated from a group of plots, it was flagged 3.
- c. Vertical sections against pressure and potential density were drawn. If a datum was anomalous on the section plots, datum flag was degraded from 2 to 3, or from 3 to 4.
- d. If there was problem in the measurement, the datum was flagged 4.
- e. If the bottle flag was 4 (did not trip correctly), a datum was flagged 4 (bad). In case of the bottle flag 3 (leaking) or 5 (unknown problem), a datum was flagged based on steps a, b, c, and d.

**(13) Results**

A notable decrease (increase) in dissolved apparent oxygen utilization (oxygen) on density surfaces was found near the bottom (Fig. 3.4.2). The increase appears due to density decrease of near-bottom water, which can be explained by a change in the mixing ratio of bottom water from near the Ad’elie Depression (Ad’elie Land Bottom Water (ALBW), higher oxygen) with that from the more distant Ross Sea (Ross Sea Bottom Water (RSBW), lower oxygen): an increased contribution of ALBW and a decreased contribution of RSBW. This change might be associated with a decrease in the RSBW supply following an earlier ice-calving event in the polynya region. Oxygen rich and dense bottom water observed in 1995/96 in troughs near 130oE disappeared in 2012/13, which also might reflect changes in bottom water production along the coast, possibly in Mertz and Dibble Polynyas.

**References**

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.

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 (1994) Requirements for WOCE Hydrographic Programme Data Reporting, WHPO Pub. 90-1 Rev. 2, May 1994 Woods Hole, Mass., USA.

Katsumata, K., H. Nakano, and Y. Kumamoto (in press) Dissolved oxygen change and freshening of Antarctic Bottom Water along 62oS in the Australian-Antarctic Basin between 1995/96 and 2012/13, Deep-Sea Res. II.

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.

Table 3.4.1. Results of the standardization (End point, E.P.) and the blank determinations (cm<sup>3</sup>).

Date (UTC)	KIO3 No.		Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> No.	DOT-7		DOT-8		Stations
	#	ID No.		E.P.	blank	E.P.	blank	
2012/11/06		20120417-03-03	20120615-16	3.970	0.003	3.964	0.002	C01,C02,C03
2012/12/04		20120417-03-11	20120615-16	3.972	0.003	3.967	0.001	008-011
2012/12/06	03	20120417-03-09	20120615-17	3.969	0.004	3.965	0.001	012-022
2012/12/09		20120417-03-06	20120615-17	3.967	0.002	3.963	0.001	023-027,402,404,406
2012/12/11		20120417-03-10	20120615-18	3.968	0.003	3.964	-0.001	408,410,050-054
2012/12/14		20120419-04-01	20120615-18	3.966	0.001	3.962	0.002	055-062
2012/12/16	04	20120419-04-09	20120615-19	3.969	0.002	3.965	0.001	063-068,C04,069-071
2012/12/21		20120419-04-07	20120615-19	3.966	0.002	3.962	0.001	072-078

2012/12/23	20120419-04-08	20120615-20	3.968	0.002	3.964	0.001	079-085
2012/12/25	20120419-04-03	20120615-20	3.966	0.003	3.962	0.002	086-088,501,502,503
2013/01/08	20120419-04-05	20120615-21	3.970	0.003	3.966	0.001	088-091
2013/01/14	20120419-04-06	20120615-21	3.970	0.002	3.966	0.002	092-102
2013/01/17	20120419-04-02	20120615-22	3.970	0.002	3.967	0.000	103-116
2013/01/20	20120419-05-01	20120615-22	3.969	0.003	3.966	0.000	117-122
2013/01/21	20120419-05-02	20120615-23	3.970	0.002	3.966	0.001	123-130,140,139,138,137
2013/01/25	20120419-05-03	20120615-23	3.969	0.004	3.966	0.003	136,135,134,131,132,133
2013/01/27	20120419-05-05	20120615-24	3.975	0.002	3.971	0.000	141-150
2013/01/29	20120419-05-04	20120615-24	3.970	0.001	3.967	0.000	151-158
2013/02/01	20120419-05-07	20120615-25	3.967	0.002	3.962	0.001	162-165,167,166

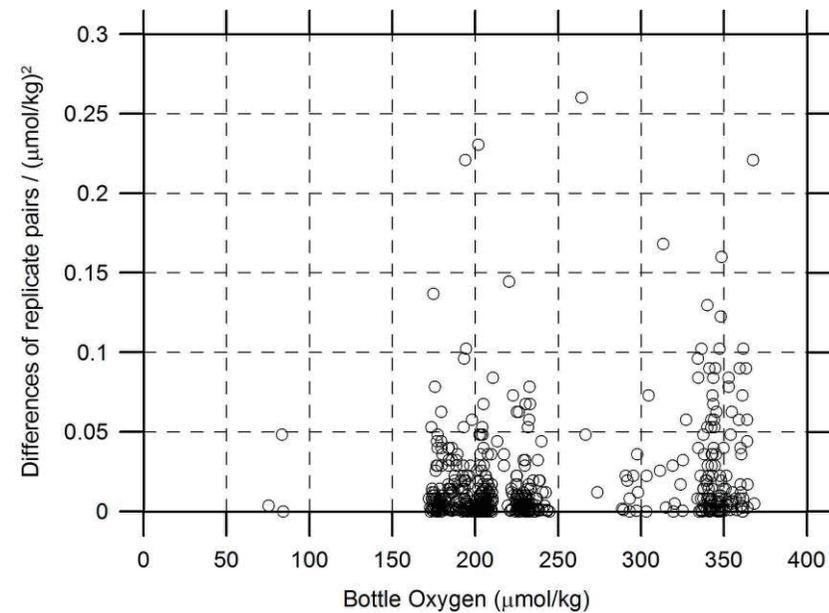


Figure 3.4.1. Oxygen difference between measurements of a replicate pair against oxygen concentration.

Table 3.4.2. Results of duplicate sample measurements.

	Leg	Stations	Pressure (dbar)	Niskins		Apparatus	Oxygen [μmol/kg]
1	1	C01	2001.9	18	X12J18	DOT-8	107.29
2	1	C01	2001.6	17	X12J17	DOT-8	107.42
3	1	C01	2001.2	16	X12J16	DOT-8	107.41
4	1	C01	2001.1	15	X12J15	DOT-8	107.56
5	1	C01	2001.0	14	X12J14	DOT-8	107.48
6	1	C01	2000.8	13	X12J13	DOT-8	107.45
7	1	C01	2000.5	12	X12J12	DOT-8	107.45
8	1	C01	2000.6	11	X12J11	DOT-8	107.47
9	1	C01	2000.4	10	X12J10	DOT-8	107.34
10	1	C01	2000.6	9	X12J09	DOT-7	107.23
11	1	C01	2000.4	8	X12J08	DOT-7	107.16
12	1	C01	2000.4	7	X12J07	DOT-7	107.23
13	1	C01	2000.6	6	X12J06	DOT-7	107.21
14	1	C01	2000.4	5	X12J05	DOT-7	107.27
15	1	C01	2000.6	4	X12J04	DOT-7	107.18
16	1	C01	2001.1	3	X12J03	DOT-7	107.32
17	1	C01	2000.4	2	X12J02	DOT-7	107.38
18	1	C01	2001.0	1	X12J01	DOT-7	107.33
19	1	C02	2003.6	36	X12J36	DOT-8	110.46
20	1	C02	2003.2	35	X12J35	DOT-8	110.35
21	1	C02	2003.5	34	X12J34	DOT-8	110.43
22	1	C02	2003.8	33	X12J33	DOT-8	110.51
23	1	C02	2003.3	32	X12J32	DOT-8	110.51

24	1	C02	2003.3	31	X12J31	DOT-8	110.47
25	1	C02	2003.2	30	X12J30	DOT-8	110.43
26	1	C02	2003.1	29	X12J29	DOT-8	110.50
27	1	C02	2002.7	28	X12J28	DOT-8	110.44
28	1	C02	2002.5	27	X12J27	DOT-7	110.43
29	1	C02	2003.0	26	X12J26	DOT-7	110.36
30	1	C02	2002.8	25	X12J25	DOT-7	110.41
31	1	C02	2002.3	24	X12J24	DOT-7	110.34
32	1	C02	2002.1	23	X12J23	DOT-7	110.40
33	1	C02	2002.4	22	X12J22	DOT-7	110.31
34	1	C02	2002.4	21	X12J21	DOT-7	110.41
35	1	C02	2001.6	20	X12J20	DOT-7	110.30
36	1	C02	2001.4	19	X12J19	DOT-7	110.34

Table 3.4.3. Results of the CSK standard (Lot DCE2131) measurements.

Date (UTC)	KIO <sub>3</sub> ID No.	DOT-1		-		Remarks
		Conc. (N)	error (N)	-	-	
2012/4/25	20120419-04-10	0.010004	0.000002	-	-	Onshore lab.
2012/4/25	20120419-05-10	0.010011	0.000004	-	-	Onshore lab.
		DOT-7		DOT-8		
		Conc. (N)	error (N)	Conc. (N)	error (N)	
2012/10/6	20120417-03-01	0.009997	0.000004	0.010000	0.000003	MR12-E03
2012/12/14	20120419-04-01	0.009996	0.000003	0.009999	0.000004	MR12-05 Leg-2
2013/01/20	20120419-05-01	0.010012	0.000004	0.010009	0.000004	MR12-05 Leg-3

Table 3.4.4. Summary of assigned quality control flags.

Flag	Definition	
2	Good	5657
3	Questionable	4
4	Bad	0
5	Not report (missing)	0
Total		5661

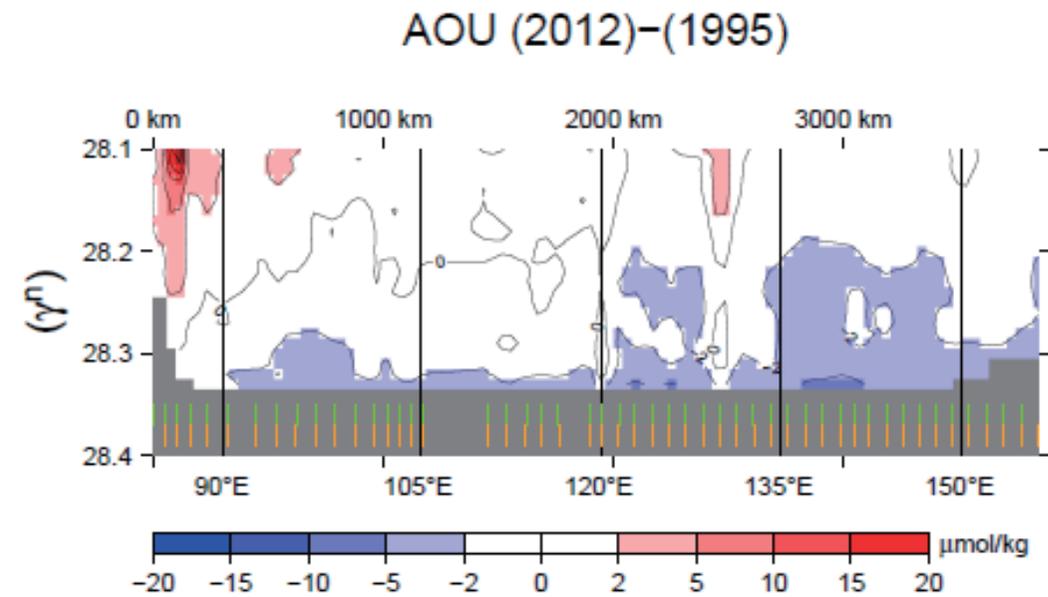


Figure 3.4.2. Differences in apparent oxygen utilization (AOU,  $\mu\text{mol kg}^{-1}$ ) on density surfaces along WHP-S4 line between 1995/96 and 2012/13 (Katsumata *et al.*, in press).

## 3.5 Nutrients

January 6, 2015

### (1) Personnel

Michio AOYAMA (Meteorological Research Institute /  
Japan Meteorological Agency, Principal Investigator)

LEG 2

Minoru KAMATA (Department of Marine Science, Marine Works Japan Ltd.)

Yasuhiro ARII (Department of Marine Science, Marine Works Japan Ltd.)

Kohei MIURA (Department of Marine Science, Marine Works Japan Ltd.)

LEG 3

Minoru KAMATA (Department of Marine Science, Marine Works Japan Ltd.)

Masanori ENOKI (Department of Marine Science, Marine Works Japan Ltd.)

Elena HAYASHI (Department of Marine Science, Marine Works Japan Ltd.)

### (2) Objectives

The objectives of nutrients analyses during the R/V Mirai MR12-05 cruise, WOCE P14S, S04 and S04I revisited cruise in 2012/2013, in the Southern Ocean are as follows;

- Describe the present status of nutrients concentration with excellent comparability.
- The determinants are nitrate, nitrite, silicate and phosphate.
- Study the temporal and spatial variation of nutrients concentration based on the previous high quality experiments data of WOCE previous P14S, S04 and S04I cruises in 1993 and 2005, GEOSECS, IGY and so on.
- Study of temporal and spatial variation of nitrate: phosphate ratio, so called Redfield ratio.
- Obtain more accurate estimation of total amount of nitrate, silicate and phosphate in the interested area.
- Provide more accurate nutrients data for physical oceanographers to use as tracers of water mass movement.

### (3) Summary of nutrients analysis

We made 142 QuAAtro 2-HR runs for the samples at 145 stations in MR12-05. The total amount of layers of the seawater sample reached up to 4292 for MR12-05. We made duplicate measurement at all layers.

### (4) Instrument and Method

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

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

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

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

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





Dissolved 1.2 g L (+)-ascorbic acid,  $C_6H_8O_6$ , in 150 ml of stock molybdate solution. After mixing, 3 ml sodium dodecyl sulphate (15 % solution in water) was added in leg 3 of this cruise, 4 mL sodium dodecyl sulphate (15 % solution in water) was added in leg 2 because to reduce relatively noisy signals. This reagent was freshly prepared before every measurement.

Reagent for sample dilution

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

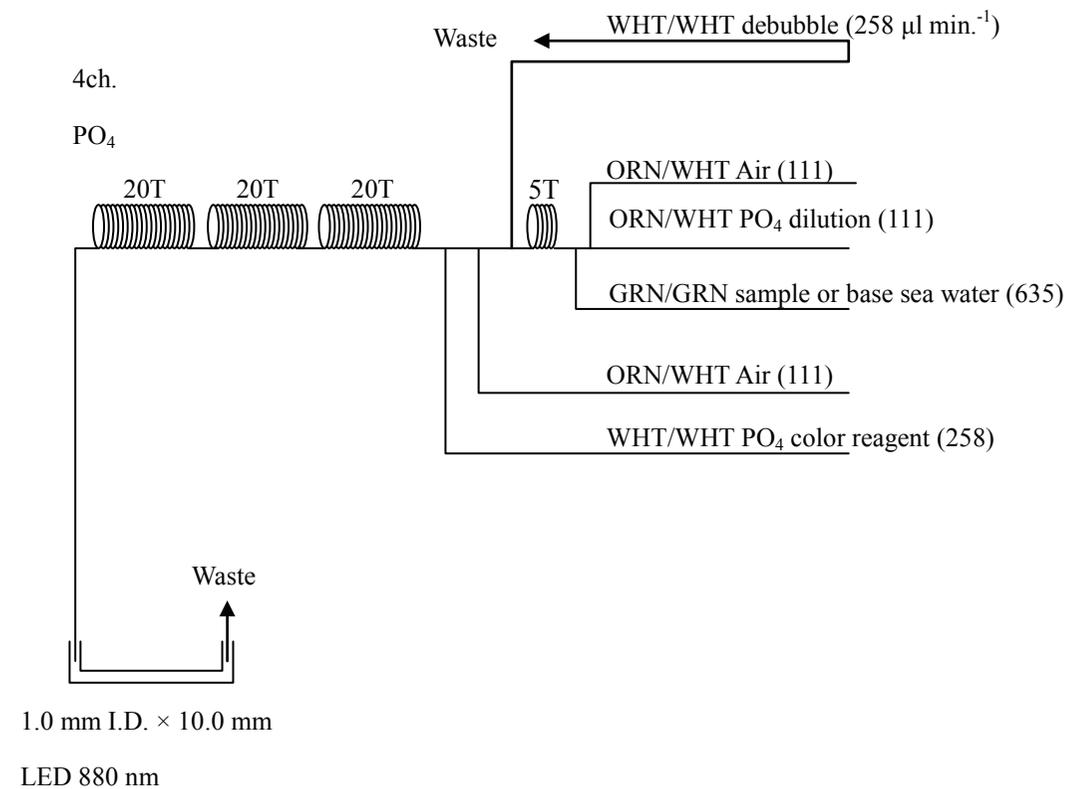


Figure 3.5.4. PO<sub>4</sub> (4ch.) Flow diagram.

#### (4.6) Sampling procedures

Sampling of nutrients followed that oxygen, salinity and trace gases. Samples were drawn into two of virgin 10 ml polyacrylates vials without sample drawing tubes. These were rinsed three times before filling and vials were capped immediately after the drawing. The vials were put into water bath adjusted to ambient temperature,  $24 \pm 2$  °C, in about 30 minutes before use to stabilize the temperature of samples in MR12-05.

No transfer was made and the vials were set an auto sampler tray directly. Samples were analyzed after collection basically within 24 hours in MR12-05.

#### (4.7) Data processing

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

- Checked baseline shift.
- Checked the shape of each peak and positions of peak values taken, and then changed the positions of peak values taken if necessary.
- Carry-over correction and baseline drift correction were applied to peak heights of each samples followed by sensitivity correction.
- Baseline correction and sensitivity correction were done basically using liner regression.
- Loaded pressure and salinity from CTD data to calculate density of seawater.
- Calibration curves to get nutrients concentration were assumed second order equations.

#### (5) Nutrients standards

##### (5.1) Volumetric laboratory ware of in-house standards

All volumetric glass ware and polymethylpentene (PMP) ware used were gravimetrically calibrated. Plastic volumetric flasks were gravimetrically calibrated at the temperature of use within 0 to 4 K.

### Volumetric flasks

Volumetric flasks of Class quality (Class A) are used because their nominal tolerances are 0.05 % or less over the size ranges likely to be used in this work. Class A flasks are made of borosilicate glass, and the standard solutions were transferred to plastic bottles as quickly as possible after they are made up to volume and well mixed in order to prevent excessive dissolution of silicate from the glass. High quality plastic (polymethylpentene, PMP, or polypropylene) volumetric flasks were gravimetrically calibrated and used only within 0 to 4 K of the calibration temperature.

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

Because of their larger temperature coefficients of cubical expansion and lack of tables constructed for these materials, the plastic volumetric flasks were gravimetrically calibrated over the temperature range of intended use and used at the temperature of calibration within 0 to 4 K. The weights obtained in the calibration weightings were corrected for the density of water and air buoyancy.

### Pipettes and pipettors

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

## (5.2) Reagents, general considerations

### Specifications

For nitrate standard, “potassium nitrate 99.995 suprapur®” provided by Merck, CAS No. : 7757-91-1, was used.

For nitrite standard, “sodium nitrite” provided by Wako, CAS No. : 7632-00-0, was used. The assay of nitrite salts was determined according JIS K8019 were 98.73 %. We use that value to adjust the weights taken.

For the silicate standard, we use “Silicon standard solution SiO<sub>2</sub> in NaOH 0.5 mol/l CertiPUR®” provided by Merck, CAS No. : 1310-73-2, of which lot number is HC097572 is used. The silicate concentration is

certified by NIST-SRM3150 with the uncertainty of 0.5 %. Factor of HC097572 was signed 1.000, however we reassigned the factor as 0.976 from the result of comparison among RMNS in MR11-E02 cruise. A history of assigned factor of Merck solutions are shown in Table 3.5.1.

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

Table 3.5.1. A history of assigned factor of Merck solutions.

Lot	Factor	Date	Reference
Merck OC551722	1.001	2006/5/24	
Merck HC623465	1.000		
Merck HC751838	0.998	2007/4/13	
Merck HC814662	0.999	2008/8/27	
Merck HC074650	0.975		
Merck HC097572	0.976	MR11-E02 (2011/06/20)	RMNS_BA, AY, BD, BE, BF

### Ultra pure water

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

### Low-Nutrient Seawater (LNSW)

Surface water having low nutrient concentration was taken and filtered using 0.45 µm pore size membrane filter. This water is stored in 20 liter cubitainer with paper box. The concentrations of nutrient of this water were measured carefully in August 2012.

### Treatment of silicate standard due to high alkalinity

Since the silicon standard solution Merck CertiPUR® is in NaOH 0.5 mol/l, we need to dilute and neutralize to avoid make precipitation of MgOH<sub>2</sub> etc. When we make B standard, silicon standard solution is diluted by factor 12 with pure water and neutralized by HCl 1.0 mol/l to be about 7. After that B standard solution is used to prepare C standards.

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

Concentrations of nutrients for A, B and C standards are set as shown in Table 3.5.2. The C standard is prepared according recipes as shown in Table 3.5.3. All volumetric laboratory tools were calibrated prior the cruise as stated in chapter (i). Then the actual concentration of nutrients in each fresh standard was calculated based on the ambient, solution temperature and determined factors of volumetric lab. wares.

The calibration curves for each run were obtained using 6 levels, C-1, C-2, C-3, C-4, C-5 and C-6.

Table 3.5.2. Nominal concentrations of nutrients for A, B and C standards.

	A	B	C-1	C-2	C-3	C-4	C-5	C-6
NO <sub>3</sub> (μM)	22500	900	BS	BU	BT	BD	BF	45
NO <sub>2</sub> (μM)	4000	20	BS	BU	BT	BD	BF	1.0
SiO <sub>2</sub> (μM)	36000	2160	BS	BU	BT	BD	BF	105
PO <sub>4</sub> (μM)	3000	60	BS	BU	BT	BD	BF	3.0

Table 3.5.3. Working calibration standard recipes.

C Std.	B-1 Std.	B-2 Std.
C-6	25 ml	25 ml

B-1 Std.: Mixture of nitrate, silicate and phosphate

B-2 Std.: Nitrite

### (5.4) Renewal of in-house standard solutions

In-house standard solutions as stated in (iii) were renewed as shown in Table 3.5.4 (a) to (c).

Table 3.5.4(a). 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. (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

Table 3.5.4(b). Timing of renewal of in-house standards.

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

Table 3.5.4(c). Timing of renewal of in-house standards for reduction estimation.

Reduction estimation	Renewal
D-1 Std. (3600 μM NO <sub>3</sub> )	8 days
43 μM NO <sub>3</sub>	when C Std. renewed
39 μM NO <sub>2</sub>	when C Std. renewed

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

To get the more accurate and high quality nutrients data to achieve the objectives stated above, huge numbers of the bottles of the reference material of nutrients in seawater (hereafter RMNS) are prepared (Aoyama et al., 2006, 2007, 2008, 2009). In the previous worldwide expeditions, such as WOCE cruises, the higher reproducibility and precision of nutrients measurements were required (Joyce and Corry, 1994). Since no standards were available for the measurement of nutrients in seawater at that time, the requirements were described in term of reproducibility. The required reproducibility was 1 %, 1 to 2 %, 1 to 3 % for nitrate, phosphate and silicate, respectively. Although nutrient data from the WOCE one-time survey was of unprecedented quality and coverage due to much care in sampling and measurements, the differences of nutrients concentration at crossover points are still found among the expeditions (Aoyama and Joyce, 1996, Mordy et al., 2000, Gouretski and Jancke, 2001). For instance, the mean offset of nitrate concentration at deep waters was 0.5  $\mu\text{mol kg}^{-1}$  for 345 crossovers at world oceans, though the maximum was 1.7  $\mu\text{mol kg}^{-1}$  (Gouretski and Jancke, 2001). At the 31 crossover points in the Pacific WHP one-time lines, the WOCE standard of reproducibility for nitrate of 1 % was fulfilled at about half of the crossover points and the maximum difference was 7 % at deeper layers below 1.6 °C in potential temperature (Aoyama and Joyce, 1996).

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

#### (6.1) RMNSs for this cruise

RMNS lots BS, BU, BT, BD and BF, which cover full range of nutrients concentrations in the Southern Ocean are prepared. 82 sets of BS, BU, BT, BD and BF are prepared.

One hundred seventy bottles of RMNS lot BV are prepared for MR12-05. Lot BV was used all stations. These RMNS assignment were completely done based on random number. The RMNS bottles were stored at

a room in the ship, REAGENT STORE, where the temperature was maintained around 15 – 33 °C.

#### (6.2) Assigned concentration for RMNSs

We assigned nutrients concentrations for RMNS lots BS, BU, BT, BD, BV, and BF as shown in Table 3.5.5.

Table 3.5.5. Assigned concentration of RMNSs.

	unit: $\mu\text{mol kg}^{-1}$			
	Nitrate	Phosphate	Silicate	Nitrite
BS*	0.07	0.063	1.61	0.02
BU*	3.96	0.378	20.27	0.07
BT*	18.18	1.318	40.94	0.47
BD*	29.82	2.191	64.30	0.05
BV**	35.32	2.541	99.55	0.06
BF***	41.39	2.809	149.71†	0.02

\* The values are assigned for this cruise on 27 July 2011.

\*\* The values are assigned for this cruise on 4 April 2009 (Table 3.4.4 in WHP P21 REVISIT DATA BOOK).

\*\*\* The values are assigned for this cruise on 21 August 2012.

† This value is changed for MR12-05 cruise.

#### (6.3) The homogeneity of RMNSs

The homogeneity of lot BV used in MR12-05 cruise and analytical precisions are shown in Table 3.5.6. These are for the assessment of the magnitude of homogeneity of the RMNS bottles those are used during the cruise. As shown in Table 3.5.6 and Figures 3.5.5 to 3.5.7, homogeneity of RMNS lot BV for nitrate, phosphate and silicate are the same magnitude of analytical precision derived from fresh raw seawater in January 2009.

Table 3.5.6. Homogeneity of lot BV derived from simultaneous 298 samples measurements and analytical precision onboard R/V Mirai in MR12-05.

	<b>Nitrate</b>	<b>Phosphate</b>	<b>Silicate</b>
	CV %	CV %	CV %
BV	0.13	0.19	0.15
Precision	0.10	0.16	0.11

BV: N=298

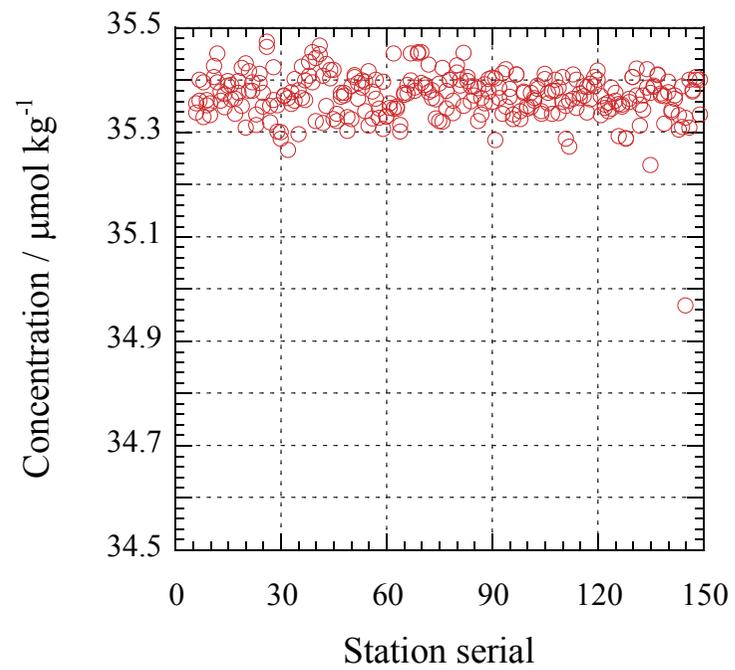


Figure 3.5.5. Time series of RMNS-BV of nitrate for MR12-05.

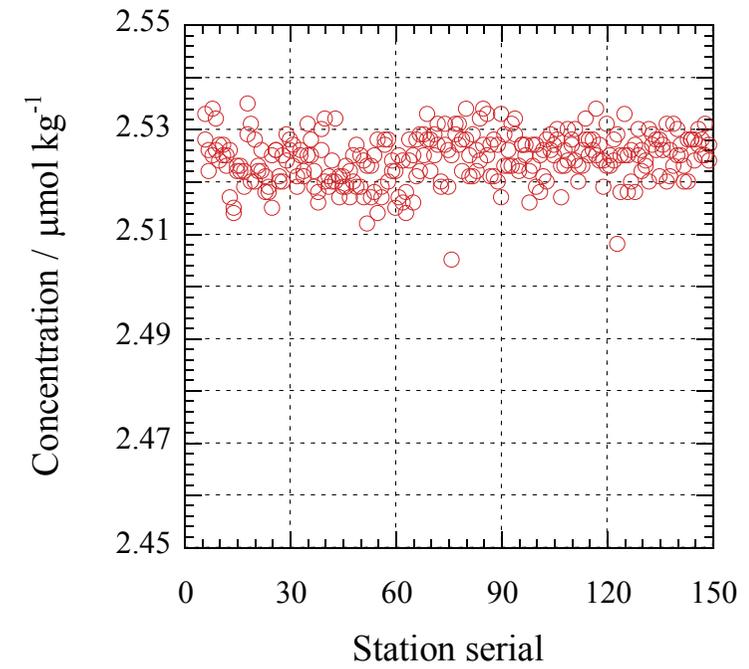


Figure 3.5.6. Time series of RMNS-BV of phosphate for MR12-05.

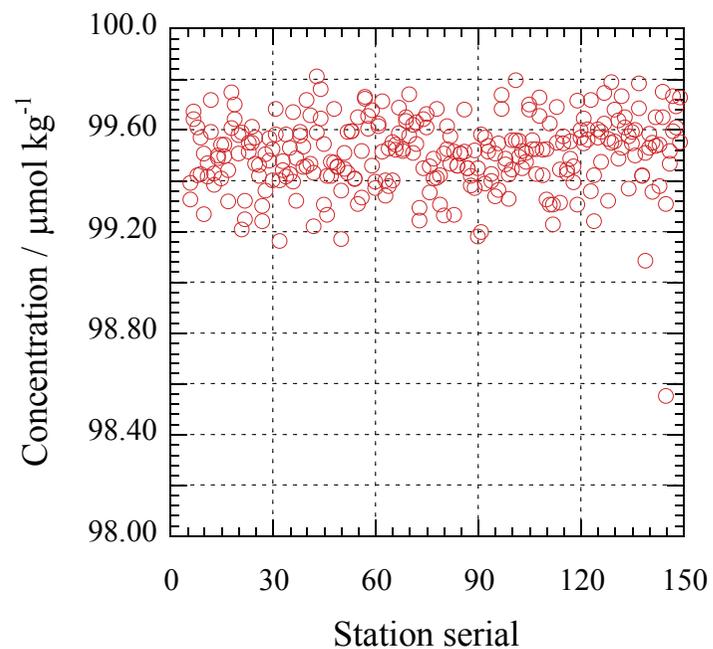


Figure 3.5.7. Time series of RMNS-BV of silicate for MR12-05.

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

Cruise-to-cruise comparability has been examined based on the results of the previous results of RMNSs measurements obtained among cruises and RMNS international comparison experiments in 2003 and 2009. The uncertainties for each value were obtained using the same method described in 7.1 in this chapter at the measurement before each cruise and inter-comparison study, shown as pre-cruise and inter-comparison, and mean of uncertainties during each cruise, only shown cruise code, respectively. As shown in Table 3.5.7, the nutrient concentrations of RMNSs were in good agreement among the measurements during the period from 2003 to 2011. For the silicate measurements, we show lot numbers and chemical company names of each cruise/measurement in the footnote. As shown in Table 3.5.7, there shows less comparability among the measurements due to less comparability among the standard solutions provided by chemical companies in the silicate measurements.

Table 3.5.7(a). Comparability for nitrate.

Cruise	RM Lots											
	BS	unc.	BU	unc.	BT	unc.	BD	unc.	BV	unc.	BF	unc.
	Nitrate											
MR07-04											41.34	0.083
MR10-05							29.80	0.097				
MR10-06							29.81	0.053			41.41	0.036
MR11-02							29.83	0.047			41.39	0.058
MR11-03					18.11	0.073	29.80	0.053			41.39	0.051
MR11-05					18.04	0.025	29.89	0.073			41.40	0.075
MR11-08	0.10	0.031	3.97	0.031	18.19	0.054	29.85	0.082			41.45	0.082
MR12-E03	0.08	0.012	3.97	0.017	18.23	0.030	29.86	0.054				
MR12-05	0.07	0.011	3.96	0.012	18.19	0.039	29.82	0.043	35.37	0.046	41.40	0.042

Table 3.5.7(b). Comparability for Phosphate.

Cruise	RM Lots												unit: $\mu\text{mol kg}^{-1}$		
	BS	unc.	BU	unc.	BT	unc.	BD	unc.	BV	unc.	BF	unc.			
	Phosphate														
MR07-04											2.803	0.006			
MR10-05							2.184	0.011							
MR10-06							2.182	0.006			2.807	0.007			
MR11-02							2.187	0.003			2.810	0.006			
MR11-03					1.316	0.011	2.187	0.004			2.815	0.007			
MR11-05					1.313	0.009	2.183	0.007			2.808	0.007			
MR11-08	0.064	0.010	0.377	0.007	1.317	0.010	2.190	0.011			2.821	0.009			
MR12-E03	0.070	0.007	0.385	0.006	1.331	0.007	2.211	0.007							
MR12-05	0.063	0.003	0.377	0.003	1.319	0.004	2.190	0.004	2.524	0.005	2.818	0.005			

Table 3.5.7(c). Comparability for Silicate.

Cruise	RM Lots												unit: $\text{mol kg}^{-1}$		
	BS	unc.	BU	unc.	BT	unc.	BD	unc.	BV	unc.	BF	unc.			
	Silicate														
MR07-04 <sup>\$\$</sup>													150.69	1.02	
MR10-05							64.40	0.10							
MR10-06							64.47	0.07				150.40	0.17		
MR11-02							64.40	0.11				150.12	0.33		
MR11-03							40.97	0.16	64.43	0.11		150.14	0.16		
MR11-05							40.96	0.09	64.40	0.07		150.18	0.13		
MR11-08 <sup>++</sup>	1.46	0.15	20.24	0.13	41.02	0.16	64.38	0.19				149.97	0.32		
MR12-E03	1.61	0.04	20.25	0.08	40.89	0.12	64.11	0.18							
MR12-05	1.58	0.08	20.23	0.07	40.88	0.10	64.13	0.13	99.50	0.15	149.64	0.26			

List of lot numbers: \$\$: Merck HC623465; ++: HC097572

## (7) Quality control

### (7.1) Precision of nutrients analyses during the cruise

Precision of nutrients analyses during the cruise was evaluated based on the 9 to 11 measurements, which are measured every 10 to 12 samples, during a run at the concentration of C-6 std. Summary of precisions are shown in [Table 3.5.8](#) and [Figures 3.5.8 to 3.5.10](#), the precisions for each parameter are generally good considering the analytical precisions during the Mirai cruises conducted in 2009 – 2012. During this cruise, analytical precisions were 0.10 % for nitrate, 0.16 % for phosphate and 0.11 % for silicate in terms of median of precision, respectively.

Table 3.5.8. Summary of precision based on the replicate analyses.

	<b>Nitrate</b>	<b>Phosphate</b>	<b>Silicate</b>
	<b>CV %</b>	<b>CV %</b>	<b>CV %</b>
Median	0.10	0.11	0.16
Mean	0.10	0.11	0.18
Maximum	0.23	0.24	0.40
Minimum	0.04	0.03	0.08
N	144	144	144

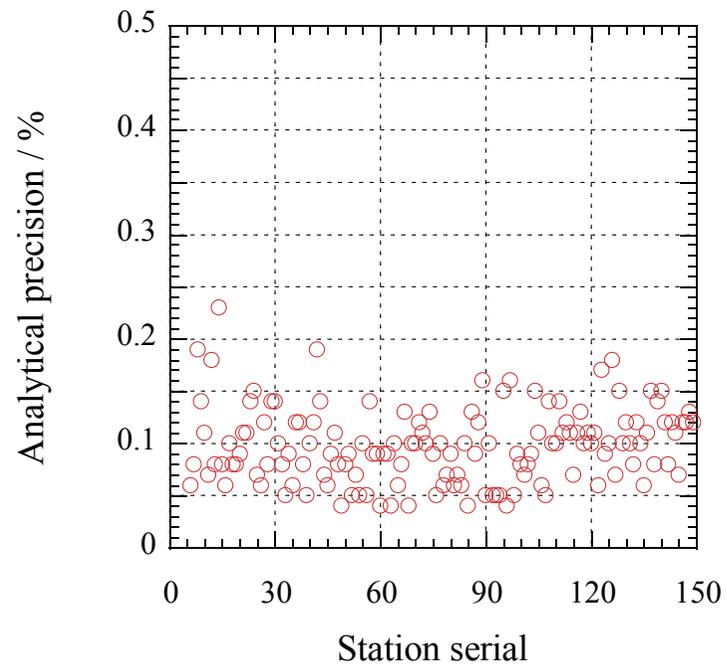


Figure 3.5.8. Time series of precision of nitrate for MR12-05.

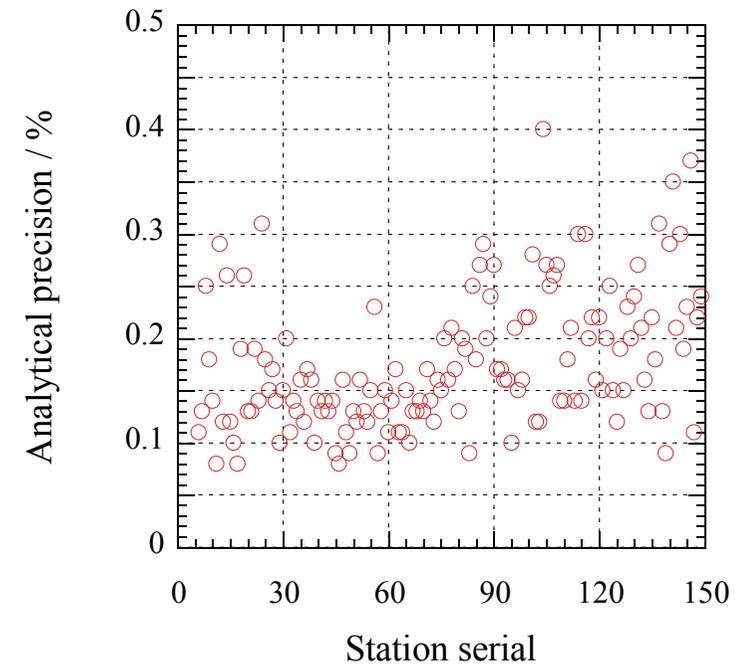


Figure 3.5.9. Time series of precision of phosphate for MR12-05.

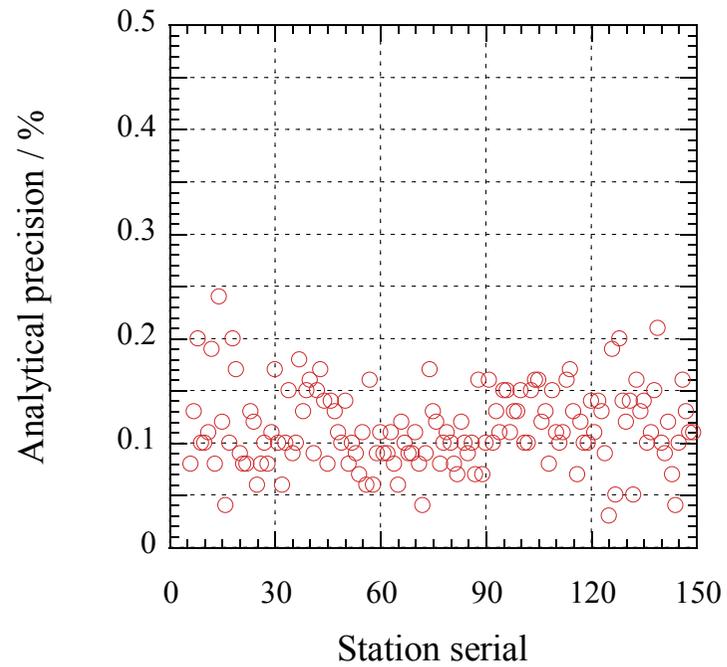


Figure 3.5.10. Time series of precision of silicate for MR12-05.

**(7.2) Carry over**

We also summarize the magnitudes of carry over throughout the cruise. These are small enough within acceptable levels as shown in [Table 3.5.9](#) and [Figures 3.5.11 – 3.5.13](#).

Table 3.5.9. Summary of carry over throughout MR12-05 cruise.

	<b>Nitrate</b>	<b>Phosphate</b>	<b>Silicate</b>
	<b>CV %</b>	<b>CV %</b>	<b>CV %</b>
Median	0.14	0.20	0.34
Mean	0.14	0.20	0.39
Maximum	0.23	0.37	0.95
Minimum	0.03	0.08	0.01
N	144	144	144

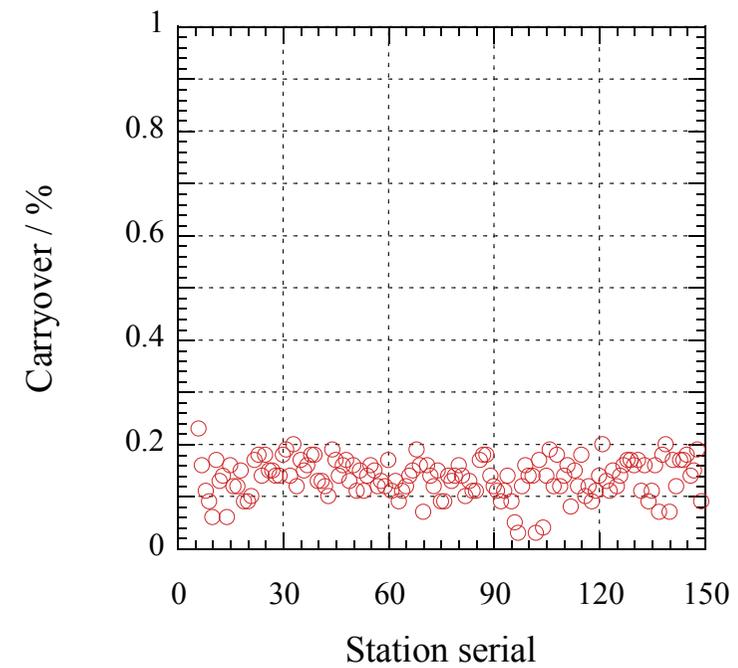


Figure 3.5.11. Time series of carryover of nitrate for MR12-05.

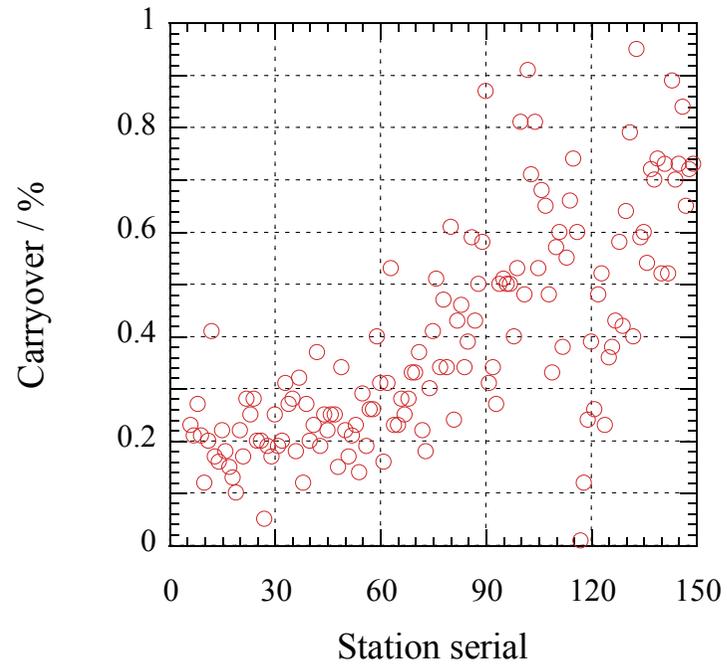


Figure 3.5.12. Time series of carryover of phosphate for MR12-05.

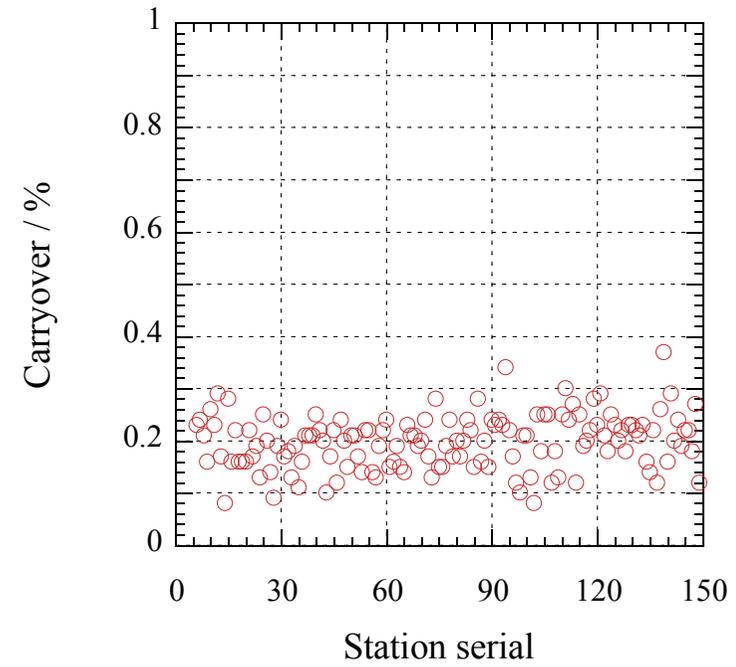


Figure 3.5.13. Time series of carryover of silicate for MR12-05.

**(7.2) Estimation of uncertainty of phosphate, nitrate and silicate concentrations**

Empirical equations, eq. (1), (2) and (3) to estimate uncertainty of measurement of phosphate, nitrate and silicate are used based on measurements of 72 sets of RMNSs during the this cruise. These empirical equations are as follows, respectively.

Phosphate Concentration  $C_p$  in  $\mu\text{mol kg}^{-1}$ :

$$\text{Uncertainty of measurement of phosphate (\%)} = 0.05668 + 0.3158 / C_p \quad - (1)$$

where  $C_p$  is phosphate concentration of sample.

Nitrate Concentration  $C_n$  in  $\mu\text{mol kg}^{-1}$ :

$$\text{Uncertainty of measurement of nitrate (\%)} = 0.09216 + 1.0861 / C_n \quad - (2)$$

where  $C_n$  is nitrate concentration of sample.

Silicate Concentration  $C_s$  in  $\mu\text{mol kg}^{-1}$ :

$$\text{Uncertainty of measurement of silicate (\%)} = 0.06383 + 7.436 / C_s \quad - (3)$$

where  $C_s$  is silicate concentration of sample.

## (8) Problems/improvements occurred and solutions

### (8.1)

During this cruise we observed relatively large carryover of phosphate measurement especially in leg 3 as shown in [Figure 3.5.12](#). We washed assemblies and a flow cell of phosphate channel a few times in leg 3, however relatively large carry over did not change.

We also found that carry over correction on the raw data was considered only “High to Low”. An equation of carry over correction is as below

$$A(i)_{\text{corrected}} = A(i) - A(i-1) \times k \quad - (4)$$

where  $A(i)$  is absorbance of sample  $i$ ,  $k$  is carry over coefficient. Although this carryover correction method is adopted in AACE software ver 6.07, this might make systematic underestimate on the nutrient concentration. A magnitude might depend a gradient of nutrient concentration and in case of phosphate it is estimated to be about  $0.002 \mu\text{mol kg}^{-1}$  at  $0.005 \mu\text{mol kg}^{-1} \text{ m}^{-1}$ .

### (8.2)

After the cruise, we found that LNSW concentration used in this cruise did not determined appropriately, especially for phosphate. We overestimate about  $0.03 \mu\text{mol kg}^{-1}$ . Therefore we corrected these overestimation and decided to report phosphate concentration  $x.xx \mu\text{mol kg}^{-1}$  NOT  $x.xxx \mu\text{mol kg}^{-1}$  considering the larger uncertainty of phosphate concentration of seawater samples.

## References

- 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., 2006: 2003 Intercomparison Exercise for Reference Material for Nutrients in Seawater in a Seawater Matrix, Technical Reports of the Meteorological Research Institute No.50, 91pp, Tsukuba, Japan.
- Aoyama, M., Susan B., Minhan, D., Hideshi, D., Louis, I. G., Kasai, H., Roger, K., Nurit, K., Doug, M., Murata, A., Nagai, N., Ogawa, H., Ota, H., Saito, H., Saito, K., Shimizu, T., Takano, H., Tsuda, A., Yokouchi, K., and Agnes, Y. 2007. Recent Comparability of Oceanographic Nutrients Data: Results of a 2003 Intercomparison Exercise Using Reference Materials. *Analytical Sciences*, 23: 1151–1154.
- Aoyama M., J. Barwell-Clarke, S. Becker, M. Blum, Braga E. S., S. C. Coverly, E. Czobik, I. Dahllorf, M. H. Dai, G. O. Donnell, C. Engelke, G. C. Gong, Gi-Hoon Hong, D. J. Hydes, M. M. Jin, H. Kasai, R. Kerouel, Y. Kiyomono, M. Knockaert, N. Kress, K. A. Kroglund, M. Kumagai, S. Leterme, Yarong Li, S. Masuda, T. Miyao, T. Moutin, A. Murata, N. Nagai, G. Nausch, M. K. Ngirchchol, A. Nybakk, H. Ogawa, J. van Ooijen, H. Ota, J. M. Pan, C. Payne, O. Pierre-Duplessix, M. Pujo-Pay, T. Raabe, K. Saito, K. Sato, C. Schmidt, M. Schuett, T. M. Shammon, J. Sun, T. Tanhua, L. White, E.M.S. Woodward, P. Worsfold, P. Yeats, T. Yoshimura, A. Youenou, J. Z. Zhang, 2008: 2006 Intercomparison Exercise for Reference Material for Nutrients in Seawater in a Seawater Matrix, Technical Reports of the Meteorological Research Institute No. 58, 104pp.
- Aoyama, M., Nishino, S., Nishijima, K., Matsushita, J., Takano, A., Sato, K., 2010a. Nutrients, In: R/V Mirai

- Cruise Report MR10-05. JAMSTEC, Yokosuka, pp. 103–122.
- Aoyama, M., Matsushita, J., Takano, A., 2010b. Nutrients, In: MR10-06 preliminary cruise report. JAMSTEC, Yokosuka, pp. 69–83
- 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.
- Grasshoff, K., Ehrhardt, M., Kremling K. et al. 1983. Methods of seawater analysis. 2nd rev. Weinheim: Verlag Chemie, Germany, West.
- Hydes, D.J., Aoyama, M., Aminot, A., Bakker, K., Becker, S., Coverly, S., Daniel, A., Dickson, A.G., Grosso, O., Kerouel, R., Ooijen, J. van, Sato, K., Tanhua, T., Woodward, E.M.S., Zhang, J.Z., 2010. Determination of Dissolved Nutrients (N, P, Si) in Seawater with High Precision and Inter-Comparability Using Gas-Segmented Continuous Flow Analysers, In: GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. IOCCP Report No. 14, ICPO Publication Series No 134.
- Joyce, T. and Corry, C. 1994. Requirements for WOCE hydrographic programmed data reporting. WHPO Publication, 90-1, Revision 2, WOCE Report No. 67/91.
- Kawano, T., Uchida, H. and Doi, T. WHP P01, P14 REVISIT DATA BOOK, (Ryoin Co., Ltd., Yokohama, 2009).
- 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. Analytical chim. Acta 27, 31–36.
- Sato, K., Aoyama, M., Becker, S., 2010. RMNS as Calibration Standard Solution to Keep Comparability for Several Cruises in the World Ocean in 2000s. In: Aoyama, M., Dickson, A.G., Hydes, D.J., Murata, A., Oh, J.R., Roose, P., Woodward, E.M.S., (Eds.), Comparability of nutrients in the world's ocean. Tsukuba, JAPAN: MOTHER TANK, pp 43–56.
- Uchida, H. and Fukasawa, M. WHP P6, A10, I3/I4 REVISIT DATA BOOK Blue Earth Global Expedition 2003 1, 2, (Aiwa Printing Co., Ltd., Tokyo, 2005).

## 3.6 Chlorofluorocarbons and Sulfur Hexafluoride

February 1, 2015

### (1) Personnel

Ken'ichi Sasaki	(MIO, JAMSTEC)
Hironori Sato	(MWJ)
Hideki Yamamoto	(MWJ)
Katsunori Sagishima	(MWJ)
Shoko Tatamisashi	(MWJ)
Masahiro Ohroi	(MWJ)

### (2) Objectives

Chlorofluorocarbons (CFCs) and sulfur hexafluoride ( $\text{SF}_6$ ) are man – made stable gases. These gases can slightly dissolve in sea surface water by air-sea gas exchange and then are spread into the ocean interior. These dissolved gases could be used as transient chemical tracers for the ocean circulation. We measured concentrations of three chemical species of CFCs, CFC-11 ( $\text{CCl}_3\text{F}$ ), CFC-12 ( $\text{CCl}_2\text{F}_2$ ) and CFC-113 ( $\text{C}_2\text{Cl}_3\text{F}_3$ ), and  $\text{SF}_6$  in seawater on board.

