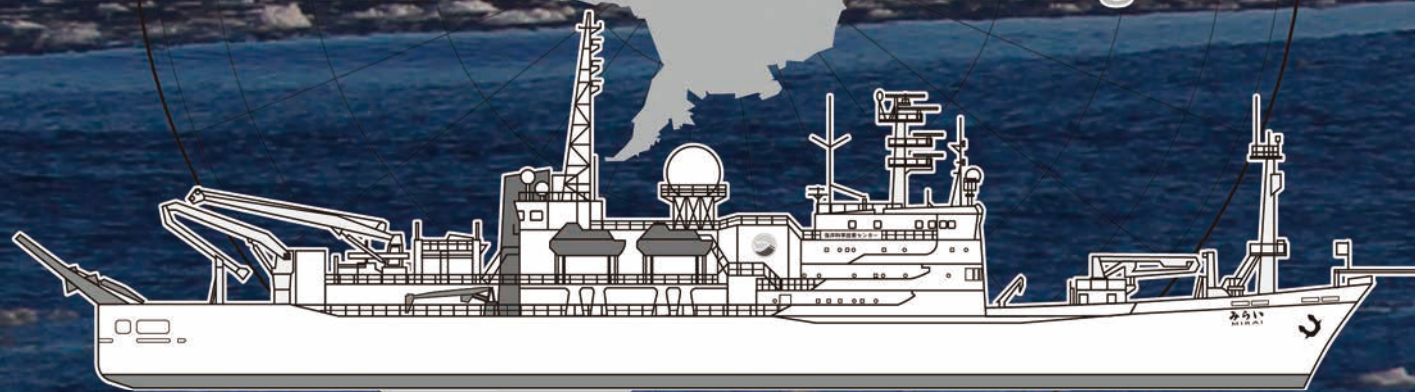# WHP P14S, S04I REVISIT IN 2012 DATA BOOK

Field Activity of JAMSTEC towards International Repeat Hydrography and Carbon Program

WHP P14S, S04I REVISIT
in 2012

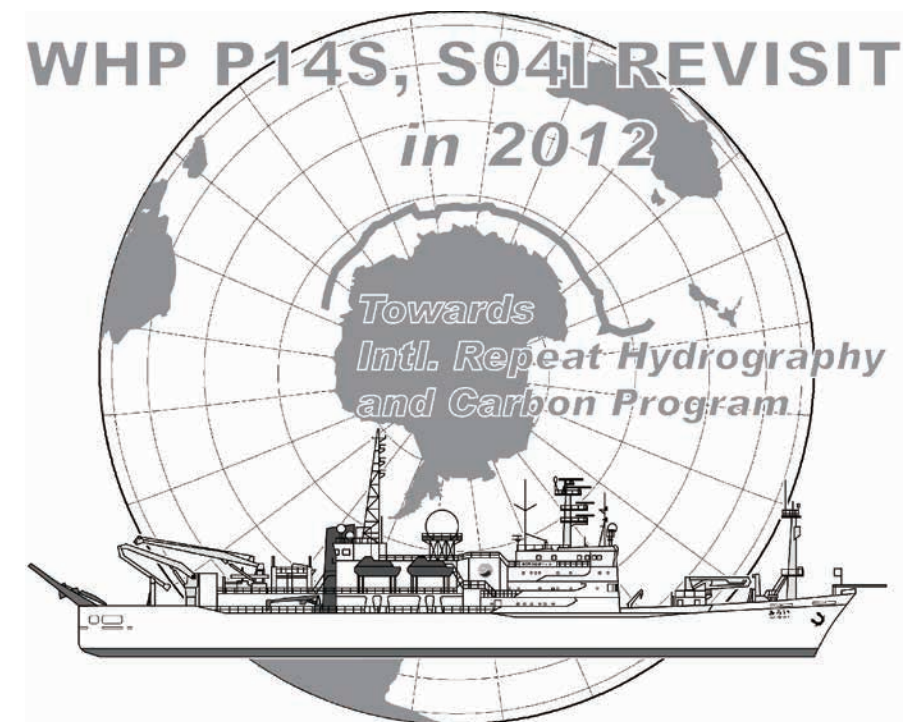Towards
Intl. Repeat Hydrography
and Carbon Program

WHP P14S, S04I REVISIT IN 2012 DATA BOOK

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

Contents

.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

*Acronyum

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)

1.1 Highlights

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

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)
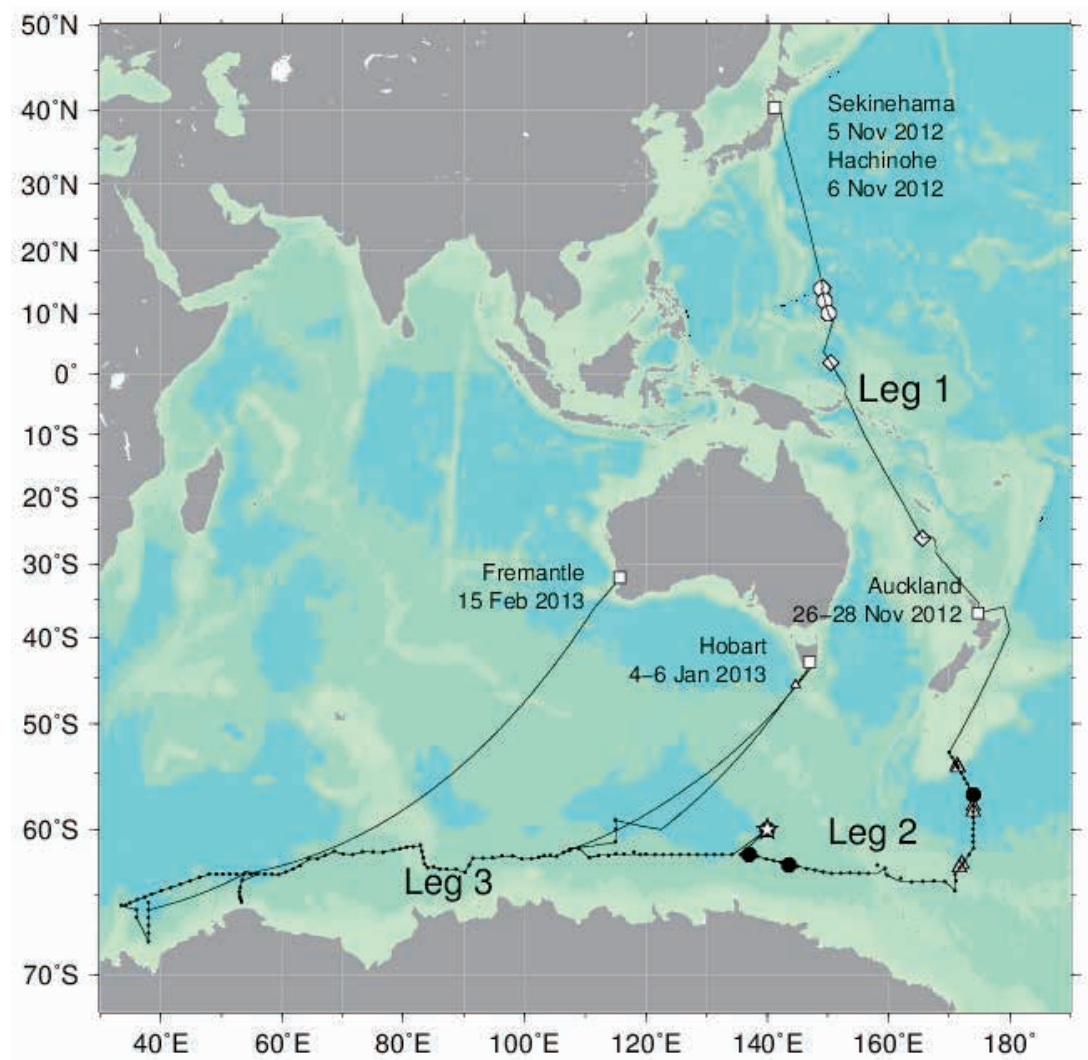
Figure 1.1.1. MR12-05 cruise track. White circles show the deployment position of Argo floats. White diamonds show neuston net sampling (the northernmost station overlaps the northern most Argo deployment). White large triangles show the XMP deployment stations. Star is the flux-buoy recovery position. 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.
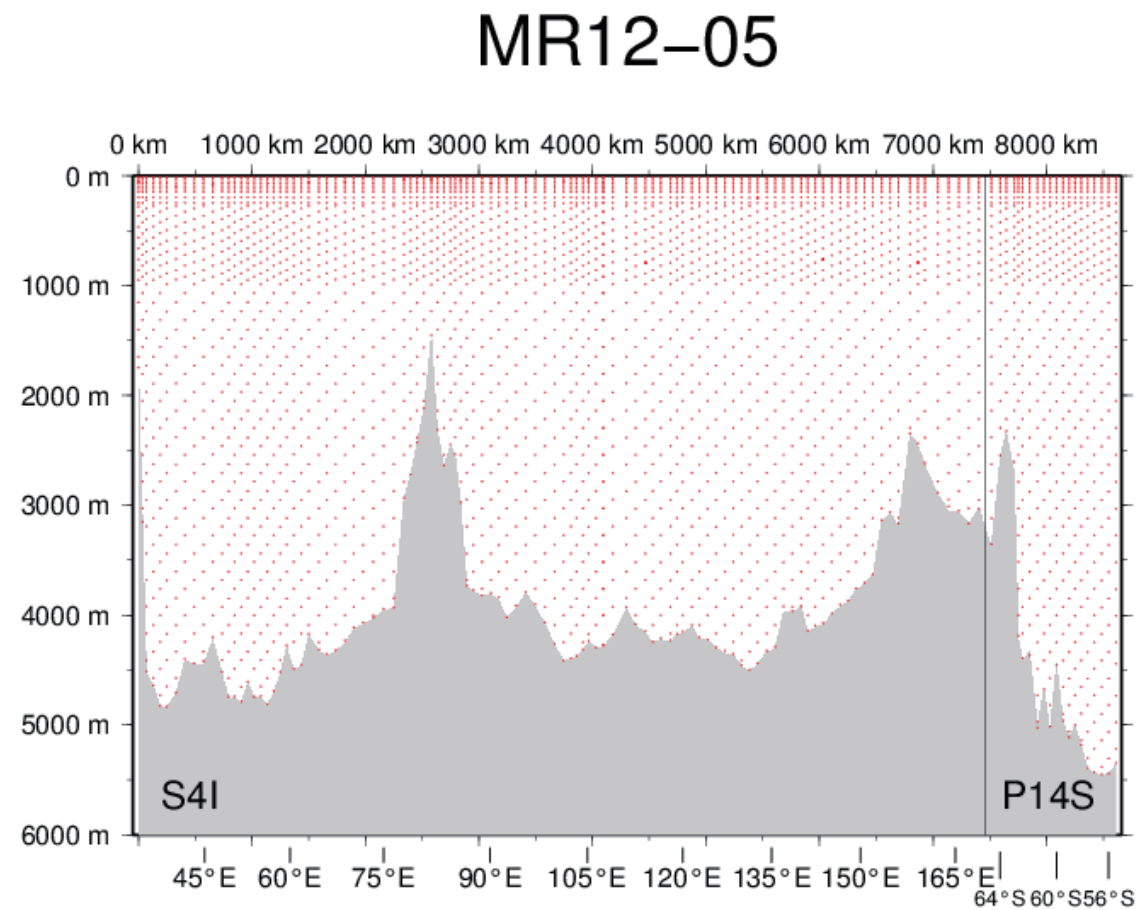
Figure 1.1.2. Water sampling positions. Meridional segments on S04I are not included.

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 174ºE, between 53ºS and 65ºS. The S04I is a zonal section nominally along 62ºS between 33ºE and 170ºE.

(2) Stations occupied

A total of 152 stations were occupied using a CTD/O_2/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_2, 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 60ºS, 140ºE was recovered successfully. An emergency recovery was conducted of SOFS buoy (Bureau of Meteorology, Australia) at approximate location of 45.7ºS, 144.6ºE.

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
Underway		
Navigation	Data Management Group (CEIST/JAMSTEC) *dmo@jamstec.go.jp*	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Bathymetry	Takeshi Matsumoto (Univ. of Ryukyus) *tak@sci.u-ryukyu.ac.jp*	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Meteorology	Data Management Group (CEIST/JAMSTEC) *dmo@jamstec.go.jp*	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Thermo-salinograph	Hiroshi Uchida (JAMSTEC) *huchida@jamtec.go.jp*	Kanako Yoshida (MWJ) (legs 1, 3) Misato Kuwahara (MWJ) (leg 2)
pCO_2	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Yoshiko Ishikawa (MWJ)
pCO_2/pCH_4 by Cavity Ring-Down Spectroscopy	Sohiko Kameyama (Hokkaido Univ.) *skameyama@ees.hokkaido.ac.jp*	Sohiko Kameyama (Hokkaido Univ.)

Parameter	PI	Operator
ADCP	Shinya Kouketsu (JAMSTEC) *skouketsu@jamstec.go.jp*	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Ceilometer	Data Management Group (CEIST/JAMSTEC) *dmo@jamstec.go.jp*	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Water Isotopes	Yasushi Fujiyoshi (Hokkaido Univ.) *fujiyo@lowtem.hokudai.ac.jp*	Souichiro Sueyoshi (GODI)
Sky Radiometer	Kazuma Aoki (Univ. of Toyama) *kazuma@sci.u-toyama.ac.jp*	None
Lidar	Nobuo Sugimoto (NIES) *nsugimot@nies.go.jp*	None
Gravity	Takeshi Matsumoto (Univ. of Ryukyus) *tak@sci.u-ryukyu.ac.jp*	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Magnetic Field	Takeshi Matsumoto (Univ. of Ryukyus) *tak@sci.u-ryukyu.ac.jp*	Souichiro Sueyoshi (GODI) (legs 1, 3) Kazuho Yoshida (GODI) (leg 2)
Cesium magnetometer	Masao Nakanishi (Chiba Univ.) *nakanisi@earth.s.chiba-u.ac.jp*	Souichiro Sueyoshi (GODI)
Photosynthetically Available Radiation	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Hiroshi Uchida (JAMSTEC)
XCTD	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Souichiro Sueyoshi (GODI) (Legs 1, 3) Kazuho Yoshida (GODI) (Leg 2)

Hydrography

Parameter	PI	Operator
CTD/O_2	Hiroshi Uchida (JAMSTEC)	Shinsuke Toyoda (MWJ)
Salinity	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Tatsuya Tanaka (MWJ)
Density	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Hiroshi Uchida (JAMSTEC)
Oxygen	Yuichiro Kumamoto (JAMSTEC) *kumamoto@jamstec.go.jp*	Misato Kuwahara (MWJ) (leg 2) Kanako Yoshida (MWJ) (leg 3)
Nutrients	Michio Aoyama (Fukushima Univ.) *r706@ipc.fukushima-u.ac.jp*	Minoru Kamata (MWJ)
CFCs/SF_6	Ken'ichi Sasaki (JAMSTEC) *ksasaki@jamstec.go.jp*	Ken'ichi Sasaki (JAMSTEC)
DIC	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Yoshiko Ishikawa (MWJ)
Alkalinity	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Tomonori Watai (MWJ)
pH	Akihiko Murata (JAMSTEC) *murataa@jamstec.go.jp*	Tomonori Watai (MWJ)
DMS and Isoprene	Sohiko Kameyama (Hokkaido Univ.) *skameyama@ees.hokkaido.ac.jp*	Sohiko Kameyama (Hokkaido Univ.)
Chlorophyll-*a*	Hiroshi Uchida (JAMSTEC) *huchida@jamstec.go.jp*	Hiroshi Uchida (JAMSTEC)
Chlorophyll isotopes	Osamu Yoshida (Rakuno Gakuen Univ.) *yoshida@rakuno.ac.jp*	Osamu Yoshida (Rakuno Gakuen Univ.)
Pigment/Bacterial abundance	Sohiko Kameyama (Hokkaido Univ.)	Sohiko Kameyama (Hokkaido Univ.)

	skameyama@ees.hokudai.ac.jp	
$\Delta^{14}C/\delta^{13}C$	Yuichiro Kumamoto (JAMSTEC)	Yuichiro Kumamoto (JAMSTEC)
	kumamoto@jamstec.go.jp	
$^{134}Cs/^{137}Cs$	Yuichiro Kumamoto (JAMSTEC)	Yuichiro Kumamoto (JAMSTEC)
	kumamoto@jamstec.go.jp	
$\delta^{18}O$	Shigeru Aoki (Hokkaido Univ.)	Katsuro Katsumata (JAMSTEC) (leg 2)
	shigeru@lowtem.hokudai.ac.jp	Kazuhiko Hayashi (JAMSTEC) (leg 3)
PFAS	Nobuyoshi Yamashita (AIST)	Nobuyoshi Yamashita (AIST) (leg 2)
	nob.yamashita@aist.go.jp	Hiroshi Uchida (JAMSTEC) (leg 3)
N_2O/CH_4	Osamu Yoshida (Rakuno Gakuen Univ.)	Osamu Yoshida (Rakuno Gakuen Univ.)
	yoshida@rakuno.ac.jp	
LADCP	Shinya Kouketsu (JAMSTEC)	Shinya Kouketsu (JAMSTEC) (leg 2)
	skouketsu@jamstec.go.jp	Hiroshi Uchida (JAMSTEC) (leg 3)
XMP	Katsuro Katsumata (JAMSTEC)	Katsuro Katsumata (JAMSTEC)
	k.katsumata@jamstec.go.jp	

Biology

Oceanic Halobates	Tetsuo Harada (Kochi Univ.)	Tetsuo Harada (Kochi Univ.)
	haratets@kochi-u.ac.jp	

Floats

ARGO/Deep NINJA floats

	Toshio Suga (JAMSTEC)	Tetsuya Tanaka (MWJ) (leg 1)
	sugat@jamstec.go.jp	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 Fourties 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 18th and 20th 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 55ºS due to JAMSTEC in-house problem with cruise documentation. It was our intention to cover the P14S section to the southern most station at 66ºS, but due to ice cover, southernmost 2 stations (south of 65ºS) 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 64ºS 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-*a*	RIGC/JAMSTEC
Tetsuo Harada	*Halobates*	Kochi University
Ryuta Ide	*Halobates*	Kochi University
Takero Sekimoto	*Halobates*	Kochi University
Kentaro Emi	*Halobates*	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 /Δ^{14}C	RIGC/JAMSTEC
Hiroshi Uchida	LADCP/density/chlorophyll-*a*	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	*Halobates*/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 Arii	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/meterology/geophysics/ADCP/XCTD	GODI
Shinya Okumura	Meteorlology/geophysics/ADCP/XCTD	GODI
Masanori Murakami	Meteorology/geophysics/ADCP/XCTD	GODI

List of Participants for leg 3

Hiroshi Uchida	Chief scientist/LADCP/density/chlorophyll-*a*	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_4 and N_2O/water sampling	Rakuno Gakuen University
Haruka Tamada	CH_4 and N_2O/water sampling	Rakuno Gakuen University
Yuko Kanayama	CH_4 and N_2O/water sampling	Rakuno Gakuen University
Okura Shinozaki	CH_4 and N_2O/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 Ushiromura	Salinity	MWJ

Takami Mori	CTD/water sampling	MWJ
Masanori Enoki	Nutrients	MWJ
Atsushi Ono	pH/total alkalinity	MWJ
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

MIO	Mutsu Institute of Oceanography
MWJ	Marine Works Japan Ltd.
RIGC	Research Institute for Global Change

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
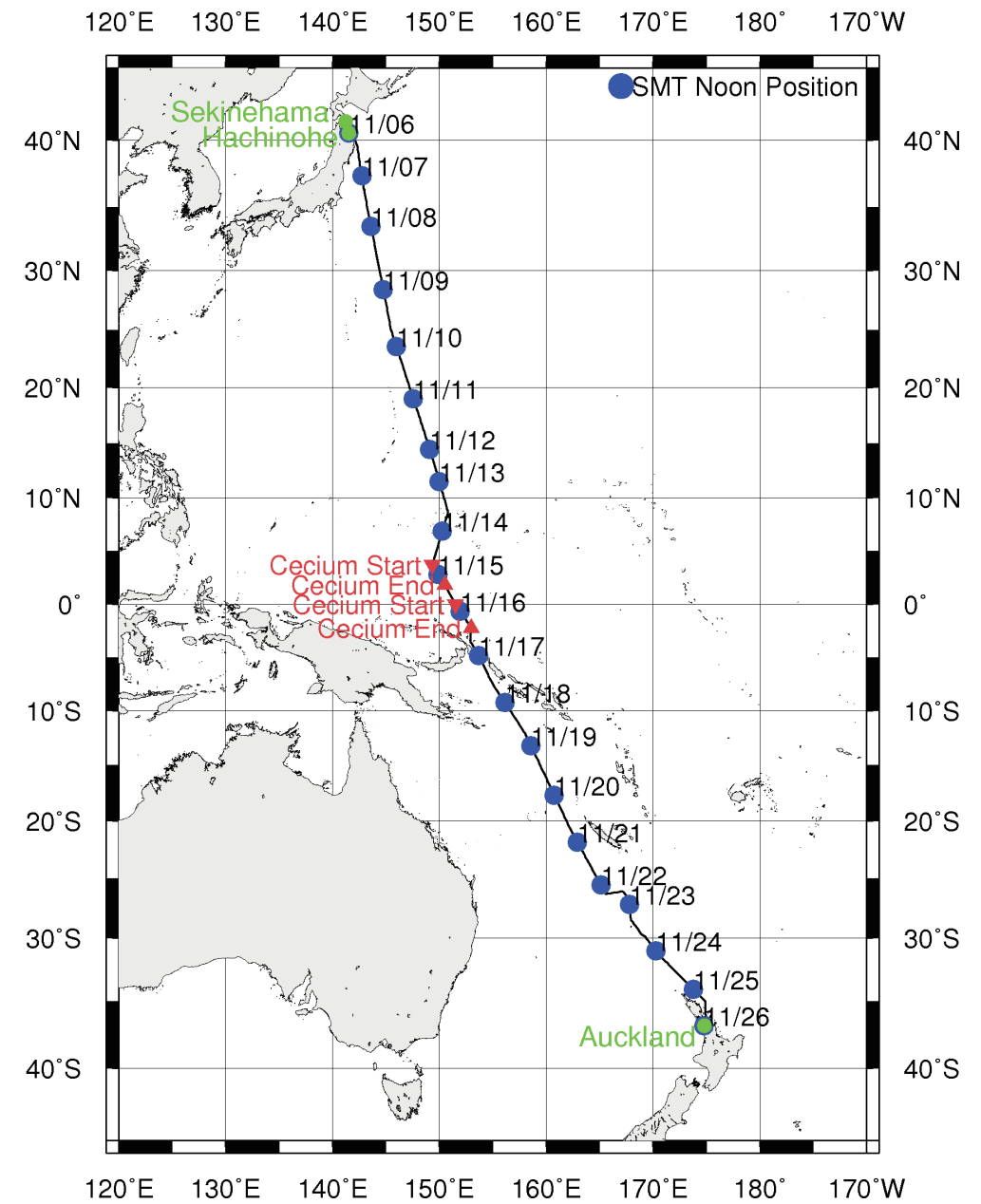
Figure 2.1.1. Cruise Track of MR12-05 Leg 1.
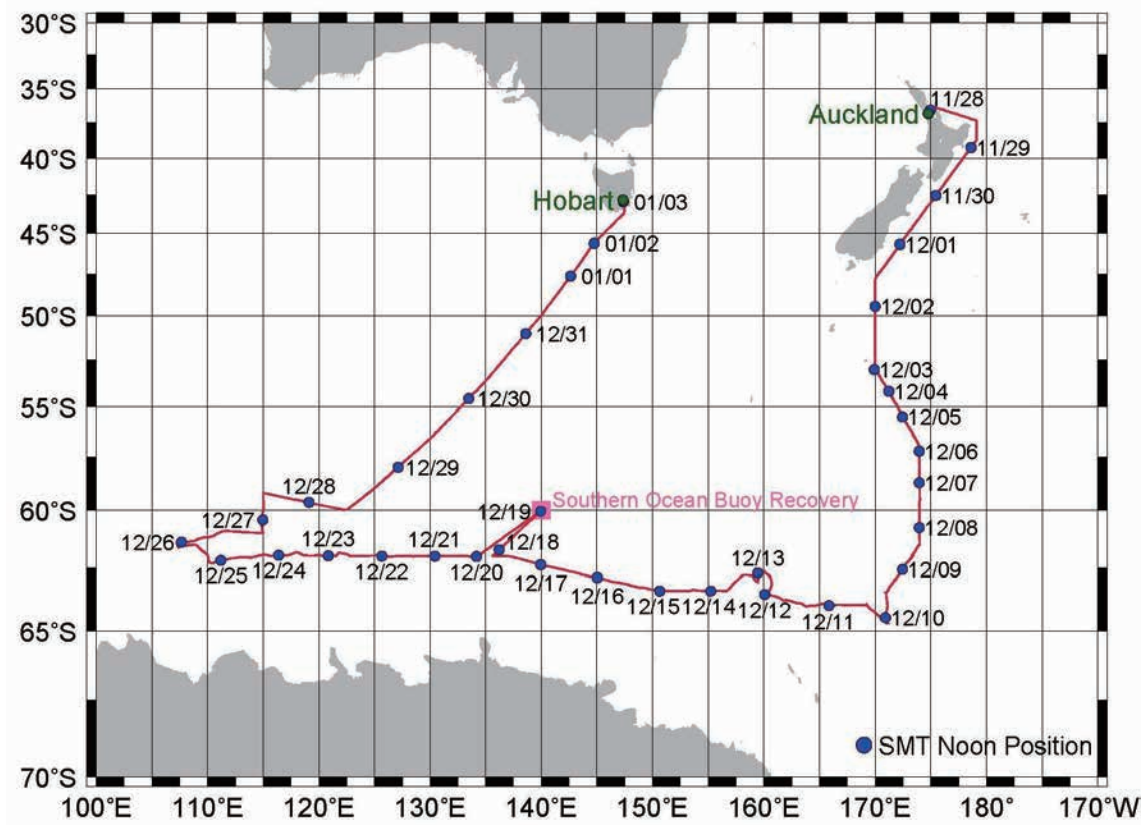
Figure 2.1.2. Cruise Track of MR12-05 Leg 2.

MR12–05 Leg3 Cruise Track
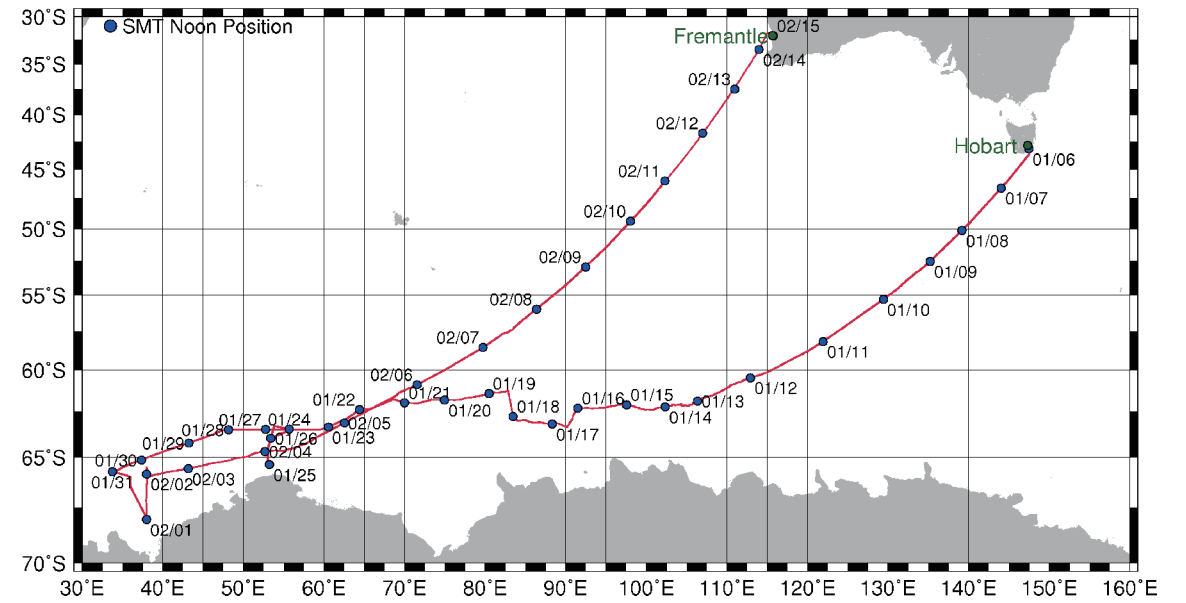
Figure 2.1.3. Cruise Track of MR12-05 Leg 3.

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.

SEABEAM 3012 (12 kHz system)

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.