### (3) Apparatuses

Measurement of CFCs and  $\text{SF}_6$  were made with three gas chromatographs attached with purging and trapping systems (modified from the original design of Bullister and Weiss (1988)). Two of them were  $\text{SF}_6$ /CFCs simultaneous analyzing systems (System A & B). Another one was CFCs analyzing system (System D). These purging and trapping systems were developed in JAMSTEC.

#### (3.1) $\text{SF}_6$ /CFCs simultaneous analyzing systems (System A &B)

Cold trap columns are 30 cm length stainless steel tubing packed the section of 5 cm with 100/120 mesh

Porapak T and followed by the section of 5 cm of 100/120 mesh Carboxen 1000. Outer diameters of the main and focus trap columns are 1/8" and 1/16", respectively.

Each gas chromatograph (GC-14B, Shimadzu LTD) has two electron capture detectors, ECD1 and ECD2 (both ECDs: ECD-14, Shimadzu LTD). A pre-column is Silica Plot capillary column [i.d.: 0.32 mm, length: 10 m, film thickness: 4  $\mu\text{m}$ ]. There are two main analytical columns. Main column 1 (MC1) is MS 5A packed column [1/16" OD, 10 cm length stainless steel tubing packed the section of 7 cm with 80/100 mesh Molecular Sieve 5A] followed by Gas Pro capillary column [i.d.: 0.32 mm, length: 35 m] connected up to ECD1 for  $\text{SF}_6$  and CFC-12. Main column 2 (MC2) is Silica Plot capillary column [i.d.: 0.32 mm, length: 30 m, film thickness: 4  $\mu\text{m}$ ] connected up to ECD2 for CFC-11 and CFC-113.

#### (3.2) CFCs System (System D)

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

A Gas chromatograph (GC-14B, Shimadzu LTD) in this system has single ECD (ECD-14, Shimadzu LTD). A pre column is Silica Plot capillary column [i.d.: 0.53 mm, length: 6 m, film thickness: 6  $\mu\text{m}$ ]. A main column is Pola Bond-Q capillary column [i.d.: 0.53 mm, length: 9 m, film thickness: 10  $\mu\text{m}$ ] followed by Silica Plot capillary column [i. d.: 0.53 mm, length: 18 m, film thickness: 6  $\mu\text{m}$ ].

### (4) Shipboard measurements

#### (4.1) Sampling

The marine water sampler was cleaned by diluted acetone before every CTD cast. Seawater sub-samples were collected from 12 liter Niskin bottles to 450 ml of glass bottles. The sub-sampling bottles were filled by pure nitrogen gas before sub-sampling. Two times of the bottle volumes of seawater sample were overflowed. The bottles filled by seawater samples were kept in thermostatic water bath (7°C). The CFC and  $\text{SF}_6$  concentrations were determined within 24 hours.

In order to confirm stabilities of standard gases and to check saturation levels of CFCs and  $\text{SF}_6$  in sea surface water, mixing ratios of CFCs and  $\text{SF}_6$  in background air collected on high sea were periodically

analyzed. Air sample was continuously led into the Environmental Research Laboratory of R/V MIRAI by 10 mm OD Dekaron tubing. The end of the tubing was put on a head of the Compass Deck and another end was connected onto an air pump in the laboratory. The tubing was relayed by a T-type union which had a small stop cock. Air sample was collected from the continuously flowing air into a 200 ml glass syringe attached on the cock. Average mixing ratios of the atmospheric CFC-11, CFC-12, CFC-113, and SF<sub>6</sub> were 229.7 ± 11.7 ppt, 525.4 ± 5.9 ppt, 71.0 ± 3.2 (n ~ 140), and 7.60 ± 0.22 ppt (n ~ 90), respectively.

## **(4.2) Analyses**

### **(4.2.1) SF<sub>6</sub>/CFCs simultaneous analyses (System A &B)**

Constant volume of sample water (200 ml) was taken into a sample loop. The aliquot was sent into stripping chamber and dissolved gases were extracted by pure nitrogen gas purging for 8 minutes. The gaseous sample was dried by magnesium perchlorate desiccant and concentrated on a main trap column cooled to -80°C. Stripping efficiencies were frequently confirmed by re-stripping of surface layer samples and more than 98 % of dissolved SF<sub>6</sub> and CFCs were extracted on the first purge. Following purging & trapping, the main trap column was isolated and heated to 170°C for 1 minute. The desorbed gases were sent onto focusing trap cooled to -80°C for 30 sec and then the trap was isolated. Gaseous sample on the focusing trap were desorbed by heating to 170°C for 1 minute and led into the pre-column. Sample gases were roughly separated in the pre-column. When SF<sub>6</sub> and CFC-12 were sent onto MC1 (and CFC-11 and CFC-113 still remain on the pre-column), main columns were switched (pre-column was followed by MC2 and another carrier gas line was connected up to MC1). SF<sub>6</sub> and CFC-12 were further separated and detected by the ECD1. CFC-11 and CFC-113 led onto MC 2 were detected by ECD2. When CFC-113 eluted from pre-column onto MC 2, the pre-column was switched onto another line and remaining compounds on the pre-column were back flushed. Temperature of the analytical column and ECD was 95 and 300°C. Mass flow rates of nitrogen gas were 5, 32, 6 and 220 ml/min for carrier gases, detector make up gases, back flush gas and seawater sample purging, respectively. Gas loops whose volumes were 0.05, 0.15, 0.3, 1, 3 and 10 ml were used for introducing standard gases into the analytical system. Calibration curves were made every several days and standard

gas analyses using largest loop (10 ml) were performed more frequently to monitor change in the detector sensitivity.

### **(4.2.2) CFCs analyses (System D)**

These systems were somewhat simple compared with the system A & B. Volume of water sample loop was 50 ml. Gas extraction time was for 8 minutes. Cooling and heating temperatures of trap column were -50 and 140°C, respectively. There was not focusing trap in the system. Stripping efficiencies were more than 99.5 % of dissolved CFCs on the first purge. Temperatures of the analytical column and ECD were 95 and 240°C. Mass flow rates of nitrogen gas were 10, 27, 15 and 120 ml/min for carrier, detector make up, back flush and seawater sample purging gases, respectively. There were three gas loops whose volumes were 1, 3 and 10 ml, respectively.

### **(4.2.3) Standard gases**

The standard gasses had been made by Japan Fine Products co. ltd. Standard gas cylinder numbers used in this cruise were listed in [Table 3.6.1](#). Cylinder of CPB15651 was used as reference gas. Precise mixing ratios of CFCs/SF<sub>6</sub> in the standard gases were calculated by gravimetric data. The standard gases have not been calibrated to SIO scale standard gases yet because SIO scale standard gasses were hard to obtain due to legal difficulties for CFCs import into Japan. The data would be corrected as soon as possible when we obtained the SIO scale standard gases.

## **(5) Quality control**

### **(5.1) Blanks**

Blanks (from sub-sampling and analytical systems) are confirmed by several analyses of CFC free water which is made from deep water purging by moist nitrogen gas in a glass chamber (10 L). Concentrations of CFC-11 and CFC-12 in the CFC free water are 0.015 ± 0.009, 0.005 ± 0.004 pmol kg<sup>-1</sup> (n = 3), respectively. These values are close to previous blanks (0.011 ± 0.003 and 0.005 ± 0.002 pmol kg<sup>-1</sup> for CFC-11 and CFC-

12, respectively) estimated from a number of analyses ( $N \approx 700$ ) of deep water in the North Pacific in 2011 (Sasaki et al., 2014). Blank values in this cruise are assumed as equivalent to the previously estimated blanks and were subtracted from all data. Significant CFC-113 and SF<sub>6</sub> were not detected in the CFC free water.

### (5.2) Major problems

Sensitivities of detectors on the System B were dramatically varied during seawater sample analysis for stations P14S-001,-003,-012, -015, -018, -020, -023, S04-404. A number of measurements for these stations are flagged '4' because it is too difficult to define adequate correction factors for the sensitivity variations.

### (5.3) Precisions

The analytical precisions were estimated from replicate sample analyses ( $N \sim 530$  pairs for CFC-12, CFC-11, and CFC-113, and 340 pairs for SF<sub>6</sub> measurements). The replicate samples were collected from four sampling depths which were around 50, 600, 1300, and 4000 m depths in every station. Precisions were estimated as better than  $\pm 0.002$  pmol kg<sup>-1</sup> or 1 % for CFC-11,  $\pm 0.004$  pmol kg<sup>-1</sup> or 1 % for CFC-12,  $\pm 0.002$  pmol kg<sup>-1</sup> or 5 % for CFC-113, and  $\pm 0.030$  fmol kg<sup>-1</sup> or 6% for SF<sub>6</sub>(whichever is greater), respectively.

### (6) References

- 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).
- Sasaki, K., K. Sagishima, S. Tatamisashi, H. Sato, and M. Orui, Chlorofluorocarbons and Sulfur Hexafluoride, *WHP P10 Revisit in 2011 Data Book*, H. Uchida et al. (Eds.), JAMSTEC, Yokosuka, Kanagawa, Japan, 72-75 (2014).

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

Cylinder No.	Base	CFC-11	CFC-12	CFC-113	SF <sub>6</sub>	remarks
		ppt	ppt	ppt	ppt	
CPB26845	Air	1304	649	130	9.99	SF <sub>6</sub> /CFC, Leg 2
CPB25863	Air	1301	649	130	10.00	SF <sub>6</sub> /CFC, Leg 2,3
CPB17252	Air	1304	652	130	9.93	SF <sub>6</sub> /CFC, Leg 3
CPB30572	Air	1301	651	130	9.98	SF <sub>6</sub> /CFC, Leg 3
CPB07911	N <sub>2</sub>	302	159	30.0	0.0	CFC, Leg 2,3
CPB15651	N <sub>2</sub>	299	159	30.2	0.0	CFC, Reference

## 3.7 Carbon Items ( $C_T$ , $A_T$ and pH)

December 19, 2014

### (1) Personnel

Akihiko Murata (JAMSTEC)

Yoshiko Ishikawa (MWJ)

Tomonori Watai (MWJ)

Emi Deguchi (MWJ)

Atsushi Ono (MWJ)

Keisuke Tsubata (MWJ)

### (2) Objectives

According to the latest report from Intergovernmental Panel on Climate Change, concentrations of  $CO_2$  in the atmosphere have increased by 40% since pre-industrial times owing to human activities such as burning of fossil fuels, deforestation, and cement production. It is evaluated that the ocean has absorbed about 30% of the emitted anthropogenic  $CO_2$ . It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric  $CO_2$ , and to clarify the mechanism of the  $CO_2$  absorption, because the magnitude of future global warming depends on the levels of  $CO_2$  in the atmosphere.

The Southern Ocean is one of the regions where uncertainty of uptake of anthropogenic  $CO_2$  is large. In this cruise, therefore, we were aimed at quantifying how much anthropogenic  $CO_2$  is absorbed in the ocean interior of the Southern Ocean. For the purpose, we measured  $CO_2$ -system parameters such as dissolved inorganic carbon ( $C_T$ ), total alkalinity ( $A_T$ ) and pH mainly along the WHP P14S and S04I lines at  $\sim 170^\circ E$  and  $\sim 60^\circ S$ , respectively, in the Southern Ocean.

### (3) Apparatus

#### i. $C_T$

Measurement of  $C_T$  was made with two total  $CO_2$  measuring systems (called as Systems C and D, respectively; Nippon ANS, Inc.), which were slightly different from each other. The systems comprised of a seawater dispensing system, a  $CO_2$  extraction system and a coulometer. In this cruise, we used a same type (Model 3000, Nippon ANS) of coulometers, for Systems C and D, respectively. Each of the two systems had almost a same specification as follows:

The seawater dispensing system has an auto-sampler (6 ports), which dispenses seawater from a 300 ml borosilicate glass bottle into a pipette of about 15 ml volume by PC control. The pipette is kept at  $20^\circ C$  by a water jacket, in which water from a water bath set at  $20^\circ C$  is circulated.  $CO_2$  dissolved in a seawater sample is extracted in a stripping chamber of the  $CO_2$  extraction system by adding phosphoric acid ( $\sim 10\%$  v/v) of about 2 ml. The stripping chamber is approx. 25 cm long and has a fine frit at the bottom. The acid is added to the stripping chamber from the bottom of the chamber by pressurizing an acid bottle for a given time to push out the right amount of acid. The pressurizing is made with nitrogen gas (99.9999 %). After the acid is transferred to the stripping chamber, a seawater sample kept in a pipette is introduced to the stripping chamber by the same method as in adding an acid. The seawater reacted with phosphoric acid is stripped of  $CO_2$  by bubbling the nitrogen gas through a fine frit at the bottom of the stripping chamber. The  $CO_2$  stripped in the chamber is carried by the nitrogen gas (flow rates is  $140\text{ ml min}^{-1}$ ) to the coulometer through a dehydrating module. The modules of Systems C and D consist of two electric dehumidifiers (kept at  $\sim 4^\circ C$ ) and a chemical desiccant ( $Mg(ClO_4)_2$ ).

The measurement sequence such as system blank (phosphoric acid blank), 1.865 %  $CO_2$  gas in a nitrogen base, sea water samples (6) is programmed to repeat. The measurement of 1.865 %  $CO_2$  gas is made to monitor response of coulometer solutions purchased from UIC, Inc. or laboratory-made.

## ii. $A_T$

Measurement of  $A_T$  was made based on spectrophotometry using a custom-made system (Nippon ANS, Inc.). The system comprises of a water dispensing unit, an auto-burette (765 Dosimat, Metrohm), and a spectrophotometer (Carry 50 Bio, Varian), which are automatically controlled by a PC. The water dispensing unit has a water-jacketed pipette and a water-jacketed titration cell. The spectrophotometer has a water-jacketed quartz cell, length and volume of which are 8 cm and 13 ml, respectively. To circulate sample seawater between the titration and the quartz cells, PFA tubes are connected to the cells.

A seawater of approx. 42 ml is transferred from a sample bottle (borosilicate glass bottle; 130 ml) into the water-jacketed (25 °C) pipette by pressurizing the sample bottle (nitrogen gas), and is introduced into the water-jacketed (25 °C) titration cell. The seawater is circulated between the titration and the quartz cells by a peristaltic pump to rinse the route. Then, Milli-Q water is introduced into the titration cell, and is circulated in the route twice to rinse the route. Next, a seawater of approx. 42 ml is weighted again by the pipette, and is transferred into the titration cell. The weighted seawater is introduced into the quartz cell. Then, for seawater blank, absorbances are measured at three wavelengths (750, 616 and 444 nm). After the measurement, an acid titrant, which is a mixture of approx. 0.05 M HCl in 0.65 M NaCl and bromocresol green (BCG) is added (about 2.1 ml) into the titration cell. The seawater + acid titrant solution is circulated for 6 minutes between the titration and the quartz cells, with stirring by a stirring tip and bubbling by wet nitrogen gas in the titration cell. Then, absorbances at the three wavelengths are measured.

Calculation of  $A_T$  is made by the following equation:

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

where  $M_A$  is the molarity of the acid titrant added to the seawater sample,  $[H^+]_T$  is the total excess hydrogen ion concentration in the seawater, and  $V_S$ ,  $V_A$  and  $V_{SA}$  are the initial seawater volume, the added acid titrant volume, and the combined seawater plus acid titrant volume, respectively.  $[H^+]_T$  is calculated from the measured absorbances based on the following equation (Yao and Byrne, 1998):

$$pH_T = -\log[H^+]_T = 4.2699 + 0.002578(35 - S) + \log((R - 0.00131)/(2.3148 - 0.1299R)) - \log(1 - 0.001005S),$$

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

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

where  $A_i$  is the absorbance at wavelength  $i$  nm.

The HCl in the acid titrant is standardized on land. The concentrations of BCG were estimated to be approx.  $2.0 \times 10^{-6}$  M in the sample seawater.

## iii. pH

Measurement of pH was made by a pH measuring system (Nippon ANS, Inc.). For the detection of pH, spectrophotometry was adopted. The system comprises of a water dispensing unit and a spectrophotometer (Bio 50 Scan, Varian). For an indicator, m-cresol purple (2 mM) was used.

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 is kept at  $25.00 \pm 0.05$  °C in a thermostated compartment. First, absorbance of seawater only is measured at three wavelengths (730, 578 and 434 nm). Then the indicator is injected and circulated for about 4 minutes to mix the indicator and seawater sufficiently. After the pump is stopped, the absorbance of seawater + indicator is measured at the same wavelengths. The pH is calculated based on the following equation (Clayton and Byrne, 1993):

$$\text{pH} = \text{pK}_2 + \log\left(\frac{A_1/A_2 - 0.00691}{2.2220 - 0.1331(A_1/A_2)}\right),$$

where  $A_1$  and  $A_2$  indicate absorbance at 578 and 434 nm, respectively, and  $\text{pK}_2$  is calculated as a function of water temperature and salinity.

#### (4) Shipboard measurement

##### (4.1) Sampling

###### i. $C_T$

All seawater samples were collected from depth with 12 liter Niskin bottles basically at every other stations. The seawater samples for  $C_T$  were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into a 300 ml borosilicate glass bottle. The glass bottle was 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 ship, a headspace of approx. 1 % of the bottle volume was made by removing seawater with a plastic pipette. A saturated mercuric chloride of 100  $\mu\text{l}$  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 5 °C in a refrigerator until analysis. A few hours just before analysis, the seawater samples were kept at 20 °C in a water bath.

###### ii. $A_T$

All seawater samples were collected from depth using 12 liter Niskin bottles basically at every other stations. The seawater samples for  $A_T$  were taken with a plastic drawing tube (PFA tubing connected to silicone rubber tubing) into borosilicate glass bottles of 130 ml. The glass bottle was filled with seawater smoothly from the bottom after rinsing it with a seawater of half a or a full bottle volume. A few hours before analysis, the seawater samples were kept at 25 °C in a water bath.

###### iii. pH

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  $C_T$  sampling. The glass bottle was filled with seawater smoothly from the bottom following a rinse with a sea water of 2 full, bottle volumes. The glass bottle was closed by a stopper, which was fitted to the bottle mouth gravimetrically without additional force.

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

##### (4.2) Analysis

###### i. $C_T$

At the start of each leg, we calibrated the measuring systems by blank and 5 kinds of  $\text{Na}_2\text{CO}_3$  solutions (nominally 500, 1000 1500, 2000, 2500  $\mu\text{mol/L}$ ). 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 measured 2%  $\text{CO}_2$  gas repeatedly until the measurements became stable. Then we started the calibration.

The measurement sequence such as system blank (phosphoric acid blank), 2 %  $\text{CO}_2$  gas in a nitrogen base, seawater samples (6) was programmed to repeat. The measurement of 2 %  $\text{CO}_2$  gas was made to monitor response of coulometer solutions (from UIC, Inc. or in-house made). For every renewal of coulometer solutions, certified reference materials (CRMs, batch 121, certified value = 2039.26  $\mu\text{mol kg}^{-1}$ ) provided by Prof. A. G. Dickson of Scripps Institution of Oceanography were analyzed. In addition, in-house reference materials (RM) (batch QRM Q23 and Q26 for leg 2 and leg 3, respectively) were measured at the initial, intermediate and end times of a coulometer solution's lifetime.

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

In the cruise, we finished all the analyses for  $C_T$  on board the ship. As we used two systems, we had not encountered such a situation as we had to abandon the measurement due to time limitation.

## ii. $A_T$

We analyzed reference materials (RM), which were produced for  $C_T$  measurement by JAMSTEC, but were efficient also for the monitor of  $A_T$  measurement. In addition, certified reference materials (CRM, batches 121, certified value =  $2225.01 \mu\text{mol kg}^{-1}$ ) were also analyzed periodically to monitor systematic differences of measured  $A_T$ . The reported values of  $A_T$  were set to be traceable to the certified value of the batch 121.

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

In the cruise, we finished all the analyses for  $A_T$  on board the ship. We did not encounter so serious problems as we had to give up the analyses.

## iii. pH

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

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

Absorbances of seawater only and seawater + indicator solutions were measured 11 times each, and the last value was used for the calculation of pH.

The preliminary values of pH were reported in a data sheet on the ship. Repeatability calculated from

replicate samples and vertical profiles of pH based on raw data for each station helped us check performance of the measuring system.

We finished all the analyses for pH on board the ship. We did not encounter so serious a problem as we had to give up the analyses.

## (5) Quality control

### i. $C_T$

We conducted quality control of the data after return to a laboratory on land. With calibration factors, which had been determined on board a ship based on blank and 5 kinds of  $\text{Na}_2\text{CO}_3$  solutions, we calculated  $C_T$  of CRM (batches 121), 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.

The repeatability of measurements was estimated to be  $0.6 \mu\text{mol kg}^{-1}$ , which was calculated from 274 differences of replicate measurements.

### ii. $A_T$

Temporal changes of  $A_T$ , which originate from analytical problems, were monitored by measuring  $A_T$  of CRM. We found no abnormal measurements during the cruises.

The repeatability of measurements was estimated to be  $0.6 \mu\text{mol kg}^{-1}$ , which was calculated from 211 differences of replicate measurements.

### iii. pH

It is recommended that correction for pH change resulting from addition of indicator solutions is made (Dickson et al., 2007). 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 (Dickson et al., 2007), although the perturbations were small. [Figure 3.7.1](#) illustrates a perturbation of absorbance ratios by adding indicator solutions for leg 2 in MR12-05 cruise. For

leg 3, the tendency was not significant statistically. Thus for correction, a value of  $6.3364 \times 10^{-5}$  was subtracted from the measured values. The reported values, which are the total scale, were set to the values at 25°C by the CO<sub>2</sub> system calculation using data for pH and C<sub>T</sub> with K1 and K2 from Mehrbach *et al.* (1973) refit by Dickson and Millero (1987).

The repeatability of measurements was estimated to be 0.0005 pH unit, which was calculated from 318 differences of replicate measurements.

During the cruise, we measured in-house TRIS buffers to monitor performance of the measuring system. Different lots of TRIS buffers were used for legs 2 and 3 of MR12-05. Averaged differences between measured and calculated pH of the TRIS buffers were  $0.0089 \pm 0.0011$  (n=37) and  $0.0140 \pm 0.0012$  (n=36) for legs 2 and 3, respectively. From these results, we decided to correct measured values of pH by subtracting 0.0089 and 0.0140 from the measured values for each cruise.

After correction, we evaluated accuracy of pH values by comparing the corrected values with those computed from measured C<sub>T</sub> and A<sub>T</sub>. Averaged differences (corrected – computed) were  $0.0059 \pm 0.0054$  and  $-0.0019 \pm 0.0056$  for legs 2 and 3, respectively.

## References

- Clayton T. D. and R. H. Byrne (1993) Spectrophotometric seawater pH measurements: total hydrogen ion concentration scale calibration of m-cresol purple and at-sea results. *Deep-Sea Research* 40, 2115-2129.
- Dickson A. G. and F. J. Millero (1987) A comparison of the equilibrium constants for the dissociation of carbonic acid in seawater media, *Deep-Sea Research*, 34, 1733–1743.
- Dickson, A. G., C. L. Sabine and J. R. Christian eds. (2007), *Guide to best practices for ocean CO<sub>2</sub> measurements*, PICES Special Publication 3, 191 pp.
- Mehrbach, C., C. H. Culberson, J. E. Hawley and R. M. Pytkowicz (1973) Measurement of the apparent dissociation constants of carbonic acid in seawater at atmospheric pressure. *Limnology and Oceanography*, 18, 897-907.
- Yao, W. and R. B. Byrne (1998) Simplified seawater alkalinity analysis: Use of linear array spectrometers.

*Deep-Sea Research* 45, 1383-1392.

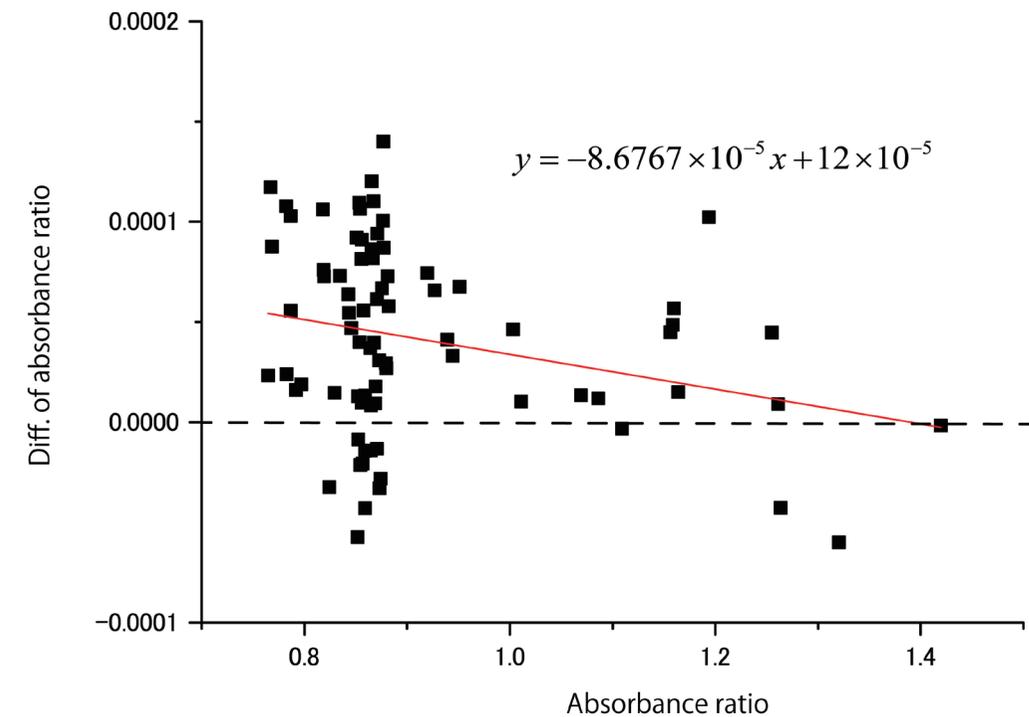


Figure 3.7.1. Perturbation of absorbance ratios by adding indicator. The line was determined by the method of least squares.

### 3.8 Chlorophyll *a*

May 10, 2013

#### (1) Personnel

Hiroshi Uchida (JAMSTEC)

Osamu Yoshida (Rakuno Gakuen University) (Leg 3)

Haruka Tamada (Rakuno Gakuen University) (Leg 3)

Yuko Kanayama (Rakuno Gakuen University) (Leg 3)

Okura Shinozaki (Rakuno Gakuen University) (Leg 3)

Kanako Yoshida (MWJ) (Legs 1, 3)

Hideki Yamamoto (MWJ) (Leg 2)

#### (2) Objectives

Chlorophyll *a* is one of the most convenient indicators of phytoplankton stock, and has been used extensively for the estimation of phytoplankton abundance in various aquatic environments. In this study, we investigate horizontal and vertical distribution of phytoplankton. The chlorophyll *a* data is also used for calibration of fluorometers used in the surface water monitoring and the CTD profiler measurements.

#### (3) Instrument and Method

Seawater samples were collected in 500 or 250 ml brown Nalgene bottles without head-space. The whole sampled water were gently filtrated by low vacuum pressure (<0.02 MPa) through Whatman GF/F filter (diameter 25 mm) in the dark room. Whole volume of each sampling bottle was precisely measured in advance. Phytoplankton pigments were immediately extracted in 7 ml of N,N-dimethylformamide (DMF) after filtration and then, the samples were stored at  $-20^{\circ}\text{C}$  under the dark condition to extract chlorophyll *a* for more than 24 hours. Fluorescence of the extracted samples was measured by the Turner fluorometer (10-AU-005, TURNER DESIGNS) which was previously calibrated against a pure chlorophyll *a* (Sigma-Aldrich Co.,

LLC). We applied the fluorometric “Non-acidification method” (Welschmeyer, 1994).

#### (4) Results

Chlorophyll *a* data obtained during the cruise are shown in Fig. 3.8.1. To estimate measurement precision, 20 pairs of replicate samples were obtained from hydrographic casts during leg 3. Ten pairs of the replicate samples were collected in 500 ml and 250 ml bottles. Difference between samples collected in 500 ml and 250 ml was small ( $\leq 0.02 \mu\text{g/L}$ ). Standard deviation from 20 pairs of the replicate samples was  $0.018 \mu\text{g/L}$ , although absolute difference was smaller than  $0.01 \mu\text{g/L}$  for 16 pairs of the replicate samples.

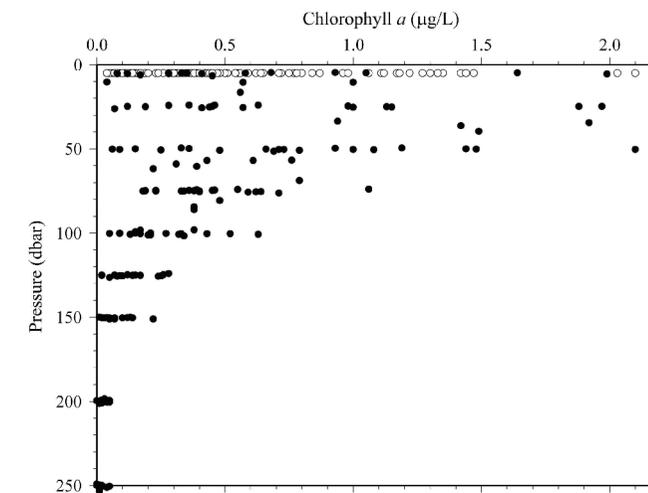


Figure 3.8.1. Vertical distribution of chlorophyll *a* obtained from hydrographic casts (closed circles) and surface water monitoring system (open circles).

#### Reference

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

### 3.9 LADCP

September 30, 2014

#### (1) Personnel

Shinya Kouketsu (JAMSTEC)

Hiroshi Uchida (JAMSTEC)

Katsuro Katsumata (JAMSTEC)

Toshimasa Doi (JAMSTEC)

#### (2) Overview of the equipment

An acoustic Doppler current profiler (ADCP) was integrated with the CTD/RMS package. The lowered ADCP (LADCP), Workhorse Monitor WHM300 (Teledyne RD Instruments, San Diego, California, USA), which has 4 downward facing transducers with 20-degree beam angles, rated to 6000 m. The LADCP makes direct current measurements at the depth of the CTD, thus providing a full profile of velocity. The LADCP was powered during the CTD casts by a 50.4 volts expendable Alkali battery pack. The LADCP unit was set for recording internally prior to each cast. After each cast the internally stored observed data was uploaded to the computer on-board. By combining the measured velocity of the sea water and bottom with respect to the instrument, and shipboard navigation data during the CTD cast, the absolute velocity profile can be obtained (e.g., Visbeck, 2002).

The instrument used in this cruise was Teledyne RD Instruments, WHM300(S/N 183240).

#### (3) Data collection

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

Bin size: 4 m

Number of bins: 25

Pings per ensemble: 1

Ping interval: 1 sec

#### (4) Data collection problems

Echo intensities are sufficiently high along the section (Fig. 3.9.1), except at the stations of 9. Since the weak echo were observed for all the beams, the weakness was not due to the instrument problem.

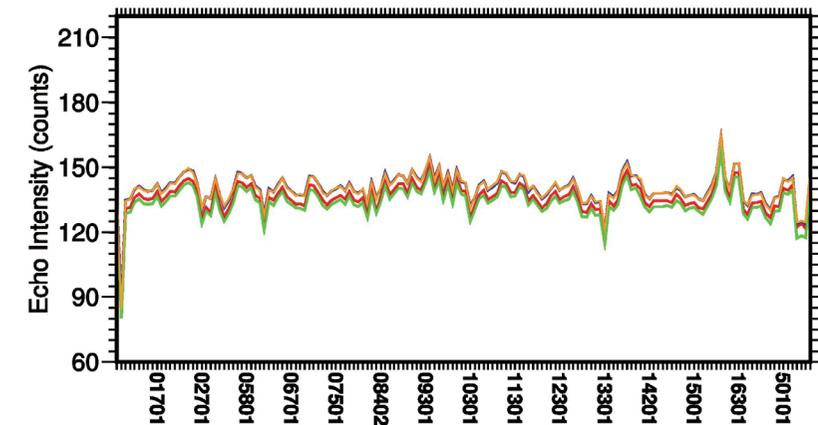


Figure 3.9.1. Cast-averaged echo intensities at the first bin. Red, blue, green and orange denote beam 1, 2, 3, and 4 respectively.

#### (4) Data process

Vertical profiles of velocity are obtained by the inversion method (Visbeck, 2002). Since the first bin from LADCP is influenced by the turbulence generated by CTD frame, the weight for the inversion is set to 0.1. GPS navigation data and the bottom-track data are used in the calculation of the reference velocities. Shipboard ADCP data averaged for 9 minute are also included in the calculation. The CTD data are used for the sound speed and depth calculation. The directions of velocity are corrected using the magnetic deviation estimated with International Geomagnetic reference field data.

However, the inversion method doesn't work well due to no-good velocity data due to the instrument problems as well as weak echo intensity at deep layers.

### **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.

### 3.10 Expendable Microstructure Profiler

September 30, 2014

#### (1) Personnel

Katsuro Katsumata (JAMSTEC)

#### (2) Objectives

Turbulence mixing in the ocean has been a difficult quantity to measure directly despite its important role in the ocean energy budget and general circulation dynamics. Recent improvements on materials such as optic fibre and on sensors such as high precision shear probes now enable the measurement using expendable microstructure profilers (XMP).

#### (3) Apparatus

XMP probe and its tow frame were manufactured by Rockland Scientific International, Canada. The expendable sensor has a cylindrical shape with a length of about 152 cm and a diameter of 18 cm. Two shear sensors, one temperature sensor, a pressure sensor, and an accelerometer are mounted on the deeper tip of the cylinder. The tail is fringed with plastic drag brushes to stabilise its drop rate.

The shear sensors measure the shear at a  $2.5 \times 10^{-3} \text{ s}^{-1}$  rms resolution. Least squares fit of the shear spectrum to the Nasmyth theoretical curve yields an estimate of the turbulent kinetic energy dissipation rate. The instrument oscillation is measured by the accelerometer and corrected during the spectrum estimation

*R/V Mirai's* A-frame was used to deploy the prove attached to the tow frame. The prove was released underwater. The measured data were transmitted to a computer in a laboratory through an optic fibre. Twelve kilometre of the fibre on a spool was used and the fibre freely came off the spool as the prove descended underwater. The fall rate was about 0.8 m/s initially but slowed down to less than 0.5 m/s at 2000 dbar as more fibre was dragged in the water. The fibre spool was mounted underwater (about 10 m depth) in a tow frame which was towed from the stern of the vessel. The vessel travelled no faster than 2 knots *relative*

to water.

The turbulent kinetic energy dissipation rate  $\epsilon$  was estimated by

$$\epsilon = \frac{15}{2} \nu \overline{u_z^2},$$

where  $\nu$  is the kinematic molecular viscosity of water and  $u_z$  is the vertical derivative of the horizontal velocity and the overbar denotes a spatial or ensemble averaging. Detailed description of the principle and sensors can be found in Lueck *et al.* (2002).

#### (4) Deployments

Six probes were deployed at six different CTD stations right after the CTD cast. Two were deployed within an area where, at the time of writing, a problem was detected in foreign clearance request documents, hence the data are not disclosed. The details of other deployments are shown below. The year is 2012.

S/N	Latitude	Longitude	Depth	Start (UT)	End (UT)
30	58-01.52°S	173-59.97°E	5201 m	6 Dec 13:06	6 Dec 14:47
31	58-30.33°S	173-58.98°E	5005 m	6 Dec 20:42	7 Dec 00:11
28	62-45.99°S	172-12.97°E	4264 m	9 Dec 05:34	9 Dec 05:37
26	63-59.72°S	171-07.46°E	2557 m	9 Dec 20:55	9 Dec 22:23

#### (5) Results

The realtime pressure reading indicated that Serial Number (SN) 31 and 26 survived to the sea bottom. SN 30 and 28 lost connection at about 2500 dbar and 30 dbar, respectively. Fig. 3.10.1 shows the vertical distribution of the eddy kinetic energy dissipation rate, tentatively estimated by quick\_look\_XMP.m in the ODAS library. The method for estimating the dissipation rate follows that of Lueck *et al.* (2002).

## References

Lueck, R.G., F. Wolk, and H. Yamazaki (2002) Oceanic Velocity Microstructure Measurements in the 20th Century. *Journal of Oceanography* 58, 153-174.

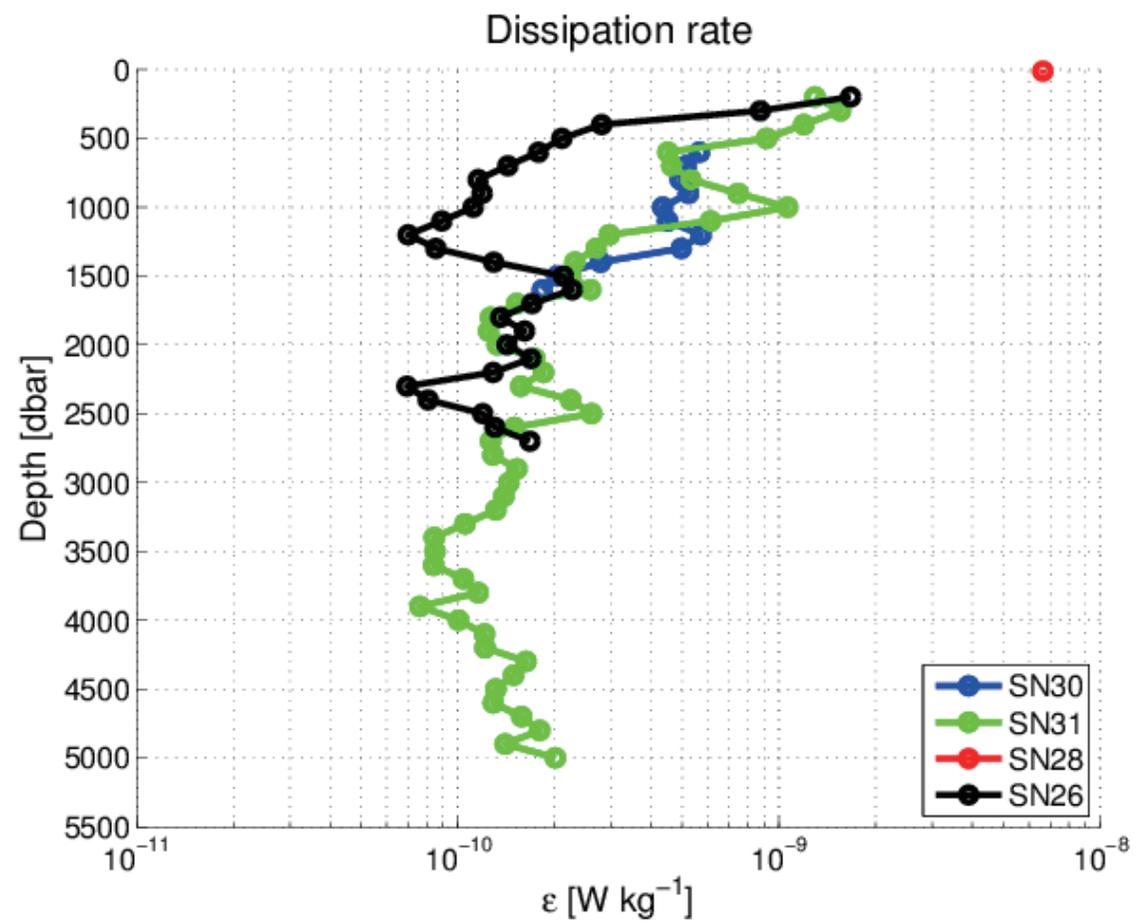


Figure 3.10.1. Kinetic energy dissipation rate estimated at intervals of 100-300 dbar, 200-400 dbar and so forth using quick\_look\_XMP.m in the ODAS library. Out of two sensors, the one which produced smaller dissipation estimate was plotted.

# Station Summary

R/V MIRAI CRUISE MR1205 LEG1

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
49NZ20121105	999	301	1	UNK	110612	0911	UN 40	29.82 N	141 47.86 E	GPS	-9	-9	-9				89	THROUGH HULL PUMP
49NZ20121105	999	302	1	UNK	110612	1239	UN 39	59.48 N	142 8.49 E	GPS	-9	-9	-9				89	THROUGH HULL PUMP
49NZ20121105	999	303	1	UNK	110612	1527	UN 39	31.61 N	142 20.15 E	GPS	-9	668	-9				89	THROUGH HULL PUMP
49NZ20121105	999	304	1	UNK	110612	1826	UN 39	1.84 N	142 26.01 E	GPS	-9	1079	-9				89	THROUGH HULL PUMP
49NZ20121105	999	305	1	UNK	110612	2117	UN 38	28.75 N	142 32.48 E	GPS	-9	1141	-9				89	THROUGH HULL PUMP
49NZ20121105	999	306	1	UNK	110612	2337	UN 38	3.27 N	142 37.03 E	GPS	-9	1286	-9				89	THROUGH HULL PUMP
49NZ20121105	999	307	1	UNK	110712	0224	UN 37	30.97 N	142 43.39 E	GPS	-9	2157	-9				89	THROUGH HULL PUMP
49NZ20121105	999	308	1	UNK	110712	0444	UN 37	3.50 N	142 49.11 E	GPS	-9	4160	-9				89	THROUGH HULL PUMP
49NZ20121105	999	309	1	UNK	110712	0732	UN 36	31.65 N	142 55.32 E	GPS	-9	6676	-9				89	THROUGH HULL PUMP
49NZ20121105	999	310	1	UNK	110712	1400	UN 36	5.60 N	143 0.96 E	GPS	-9	4197	-9				89	THROUGH HULL PUMP
49NZ20121105	999	311	1	UNK	110712	1652	UN 35	32.57 N	143 8.80 E	GPS	-9	6072	-9				89	THROUGH HULL PUMP
49NZ20121105	999	312	1	UNK	110712	1921	UN 35	3.79 N	143 15.05 E	GPS	-9	5485	-9				89	THROUGH HULL PUMP
49NZ20121105	999	313	1	UNK	110812	0041	UN 34	0.85 N	143 30.01 E	GPS	-9	5357	-9				89	THROUGH HULL PUMP
49NZ20121105	999	314	1	UNK	110812	0529	UN 33	1.74 N	143 43.68 E	GPS	-9	5382	-9				89	THROUGH HULL PUMP
49NZ20121105	999	315	1	UNK	110812	1015	UN 32	2.33 N	143 57.01 E	GPS	-9	5659	-9				89	THROUGH HULL PUMP
49NZ20121105	999	316	1	UNK	110812	1434	UN 31	5.49 N	144 10.18 E	GPS	-9	5778	-9				89	THROUGH HULL PUMP
49NZ20121105	999	317	1	UNK	110912	0002	UN 29	2.20 N	144 37.73 E	GPS	-9	6000	-9				89	THROUGH HULL PUMP
49NZ20121105	999	318	1	UNK	110912	0942	UN 27	3.88 N	145 3.14 E	GPS	-9	3720	-9				89	THROUGH HULL PUMP
49NZ20121105	999	319	1	UNK	110912	1952	UN 25	2.24 N	145 29.51 E	GPS	-9	5595	-9				89	THROUGH HULL PUMP
49NZ20121105	999	320	1	UNK	111212	0442	UN 14	4.77 N	149 14.03 E	GPS	-9	4638	-9				89	THROUGH HULL PUMP
49NZ20121105	999	321	1	UNK	111212	0359	BE 14	7.07 N	149 13.51 E	GPS	-9	5707	-9					3-AXIS MAGNETOMETER CALIBRATION
49NZ20121105	999	321	1	UNK	111212	0424	EN 14	6.57 N	149 13.51 E	GPS	-9	5693	-9					3-AXIS MAGNETOMETER CALIBRATION
49NZ20121105	999	C01	1	ROS	111212	0556	BE 14	0.01 N	149 16.00 E	GPS	-9	5130	-9					
49NZ20121105	999	C01	1	ROS	111212	0632	BO 14	0.13 N	149 15.84 E	GPS	-9	5110	-9	1983	2001		36 1,2	
49NZ20121105	999	C01	1	ROS	111212	0736	EN 14	0.30 N	149 15.70 E	GPS	-9	5037	-9					
49NZ20121105	999	C01	1	FLT	111212	0744	DE 14	0.21 N	149 15.77 E	GPS	-9	5020	-9					ARGO 112258
49NZ20121105	999	322	1	BIO	111212	0757	BE 13	59.90 N	149 15.91 E	GPS	-9	5111	-9					NEUSTON NET
49NZ20121105	999	322	1	BIO	111212	0954	EN 13	56.82 N	149 17.81 E	GPS	-9	5977	-9					NEUSTON NET
49NZ20121105	999	C02	1	ROS	111212	2156	BE 11	59.90 N	149 50.94 E	GPS	-9	5922	-9					
49NZ20121105	999	C02	1	XCT	111212	2209	DE 11	59.95 N	149 50.90 E	GPS	-9	5920	-9					XCTD-2 SN11021853
49NZ20121105	999	C02	1	ROS	111212	2230	BO 12	0.01 N	149 50.86 E	GPS	-9	5927	-9	1981	2002		36 1,2,34	
49NZ20121105	999	C02	1	ROS	111212	2331	EN 12	0.20 N	149 50.81 E	GPS	-9	5917	-9					
49NZ20121105	999	C02	1	FLT	111212	2338	DE 12	0.13 N	149 50.82 E	GPS	-9	5918	-9					ARGO 112255
49NZ20121105	999	C03	1	ROS	111312	0914	BE 10	0.06 N	150 26.95 E	GPS	-9	5728	-9					
49NZ20121105	999	C03	1	XCT	111312	0927	DE 10	0.16 N	150 26.83 E	GPS	-9	5732	-9					XCTD-2 SN12026191
49NZ20121105	999	C03	1	ROS	111312	0947	BO 10	0.19 N	150 26.82 E	GPS	-9	5730	-9	1980	2001		36 1,2	
49NZ20121105	999	C03	1	ROS	111312	1050	EN 10	0.42 N	150 26.67 E	GPS	-9	5734	-9					
49NZ20121105	999	C03	1	FLT	111312	1057	DE 10	0.31 N	150 26.62 E	GPS	-9	5730	-9					ARGO 112256
49NZ20121105	999	323	1	UNK	111412	1956	BE 03	44.14 N	149 20.27 E	GPS	-9	4385	-9					TOWED MAGNETOMETER
49NZ20121105	999	324	1	UNK	111412	2018	BE 03	42.26 N	149 19.67 E	GPS	-9	4408	-9					MAGNETOMETER CALIBRATION
49NZ20121105	999	324	1	UNK	111412	2046	EN 03	42.32 N	149 19.66 E	GPS	-9	4411	-9					MAGNETOMETER CALIBRATION
49NZ20121105	999	325	1	UNK	111512	0055	UN 03	1.36 N	149 44.58 E	GPS	-9	5635	-9				89	THROUGH HULL PUMP
49NZ20121105	999	326	1	XCT	111512	0230	DE 02	45.51 N	149 55.02 E	GPS	-9	5596	-9					XCTD-1 SN11011546

49NZ20121105	999	323	1	UNK	111512	0817	EN	01	51.90	N	150	31.42	E	GPS	-9	5167	-9
49NZ20121105	999	327	1	BIO	111512	0842	BE	01	55.34	N	150	31.25	E	GPS	-9	4752	-9
49NZ20121105	999	327	1	BIO	111512	1047	EN	02	0.01	N	150	31.07	E	GPS	-9	5113	-9
49NZ20121105	999	328	1	UNK	111512	2156	BE	00	0.89	N	151	31.92	E	GPS	-9	5130	-9
49NZ20121105	999	329	1	XCT	111612	0330	DE	00	53.80	N	152	7.69	E	GPS	-9	5060	-9
49NZ20121105	999	330	1	UNK	111612	1117	BE	02	12.47	S	153	0.25	E	GPS	-9	3559	-9
49NZ20121105	999	330	1	UNK	111612	1157	EN	02	13.12	S	153	0.61	E	GPS	-9	3531	-9
49NZ20121105	999	328	1	UNK	111612	1235	EN	02	14.75	S	153	1.39	E	GPS	-9	3196	-9
49NZ20121105	999	331	1	UNK	112212	0550	BE	26	17.98	S	165	36.06	E	GPS	-9	3302	-9
49NZ20121105	999	332	1	UNK	112212	0605	UN	26	17.97	S	165	36.29	E	GPS	-9	3300	-9
49NZ20121105	999	331	1	UNK	112212	0618	EN	26	17.93	S	165	36.24	E	GPS	-9	3300	-9
49NZ20121105	999	333	1	BIO	112212	0731	BE	26	18.33	S	165	35.83	E	GPS	-9	3297	-9
49NZ20121105	999	333	1	BIO	112212	0930	EN	26	19.46	S	165	31.62	E	GPS	-9	3188	-9

89

TOWED MAGNETOMETER  
NEUSTON NET  
NEUSTON NET  
TOWED MAGNETOMETER  
XCTD-1 SN11011547  
MAGNETOMETER CALIBRATION  
MAGNETOMETER CALIBRATION  
TOWED MAGNETOMETER  
3-AXIS MAGNETOMETER CALIBRATION  
THROUGH HULL PUMP  
3-AXIS MAGNETOMETER CALIBRATION  
NEUSTON NET  
NEUSTON NET

R/V MIRAI CRUISE MR1205 LEG2

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
49NZ20121128	P14S	8	1	ROS	120412	2315	BE	55 30.37 S	172 27.04 E	GPS	-9	5345					
49NZ20121128	P14S	8	1	BUC	120412	2325	UN	55 30.26 S	172 27.02 E	GPS	-9	5339				1,20	7.1C
49NZ20121128	P14S	8	1	ROS	120512	0039	BO	55 29.85 S	172 27.62 E	GPS	-9	5355	10	5356	5462	35	1-8,20,27,93
49NZ20121128	P14S	8	1	ROS	120512	0251	EN	55 29.67 S	172 28.83 E	GPS	-9	5345					
49NZ20121128	P14S	9	1	ROS	120512	0557	BE	55 59.96 S	173 0.42 E	GPS	-9	5451					
49NZ20121128	P14S	9	1	BUC	120512	0605	UN	55 59.96 S	173 0.31 E	GPS	-9	5450				1,20	7.4C
49NZ20121128	P14S	9	1	UNK	120512	0642	UN	55 59.95 S	173 0.04 E	GPS	-9	5445				22,89	THROUGH HULL PUMP
49NZ20121128	P14S	9	1	ROS	120512	0721	BO	55 59.90 S	172 59.70 E	GPS	-9	5441	8	5472	5565	36	1-8,20,23,24,26,27,93
49NZ20121128	P14S	9	1	ROS	120512	0933	EN	55 59.54 S	172 57.68 E	GPS	-9	5444					
49NZ20121128	P14S	10	1	ROS	120512	1245	BE	56 29.26 S	173 30.08 E	GPS	-9	5372					
49NZ20121128	P14S	10	1	BUC	120512	1253	UN	56 29.17 S	173 29.97 E	GPS	-9	5389				1,20	7.4C
49NZ20121128	P14S	10	1	ROS	120512	1411	BO	56 28.73 S	173 28.81 E	GPS	-9	5464	11	5499	5572	36	1-8,20,27,34,93
49NZ20121128	P14S	10	1	ROS	120512	1625	EN	56 27.95 S	173 27.21 E	GPS	-9	5500					
49NZ20121128	P14S	11	1	ROS	120512	1945	BE	56 59.71 S	173 58.67 E	GPS	-9	5444					
49NZ20121128	P14S	11	1	BUC	120512	1953	UN	56 59.68 S	173 58.73 E	GPS	-9	5448				1,20	7.1C
49NZ20121128	P14S	11	1	ROS	120512	2110	BO	56 59.68 S	173 59.16 E	GPS	-9	5442	9	5433	5552	35	1-8,12,13,20,23,24,26,27,37,42,92-95
49NZ20121128	P14S	11	1	ROS	120512	2316	EN	56 59.83 S	173 59.55 E	GPS	-9	5443					
49NZ20121128	P14S	11	1	FLT	120512	2329	DE	56 59.87 S	173 59.31 E	GPS	-9	5457					DEEP ARGO #4/ID300234011980570
49NZ20121128	P14S	12	1	ROS	120612	0317	BE	57 30.31 S	173 58.42 E	GPS	-9	5379					
49NZ20121128	P14S	12	1	BUC	120612	0327	UN	57 30.35 S	173 58.51 E	GPS	-9	5380				1,20	7.1C
49NZ20121128	P14S	12	1	ROS	120612	0443	BO	57 30.50 S	173 58.84 E	GPS	-9	5399	9	5400	5517	36	1-8,20,27,93
49NZ20121128	P14S	12	1	ROS	120612	0649	EN	57 30.72 S	173 59.36 E	GPS	-9	5463					
49NZ20121128	P14S	13	1	ROS	120612	0931	BE	58 0.15 S	173 59.60 E	GPS	-9	5202					
49NZ20121128	P14S	13	1	BUC	120612	0939	UN	58 0.23 S	173 59.57 E	GPS	-9	5199				1,20	6.7C
49NZ20121128	P14S	13	1	ROS	120612	1052	BO	58 0.66 S	173 59.83 E	GPS	-9	5194	10	5196	5297	35	1-8,20,27,93
49NZ20121128	P14S	13	1	ROS	120612	1256	EN	58 1.31 S	174 0.10 E	GPS	-9	5196					
49NZ20121128	P14S	13	1	XMP	120612	1306	DE	58 1.52 S	173 59.97 E	GPS	-9	5201					#30
49NZ20121128	P14S	13	1	XMP	120612	1447	EN	58 4.15 S	173 58.44 E	GPS	-9	5265					FAIL AT 3000 DBAR
49NZ20121128	P14S	14	1	ROS	120612	1713	BE	58 30.26 S	173 58.26 E	GPS	-9	5013					
49NZ20121128	P14S	14	1	BUC	120612	1722	UN	58 30.22 S	173 58.37 E	GPS	-9	5016				1,20	5.7C
49NZ20121128	P14S	14	1	ROS	120612	1833	BO	58 30.21 S	173 58.69 E	GPS	-9	5015	10	5008	5110	33	1-8,20,23,24,26,27,31,37,42,93-95
49NZ20121128	P14S	14	1	ROS	120612	2033	EN	58 30.16 S	173 58.96 E	GPS	-9	5012					
49NZ20121128	P14S	14	1	XMP	120612	2042	DE	58 30.33 S	173 58.98 E	GPS	-9	5005					#31
49NZ20121128	P14S	14	1	XMP	120712	0011	EN	58 35.64 S	173 57.47 E	GPS	-9	5081					REACH BTM
49NZ20121128	P14S	15	1	ROS	120712	0224	BE	58 59.69 S	173 59.96 E	GPS	-9	5135					
49NZ20121128	P14S	15	1	BUC	120712	0231	UN	58 59.58 S	173 59.94 E	GPS	-9	5132				1,20	6.5C
49NZ20121128	P14S	15	1	ROS	120712	0343	BO	58 59.24 S	174 0.23 E	GPS	-9	5116	9	5117	5224	35	1-8,12,13,20,23,24,26,27,93
49NZ20121128	P14S	15	1	ROS	120712	0553	EN	58 58.50 S	174 0.67 E	GPS	-9	5072					
49NZ20121128	P14S	16	1	ROS	120712	0837	BE	59 28.66 S	173 59.82 E	GPS	-9	5016					
49NZ20121128	P14S	16	1	BUC	120712	0843	UN	59 28.61 S	173 59.93 E	GPS	-9	5011				1,20	5.3C
49NZ20121128	P14S	16	1	ROS	120712	0954	BO	59 28.27 S	174 0.98 E	GPS	-9	4968	10	4985	5066	34	1-8,20,27,93
49NZ20121128	P14S	16	1	ROS	120712	1152	EN	59 28.11 S	174 2.83 E	GPS	-9	4978					
49NZ20121128	P14S	17	1	ROS	120712	1431	BE	59 57.83 S	173 57.92 E	GPS	-9	4484					
49NZ20121128	P14S	17	1	BUC	120712	1438	UN	59 57.82 S	173 57.92 E	GPS	-9	4480				1,20,90	4.8C
49NZ20121128	P14S	17	1	UNK	120712	1459	UN	59 57.83 S	173 57.99 E	GPS	-9	4468				22,89	THROUGH HULL PUMP
49NZ20121128	P14S	17	1	ROS	120712	1542	BO	59 57.90 S	173 58.08 E	GPS	-9	4443	10	4469	4547	31	1-8,20,23,24,26,27,31,37,42,90,93-95
49NZ20121128	P14S	17	1	ROS	120712	1734	EN	59 58.02 S	173 58.10 E	GPS	-9	4427					