(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

            22:41, 25 Dec. 2012

      Leg3: 06:15, 24 Jan. 2013

            01:25, 13 Feb. 2013

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^2	6sec. averaged
20	Down welling infra-red radiation	W/m^2	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)
Zeno/Met			
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)
PRP			
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	
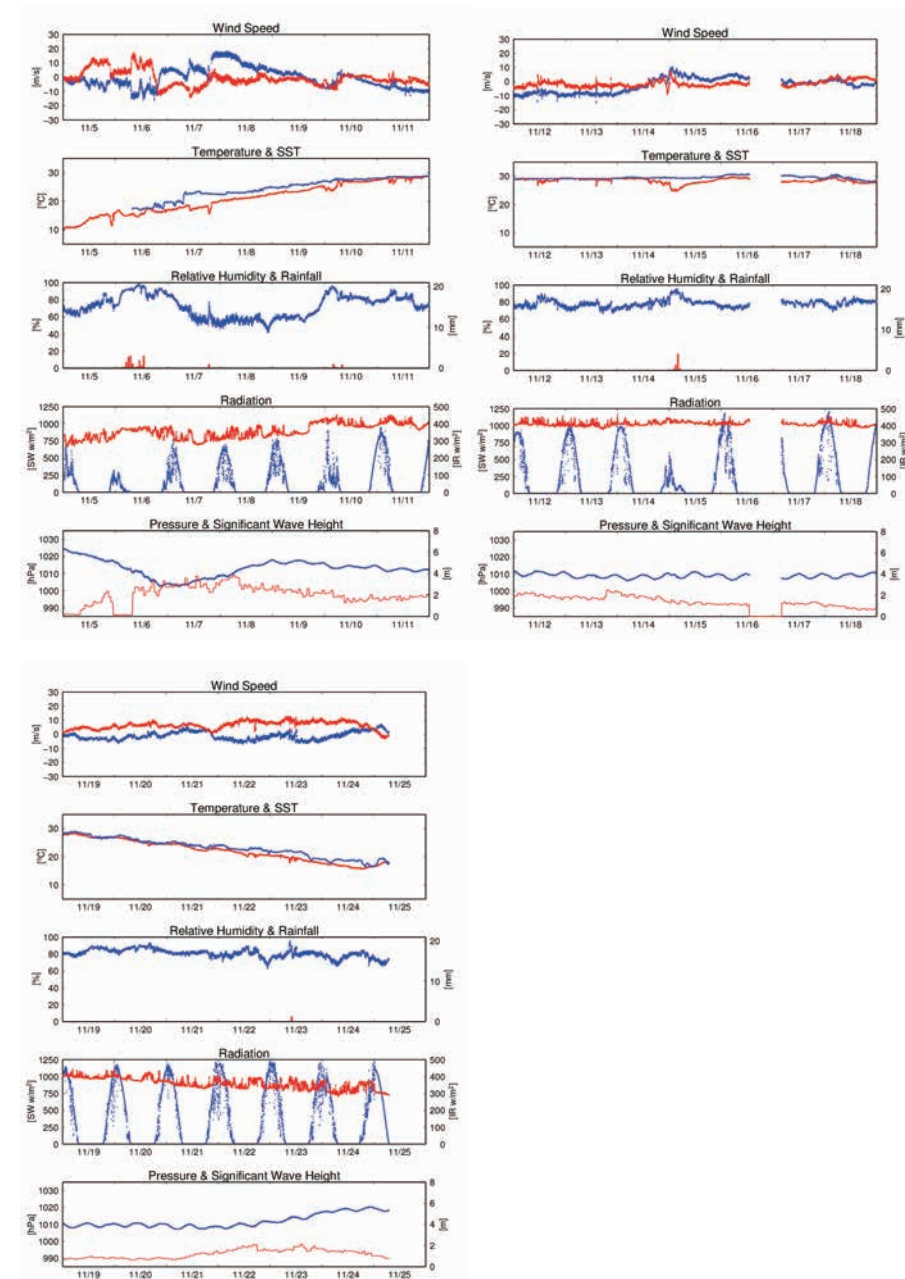
Figure 2.3.1. Time series of surface meteorological parameters during the MR12-05 leg1 cruise.
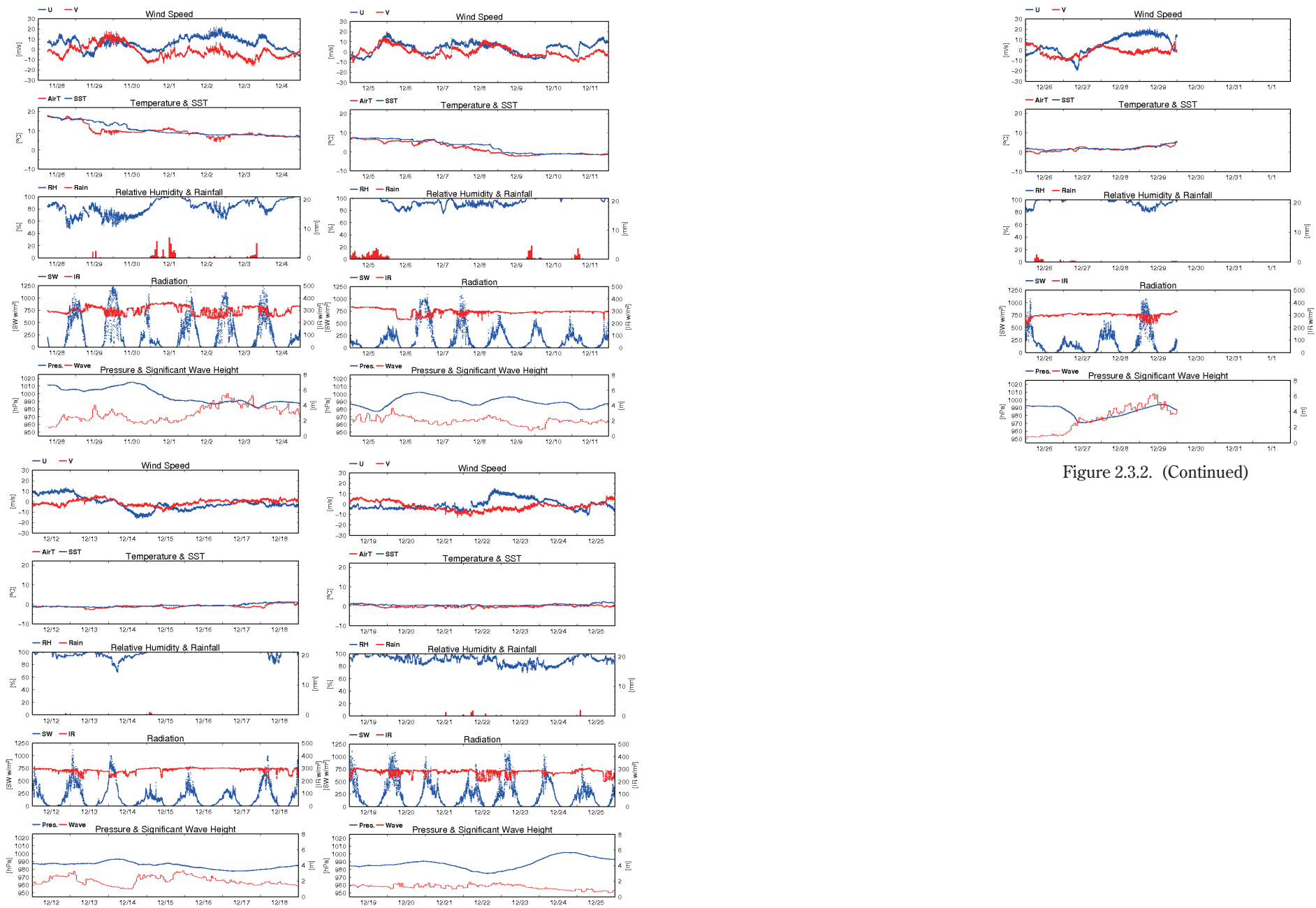
Figure 2.3.2. (Continued)

Figure 2.3.2. Time series of surface meteorological parameters during the MR12-05 leg2 cruise.
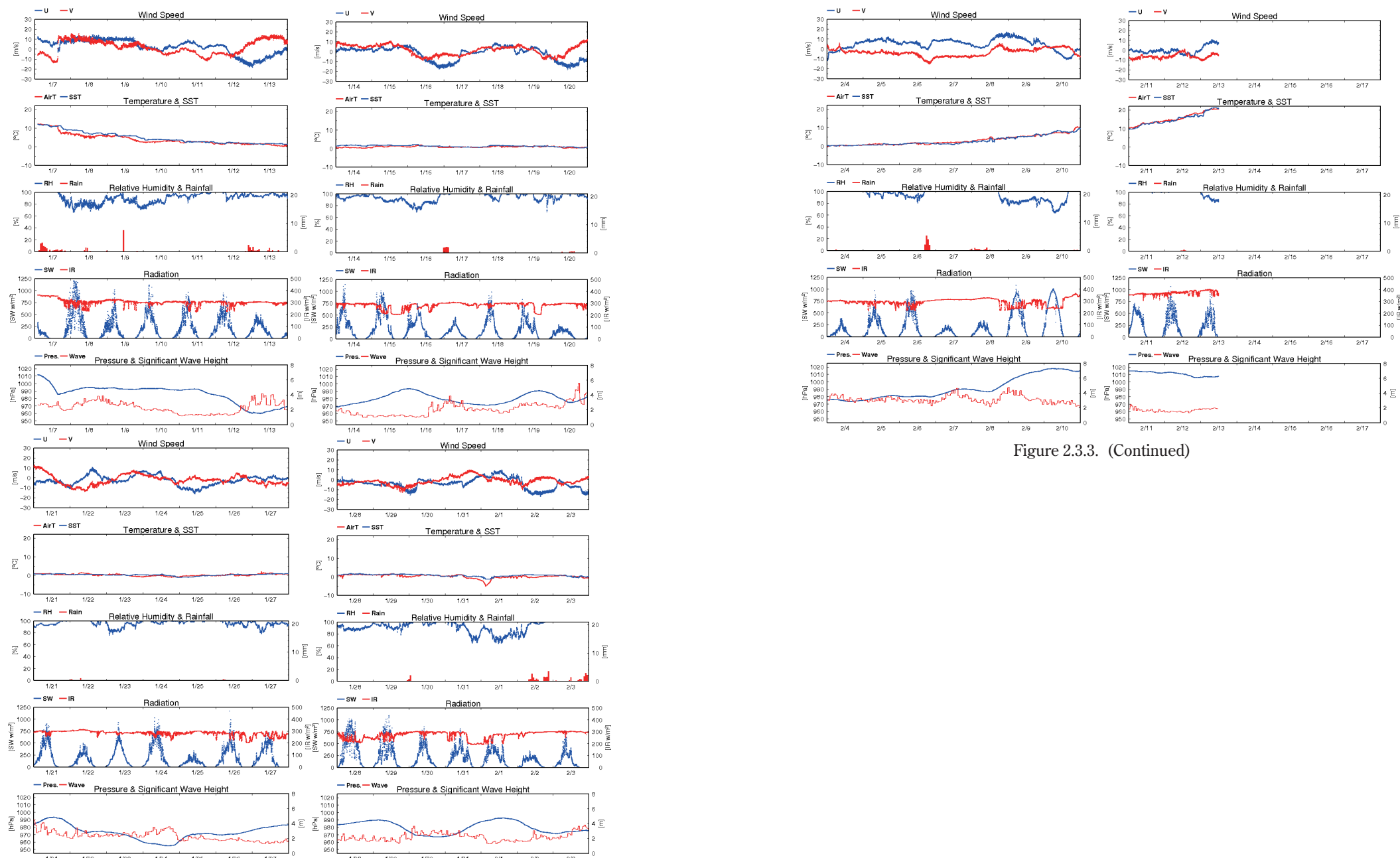
Figure 2.3.3. (Continued)

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
Medel:	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 ≤ 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 ºC 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 [μmol/kg]) and fluorescence (Fl [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

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

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

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

where t is days from a reference time, T is temperature in °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 µE/(m^2 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°S and 13°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-a1 is chlorophyll a calculated by using the set of coefficients A, and Chl-a$_2$ 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
Salinity				
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	
Dissolved oxygen				
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
Chlorophyll a				
1	5.352958e-02	0.1296275 (A: for latitude ≤ 14°S or latitude ≥ 5°S)		
	5.352958e-02	0.3467123 (B: for latitude > 13°S and latitude < 5°S)		
2	0.1141853	5.968889e-02		
3	1.445487e-02	5.716477e-02		
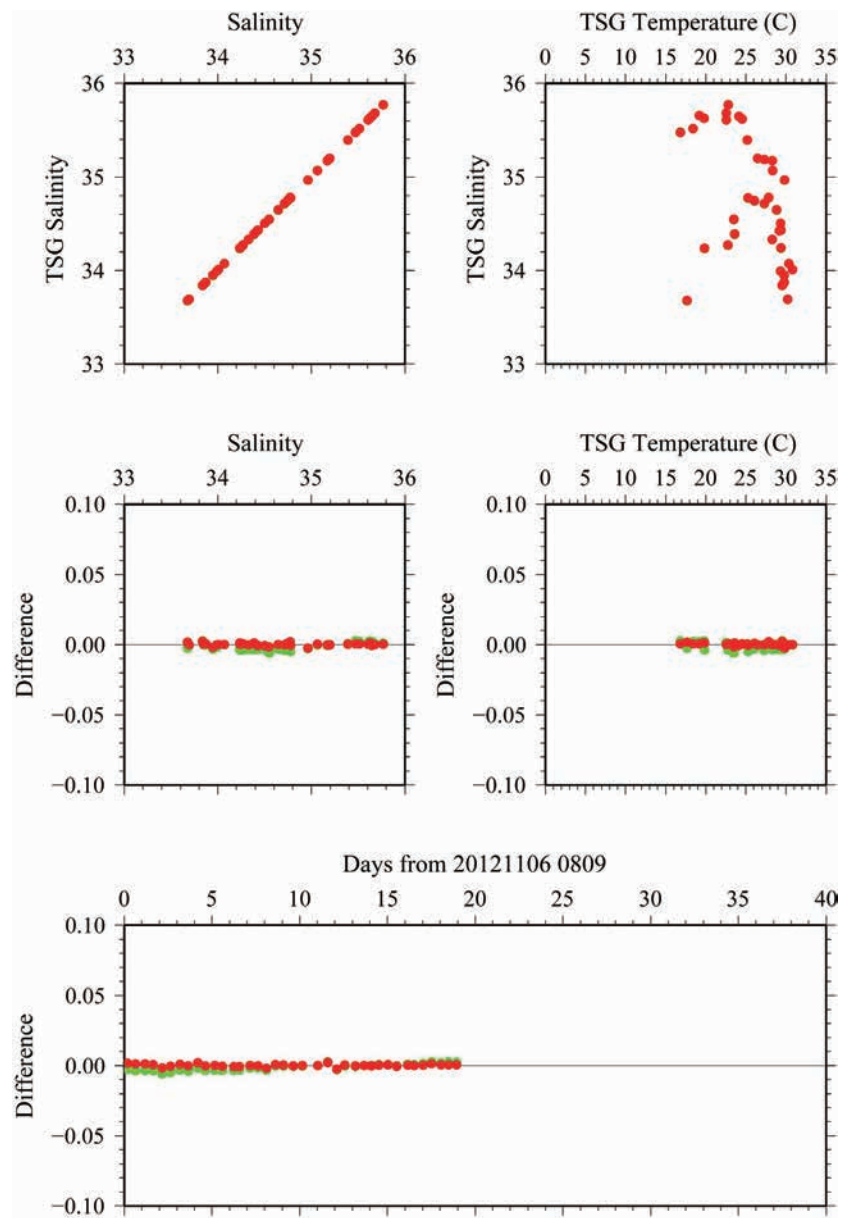
Figure 2.4.1. Comparison between TSG salinity (green: before correction, red: after correction) and sampled