49NZ20121128	S04	56	1	ROS 121412 1220	BE 63 25.68 S 152 10.85 E GPS	-9	3644						
49NZ20121128	S04	56	1	BUC 121412 1229	UN 63 25.70 S 152 10.77 E GPS	-9	3649				1,20		-0.7C
49NZ20121128	S04	56	1	ROS 121412 1318	BO 63 25.71 S 152 10.79 E GPS	-9	3644	10	3636	3698	28	1-8,20,27,93	STOP 25MIN AT 2140M UP CAST DUE TO WINCH TROUBLE
49NZ20121128	S04	56	1	ROS 121412 1526	EN 63 25.69 S 152 10.77 E GPS	-9	3652						
49NZ20121128	S04	57	1	ROS 121412 2332	BE 63 26.00 S 150 39.77 E GPS	-9	3715						
49NZ20121128	S04	57	1	BUC 121412 2343	UN 63 26.02 S 150 39.75 E GPS	-9	3719				1,20		-0.7C
49NZ20121128	S04	57	1	ROS 121512 0034	BO 63 26.04 S 150 39.76 E GPS	-9	3717	9	3707	3776	28	1-8,12,13,20,23,24,26,27,31,37,42,93-95	
49NZ20121128	S04	57	1	ROS 121512 0212	EN 63 26.06 S 150 39.78 E GPS	-9	3728						
49NZ20121128	S04	58	1	ROS 121512 0531	BE 63 18.55 S 149 12.51 E GPS	-9	3754						
49NZ20121128	S04	58	1	BUC 121512 0538	UN 63 18.50 S 149 12.50 E GPS	-9	3760				1,20		-0.8C
49NZ20121128	S04	58	1	ROS 121512 0630	BO 63 18.32 S 149 12.39 E GPS	-9	3770	9	3762	3829	28	1-8,20,27,93	
49NZ20121128	S04	58	1	ROS 121512 0806	EN 63 18.13 S 149 12.37 E GPS	-9	3770						
49NZ20121128	S04	59	1	ROS 121512 1119	BE 63 10.77 S 147 50.78 E GPS	-9	3878						
49NZ20121128	S04	59	1	BUC 121512 1128	UN 63 10.82 S 147 50.71 E GPS	-9	3883				1,20		-0.2C
49NZ20121128	S04	59	1	ROS 121512 1222	BO 63 10.98 S 147 50.41 E GPS	-9	3875	9	3872	3943	29	1-8,20,23,24,26,27,34,92,93	
49NZ20121128	S04	59	1	ROS 121512 1402	EN 63 10.98 S 147 50.04 E GPS	-9	3880						
49NZ20121128	S04	60	1	ROS 121512 1723	BE 63 4.34 S 146 28.05 E GPS	-9	3925						
49NZ20121128	S04	60	1	BUC 121512 1732	UN 63 4.28 S 146 28.09 E GPS	-9	3923				1,20		-0.4C
49NZ20121128	S04	60	1	ROS 121512 1826	BO 63 4.14 S 146 28.09 E GPS	-9	3924	12	3908	3980	29	1-8,20,27,93	
49NZ20121128	S04	60	1	ROS 121512 2004	EN 63 3.86 S 146 26.32 E GPS	-9	3922						
49NZ20121128	S04	61	1	ROS 121512 2332	BE 62 54.23 S 145 3.18 E GPS	-9	3990						
49NZ20121128	S04	61	1	BUC 121512 2340	UN 62 54.26 S 145 3.02 E GPS	-9	3991				1,20		-0.6C
49NZ20121128	S04	61	1	ROS 121612 0035	BO 62 54.06 S 145 2.60 E GPS	-9	3994	8	4007	4062	29	1-8,12,13,20,23,24,26,27,93	
49NZ20121128	S04	61	1	ROS 121612 0218	EN 62 53.58 S 145 1.69 E GPS	-9	3999						
49NZ20121128	S04	62	1	ROS 121612 0540	BE 62 45.83 S 143 36.07 E GPS	-9	4087						
49NZ20121128	S04	62	1	ROS 121612 0554	BO 62 45.89 S 143 35.85 E GPS	-9	4086	-9	564	572	36	22,89	
49NZ20121128	S04	62	1	ROS 121612 0616	EN 62 45.89 S 143 35.65 E GPS	-9	4087						
49NZ20121128	S04	62	2	ROS 121612 0726	BE 62 45.88 S 143 36.20 E GPS	-9	4088						
49NZ20121128	S04	62	2	BUC 121612 0733	UN 62 45.90 S 143 36.15 E GPS	-9	4088				1,20		-0.4C
49NZ20121128	S04	62	2	UNK 121612 0750	UN 62 45.90 S 143 36.12 E GPS	-9	4086				22,89		THROUGH HULL PUMP
49NZ20121128	S04	62	2	ROS 121612 0829	BO 62 45.91 S 143 36.11 E GPS	-9	4089	10	4086	4155	36	1-8,20,22,23,24,26,27,89,93	
49NZ20121128	S04	62	2	ROS 121612 1010	EN 62 45.85 S 143 35.92 E GPS	-9	4089						
49NZ20121128	S04	62	1	FLT 121612 1020	DE 62 45.73 S 143 36.05 E GPS	-9	4088						DEEP ARGO #6/ID300234011988560
49NZ20121128	S04	63	1	ROS 121612 1346	BE 62 35.85 S 142 12.65 E GPS	-9	4103						
49NZ20121128	S04	63	1	BUC 121612 1355	UN 62 35.83 S 142 12.90 E GPS	-9	4104				1,20		-0.4C
49NZ20121128	S04	63	1	ROS 121612 1452	BO 62 35.73 S 142 13.80 E GPS	-9	4110	8	4103	4175	30	1-8,20,27,93	
49NZ20121128	S04	63	1	ROS 121612 1637	EN 62 35.32 S 142 15.62 E GPS	-9	4111						
49NZ20121128	S04	64	1	ROS 121612 1938	BE 62 28.16 S 141 2.98 E GPS	-9	4165						
49NZ20121128	S04	64	1	BUC 121612 1946	UN 62 28.16 S 141 2.75 E GPS	-9	4160				1,20		-0.3C
49NZ20121128	S04	64	1	ROS 121612 2043	BO 62 28.03 S 141 2.04 E GPS	-9	4156	9	4151	4222	30	1-8,12,13,20,23,24,26,27,92,93	STOP 3MIN AT UPCAST 720M DUE TO C SESOR TROUBLE
49NZ20121128	S04	64	1	ROS 121612 2233	EN 62 27.79 S 141 1.26 E GPS	-9	4144						
49NZ20121128	S04	65	1	ROS 121712 0114	BE 62 21.48 S 139 53.55 E GPS	-9	3930						
49NZ20121128	S04	65	1	BUC 121712 0124	UN 62 21.44 S 139 53.47 E GPS	-9	3932				1,20		-0.4C
49NZ20121128	S04	65	1	ROS 121712 0219	BO 62 21.30 S 139 53.21 E GPS	-9	3927	11	3924	3994	30	1-8,20,27,93	
49NZ20121128	S04	65	1	ROS 121712 0405	EN 62 20.91 S 139 52.81 E GPS	-9	3932						
49NZ20121128	S04	66	1	ROS 121712 0735	BE 62 9.53 S 138 27.15 E GPS	-9	3977						
49NZ20121128	S04	66	1	BUC 121712 0743	UN 62 9.56 S 138 27.20 E GPS	-9	3977				1,20		-0.6C
49NZ20121128	S04	66	1	ROS 121712 0837	BO 62 9.64 S 138 27.12 E GPS	-9	3973	9	3972	4043	30	1-8,20,23,24,26,27,93	
49NZ20121128	S04	66	1	ROS 121712 1016	EN 62 9.72 S 138 27.08 E GPS	-9	3971						



49NZ20121128	S04	75	1	ROS 122212 0013	BO 62	0.18	S 125	39.35	E GPS	-9	4302	9	4298	4379	31	1-8,12,13,20,23,24,26,27,31,37,42,93-95	
49NZ20121128	S04	75	1	ROS 122212 0205	EN 62	0.27	S 125	39.04	E GPS	-9	4301						
49NZ20121128	S04	76	1	ROS 122212 0557	BE 62	0.12	S 124	15.41	E GPS	-9	4232						
49NZ20121128	S04	76	1	BUC 122212 0605	UN 62	0.14	S 124	15.37	E GPS	-9	4230				1,20		0.9C
49NZ20121128	S04	76	1	ROS 122212 0702	BO 62	0.15	S 124	15.24	E GPS	-9	4231	9	4225	4306	30	1-8,20,27,93	
49NZ20121128	S04	76	1	ROS 122212 0910	EN 62	0.14	S 124	15.23	E GPS	-9	4231						REPLACED CTD DECK UNIT AT UP CAST (2888DB)
49NZ20121128	S04	77	1	ROS 122212 1258	BE 62	0.22	S 122	50.32	E GPS	-9	4214						
49NZ20121128	S04	77	1	BUC 122212 1306	UN 62	0.22	S 122	50.23	E GPS	-9	4215				1,20		0.3C
49NZ20121128	S04	77	1	ROS 122212 1404	BO 62	0.17	S 122	50.31	E GPS	-9	4216	9	4208	4285	31	1-8,20,27,34,93	
49NZ20121128	S04	77	1	ROS 122212 1600	EN 62	0.13	S 122	50.15	E GPS	-9	4213						
49NZ20121128	S04	78	1	ROS 122212 2017	BE 61	59.87	S 121	31.48	E GPS	-9	4103						
49NZ20121128	S04	78	1	BUC 122212 2025	UN 61	59.93	S 121	31.52	E GPS	-9	4102				1,20		0.5C
49NZ20121128	S04	78	1	ROS 122212 2134	BO 61	59.98	S 121	31.57	E GPS	-9	4104	10	4098	4173	30	1-8,12,13,20,23,24,26,27,31,37,42,92-95	
49NZ20121128	S04	78	1	ROS 122212 2306	EN 62	0.18	S 121	31.78	E GPS	-9	4108						
49NZ20121128	S04	79	1	ROS 122312 0314	BE 61	56.98	S 120	1.41	E GPS	-9	4165						
49NZ20121128	S04	79	1	BUC 122312 0324	UN 61	57.00	S 120	1.43	E GPS	-9	4166				1,20		0.4C
49NZ20121128	S04	79	1	ROS 122312 0422	BO 61	57.22	S 120	1.46	E GPS	-9	4169	9	4161	4234	30	1-8,20,27,93	
49NZ20121128	S04	79	1	ROS 122312 0615	EN 61	57.60	S 120	1.56	E GPS	-9	4167						
49NZ20121128	S04	80	1	ROS 122312 0902	BE 61	59.08	S 119	2.28	E GPS	-9	4183						
49NZ20121128	S04	80	1	BUC 122312 0910	UN 61	59.12	S 119	2.38	E GPS	-9	4182				1,20		0.5C
49NZ20121128	S04	80	1	ROS 122312 1006	BO 61	59.16	S 119	2.34	E GPS	-9	4183	9	4177	4234	31	1-8,20,27,93	
49NZ20121128	S04	80	1	ROS 122312 1152	EN 61	59.28	S 119	2.23	E GPS	-9	4184						
49NZ20121128	S04	81	1	ROS 122312 1443	BE 61	50.03	S 118	1.54	E GPS	-9	4246						
49NZ20121128	S04	81	1	BUC 122312 1451	UN 61	50.04	S 118	1.48	E GPS	-9	4246				1,20,90		0.6C
49NZ20121128	S04	81	1	ROS 122312 1550	BO 61	50.14	S 118	1.39	E GPS	-9	4248	10	4234	4315	31	1-8,20,23,24,26,27,31,37,42,90,92-95	
49NZ20121128	S04	81	1	ROS 122312 1747	EN 61	50.48	S 118	1.24	E GPS	-9	4243						
49NZ20121128	S04	82	1	ROS 122312 2206	BE 61	57.41	S 116	24.10	E GPS	-9	4232						
49NZ20121128	S04	82	1	BUC 122312 2215	UN 61	57.42	S 116	24.11	E GPS	-9	4229				1,20		0.5C
49NZ20121128	S04	82	1	ROS 122312 2314	BO 61	57.51	S 116	24.15	E GPS	-9	4223	10	4224	4295	30	1-8,20,27,93	
49NZ20121128	S04	82	1	ROS 122412 0103	EN 61	57.60	S 116	24.48	E GPS	-9	4227						
49NZ20121128	S04	83	1	ROS 122412 0436	BE 61	56.12	S 115	3.90	E GPS	-9	4255						
49NZ20121128	S04	83	1	BUC 122412 0444	UN 61	56.14	S 115	3.98	E GPS	-9	4255				1,20		1.1C
49NZ20121128	S04	83	1	ROS 122412 0543	BO 61	56.29	S 115	4.34	E GPS	-9	4252	9	4252	4329	31	1-8,12,13,20,23,24,26,27,92,93	
49NZ20121128	S04	83	1	ROS 122412 0738	EN 61	56.40	S 115	4.68	E GPS	-9	4254						
49NZ20121128	S04I	84	1	ROS 122412 1052	BE 62	2.98	S 113	49.83	E GPS	-9	4162						
49NZ20121128	S04I	84	1	ROS 122412 1109	BO 62	3.05	S 113	49.74	E GPS	-9	4160	-9	595	603	36	22,89	
49NZ20121128	S04I	84	1	ROS 122412 1130	EN 62	3.12	S 113	49.59	E GPS	-9	4160						
49NZ20121128	S04I	84	1	UNK 122412 1215	UN 62	3.96	S 113	49.86	E GPS	-9	4156				22,89		THROUGH HULL PUMP
49NZ20121128	S04I	84	2	ROS 122412 1230	BE 62	4.03	S 113	49.78	E GPS	-9	4158						
49NZ20121128	S04I	84	2	BUC 122412 1237	UN 62	4.11	S 113	49.71	E GPS	-9	4157				1,20		1.4C
49NZ20121128	S04I	84	2	ROS 122412 1334	BO 62	4.27	S 113	49.48	E GPS	-9	4162	9	4151	4227	34	1-8,20,27,93	
49NZ20121128	S04I	84	2	ROS 122412 1519	EN 62	4.58	S 113	48.85	E GPS	-9	4162						
49NZ20121128	S04I	85	1	ROS 122412 1941	BE 62	5.28	S 112	10.07	E GPS	-9	4100						
49NZ20121128	S04I	85	1	BUC 122412 1949	UN 62	5.27	S 112	10.01	E GPS	-9	4098				1,20		1.2C
49NZ20121128	S04I	85	1	ROS 122412 2046	BO 62	5.23	S 112	9.77	E GPS	-9	4095	10	4088	4161	30	1-8,20,23,24,26,27,31,37,42,92-95	
49NZ20121128	S04I	85	1	ROS 122412 2232	EN 62	5.22	S 112	9.08	E GPS	-9	4094						
49NZ20121128	S04I	86	1	ROS 122512 0227	BE 62	15.91	S 110	40.06	E GPS	-9	3942						
49NZ20121128	S04I	86	1	BUC 122512 0236	UN 62	15.87	S 110	40.02	E GPS	-9	3942				1,20		0.9C
49NZ20121128	S04I	86	1	ROS 122512 0330	BO 62	15.71	S 110	39.84	E GPS	-9	3939	10	3931	3999	31	1-8,20,27,93	
49NZ20121128	S04I	86	1	ROS 122512 0515	EN 62	15.40	S 110	39.19	E GPS	-9	3933						

49NZ20121128	S04I	87	1	ROS	122512	1231	BE	61	31.53	S	108	57.32	E	GPS	-9	4197					
49NZ20121128	S04I	87	1	BUC	122512	1240	UN	61	31.54	S	108	57.48	E	GPS	-9	4192			1,20	1.8C	
49NZ20121128	S04I	87	1	ROS	122512	1338	BO	61	31.55	S	108	57.72	E	GPS	-9	4192	9	4180	4259	30	1-8,12,13,20,23,24,26,27,31,37,42,92-95
49NZ20121128	S04I	87	1	ROS	122512	1525	EN	61	31.62	S	108	58.18	E	GPS	-9	4192					
49NZ20121128	S04I	88	1	ROS	122512	1931	BE	61	38.48	S	107	26.57	E	GPS	-9	4285					
49NZ20121128	S04I	88	1	BUC	122512	1939	UN	61	38.49	S	107	26.59	E	GPS	-9	4285				1,20	2.0C
49NZ20121128	S04I	88	1	ROS	122512	2039	BO	61	38.45	S	107	26.74	E	GPS	-9	4285	10	4273	4353	30	1-8,20,27,93
49NZ20121128	S04I	88	1	ROS	122512	2227	EN	61	38.28	S	107	26.75	E	GPS	-9	4285					
49NZ20121128	I09S	501	1	ROS	122612	1908	BE	61	0.60	S	115	0.22	E	GPS	-9	4395					
49NZ20121128	I09S	501	1	BUC	122612	1916	UN	61	0.63	S	115	0.15	E	GPS	-9	4387				1,20	1.5C
49NZ20121128	I09S	501	1	ROS	122612	2018	BO	61	0.70	S	114	59.80	E	GPS	-9	4390	10	4379	4466	31	1-8,20,23,24,26,27,92,93
49NZ20121128	I09S	501	1	ROS	122612	2213	EN	61	0.86	S	114	58.76	E	GPS	-9	4390					
49NZ20121128	I09S	502	1	ROS	122712	0359	BE	59	48.24	S	115	2.10	E	GPS	-9	4493					
49NZ20121128	I09S	502	1	BUC	122712	0408	UN	59	48.27	S	115	2.13	E	GPS	-9	4494				1,20	1.8C
49NZ20121128	I09S	502	1	ROS	122712	0511	BO	59	48.33	S	115	2.28	E	GPS	-9	4493	9	4479	4577	31	1-8,20,23,24,26,27,93
49NZ20121128	I09S	502	1	ROS	122712	0707	EN	59	48.41	S	115	2.20	E	GPS	-9	4494					
49NZ20121128	I09S	503	1	ROS	122712	1014	BE	59	12.23	S	114	59.97	E	GPS	-9	4524					
49NZ20121128	I09S	503	1	BUC	122712	1024	UN	59	12.21	S	114	59.79	E	GPS	-9	4523				1,20	2.2C
49NZ20121128	I09S	503	1	ROS	122712	1126	BO	59	12.17	S	114	59.56	E	GPS	-9	4525	10	4518	4606	32	1-8,20,23,24,26,27,92,93
49NZ20121128	I09S	503	1	ROS	122712	1318	EN	59	11.97	S	114	58.84	E	GPS	-9	4522					
49NZ20121128	999	803	1	MOR	010213	0437	BE	45	41.68	S	144	43.61	E	GPS	-9	-9					SOFS BUOY
49NZ20121128	999	803	1	MOR	010213	0828	RE	45	43.40	S	144	41.16	E	GPS	-9	-9					

R/V MIRAI CRUISE MR1205 LEG3

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
49NZ20130106	S04I	88	2	ROS	011213	1904	BE	61 37.30 S	107 26.83 E	GPS	-9	4292					
49NZ20130106	S04I	88	2	BUC	011213	1915	UN	61 37.32 S	107 26.84 E	GPS	-9	4293				1,20	2.1C
49NZ20130106	S04I	88	2	ROS	011213	2018	BO	61 37.21 S	107 26.72 E	GPS	-9	4291	9	4282	4362	32	1-8,20,27,34,93
49NZ20130106	S04I	88	2	ROS	011213	2228	EN	61 36.89 S	107 26.61 E	GPS	-9	4291					A FUSE OF CTD DECK UNIT BLEW AT 3000DB
49NZ20130106	S04I	89	1	ROS	011313	0234	BE	61 52.37 S	106 21.75 E	GPS	-9	4305					
49NZ20130106	S04I	89	1	BUC	011313	0243	UN	61 52.35 S	106 21.77 E	GPS	-9	4306				1,20	1.7C
49NZ20130106	S04I	89	1	ROS	011313	0343	BO	61 52.10 S	106 21.83 E	GPS	-9	4307	9	4302	4380	31	1-8,20,27,34,93
49NZ20130106	S04I	89	1	ROS	011313	0535	EN	61 51.71 S	106 21.74 E	GPS	-9	4307					
49NZ20130106	S04I	90	1	ROS	011313	0911	BE	62 8.81 S	105 16.46 E	GPS	-9	4242					
49NZ20130106	S04I	90	1	BUC	011313	0921	UN	62 8.83 S	105 16.57 E	GPS	-9	4244				1,20,31,33	1.9C
49NZ20130106	S04I	90	1	ROS	011313	1019	BO	62 8.63 S	105 16.46 E	GPS	-9	4244	9	4249	4318	31	1-8,12,13,20,23,24,26,27,31,33,37,42,92-95
49NZ20130106	S04I	90	1	ROS	011313	1218	EN	62 8.35 S	105 16.36 E	GPS	-9	4244					
49NZ20130106	S04I	91	1	ROS	011313	1526	BE	62 2.00 S	104 18.97 E	GPS	-9	4324					
49NZ20130106	S04I	91	1	BUC	011313	1536	UN	62 2.00 S	104 18.89 E	GPS	-9	4323				1,20	1.7C
49NZ20130106	S04I	91	1	ROS	011313	1634	BO	62 2.02 S	104 18.51 E	GPS	-9	4322	8	4314	4400	31	1-8,20,27,93
49NZ20130106	S04I	91	1	ROS	011313	1829	EN	62 2.08 S	104 17.57 E	GPS	-9	4324					
49NZ20130106	S04I	92	1	ROS	011313	2136	BE	62 4.92 S	103 15.76 E	GPS	-9	4380					
49NZ20130106	S04I	92	1	BUC	011313	2145	UN	62 4.91 S	103 15.60 E	GPS	-9	4383				1,20	1.5C
49NZ20130106	S04I	92	1	ROS	011313	2245	BO	62 5.06 S	103 14.79 E	GPS	-9	4387	9	4380	4458	31	1-8,20,23,24,26,27,37,42,93-95
49NZ20130106	S04I	92	1	ROS	011413	0040	EN	62 5.36 S	103 13.14 E	GPS	-9	4387					
49NZ20130106	S04I	93	1	ROS	011413	0316	BE	62 12.89 S	102 20.76 E	GPS	-9	4401					
49NZ20130106	S04I	93	1	BUC	011413	0324	UN	62 12.88 S	102 20.77 E	GPS	-9	4400				1,20	1.9C
49NZ20130106	S04I	93	1	ROS	011413	0423	BO	62 12.81 S	102 20.65 E	GPS	-9	4401	8	4396	4482	31	1-8,20,27,93
49NZ20130106	S04I	93	1	ROS	011413	0617	EN	62 12.50 S	102 20.73 E	GPS	-9	4402					
49NZ20130106	S04I	94	1	ROS	011413	0938	BE	62 19.73 S	101 5.08 E	GPS	-9	4422					
49NZ20130106	S04I	94	1	BUC	011413	0945	UN	62 19.74 S	101 5.10 E	GPS	-9	4419				1,20,31,33	2.1C
49NZ20130106	S04I	94	1	ROS	011413	1046	BO	62 19.75 S	101 5.36 E	GPS	-9	4419	9	4414	4503	33	1-8,12,13,20,23,24,26,27,31,33,92,93,96
49NZ20130106	S04I	94	1	ROS	011413	1247	EN	62 19.82 S	101 6.33 E	GPS	-9	4421					
49NZ20130106	S04I	95	1	ROS	011413	1656	BE	62 20.05 S	099 33.53 E	GPS	-9	4273					
49NZ20130106	S04I	95	1	BUC	011413	1705	UN	62 20.05 S	099 33.55 E	GPS	-9	4272				1,20	1.5C
49NZ20130106	S04I	95	1	ROS	011413	1802	BO	62 20.01 S	099 33.98 E	GPS	-9	4274	9	4265	4347	31	1-8,20,27,34,93
49NZ20130106	S04I	95	1	ROS	011413	1956	EN	62 20.04 S	099 34.26 E	GPS	-9	4279					
49NZ20130106	S04I	96	1	ROS	011513	0002	BE	62 6.61 S	098 1.24 E	GPS	-9	4081					
49NZ20130106	S04I	96	1	BUC	011513	0010	UN	62 6.62 S	098 1.29 E	GPS	-9	4080				1,20	2.0C
49NZ20130106	S04I	96	1	UNK	011513	0032	UN	62 6.62 S	098 1.39 E	GPS	-9	4087				90	THROUGH HULL PUMP
49NZ20130106	S04I	96	1	ROS	011513	0106	BO	62 6.64 S	098 1.45 E	GPS	-9	4082	10	4078	4147	30	1-8,20,23,24,26,27,37,42,93-95
49NZ20130106	S04I	96	1	ROS	011513	0250	EN	62 6.54 S	098 1.68 E	GPS	-9	4088					
49NZ20130106	S04I	97	1	ROS	011513	0710	BE	62 7.17 S	096 18.94 E	GPS	-9	3925					
49NZ20130106	S04I	97	1	BUC	011513	0718	UN	62 7.17 S	096 18.98 E	GPS	-9	3929				1,20	2.2C
49NZ20130106	S04I	97	1	ROS	011513	0812	BO	62 7.18 S	096 19.24 E	GPS	-9	3923	10	3906	3977	29	1-8,20,27,93
49NZ20130106	S04I	97	1	ROS	011513	1000	EN	62 7.03 S	096 19.99 E	GPS	-9	3914					
49NZ20130106	S04I	98	1	ROS	011513	1410	BE	62 15.11 S	094 44.57 E	GPS	-9	3805					
49NZ20130106	S04I	98	1	BUC	011513	1418	UN	62 15.14 S	094 44.68 E	GPS	-9	3807				1,20,31,33	1.7C
49NZ20130106	S04I	98	1	ROS	011513	1510	BO	62 15.13 S	094 45.58 E	GPS	-9	3799	9	3815	3860	31	1-8,12,13,20,23,24,26,27,31,33,93,96
49NZ20130106	S04I	98	1	ROS	011513	1655	EN	62 15.15 S	094 47.73 E	GPS	-9	3799					
49NZ20130106	S04I	99	1	ROS	011513	2120	BE	62 16.43 S	093 8.48 E	GPS	-9	3924					

49NZ20130106	S04I	99	1	BUC	011513	2127	UN	62	16.45	S	093	8.56	E	GPS	-9	3928				1,20	1.7C	
49NZ20130106	S04I	99	1	ROS	011513	2222	BO	62	16.54	S	093	8.91	E	GPS	-9	3935	10	3914	3989	29	1-8,20,27,93	
49NZ20130106	S04I	99	1	ROS	011613	0002	EN	62	16.73	S	093	9.42	E	GPS	-9	3934						
49NZ20130106	S04I	100	1	ROS	011613	0409	BE	62	16.71	S	091	31.16	E	GPS	-9	4032						
49NZ20130106	S04I	100	1	BUC	011613	0418	UN	62	16.77	S	091	31.12	E	GPS	-9	4033					1,20	2.4C
49NZ20130106	S04I	100	1	ROS	011613	0512	BO	62	17.10	S	091	31.06	E	GPS	-9	4035	9	4026	4098	30	1-8,20,23,24,26,27,34,37,42,92-95	
49NZ20130106	S04I	100	1	ROS	011613	0701	EN	62	17.49	S	091	30.54	E	GPS	-9	4032						
49NZ20130106	S04I	101	1	ROS	011613	1022	BE	62	48.77	S	090	51.83	E	GPS	-9	3855						
49NZ20130106	S04I	101	1	BUC	011613	1029	UN	62	48.73	S	090	51.83	E	GPS	-9	3870					1,20	1.6C
49NZ20130106	S04I	101	1	ROS	011613	1121	BO	62	48.62	S	090	51.52	E	GPS	-9	3863	8	3841	3911	29	1-8,20,27,93	
49NZ20130106	S04I	101	1	ROS	011613	1302	EN	62	48.46	S	090	51.01	E	GPS	-9	3852						
49NZ20130106	S04I	102	1	ROS	011613	1630	BE	63	21.44	S	090	10.72	E	GPS	-9	3809						
49NZ20130106	S04I	102	1	BUC	011613	1639	UN	63	21.44	S	090	10.64	E	GPS	-9	3812					1,20,31,33,34,82	1.5C
49NZ20130106	S04I	102	1	UNK	011613	1713	UN	63	21.43	S	090	10.59	E	GPS	-9	3811					90	THROUGH HULL PUMP
49NZ20130106	S04I	102	1	ROS	011613	1731	BO	63	21.44	S	090	10.65	E	GPS	-9	3812	10	-9	3871	31	1-8,20,23,24,26,27,31,33,34,37,42,93-96	
49NZ20130106	S04I	102	1	ROS	011613	1915	EN	63	21.45	S	090	10.50	E	GPS	-9	3813						
49NZ20130106	S04I	103	1	ROS	011713	0018	BE	63	7.11	S	088	41.29	E	GPS	-9	3828						
49NZ20130106	S04I	103	1	BUC	011713	0027	UN	63	7.14	S	088	41.26	E	GPS	-9	3829					1,20	1.1C
49NZ20130106	S04I	103	1	ROS	011713	0119	BO	63	7.12	S	088	41.25	E	GPS	-9	3830	9	3823	3892	29	1-8,20,27,93	
49NZ20130106	S04I	103	1	ROS	011713	0257	EN	63	6.97	S	088	41.72	E	GPS	-9	3830						
49NZ20130106	S04I	104	1	ROS	011713	0659	BE	63	6.74	S	087	7.80	E	GPS	-9	3786						
49NZ20130106	S04I	104	1	BUC	011713	0708	UN	63	6.71	S	087	7.81	E	GPS	-9	3788					1,20	1.1C
49NZ20130106	S04I	104	1	ROS	011713	0759	BO	63	6.55	S	087	7.94	E	GPS	-9	3780	9	-9	3843	29	1-8,12,20,23,24,26,27,92,93	
49NZ20130106	S04I	104	1	ROS	011713	0943	EN	63	6.35	S	087	7.75	E	GPS	-9	3776						
49NZ20130106	S04I	105	1	ROS	011713	1254	BE	63	6.24	S	085	58.74	E	GPS	-9	3739						
49NZ20130106	S04I	105	1	BUC	011713	1303	UN	63	6.21	S	085	58.72	E	GPS	-9	3738					1,20	1.0C
49NZ20130106	S04I	105	1	UNK	011713	1322	UN	63	6.21	S	085	58.61	E	GPS	-9	3737					90	THROUGH HULL PUMP
49NZ20130106	S04I	105	1	ROS	011713	1353	BO	63	6.24	S	085	58.55	E	GPS	-9	3735	10	3736	3801	29	1-8,20,27,93	
49NZ20130106	S04I	105	1	ROS	011713	1533	EN	63	6.40	S	085	58.36	E	GPS	-9	3727						
49NZ20130106	S04I	106	1	ROS	011713	1813	BE	62	57.68	S	084	59.33	E	GPS	-9	2972						
49NZ20130106	S04I	106	1	BUC	011713	1822	UN	62	57.64	S	084	59.30	E	GPS	-9	2972					1,20,31,33	1.0C
49NZ20130106	S04I	106	1	ROS	011713	1902	BO	62	57.41	S	084	59.23	E	GPS	-9	2982	9	-9	3024	26	1-8,20,23,24,26,27,31,33,34,37,42,93-96	
49NZ20130106	S04I	106	1	ROS	011713	2028	EN	62	57.12	S	084	59.22	E	GPS	-9	2992						
49NZ20130106	S04I	107	1	ROS	011713	2303	BE	63	0.70	S	084	1.20	E	GPS	-9	2544						
49NZ20130106	S04I	107	1	BUC	011713	2310	UN	63	0.69	S	084	1.21	E	GPS	-9	2545					1,20	0.8C
49NZ20130106	S04I	107	1	UNK	011713	2332	UN	63	0.67	S	084	1.22	E	GPS	-9	2547					90	THROUGH HULL PUMP
49NZ20130106	S04I	107	1	ROS	011713	2345	BO	63	0.66	S	084	1.23	E	GPS	-9	2545	9	2523	2578	24	1-8,20,27,93	
49NZ20130106	S04I	107	1	ROS	011813	0101	EN	63	0.66	S	084	1.53	E	GPS	-9	2548						
49NZ20130106	S04I	108	1	ROS	011813	0310	BE	62	44.88	S	083	28.32	E	GPS	-9	2461						
49NZ20130106	S04I	108	1	BUC	011813	0319	UN	62	44.87	S	083	28.35	E	GPS	-9	2462					1,20	1.1C
49NZ20130106	S04I	108	1	ROS	011813	0353	BO	62	44.86	S	083	28.42	E	GPS	-9	2460	9	2437	2489	23	1-8,20,23,24,26,27,93	
49NZ20130106	S04I	108	1	ROS	011813	0506	EN	62	44.76	S	083	28.82	E	GPS	-9	2463						
49NZ20130106	S04I	109	1	ROS	011813	0758	BE	62	15.02	S	083	14.92	E	GPS	-9	2653						
49NZ20130106	S04I	109	1	BUC	011813	0806	UN	62	15.02	S	083	14.90	E	GPS	-9	2651					1,20	1.8C
49NZ20130106	S04I	109	1	ROS	011813	0841	BO	62	15.00	S	083	15.01	E	GPS	-9	2649	8	2580	2681	24	1-8,20,27,93	
49NZ20130106	S04I	109	1	ROS	011813	1002	EN	62	15.14	S	083	15.57	E	GPS	-9	2662						
49NZ20130106	S04I	110	1	ROS	011813	1253	BE	61	45.47	S	083	1.53	E	GPS	-9	2321						
49NZ20130106	S04I	110	1	BUC	011813	1303	UN	61	45.50	S	083	1.56	E	GPS	-9	2322					1,20	2.0C
49NZ20130106	S04I	110	1	ROS	011813	1332	BO	61	45.55	S	083	1.60	E	GPS	-9	2325	9	2316	2349	23	1-8,20,23,24,26,27,93	
49NZ20130106	S04I	110	1	ROS	011813	1443	EN	61	45.67	S	083	1.72	E	GPS	-9	2322						
49NZ20130106	S04I	111	1	ROS	011813	1742	BE	61	16.00	S	082	49.62	E	GPS	-9	1479						

49NZ20130106	S04I	111	1	BUC	011813	1750	UN	61	15.97	S	082	49.67	E	GPS	-9	1472				1,20,31,33,34,96	1.8C	
49NZ20130106	S04I	111	1	ROS	011813	1810	BO	61	15.97	S	082	49.69	E	GPS	-9	1470	9	1456	1475	20	1-8,20,23,24,26,27,31,33,34,37,42,92-96	
49NZ20130106	S04I	111	1	ROS	011813	1907	EN	61	16.03	S	082	49.85	E	GPS	-9	1458						
49NZ20130106	S04I	112	1	ROS	011813	2250	BE	61	23.21	S	081	37.25	E	GPS	-9	2129						
49NZ20130106	S04I	112	1	BUC	011813	2257	UN	61	23.23	S	081	37.30	E	GPS	-9	2132					1,20	1.5C
49NZ20130106	S04I	112	1	ROS	011813	2327	BO	61	23.31	S	081	37.60	E	GPS	-9	2126	10	2124	2149	22	1-8,20,27,93	
49NZ20130106	S04I	112	1	ROS	011913	0032	EN	61	23.37	S	081	38.09	E	GPS	-9	2125						
49NZ20130106	S04I	113	1	ROS	011913	0342	BE	61	24.95	S	080	29.36	E	GPS	-9	2436						
49NZ20130106	S04I	113	1	BUC	011913	0350	UN	61	24.94	S	080	29.37	E	GPS	-9	2438					1,20	1.5C
49NZ20130106	S04I	113	1	UNK	011913	0408	UN	61	24.93	S	080	29.38	E	GPS	-9	2440					90	THROUGH HULL PUMP
49NZ20130106	S04I	113	1	ROS	011913	0422	BO	61	24.93	S	080	29.39	E	GPS	-9	2438	7	2428	2467	24	1-8,12,13,20,23,24,26,27,93	
49NZ20130106	S04I	113	1	ROS	011913	0537	EN	61	24.95	S	080	29.53	E	GPS	-9	2439						
49NZ20130106	S04I	114	1	ROS	011913	0837	BE	61	32.94	S	079	27.87	E	GPS	-9	2731						
49NZ20130106	S04I	114	1	BUC	011913	0844	UN	61	32.93	S	079	27.98	E	GPS	-9	2731					1,20	1.4C
49NZ20130106	S04I	114	1	ROS	011913	0922	BO	61	32.95	S	079	28.51	E	GPS	-9	2727	9	2739	2767	24	1-8,20,27,93	
49NZ20130106	S04I	114	1	ROS	011913	1045	EN	61	33.12	S	079	29.69	E	GPS	-9	2711						
49NZ20130106	S04I	115	1	ROS	011913	1354	BE	61	38.82	S	078	24.79	E	GPS	-9	2950						
49NZ20130106	S04I	115	1	BUC	011913	1402	UN	61	38.81	S	078	24.85	E	GPS	-9	2945					1,20,31,33,34,82	1.6C
49NZ20130106	S04I	115	1	ROS	011913	1442	BO	61	38.82	S	078	24.85	E	GPS	-9	2942	9	2937	2983	26	1-8,20,23,24,26,27,31,33,34,82,93,96	
49NZ20130106	S04I	115	1	ROS	011913	1609	EN	61	38.80	S	078	24.91	E	GPS	-9	2943						
49NZ20130106	S04I	116	1	ROS	011913	2050	BE	61	48.51	S	076	41.07	E	GPS	-9	3939						
49NZ20130106	S04I	116	1	BUC	011913	2058	UN	61	48.52	S	076	41.04	E	GPS	-9	3940					1,20	1.5C
49NZ20130106	S04I	116	1	ROS	011913	2152	BO	61	48.54	S	076	40.87	E	GPS	-9	3940	7	3934	4007	30	1-8,12,13,20,23,24,26,27,37,42,92-95	
49NZ20130106	S04I	116	1	ROS	011913	2340	EN	61	48.66	S	076	39.97	E	GPS	-9	3942						
49NZ20130106	S04I	117	1	ROS	012013	0355	BE	61	48.28	S	074	58.74	E	GPS	-9	3956						
49NZ20130106	S04I	117	1	BUC	012013	0404	UN	61	48.23	S	074	58.66	E	GPS	-9	3955					1,20	0.9C
49NZ20130106	S04I	117	1	ROS	012013	0458	BO	61	48.12	S	074	58.50	E	GPS	-9	3958	8	3951	4021	29	1-8,20,27,93	
49NZ20130106	S04I	117	1	ROS	012013	0645	EN	61	47.96	S	074	58.19	E	GPS	-9	3958						
49NZ20130106	S04I	118	1	ROS	012013	1104	BE	61	47.86	S	073	15.58	E	GPS	-9	4035						
49NZ20130106	S04I	118	1	BUC	012013	1114	UN	61	47.85	S	073	15.58	E	GPS	-9	4037					1,20	1.2C
49NZ20130106	S04I	118	1	ROS	012013	1209	BO	61	47.82	S	073	15.39	E	GPS	-9	4032	9	4031	4102	30	1-8,20,27,93	
49NZ20130106	S04I	118	1	ROS	012013	1403	EN	61	47.86	S	073	15.40	E	GPS	-9	4035						
49NZ20130106	S04I	119	1	ROS	012013	1829	BE	62	0.78	S	071	38.02	E	GPS	-9	4082						
49NZ20130106	S04I	119	1	BUC	012013	1840	UN	62	0.72	S	071	38.06	E	GPS	-9	4088					1,20	0.6C
49NZ20130106	S04I	119	1	UNK	012013	1913	UN	62	0.62	S	071	38.04	E	GPS	-9	4083					90	THROUGH HULL PUMP
49NZ20130106	S04I	119	1	ROS	012013	1935	BO	62	0.58	S	071	38.06	E	GPS	-9	4087	9	4076	4152	30	1-8,12,13,23,24,26,27,37,42,93-95	
49NZ20130106	S04I	119	1	ROS	012013	2124	EN	62	0.14	S	071	38.32	E	GPS	-9	4080						
49NZ20130106	S04I	120	1	ROS	012113	0136	BE	61	57.81	S	070	0.70	E	GPS	-9	4121						
49NZ20130106	S04I	120	1	BUC	012113	0146	UN	61	57.79	S	070	0.76	E	GPS	-9	4121					1,20	1.0C
49NZ20130106	S04I	120	1	ROS	012113	0242	BO	61	57.71	S	070	0.97	E	GPS	-9	4124	9	4118	4191	30	1-8,20,27,93	
49NZ20130106	S04I	120	1	ROS	012113	0426	EN	61	57.67	S	070	1.49	E	GPS	-9	4119						
49NZ20130106	S04I	121	1	ROS	012113	0804	BE	61	46.07	S	068	36.31	E	GPS	-9	4261						
49NZ20130106	S04I	121	1	BUC	012113	0812	UN	61	46.04	S	068	36.32	E	GPS	-9	4264					1,20,31,33	1.0C
49NZ20130106	S04I	121	1	ROS	012113	0911	BO	61	45.89	S	068	36.50	E	GPS	-9	4262	-9	4256	4334	31	1-8,20,23,24,26,27,31,33,34,93,96	
49NZ20130106	S04I	121	1	ROS	012113	1104	EN	61	45.68	S	068	36.51	E	GPS	-9	4261						
49NZ20130106	S04I	122	1	ROS	012113	1444	BE	62	3.00	S	067	12.22	E	GPS	-9	4327						
49NZ20130106	S04I	122	1	BUC	012113	1452	UN	62	2.94	S	067	12.18	E	GPS	-9	4328					1,20	1.1C
49NZ20130106	S04I	122	1	ROS	012113	1551	BO	62	2.82	S	067	12.06	E	GPS	-9	4328	9	4324	4406	31	1-8,20,27,34,93	
49NZ20130106	S04I	122	1	ROS	012113	1744	EN	62	2.76	S	067	12.18	E	GPS	-9	4327						
49NZ20130106	S04I	123	1	ROS	012113	2139	BE	62	18.96	S	065	47.85	E	GPS	-9	4373						
49NZ20130106	S04I	123	1	BUC	012113	2147	UN	62	18.94	S	065	47.77	E	GPS	-9	4370					1,20	0.7C



49NZ20130106	S04I	138	1	BUC	012513	0722	UN	65	13.47	S	053	7.95	E	GPS	-9	1879				1,20	-0.6C	
49NZ20130106	S04I	138	1	ROS	012513	0747	BO	65	13.45	S	053	7.91	E	GPS	-9	1878	9	1865	1892	21	1-8,20,23,24,26,27,37,42,92-95	
49NZ20130106	S04I	138	1	ROS	012513	0849	EN	65	13.33	S	053	7.80	E	GPS	-9	1882						
49NZ20130106	S04I	137	1	ROS	012513	1050	BE	65	6.25	S	053	1.06	E	GPS	-9	2468						
49NZ20130106	S04I	137	1	BUC	012513	1058	UN	65	6.24	S	053	1.05	E	GPS	-9	2479					1,20	-0.3C
49NZ20130106	S04I	137	1	ROS	012513	1133	BO	65	6.21	S	053	1.00	E	GPS	-9	2492	11	2484	2522	24	1-8,20,27,93	
49NZ20130106	S04I	137	1	ROS	012513	1245	EN	65	6.19	S	053	0.87	E	GPS	-9	2499						
49NZ20130106	S04I	136	1	ROS	012513	1448	BE	64	47.00	S	052	59.12	E	GPS	-9	3434						
49NZ20130106	S04I	136	1	BUC	012513	1457	UN	64	46.99	S	052	59.11	E	GPS	-9	3426					1,20	0.0C
49NZ20130106	S04I	136	1	ROS	012513	1544	BO	64	46.92	S	052	59.29	E	GPS	-9	3418	7	3446	3497	27	1-8,20,27,93	
49NZ20130106	S04I	136	1	ROS	012513	1719	EN	64	46.93	S	052	59.40	E	GPS	-9	3422						
49NZ20130106	S04I	135	1	ROS	012513	1924	BE	64	26.06	S	053	4.21	E	GPS	-9	4149						
49NZ20130106	S04I	135	1	BUC	012513	1931	UN	64	26.05	S	053	4.27	E	GPS	-9	4146					1,20,31,33,34,82	0.1C
49NZ20130106	S04I	135	1	UNK	012513	1955	UN	64	26.05	S	053	4.29	E	GPS	-9	4149					90	THROUGH HULL PUMP
49NZ20130106	S04I	135	1	ROS	012513	2030	BO	64	26.03	S	053	4.29	E	GPS	-9	4146	10	4172	4243	32	1-8,20,23,24,26,27,31,33,34,37,42,82,93-95	
49NZ20130106	S04I	135	1	ROS	012513	2217	EN	64	25.88	S	053	4.18	E	GPS	-9	4160						
49NZ20130106	S04I	134	1	ROS	012613	0106	BE	63	58.10	S	053	25.15	E	GPS	-9	4347						
49NZ20130106	S04I	134	1	BUC	012613	0114	UN	63	58.09	S	053	25.15	E	GPS	-9	4350					1,20	0.3C
49NZ20130106	S04I	134	1	ROS	012613	0214	BO	63	58.07	S	053	25.21	E	GPS	-9	4345	8	4337	4420	31	1-8,20,27,93	
49NZ20130106	S04I	134	1	ROS	012613	0408	EN	63	58.12	S	053	25.13	E	GPS	-9	4343						
49NZ20130106	S04I	131	1	ROS	012613	1048	BE	63	30.00	S	055	59.59	E	GPS	-9	4820						
49NZ20130106	S04I	131	1	BUC	012613	1056	UN	63	29.99	S	055	59.57	E	GPS	-9	4818					1,20,31,33	0.7C
49NZ20130106	S04I	131	1	UNK	012613	1118	UN	63	30.00	S	055	59.50	E	GPS	-9	4818					90	THROUGH HULL PUMP
49NZ20130106	S04I	131	1	ROS	012613	1202	BO	63	30.00	S	055	59.54	E	GPS	-9	4820	10	4814	4912	34	1-8,20,23,24,26,27,31,33,34,93,96	
49NZ20130106	S04I	131	1	ROS	012613	1403	EN	63	29.96	S	055	59.43	E	GPS	-9	4822						
49NZ20130106	S04I	132	1	ROS	012613	1643	BE	63	29.95	S	054	49.38	E	GPS	-9	4751						
49NZ20130106	S04I	132	1	BUC	012613	1651	UN	63	29.93	S	054	49.32	E	GPS	-9	4751					1,20,90	0.6C
49NZ20130106	S04I	132	1	ROS	012613	1754	BO	63	29.92	S	054	49.37	E	GPS	-9	4750	9	4743	4839	33	1-8,20,27,90,93	
49NZ20130106	S04I	132	1	ROS	012613	1956	EN	63	29.95	S	054	49.34	E	GPS	-9	4749						
49NZ20130106	S04I	133	1	ROS	012613	2251	BE	63	29.87	S	053	40.77	E	GPS	-9	4757						
49NZ20130106	S04I	133	1	BUC	012613	2259	UN	63	29.93	S	053	40.73	E	GPS	-9	4755					1,20	0.8C
49NZ20130106	S04I	133	1	ROS	012713	0005	BO	63	30.10	S	053	40.61	E	GPS	-9	4751	8	4752	4843	32	1-8,12,13,20,23,24,26,27,37,42,92-95	
49NZ20130106	S04I	133	1	ROS	012713	0201	EN	63	30.13	S	053	40.78	E	GPS	-9	4754						
49NZ20130106	S04I	141	1	ROS	012713	0448	BE	63	29.53	S	052	29.70	E	GPS	-9	4622						
49NZ20130106	S04I	141	1	BUC	012713	0455	UN	63	29.56	S	052	29.76	E	GPS	-9	4624					1,20	0.8C
49NZ20130106	S04I	141	1	ROS	012713	0559	BO	63	29.66	S	052	30.45	E	GPS	-9	4616	10	4621	4703	32	1-8,20,27,93	
49NZ20130106	S04I	141	1	ROS	012713	0758	EN	63	29.74	S	052	31.14	E	GPS	-9	4614						
49NZ20130106	S04I	142	1	ROS	012713	1031	BE	63	30.01	S	051	24.71	E	GPS	-9	4799						
49NZ20130106	S04I	142	1	BUC	012713	1039	UN	63	30.00	S	051	24.68	E	GPS	-9	4797					1,20	1.0C
49NZ20130106	S04I	142	1	ROS	012713	1145	BO	63	29.99	S	051	24.65	E	GPS	-9	4798	9	4791	4888	33	1,20,23,24,26,27,93	
49NZ20130106	S04I	142	1	ROS	012713	1344	EN	63	30.01	S	051	24.64	E	GPS	-9	4797						
49NZ20130106	S04I	143	1	ROS	012713	1625	BE	63	29.99	S	050	15.12	E	GPS	-9	4753						
49NZ20130106	S04I	143	1	BUC	012713	1633	UN	63	30.00	S	050	15.11	E	GPS	-9	4751					1,20	1.1C
49NZ20130106	S04I	143	1	ROS	012713	1641	EN	63	29.99	S	050	15.12	E	GPS	-9	4755						AT SURFACE, NOT ON DECK
49NZ20130106	S04I	143	2	ROS	012713	1644	BE	63	30.00	S	050	15.11	E	GPS	-9	4755						
49NZ20130106	S04I	143	2	ROS	012713	1753	BO	63	29.98	S	050	15.10	E	GPS	-9	4753	9	4745	4840	33	1-8,20,27,37,93,94	
49NZ20130106	S04I	143	2	ROS	012713	1952	EN	63	29.98	S	050	15.04	E	GPS	-9	4753						
49NZ20130106	S04I	144	1	ROS	012713	2236	BE	63	29.94	S	049	9.96	E	GPS	-9	4760						
49NZ20130106	S04I	144	1	BUC	012713	2244	UN	63	29.95	S	049	9.90	E	GPS	-9	4755					1,20	1.2C
49NZ20130106	S04I	144	1	ROS	012713	2349	BO	63	29.99	S	049	9.79	E	GPS	-9	4758	9	4748	4845	33	1-8,20,23,24,26,27,37,42,93-95	
49NZ20130106	S04I	144	1	ROS	012813	0147	EN	63	30.06	S	049	10.04	E	GPS	-9	4759						

49NZ20130106	S04I	145	1	ROS	012813	0431	BE	63	29.98	S	048	0.11	E	GPS	-9	4534						
49NZ20130106	S04I	145	1	BUC	012813	0438	UN	63	29.97	S	048	0.08	E	GPS	-9	4533				1,20		1.6C
49NZ20130106	S04I	145	1	ROS	012813	0540	BO	63	30.00	S	048	0.19	E	GPS	-9	4531	9	4526	4614	32	1-8,20,27,93	
49NZ20130106	S04I	145	1	ROS	012813	0734	EN	63	30.03	S	048	0.12	E	GPS	-9	4536						
49NZ20130106	S04I	146	1	ROS	012813	1119	BE	63	44.18	S	046	24.31	E	GPS	-9	4213						
49NZ20130106	S04I	146	1	BUC	012813	1127	UN	63	44.20	S	046	24.23	E	GPS	-9	4220				1,20,31,33,34		1.5C
49NZ20130106	S04I	146	1	ROS	012813	1225	BO	63	44.22	S	046	24.18	E	GPS	-9	4225	9	4204	4284	32	1-8,12,13,20,23,24,26,27,31,33,34,92,93	
49NZ20130106	S04I	146	1	ROS	012813	1417	EN	63	44.25	S	046	24.10	E	GPS	-9	4214						
49NZ20130106	S04I	147	1	ROS	012813	1758	BE	63	59.01	S	044	50.73	E	GPS	-9	4436						
49NZ20130106	S04I	147	1	BUC	012813	1806	UN	63	59.03	S	044	50.71	E	GPS	-9	4441				1,20		1.4C
49NZ20130106	S04I	147	1	ROS	012813	1906	BO	63	58.97	S	044	50.61	E	GPS	-9	4451	8	4423	4507	32	1-8,20,27,93	
49NZ20130106	S04I	147	1	ROS	012813	2059	EN	63	58.89	S	044	50.50	E	GPS	-9	4434						
49NZ20130106	S04I	148	1	ROS	012913	0102	BE	64	13.43	S	043	15.55	E	GPS	-9	4449						
49NZ20130106	S04I	148	1	BUC	012913	0110	UN	64	13.44	S	043	15.54	E	GPS	-9	4445				1,20		1.3C
49NZ20130106	S04I	148	1	ROS	012913	0211	BO	64	13.40	S	043	15.52	E	GPS	-9	4447	8	4449	4530	31	1-8,20,23,24,26,27,37,42,93-95	
49NZ20130106	S04I	148	1	ROS	012913	0402	EN	64	13.30	S	043	15.36	E	GPS	-9	4452						
49NZ20130106	S04I	149	1	ROS	012913	0745	BE	64	27.82	S	041	37.00	E	GPS	-9	4408						
49NZ20130106	S04I	149	1	BUC	012913	0753	UN	64	27.79	S	041	36.87	E	GPS	-9	4414				1,20		1.5C
49NZ20130106	S04I	149	1	ROS	012913	0854	BO	64	27.74	S	041	36.93	E	GPS	-9	4414	9	4406	4491	31	1-8,20,27,93	
49NZ20130106	S04I	149	1	ROS	012913	1048	EN	64	27.69	S	041	37.00	E	GPS	-9	4413						
49NZ20130106	S04I	150	1	ROS	012913	1416	BE	64	41.28	S	040	5.19	E	GPS	-9	4712						
49NZ20130106	S04I	150	1	BUC	012913	1424	UN	64	41.30	S	040	5.16	E	GPS	-9	4714				1,20,31,33		1.6C
49NZ20130106	S04I	150	1	ROS	012913	1529	BO	64	41.31	S	040	5.10	E	GPS	-9	4714	9	4709	4805	34	1-8,20,23,24,26,27,31,33,34,93	
49NZ20130106	S04I	150	1	ROS	012913	1729	EN	64	41.29	S	040	4.99	E	GPS	-9	4713						
49NZ20130106	S04I	151	1	ROS	012913	2132	BE	64	56.19	S	038	28.26	E	GPS	-9	4839						
49NZ20130106	S04I	151	1	BUC	012913	2140	UN	64	56.19	S	038	28.25	E	GPS	-9	4842				1,20		1.5C
49NZ20130106	S04I	151	1	ROS	012913	2247	BO	64	56.10	S	038	28.14	E	GPS	-9	4843	9	4834	4934	33	1-8,20,23,24,26,27,37,42,92-95	
49NZ20130106	S04I	151	1	ROS	013013	0050	EN	64	55.89	S	038	27.84	E	GPS	-9	4841						
49NZ20130106	S04I	152	1	ROS	013013	0344	BE	65	8.07	S	037	20.95	E	GPS	-9	4836						
49NZ20130106	S04I	152	1	BUC	013013	0352	UN	65	8.07	S	037	20.90	E	GPS	-9	4836				1,20		1.3C
49NZ20130106	S04I	152	1	ROS	013013	0458	BO	65	7.95	S	037	20.74	E	GPS	-9	4836	8	4841	4932	33	1-8,20,27,93	
49NZ20130106	S04I	152	1	ROS	013013	0659	EN	65	7.77	S	037	20.66	E	GPS	-9	4836						
49NZ20130106	S04I	153	1	ROS	013013	0951	BE	65	18.04	S	036	7.42	E	GPS	-9	4647						
49NZ20130106	S04I	153	1	BUC	013013	0959	UN	65	18.01	S	036	7.33	E	GPS	-9	4650				1,20		1.1C
49NZ20130106	S04I	153	1	ROS	013013	1104	BO	65	18.03	S	036	7.26	E	GPS	-9	4645	10	4642	4734	33	1-8,12,13,20,23,24,26,27,37,42,93-95	
49NZ20130106	S04I	153	1	ROS	013013	1307	EN	65	17.98	S	036	7.17	E	GPS	-9	4648						
49NZ20130106	S04I	154	1	ROS	013013	1615	BE	65	32.53	S	034	55.75	E	GPS	-9	4529						
49NZ20130106	S04I	154	1	BUC	013013	1624	UN	65	32.53	S	034	55.73	E	GPS	-9	4527				1,20		1.0C
49NZ20130106	S04I	154	1	ROS	013013	1726	BO	65	32.49	S	034	55.54	E	GPS	-9	4526	10	4523	4610	32	1-8,20,27,93	
49NZ20130106	S04I	154	1	ROS	013013	1921	EN	65	32.27	S	034	55.49	E	GPS	-9	4528						
49NZ20130106	S04I	155	1	ROS	013013	2119	BE	65	41.84	S	034	14.85	E	GPS	-9	3155						
49NZ20130106	S04I	155	1	BUC	013013	2127	UN	65	41.82	S	034	14.84	E	GPS	-9	3154				1,20		0.3C
49NZ20130106	S04I	155	1	ROS	013013	2211	BO	65	41.78	S	034	14.84	E	GPS	-9	3158	10	3157	3207	26	1-8,20,23,24,26,27,93	
49NZ20130106	S04I	155	1	ROS	013013	2339	EN	65	41.74	S	034	14.72	E	GPS	-9	3162						
49NZ20130106	S04I	156	1	ROS	013113	0141	BE	65	41.97	S	033	29.30	E	GPS	-9	1757						
49NZ20130106	S04I	156	1	BUC	013113	0149	UN	65	41.95	S	033	29.30	E	GPS	-9	1761				1,20,31,33,34,82		0.5C
49NZ20130106	S04I	156	1	ROS	013113	0212	BO	65	41.91	S	033	29.29	E	GPS	-9	1761	10	1748	1769	23	1-8,20,23,24,26,27,31,33,34,82,92,93,96	
49NZ20130106	S04I	156	1	ROS	013113	0315	EN	65	41.77	S	033	29.21	E	GPS	-9	1767						
49NZ20130106	S04I	157	1	ROS	013113	0903	BE	66	0.01	S	036	0.00	E	GPS	-9	4366						
49NZ20130106	S04I	157	1	BUC	013113	0911	UN	66	0.01	S	035	59.97	E	GPS	-9	4361				1,20,90		1.1C
49NZ20130106	S04I	157	1	ROS	013113	1011	BO	66	0.02	S	036	0.14	E	GPS	-9	4365	10	4356	4441	32	1-8,20,23,24,26,27,37,42,90,93-95	

49NZ20130106	S04I	157	1	ROS	013113	1202	EN	65	59.87	S	036	0.34	E	GPS	-9	4360					
49NZ20130106	S04I	158	1	ROS	013113	1456	BE	66	29.96	S	035	59.93	E	GPS	-9	4514					
49NZ20130106	S04I	158	1	BUC	013113	1504	UN	66	29.95	S	035	59.97	E	GPS	-9	4512			1,20	0.3C	
49NZ20130106	S04I	158	1	UNK	013113	1520	UN	66	29.96	S	036	0.00	E	GPS	-9	4511			90	THROUGH HULL PUMP	
49NZ20130106	S04I	158	1	ROS	013113	1606	BO	66	29.97	S	035	59.97	E	GPS	-9	4510	7	4507	4597	32	1-8,20,23,24,26,27,37,42,93-95
49NZ20130106	S04I	158	1	ROS	013113	1801	EN	66	29.91	S	036	0.27	E	GPS	-9	4509					
49NZ20130106	S04I	162	1	ROS	020113	0326	BE	68	3.65	S	037	58.64	E	GPS	-9	3271					
49NZ20130106	S04I	162	1	BUC	020113	0335	UN	68	3.60	S	037	58.64	E	GPS	-9	3274				1,20,31,33,34	-1.2C
49NZ20130106	S04I	162	1	ROS	020113	0421	BO	68	3.41	S	037	58.96	E	GPS	-9	3277	9	3282	3324	28	1-8,20,23,24,26,27,31,33,34,37,42,92-96
49NZ20130106	S04I	162	1	ROS	020113	0550	EN	68	3.08	S	037	59.05	E	GPS	-9	3287					
49NZ20130106	S04I	163	1	ROS	020113	0909	BE	67	29.99	S	037	59.97	E	GPS	-9	4094					
49NZ20130106	S04I	163	1	BUC	020113	0917	UN	67	30.00	S	037	59.99	E	GPS	-9	4095				1,20	0.4C
49NZ20130106	S04I	163	1	ROS	020113	1013	BO	67	30.05	S	038	0.04	E	GPS	-9	4089	9	4088	4165	31	1-8,20,27,93
49NZ20130106	S04I	163	1	ROS	020113	1209	EN	67	30.00	S	037	59.94	E	GPS	-9	4091					
49NZ20130106	S04I	164	1	ROS	020113	1513	BE	66	60.00	S	037	59.81	E	GPS	-9	4415					
49NZ20130106	S04I	164	1	BUC	020113	1521	UN	67	0.03	S	037	59.71	E	GPS	-9	4416				1,20	0.5C
49NZ20130106	S04I	164	1	ROS	020113	1620	BO	67	0.09	S	037	59.78	E	GPS	-9	4413	8	4417	4500	33	1-8,20,23,24,26,27,34,37,42,93-95
49NZ20130106	S04I	164	1	ROS	020113	1815	EN	67	0.19	S	037	59.56	E	GPS	-9	4417					
49NZ20130106	S04I	165	1	ROS	020113	2110	BE	66	30.11	S	037	59.88	E	GPS	-9	4604					
49NZ20130106	S04I	165	1	BUC	020113	2118	UN	66	30.17	S	037	59.87	E	GPS	-9	4603				1,20	0.9C
49NZ20130106	S04I	165	1	ROS	020113	2125	EN	66	30.19	S	037	59.86	E	GPS	-9	4603					ABORTED, A JELLYFISH IN TC-DUCT
49NZ20130106	S04I	165	2	ROS	020113	2140	BE	66	30.22	S	037	59.90	E	GPS	-9	4601					
49NZ20130106	S04I	165	2	ROS	020113	2251	BO	66	30.30	S	037	59.98	E	GPS	-9	4601	9	4596	4688	33	1-8,20,27,34,93
49NZ20130106	S04I	165	2	ROS	020213	0050	EN	66	30.33	S	038	0.07	E	GPS	-9	4604					
49NZ20130106	S04I	167	1	ROS	020213	0550	BE	65	29.97	S	037	59.99	E	GPS	-9	4788					
49NZ20130106	S04I	167	1	BUC	020213	0558	UN	65	29.96	S	038	0.01	E	GPS	-9	4787				1,20	1.3C
49NZ20130106	S04I	167	1	XCT	020213	0603	DE	65	29.95	S	038	0.03	E	GPS	-9	4788					TSK XCTD-4 #12099194
49NZ20130106	S04I	167	1	ROS	020213	0703	BO	65	29.85	S	037	59.88	E	GPS	-9	4787	10	4786	4879	34	1-8,20,27,34,93
49NZ20130106	S04I	167	1	ROS	020213	0911	EN	65	29.60	S	037	59.58	E	GPS	-9	4786					
49NZ20130106	S04I	166	1	ROS	020213	1159	BE	66	0.11	S	038	0.09	E	GPS	-9	4722					
49NZ20130106	S04I	166	1	BUC	020213	1206	UN	66	0.12	S	038	0.09	E	GPS	-9	4721				1,20	1.1C
49NZ20130106	S04I	166	1	XCT	020213	1212	DE	66	0.11	S	038	0.09	E	GPS	-9	4720					TSK XCTD-4 #12099193
49NZ20130106	S04I	166	1	ROS	020213	1311	BO	65	59.99	S	038	0.05	E	GPS	-9	4723	8	4719	4813	33	1-8,20,23,24,26,27,34,37,42,92-95
49NZ20130106	S04I	166	1	ROS	020213	1512	EN	65	59.93	S	038	0.02	E	GPS	-9	4720					
49NZ20130106	999	903	1	UNK	020213	1524	BE	66	0.01	S	038	1.93	E	GPS	-9	4720					3-AXIS MAGNETMETER CALIBRATION
49NZ20130106	999	903	1	UNK	020213	1554	EN	66	0.32	S	038	2.11	E	GPS	-9	4723					
49NZ20130106	999	904	1	UNK	020913	0000	BE	53	23.66	S	091	38.02	E	GPS	-9	4361					3-AXIS MAGNETMETER CALIBRATION
49NZ20130106	999	904	1	UNK	020913	0030	EN	53	23.21	S	091	38.89	E	GPS	-9	4362					
49NZ20130106	999	905	1	UNK	021313	0702	BE	37	43.65	S	110	38.18	E	GPS	-9	4319					3-AXIS MAGNETMETER CALIBRATION
49NZ20130106	999	905	1	UNK	021313	0729	EN	37	44.19	S	110	38.49	E	GPS	-9	4301					

Water sample parameters:

Number	Parameter	Mnemonic	Mnemonic for expected error
1	Salinity	ALNTY	
2	Oxygen	OXYGEN	
3	Silicate	SILCAT	SILUNC *1
4	Nitrate	NITRAT	NRAUNC *1
5	Nitrite	NITRIT	NRIUNC *1
6	Phosphate	PHSPHT	PHPUNC *1
7	Freon-11	CFC-11	
8	Freon-12	CFC-12	
12	14Carbon	DELC14	C14ERR
13	13Carbon	DELC13	C13ERR
20	Ratio of O18 to O16	O18/O16	
22	137Cesium	CS-137	CS137ER *2
23	Total carbon	TCARBN	
24	Total alkalinity	ALKALI	
26	pH	PH	
27	Freon-113	CFC113	
28	Carbon tetrachloride	CCL4	
31	Methane	CH4	
33	Nitrous oxide	N2O	
34	Chlorophyll-a	CHLORA	
37	Biogenic sulfur compounds	DMS	
40	Particulate organic carbon	PO14C	
42	Abundance of bacteriaBACT		
47	Plutonium	PLUTO	PLUTOER *2
64	Incubation		
81	Particulate organic matter	POM	
82	15N-Nitrate	15NO3	
83	Particulate inorganic matter	PIM	
89	134Cesium	CS-134	CS134ER
90	Perfluoroalkyl substances	PFAS	
91	Iodine-129	I-129	
92	Density salinity	DNSSAL	
93	Sulfur hexafluoride	SF6	
94	Isoprene		
95	Pigment		
96	Chlorophyll-a isotope		

## Figure captions

- Figure 1 Station locations for WHP P14S, S04I revisit in 2012 cruise with bottom topography.
- Figure 2 Bathymetry measured by Multi Narrow Beam Echo Sounding system.
- Figure 3 Surface wind measured at 25 m above sea level. Wind data is averaged over 6-hour.
- Figure 4 (a) Sea surface temperature ( $^{\circ}\text{C}$ ), (b) sea surface salinity (psu), (c) sea surface oxygen ( $\mu\text{mol}/\text{kg}$ ), and (d) sea surface chlorophyll *a* ( $\text{mg}/\text{m}^3$ ) measured by the Continuous Sea Surface Water Monitoring System.
- Figure 5 Difference in the partial pressure of  $\text{CO}_2$  between the ocean and the atmosphere,  $\Delta p\text{CO}_2$ .
- Figure 6 Surface current at 100 m depth measured by ship board acoustic Doppler current profiler (ADCP).
- Figure 7 Potential temperature ( $^{\circ}\text{C}$ ) cross sections calculated by using CTD temperature and salinity data calibrated by bottle salinity measurements. Vertical exaggeration of the 0-6500 m section is 1000:1, and expanded section of the upper 1000 m is made with a vertical exaggeration of 2500:1, except for short meridional sections ( $38^{\circ}\text{E}$ ,  $53^{\circ}\text{E}$ ). For the short sections, vertical exaggeration of the 0-6500 m and 0-1000 m section are 250:1 and 625:1, respectively.
- Figure 8 CTD salinity (psu) cross sections calibrated by bottle salinity measurements. Vertical exaggeration is same as Fig. 7.
- Figure 9 Absolute salinity ( $\text{g}/\text{kg}$ ) cross sections calculated by using CTD salinity data. Vertical exaggeration is same as Fig. 7.
- Figure 10 Density (upper:  $\sigma_0$ , lower:  $\sigma_t$ ) ( $\text{kg}/\text{m}^3$ ) cross sections calculated by using CTD temperature and salinity data. Vertical exaggeration of the 0-1500 m and 1500-6500 m section are 2500:1 and 1000:1, respectively, except for short meridional sections ( $38^{\circ}\text{E}$ ,  $53^{\circ}\text{E}$ ). For the short sections, vertical exaggeration of the 0-1500 m and 1500-6500 m section are 250:1 and 625:1, respectively. (a) EOS-80 and (b) TEOS-10 definition.
- Figure 11 Neutral density ( $\gamma^n$ ) ( $\text{kg}/\text{m}^3$ ) cross sections calculated by using CTD temperature and salinity data. Vertical exaggeration is same as Fig. 7.
- Figure 12 CTD oxygen ( $\mu\text{mol}/\text{kg}$ ) cross sections. Vertical exaggeration is same as Fig. 7.
- Figure 13 CTD chlorophyll *a* ( $\mu\text{g}/\text{L}$ ) cross sections. Vertical exaggeration of the upper 1000 m section is same as Fig. 7.
- Figure 14 CTD beam attenuation coefficient ( $\text{m}^{-1}$ ) cross sections. Vertical exaggeration is same as Fig. 7.
- Figure 15 Bottle sampled dissolved oxygen ( $\mu\text{mol}/\text{kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.
- Figure 16 Silicate ( $\mu\text{mol}/\text{kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 17 Nitrate ( $\mu\text{mol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 18 Nitrite ( $\mu\text{mol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration of the upper 1000 m section is same as Fig. 7.

Figure 19 Phosphate ( $\mu\text{mol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 20 Dissolved inorganic carbon ( $\mu\text{mol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 21 Total alkalinity ( $\mu\text{mol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

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

Figure 23 CFC-11 ( $\text{pmol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 24 CFC-12 ( $\text{pmol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 25 CFC-113 ( $\text{pmol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 26  $\text{SF}_6$  ( $\text{fmol/kg}$ ) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 27 Cross sections of current velocity ( $\text{cm/s}$ ) normal to the cruise track measured by LADCP (eastward or northward is positive). Vertical exaggeration is same as Fig. 7.

Figure 28 Difference in potential temperature ( $^{\circ}\text{C}$ ) between results from the WOCE cruise in 1995/96 and the revisit in 2012/13. Red and blue areas show areas where potential temperature increased and decreased in the revisit cruise, respectively. On white areas differences in temperature do not exceed the detection limit of  $0.002^{\circ}\text{C}$ . Vertical exaggeration is same as Fig. 7.

Figure 29 Same as Fig. 28, but for salinity (psu). CTD salinity data with SSW batch correction<sup>1</sup> were used. On white areas differences in salinity do not exceed the detection limit of  $0.002$  psu.

Figure 30 Same as Fig. 28, but for dissolved oxygen ( $\mu\text{mol/kg}$ ). CTD oxygen data were used. On white areas differences in dissolved oxygen do not exceed the detection limit of  $2 \mu\text{mol/kg}$ .

Figure 31 Same as Fig. 30, but for bottle sampled dissolved oxygen ( $\mu\text{mol/kg}$ ).

#### Note

1. As for the traceability of SSW to Kawano's value (Kawano et al., 2006), the offset for the batches P108 (WOCE S04P), P114 (WOCE P14S), P123 (WOCE S04), P124 (WOCE I09S), P125 (WOCE S04I) and P155 (the revisit) are 0.0017, 0.0020, 0.0007, 0.0006, 0.0002 and 0.0001, respectively. The offset values for the recent batches are listed in [Table A1](#) (Uchida et al., in preparation).

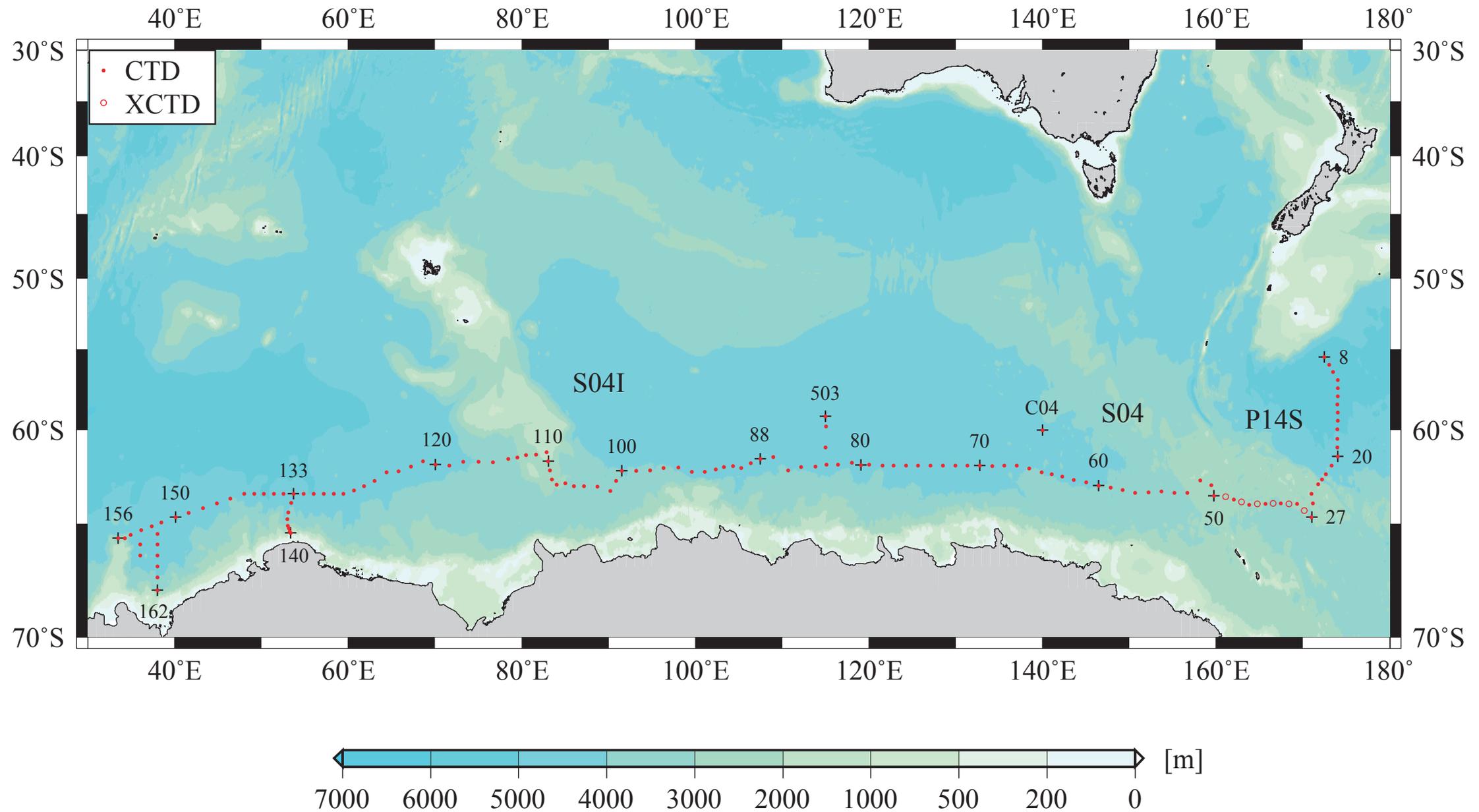
Table A1. SSW batch to batch differences from P145 to P157 (Uchida et al., in preparation). The difference of P145 is reevaluated.

Batch no.	Production date	K15	Sp	Batch to batch difference ( $\times 10^{-3}$ )	
				Mantyla's standard	Kawano's standard
P145	2004/07/15	0.99981	34.9925	-2.3	-1.0
P146	2005/05/12	0.99979	34.9917	-2.8	-1.5
P147	2006/06/06	0.99982	34.9929	-1.9	-0.6
P148	2006/10/01	0.99982	34.9929	-1.3	0.0
P149	2007/10/05	0.99984	34.9937	-0.6	0.7
P150	2008/05/22	0.99978	34.9913	-0.6	0.7
P151	2009/05/20	0.99997	34.9984	-1.7	-0.4
P152	2010/05/05	0.99981	34.9926	-1.3	0.0
P153	2011/03/08	0.99979	34.9918	-0.9	0.4
P154	2011/10/20	0.99990	34.9961	-0.7	0.6
P155	2012/09/19	0.99981	34.9925	-1.2	0.1
P156	2013/07/23	0.99984	34.9937	-0.9	0.4
P157	2014/05/15	0.99985	34.9941	-2.0	-0.7

#### Reference

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

**Figure 1**  
**Station locations**



**Figure 2**

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

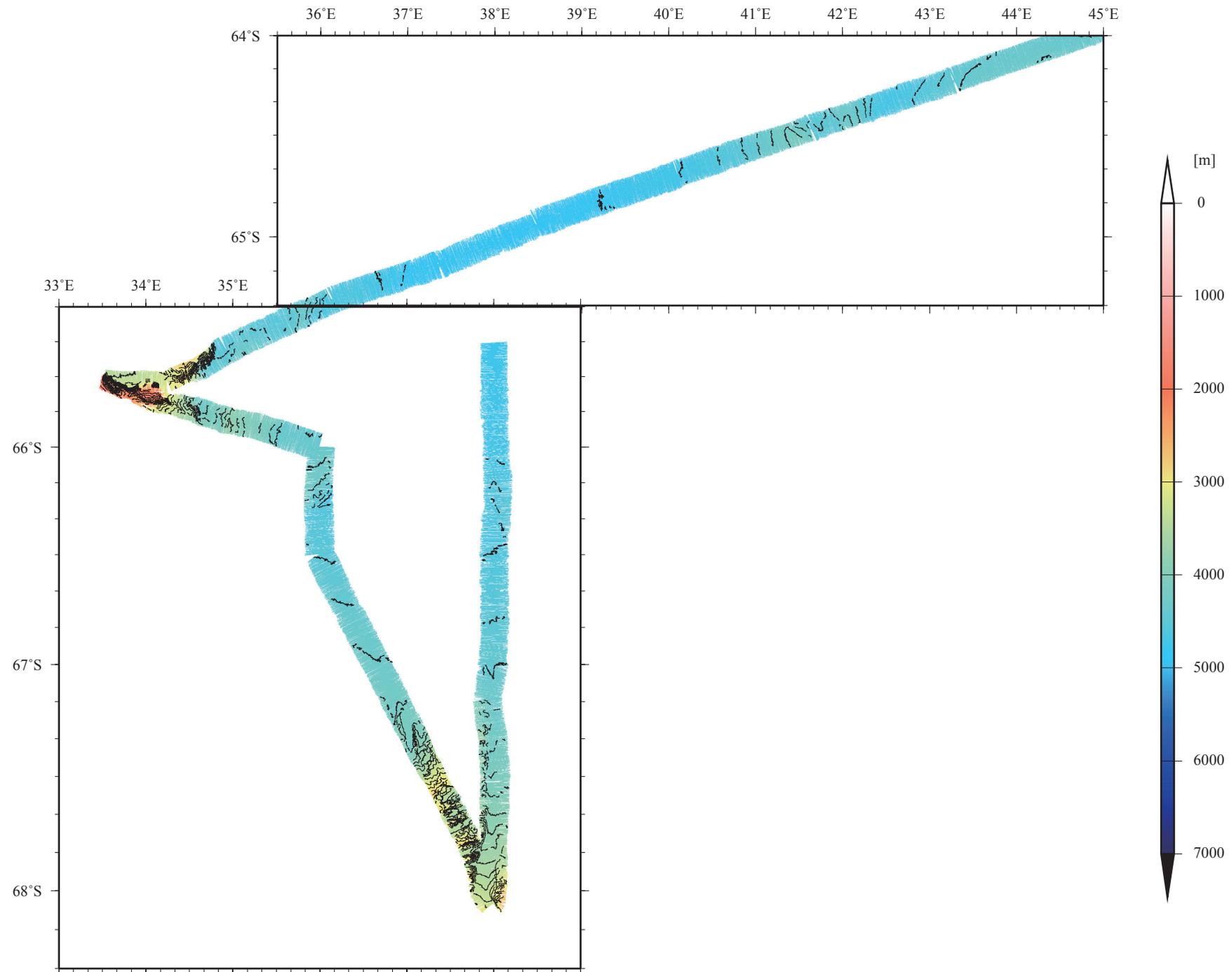


Figure 2  
Continued

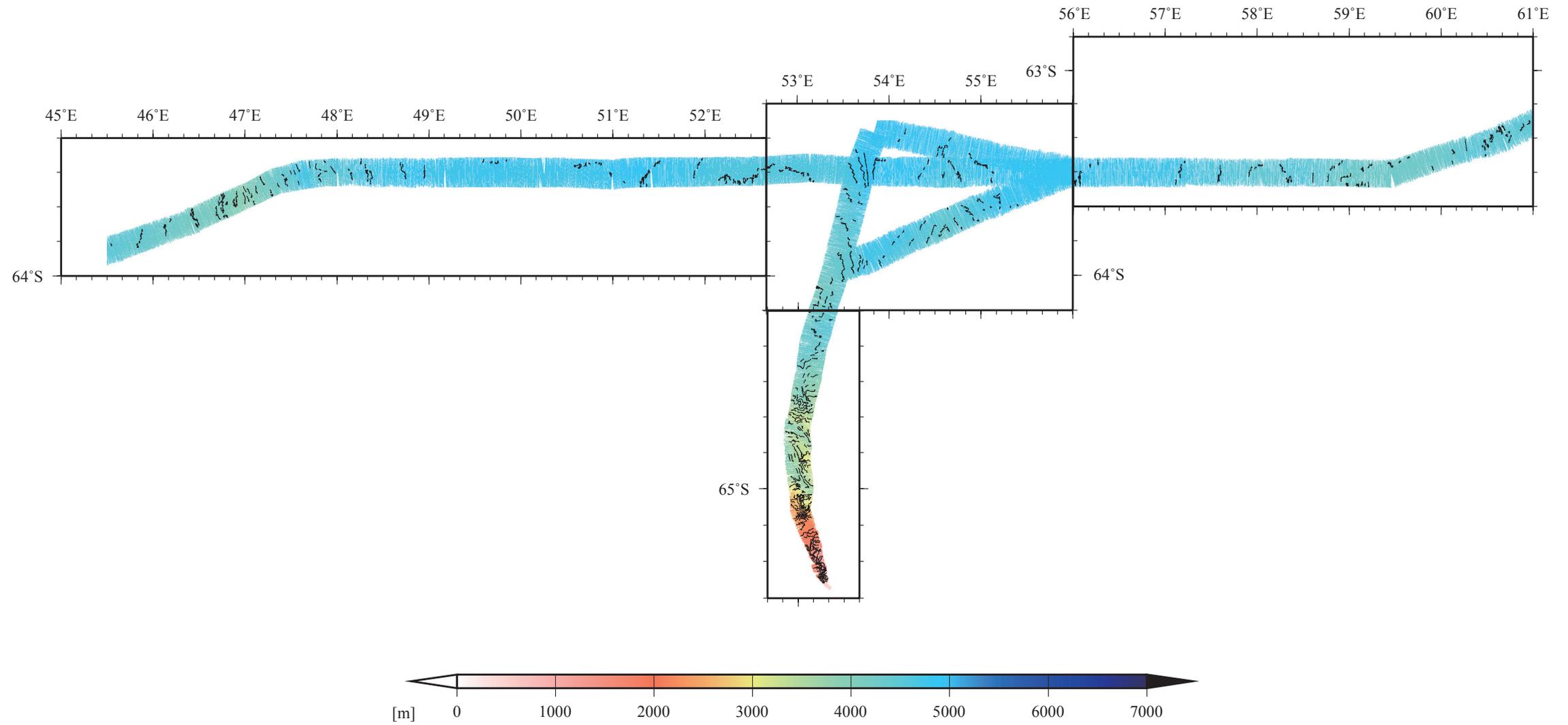
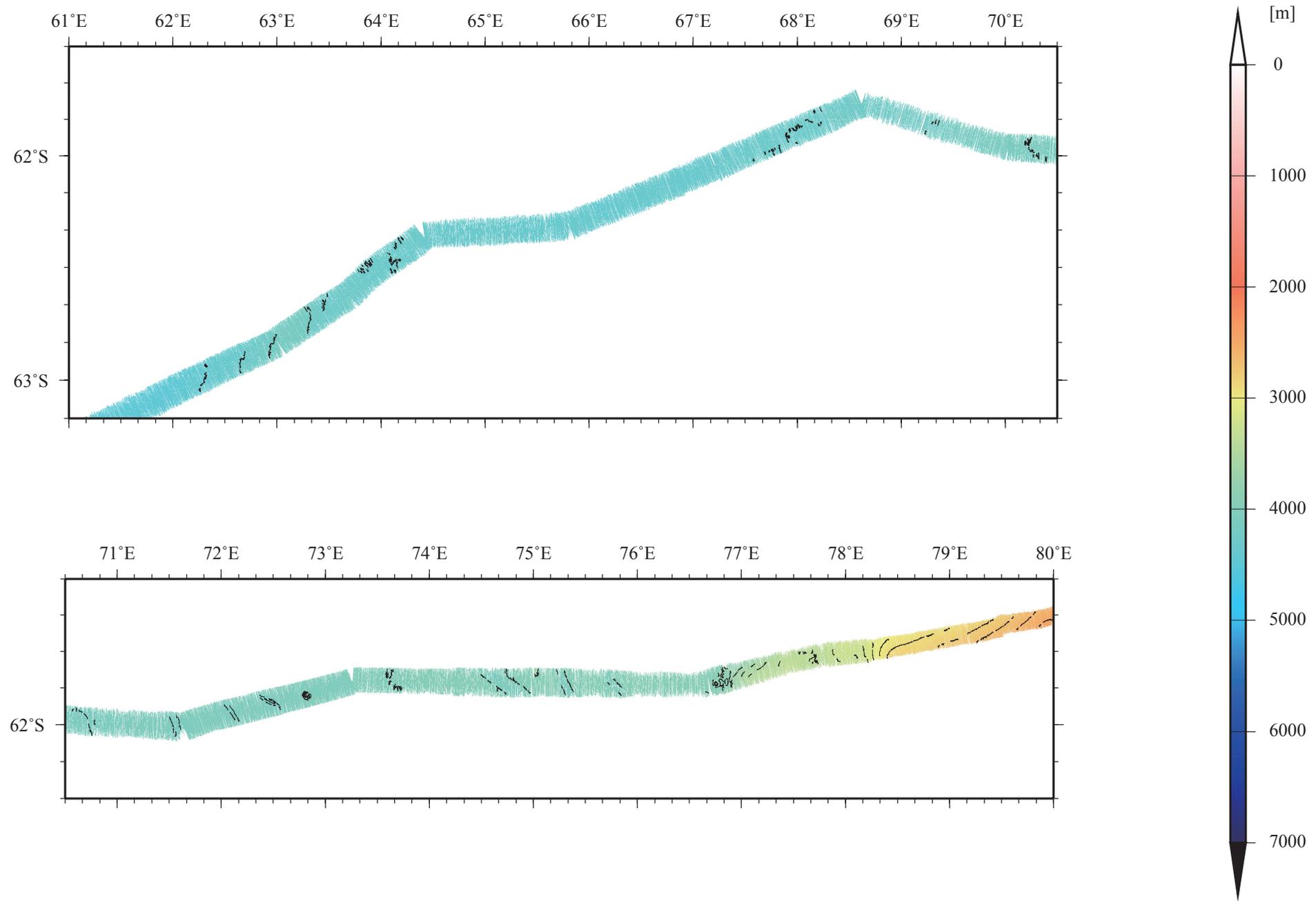
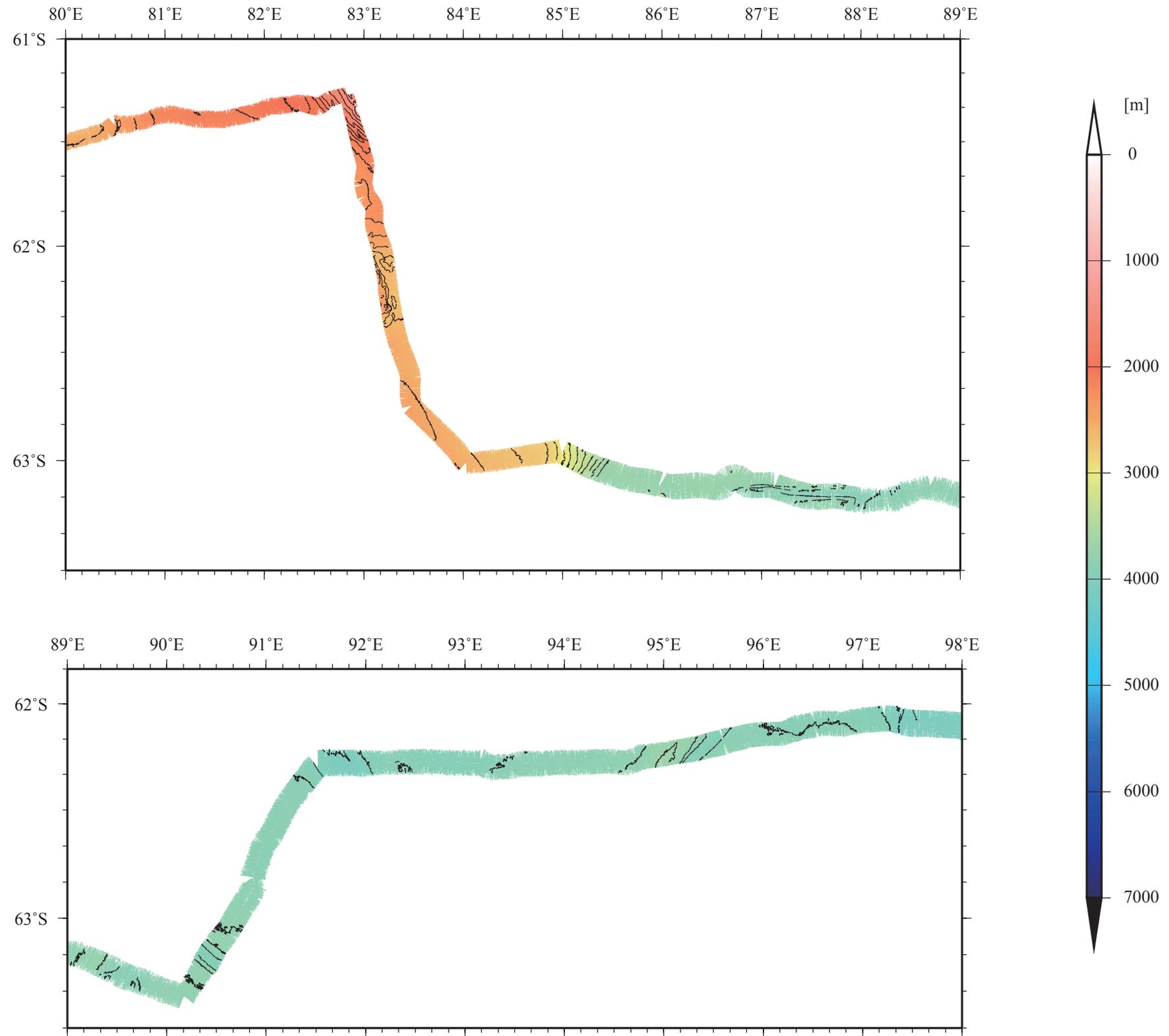


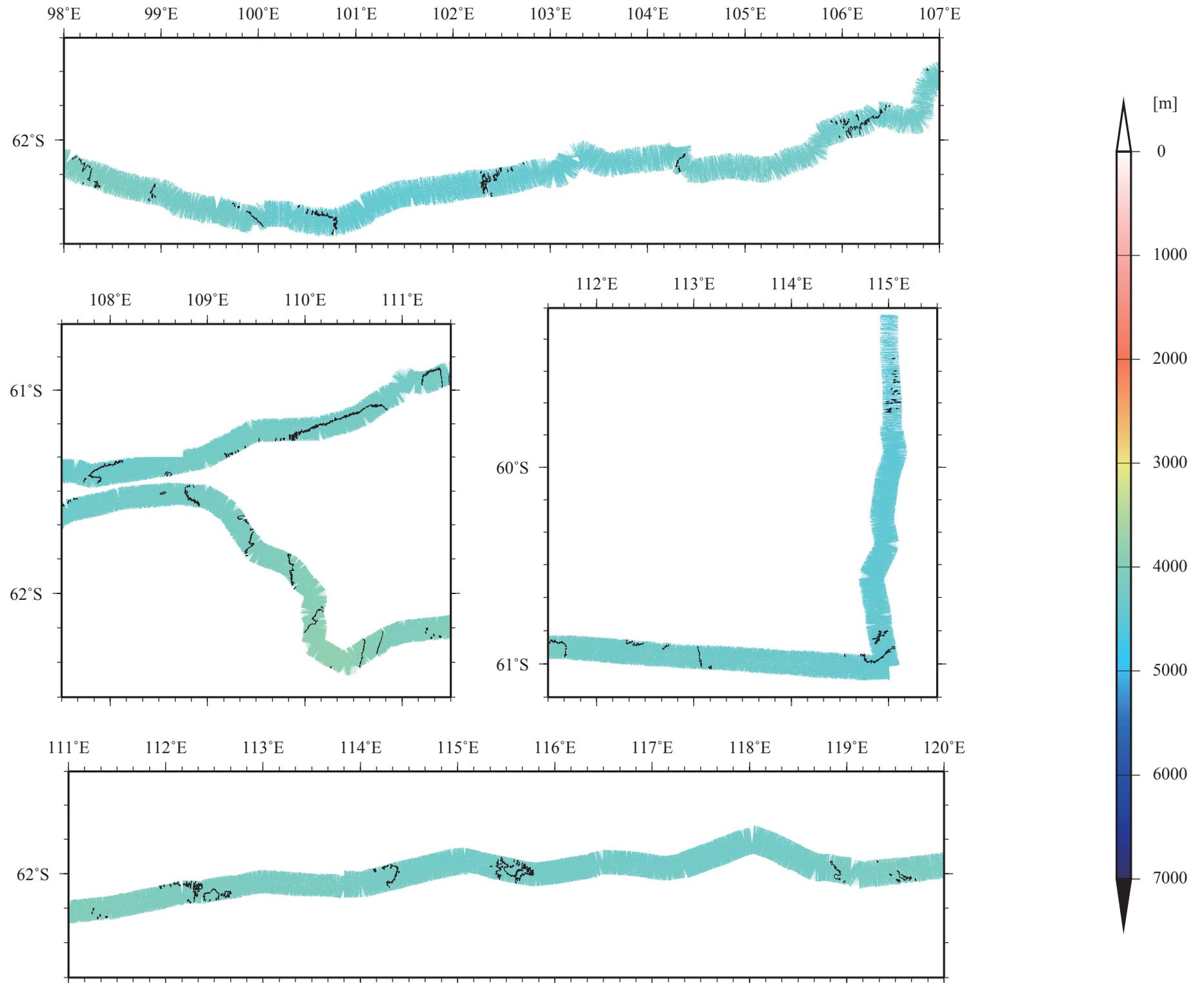
Figure 2  
Continued



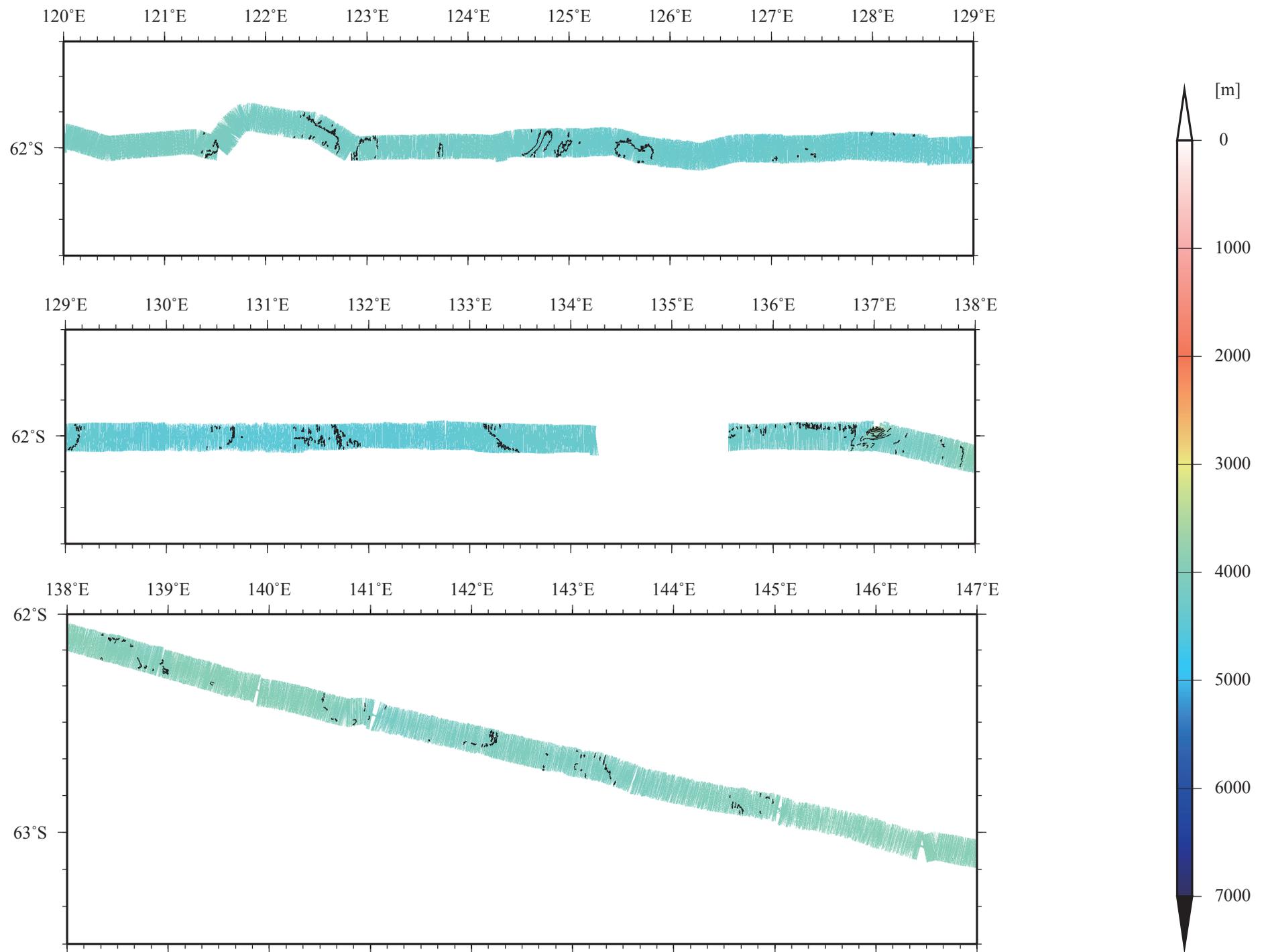
**Figure 2**  
**Continued**



**Figure 2**  
**Continued**



**Figure 2**  
**Continued**



**Figure 2**  
**Continued**

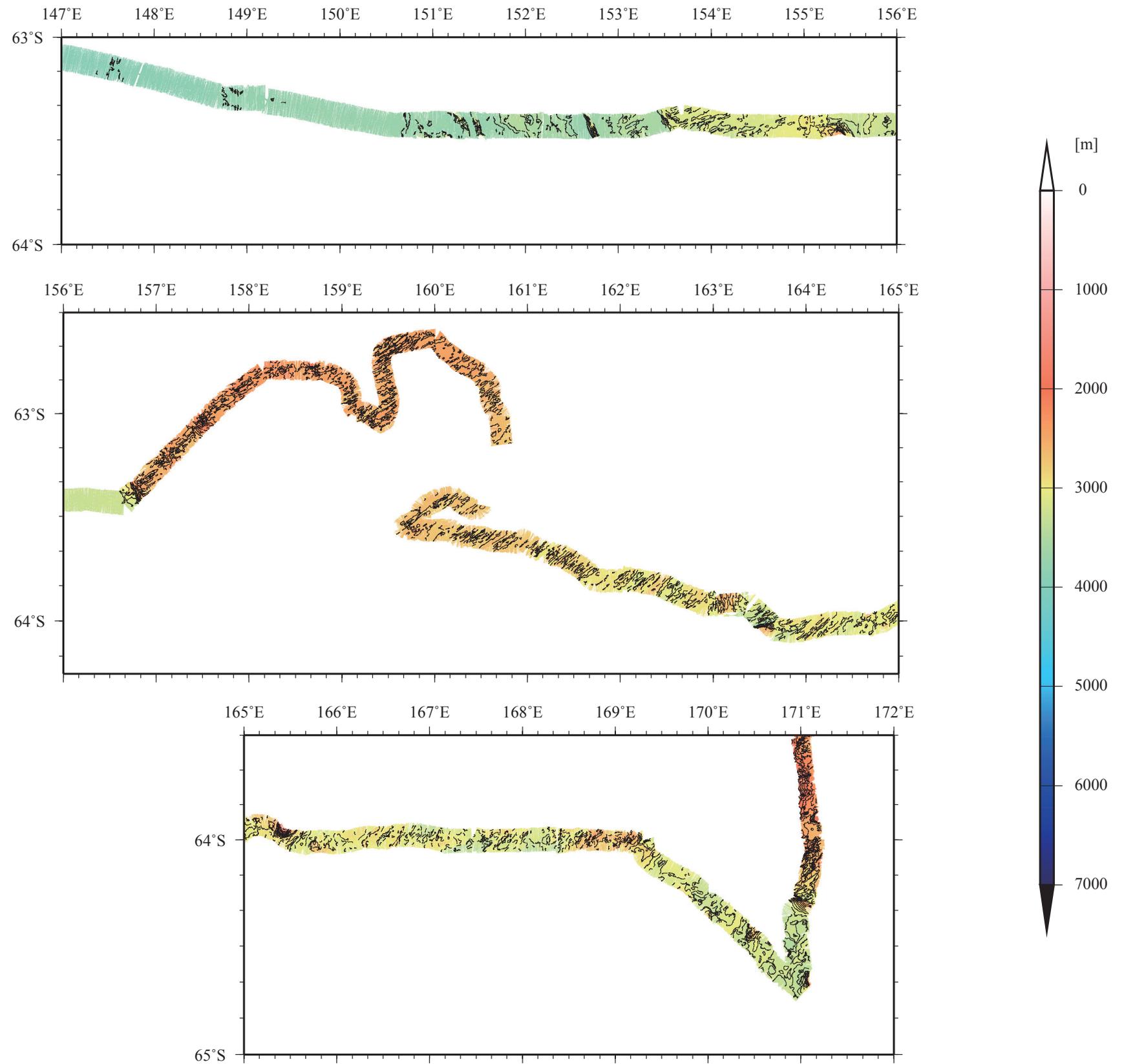
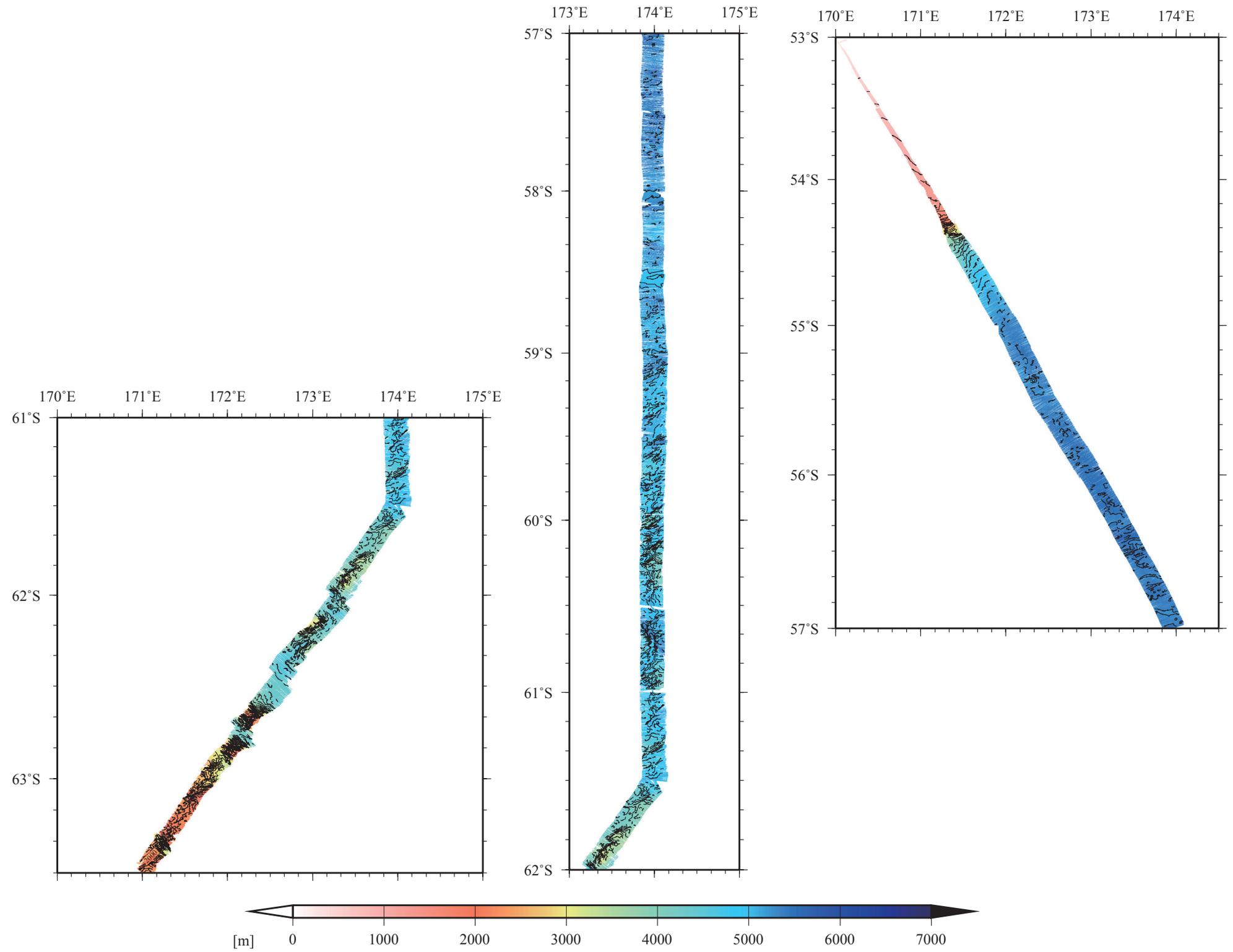