salinity for leg 1.
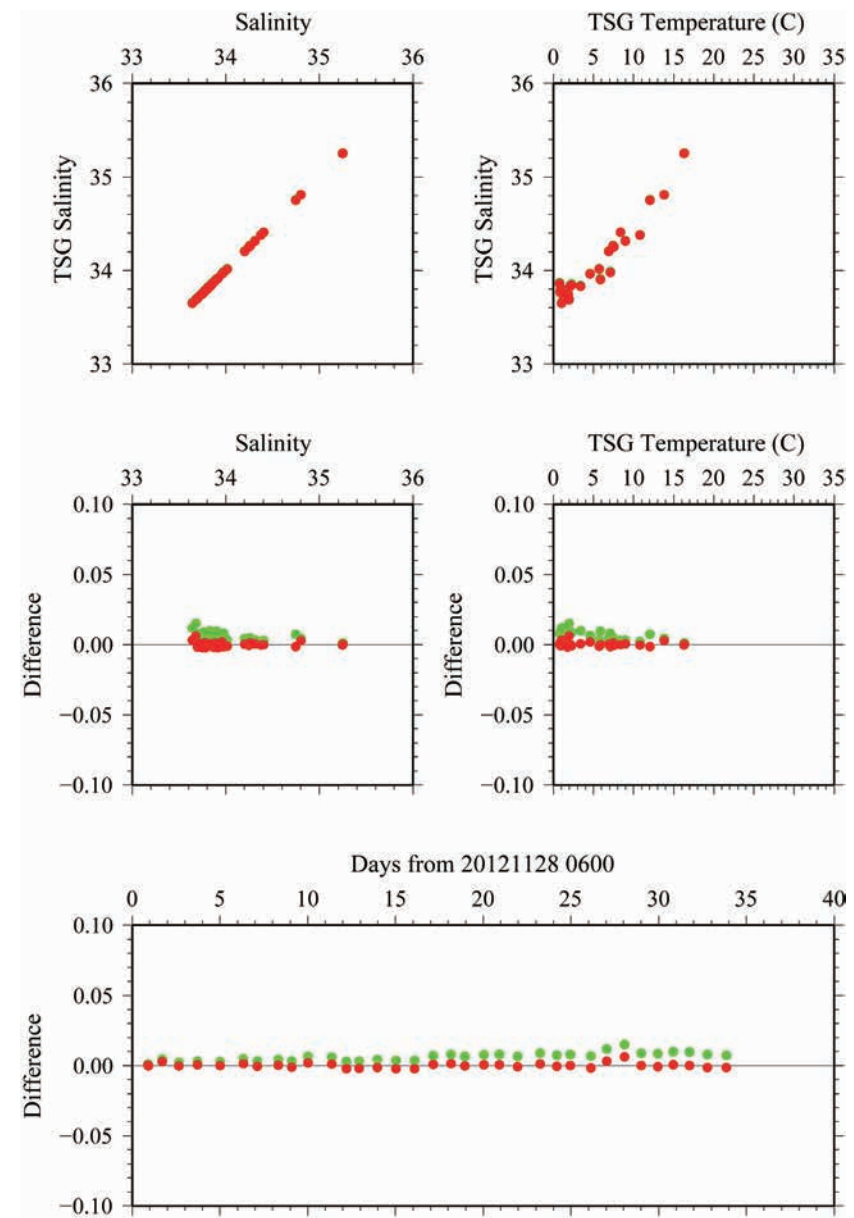
Figure 2.4.2. Same as Fig. 2.4.1, but for leg 2.
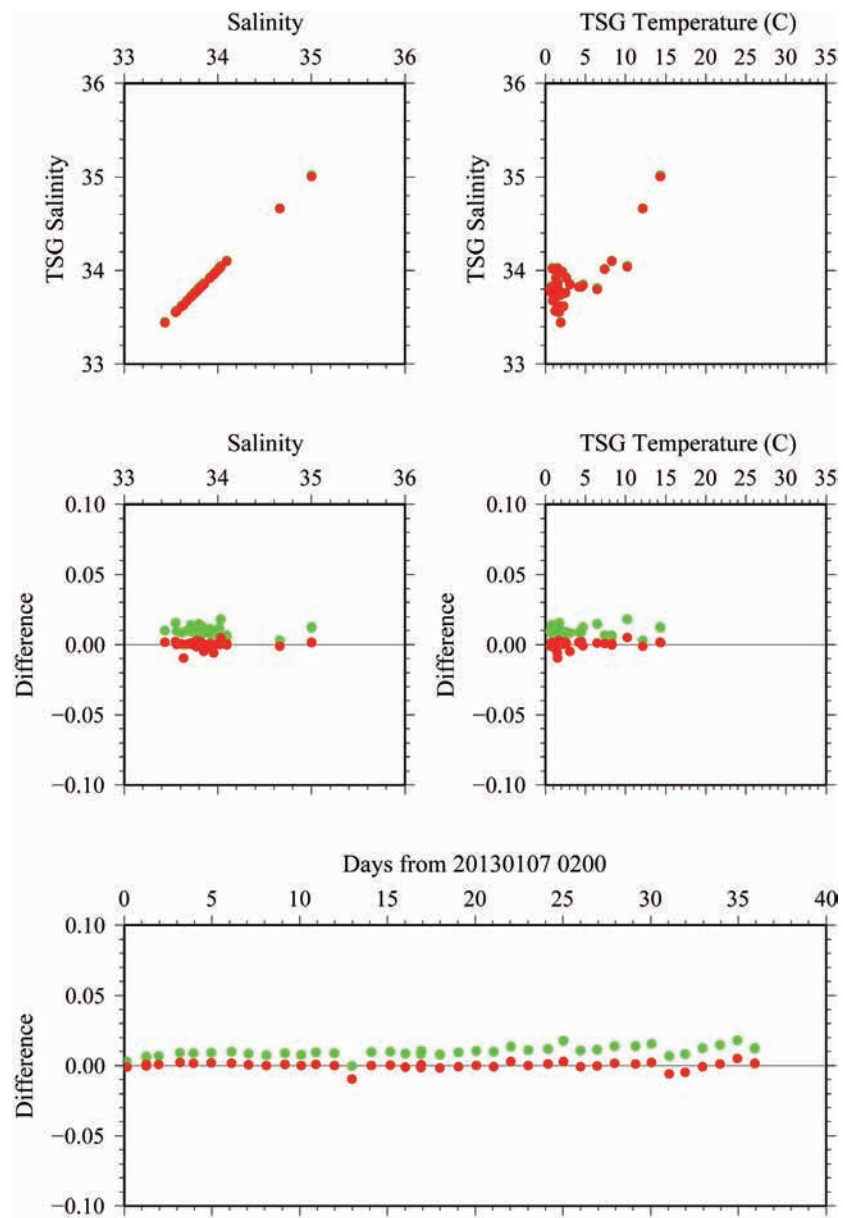
Figure 2.4.3. Same as Fig. 2.4.1, but for leg 3.
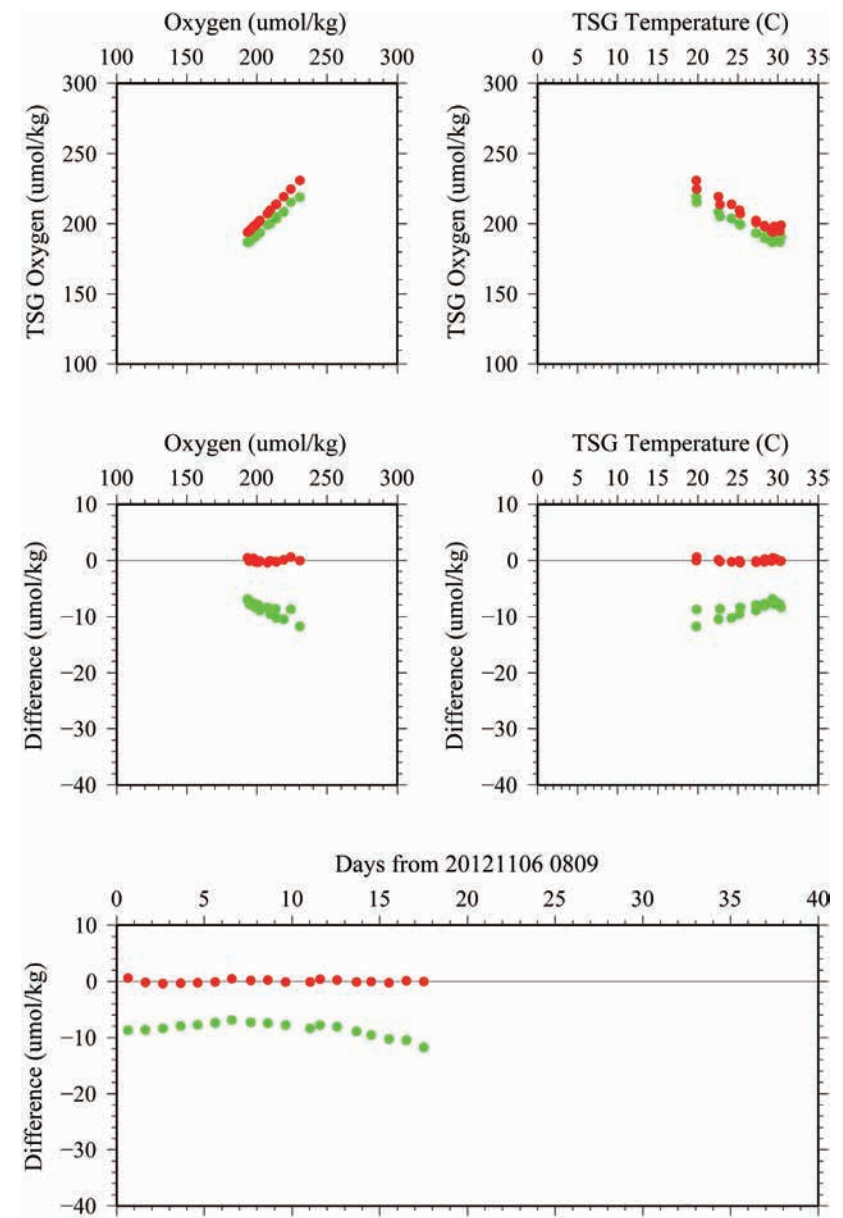
Figure 2.4.4. Comparison between TSG oxygen (green: before correction, red: after correction) and sampled oxygen for leg 1.
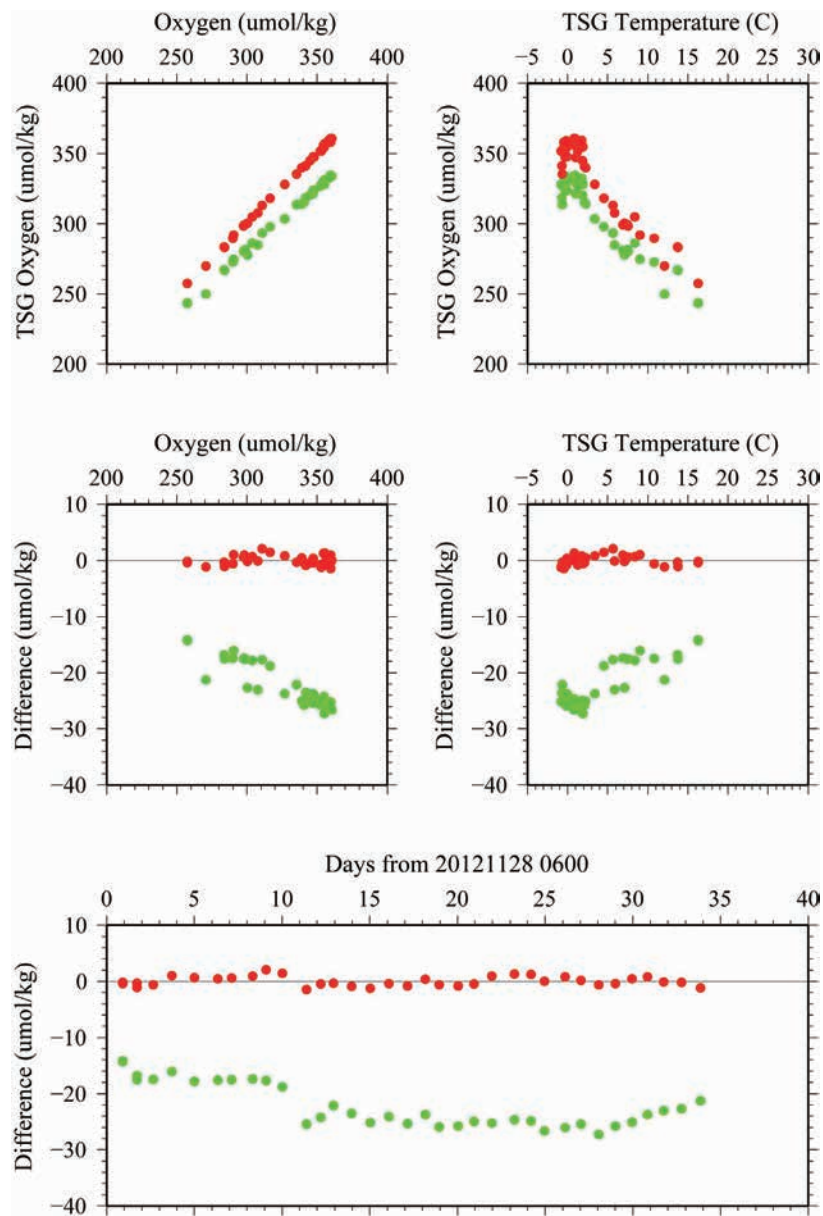
Figure 2.4.5. Same as Fig. 2.4.4, but for leg 2.
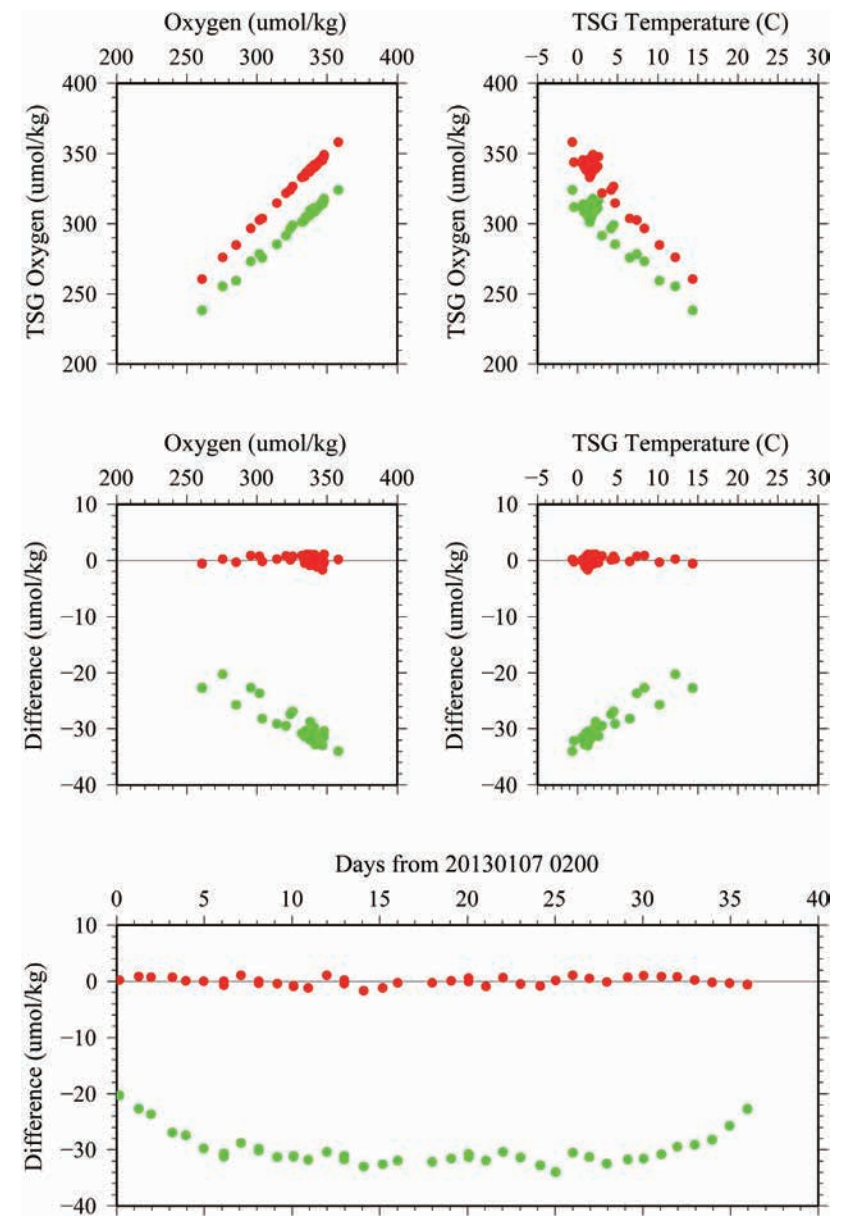
Figure 2.4.6. Same as Fig. 2.4.4, but for leg 3.
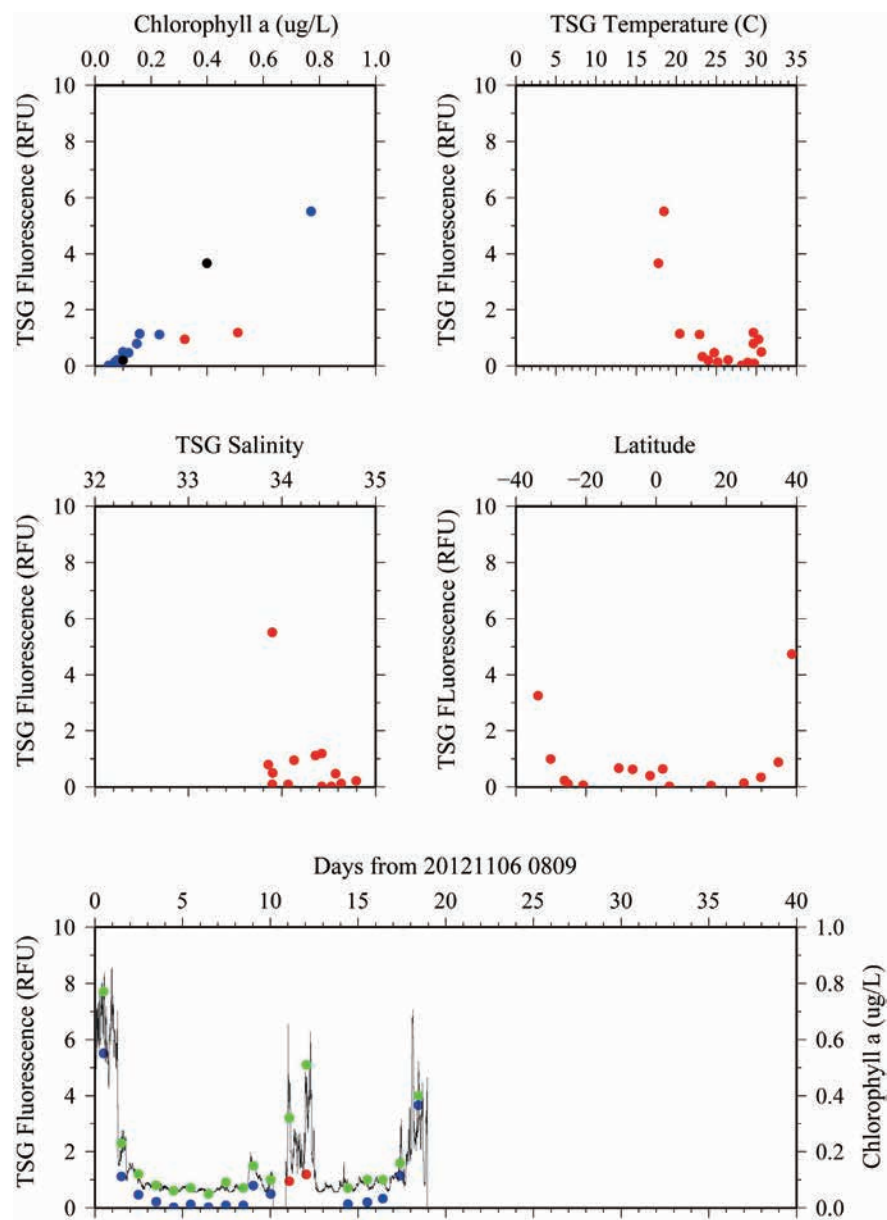
Figure 2.4.7. Comparison between TSG fluorescence and sampled chlorophyll *a* for leg 1. Black dots indicate the daytime data. For bottom panel, blue or red dots indicate fluorescence and green dots indicate water sampled chlorophyll *a*. Line indicates chlorophyll *a* estimated from fluoremeter.
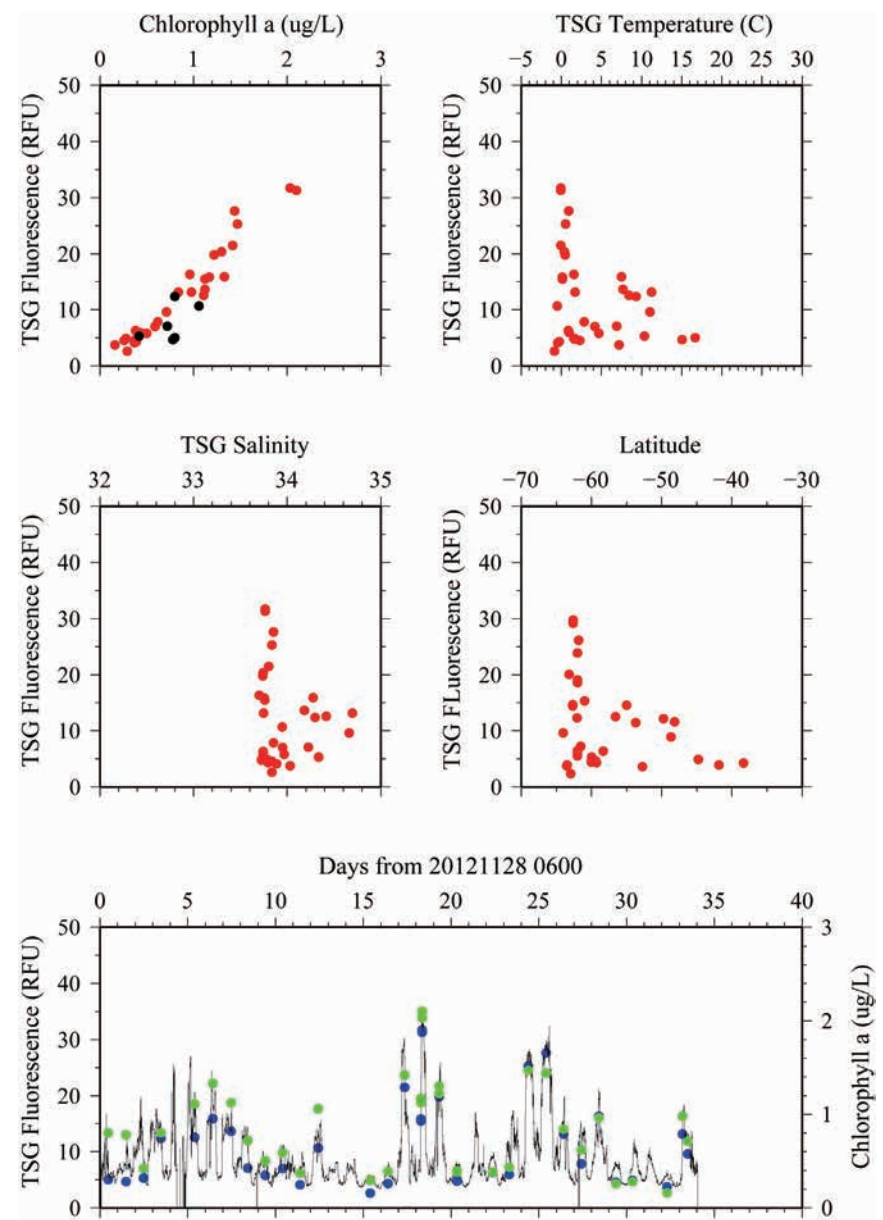
Figure 2.4.8. Same as Fig. 2.4.7, but for leg 2.
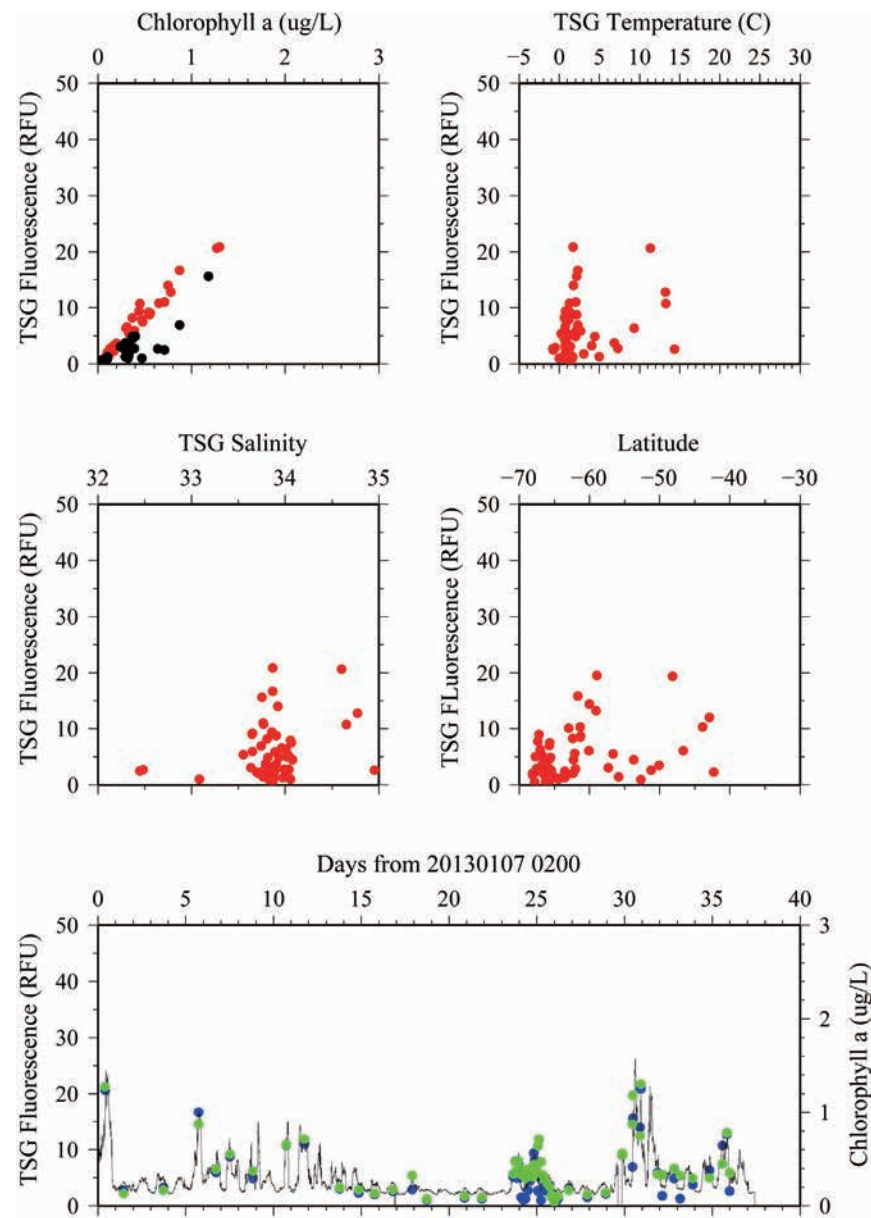
Figure 2.4.9. Same as Fig. 2.4.7, but for leg 3.
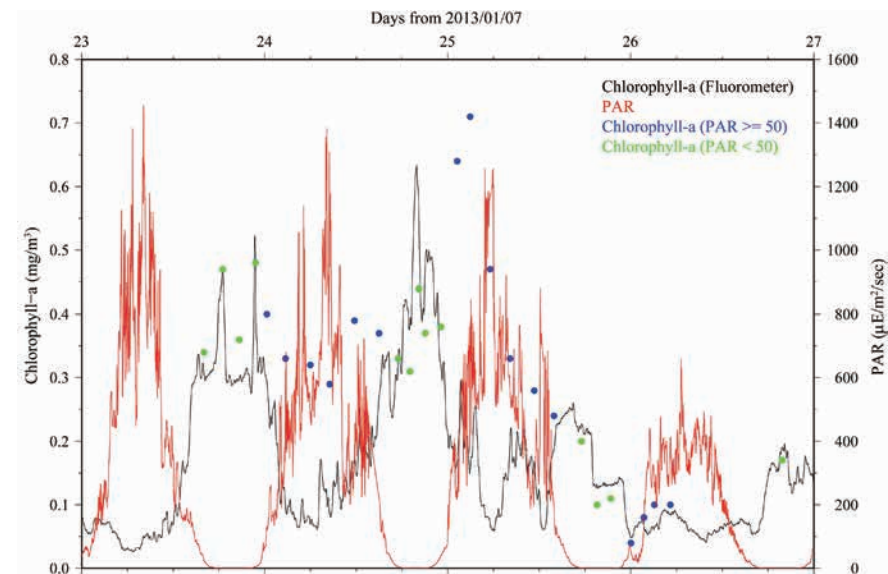
Figure 2.4.10. Diurnal variation of the chlorophyll a estimated from the fluorometer. Water sampled chlorophyll a (blue and green dots) does not show such diurnal variation.

2.5 Underway pCO$_2$

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_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 atmospheric and surface seawater partial pressures of CO_2 (pCO$_2$) 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$_2$ were made with the CO_2 measuring system (Nippon ANS, Ltd) installed in the R/V *Mirai* of JAMSTEC. The system comprises of a non-dispersive infrared gas analyzer (Li-COR LI-7000), an air-circulation module and a showerhead-type equilibrator. To measure concentrations (mole fraction) of CO_2 in dry air (xCO$_2$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 $(Mg(ClO_4)_2)$. The flow rate of the air was 500 ml min^{-1}. To measure surface seawater concentrations of CO_2 in dry air (xCO$_2$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$_2$a. The flow rate of the equilibrated air was 700 – 800 ml min^{-1}. 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^{-1}.

The CO_2 measuring system was set to repeat the measurement cycle such as 4 kinds of CO_2 standard gases (Table 2.5.1), xCO$_2$a (twice), xCO$_2$s (7 times). This measuring system was run automatically throughout the cruise by a PC control.

Quality control

Concentrations of CO_2 of the standard gases are listed in Table 2.5.1, which were calibrated after cruise by the JAMSTEC primary standard gases. The CO_2 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$_2$s were adjusted based on Takahashi *et al*. (1993), although the temperature increases were slight, being ~0.3 °C.

We checked values of xCO$_2$a and xCO$_2$s by examining signals of the NDIR by plotting the xCO$_2$a and

xCO_2s 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_2 and nutrients in the high-latitude surface oceans: a comparative study, *Global Biogeochem. Cycles*, 7,

    843 – 878.

Table 2.5.1. Concentrations of CO_2 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)
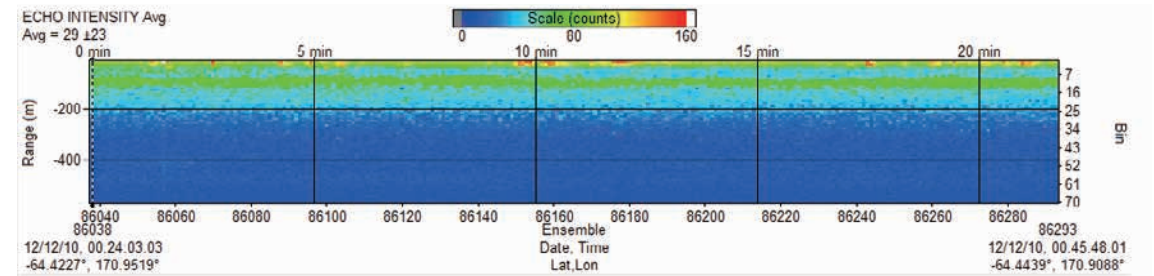
Figure 2.6.1. Time series of Echo Intensity profile between P14S-26 and P14S-27.

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^{-1}	±0.03 mS cm^{-1}
Temperature	−2 ~ 35 °C	±0.02 °C
Depth	0 ~ 1000 m (for XCTD-1)	5 m or 2%, whichever is greater *
	0 ~ 1850 m (for XCTD-2 and XCTD-4)	

* 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^2)	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 ± 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
Mean	0.015 ± 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.

Uchida, H., A. Murata, and T. Doi (2014): WHP P10 Revisit in 2011 Data Book, 179 pp., JAMSTEC.
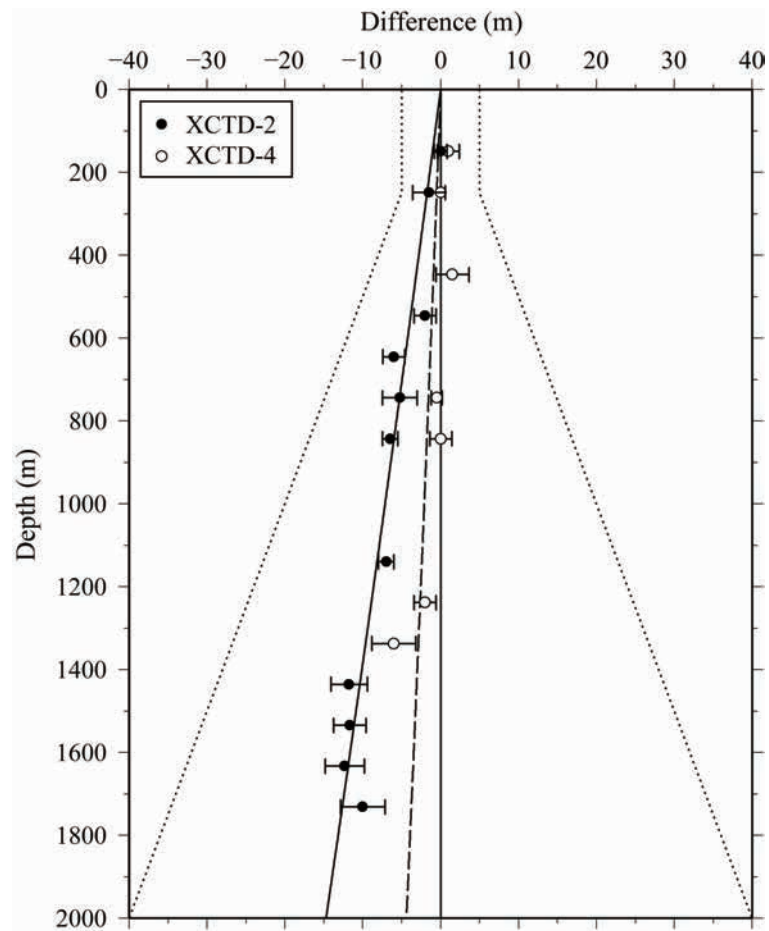
Figure 2.7.1. Differences between XCTD and CTD depths for XTD-2 and XCTD-4. Differences were estimated with the same method as Uchida et al. (2011). Standard deviation of the estimates (horizontal bars) and the manufacturer's specification for XCTD depth error (dotted lines) are shown. The regressions for the XCTD-2 data (solid line) and for the XCTD-4 data (broken line) are also shown.
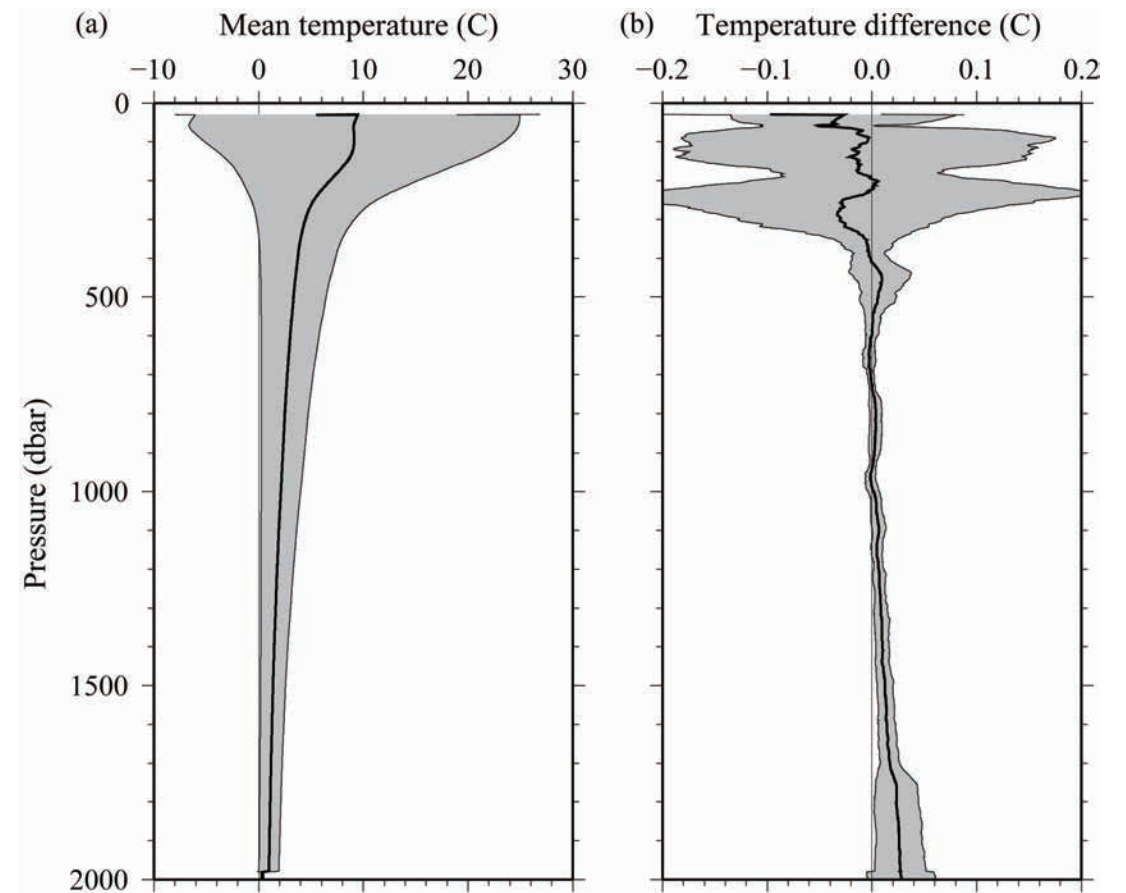
Figure 2.7.2. Comparison between XCTD and CTD temperature profiles. (a) Mean temperature files of CTD profiles with standard deviation (shade) and (b) mean temperature difference with standard deviation (shade) between the XCTD and CTD. Mean profiles were low-pass filtered by a running mean with a window of 51 dbar.
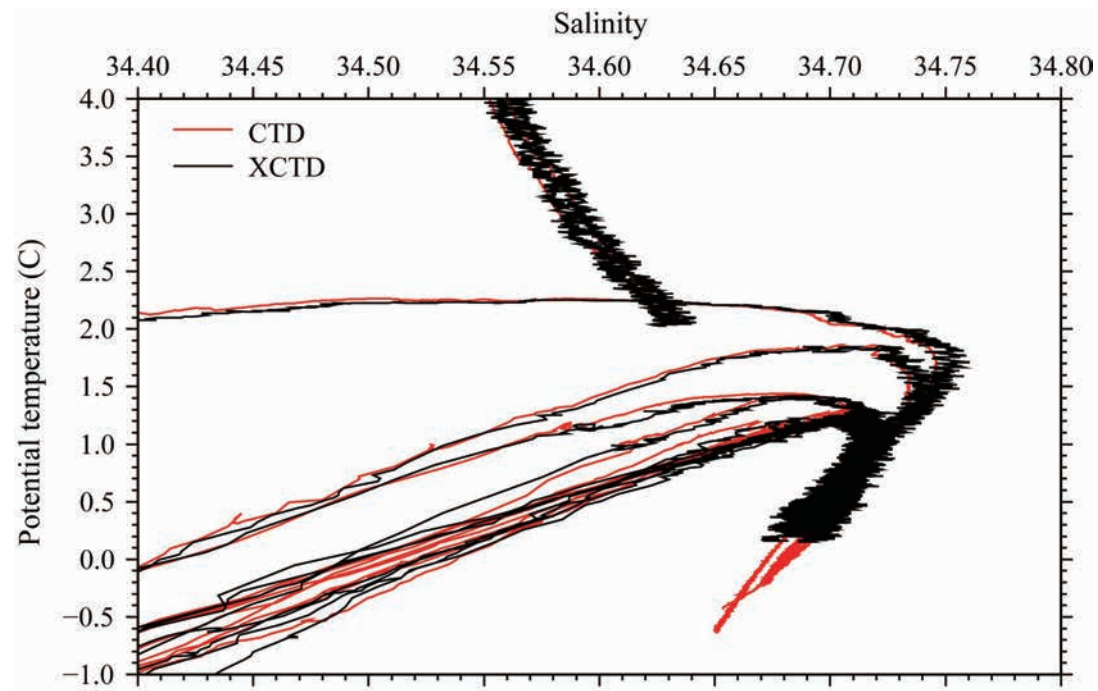
Figure 2.7.3. Comparison of temperature-salinity profiles of CTD (red lines) data used for the XCTD salinity

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 μE/(cm² 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).
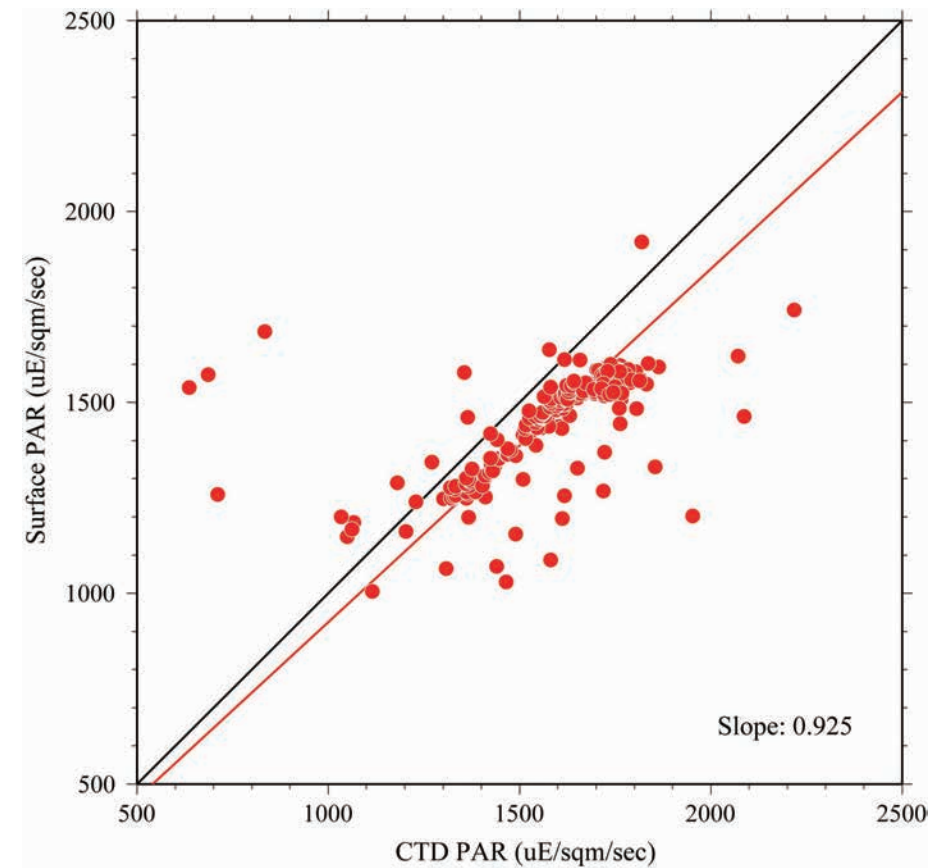
Figure 2.8.1. Comparison of two PAR sensors used for the surface PAR measurement and the CTD profiler measurement.