Figure 2  
Continued



**Figure 3**

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

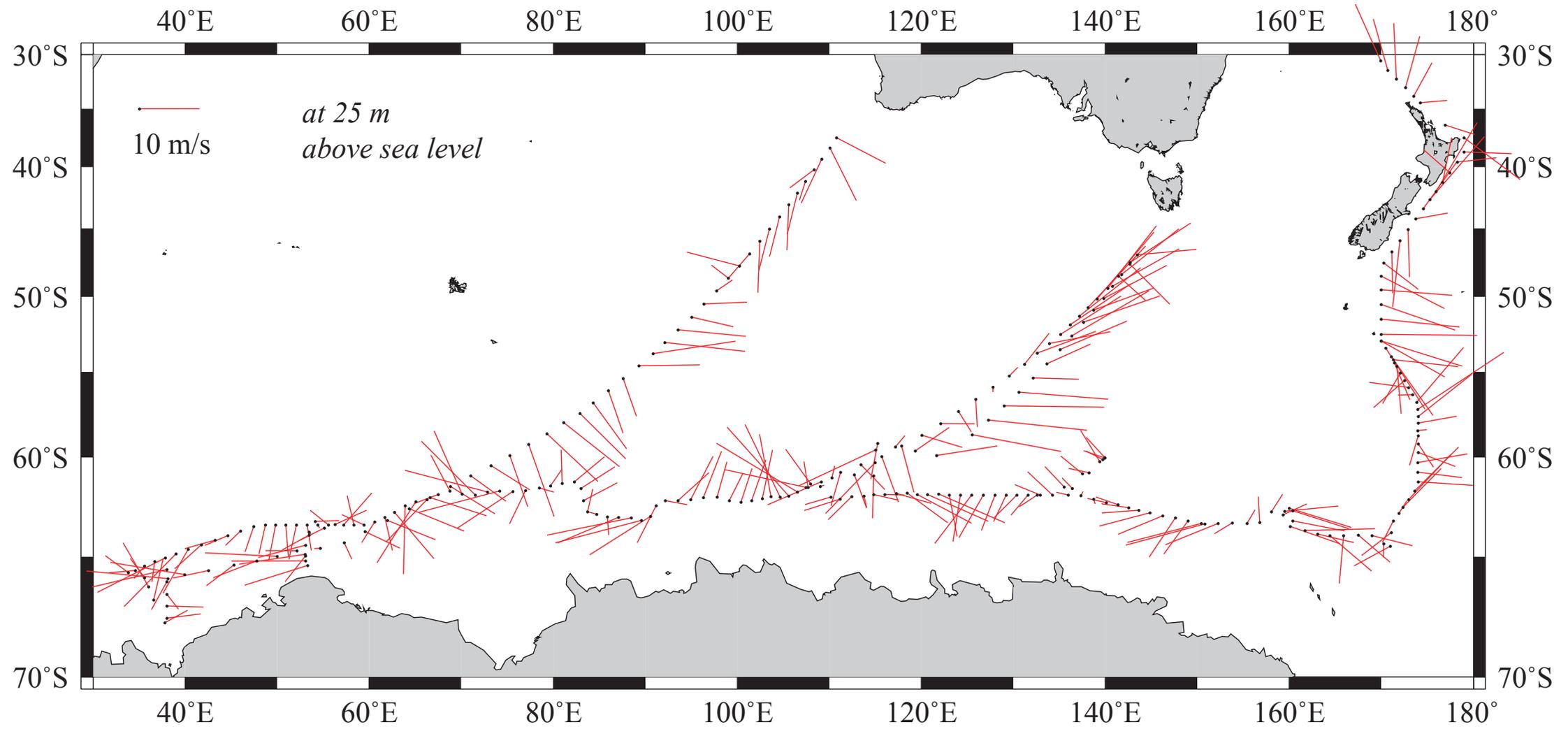


Figure 4a

Sea surface temperature (°C)

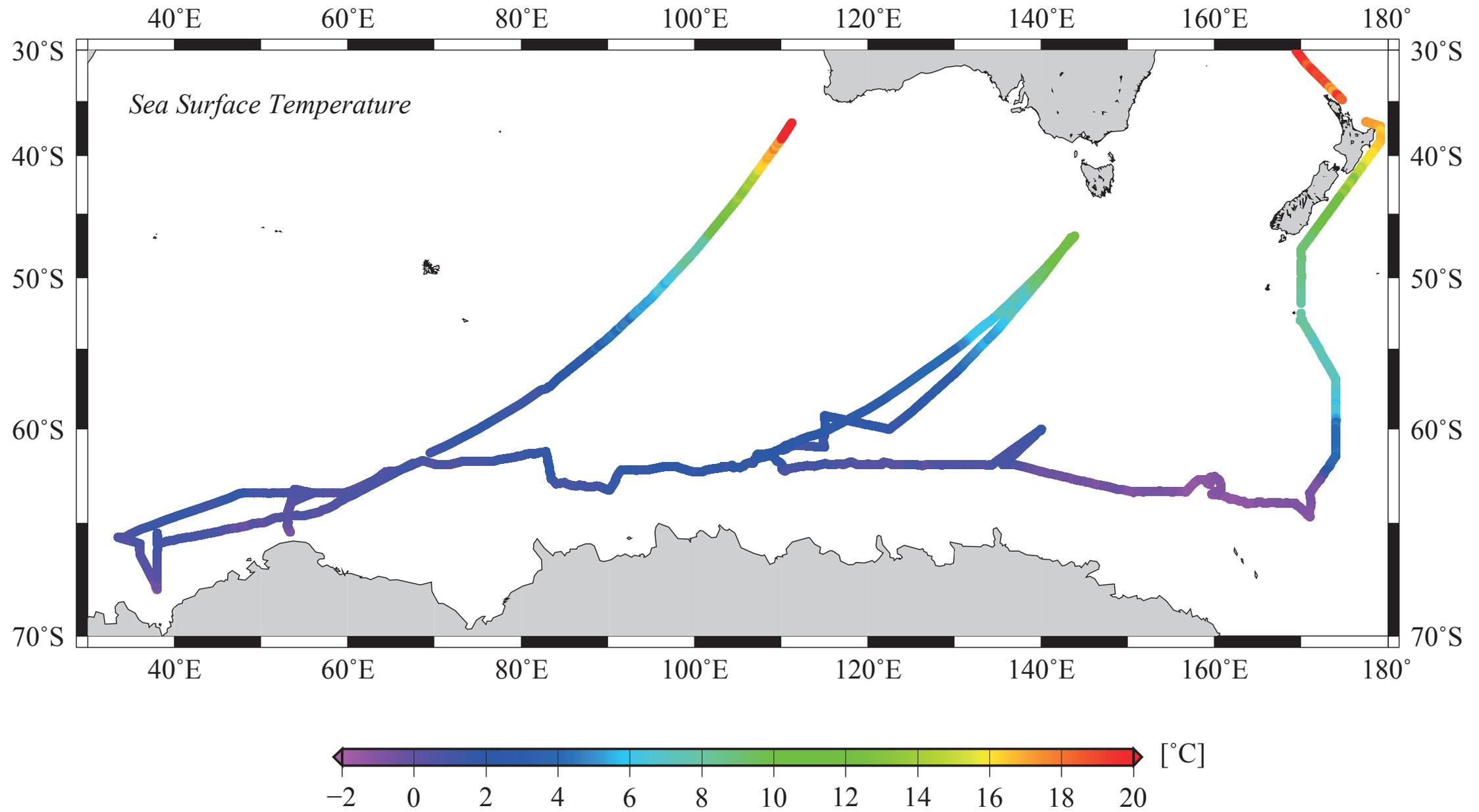


Figure 4b

Sea surface salinity (psu)

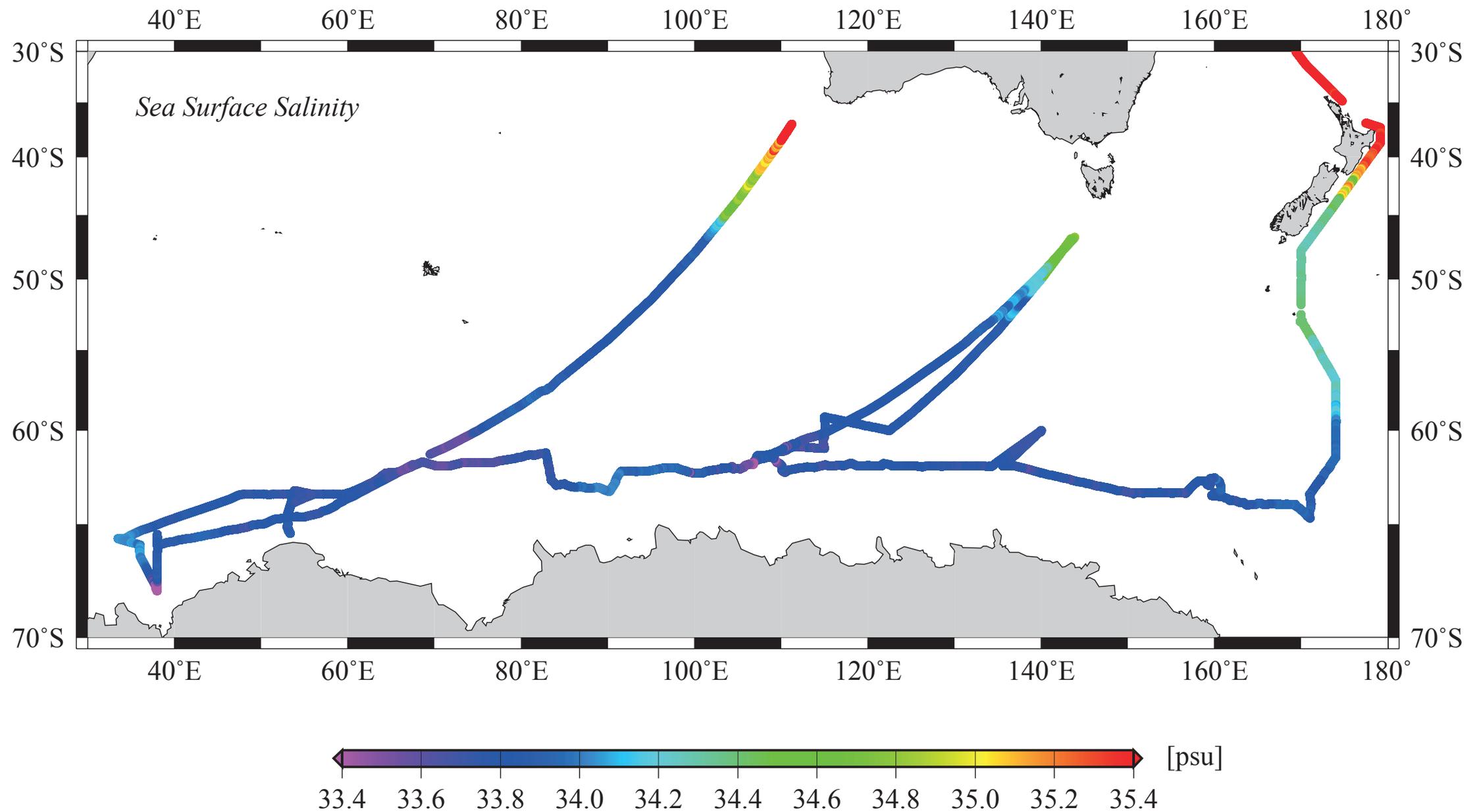


Figure 4c

Sea surface oxygen ( $\mu\text{mol/kg}$ )

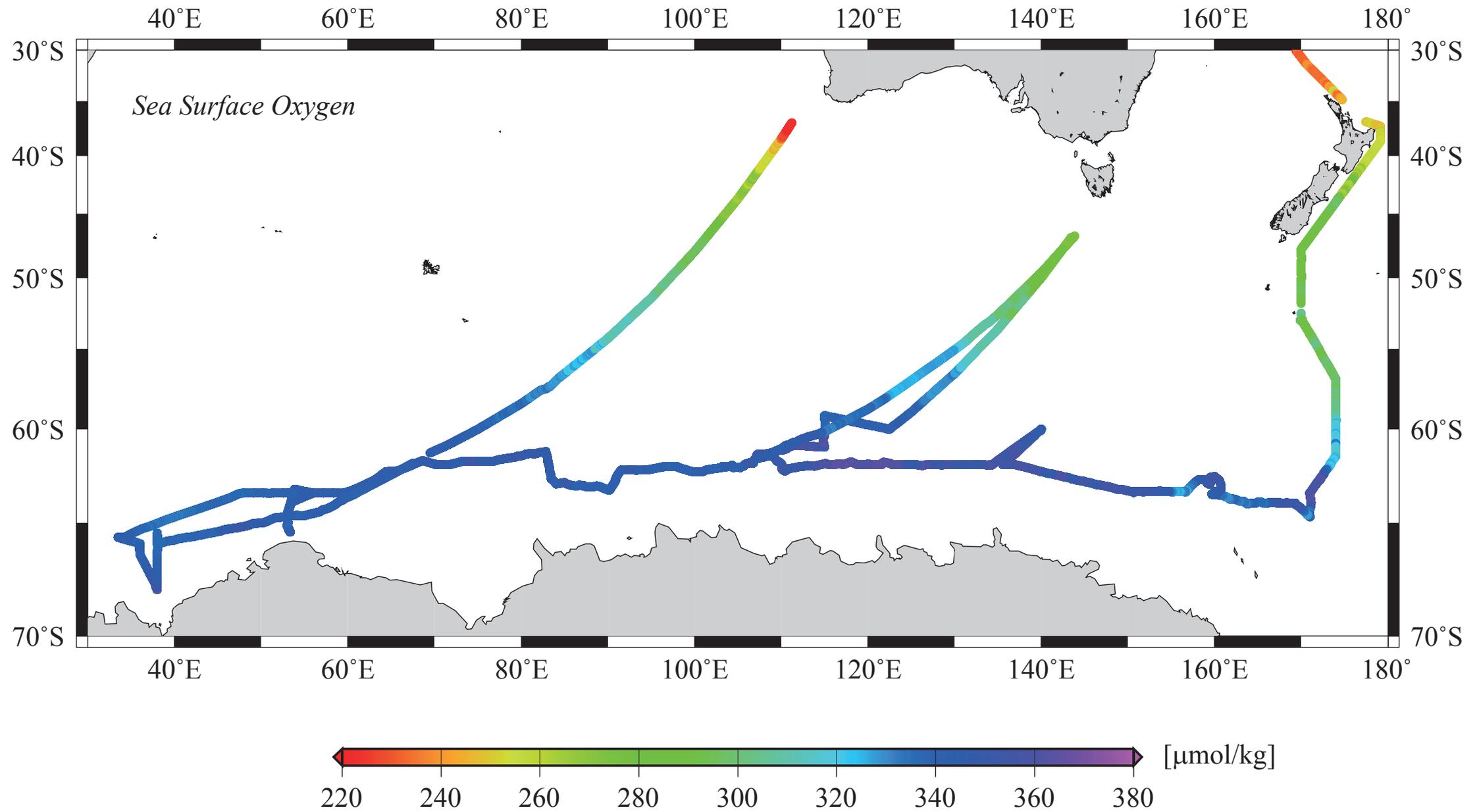


Figure 4d

Sea surface chlorophyll *a* (mg/m<sup>3</sup>)

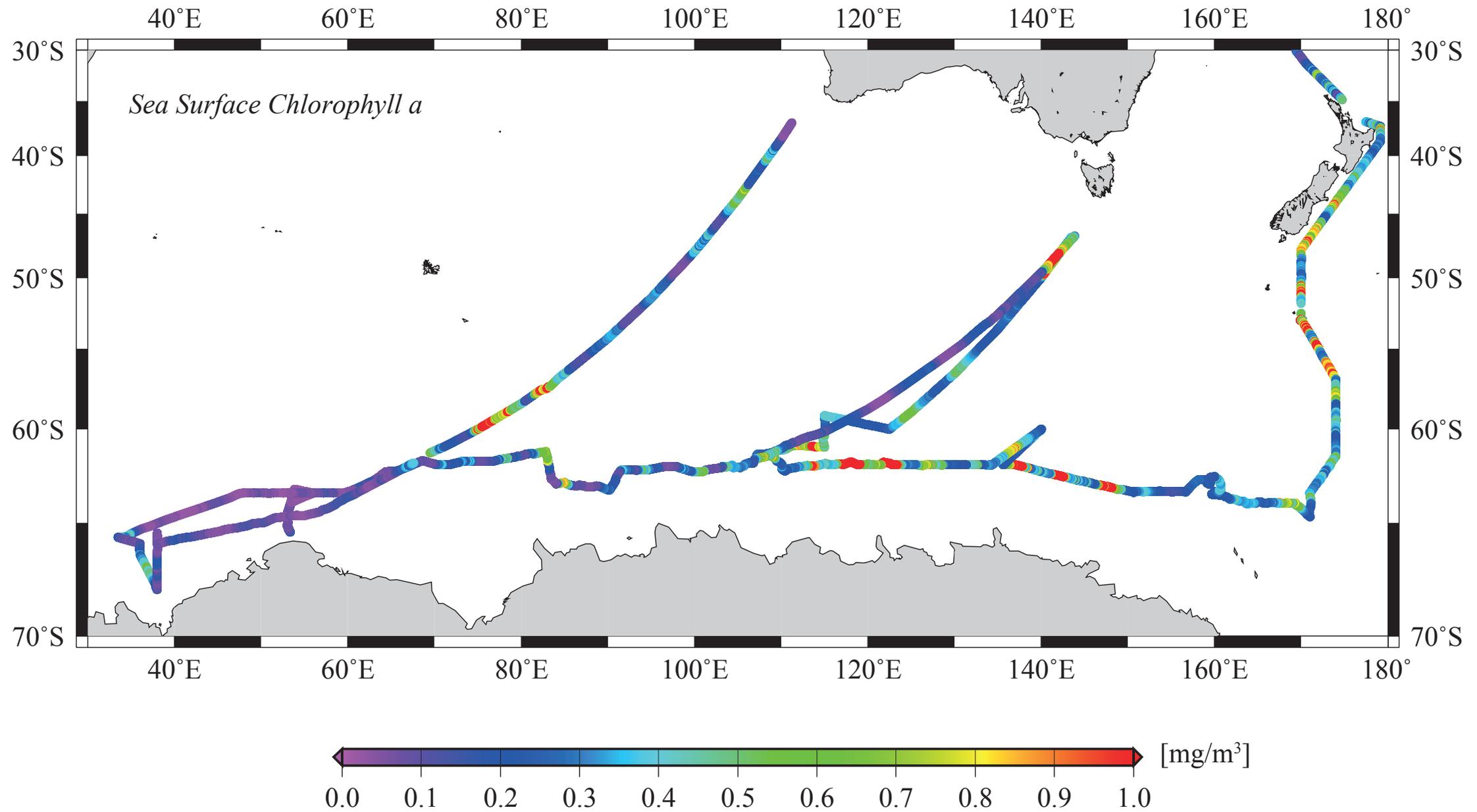
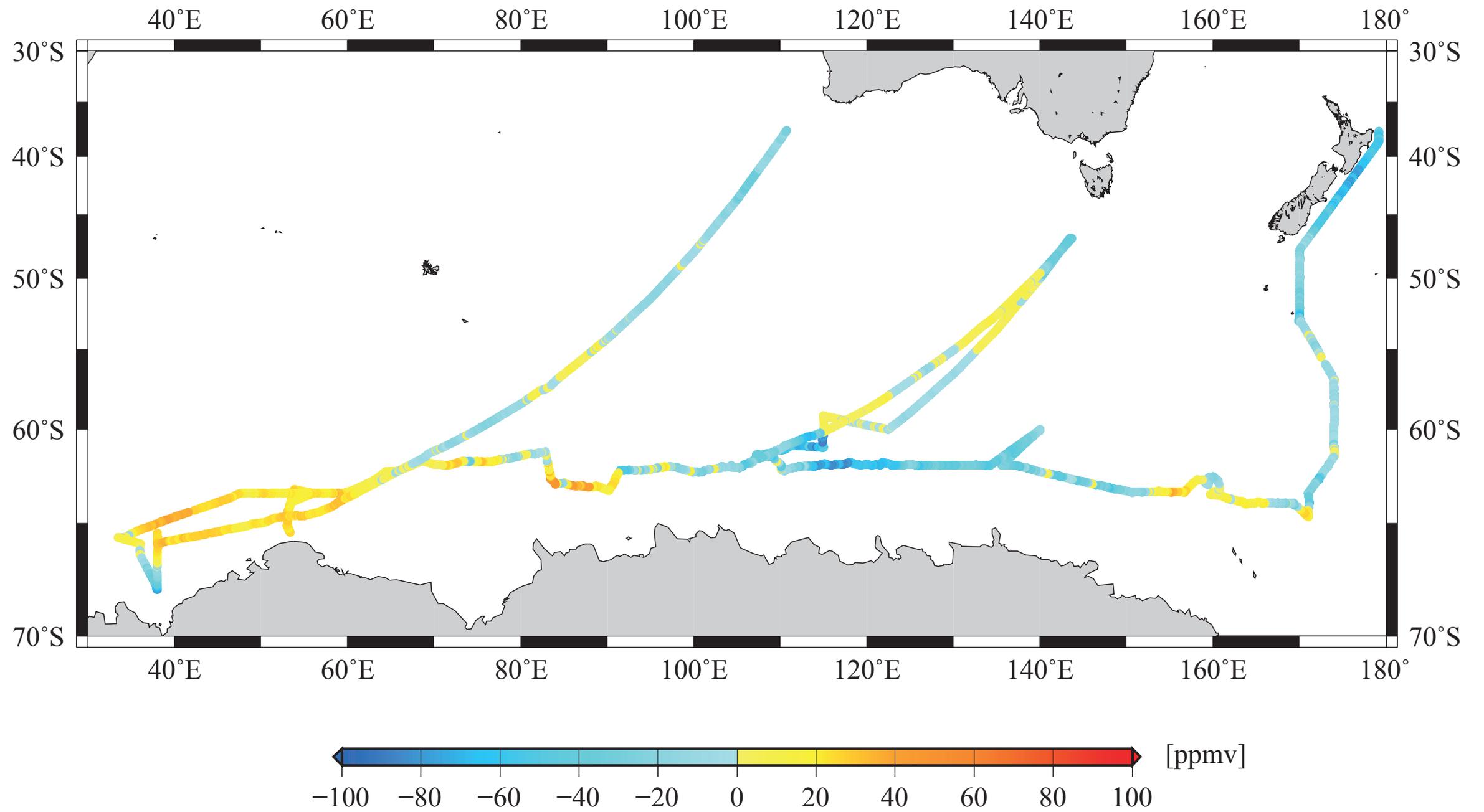
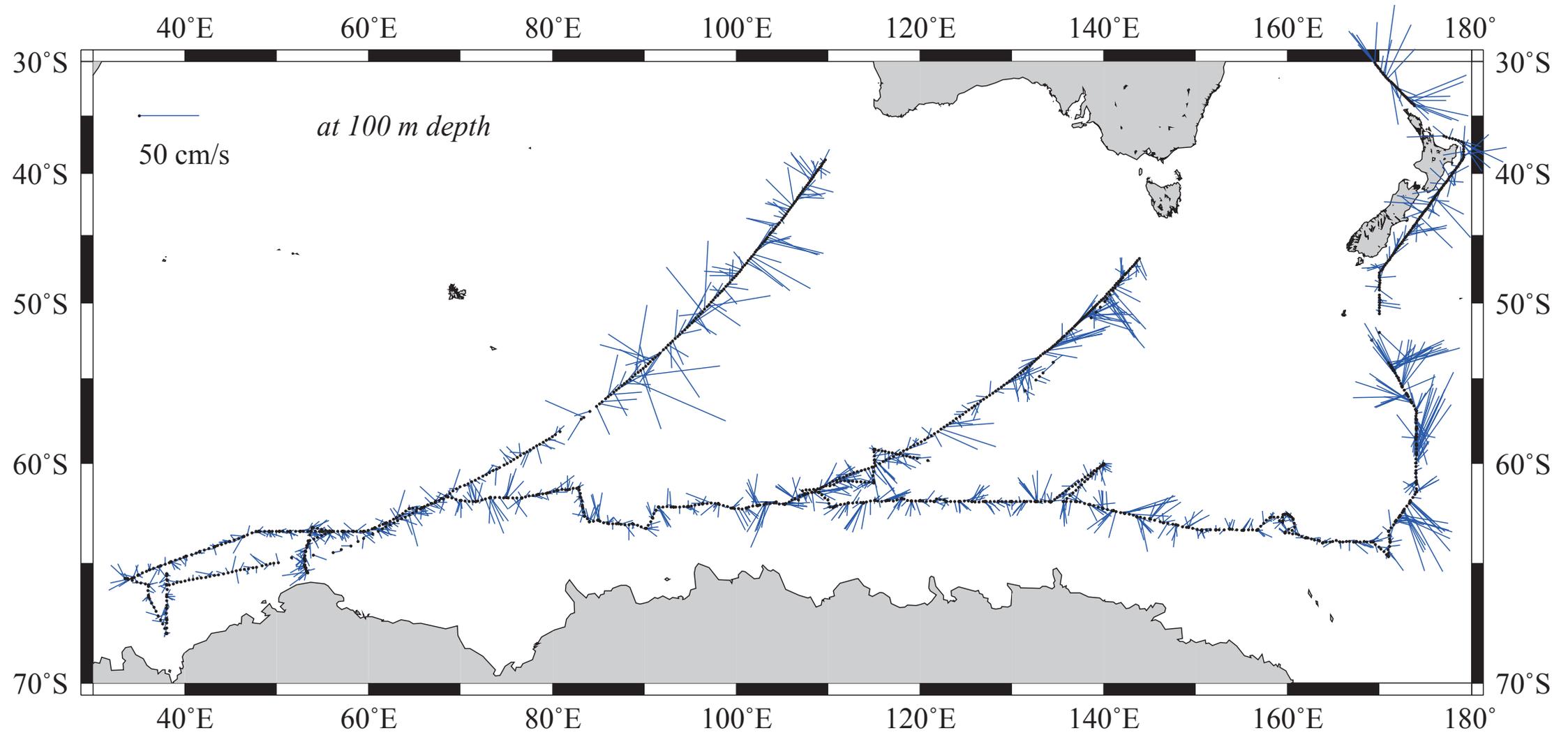


Figure 5

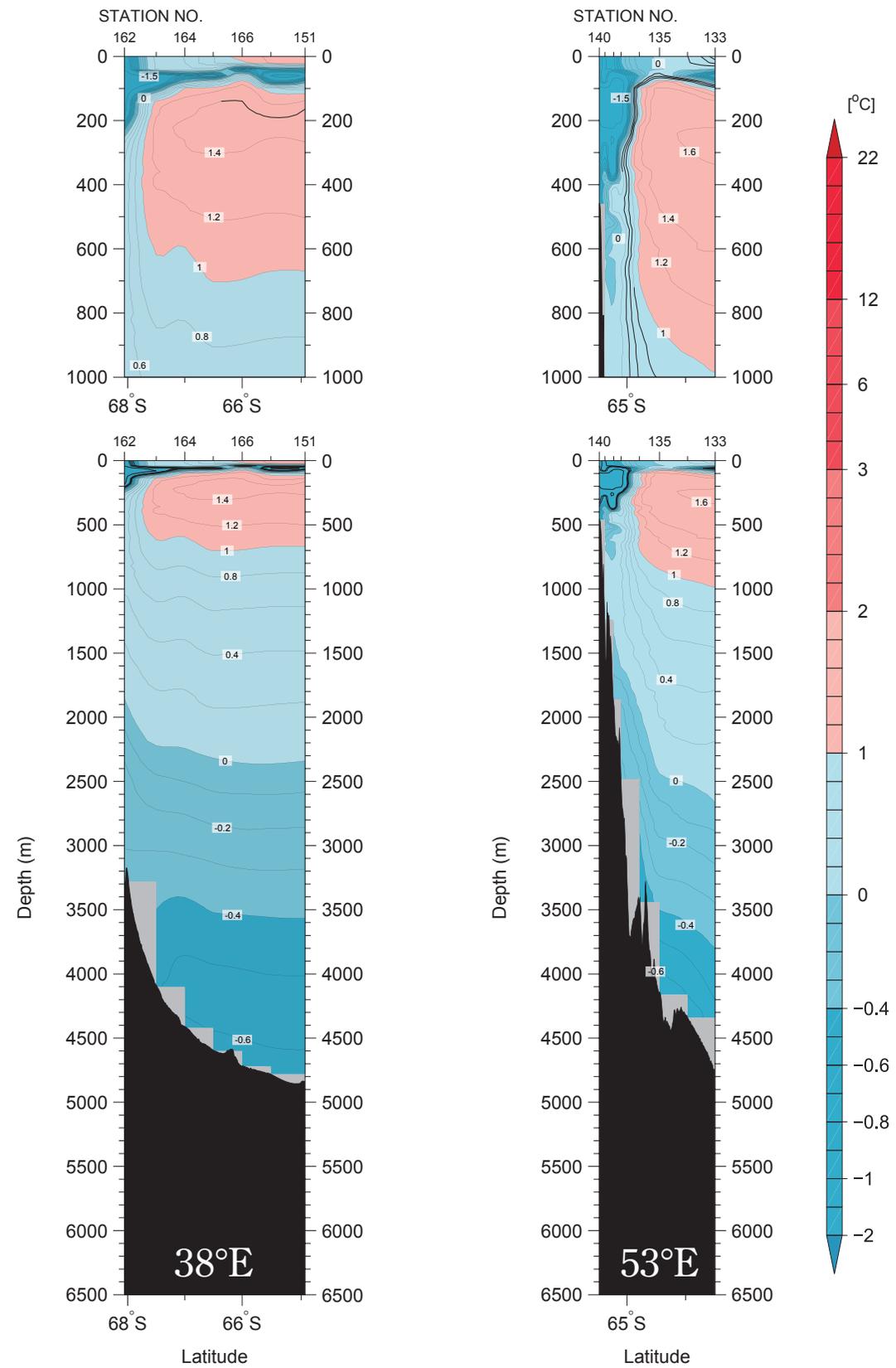
$\Delta p\text{CO}_2$  (ppmv)



**Figure 6**  
**Surface current measured by shipboard ADCP**



**Figure 7**  
**Potential temperature (°C)**



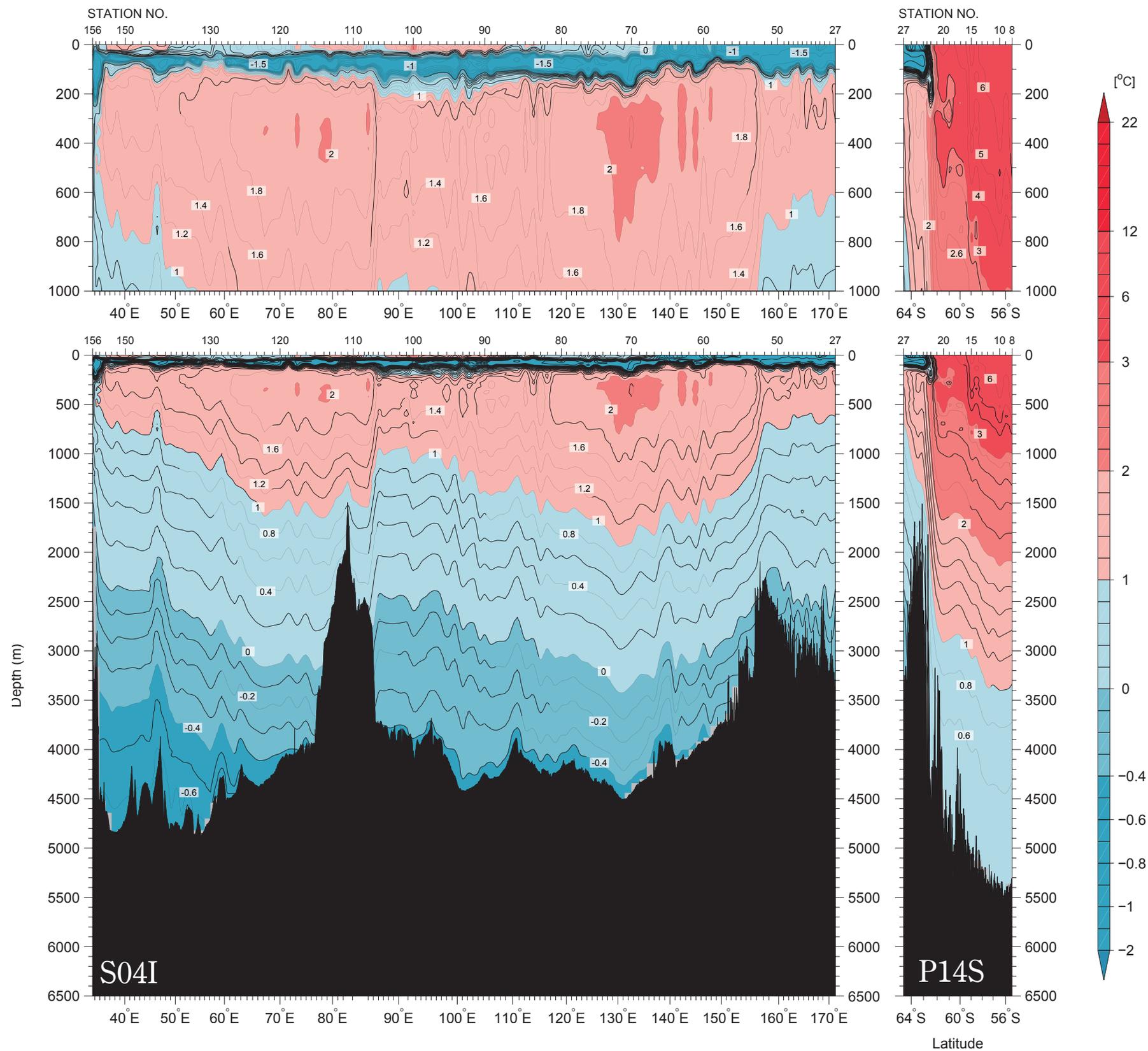
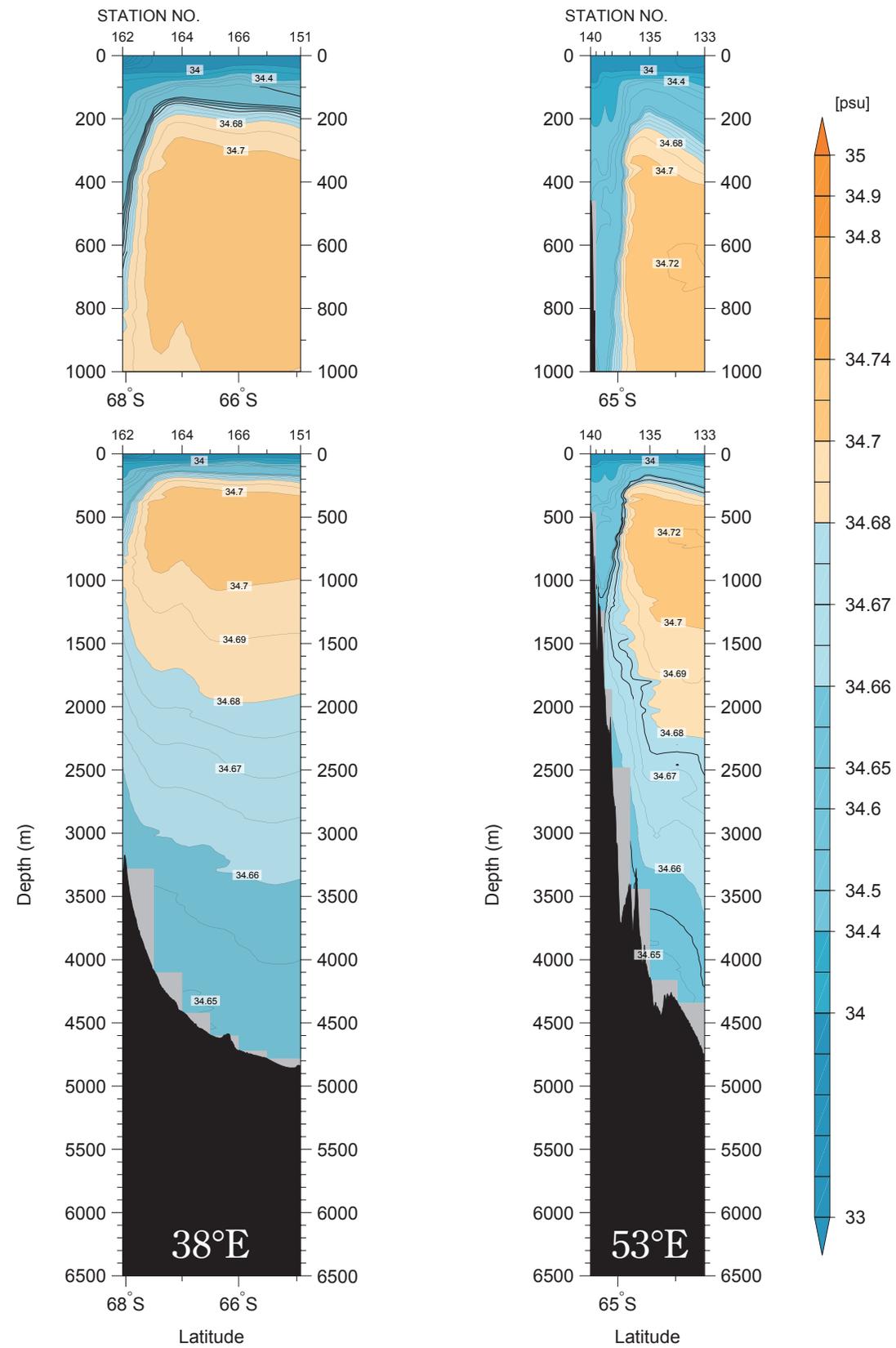
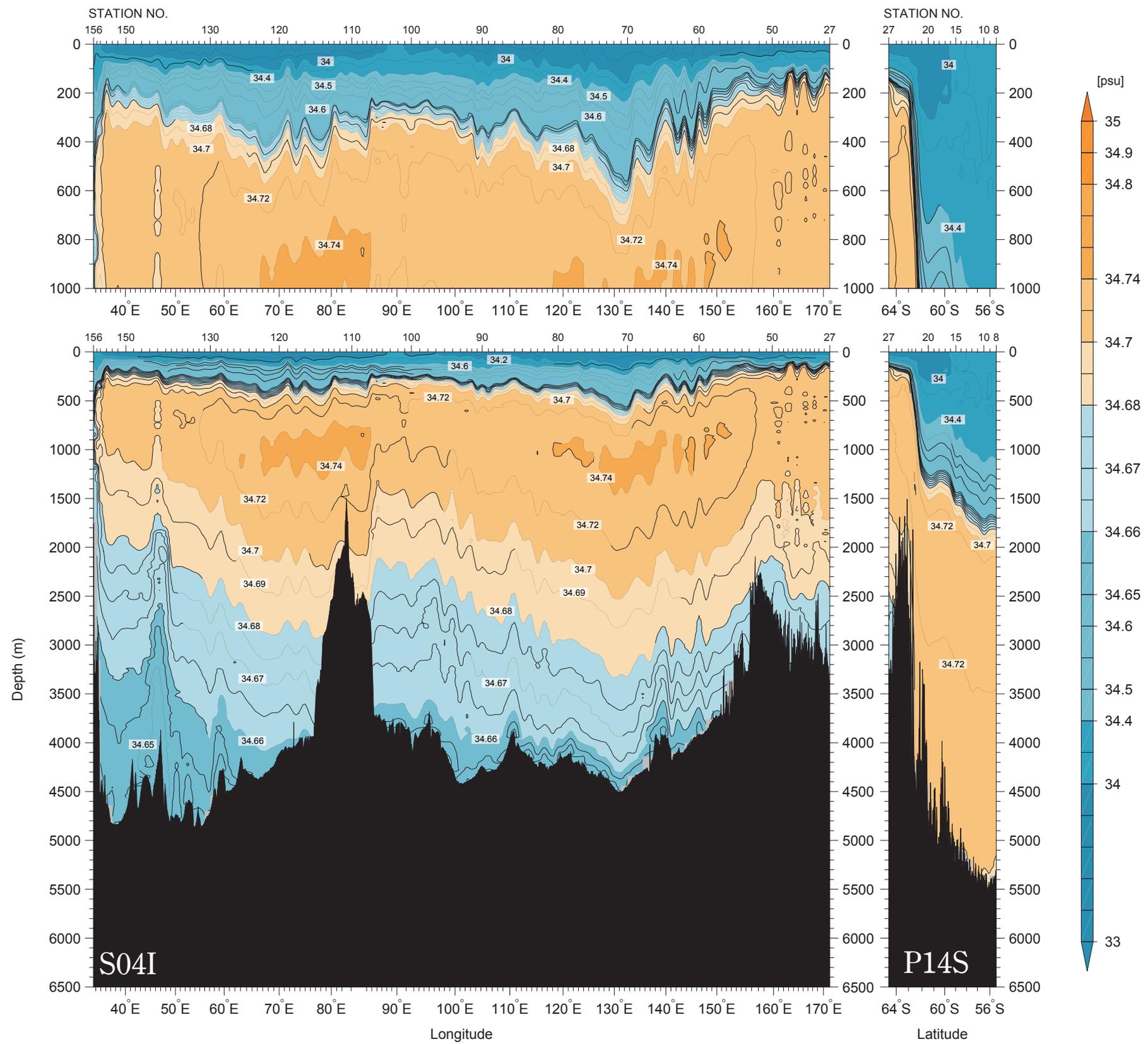
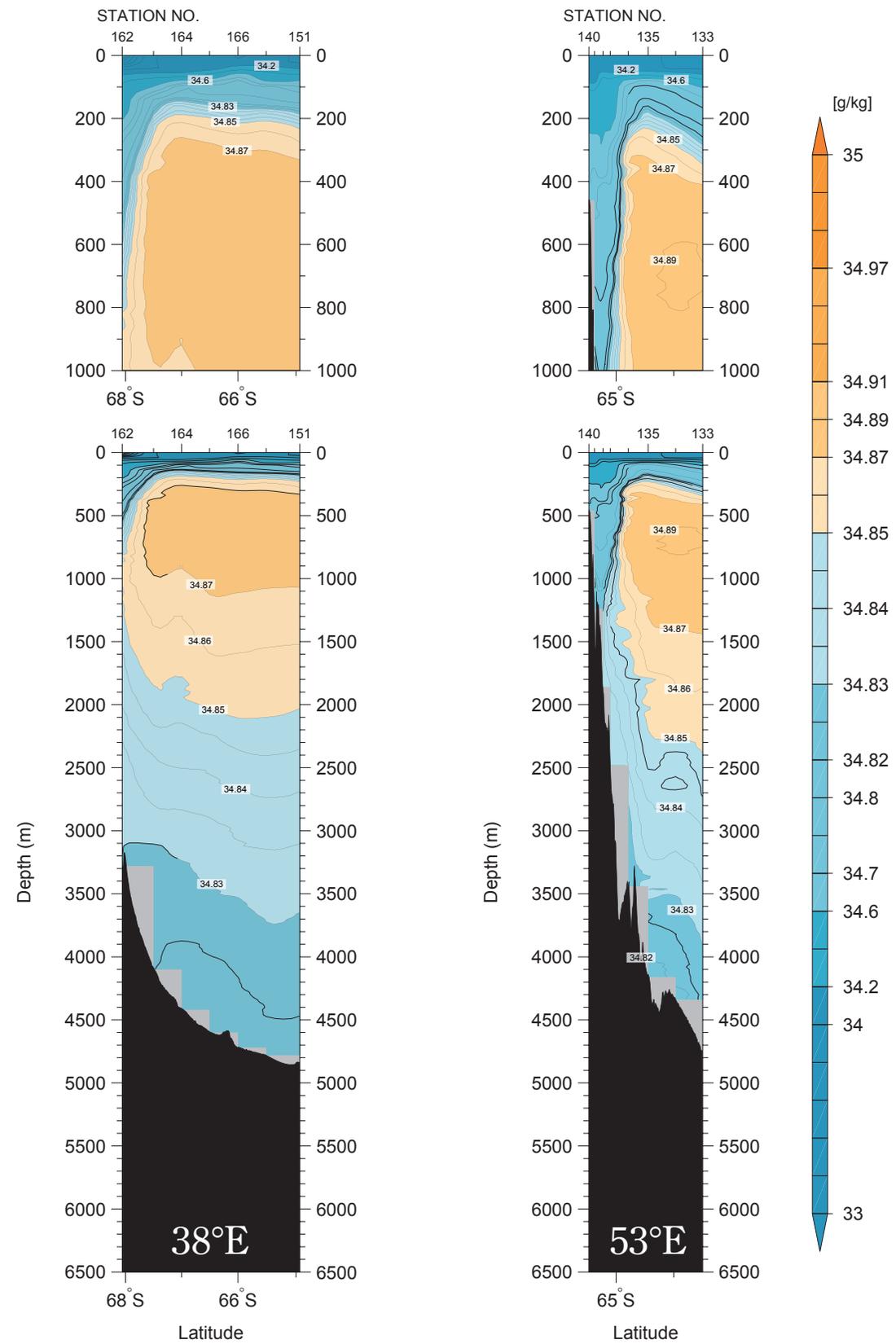


Figure 8  
CTD salinity





**Figure 9**  
**Absolute Salinity (g/kg)**



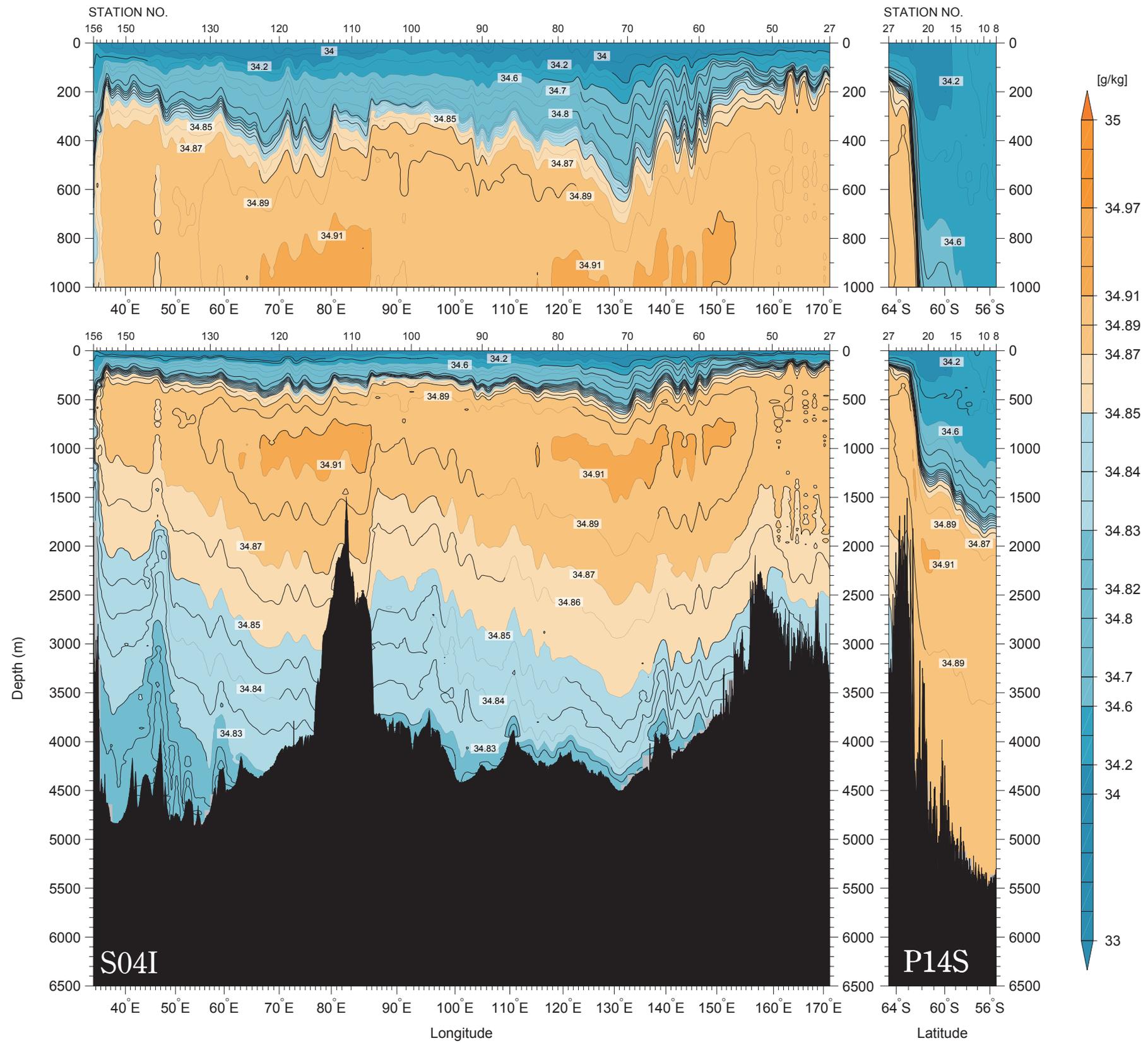
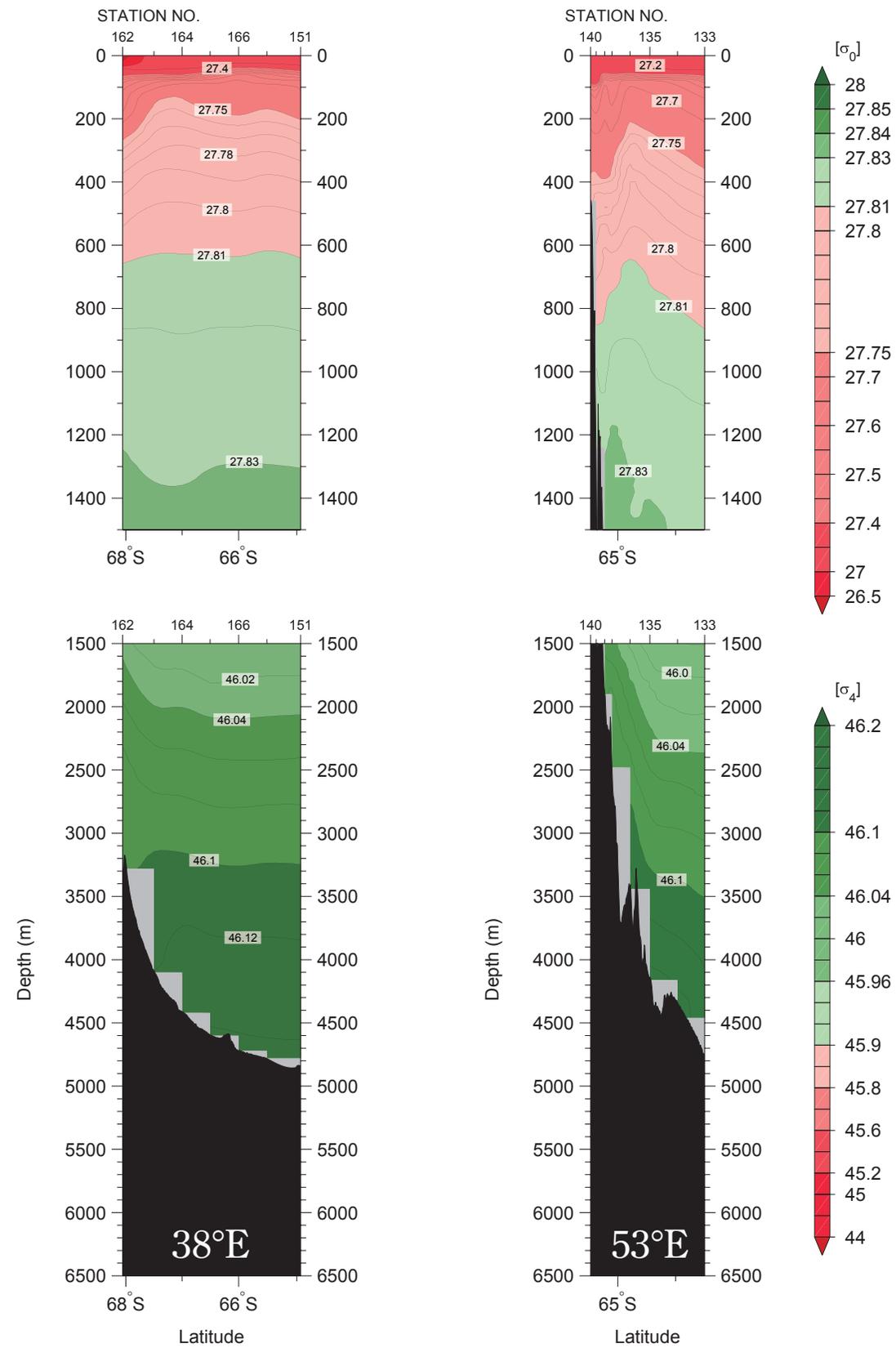