3 Hydrographic Measurement Techniques and Calibrations

3.1 CTDO$_2$ 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 [°C/dbar]

S/N 1464, –7.75293156e–9 [°C/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 °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 °C) and GaMP (29.7646 °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 × 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 (for S/N 0024)

H1 = 0.008 (for S/N 0079 and 0037)

H2 = 5000 dbar

H3 = 2000 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):

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

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 (°C) and V_b is raw output (volts). V_0 and V are normalized by the output in the absence of oxygen at 0°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 García 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 know 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 ≤ 500 dbar for station from C01_1 to C03_1, depths ≤ 100 dbar for station from 063_1 to 068_1, depths ≤ 200 dbar for station from C04_1 to 073_1, depths ≤ 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 (σ_θ).

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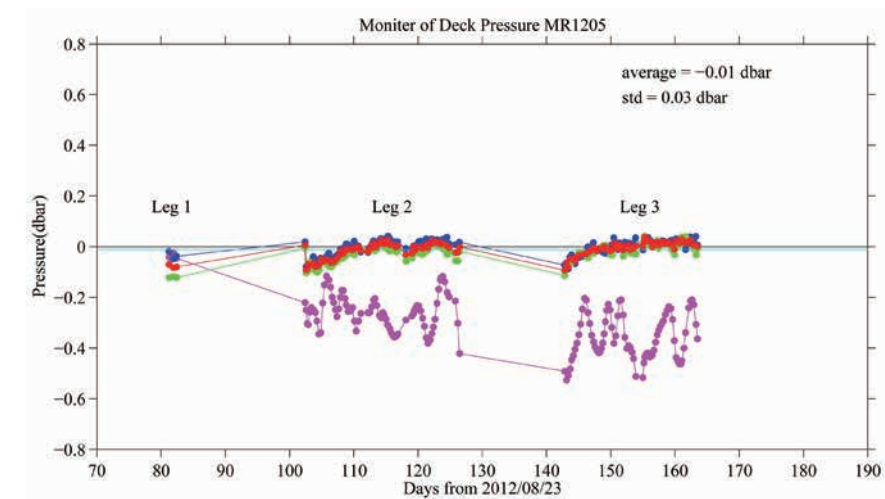
Figure 3.1.1. Time series of the CTD deck pressure. Atmospheric pressure deviation (magenta dots) from a standard atmospheric pressure was subtracted from the CTD deck pressure. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dots indicate averages of the pre- and the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

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 c0, 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.
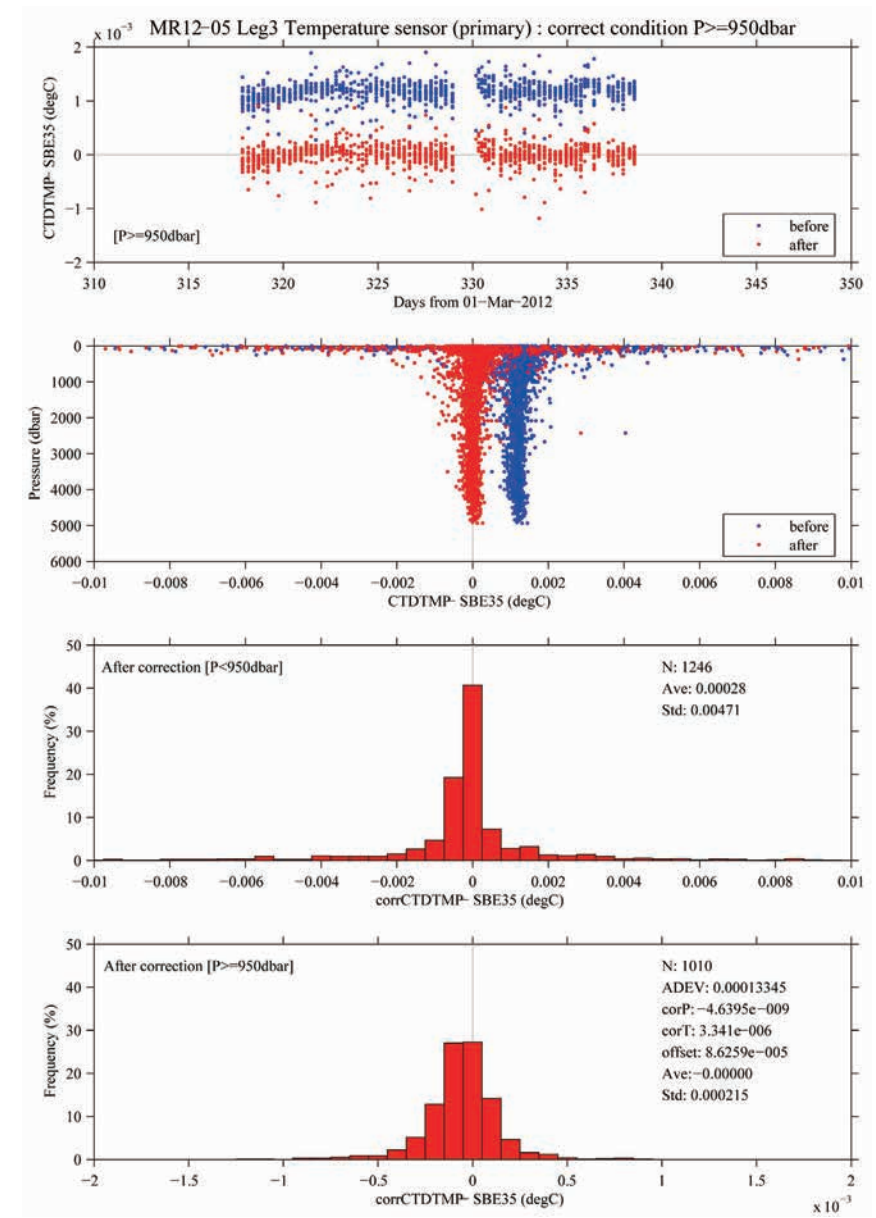
Figure 3.1.5. Same as Fig. 3.1.2, but for leg 3.
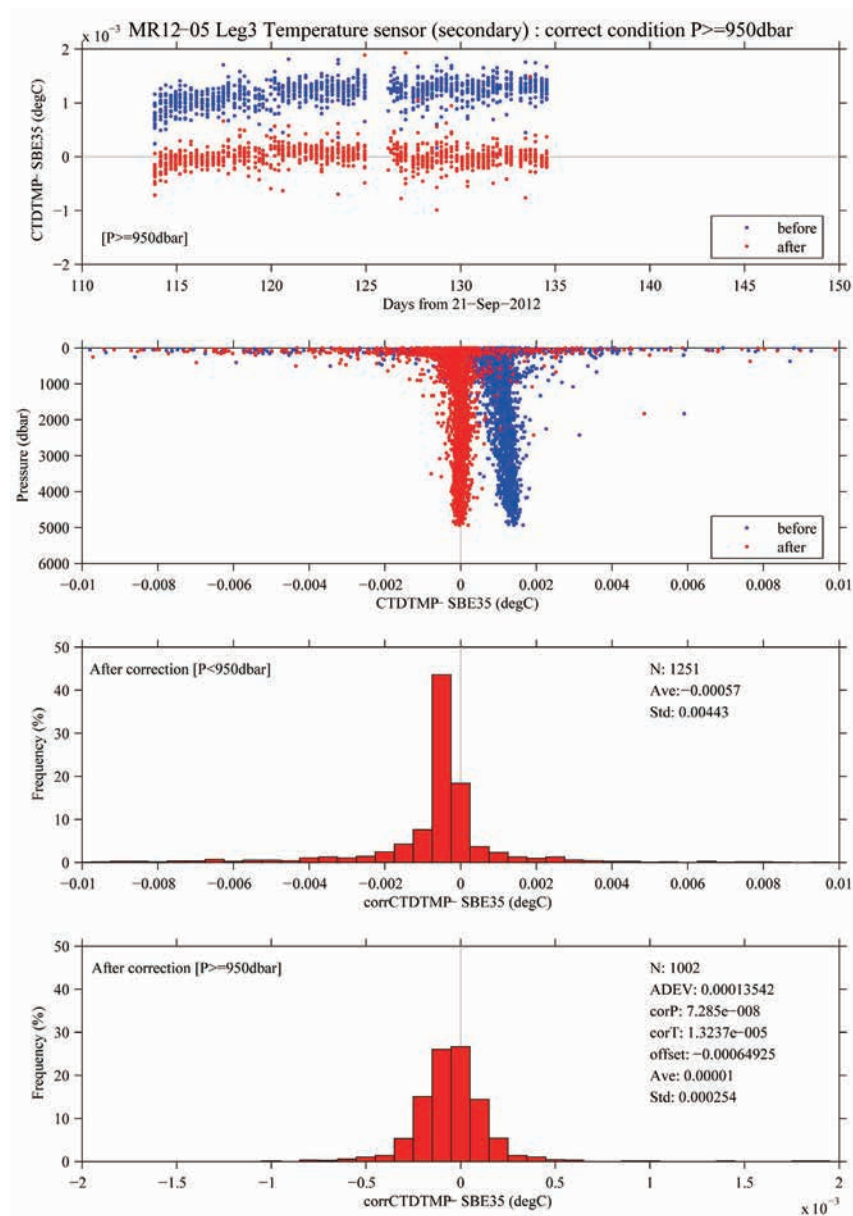
Figure 3.1.6. Same as Fig. 3.1.2, but for secondary temperature sensor for leg 3.

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

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 10−3) 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
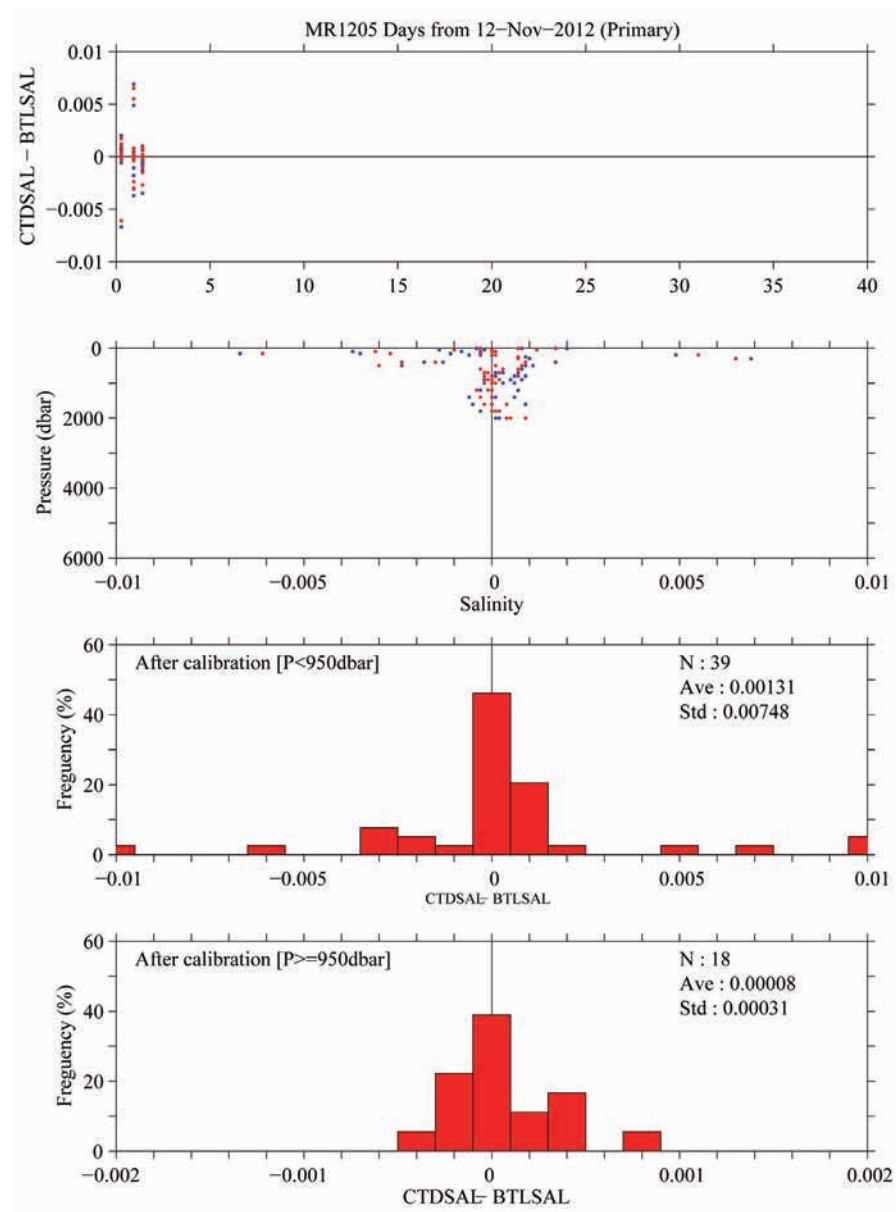
Figure 3.1.7. Difference between the CTD salinity (primary) and the bottle salinity for leg 1. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration.
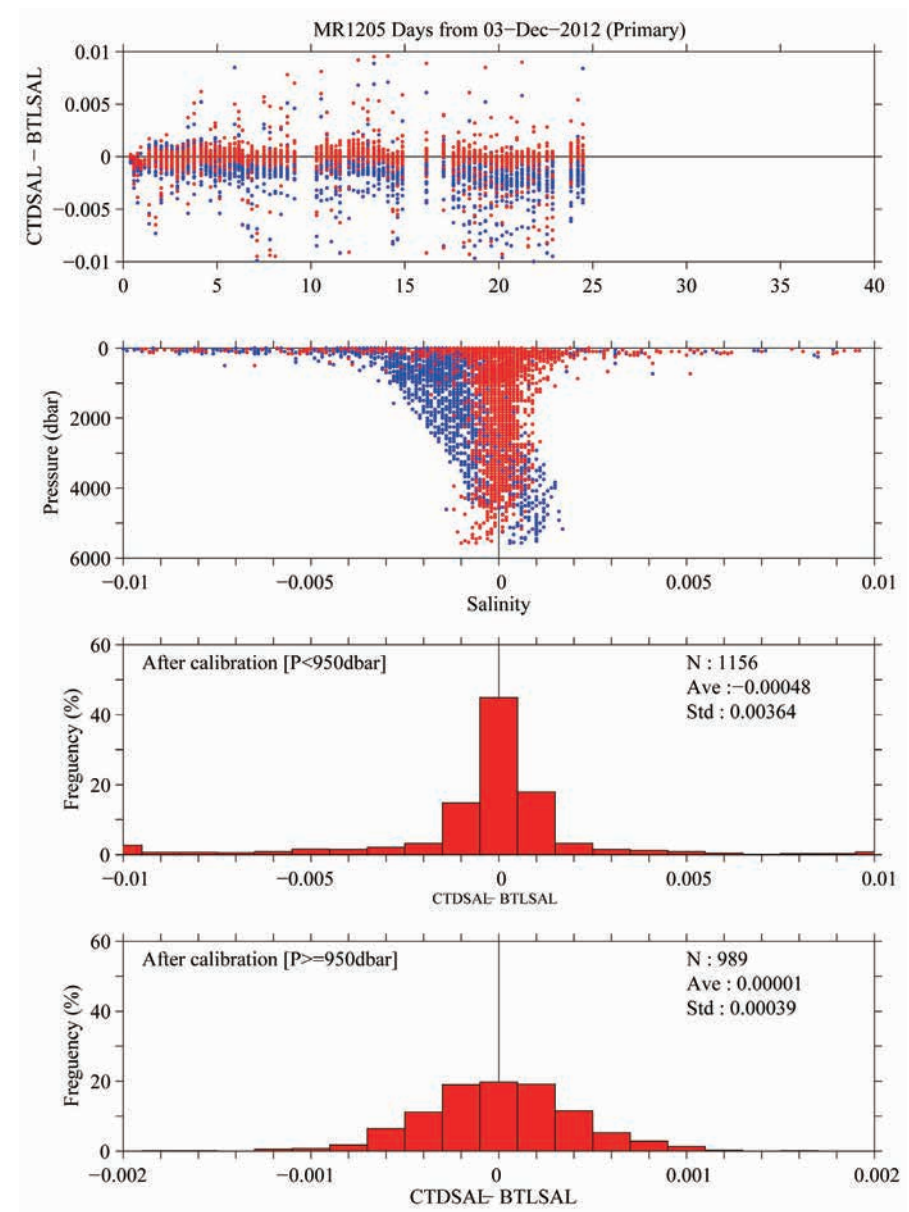
Figure 3.1.8. Same as Fig. 3.1.7, but for leg 2.
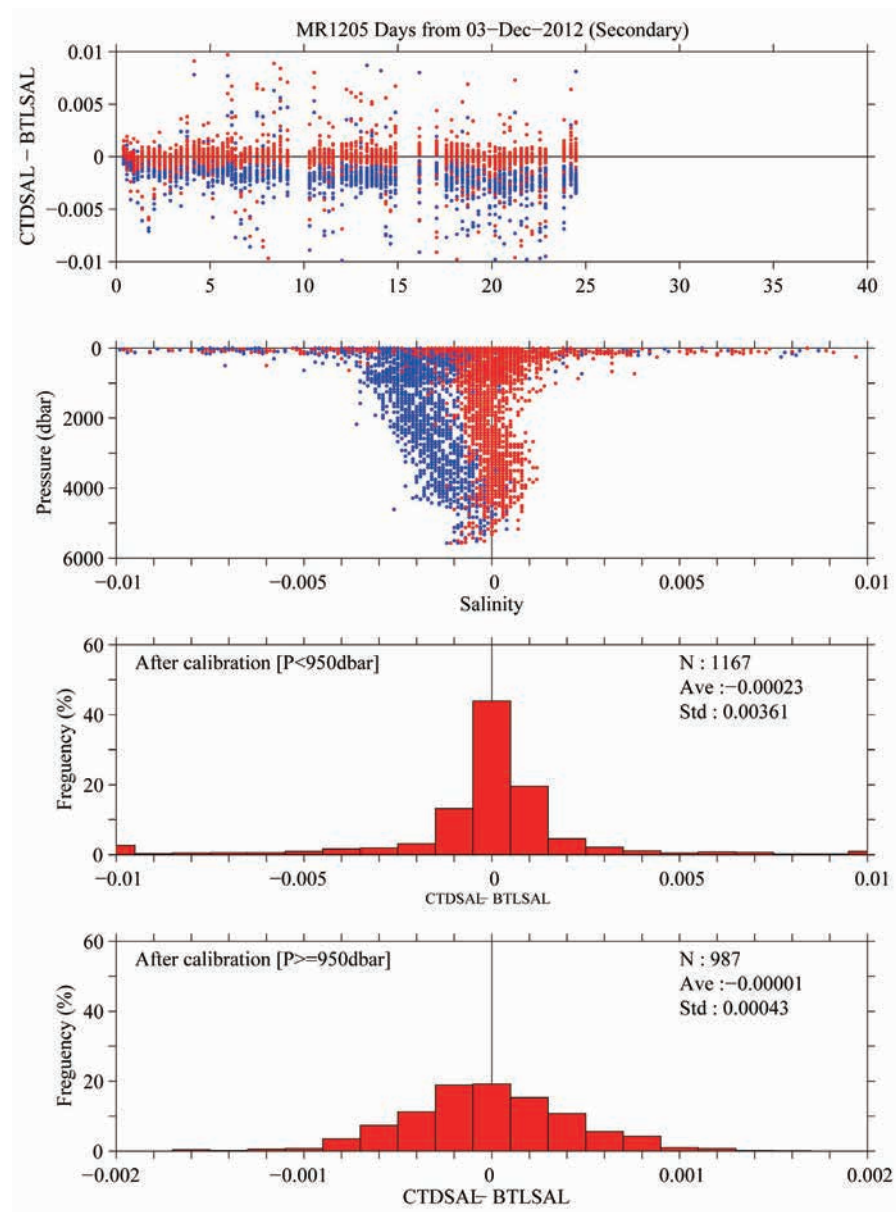
Figure 3.1.9. Same as Fig. 3.1.7, but for secondary salinity data for leg 2.
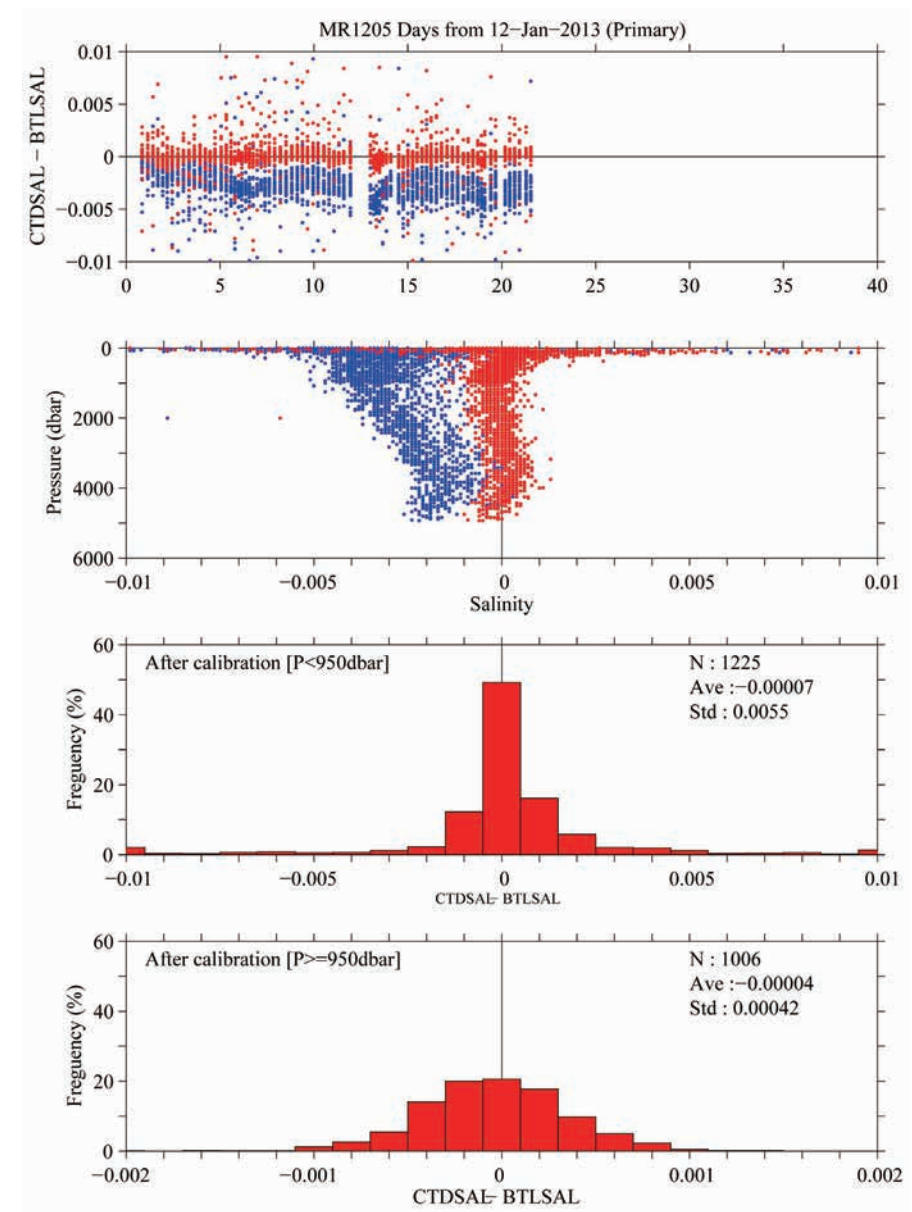
Figure 3.1.10. Same as Fig. 3.1.7, but for leg 3.
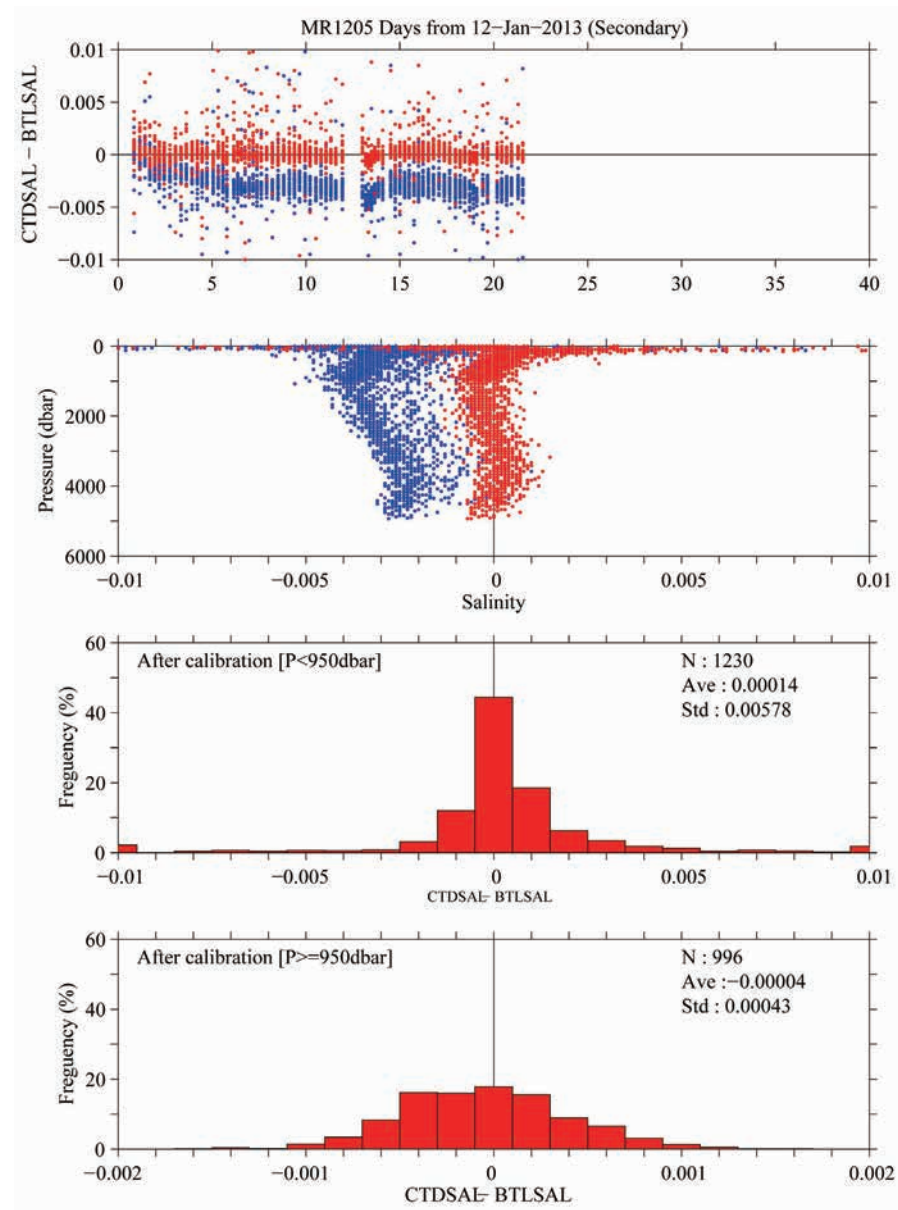
Figure 3.1.11. Same as Fig. 3.1.7, but for secondary salinity data for leg 3.

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:

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

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

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

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

where V_b is the RINKO output (voltage), V_0 is voltage in the absence of oxygen, T is temperature in °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_6	c_7
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 ooxygen 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	Sdev	Number	Mean	Sdev
			[μmol/kg]			[μmol/kg]	
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
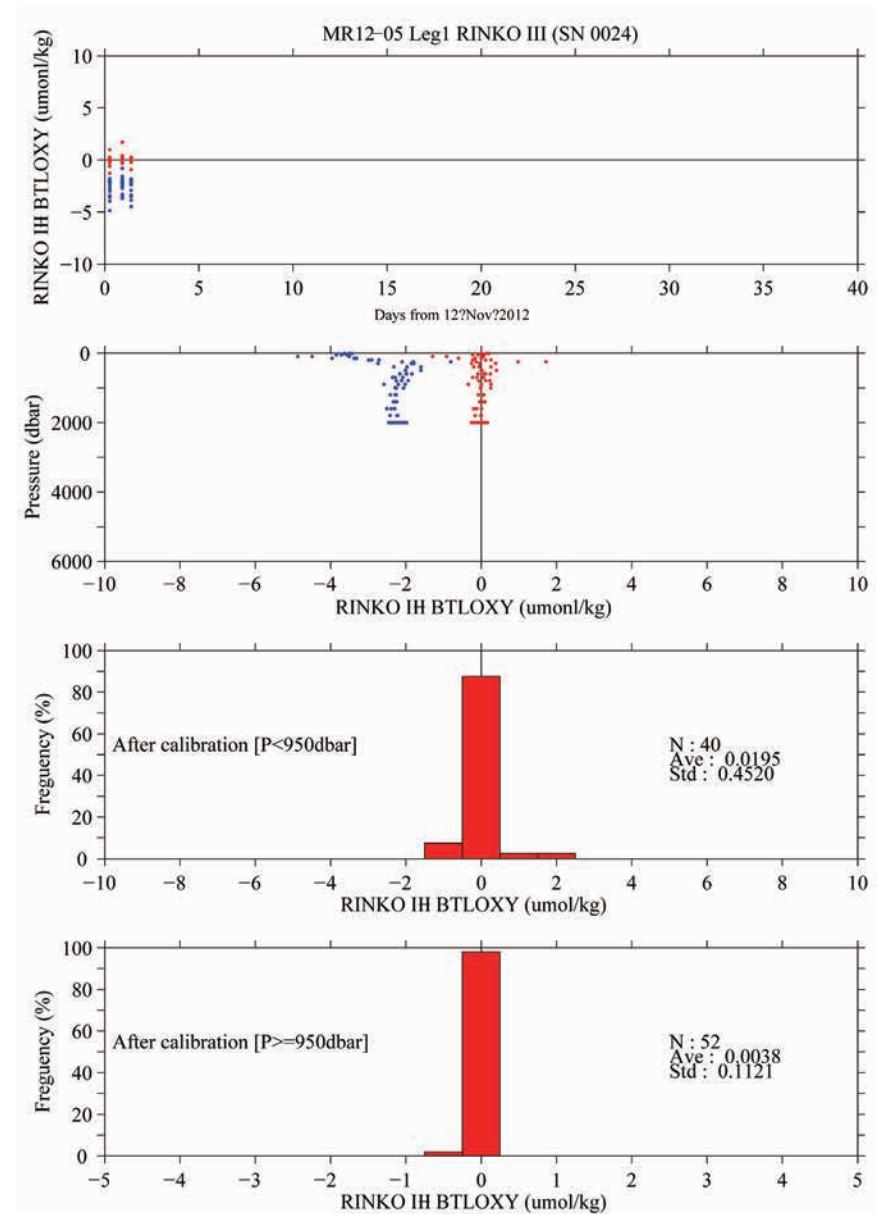
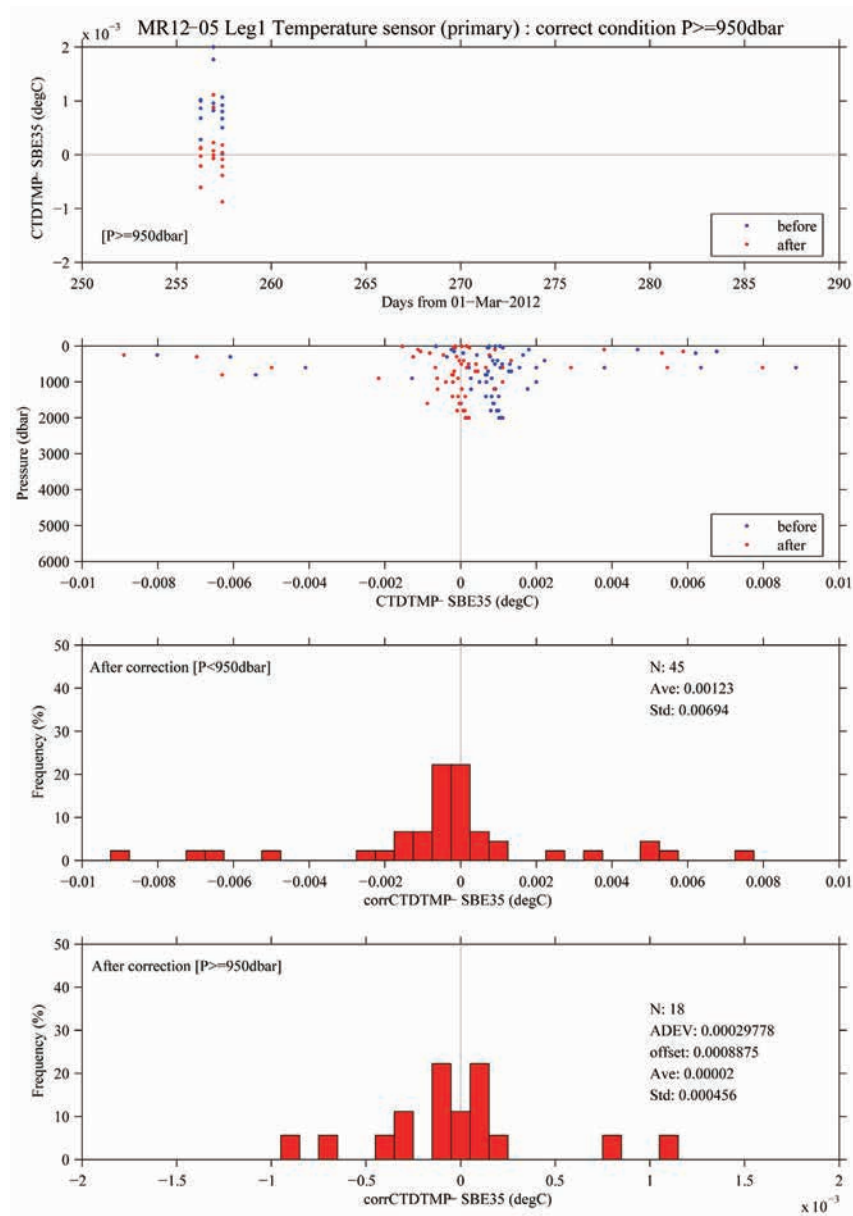

Figure 3.1.12. Difference between the CTD oxygen and the bottle oxygen for leg 1. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration.
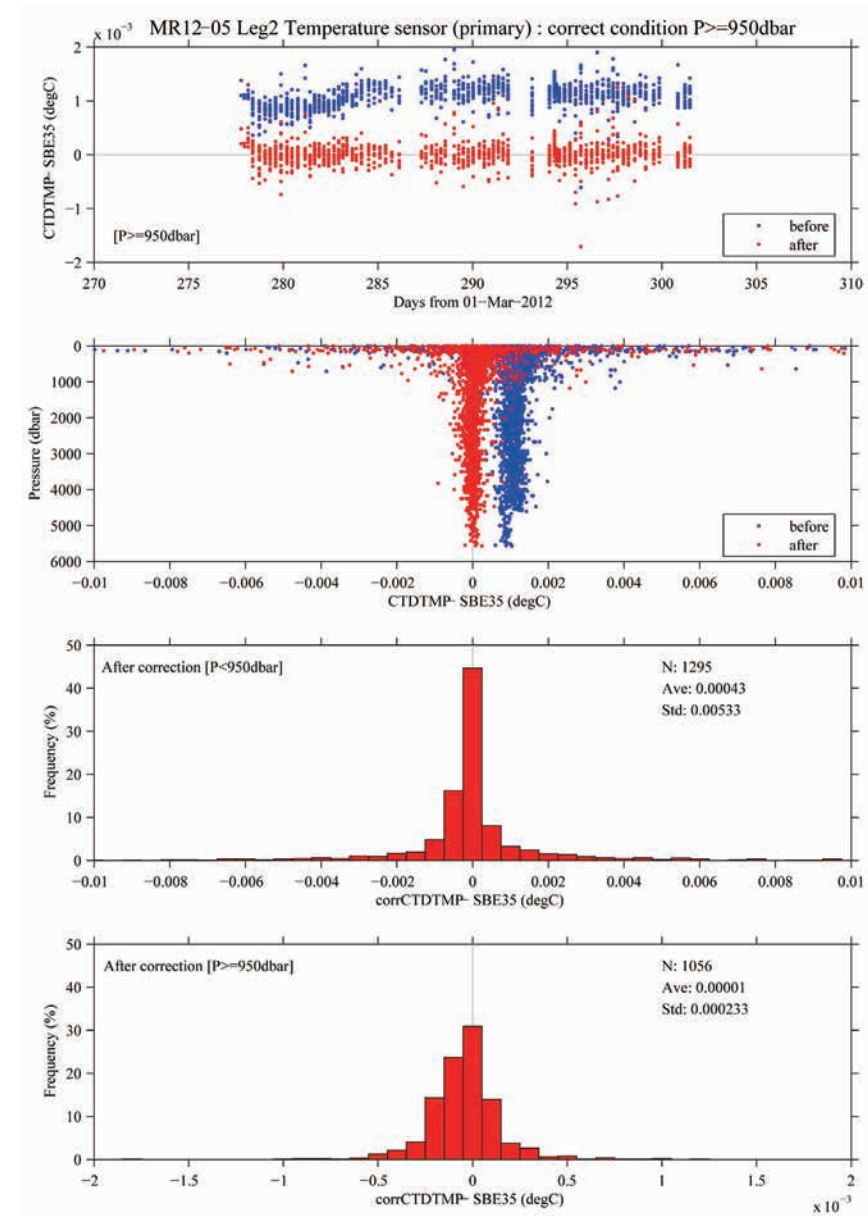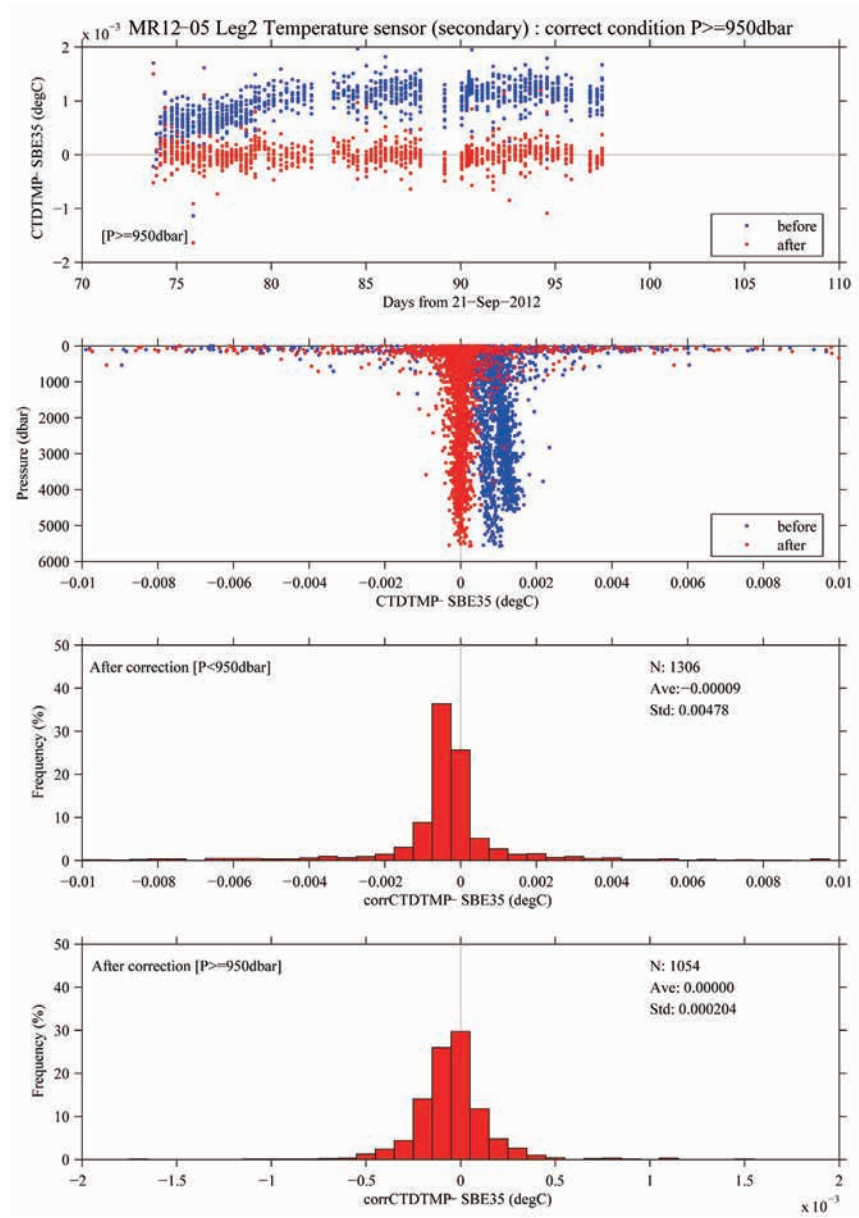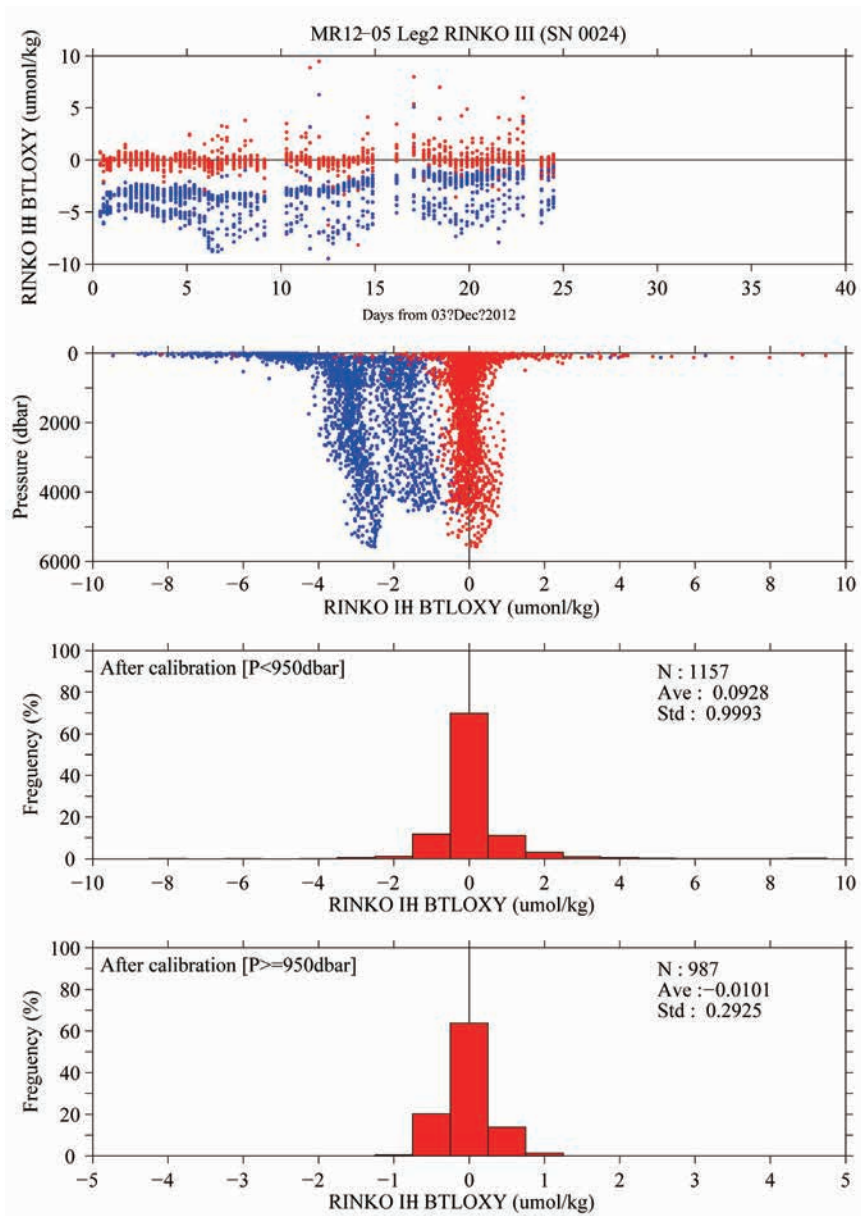
Figure 3.1.13. Same as Fig. 3.1.12, but for leg 2.
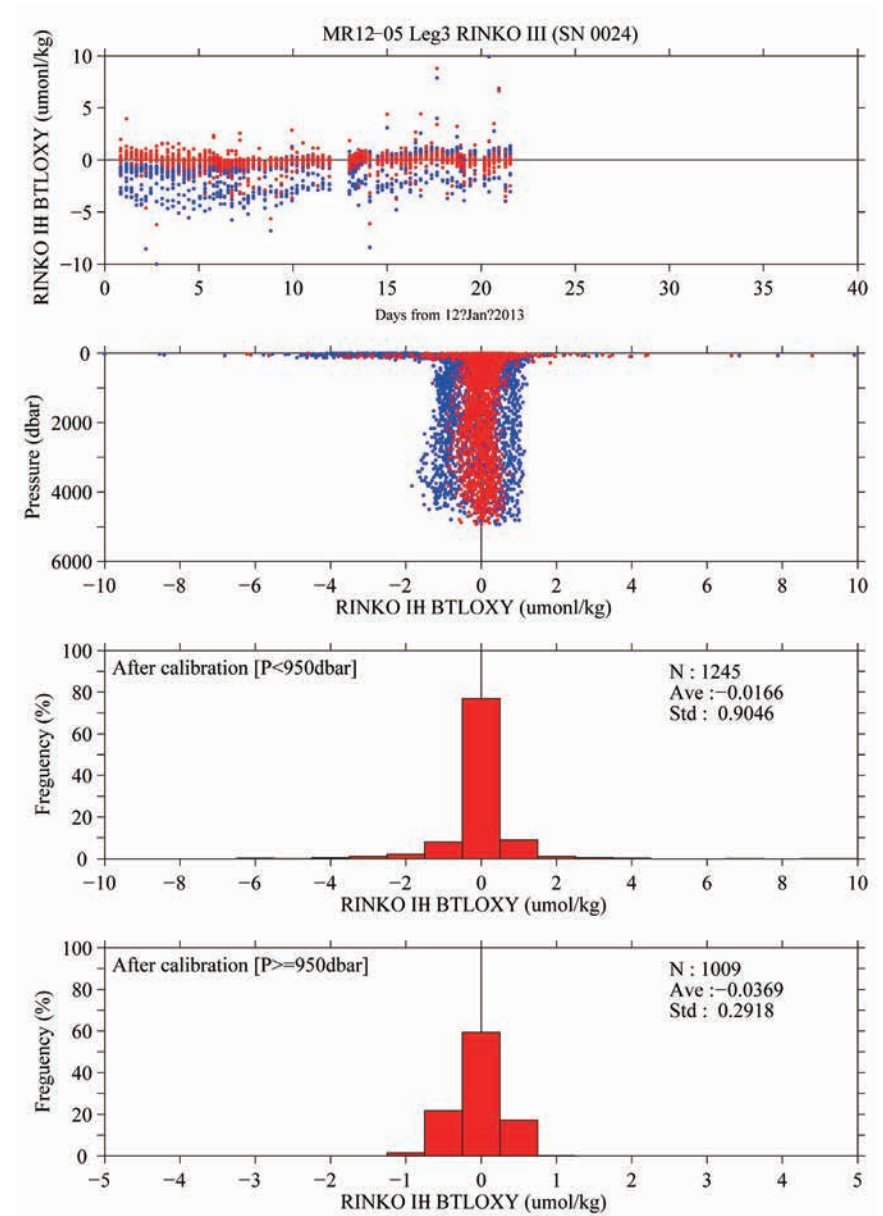
Figure 3.1.14. Same as Fig. 3.1.12, but for leg 3.

v. Fluorometer

The CTD fluorometer (FLUOR in µg/L) was calibrated by comparing with the bottle sampled chlorophyll-a as

$$FLUORc = c_0 + c_1 \times FLUOR + c_2 \times \ln (c_3 \times FLUOR + 1)$$

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 µE/(m² 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 µg/L	0.10 µg/L
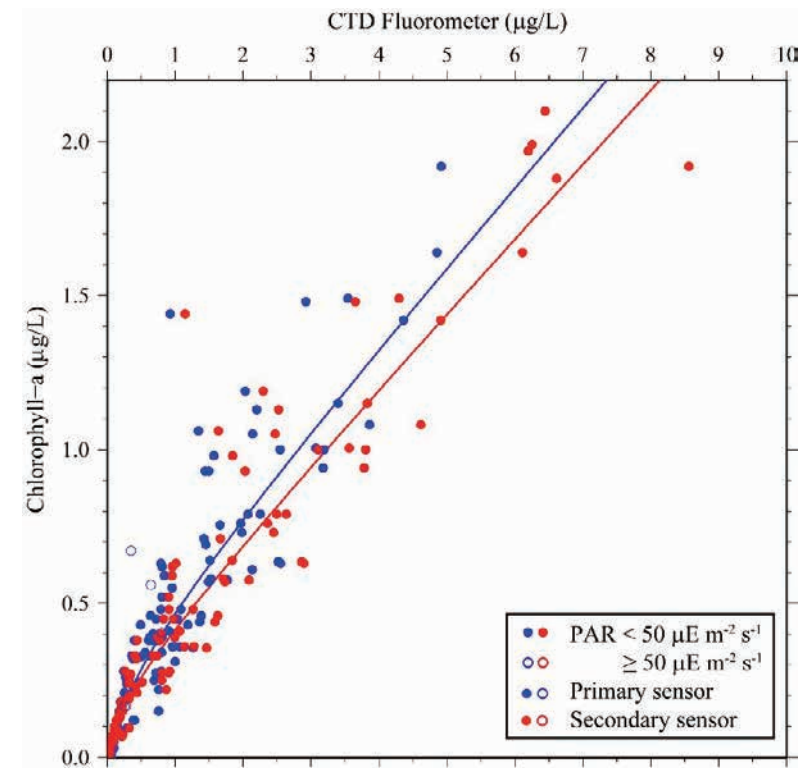
Figure 3.1.15. Comparison of the CTD fluorometer and the bottle sampled chlorophyll-a. The regression lines are also shown.

vi. Transmissometer

The transmissometer (T_r in %) is calibrated as

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

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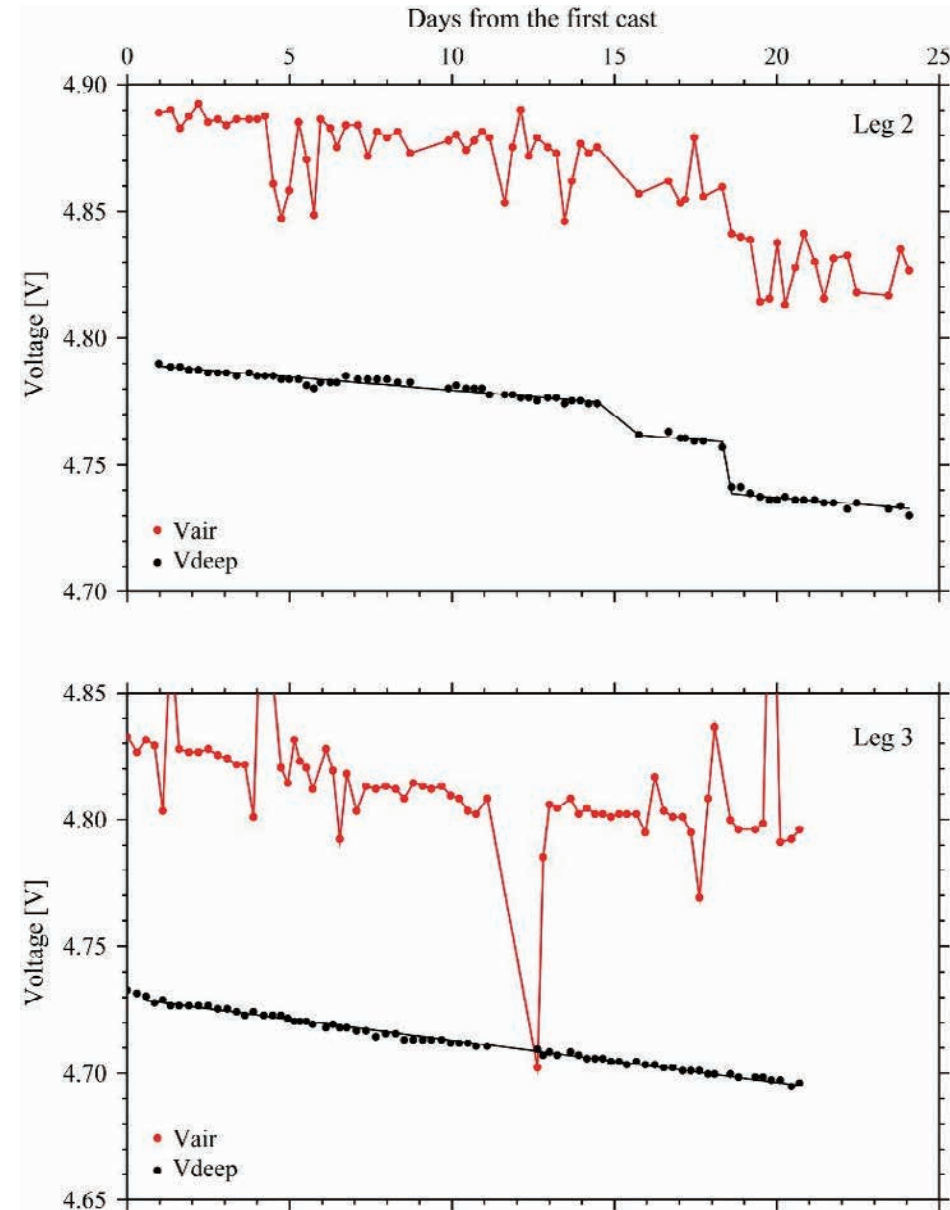
Figure 3.1.16. Time series of an output signal (voltage) from transmissometer at on deck before CTD casts (Vair) and deep ocean (Vdeep) for leg 2 (upper panel) and leg 3 (lower panel). The black solid line indicates the modeled signal in the deep clear ocean.

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:

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

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3.2 Bottle Salinity

October 2, 2014

(1) Personnel

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Hiroki Ushiromura (MWJ) (Leg 3)

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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 ±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 grater 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±0001 (leg 1), 5432±0002 (leg 2), and 5438±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 3.2.2. Same as Fig. 3.2.1, but for leg 2.

Figure 3.2.1. History of double conductivity ratio measurement of the Standard Seawater (P154) during leg1. Horizontal and vertical axes represents date and double conductivity ratio, respectively. Blue dots indicate raw data and red dots indicate corrected data.
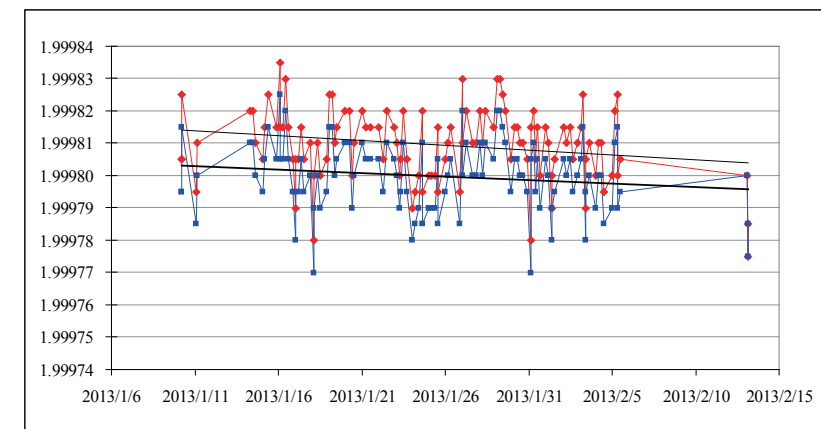
Figure 3.2.3. Same as Fig. 3.2.1, but for leg 3.

ii. Sub-Standard Seawater

We also used sub-standard seawater which was deep-sea water filtered by pore size of 0.45 μm 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 deference were 0.00015 (leg 1), 0.00018 (leg 2), and 0.00020 (leg 3).
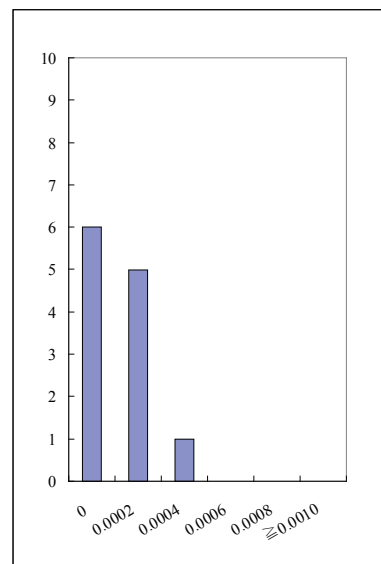
Figure 3.2.4. Histogram of the absolute difference between replicate samples for leg 1. Horizontal axis is absolute difference in salinity and vertical axis is frequency.
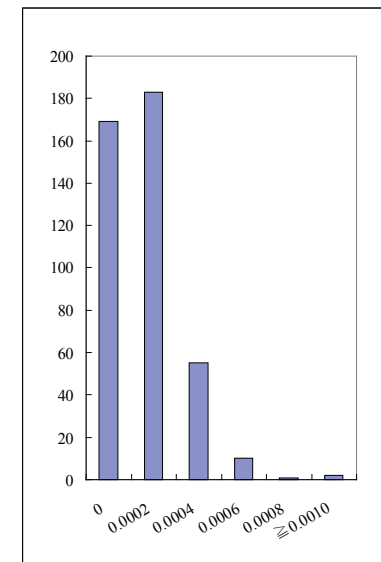
Figure 3.2.5. Same as Fig. 3.2.4, but for leg 2.
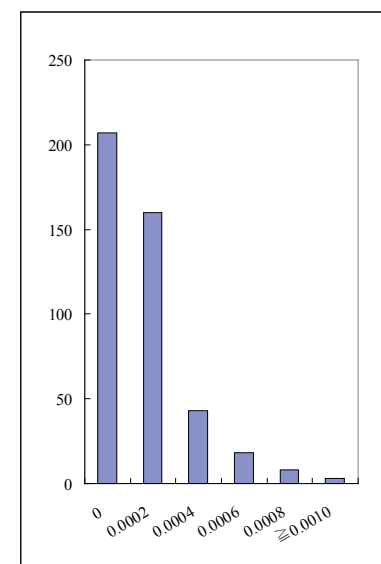
Figure 3.2.6. Same as Fig. 3.2.4, but for leg 3.

References

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3.3 Density

March 21, 2015

(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 ℃) upside down. The bottles were warmed up in a water bath (~30 ℃) 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 ℃ 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 ℃ of the Milli-Q water was estimated to be 998.2042 kg m^{-3} from the isotopic composition ($\delta D = -8.76$ ‰, $\delta^{18}O = -56.86$ ‰) 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 ($\rho_{Milli-Q}$) with a slight modification of the density dependency (Uchida et al., 2011). The offset (ρ_{offset}) of the measured density (ρ) was estimated from the following equation:

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

$C = 0.000241$ [leg 2]

$C = 0.000296$ [leg 3]

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. The correction factor (C) for leg 3 was reevaluated on 20 March 2015 by examining measured density of the Dn-RM1.