Figure 10a

Density (upper:  $\sigma_0$ , lower:  $\sigma_4$ )  
( $\text{kg/m}^3$ ) (EOS-80)



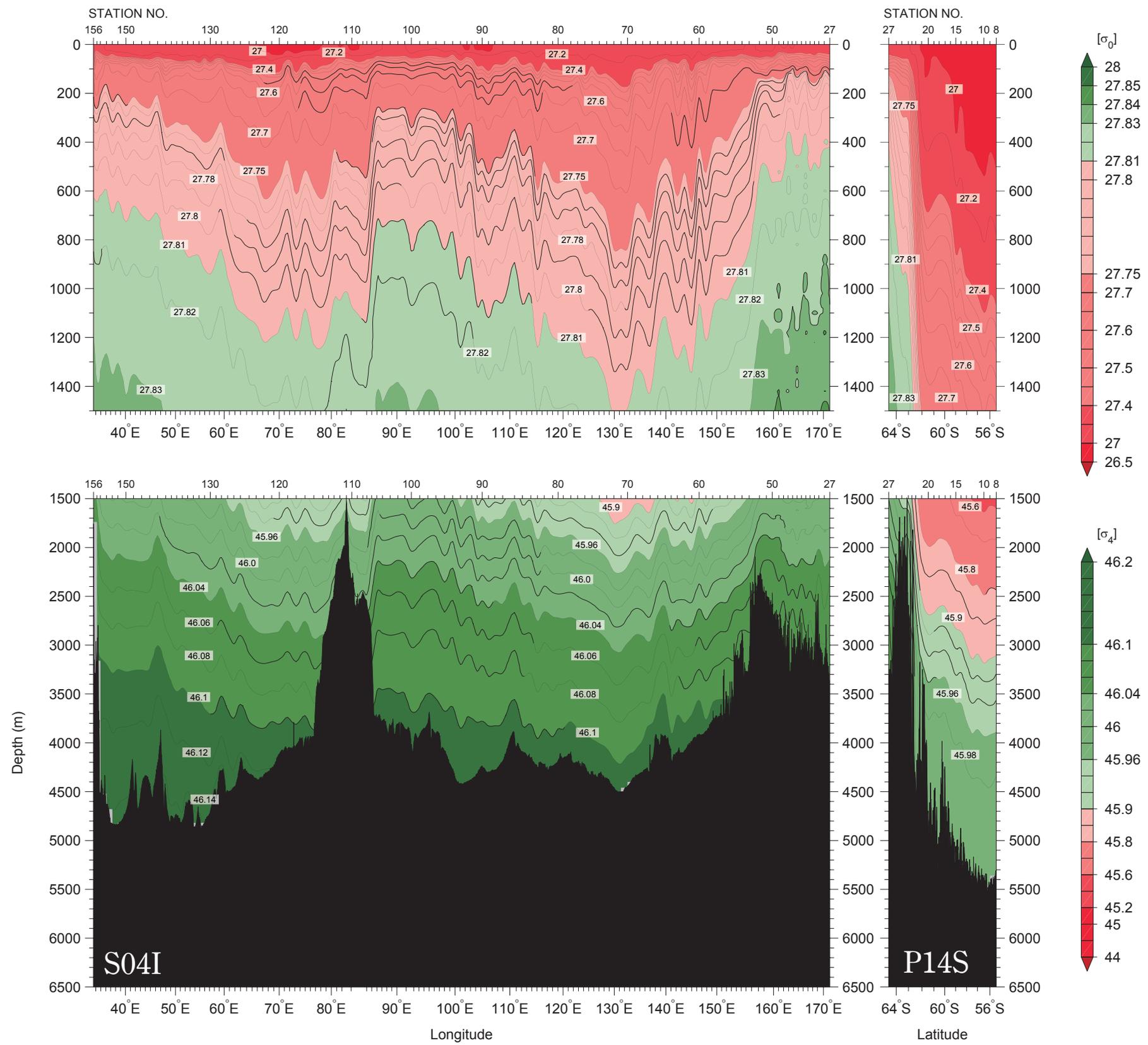
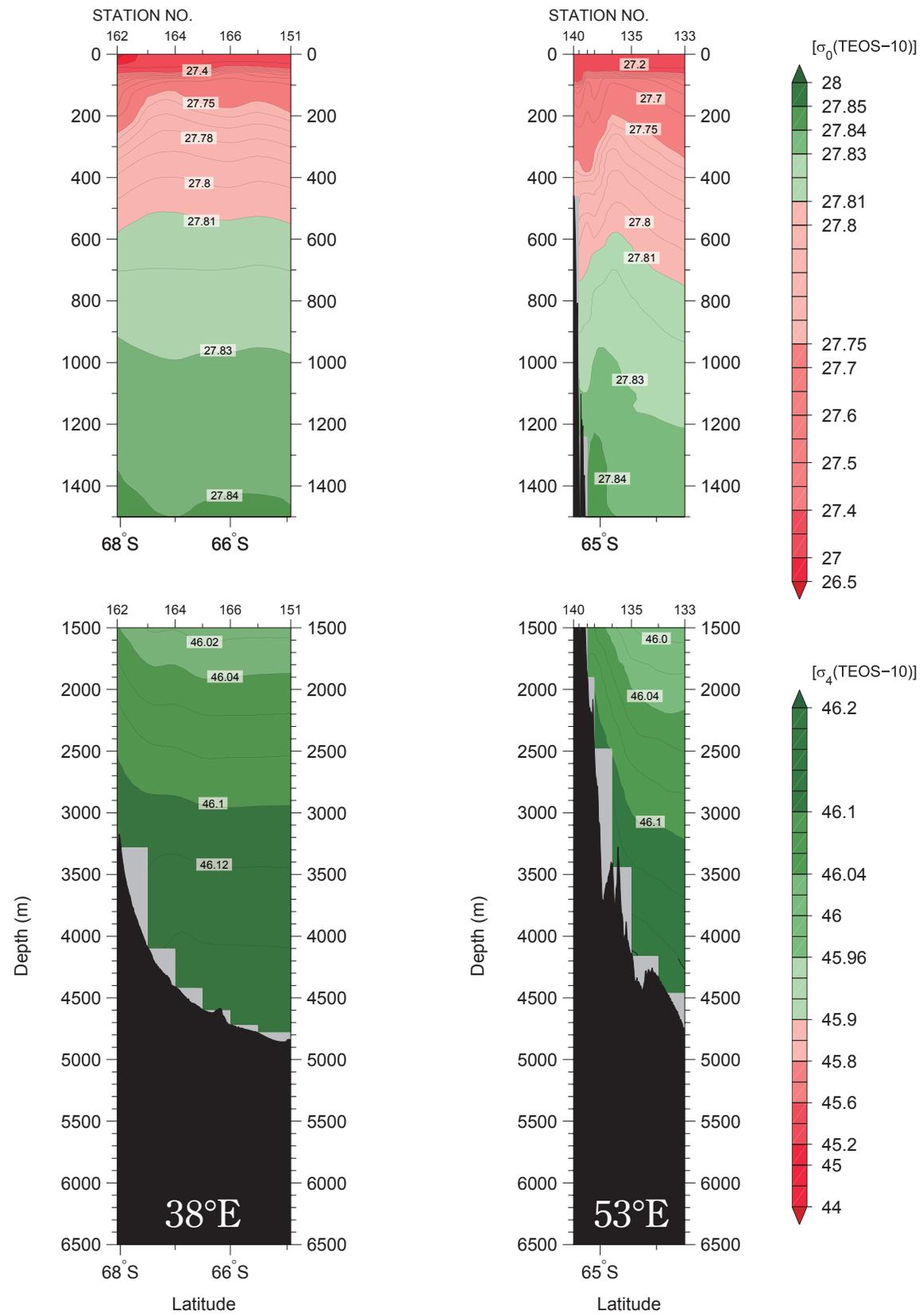
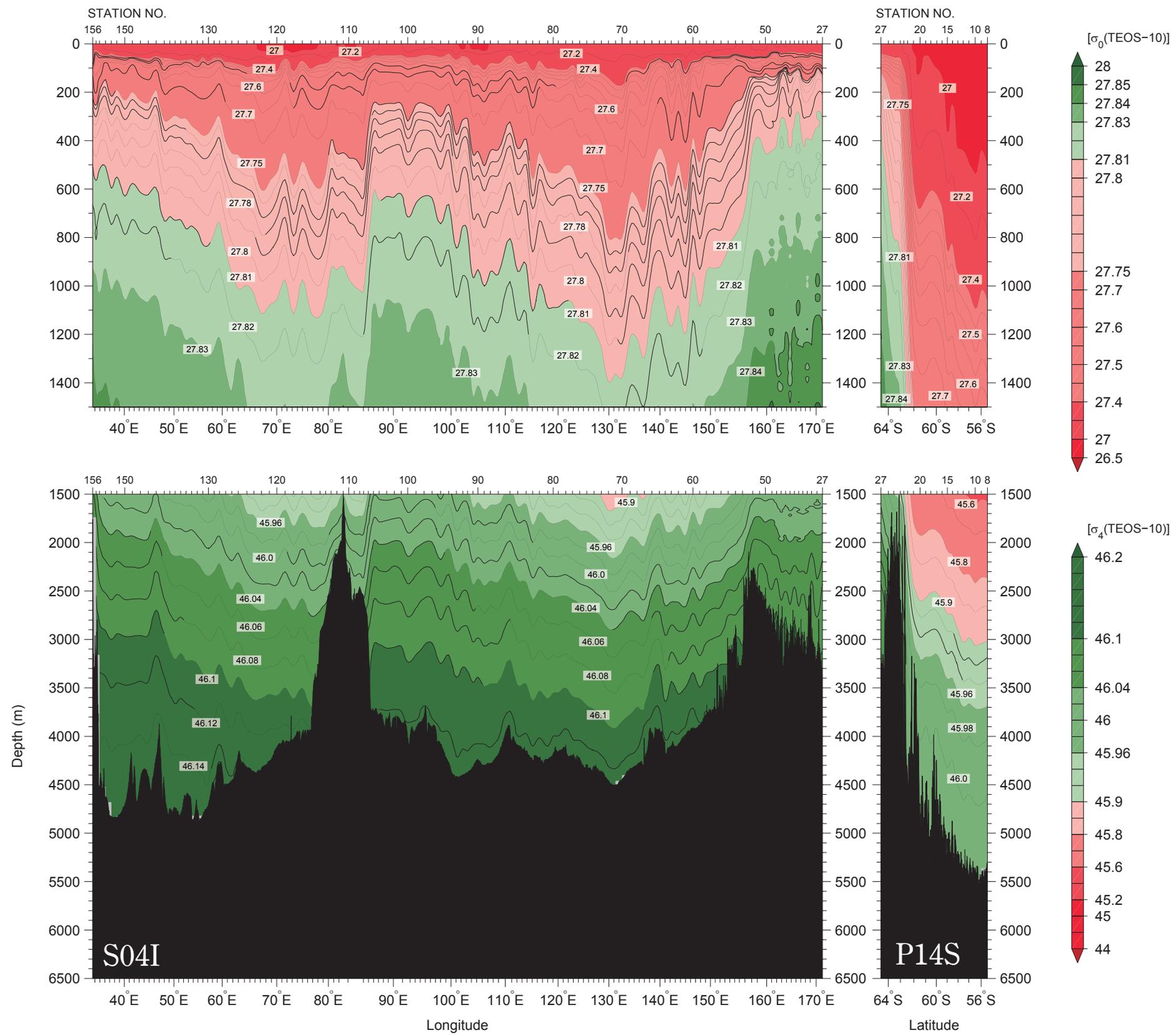


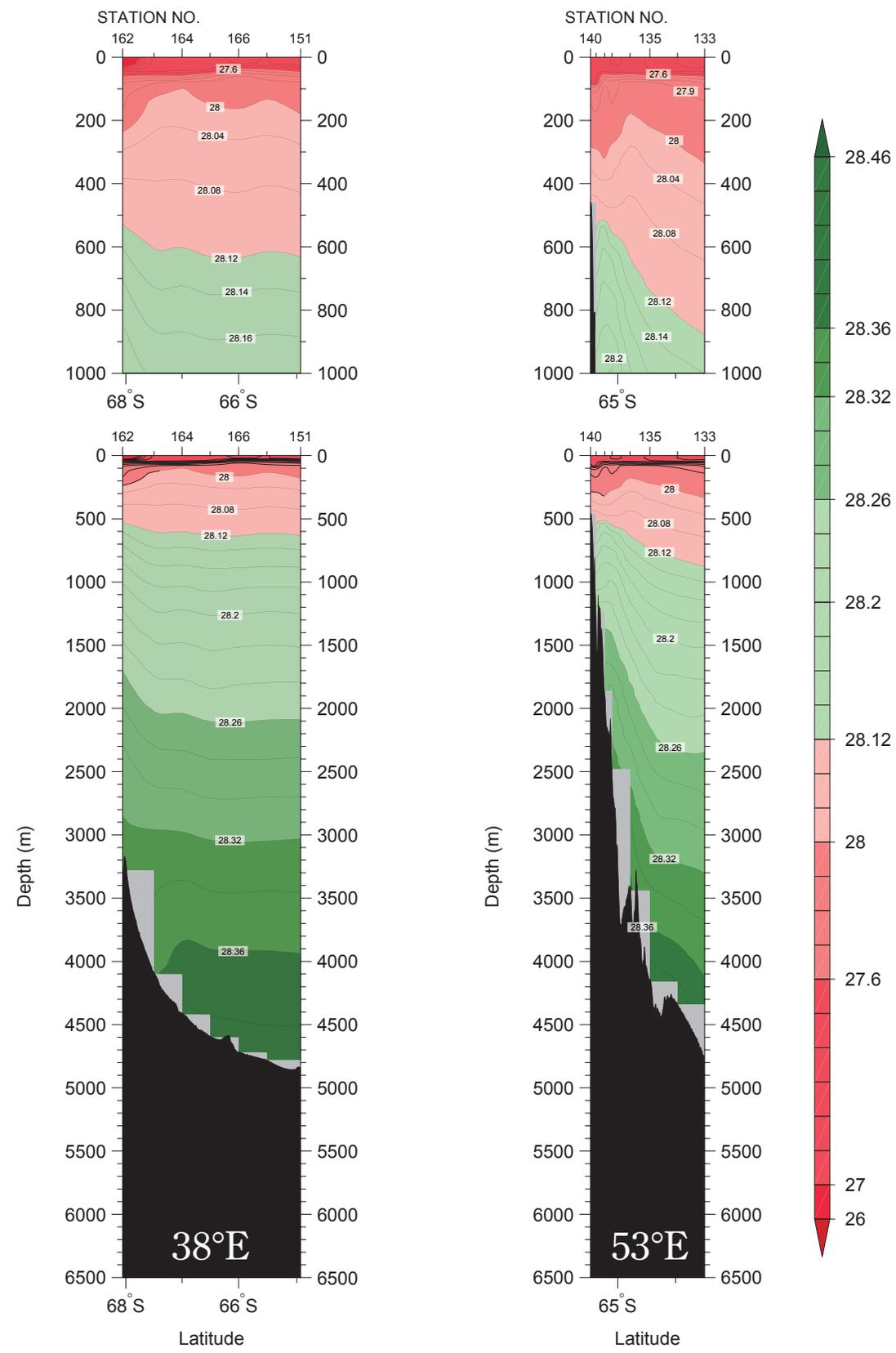
Figure 10b

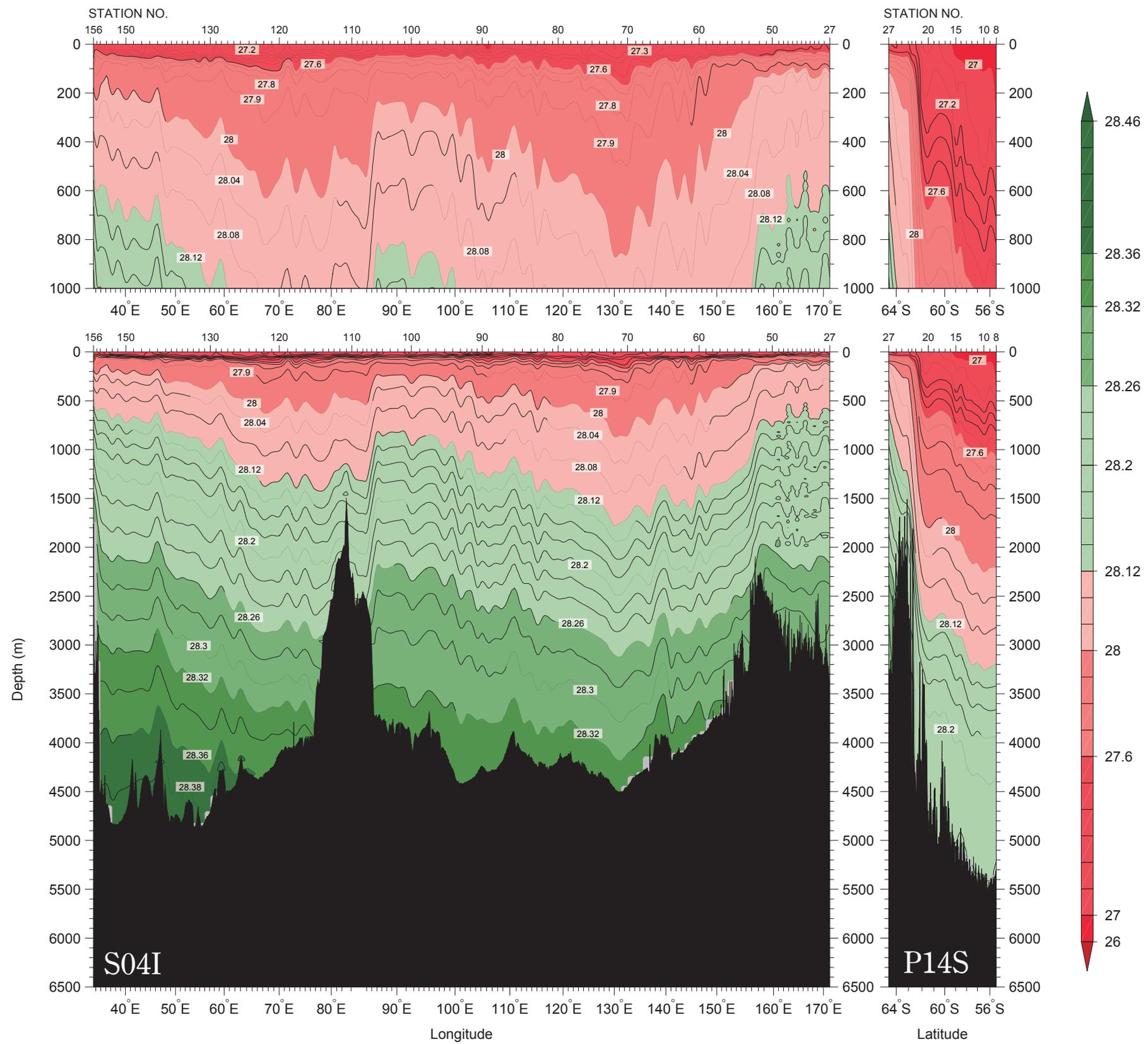
Density (upper:  $\sigma_0$ , lower:  $\sigma_4$ )  
( $\text{kg/m}^3$ ) (TEOS-10)



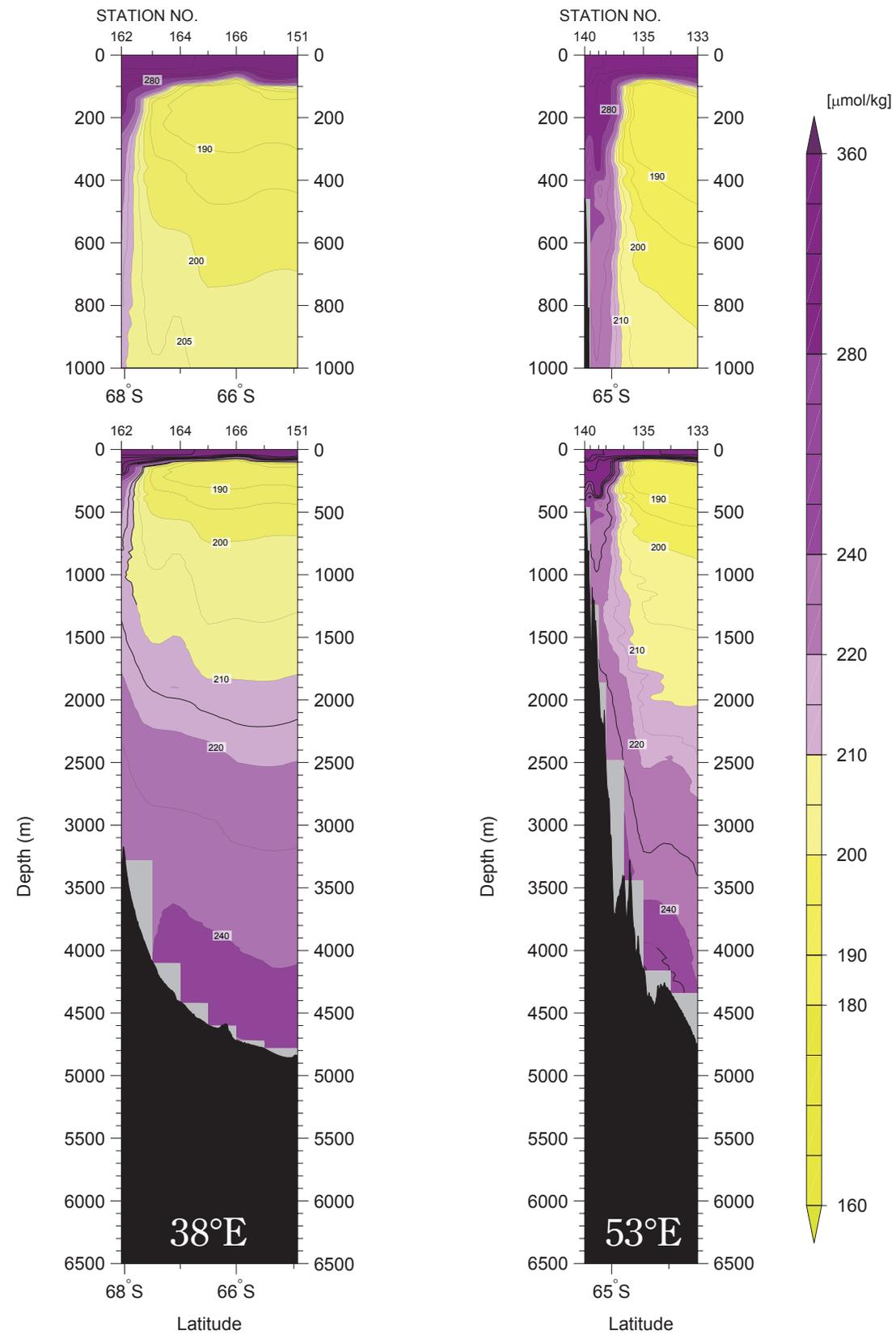


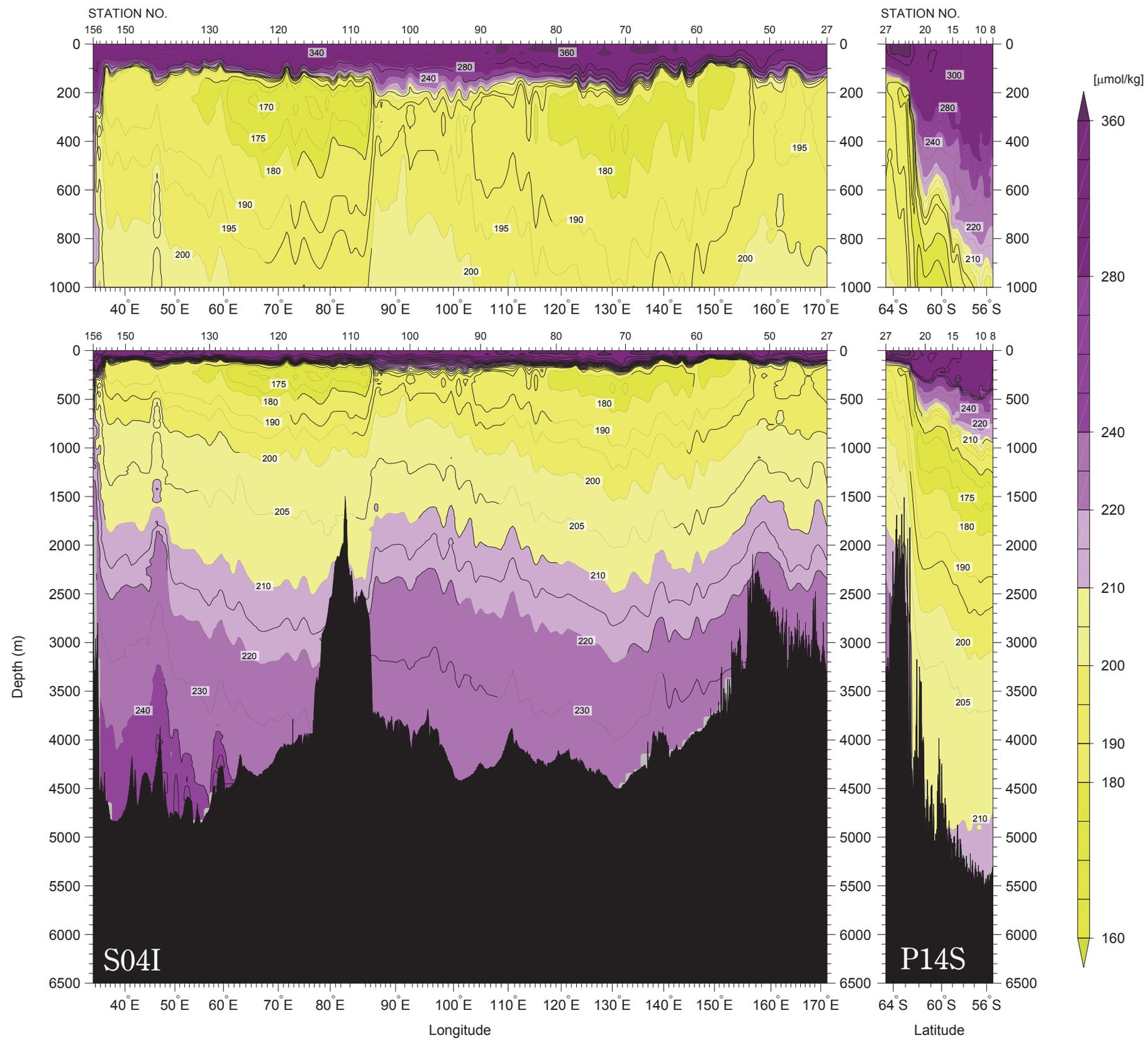
**Figure 11**  
**Density ( $\gamma^n$ ) ( $\text{kg/m}^3$ )**





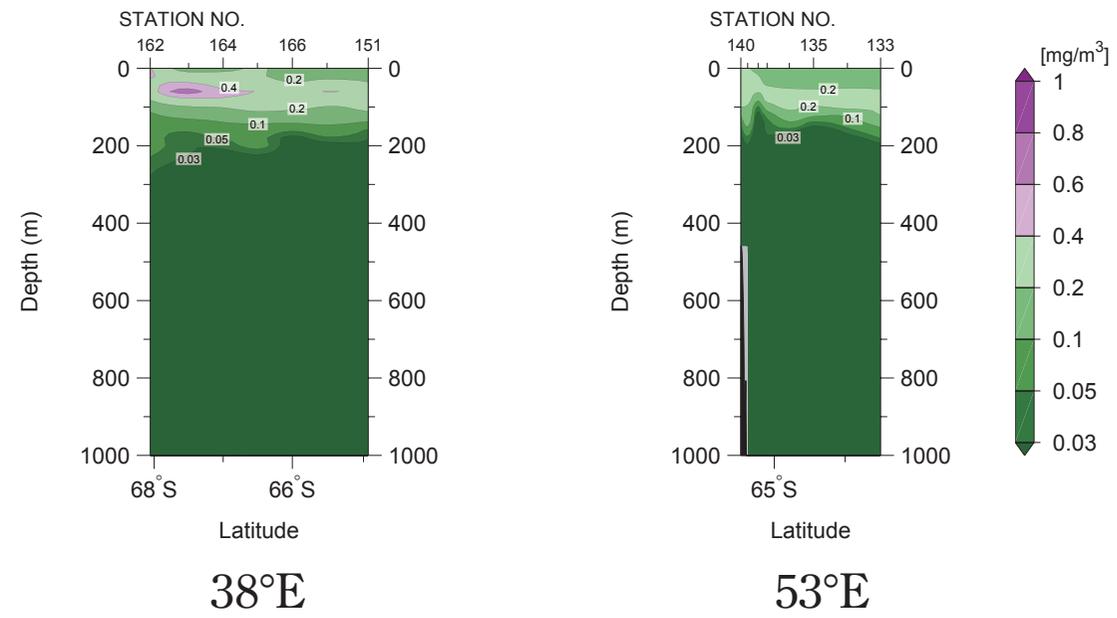
**Figure 12**  
**CTD oxygen ( $\mu\text{mol/kg}$ )**

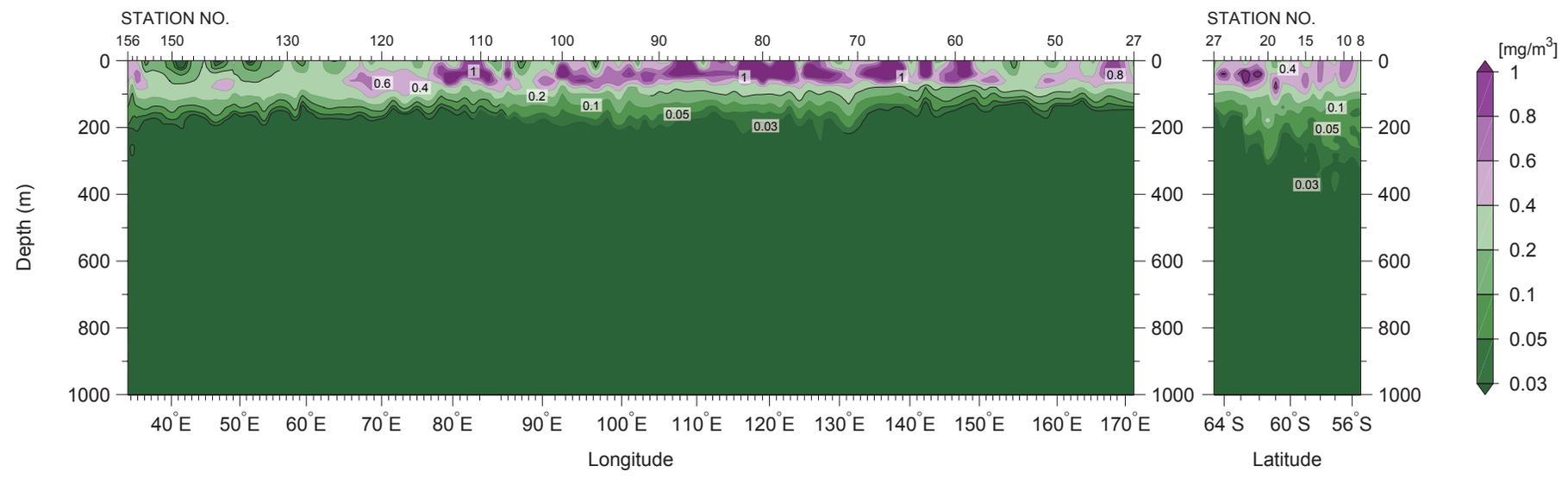




# Figure 13

## CTD chlorophyll *a* ( $\text{mg}/\text{m}^3$ )

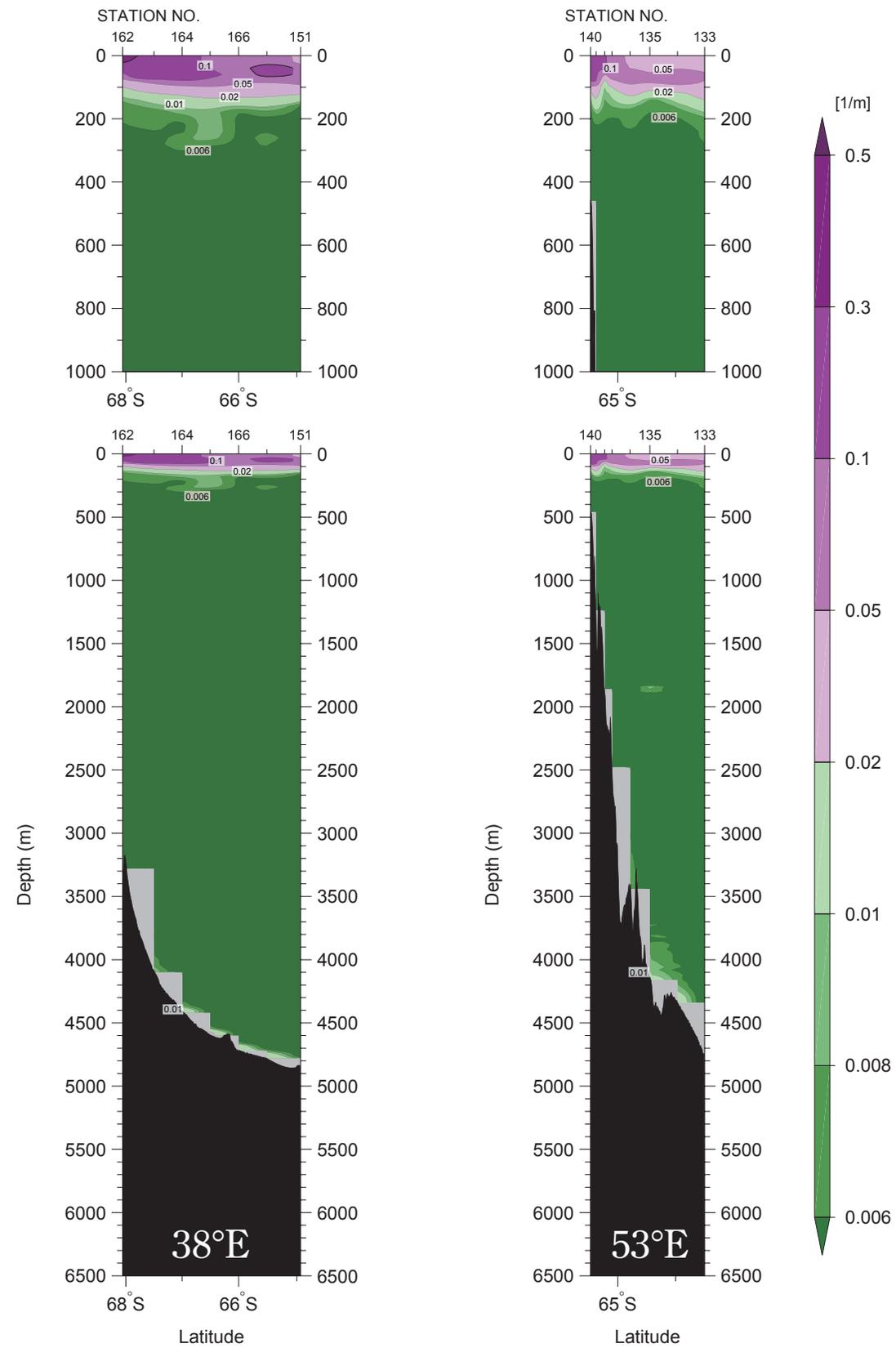


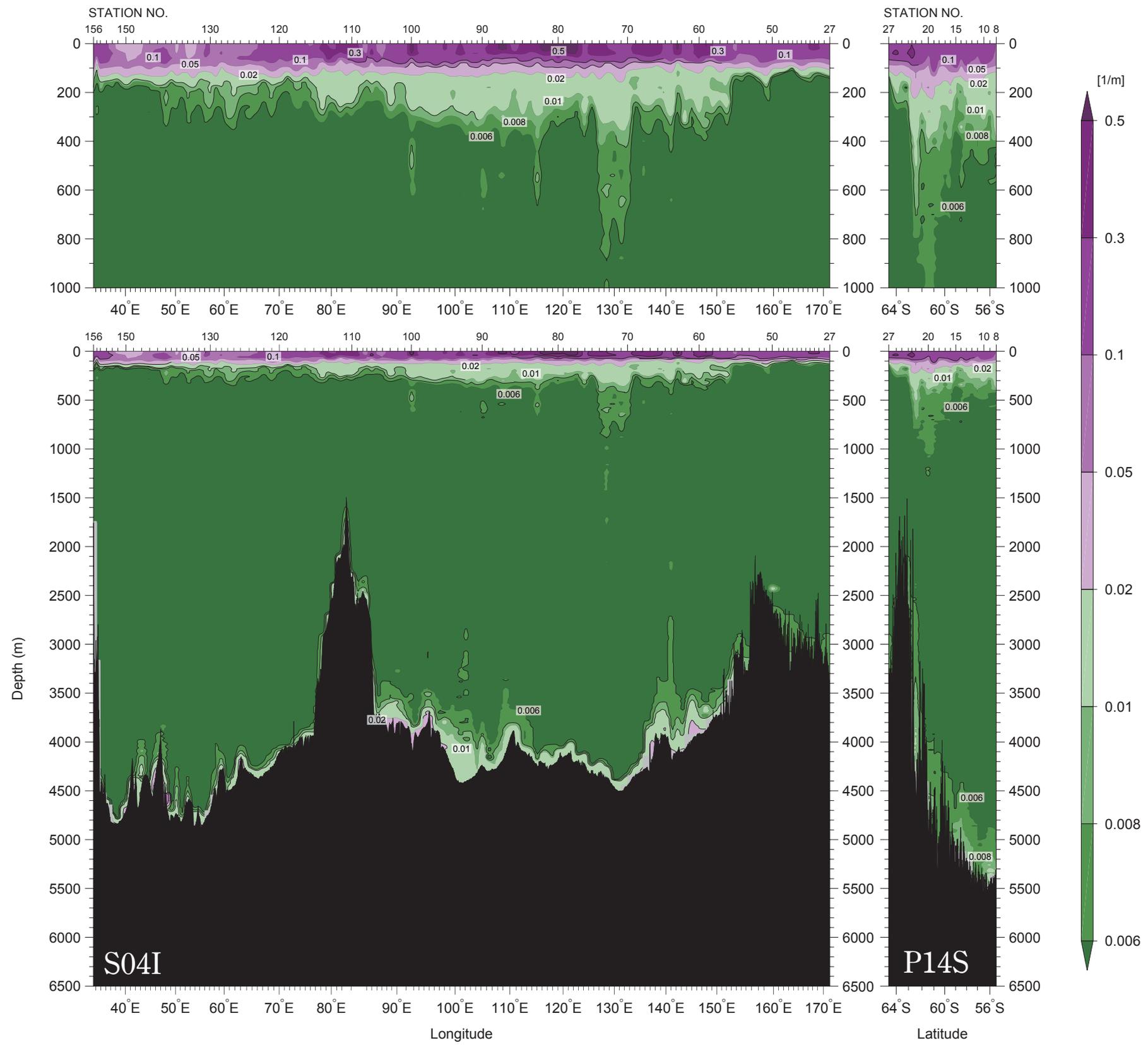


S04I

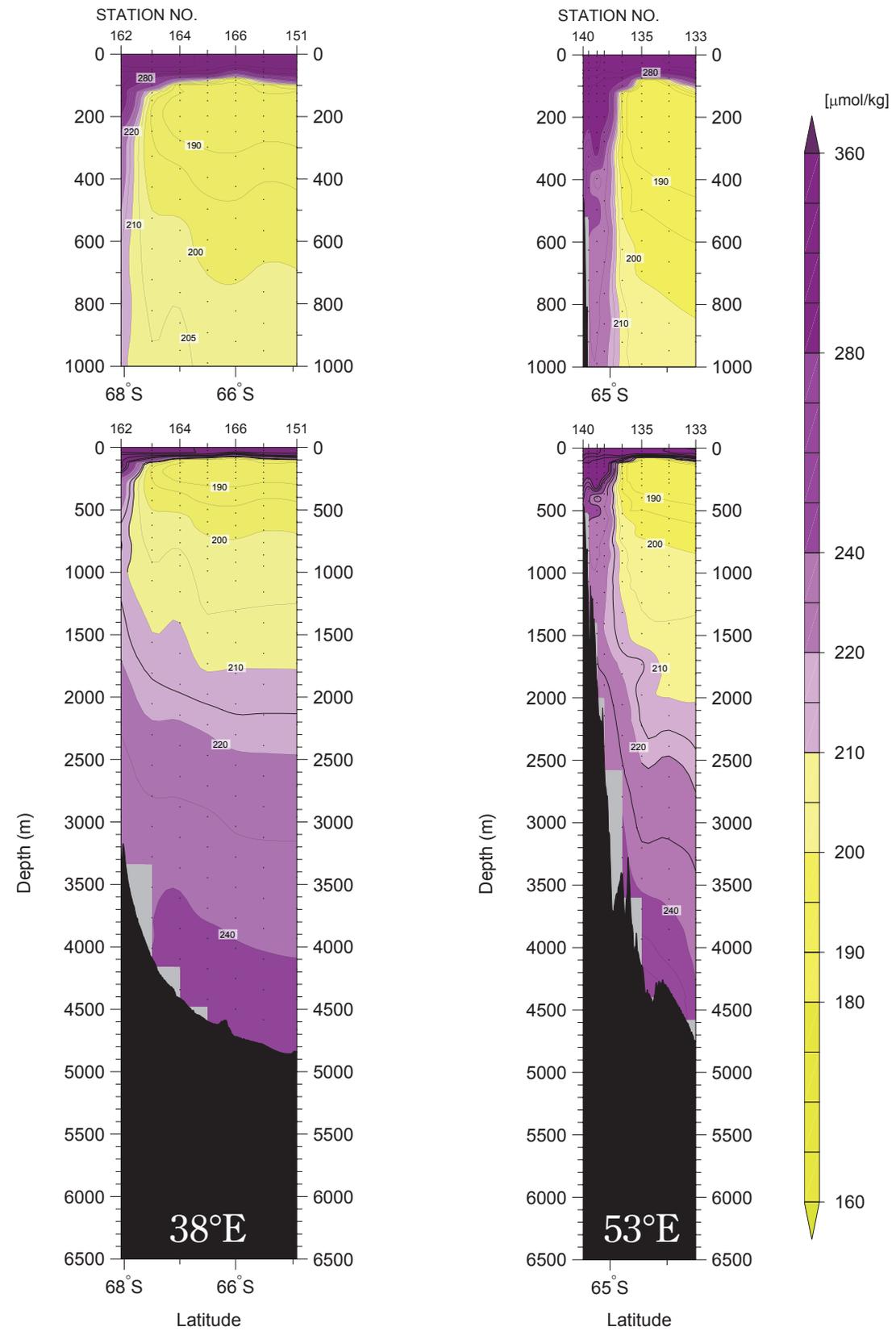
P14S

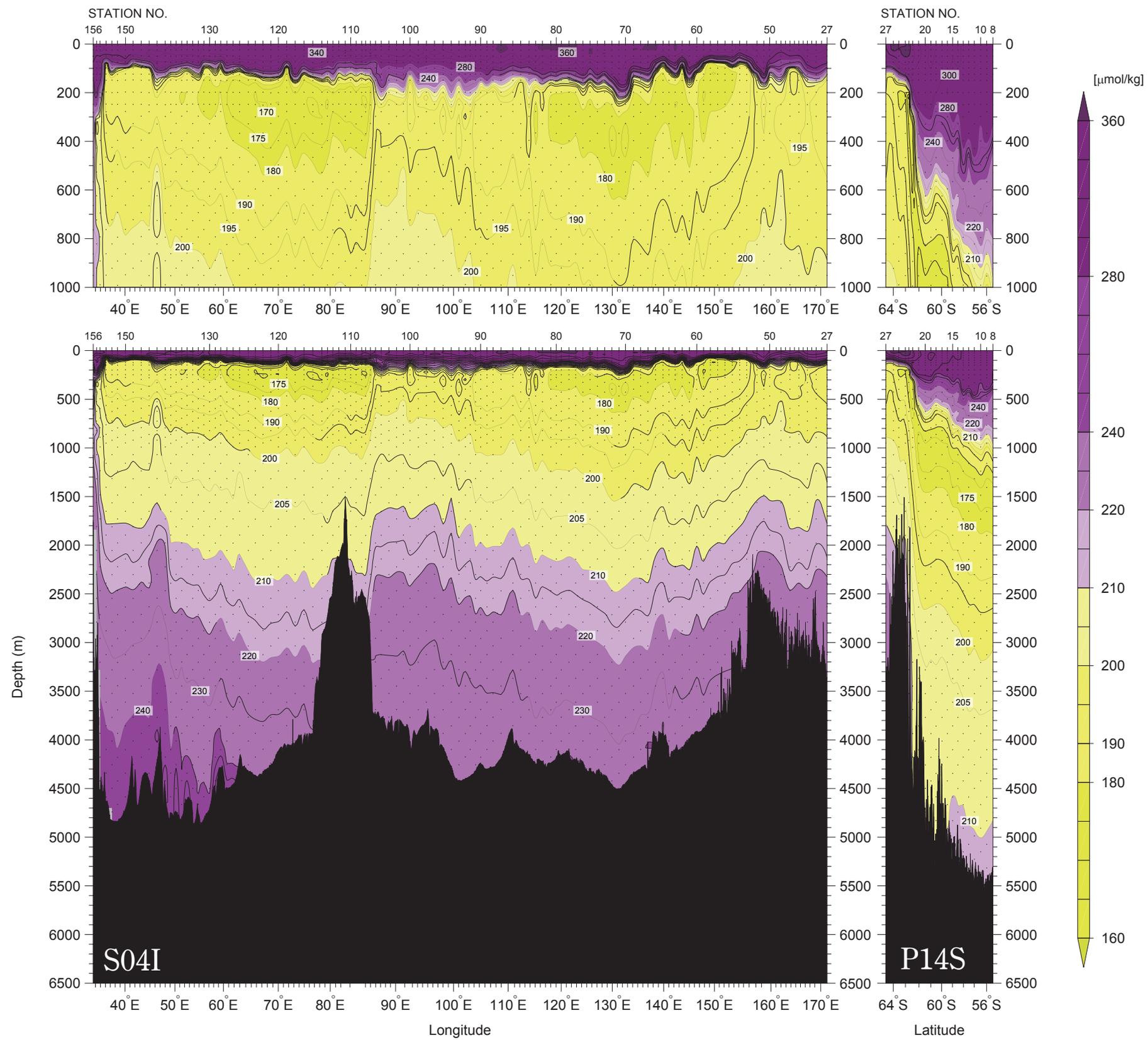
**Figure 14**  
**CTD beam attenuation**  
**coefficient ( $\text{m}^{-1}$ )**



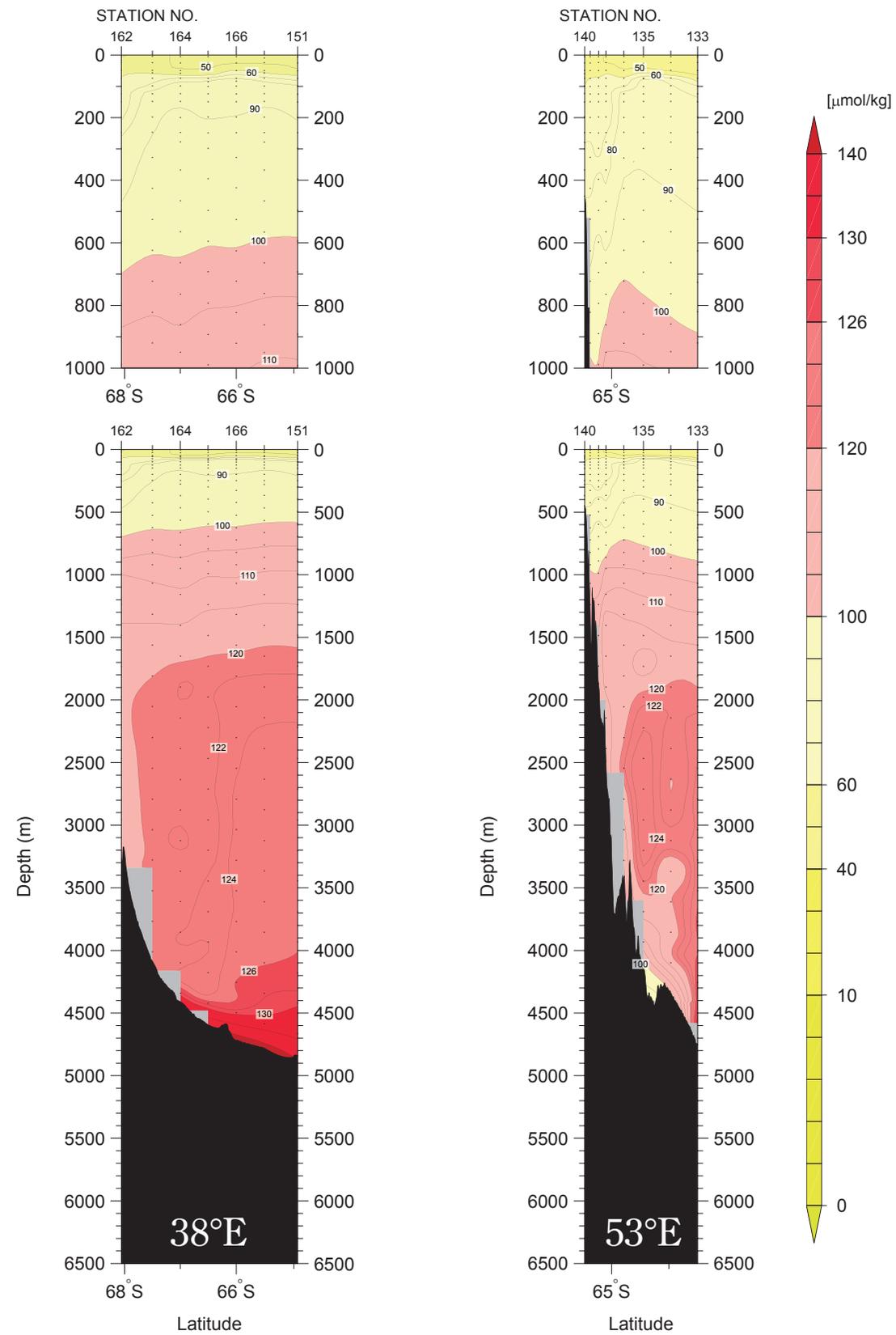


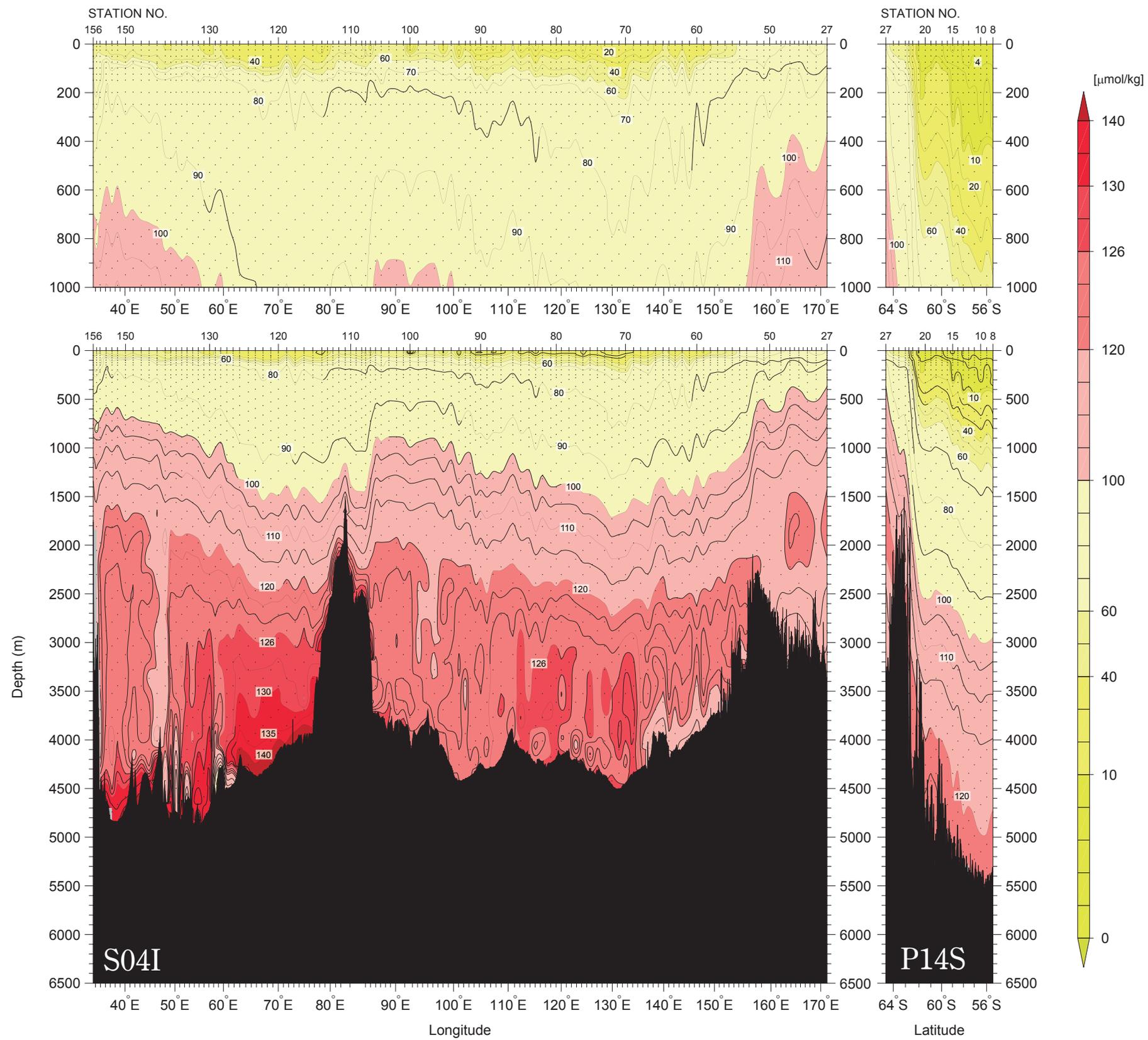
**Figure 15**  
**Bottle sampled dissolved**  
**oxygen ( $\mu\text{mol/kg}$ )**



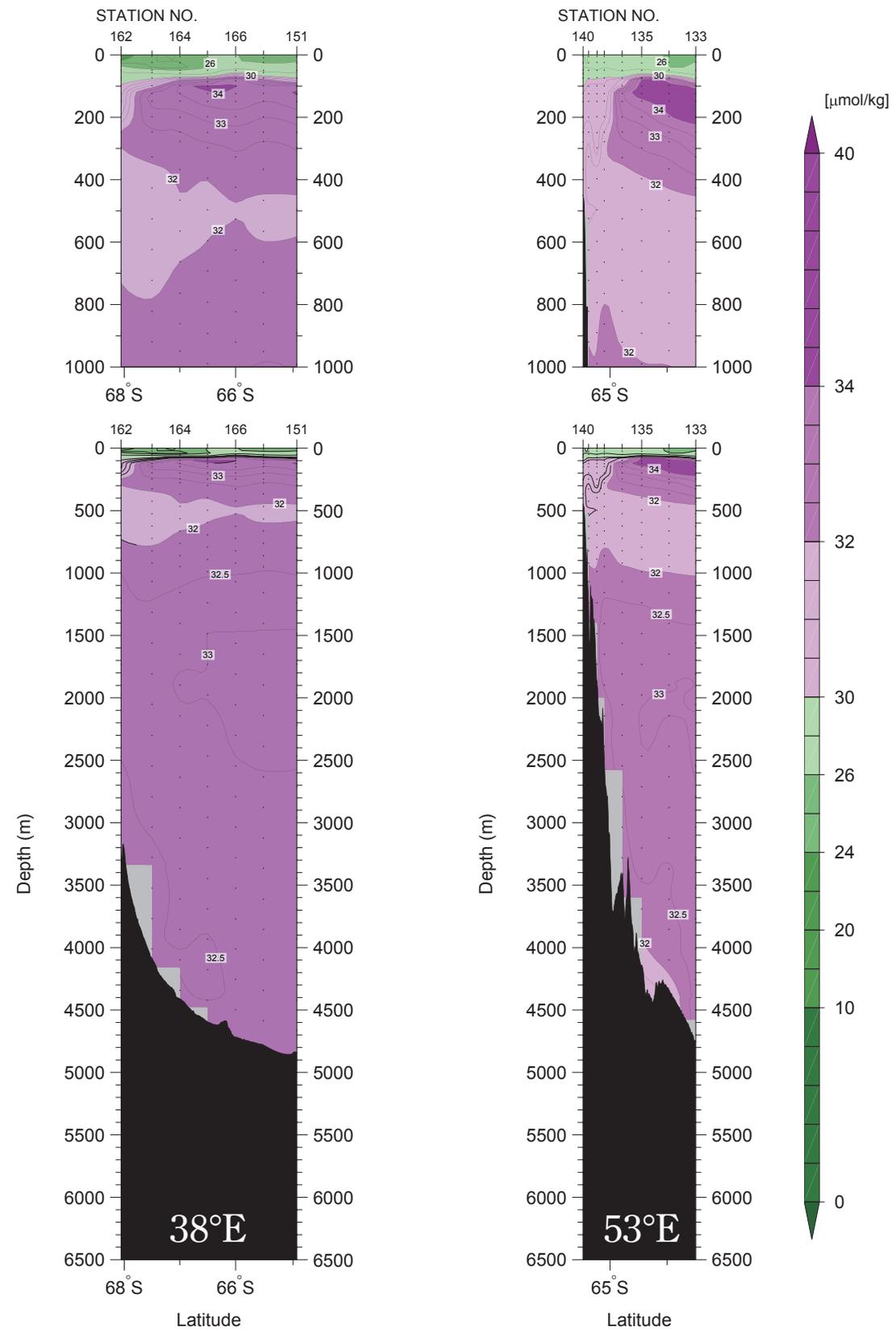


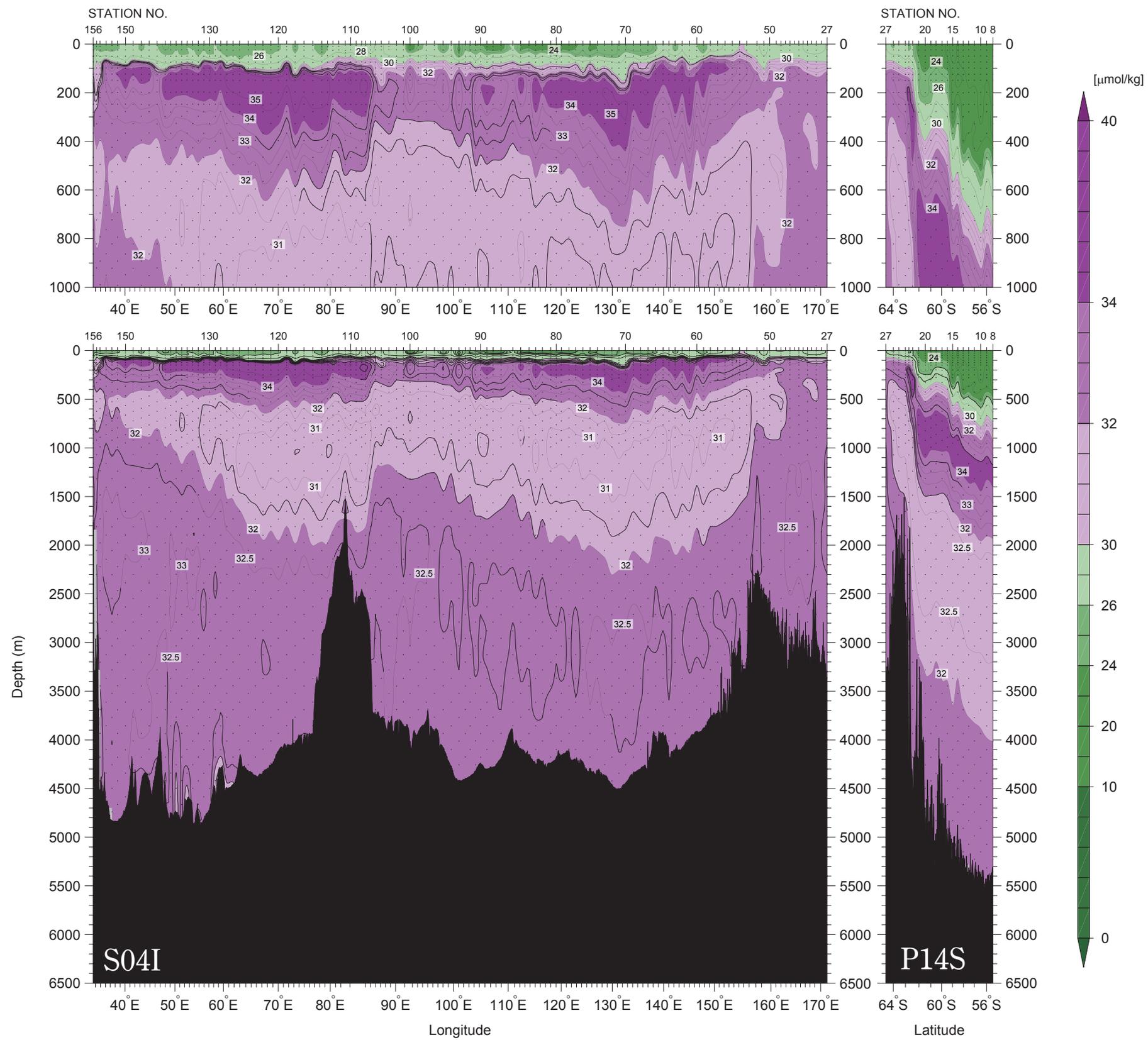
**Figure 16**  
**Silicate ( $\mu\text{mol/kg}$ )**



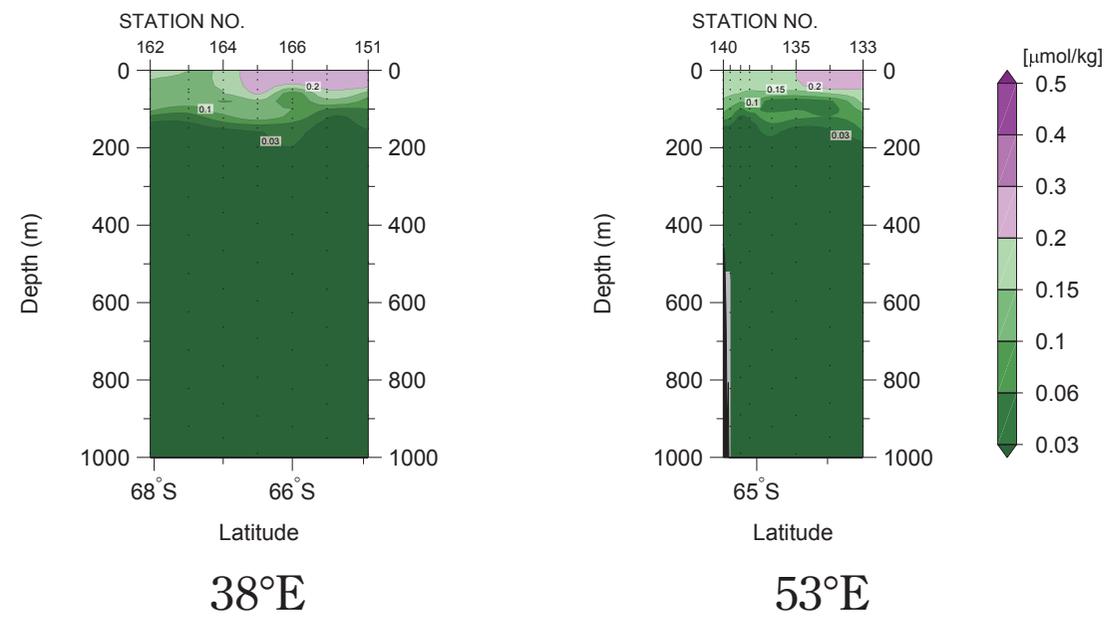


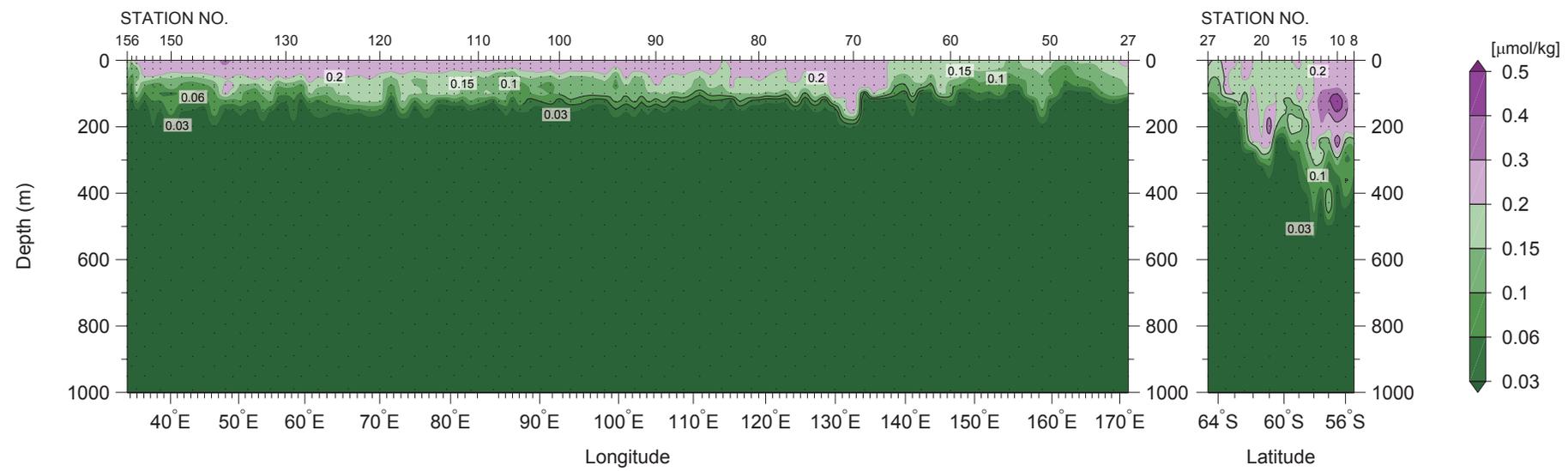
**Figure 17**  
**Nitrate ( $\mu\text{mol/kg}$ )**





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

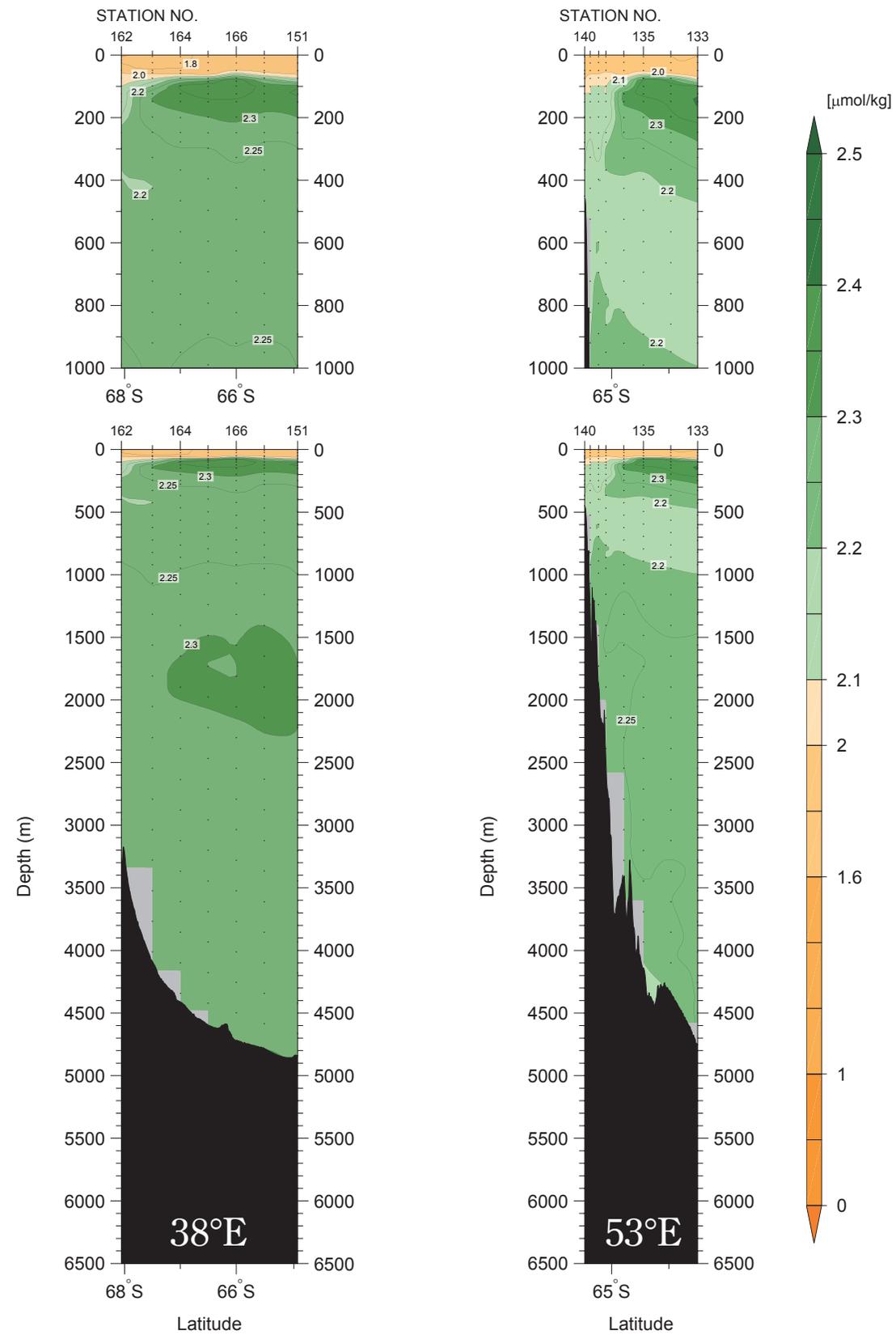


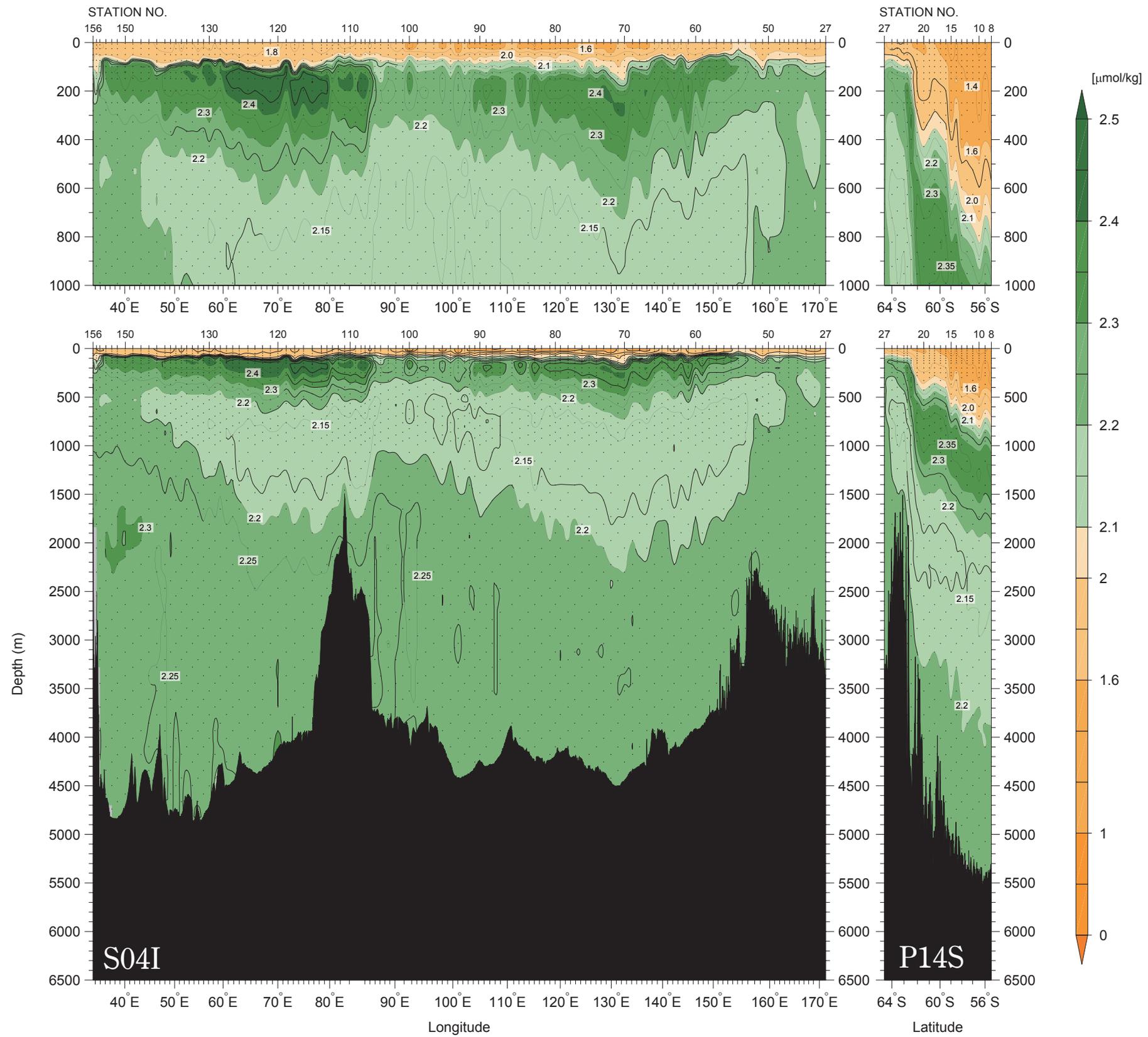


S04I

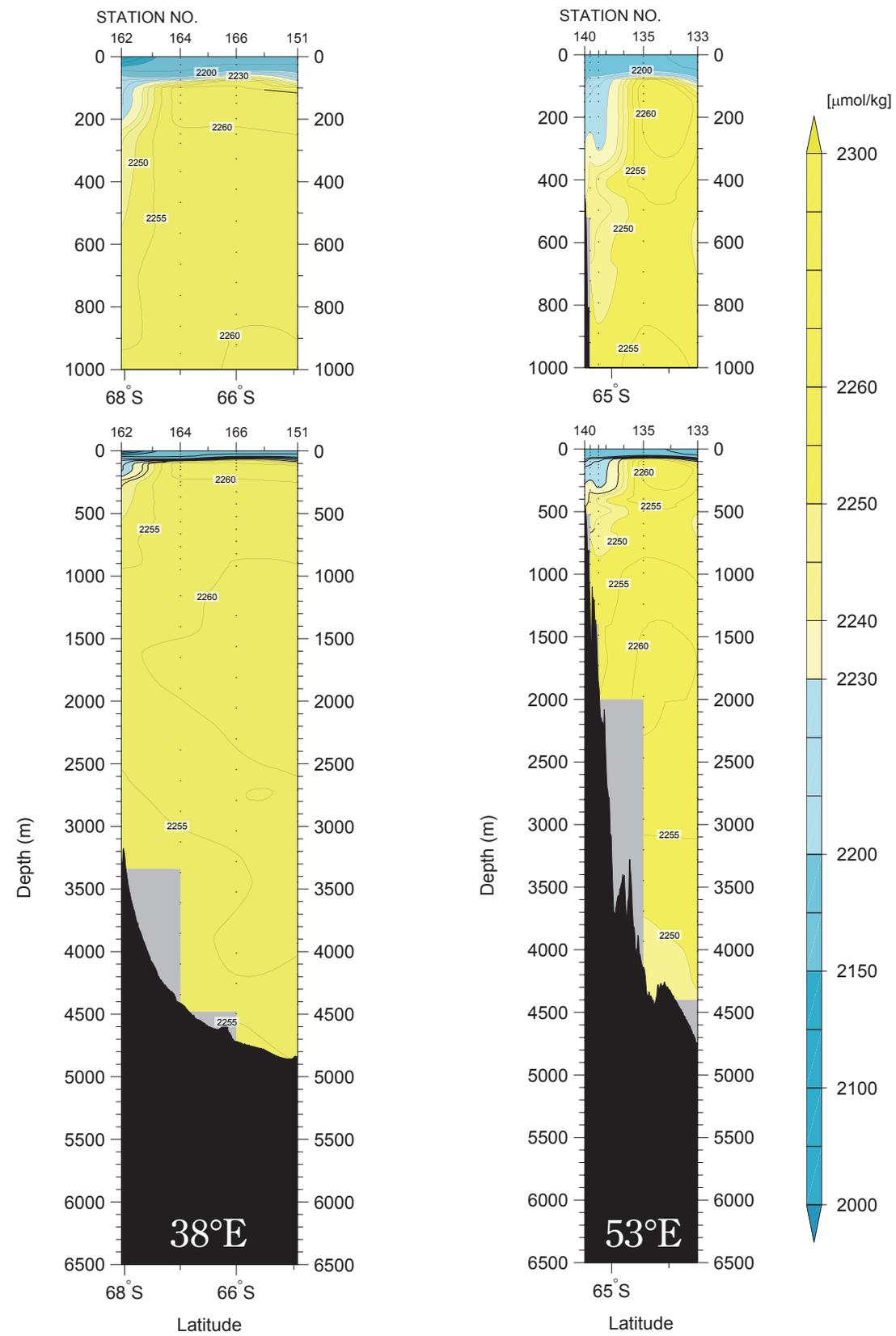
P14S

**Figure 19**  
**Phosphate ( $\mu\text{mol/kg}$ )**





**Figure 20**  
**Dissolved inorganic carbon**  
**( $C_T$ ) ( $\mu\text{mol/kg}$ )**



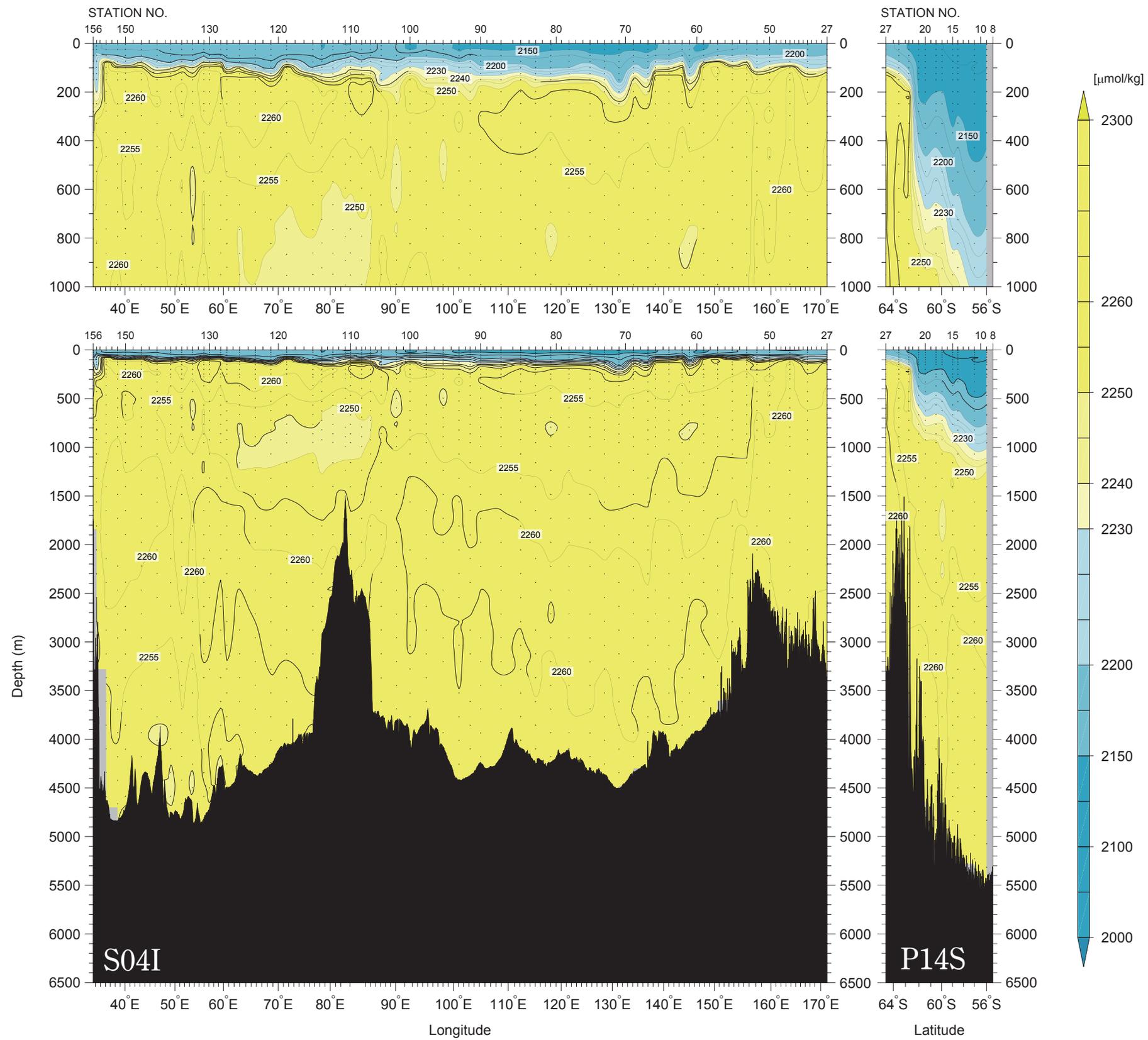
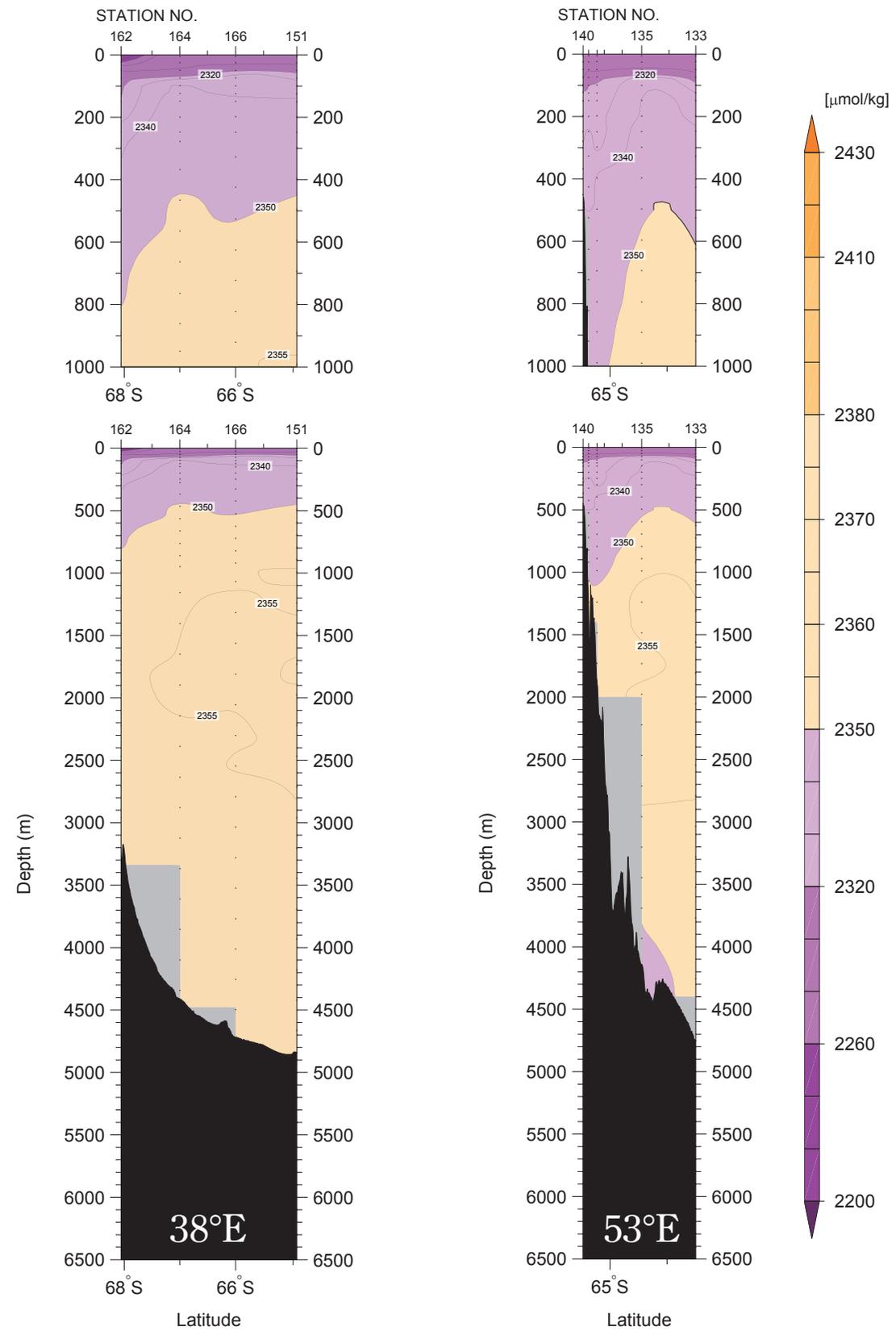
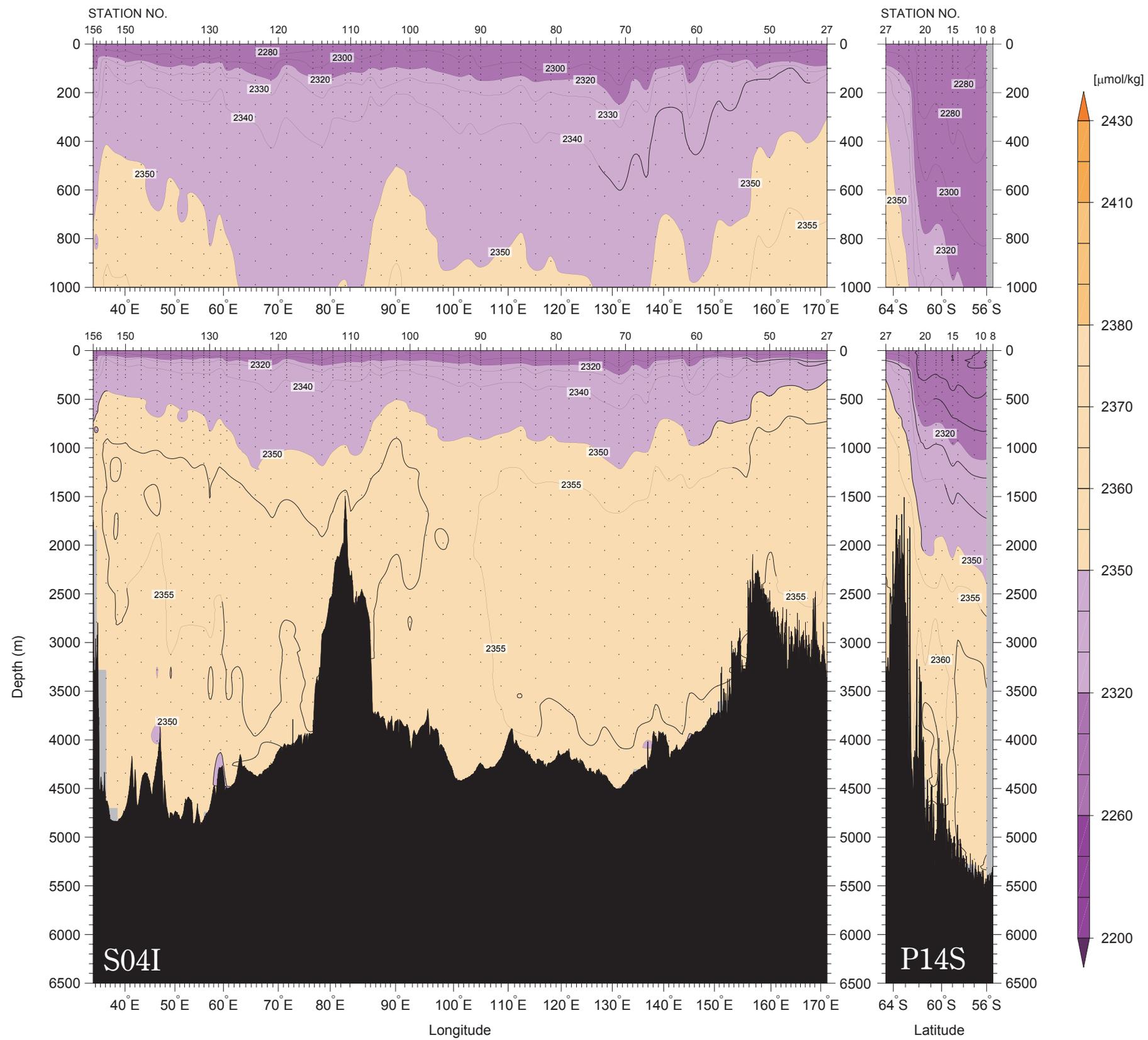


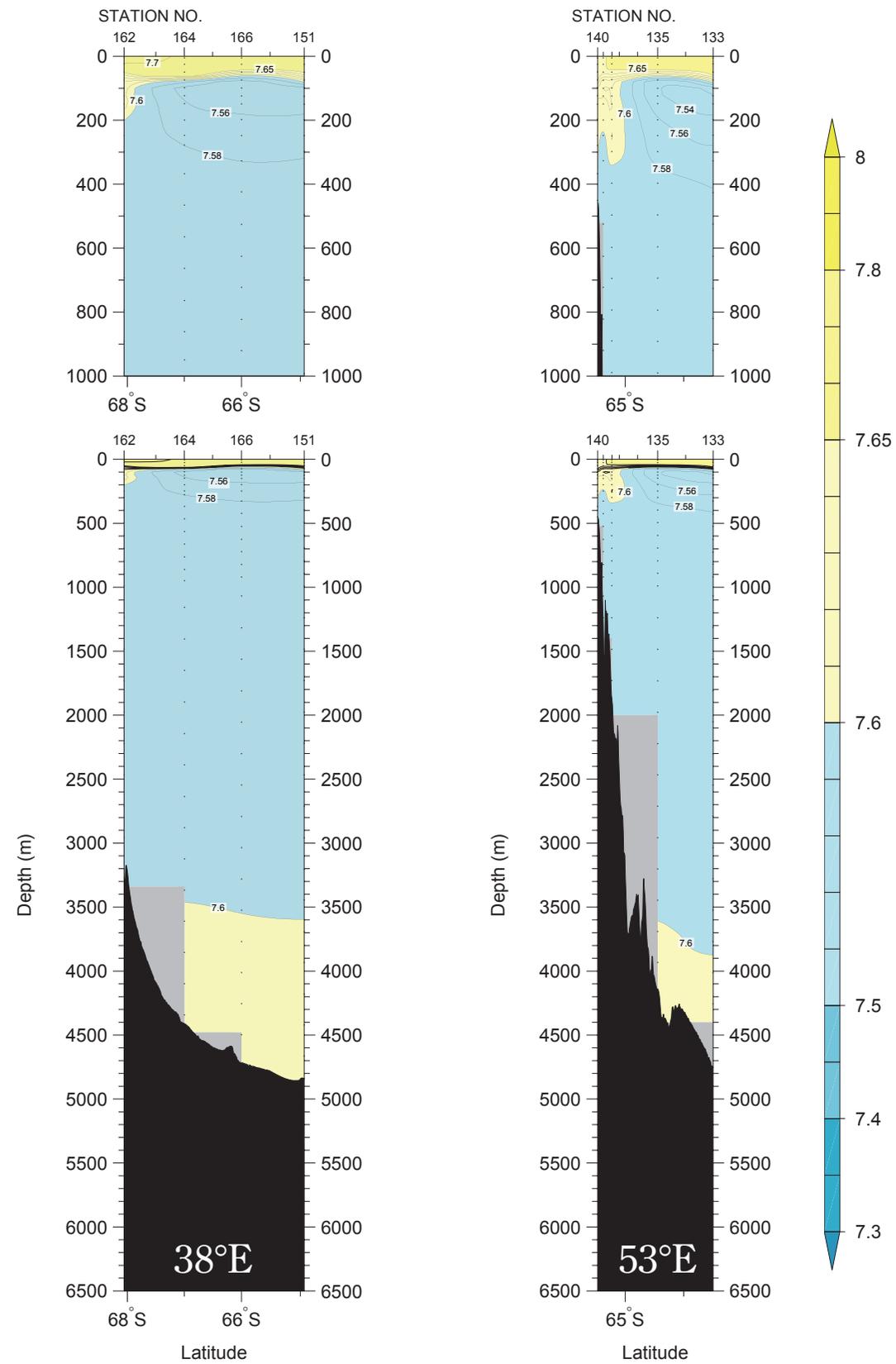
Figure 21

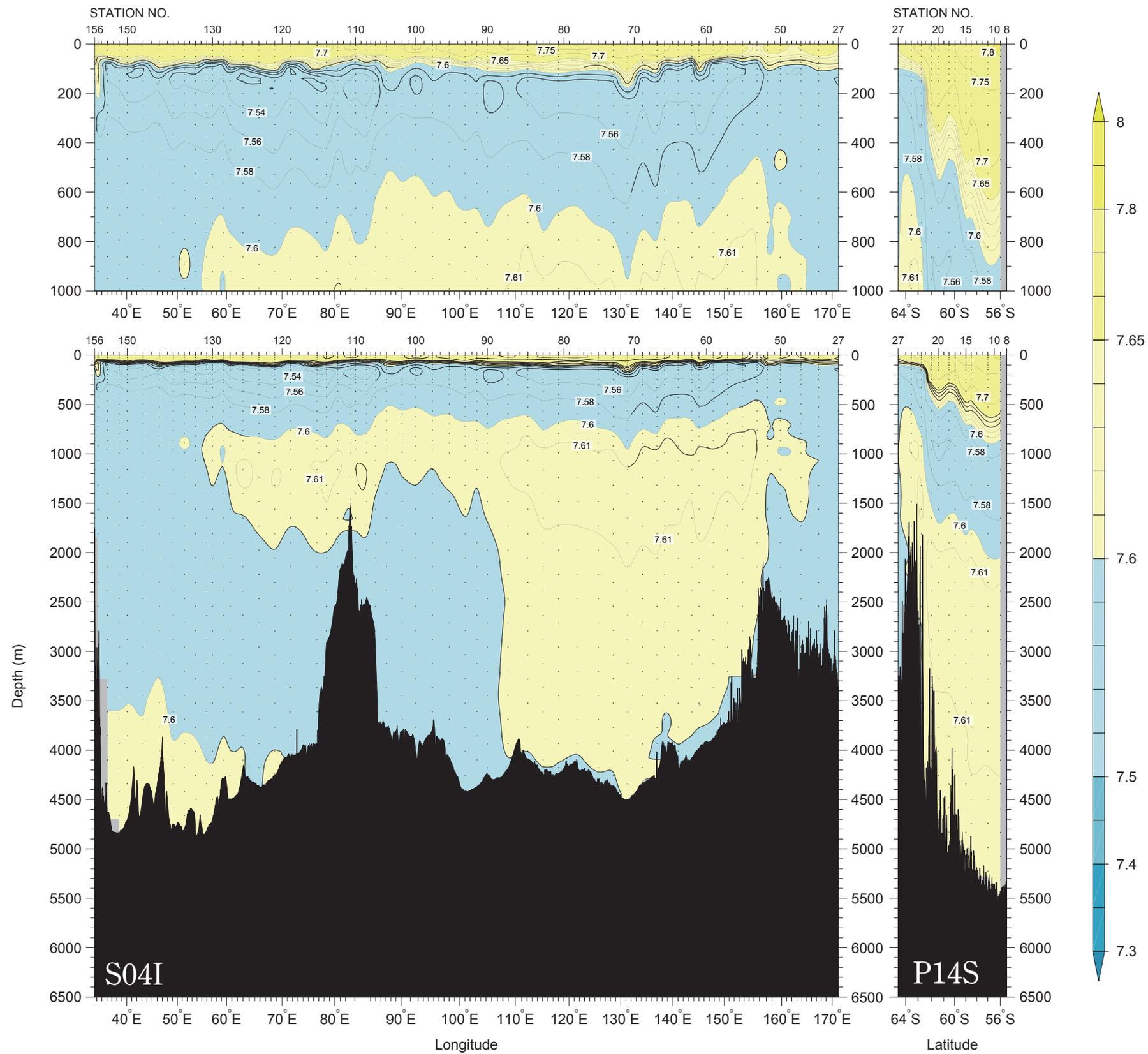
Total alkalinity ( $A_T$ ) ( $\mu\text{mol/kg}$ )