Density salinity can be back calculated from measured density and temperature (20 ℃) 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^3/hour) for the results on January 15 and biased (about $+0.0196$ kg/m^3) 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 (1024.2618 kg/m^3) 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 (δS_A) are shown in Fig. 3.3.1. The measured δS_A well agree with calculated δS_A from Pawlowicz et al. (2011) which exploits the correlation between δS_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^3)	Note
Leg 2			
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)

Date	Stations (sample no.)	Mean density of Dn-RM1 (kg/m^3)	Note
Leg 3			
2013/01/15	090	1024.2580*	1024.2613 after drift correction
2013/01/16	094	1024.2608	
2013/01/18	100	1024.2618	
2013/01/19	104	1024.2625	
2013/01/21	111,116	1024.2633	
2013/01/23	123	1024.2621	

2013/01/25	128	1024.2646	
2013/01/27	140,138	1024.2307*	1024.2619 after bias correction
2013/01/28	133	1024.2611	
2013/01/30	none	1024.2612	
2013/01/31	146,151	1024.2621	
2013/02/02	156	1024.2815*	1024.2621 after bias correction
			bottles #1,17-30,32,33,35,36
2013/02/03	162,156,166	1024.2604	bottles #31,34 for station 156

Average: 1024.2620 ± 0.0013 (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^3]	Note

Leg 2

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

Leg 3

2013/01/16	SSW P154	1024.7640	
2013/01/21	SSW P154	1024.7659	
2013/01/31	SSW P154	1024.7636	

Average: 1024.7645 ± 0.0012
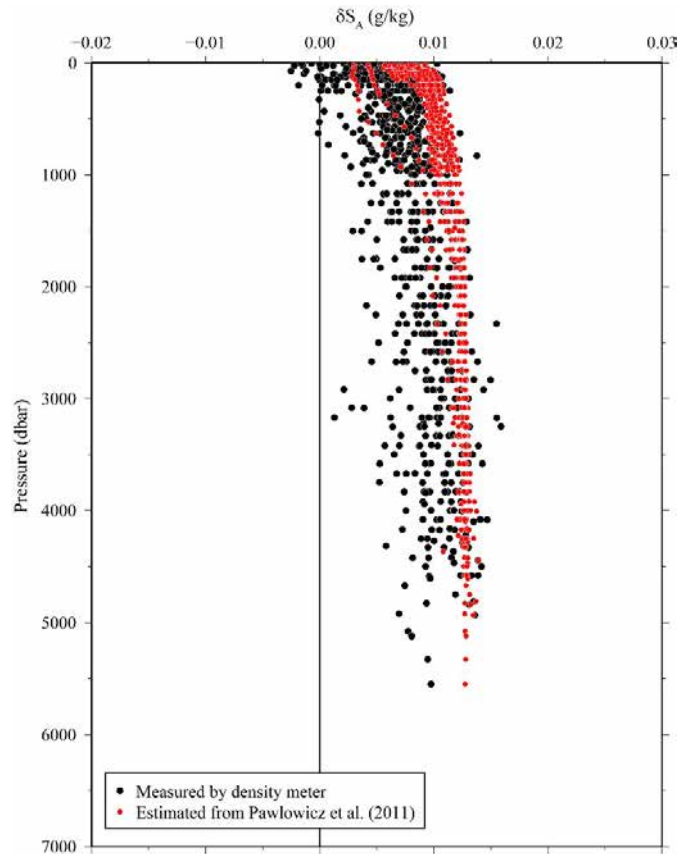
Figure 3.3.1. Vertical distribution of density salinity anomaly measured by the density meter. Absolute Salinity anomaly estimated from nutrients and carbonate parameters (Pawlowicz et al., 2011) are also shown for comparison.

(5) 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.

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3.4 Oxygen

September 29, 2014

(1) Personnel

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(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^3 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^3). 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^3 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^3 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 (µmol 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^3 in a calibrated volumetric flask (0.001667M). 10 cm^3 of the standard potassium iodate solution was added to a flask using a volume-calibrated dispenser. Then 90 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were added into the flask in order. Amount of titrated volume of sodium thiosulfate (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 µmol kg^{-1}.

(8) Determination of the blank

The oxygen in the pickling reagents I (0.5 cm^3) and II (0.5 cm^3) was assumed to be 3.8×10^{-8} mol (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^3 of the standard potassium iodate solution were added to two flasks respectively. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I each were added into the two flasks in order. The blank was determined by difference between the two times of the first (1 cm^3 of KIO$_3$) titrated volume of the sodium thiosulfate and the second (2 cm^3 of KIO$_3$) one. The results of 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^3, 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 µmol 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 µmol 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$_3$ standards as samples before and during the cruise (Table 3.4.3). A good agreement among them confirms that concentration of the KIO$_3$ 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 Depresion (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.

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Table 3.4.1. Results of the standardization (End point, E.P.) and the blank determinations (cm^3).

Date		KIO3 No.	Na$_2$S$_2$O$_3$ No.	DOT-7		DOT-8		Stations
(UTC)	#	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	05	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
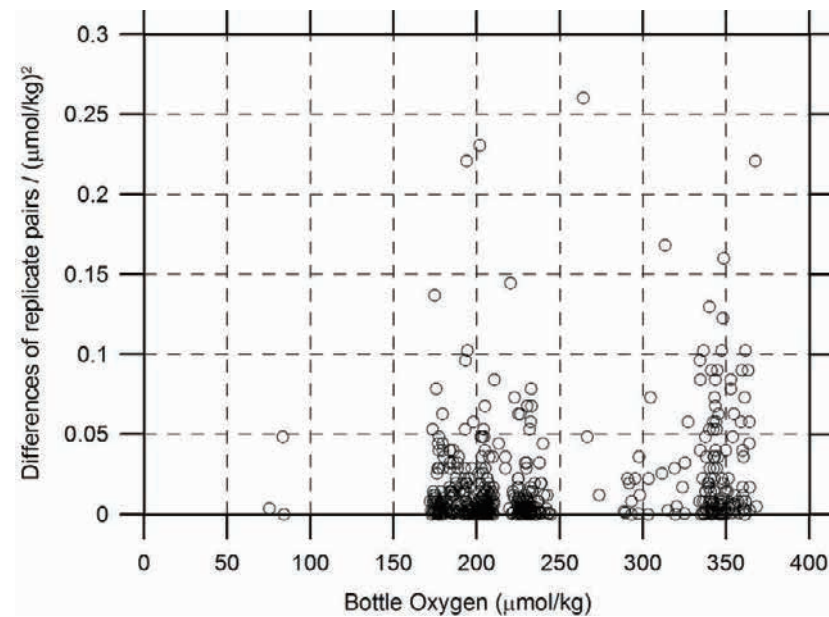
Figure 3.4.1. Oxygen difference between measurements of a replicate pair against oxygen concentration.

Table 3.4.2. Results of duplicate sample measurements.

	Leg	Stations	Pressure (dbar)	Niskins		Apparatus	Oxygen [umol/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$_3$ 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
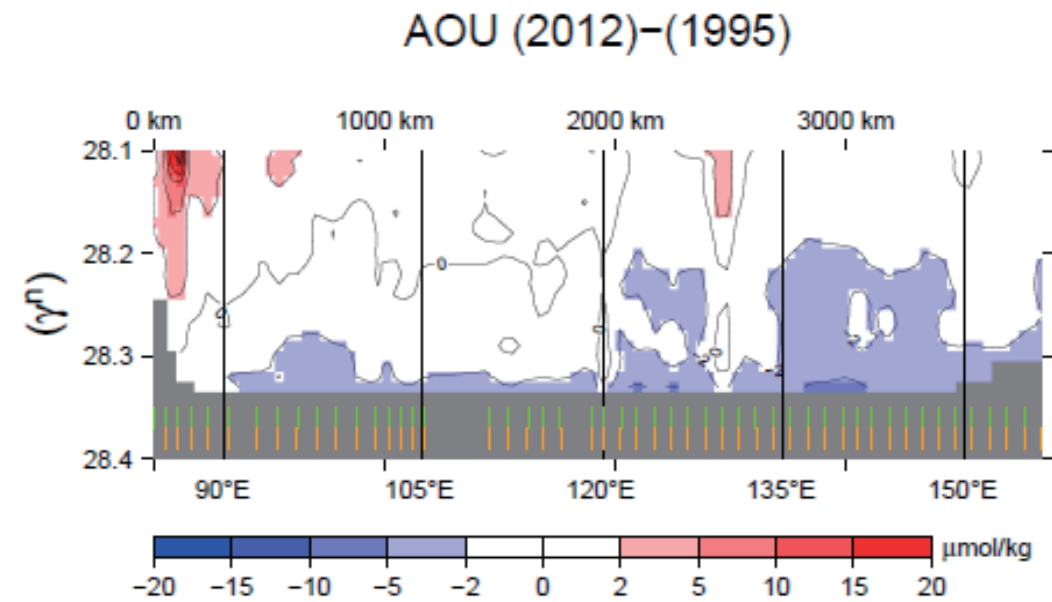
Figure 3.4.2. Differences in apparent oxygen utilization (AOU, μmol kg^{-1}) on density surfaces along WHP-S4 line between 1995/96 and 2012/13 (Katsumata et al., in press).

3.5 Nutrients

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(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 streamed 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.

(4.2) Nitrate Reagents

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

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

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

Dissolve 10 g sulfanilamide, $4-NH_2C_6H_4SO_3H$, in 900 ml of DIW, add 100 ml concentrated HCl. After mixing, 2 ml Triton(R)X-100 (50 %f solution in ethanol) is added.

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

Dissolve 1 g NEDA, $C_{10}H_7NHCH_2CH_2NH_2 \bullet 2HCl$, in 1000 ml of DIW and add 10 ml concentrated HCl. After mixing, 1 ml Triton(R)X-100 (50 %f solution in ethanol) is added.

Stored in a dark bottle.
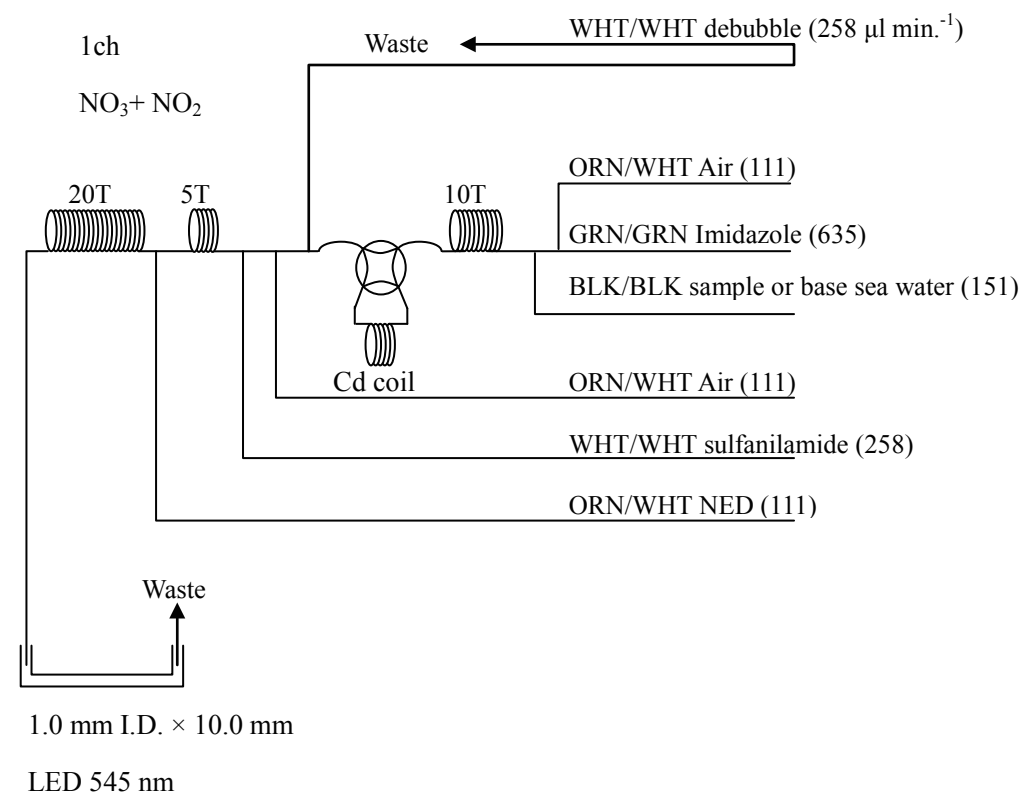
Figure 3.5.1. $NO_3 + NO_2$ (1ch.) Flow diagram.

(4.3) Nitrite Reagents

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

Dissolve 10 g sulfanilamide, $4-NH_2C_6H_4SO_3H$, in 900 ml of DIW, add 100 ml concentrated HCl. After mixing, 2 ml Triton(R)X-100 (50 % solution in ethanol) is added.

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

Dissolve 1 g NEDA, $C_{10}H_7NHCH_2CH_2NH_2 \bullet 2HCl$, in 1000 ml of DIW and add 10 ml concentrated HCl. After mixing, 1 ml Triton(R)X-100 (50 %f solution in ethanol) is added. This reagent was stored in a dark bottle.
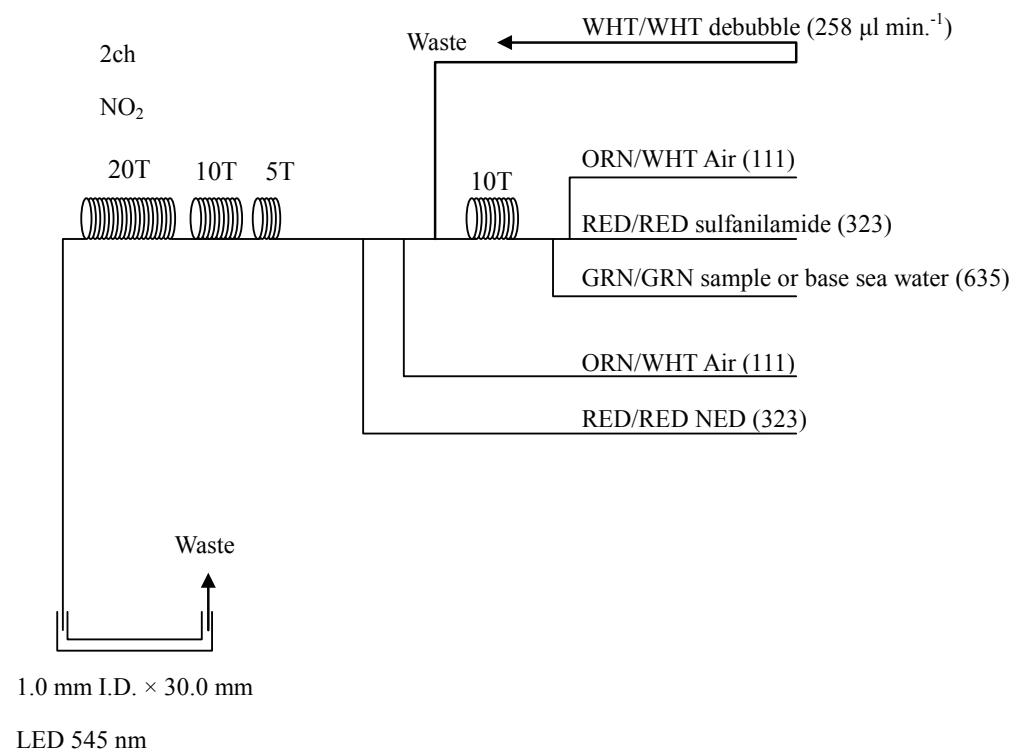
Figure 3.5.2. NO_2 (2ch.) Flow diagram.

(4.4) Silicate Reagents

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

Dissolve 15 g disodium Molybdate (VI) dihydrate, $Na_2M_oO_4•2H_2O$, in 980 ml DIW, add 8 ml concentrated H_2SO_4. After mixing, 20 ml sodium dodecyl sulphate (15 % solution in water) is added.

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

Dissolved 50 g oxalic acid anhydrous, HOOC: COOH, in 950 ml of DIW.

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

Dissolved 2.5g L (+)- ascorbic acid, $C_6H_8O_6$, in 100 ml of DIW. This reagent was freshly prepared before every measurement.
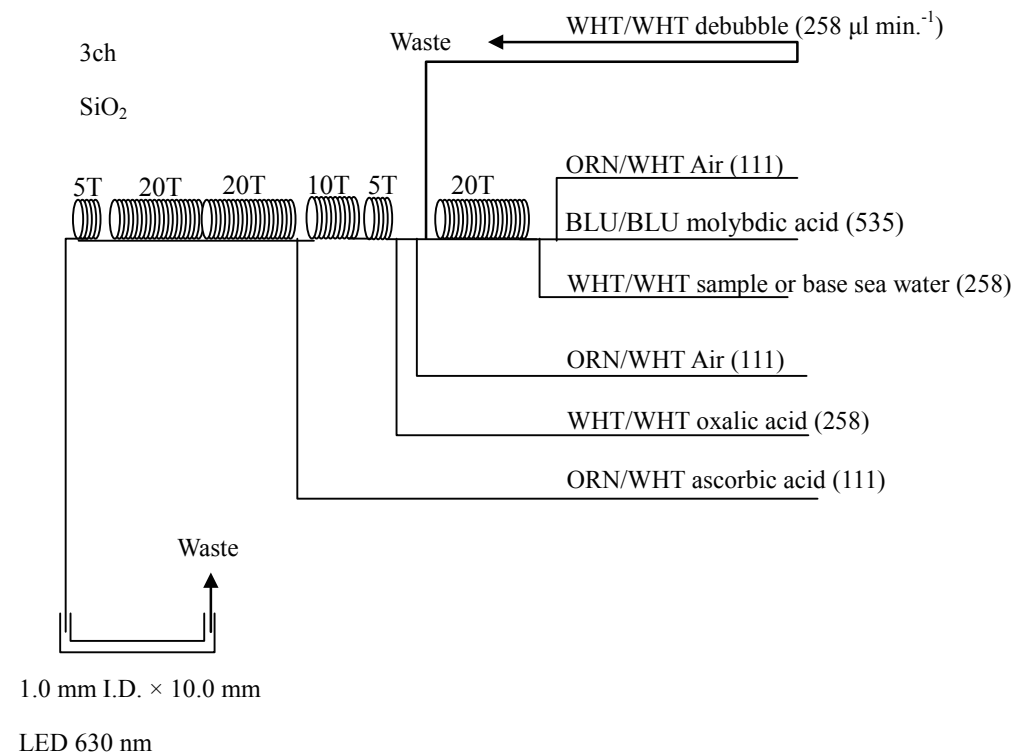
Figure 3.5.3. SiO_2 (3ch.) Flow diagram.

(4.5) Phosphate Reagents

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

Dissolved 8 g disodium molybdate(VI) dihydrate, $Na_2M_oO_4•2H_2O$, and 0.17 g antimony potassium tartrate, $C_8H_4K_2O_{12}Sb_2•3H_2O$, in 950 ml of DIW and added 50 ml concentrated H_2SO_4.

Mixed Reagent

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.
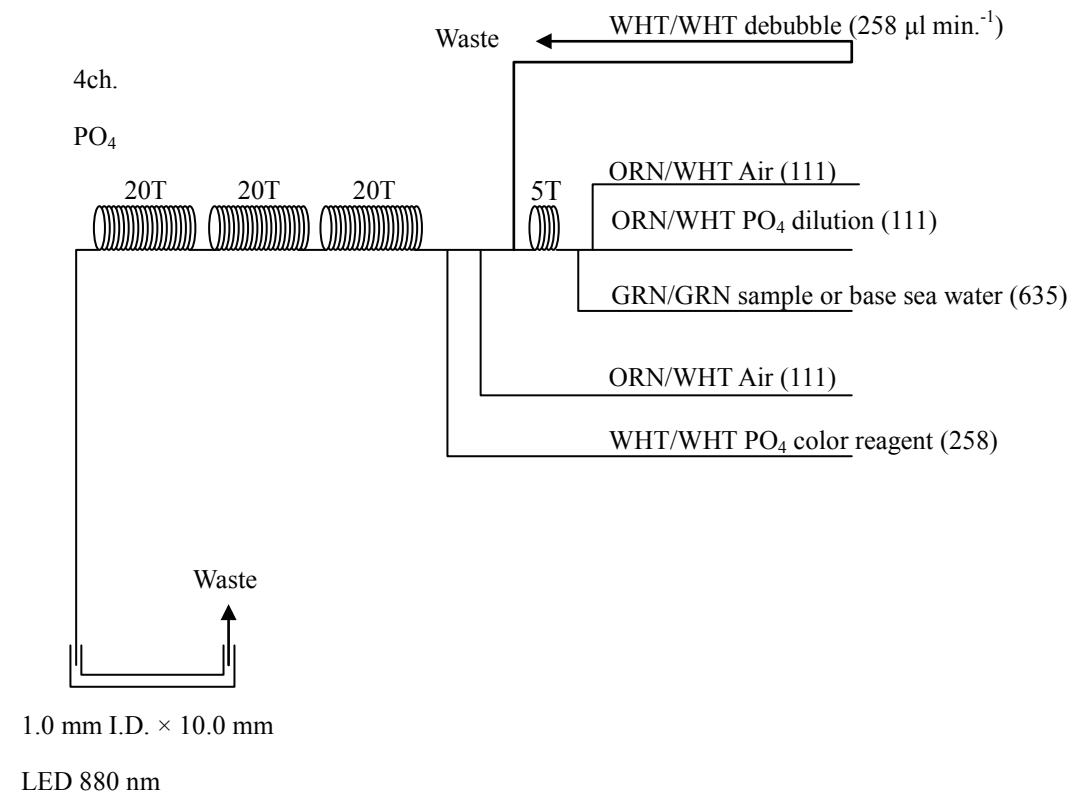
Figure 3.5.4. PO4 (4ch.) Flow diagram.

(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 ± 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_2 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 $MgOH_2$ 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
$NO_3(\mu M)$	22500	900	BS	BU	BT	BD	BF	45
$NO_2(\mu M)$	4000	20	BS	BU	BT	BD	BF	1.0
$SiO_2(\mu M)$	36000	2160	BS	BU	BT	BD	BF	105
$PO_4(\mu M)$	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_3, NO_2, SiO_2, PO_4	Renewal
A-1 Std. (NO_3)	maximum 1 month
A-2 Std. (NO_2)	maximum 1 month
A-3 Std. (SiO_2)	commercial prepared solution
A-4 Std. (PO_4)	maximum 1 month
B-1 Std. (mixture of NO_3, SiO_2, PO_4)	8 days
B-2 Std. (NO_2)	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_3)	8 days
43 μM NO_3	when C Std. renewed
39 μM NO_2	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 µmol kg^{-1} for 345 crossovers at world oceans, though the maximum was 1.7 µmol kg^{-1} (Gouretski and Jancke, 2001). At the 31 crossover points in the Pacific WHP one-time lines, the WOCE standard of reproducibility for nitrate of 1 % was fulfilled at about half of the crossover points and the maximum difference was 7 % at deeper layers below 1.6 ºC 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 ºC.

(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: µmol 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.

	Nitrate	**Phosphate**	**Silicate**
	CV %	CV %	CV %
BV	0.13	0.19	0.15
Precision	0.10	0.16	0.11

BV: N=298

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

Figure 3.5.5. Time series of RMNS-BV of nitrate for MR12-05.
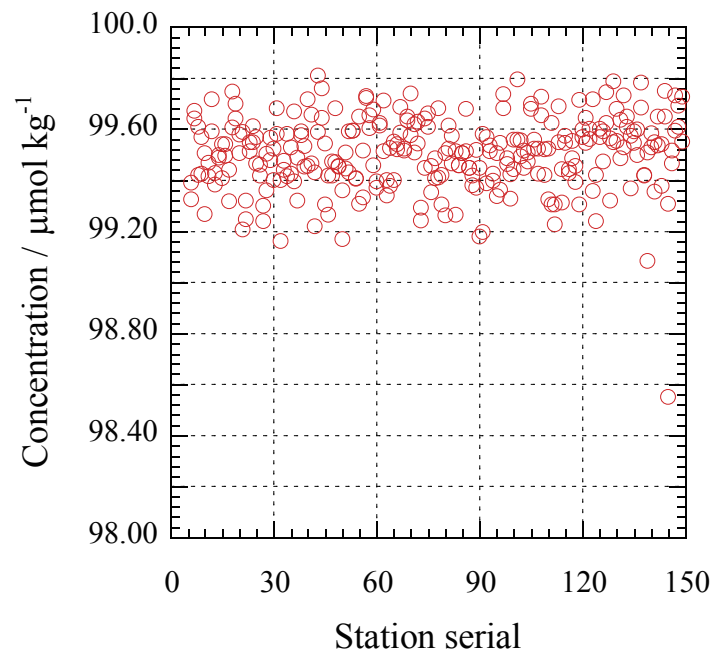
Figure 3.5.7. Time series of RMNS-BV of silicate for MR12-05.

Table 3.5.7(a). Comparability for nitrate.

unit: μmol kg^{-1}

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

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

Cruise-to-cruise comparability has 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 similar method described in 7.1 in this chapter at the measurement before each cruise and inter-comparison study, shown as precruise and intercomparison, and mean of uncertainties during each cruise, only shown cruise code, respectively. As shown in Table 3.5.7, the nutrients 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(b). Comparability for Phosphate.

unit: µmol kg^{-1}

Cruise	RM Lots											
	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.

unit: mol kg^{-1}

Cruise	RM Lots											
	BS	unc.	BU	unc.	BT	unc.	BD	unc.	BV	unc.	BF	unc.
	Silicate											
MR07-04[$$]											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[++]	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 cruses 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.

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
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 3.5.9. Time series of precision of phosphate for MR12-05.

Figure 3.5.8. Time series of precision of nitrate for MR12-05.
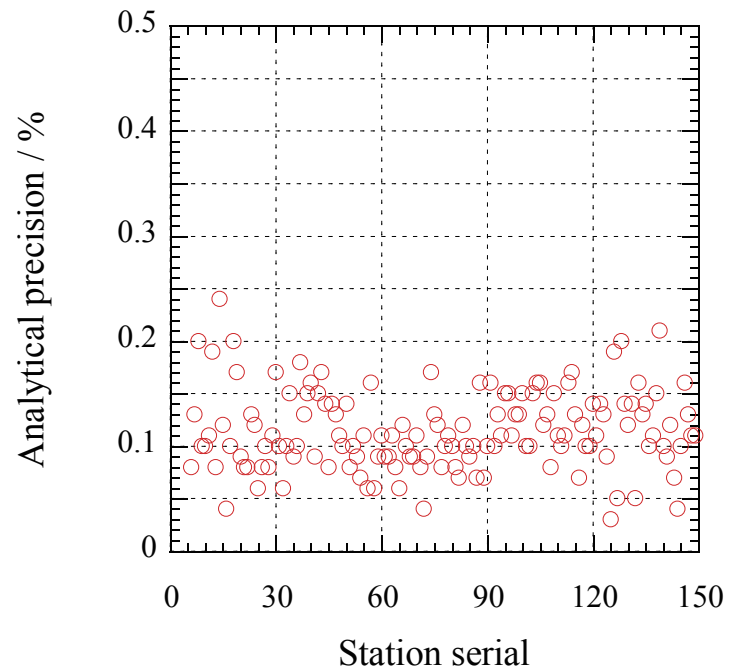
Figure 3.5.10. Time series of precision of silicate for MR12-05.

(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.