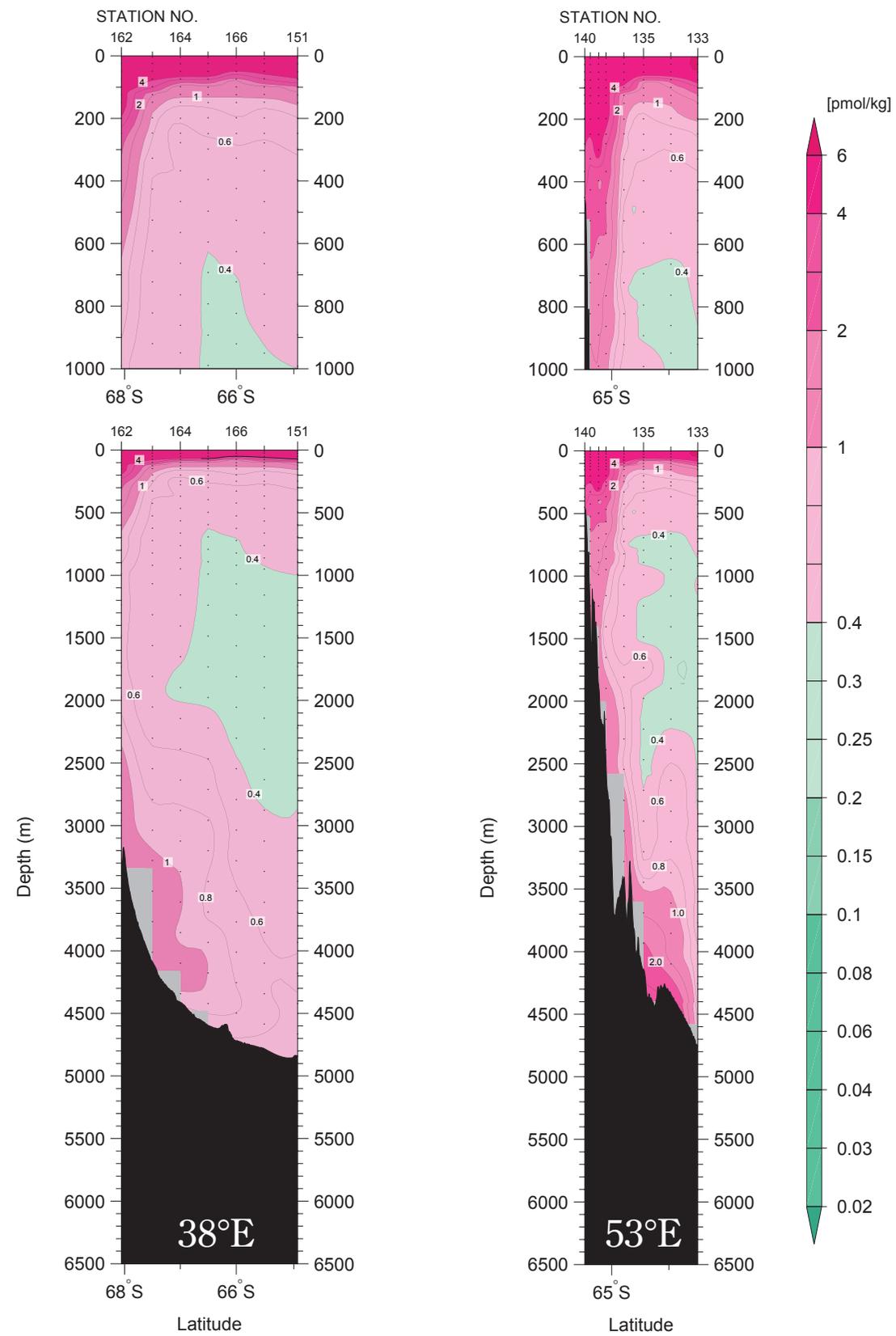


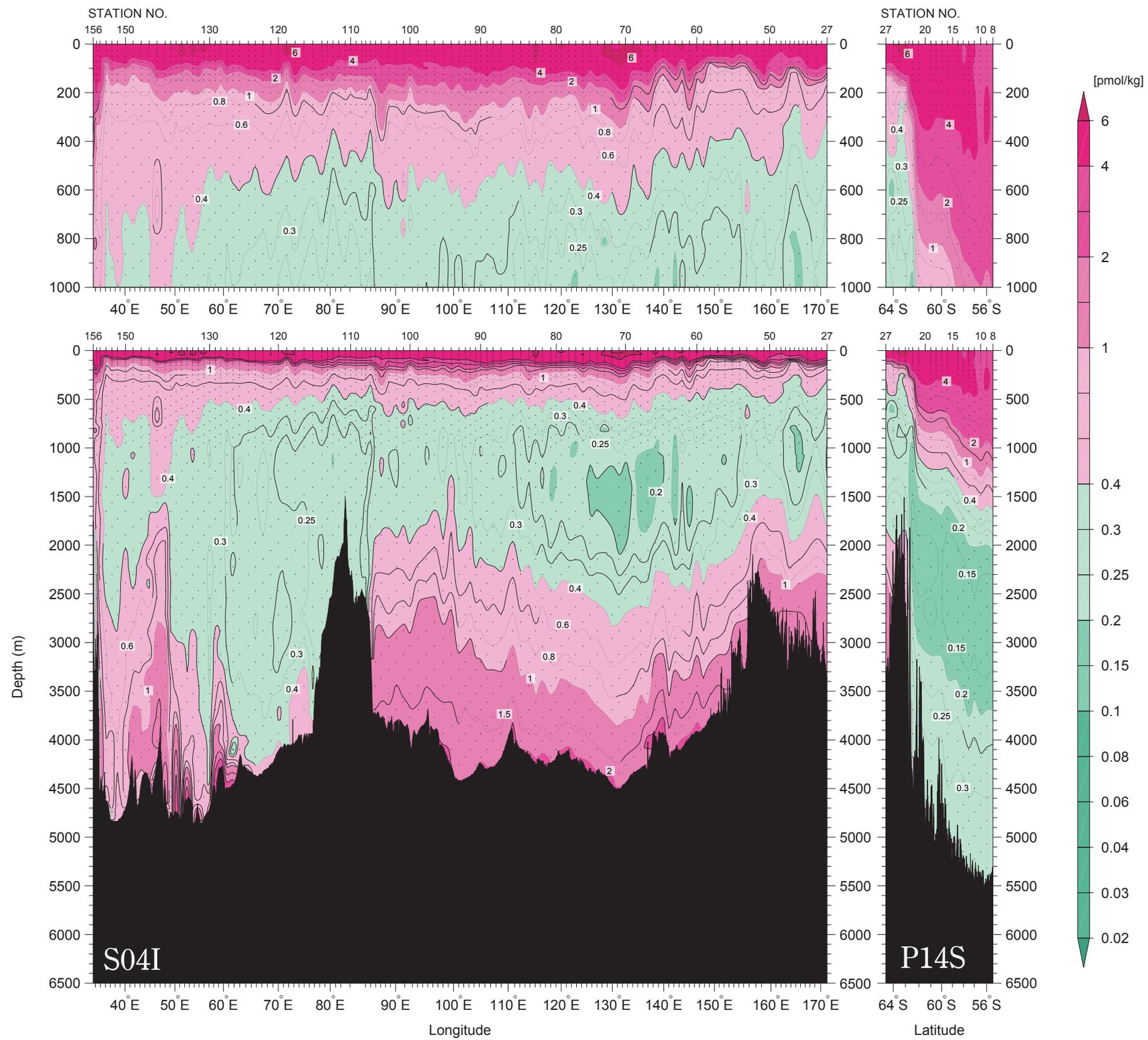
**Figure 22**  
**pH (pH<sub>T</sub>)**



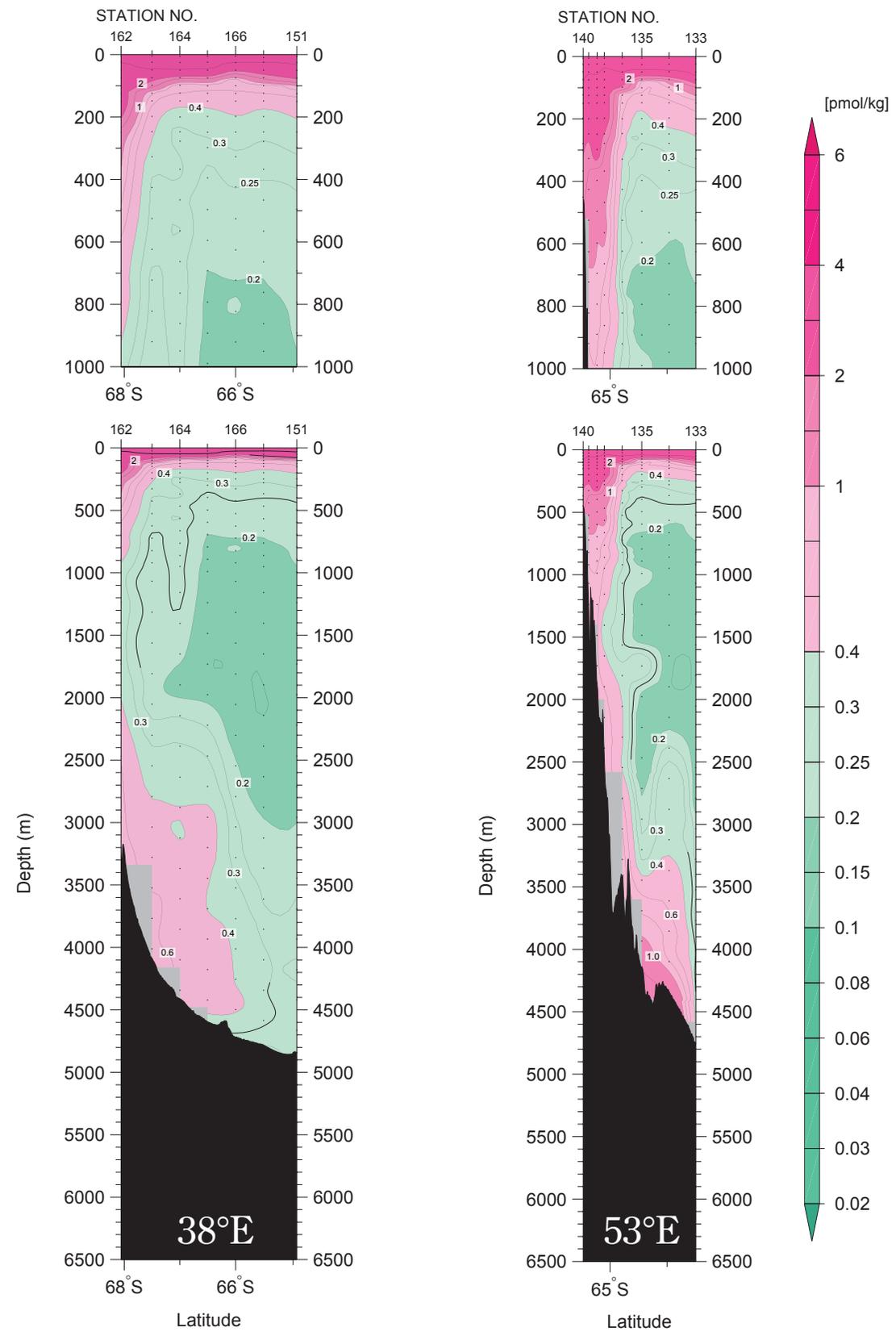


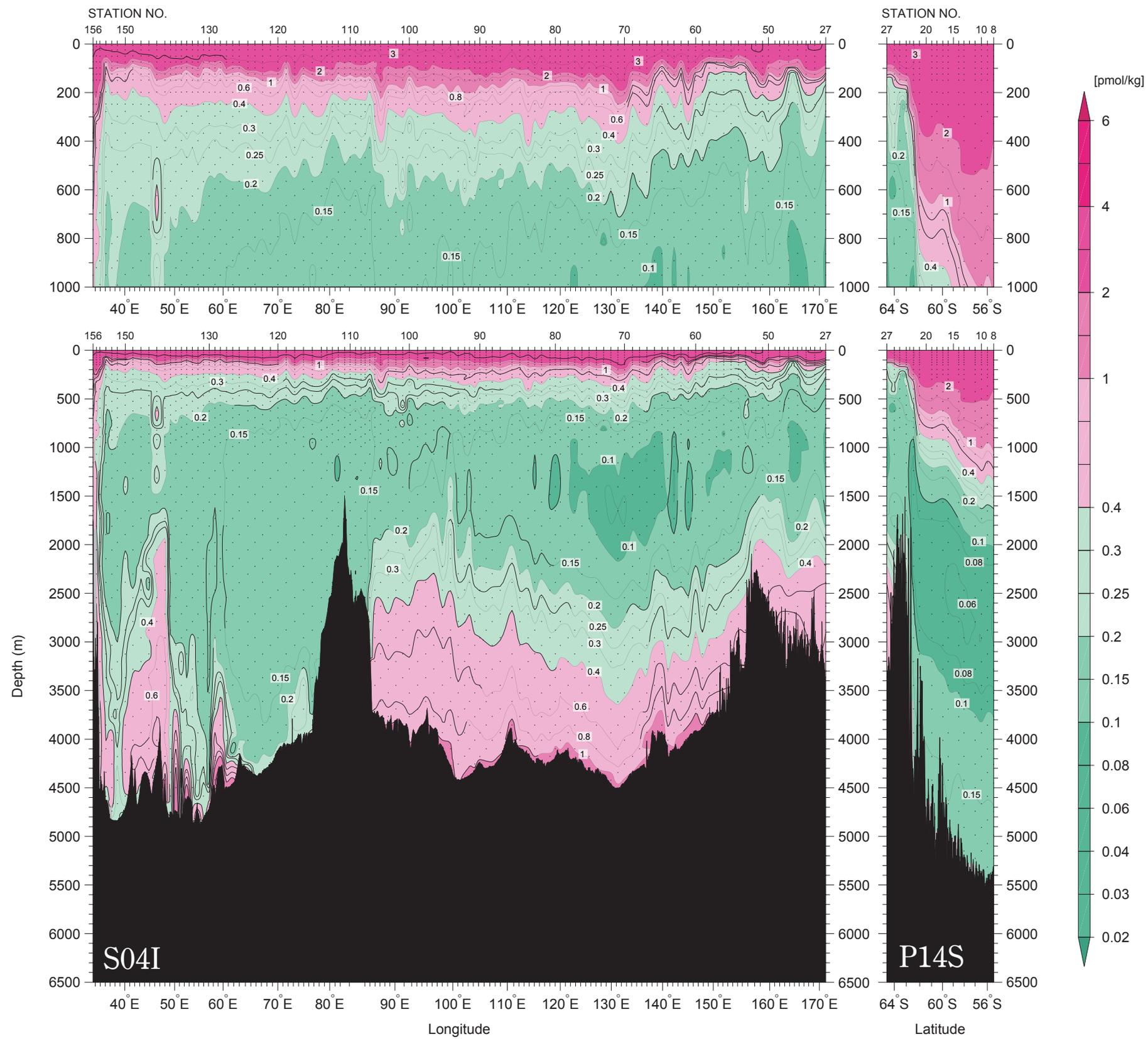
**Figure 23**  
**CFC-11 (pmol/kg)**



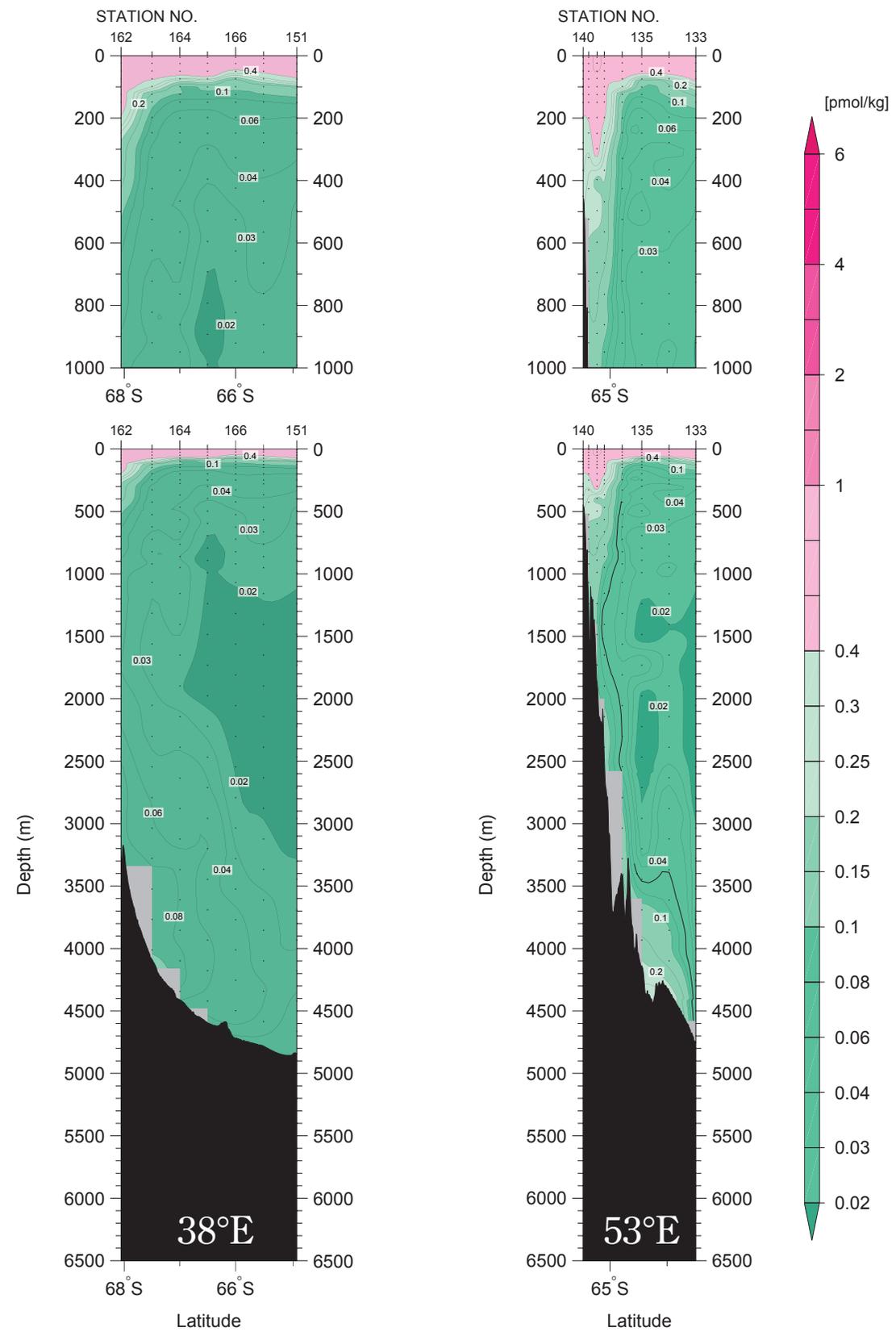


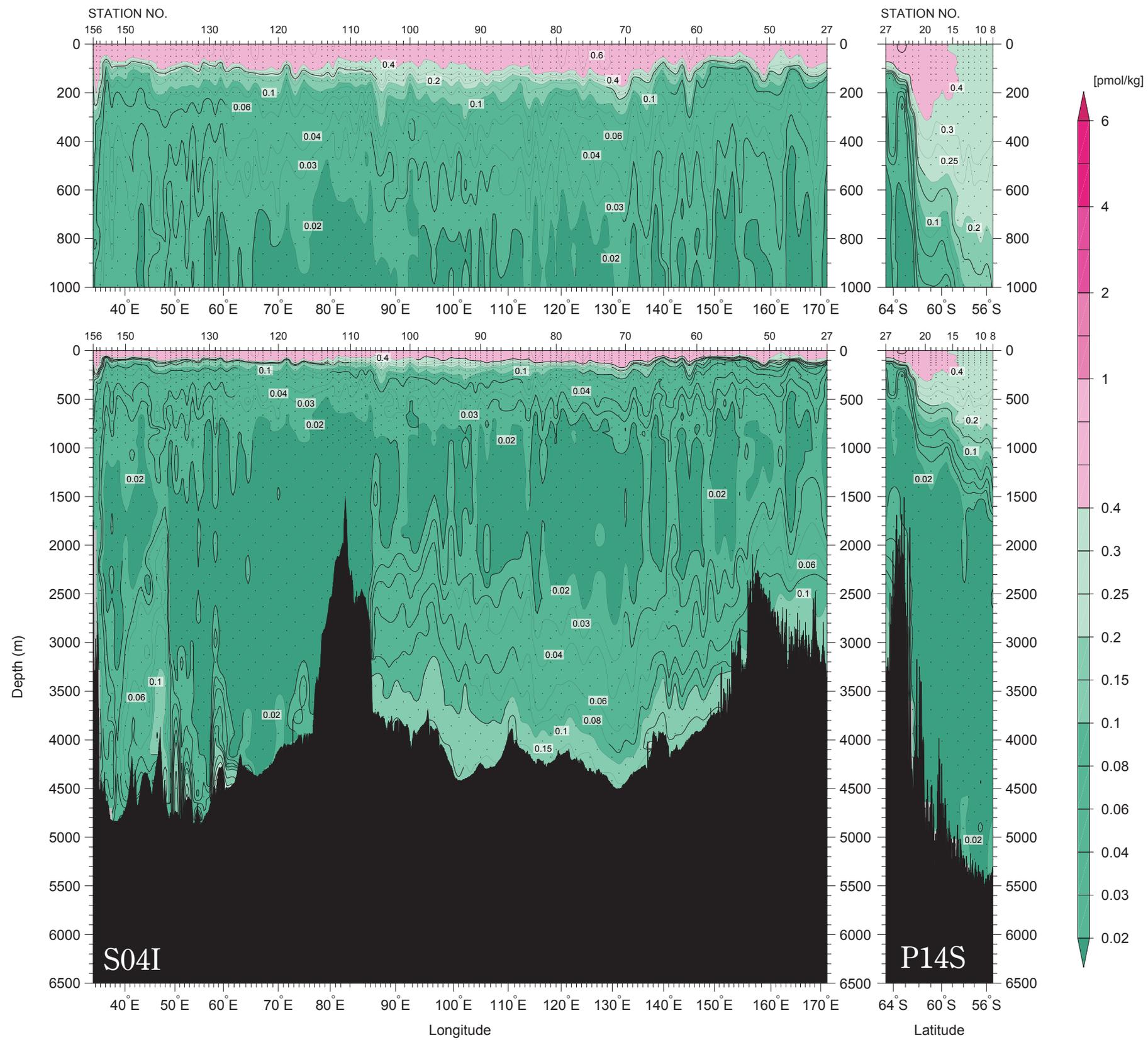
**Figure 24**  
**CFC-12 (pmol/kg)**



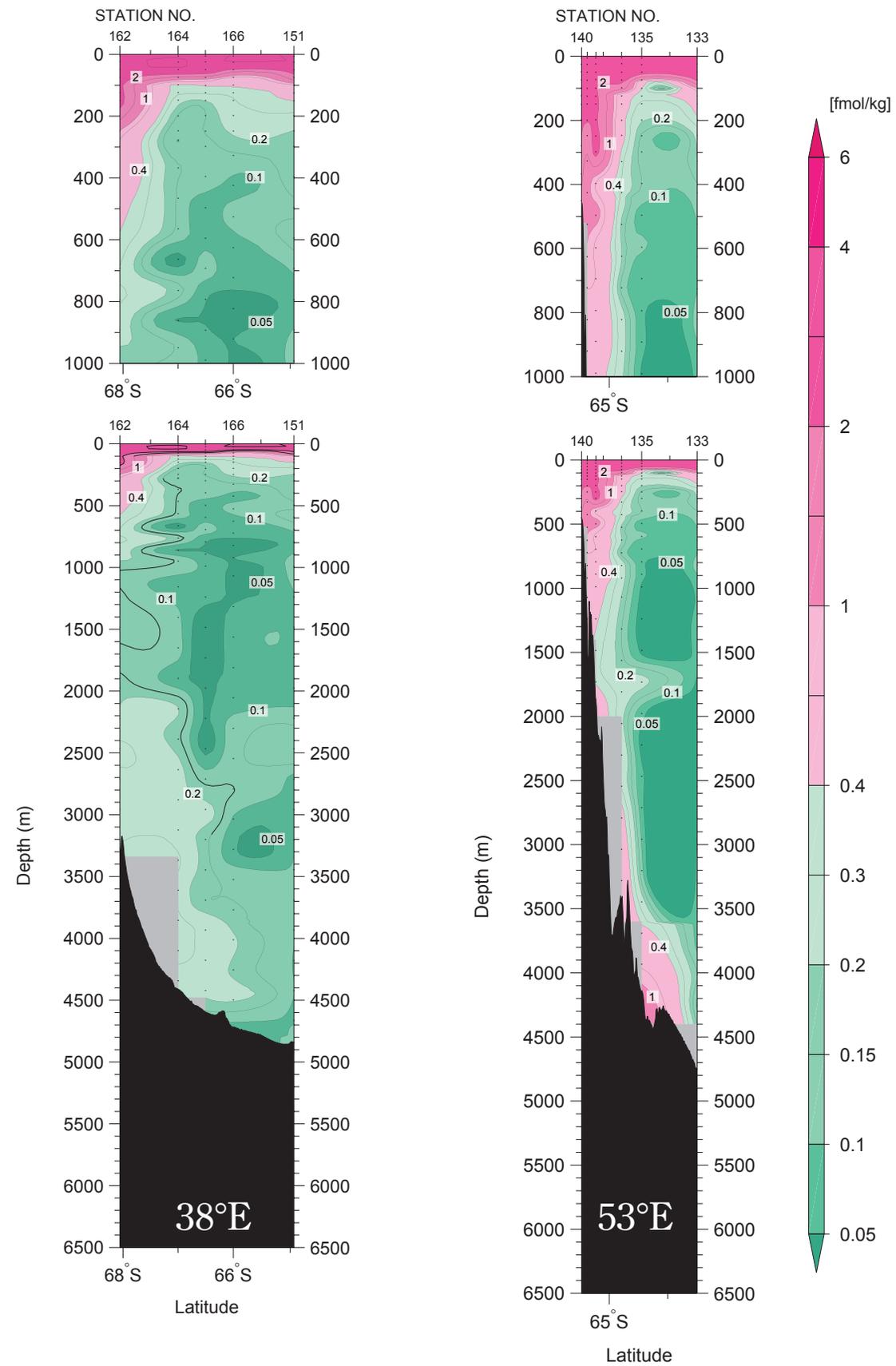


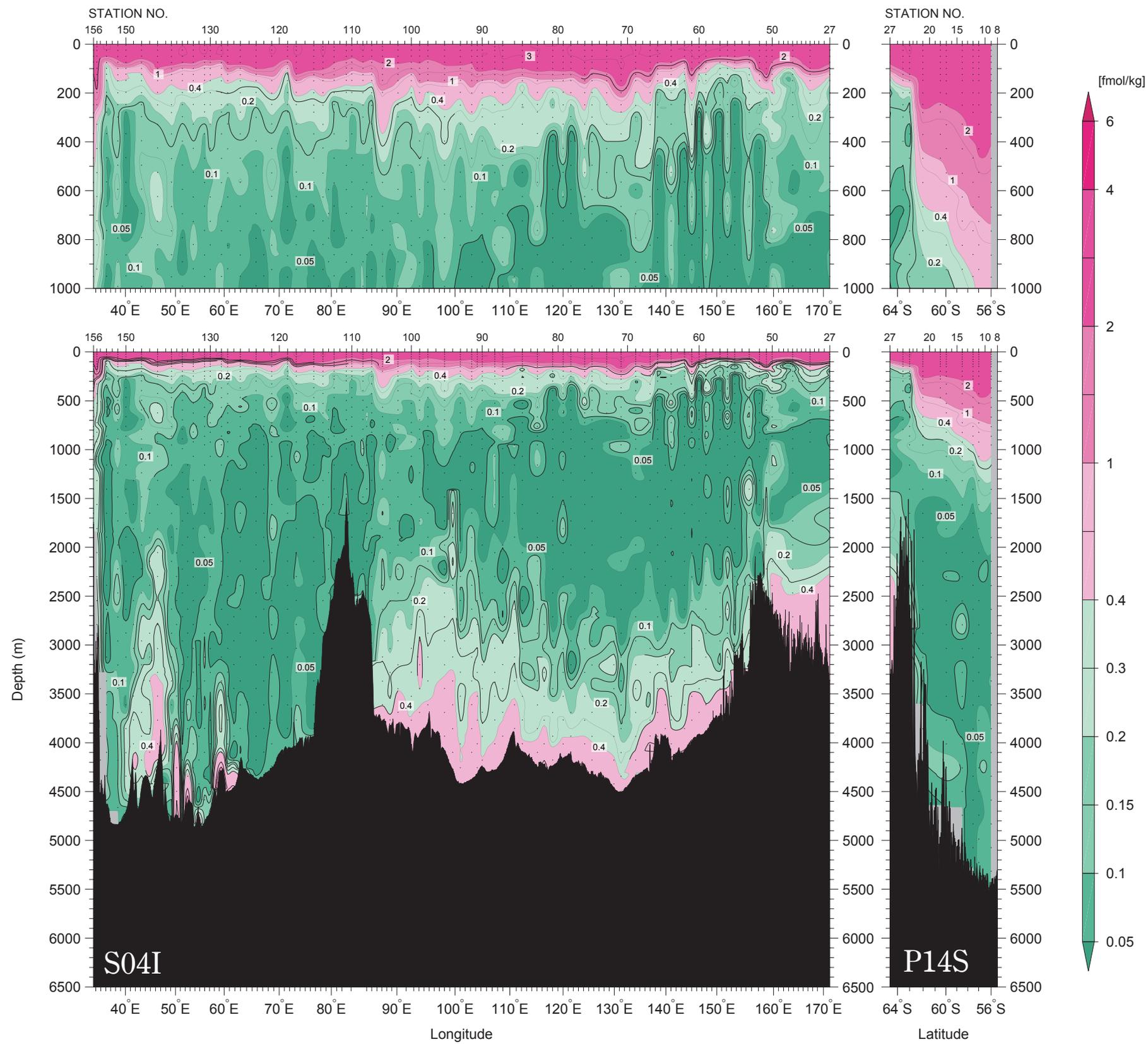
**Figure 25**  
**CFC-113 (pmol/kg)**





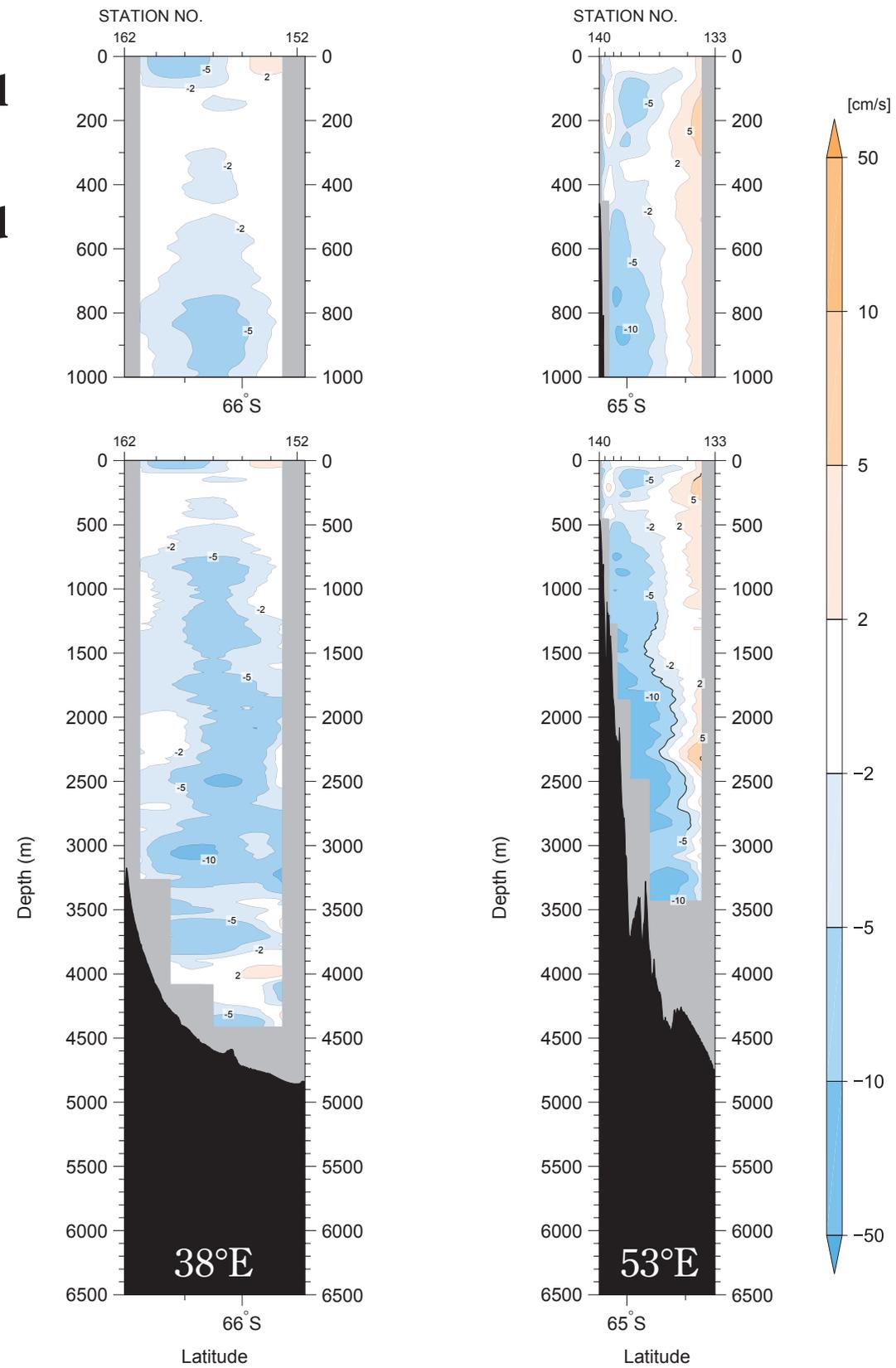
**Figure 26**  
**SF<sub>6</sub> (fmol/kg)**

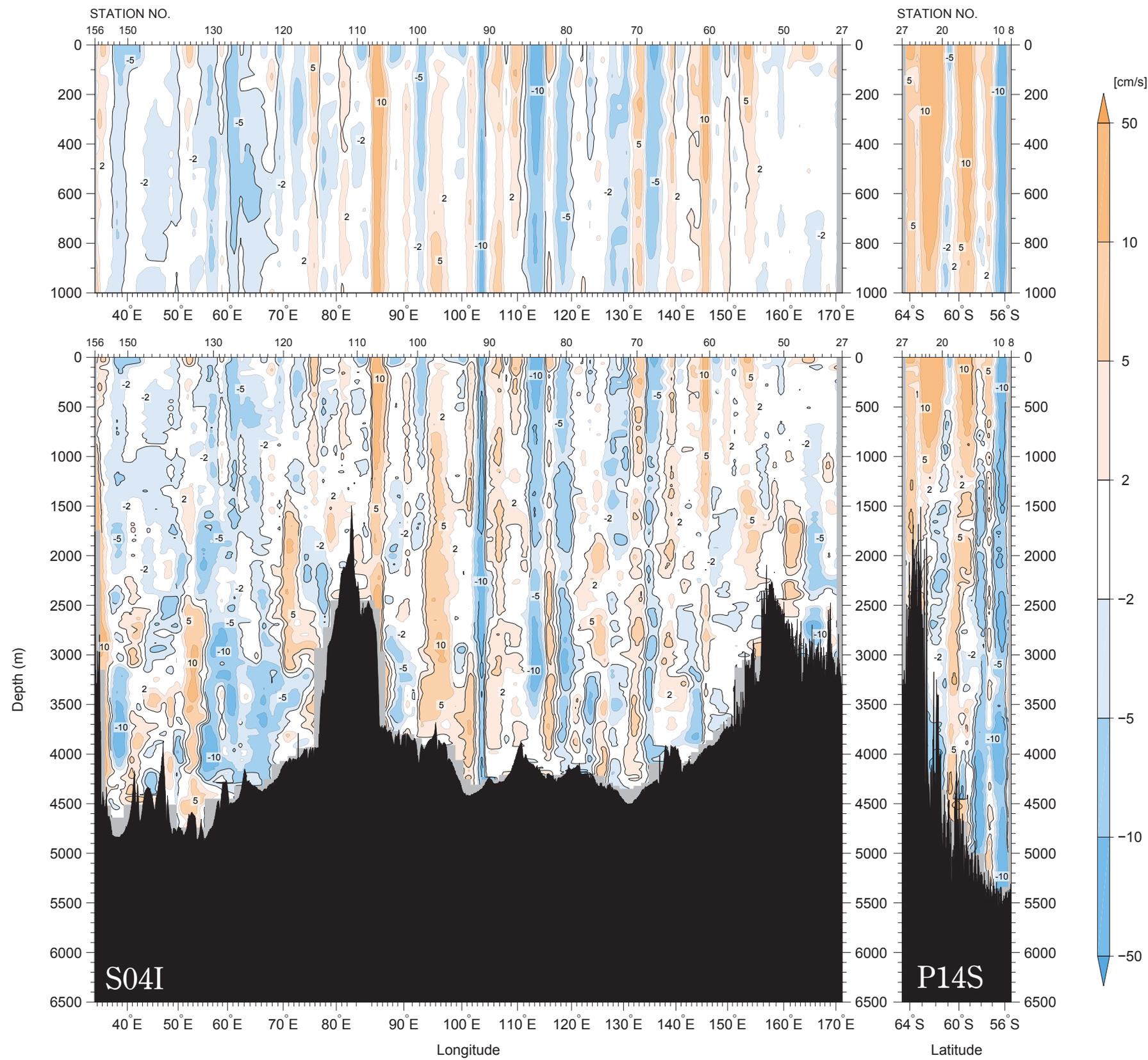




**Figure 27**

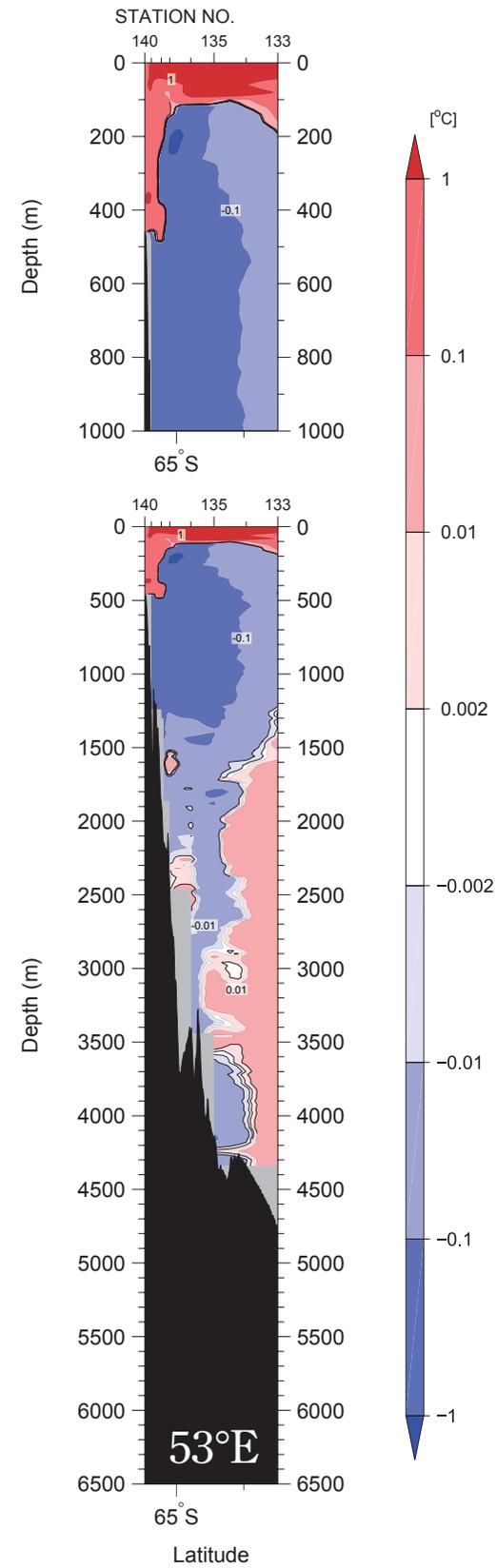
**Current velocity (cm/s) normal  
to the cruise track measured  
By LADCP (eastward or northward  
is positive)**

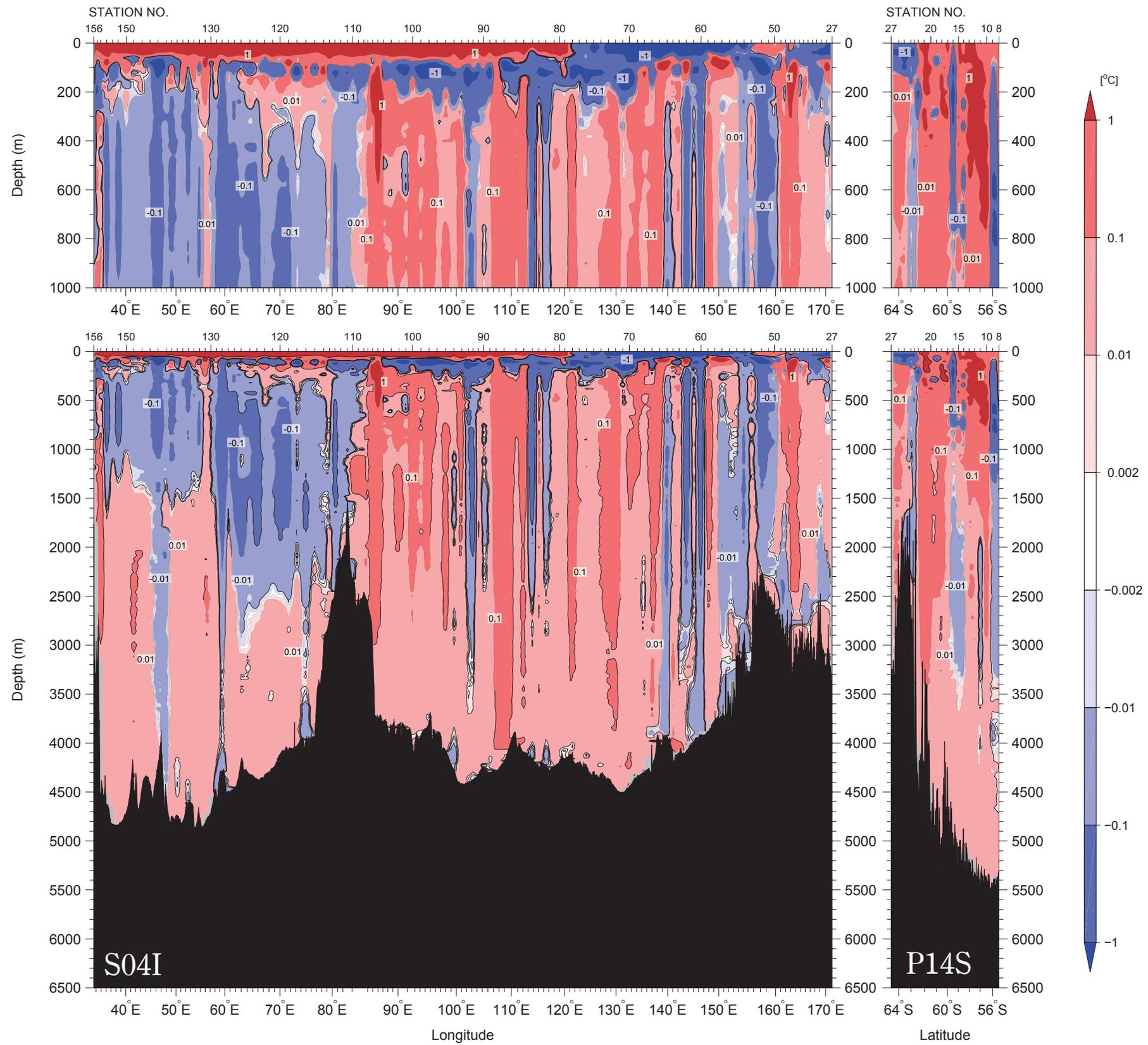




# Figure 28

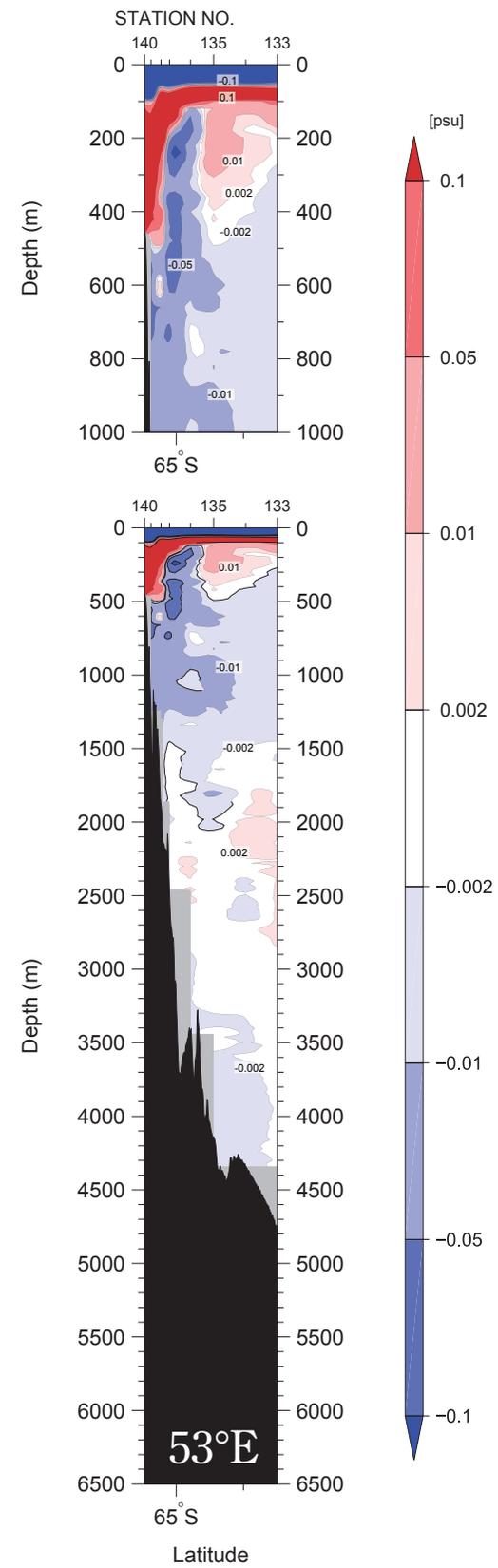
Difference in potential temperature (°C) between results from WOCE in 1995/96 and the revisit in 2012/13

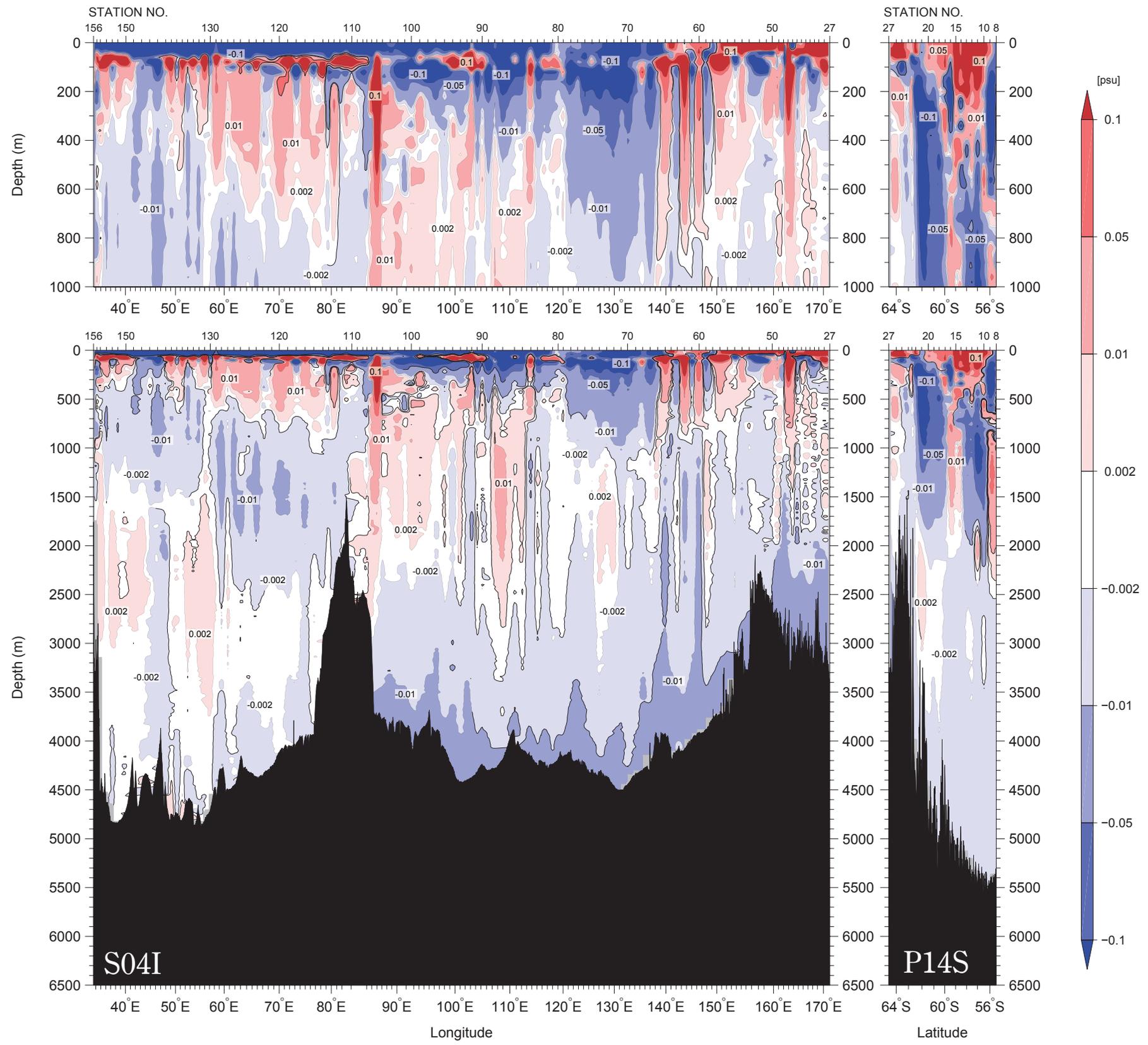




# Figure 29

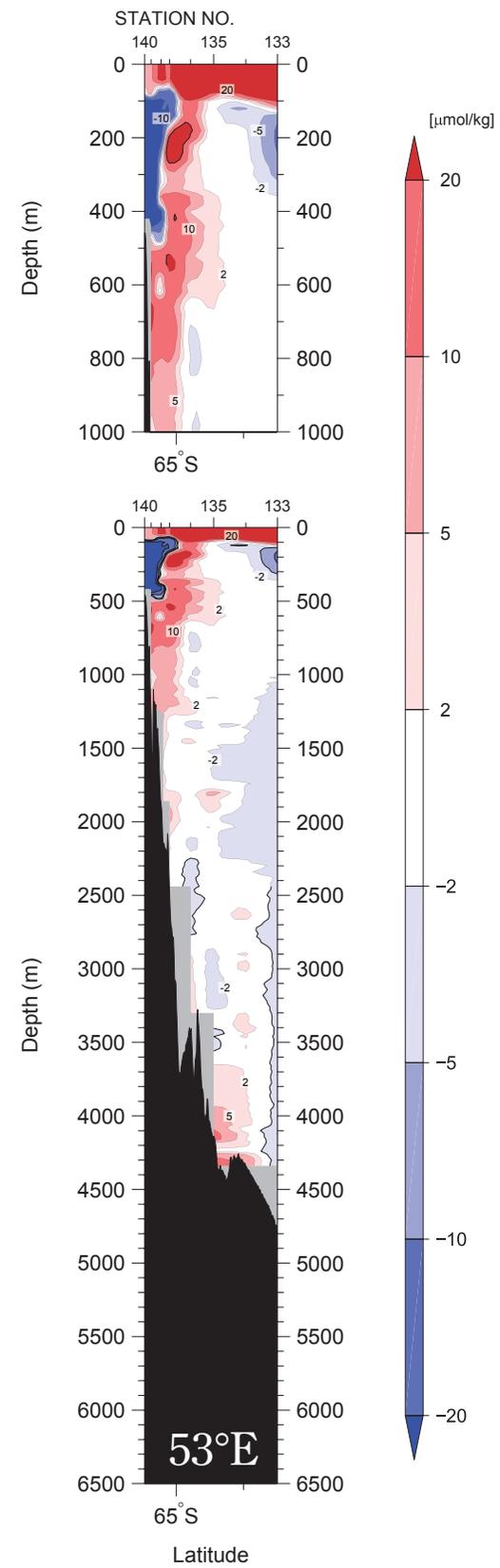
Difference in CTD salinity between results from WOCE in 1995/96 and the revisit in 2012/13

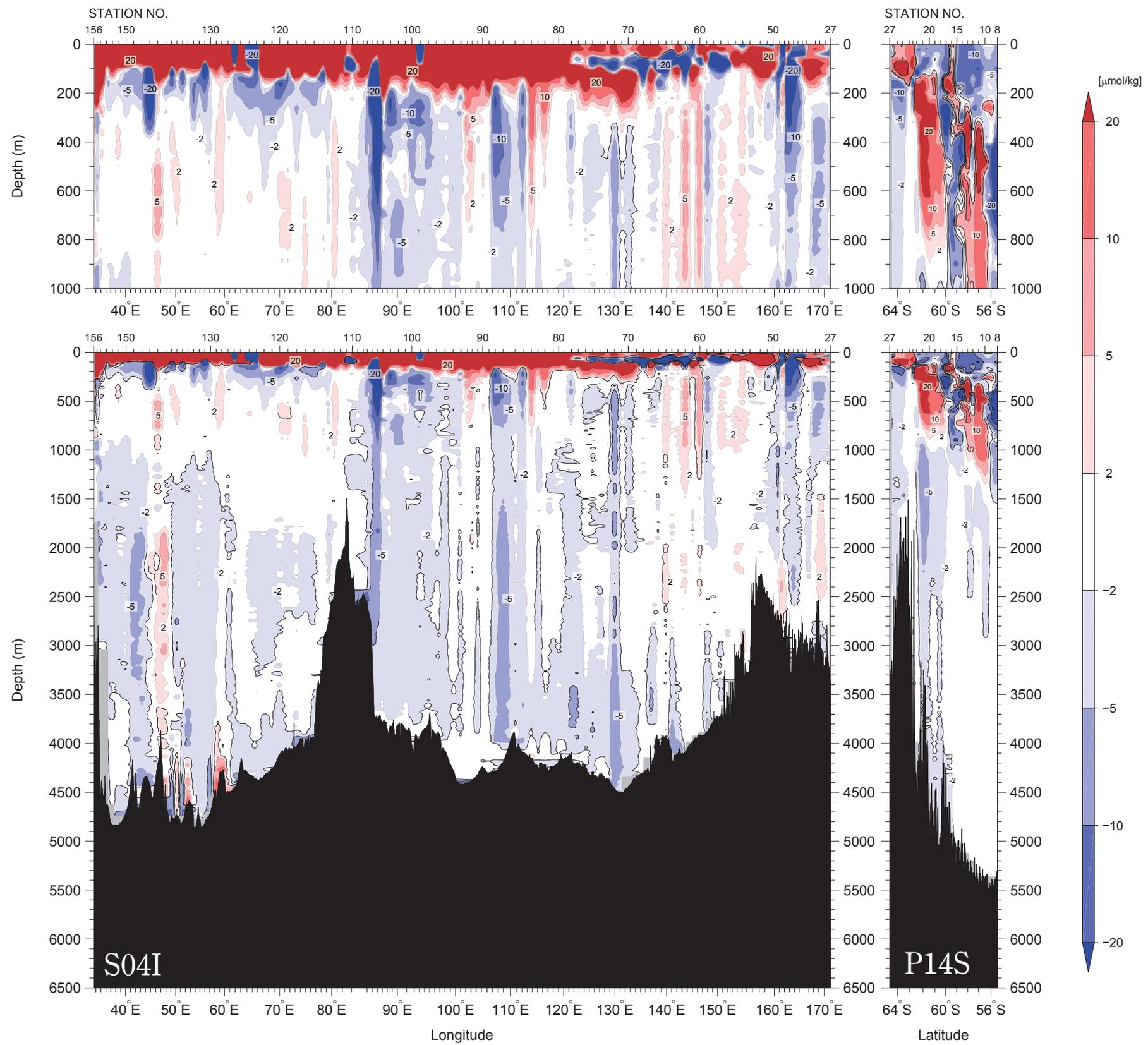




# Figure 30

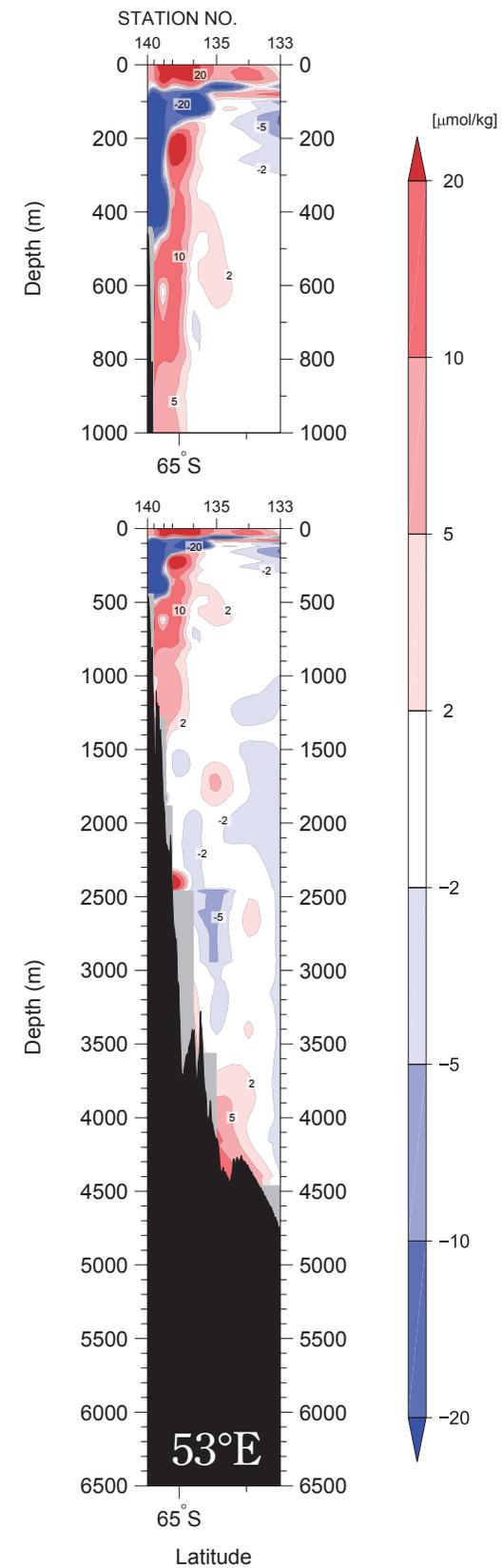
Difference in CTD oxygen ( $\mu\text{mol/kg}$ ) between results from WOCE in 1995/96 and the revisit in 2012/13





# Figure 31

Difference in bottle sampled dissolved oxygen ( $\mu\text{mol/kg}$ ) between results from WOCE in 1995/96 and the revisit in 2012/13





## CCHDO Data Processing Notes

### Leg 3 (449NZ20130106)

Date 2013-11-05  
Data Type BTL/CTD  
Action Submitted  
Summary to go online  
Name Hiroshi Uchida  
Note Documents will be submitted later.

Date 2013-11-07  
Data Type CTD  
Action Website Update  
Summary Available under 'Files as received'  
Name CCHDO Staff  
Note The following files are now available online under 'Files as received', unprocessed by the CCHDO.  
49NZ20130106\_ct1.zip

Date 2013-11-07  
Data Type SUM  
Action Website Update  
Summary Available under 'Files as received'  
Name CCHDO Staff  
Note The following files are now available online under 'Files as received', unprocessed by the CCHDO.  
49NZ20130106\_sum.txt

Date 2014-03-13  
Data Type CTD\_SUM  
Action Website Update  
Summary CTD and SUM files online  
Name Carolina Berys  
Note =====  
S04I 2013 49NZ20130106 processing - CTD/SUM  
=====

2014-03-13  
C Berys

.. contents:: :depth: 2

Submission  
=====

filename	submitted by	date	data type	id
49NZ20130106_ct1.zip	cchdo_admin	2013-11-07	CTD	1095
49NZ20130106_sum.txt	cchdo_admin	2013-11-07	SUM	1095

Parameters

-----  
49NZ20130106

\_ct1.zip

~~~~~

- CTDP RS [1]\_

- CTDTMP [1]\_

- CTDSAL [1]\_  
- CTDOXY [1]\_  
- XMISS [1]\_ [3]\_  
- FLUOR [1]\_ [3]\_  
- XMISSCP [3]\_  
- PAR [1]\_ [3]\_

.. [1] parameter has quality flag column  
.. [2] parameter only has fill values/no reported measured data  
.. [3] not in WOCE bottle file  
.. [4] merged, see merge\_

Process

=====

Changes

-----

49NZ20130106\_ct1.zip

~~~~~

- Comma removed from units line and data lines  
- added END\_DATA

49NZ20130106\_sum.txt

~~~~~

- none

.. \_merge:

Merge

-----

- none

Conversion

-----

```
=====
file converted from software
=====
18HU19990627_nc_ctd.zip 18HU19990627_ct1.csv hydro 0.8.0-110-g7da02f9
=====
```

All converted files opened in JOA with no apparent problems.

Directories

=====

:working directory:

/data/co2clivar/southern/s04/s04i\_49NZ20130106/original/2014.03.13\_CTD\_SUM\_CBG

:cruise directory:

/data/co2clivar/southern/s04/s04i\_49NZ20130106

Updated Files Manifest

=====

| file                    | stamp               |
|-------------------------|---------------------|
| 49NZ20130106_nc_ctd.zip | 20130515JAMSTECRIGC |
| 49NZ20130106su.txt      |                     |
| 49NZ20130106_ct1.zip    | 20130515JAMSTECRIGC |

=====