	Nitrate	Phosphate	Silicate
	CV %	CV %	CV %
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
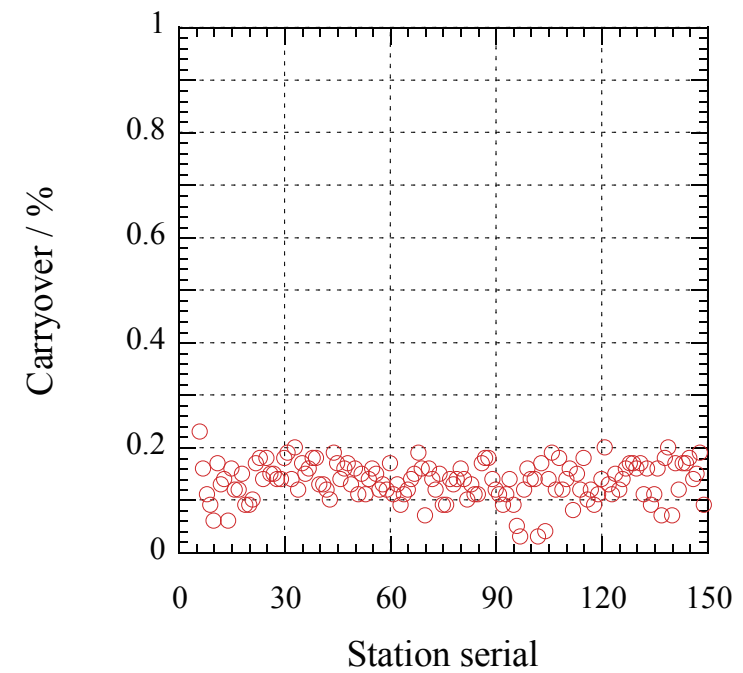
Figure 3.5.11. Time series of carryover of nitrate for MR12-05.
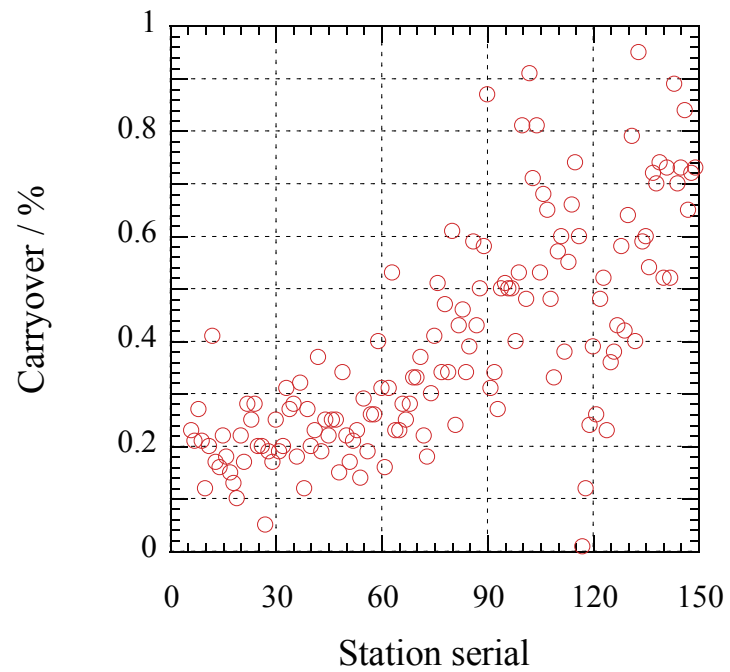
Figure 3.5.12. Time series of carryover of phosphate for MR12-05.
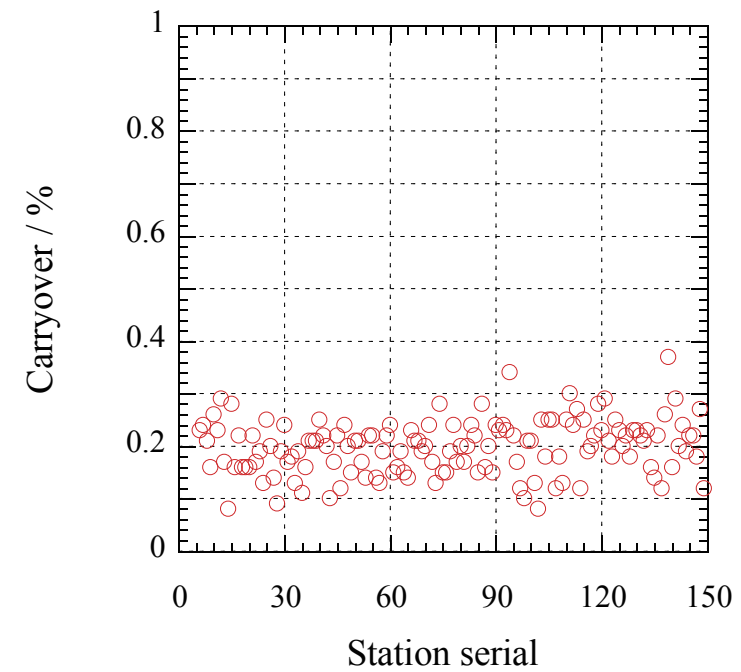
Figure 3.5.13. Time series of carryover of silicate for MR12-05.

(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 Cp in µmol kg^{-1}:

Uncertainty of measurement of phosphate (%) = 0.05668 + 0.3158 / Cp — (1)

where Cp is phosphate concentration of sample.

Nitrate Concentration Cn in µmol kg^{-1}:

Uncertainty of measurement of nitrate (%) = 0.09216 + 1.0861 / Cn — (2)

where Cn is nitrate concentration of sample.

Silicate Concentration Cs in μmol kg^{-1}:

$$\text{Uncertainty of measurement of silicate (\%)} = 0.06383 + 7.436 / Cs \qquad — (3)$$

where Cs 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 changed.

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

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

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 μmol kg^{-1} at 0.005 μmol kg^{-1} 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 μmol kg^{-1}. Therefore we corrected these overestimation and decided to report phosphate concentration x.xx μmol kg^{-1} NOT x.xxx μmol kg^{-1} considering the larger uncertainty of phosphate concentration of seawater samples.

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3.6 Chlorofluorocarbons and Sulfur Hexafluoride

February 1, 2015

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(2) Objectives

Chlorofluorocarbons (CFCs) and sulfur hexafluoride (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 (CCl_3F), CFC-12 (CCl_2F_2) and CFC-113 ($C2Cl_3F_3$), and SF_6 in seawater on board.

(3) Apparatuses

Measurement of CFCs and 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 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) 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 μm]. 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 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 μm] 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 μm]. A main column is Pola Bond-Q capillary column [i.d.: 0.53 mm, length: 9 m, film thickness: 10 μm] followed by Silica Plot capillary column [i. d.: 0.53 mm, length: 18 m, film thickness: 6 μm].

(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 litter 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 SF_6 concentrations were determined within 24 hours.

In order to confirm stabilities of standard gases and to check saturation levels of CFCs and SF_6 in sea surface water, mixing ratios of CFCs and 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_6 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_6/CFCs simultaneous analyses (System A &B)

Constant volume of sample water (200 ml) was taken into a sample loop. The aliquot was send 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 –80ºC. Stripping efficiencies were frequently confirmed by re-stripping of surface layer samples and more than 98 % of dissolved SF_6 and CFCs were extracted on the first purge. Following purging & trapping, the main trap column was isolated and heated to 170ºC for 1 minute. The desorbed gases were sent onto focusing trap cooled to –80ºC for 30 sec and then the trap was isolated. Gaseous sample on the focusing trap were desorbed by heating to170ºC for 1 minute and led into the pre-column. Sample gases were roughly separated in the pre-column. When SF_6 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_6 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 140ºC, 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_6 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^{-1} (n = 3), respectively. These values are close to previous blanks (0.011 ± 0.003 and 0.005 ± 0.002 pmol kg^{-1} for CFC-11 and CFC-

12, respectively) estimated from a number of analyses (N ≈ 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_6 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 ~ 530 pairs for CFC-12, CFC-11, and CFC-113, and 340 pairs for SF_6 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 ±0.002 pmol kg^{-1} or 1 % for CFC-11, ±0.004 pmol kg^{-1} or 1 % for CFC-12, ±0.002 pmol kg^{-1} or 5 % for CFC-113 , and ±0.030 fmol kg^{-1} or 6% for SF_6(whichever is greater), respectively.

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

Cylinder No.	Base	CFC-11	CFC-12	CFC-113	SF6	remarks
		ppt	ppt	ppt	ppt	
CPB26845	Air	1304	649	130	9.99	SF_6/CFC, Leg 2
CPB25863	Air	1301	649	130	10.00	SF_6/CFC, Leg 2,3
CPB17252	Air	1304	652	130	9.93	SF_6/CFC, Leg 3
CPB30572	Air	1301	651	130	9.98	SF_6/CFC, Leg 3
CPB07911	N_2	302	159	30.0	0.0	CFC, Leg 2,3
CPB15651	N_2	299	159	30.2	0.0	CFC, Reference

3.7 Carbon Items (C_T, A_T and pH)

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(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 ~170°E and ~60°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 °C by a water jacket, in which water from a water bath set at 20 °C is circulated. CO_2 dissolved in a seawater sample is extracted in a stripping chamber of the CO_2 extraction system by adding phosphoric acid (~ 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 ml min⁻¹) to the coulometer through a dehydrating module. The modules of Systems C and D consist of two electric dehumidifiers (kept at ~4 °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 ºC) pipette by pressurizing the sample bottle (nitrogen gas), and is introduced into the water-jacketed (25 ºC) titration cell. The seawater is circulated between the titration and the quartz cells by a peristaric 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:

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

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. 2.0×10^{-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 ± 0.05 ºC 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):

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

where A_1 and A_2 indicate absorbance at 578 and 434 nm, respectively, and 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 µl was added to poison seawater samples. The glass bottles were sealed with a greased (Apiezon M, M&I Materials Ltd) ground glass stopper and the clips were secured. The seawater samples were kept at 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 Na_2CO_3 solutions (nominally 500, 1000 1500, 2000, 2500 µmol/L). As it was empirically known that coulometers do not show a stable signal (low repeatability) with fresh (low absorption of carbon) coulometer solutions. Therefore we measured 2% CO_2 gas repeatedly until the measurements became stable. Then we started the calibration.

The measurement sequence such as system blank (phosphoric acid blank), 2 % CO_2 gas in a nitrogen base, seawater samples (6) was programmed to repeat. The measurement of 2 % CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc. or in-house made). For every renewal of coulometer solutions, certified reference materials (CRMs, batch 121, certified value = 2039.26 µmol 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 µmol kg^{-1}) were also analyzed periodically to monitor systematic differences of measured A_T. The reported values of A_T were set to be traceable to the certified value 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® 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® 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 Na_2CO_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 µmol 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 µmol 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 6.3364×10^{-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_2 system calculation using data for pH and C_T 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 ± 0.0011 (n=37) and 0.0140 ± 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_T and A_T. Averaged differences (corrected – computed) were 0.0059 ± 0.0054 and -0.0019 ± 0.0056 for legs 2 and 3, respectively.

References

Clayton T. D. and R. H. Byrne (1993) Spectrophotometric seawater pH measurements: total hydrogen ion concentrtaion 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 CO2 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 Oceangography, 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.
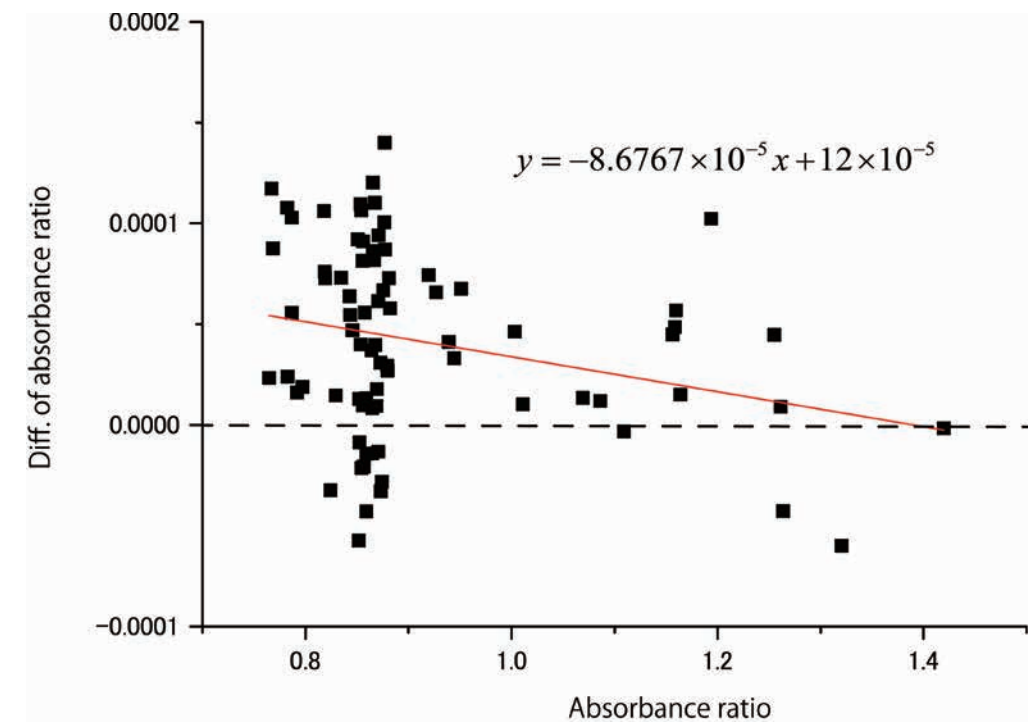
Figure 3.7.1. Perturbation of absorbance ratios by adding indicator. The line was determined by the method of least squares.

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 $-20°$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 (≤ 0.02 µg/L). Standard deviation from 20 pairs of the replicate samples was 0.018 µg/L, although absolute difference was smaller than 0.01 µg/L for 16 pairs of the replicate samples.
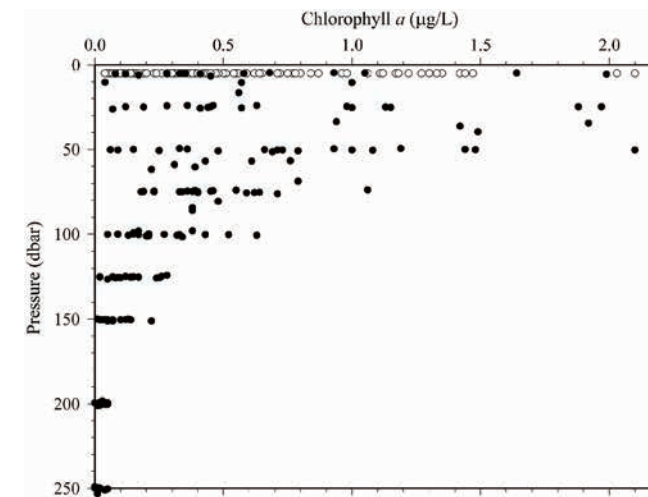
Figure 3.8.1. Vertical distribution of chlorophyll *a* obtained from hydrographic casts (closed circles) and surface water monitoring system (open circles).

Reference

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

3.9 LADCP

September 30, 2014

(1) Personnel

Shinya Kouketsu (JAMSTEC)

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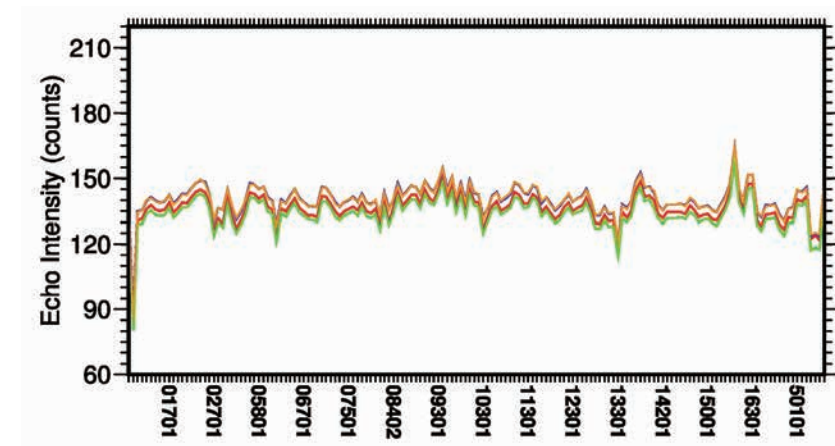
Figure 3.9.1. Cast-averaged echo intensities at the first bin. Red, blue, green and orange denote beam 1, 2, 3, and 4 respectively.

(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 2.5×10^{-3} 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. Twlelve 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 ε was estimated by

$$\varepsilon = \frac{15}{2} v \overline{u_z^2} \ ,$$

where v 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 lsbe 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.
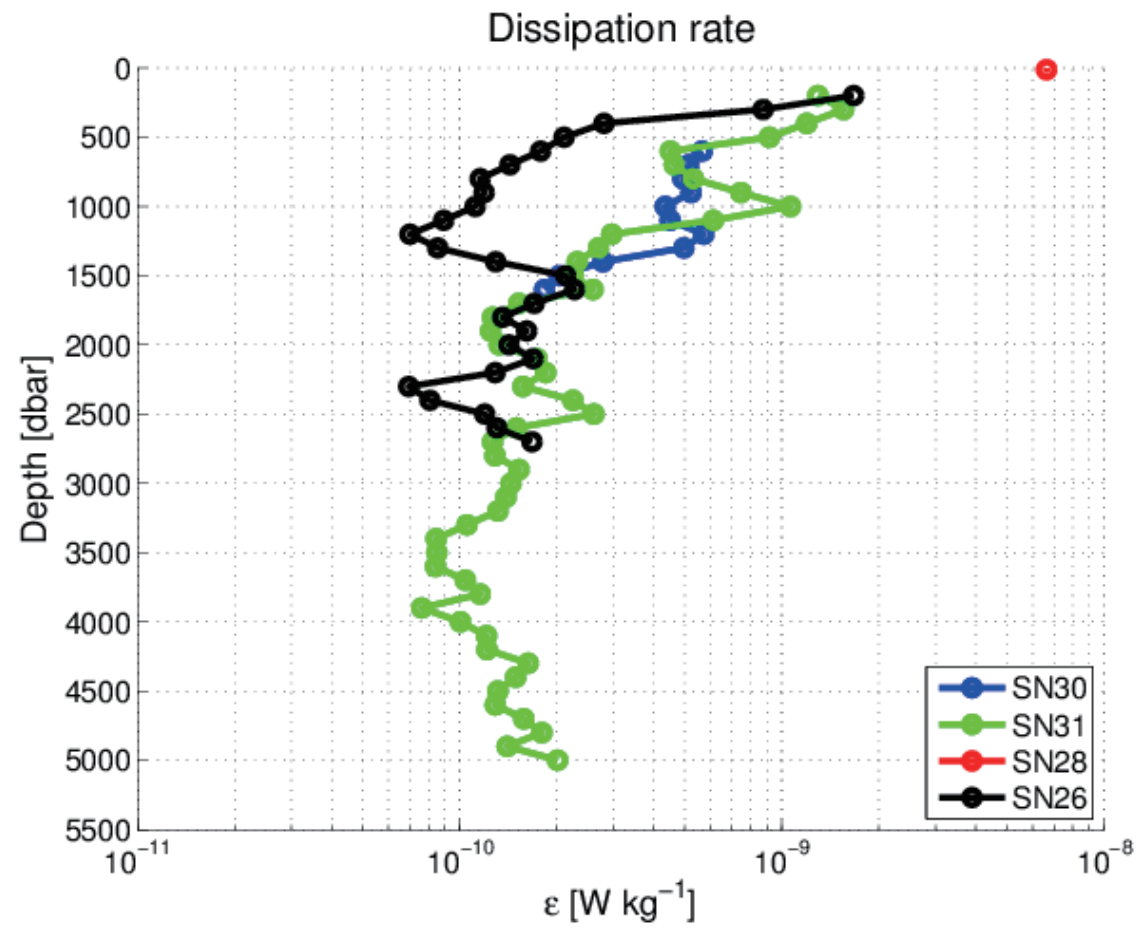
Figure 3.10.1. Kinetic energy dissipation rate estimated at intervals of 100-300 dbar, 200-400 dbar and so forth

using quick_look_XMP.m in the ODAS library. Out of two sensors, the one which produced smaller

dissipation estimate was plotted.

```
R/V MIRAI CRUISE MR1205 LEG1
SHIP/CRS    WOCE                CAST        UTC EVENT         POSITION          UNC   COR HT ABOVE   WIRE    MAX  NO. OF
EXPOCODE    SECT  STNNBR CASTNO TYPE DATE   TIME  CODE LATITUDE   LONGITUDE  NAV DEPTH DEPTH BOTTOM   OUT  PRESS BOTTLES PARAMETERS          COMMENTS
----------------------------------------------------------------------------------------------------------------------------------------------------
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
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49NZ20121105  999   323   1  UNK 111512 0817   EN 01 51.90 N 150 31.42 E GPS   -9   5167   -9                          TOWED MAGNETOMETER
49NZ20121105  999   327   1  BIO 111512 0842   BE 01 55.34 N 150 31.25 E GPS   -9   4752   -9                          NEUSTON NET
49NZ20121105  999   327   1  BIO 111512 1047   EN 02  0.01 N 150 31.07 E GPS   -9   5113   -9                          NEUSTON NET
49NZ20121105  999   328   1  UNK 111512 2156   BE 00  0.89 N 151 31.92 E GPS   -9   5130   -9                          TOWED MAGNETOMETER
49NZ20121105  999   329   1  XCT 111612 0330   DE 00 53.80 N 152  7.69 E GPS   -9   5060   -9                          XCTD-1 SN11011547
49NZ20121105  999   330   1  UNK 111612 1117   BE 02 12.47 S 153  0.25 E GPS   -9   3559   -9                          MAGNETOMETER CALIBRATION
49NZ20121105  999   330   1  UNK 111612 1157   EN 02 13.12 S 153  0.61 E GPS   -9   3531   -9                          MAGNETOMETER CALIBRATION
49NZ20121105  999   328   1  UNK 111612 1235   EN 02 14.75 S 153  1.39 E GPS   -9   3196   -9                          TOWED MAGNETOMETER
49NZ20121105  999   331   1  UNK 112212 0550   BE 26 17.98 S 165 36.06 E GPS   -9   3302   -9                          3-AXIS MAGNETOMETER CALIBRATION
49NZ20121105  999   332   1  UNK 112212 0605   UN 26 17.97 S 165 36.29 E GPS   -9   3300   -9              89          THROUGH HULL PUMP
49NZ20121105  999   331   1  UNK 112212 0618   EN 26 17.93 S 165 36.24 E GPS   -9   3300   -9                          3-AXIS MAGNETOMETER CALIBRATION
49NZ20121105  999   333   1  BIO 112212 0731   BE 26 18.33 S 165 35.83 E GPS   -9   3297   -9                          NEUSTON NET
49NZ20121105  999   333   1  BIO 112212 0930   EN 26 19.46 S 165 31.62 E GPS   -9   3188   -9                          NEUSTON NET
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R/V MIRAI CRUISE MR1205 LEG2
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SHIP/CRS EXPOCODE	WOCE SECT	STNNBR	CASTNO	CAST TYPE	DATE	UTC TIME	EVENT CODE	LATITUDE	LONGITUDE	NAV	UNC DEPTH	COR DEPTH	HT ABOVE BOTTOM	WIRE OUT	MAX PRESS	NO. OF BOTTLES	PARAMETERS	COMMENTS
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						

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49NZ20121128 P14S     18     1  ROS 120712 2021    BE 60 30.36 S 173 57.91 E GPS   -9   5038
49NZ20121128 P14S     18     1  BUC 120712 2029    UN 60 30.38 S 173 58.04 E GPS   -9   5024                           1,20                               4.0C
49NZ20121128 P14S     18     1  ROS 120712 2139    BO 60 30.65 S 173 58.37 E GPS   -9   5048     10   5024  5124   34 1-8,20,23,24,26,27,92,93
49NZ20121128 P14S     18     1  ROS 120712 2341    EN 60 30.95 S 173 58.65 E GPS   -9   5047
49NZ20121128 P14S     19     1  ROS 120812 0217    BE 60 59.22 S 173 58.73 E GPS   -9   4708
49NZ20121128 P14S     19     1  BUC 120812 0227    UN 60 59.27 S 173 58.59 E GPS   -9   4708                           1,20                               4.1C
49NZ20121128 P14S     19     1  ROS 120812 0331    BO 60 59.40 S 173 58.56 E GPS   -9   4674      9   4679  4772   32 1-8,20,27,93
49NZ20121128 P14S     19     1  ROS 120812 0524    EN 60 59.82 S 173 58.34 E GPS   -9   4723
49NZ20121128 P14S     20     1  ROS 120812 0807    BE 61 30.04 S 174  0.37 E GPS   -9   5036
49NZ20121128 P14S     20     1  BUC 120812 0814    UN 61 30.09 S 174  0.51 E GPS   -9   5036                           1,20                               3.1C
49NZ20121128 P14S     20     1  ROS 120812 0926    BO 61 30.39 S 174  0.92 E GPS   -9   5005      9   5053  5134   34 1-8,12,13,20,23,24,26,27,93
49NZ20121128 P14S     20     1  ROS 120812 1124    EN 61 30.70 S 174  1.53 E GPS   -9   4879
49NZ20121128 P14S     21     1  ROS 120812 1502    BE 62  0.16 S 173 16.45 E GPS   -9   4451
49NZ20121128 P14S     21     1  BUC 120812 1514    UN 62  0.31 S 173 16.80 E GPS   -9   4404                           1,20                               3.7C
49NZ20121128 P14S     21     1  ROS 120812 1613    BO 62  0.84 S 173 18.18 E GPS   -9   4330      3   4441  4459   31 1-8,20,23,24,26,27,31,37,42,93-95
49NZ20121128 P14S     21     1  ROS 120812 1805    EN 62  1.68 S 173 20.43 E GPS   -9   4088
49NZ20121128 P14S     22     1  ROS 120812 2114    BE 62 26.99 S 172 35.24 E GPS   -9   4420
49NZ20121128 P14S     22     1  BUC 120812 2122    UN 62 27.12 S 172 35.45 E GPS   -9   4424                           1,20                               1.8C
49NZ20121128 P14S     22     1  ROS 120812 2225    BO 62 27.69 S 172 36.20 E GPS   -9   4412      8   4458  4483   31 1-8,20,27,93
49NZ20121128 P14S     22     1  ROS 120912 0013    EN 62 28.70 S 172 38.35 E GPS   -9   4427
49NZ20121128 P14S     23     1  ROS 120912 0234    BE 62 44.68 S 172  9.00 E GPS   -9   4212
49NZ20121128 P14S     23     1  BUC 120912 0243    UN 62 44.75 S 172  9.35 E GPS   -9   4205                           1,20                               -0.1C
49NZ20121128 P14S     23     1  ROS 120912 0340    BO 62 45.06 S 172 10.19 E GPS   -9   4217     10   4201  4272   30 1-8,20,23,24,26,27,92,93
49NZ20121128 P14S     23     1  ROS 120912 0524    EN 62 45.87 S 172 12.94 E GPS   -9   4265
49NZ20121128 P14S     23     1  XMP 120912 0534    DE 62 45.99 S 172 12.97 E GPS   -9   4264                                                              #28
49NZ20121128 P14S     23     1  XMP 120912 0537    EN 62 46.04 S 172 12.89 E GPS   -9   4261                                                              FAIL AT 26DBAR
49NZ20121128 P14S     24     1  ROS 120912 0749    BE 63  0.01 S 171 45.02 E GPS   -9   2610
49NZ20121128 P14S     24     1  BUC 120912 0757    UN 63  0.02 S 171 45.09 E GPS   -9   2625                           1,20                               -0.5C
49NZ20121128 P14S     24     1  ROS 120912 0834    BO 63  0.09 S 171 45.44 E GPS   -9   2697      8   2612  2648   24 1-8,20,27,34,93
49NZ20121128 P14S     24     1  UNK 120912 0834    UN 63  0.09 S 171 45.44 E GPS   -9   2697                           22,89                              THROUGH HULL PUMP
49NZ20121128 P14S     24     1  ROS 120912 0945    EN 63  0.24 S 171 46.16 E GPS   -9   2637
49NZ20121128 P14S     24     1  XMP 120912 2055    DE 63 59.72 S 171  7.46 E GPS   -9   2557                                                              #26
49NZ20121128 P14S     24     1  XMP 120912 2223    EN 64  6.16 S 171  6.71 E GPS   -9   2645                                                              REACH BTM
49NZ20121128 P14S     25     1  ROS 120912 1501    BE 63 30.17 S 170 59.53 E GPS   -9   2385
49NZ20121128 P14S     25     1  BUC 120912 1509    UN 63 30.23 S 170 59.42 E GPS   -9   2357                           1,20                               -0.8C
49NZ20121128 P14S     25     1  XCT 120912 1514    DE 63 30.26 S 170 59.34 E GPS   -9   2349                                                              TSK XCTD-2 #11021852
49NZ20121128 P14S     25     1  ROS 120912 1542    BO 63 30.33 S 170 58.98 E GPS   -9   2338      9   2336  2362   23 1-8,12,13,20,23,24,26,27,31,37,42,93-95
49NZ20121128 P14S     25     1  ROS 120912 1646    EN 63 30.40 S 170 58.51 E GPS   -9   2297
49NZ20121128 P14S     26     1  ROS 120912 1948    BE 63 59.72 S 171  7.05 E GPS   -9   2557
49NZ20121128 P14S     26     1  BUC 120912 1955    UN 63 59.67 S 171  7.16 E GPS   -9   2556                           1,20                               -0.6C
49NZ20121128 P14S     26     1  ROS 120912 2031    BO 63 59.68 S 171  7.37 E GPS   -9   2558      9   2519  2586   23 1-8,20,27,93
49NZ20121128 P14S     26     1  ROS 120912 2141    EN 63 59.49 S 171  7.88 E GPS   -9   2562
49NZ20121128 P14S     27     1  ROS 121012 0211    BE 64 41.34 S 170 59.53 E GPS   -9   3378
49NZ20121128 P14S     27     1  BUC 121012 0219    UN 64 41.35 S 170 59.52 E GPS   -9   3376                           1,20                               -1.0C
49NZ20121128 P14S     27     1  ROS 121012 0307    BO 64 41.34 S 170 59.45 E GPS   -9   3379      9   3361  3416   27 1-8,20,23,24,26,27,92,93
49NZ20121128 P14S     27     1  ROS 121012 0436    EN 64 41.38 S 170 59.24 E GPS   -9   3366
49NZ20121128  S04    401     1  XCT 121012 0756    DE 64 20.31 S 170  7.77 E GPS   -9   3139                                                              TSK XCTD-2 #11021857
49NZ20121128  S04    402     1  ROS 121012 1115    BE 64  0.04 S 169 17.24 E GPS   -9   3041
49NZ20121128  S04    402     1  BUC 121012 1123    UN 64  0.09 S 169 17.26 E GPS   -9   3039                           1,20                               -0.7C
49NZ20121128  S04    402     1  XCT 121012 1128    DE 64  0.11 S 169 17.27 E GPS   -9   3042                                                              TSK XCTD-2 #12026192
49NZ20121128  S04    402     1  ROS 121012 1206    BO 64  0.25 S 169 17.24 E GPS   -9   3029      8   3043  3085   26 1-8,20,27,93
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49NZ20121128  S04    402    1  ROS 121012 1327    EN 64  0.52 S 169 17.08 E GPS    -9   3012
49NZ20121128  S04    403    1  XCT 121012 1551    DE 64  0.10 S 168 22.73 E GPS    -9   3159                                                                          TSK XCTD-2 #11021854
49NZ20121128  S04    404    1  ROS 121012 1830    BE 63 59.59 S 167 27.89 E GPS    -9   3176
49NZ20121128  S04    404    1  BUC 121012 1841    UN 63 59.60 S 167 27.86 E GPS    -9   3178                                        1,20                             -0.8C
49NZ20121128  S04    404    1  ROS 121012 1925    BO 63 59.71 S 167 27.69 E GPS    -9   3168      9   3177   3222   26 1-8,12,13,20,23,24,26,27,31,37,42,92-95
49NZ20121128  S04    404    1  ROS 121012 2047    EN 64  0.05 S 167 27.52 E GPS    -9   3151
49NZ20121128  S04    405    1  XCT 121012 2302    DE 63 59.20 S 166 33.97 E GPS    -9   2933                                                                          TSK XCTD-2 #11021856
49NZ20121128  S04    406    1  ROS 121112 0137    BE 64  0.63 S 165 38.97 E GPS    -9   3057
49NZ20121128  S04    406    1  BUC 121112 0145    UN 64  0.66 S 165 39.06 E GPS    -9   3056                                        1,20                             -1.0C
49NZ20121128  S04    406    1  ROS 121112 0228    BO 64  0.65 S 165 39.28 E GPS    -9   3064     10   3054   3101   26 1-8,20,27,93
49NZ20121128  S04    406    1  ROS 121112 0351    EN 64  0.85 S 165 39.23 E GPS    -9   3064
49NZ20121128  S04    407    1  XCT 121112 0621    DE 64  0.46 S 164 44.68 E GPS    -9   3096                                                                          TSK XCTD-2 #11021855
49NZ20121128  S04    408    1  ROS 121112 0900    BE 64  2.65 S 163 49.18 E GPS    -9   3033
49NZ20121128  S04    408    1  BUC 121112 0907    UN 64  2.64 S 163 49.16 E GPS    -9   3027                                        1,20                             -1.2C
49NZ20121128  S04    408    1  ROS 121112 0949    BO 64  2.72 S 163 49.05 E GPS    -9   3053      8   3016   3065   26 1-8,20,23,24,26,27,34,93
49NZ20121128  S04    408    1  ROS 121112 1107    EN 64  2.82 S 163 48.71 E GPS    -9   3138
49NZ20121128  S04    409    1  XCT 121112 1415    DE 63 55.26 S 162 54.70 E GPS    -9   2968                                                                          TSK XCTD-2 #11021859
49NZ20121128  S04    410    1  ROS 121112 1701    BE 63 47.58 S 162  0.23 E GPS    -9   2899
49NZ20121128  S04    410    1  BUC 121112 1708    UN 63 47.63 S 162  0.27 E GPS    -9   2900                                        1,20                             -1.3C
49NZ20121128  S04    410    1  ROS 121112 1749    BO 63 47.94 S 162  0.41 E GPS    -9   2904     10   2921   2932   25 1-8,20,27,93
49NZ20121128  S04    410    1  ROS 121112 1907    EN 63 48.39 S 162  0.95 E GPS    -9   2806
49NZ20121128  S04    411    1  XCT 121112 2157    DE 63 39.12 S 161  5.26 E GPS    -9   2808                                                                          TSK XCTD-2 #11021858
49NZ20121128  S04     50    1  ROS 121212 0207    BE 63 33.55 S 159 43.40 E GPS    -9   2546
49NZ20121128  S04     50    1  BUC 121212 0216    UN 63 33.62 S 159 43.55 E GPS    -9   2570                                        1,20                             -1.3C
49NZ20121128  S04     50    1  ROS 121212 0255    BO 63 33.94 S 159 43.74 E GPS    -9   2640     10   2643   2662   24 1-8,12,13,20,23,24,26,27,31,37,42,93-95
49NZ20121128  S04     50    1  ROS 121212 0408    EN 63 34.39 S 159 43.91 E GPS    -9   2644
49NZ20121128  S04    801    1  UNK 121212 2001    UN 62 38.09 S 160  0.56 E GPS    -9   2489                                                                          3-AXIS MAGNETOMETER CALIBRATION
49NZ20121128  S04     51    1  ROS 121312 0456    BE 63  2.56 S 159 26.51 E GPS    -9   2446
49NZ20121128  S04     51    1  ROS 121312 0511    BO 63  2.53 S 159 26.39 E GPS    -9   2457     -9    593    602   36 22,89
49NZ20121128  S04     51    1  ROS 121312 0533    EN 63  2.54 S 159 26.36 E GPS    -9   2457
49NZ20121128  S04     51    2  ROS 121312 0630    BE 63  2.57 S 159 26.29 E GPS    -9   2456
49NZ20121128  S04     51    2  BUC 121312 0638    UN 63  2.59 S 159 26.25 E GPS    -9   2454                                        1,20                             -1.1C
49NZ20121128  S04     51    2  ROS 121312 0710    BO 63  2.66 S 159 26.22 E GPS    -9   2451     10   2437   2473   23 1-8,20,22,27,89,93
49NZ20121128  S04     51    2  UNK 121312 0733    UN 63  2.71 S 159 26.17 E GPS    -9   2437                                        22,89                            THROUGH HULL PUMP
49NZ20121128  S04     51    2  ROS 121312 0816    EN 63  2.77 S 159 26.08 E GPS    -9   2437
49NZ20121128  S04     52    1  ROS 121312 1214    BE 62 47.40 S 158  9.70 E GPS    -9   2373
49NZ20121128  S04     52    1  BUC 121312 1223    UN 62 47.44 S 158  9.66 E GPS    -9   2361                                        1,20                             -1.2C
49NZ20121128  S04     52    1  ROS 121312 1255    BO 62 47.55 S 158  9.59 E GPS    -9   2349     11   2351   2381   23 1-8,20,23,24,26,27,93
49NZ20121128  S04     52    1  ROS 121312 1403    EN 62 47.65 S 158  9.24 E GPS    -9   2350
49NZ20121128  S04     53    1  ROS 121312 1918    BE 63 25.91 S 156 38.95 E GPS    -9   3163
49NZ20121128  S04     53    1  BUC 121312 1926    UN 63 25.94 S 156 38.96 E GPS    -9   3161                                        1,20                             -1.2C
49NZ20121128  S04     53    1  ROS 121312 2011    BO 63 26.08 S 156 39.16 E GPS    -9   3187      7   3174   3223   27 1-8,12,13,20,23,24,26,27,31,37,42,92-95
49NZ20121128  S04     53    1  ROS 121312 2139    EN 63 26.26 S 156 39.36 E GPS    -9   3269
49NZ20121128  S04     54    1  ROS 121412 0118    BE 63 25.95 S 155 10.70 E GPS    -9   3053
49NZ20121128  S04     54    1  BUC 121412 0127    UN 63 25.97 S 155 10.67 E GPS    -9   3062                                        1,20                             -1.2C
49NZ20121128  S04     54    1  ROS 121412 0210    BO 63 26.08 S 155 10.98 E GPS    -9   3072     10   3072   3114   26 1-8,20,27,93
49NZ20121128  S04     54    1  ROS 121412 0337    EN 63 26.36 S 155 11.13 E GPS    -9   2994
49NZ20121128  S04     55    1  ROS 121412 0656    BE 63 23.16 S 153 41.15 E GPS    -9   3138
49NZ20121128  S04     55    1  BUC 121412 0703    UN 63 23.11 S 153 41.10 E GPS    -9   3143                                        1,20,90                          -0.8C
49NZ20121128  S04     55    1  ROS 121412 0745    BO 63 23.04 S 153 41.04 E GPS    -9   3146     10   3136   3188   26 1-8,20,23,24,26,27,90,93
49NZ20121128  S04     55    1  ROS 121412 0910    EN 63 22.73 S 153 40.09 E GPS    -9   3127
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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
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49NZ20121128  S04   67    1  ROS 121712 1336   BE 61 59.96 S 137  1.19 E GPS   -9  3905
49NZ20121128  S04   67    1  BUC 121712 1346   UN 62  0.01 S 137  1.15 E GPS   -9  3908                                      1,20                                      0.0C
49NZ20121128  S04   67    1  ROS 121712 1441   BO 62  0.16 S 137  0.81 E GPS   -9  3969     10  3932  3997   29 1-8,12,13,20,23,24,26,27,37,42,93-95
49NZ20121128  S04   67    1  ROS 121712 1623   EN 62  0.41 S 137  0.79 E GPS   -9  4064
49NZ20121128  S04   67    1  FLT 121712 1633   DE 62  0.38 S 137  0.42 E GPS   -9  4066                                                                                DEEP ARGO #5/ID300234011981560
49NZ20121128  S04   68    1  ROS 121712 1950   BE 62  0.24 S 135 35.02 E GPS   -9  4308
49NZ20121128  S04   68    1  BUC 121712 1957   UN 62  0.24 S 135 34.92 E GPS   -9  4308                                      1,20                                      0.8C
49NZ20121128  S04   68    1  ROS 121712 2057   BO 62  0.25 S 135 34.41 E GPS   -9  4306     10  4297  4376   31 1-8,20,27,93
49NZ20121128  S04   68    1  ROS 121712 2246   EN 62  0.26 S 135 33.49 E GPS   -9  4305
49NZ20121128  999   802   1  UNK 121812 1315   UN 60  2.70 S 139 53.99 E GPS   -9  4441                                                                                3-AXIS MAGNETOMETER CALIBRATION
49NZ20121128  999   C04   1  XCT 121812 1359   BE 60  1.63 S 139 56.93 E GPS   -9  4445                                                                                TSK XCTD-2 #11021991
49NZ20121128  999   C04   1  MOR 121812 1857   BE 60  1.48 S 139 57.90 E GPS   -9  4445                                                                                SOUTHERN OCEAN BUOY RECOVERY
49NZ20121128  999   C04   1  ROS 121912 0229   BE 60  0.59 S 139 59.07 E GPS   -9  4448
49NZ20121128  999   C04   1  MOR 121912 0046   RE 60  2.46 S 139 56.13 E GPS   -9  4442
49NZ20121128  999   C04   1  BUC 121912 0238   UN 60  0.58 S 139 59.01 E GPS   -9  4446                                      1,20,90                                   1.4C
49NZ20121128  999   C04   1  ROS 121912 0340   BO 60  0.57 S 139 58.95 E GPS   -9  4446      9  4440  4526   31 1-8,20,27,90,93
49NZ20121128  999   C04   1  ROS 121912 0531   EN 60  0.55 S 139 58.99 E GPS   -9  4448
49NZ20121128  999   C04   1  FLT 121912 0542   DE 60  0.62 S 139 56.12 E GPS   -9  4447                                                                                DEEP ARGO #3/ID300234010565570
49NZ20121128  S04   69    1  ROS 122012 0029   BE 62  1.39 S 134 11.18 E GPS   -9  4337
49NZ20121128  S04   69    1  BUC 122012 0037   UN 62  1.35 S 134 11.23 E GPS   -9  4337                                      1,20,90                                   0.8C
49NZ20121128  S04   69    1  ROS 122012 0137   BO 62  1.16 S 134 11.67 E GPS   -9  4337      9  4338  4413   31 1-8,20,23,24,26,27,31,37,42,90,93-95
49NZ20121128  S04   69    1  ROS 122012 0330   EN 62  0.87 S 134 12.07 E GPS   -9  4337
49NZ20121128  S04   70    1  ROS 122012 0711   BE 61 59.92 S 132 45.55 E GPS   -9  4440
49NZ20121128  S04   70    1  ROS 122012 0746   BO 61 59.81 S 132 45.71 E GPS   -9  4441     -9  2054  2082   36 22,89
49NZ20121128  S04   70    1  ROS 122012 0827   EN 61 59.74 S 132 45.77 E GPS   -9  4441
49NZ20121128  S04   70    1  UNK 122012 0910   UN 61 59.98 S 132 36.06 E GPS   -9  4451                                      22,89                                     THROUGH HULL PUMP
49NZ20121128  S04   70    2  ROS 122012 0930   BE 61 59.91 S 132 36.47 E GPS   -9  4446
49NZ20121128  S04   70    2  ROS 122012 1039   BO 61 59.76 S 132 36.67 E GPS   -9  4447      9  4445  4530   36 22,89
49NZ20121128  S04   70    2  ROS 122012 1152   EN 61 59.67 S 132 36.74 E GPS   -9  4448
49NZ20121128  S04   70    3  ROS 122012 1302   BE 61 59.90 S 132 36.21 E GPS   -9  4448
49NZ20121128  S04   70    3  BUC 122012 1310   UN 61 59.84 S 132 36.13 E GPS   -9  4449                                      1,20                                      0.6C
49NZ20121128  S04   70    3  ROS 122012 1412   BO 61 59.67 S 132 36.28 E GPS   -9  4449      9  4445  4530   35 1-8,20,22,27,89,93
49NZ20121128  S04   70    3  ROS 122012 1603   EN 61 59.26 S 132 36.37 E GPS   -9  4452
49NZ20121128  S04   71    1  ROS 122012 1928   BE 62  0.53 S 131 19.91 E GPS   -9  4505
49NZ20121128  S04   71    1  BUC 122012 1935   UN 62  0.51 S 131 19.83 E GPS   -9  4505                                      1,20                                      0.7C
49NZ20121128  S04   71    1  ROS 122012 2037   BO 62  0.40 S 131 19.50 E GPS   -9  4508      9  4507  4589   32 1-8,12,13,20,23,24,26,27,31,37,42,92-95
49NZ20121128  S04   71    1  ROS 122012 2230   EN 62  0.20 S 131 18.89 E GPS   -9  4505
49NZ20121128  S04   72    1  ROS 122112 0217   BE 62  0.21 S 129 56.78 E GPS   -9  4462
49NZ20121128  S04   72    1  BUC 122112 0226   UN 62  0.20 S 129 56.71 E GPS   -9  4462                                      1,20                                      0.8C
49NZ20121128  S04   72    1  ROS 122112 0327   BO 62  0.09 S 129 56.31 E GPS   -9  4466      9  4465  4544   32 1-8,20,27,93
49NZ20121128  S04   72    1  ROS 122112 0520   EN 61 59.78 S 129 55.90 E GPS   -9  4465
49NZ20121128  S04   73    1  ROS 122112 0920   BE 62  0.82 S 128 31.49 E GPS   -9  4366
49NZ20121128  S04   73    1  BUC 122112 0928   UN 62  0.85 S 128 31.48 E GPS   -9  4366                                      1,20                                      0.6C
49NZ20121128  S04   73    1  ROS 122112 1028   BO 62  0.86 S 128 31.40 E GPS   -9  4366     10  4361  4443   31 1-8,20,23,24,26,27,34,93
49NZ20121128  S04   73    1  ROS 122112 1218   EN 62  0.92 S 128 31.34 E GPS   -9  4366
49NZ20121128  S04   74    1  ROS 122112 1613   BE 62  0.47 S 127  5.45 E GPS   -9  4343
49NZ20121128  S04   74    1  BUC 122112 1621   UN 62  0.48 S 127  5.44 E GPS   -9  4345                                      1,20                                      0.7C
49NZ20121128  S04   74    1  ROS 122112 1721   BO 62  0.47 S 127  5.43 E GPS   -9  4351      9  4330  4412   31 1-8,20,27,93
49NZ20121128  S04   74    1  ROS 122112 1916   EN 62  0.51 S 127  5.18 E GPS   -9  4339
49NZ20121128  S04   75    1  ROS 122112 2305   BE 62  0.23 S 125 39.50 E GPS   -9  4302
49NZ20121128  S04   75    1  BUC 122112 2314   UN 62  0.22 S 125 39.43 E GPS   -9  4303                                      1,20                                      0.7C
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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
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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
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R/V MIRAI CRUISE MR1205 LEG3

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

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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
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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
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49NZ20130106 S04I   123   1  UNK 012113 2214   UN 62 18.88 S 065 47.61 E GPS   -9  4376                              90              THROUGH HULL PUMP
49NZ20130106 S04I   123   1  ROS 012113 2248   BO 62 18.82 S 065 47.43 E GPS   -9  4371    10  4365  4443  31 1-8,12,13,20,23,24,26,27,37,42,92-95
49NZ20130106 S04I   123   1  ROS 012213 0038   EN 62 18.65 S 065 46.98 E GPS   -9  4371
49NZ20130106 S04I   124   1  ROS 012213 0406   BE 62 21.68 S 064 24.42 E GPS   -9  4331
49NZ20130106 S04I   124   1  BUC 012213 0415   UN 62 21.63 S 064 24.44 E GPS   -9  4326                              1,20            0.7C
49NZ20130106 S04I   124   1  ROS 012213 0514   BO 62 21.63 S 064 24.28 E GPS   -9  4327    10  4319  4400  31 1-8,20,27,93
49NZ20130106 S04I   124   1  ROS 012213 0707   EN 62 21.50 S 064 23.86 E GPS   -9  4327
49NZ20130106 S04I   125   1  ROS 012213 1139   BE 62 50.00 S 062 59.84 E GPS   -9  4185
49NZ20130106 S04I   125   1  BUC 012213 1148   UN 62 50.00 S 062 59.76 E GPS   -9  4194                              1,20,31,33      0.7C
49NZ20130106 S04I   125   1  ROS 012213 1246   BO 62 49.98 S 062 59.80 E GPS   -9  4187    10  4176  4256  32 1-8,20,23,24,26,27,31,33,34,93
49NZ20130106 S04I   125   1  ROS 012213 1436   EN 62 50.05 S 062 59.77 E GPS   -9  4189
49NZ20130106 S04I   126   1  ROS 012213 1812   BE 63  5.42 S 061 48.94 E GPS   -9  4469
49NZ20130106 S04I   126   1  BUC 012213 1820   UN 63  5.42 S 061 48.90 E GPS   -9  4466                              1,20            0.7C
49NZ20130106 S04I   126   1  ROS 012213 1922   BO 63  5.40 S 061 48.78 E GPS   -9  4465    10  4457  4542  31 1-8,20,27,93
49NZ20130106 S04I   126   1  ROS 012213 2115   EN 63  5.53 S 061 48.11 E GPS   -9  4466
49NZ20130106 S04I   127   1  ROS 012313 0033   BE 63 19.88 S 060 39.91 E GPS   -9  4503
49NZ20130106 S04I   127   1  BUC 012313 0043   UN 63 19.91 S 060 39.89 E GPS   -9  4507                              1,20            0.4C
49NZ20130106 S04I   127   1  ROS 012313 0143   BO 63 19.96 S 060 39.88 E GPS   -9  4502    10  4494  4580  31 1-8,20,23,24,26,27,37,42,93-95
49NZ20130106 S04I   127   1  ROS 012313 0336   EN 63 20.02 S 060 40.02 E GPS   -9  4502
49NZ20130106 S04I   128   1  ROS 012313 0655   BE 63 30.41 S 059 27.12 E GPS   -9  4292
49NZ20130106 S04I   128   1  BUC 012313 0704   UN 63 30.42 S 059 27.10 E GPS   -9  4296                              1,20            0.4C
49NZ20130106 S04I   128   1  ROS 012313 0803   BO 63 30.37 S 059 26.84 E GPS   -9  4294    10  4291  4365  31 1-8,12,13,20,23,24,26,27,92,93
49NZ20130106 S04I   128   1  ROS 012313 0954   EN 63 30.22 S 059 26.01 E GPS   -9  4300
49NZ20130106 S04I   129   1  ROS 012313 1250   BE 63 30.13 S 058 20.24 E GPS   -9  4533
49NZ20130106 S04I   129   1  BUC 012313 1259   UN 63 30.11 S 058 20.21 E GPS   -9  4537                              1,20            0.1C
49NZ20130106 S04I   129   1  ROS 012313 1400   BO 63 30.06 S 058 20.16 E GPS   -9  4535    10  4526  4614  32 1-8,20,27,93
49NZ20130106 S04I   129   1  ROS 012313 1555   EN 63 30.04 S 058 20.35 E GPS   -9  4537
49NZ20130106 S04I   130   1  ROS 012313 1901   BE 63 29.95 S 057  9.55 E GPS   -9  4703
49NZ20130106 S04I   130   1  BUC 012313 1909   UN 63 29.95 S 057  9.59 E GPS   -9  4700                              1,20            0.6C
49NZ20130106 S04I   130   1  ROS 012313 2014   BO 63 30.00 S 057  9.67 E GPS   -9  4702    -9  3904  4085  0                         A FUSE OF CTD DECK UNIT BLEW, ABORTED
49NZ20130106 S04I   130   1  ROS 012313 2113   EN 63 29.96 S 057  9.74 E GPS   -9  4702                                              AT 10M, NOT ON DECK
49NZ20130106 S04I   130   2  ROS 012313 2113   BE 63 29.96 S 057  9.74 E GPS   -9  4702
49NZ20130106 S04I   130   2  ROS 012313 2226   BO 63 29.95 S 057  9.81 E GPS   -9  4705    10  4699  4793  32 1-8,20,23,24,26,27,37,42,93-95
49NZ20130106 S04I   130   2  ROS 012413 0023   EN 63 29.99 S 057 10.17 E GPS   -9  4701
49NZ20130106  999   901   1  UNK 012413 0833   BE 63 18.00 S 053 50.06 E GPS   -9  4939                                              WEIGHT OF 300KG WITHOUT CTD/RMS
49NZ20130106  999   901   1  UNK 012413 1104   EN 63 18.04 S 053 50.23 E GPS   -9  4937
49NZ20130106  999   902   1  UNK 012413 1112   BE 63 18.45 S 053 49.91 E GPS   -9  4936                                              3-AXIS MAGNETMETER CALIBRATION
49NZ20130106  999   902   1  UNK 012413 1137   EN 63 18.62 S 053 49.91 E GPS   -9  4937
49NZ20130106 S04I   140   1  ROS 012413 2359   BE 65 27.33 S 053 21.69 E GPS   -9   465
49NZ20130106 S04I   140   1  BUC 012513 0001   UN 65 27.32 S 053 21.68 E GPS   -9   464                              1,20,31,33      -0.9C
49NZ20130106 S04I   140   1  ROS 012513 0013   BO 65 27.28 S 053 21.66 E GPS   -9   463     9   449   455  13 1-8,20,23,24,26,27,31,33,34,37,42,92-95
49NZ20130106 S04I   140   1  ROS 012513 0043   EN 65 27.26 S 053 21.60 E GPS   -9   464
49NZ20130106 S04I   139   1  ROS 012513 0245   BE 65 22.35 S 053 14.85 E GPS   -9  1161
49NZ20130106 S04I   139   1  BUC 012513 0254   UN 65 22.34 S 053 14.80 E GPS   -9  1167                              1,20            -0.7C
49NZ20130106 S04I   139   1  ROS 012513 0310   BO 65 22.30 S 053 14.76 E GPS   -9  1177     9  1143  1157  0                         ABORTED DUT TO ERROR
49NZ20130106 S04I   139   1  UNK 012513 0312   UN 65 22.31 S 053 14.76 E GPS   -9  1173                              90              THROUGH HULL PUMP
49NZ20130106 S04I   139   1  ROS 012513 0330   EN 65 22.26 S 053 14.77 E GPS   -9  1202
49NZ20130106 S04I   139   2  ROS 012513 0358   BE 65 22.10 S 053 14.98 E GPS   -9  1280
49NZ20130106 S04I   139   2  ROS 012513 0423   BO 65 22.09 S 053 14.77 E GPS   -9  1261     9  1238  1253  18 1-8,20,23,24,26,27,37,42,93-95
49NZ20130106 S04I   139   2  ROS 012513 0514   EN 65 22.12 S 053 14.18 E GPS   -9  1267
49NZ20130106 S04I   138   1  ROS 012513 0714   BE 65 13.49 S 053  7.98 E GPS   -9  1875
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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
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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
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49NZ20130106 S04I    147    1  BUC 012813 1806    UN 63 59.03 S 044 50.71 E GPS    -9  4441                              1,20                                          1.4C
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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
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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
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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
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49NZ20130106 S04I    152    1  ROS 013013 0659    EN 65  7.77 S 037 20.66 E GPS    -9  4836
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49NZ20130106 S04I    153    1  ROS 013013 1307    EN 65 17.98 S 036  7.17 E GPS    -9  4648
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49NZ20130106 S04I    154    1  ROS 013013 1921    EN 65 32.27 S 034 55.49 E GPS    -9  4528
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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
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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
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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
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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
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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
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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 bacteria	BACT	
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 (°C), (b) sea surface salinity (psu), (c) sea surface oxygen (μmol/ kg), and (d) sea surface chlorophyll a (mg/m^3) measured by the Continuous Sea Surface Water Monitoring System.

Figure 5　Difference in the partial pressure of CO_2 between the ocean and the atmosphere, ΔpCO_2.

Figure 6　Surface current at 100 m depth measured by ship board acoustic Doppler current profiler (ADCP).

Figure 7　Potential temperature (°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°E, 53°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 (g/kg) cross sections calculated by using CTD salinity data. Vertical exaggeration is same as Fig. 7.

Figure 10　Density (upper: σ_0, lower: σ_4) (kg/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°E, 53°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 (γ^n) (kg/m^3) cross sections calculated by using CTD temperature and salinity data. Vertical exaggeration is same as Fig. 7.

Figure 12　CTD oxygen (μmol/kg) cross sections. Vertical exaggeration is same as Fig. 7.

Figure 13　CTD chlorophyll a (μg/L) cross sections. Vertical exaggeration of the upper 1000 m section is same as Fig. 7.

Figure 14　CTD beam attenuation coefficient (m^{-1}) cross sections. Vertical exaggeration is same as Fig. 7.

Figure 15　Bottle sampled dissolved oxygen (μmol/kg) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 16　Silicate (μmol/kg) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

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

Figure 18   Nitrite (µmol/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 (µmol/kg) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 20   Dissolved inorganic carbon (µmol/kg) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

Figure 21   Total alkalinity (µmol/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 (pmol/kg) cross sections. Data with quality flags of 2 were plotted. Vertical exaggeration is same as Fig. 7.

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

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

Figure 26 SF_6 (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 (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 (°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 °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[1] 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 (µmol/kg). CTD oxygen data were used. On white areas differences in dissolved oxygen do not exceed the detection limit of 2 µmol/kg.

Figure 31   Same as Fig. 30, but for bottle sampled dissolved oxygen (µmol/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
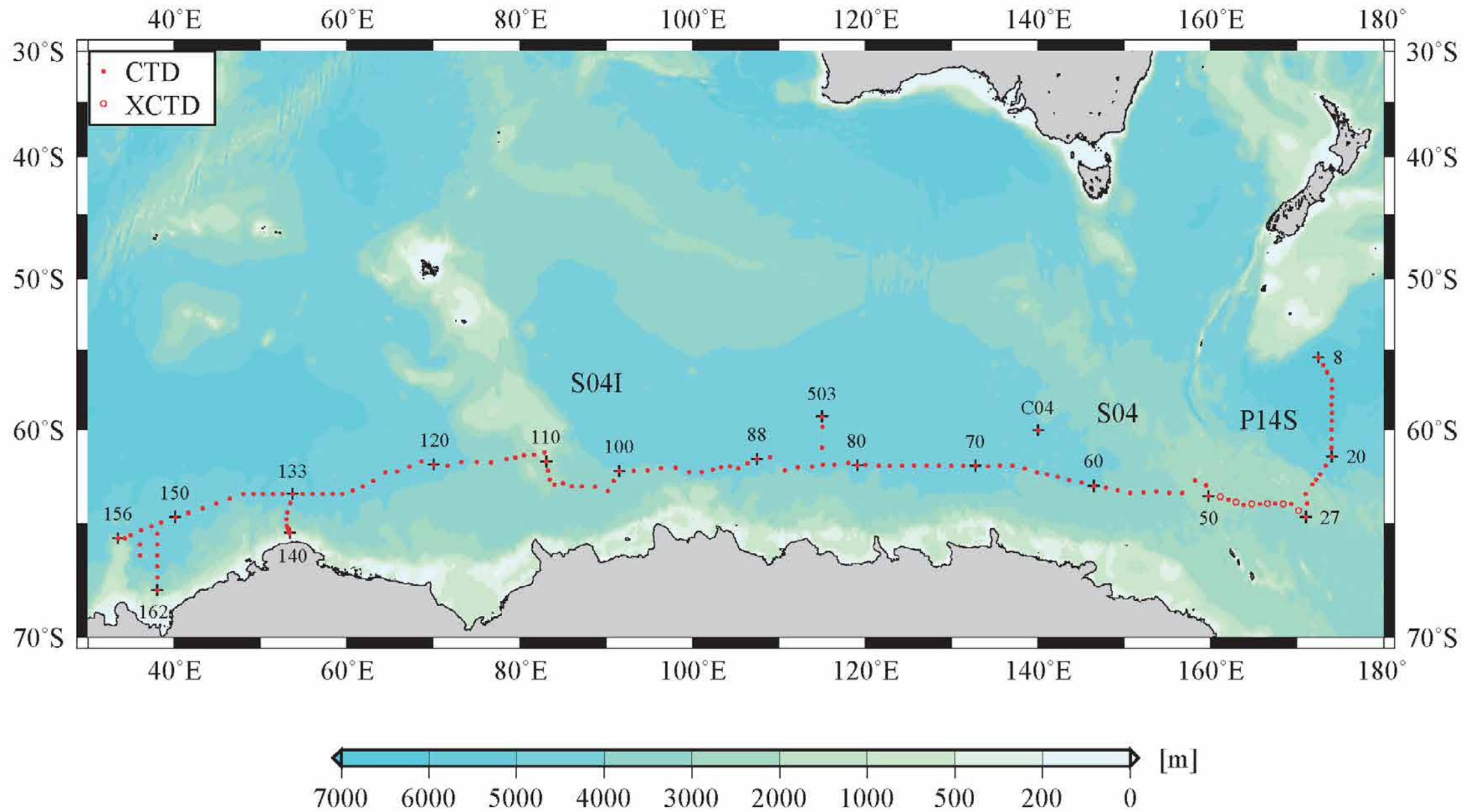
Figure 2

Bathymetry measured by Multi Narrow Beam Echo Sounding system
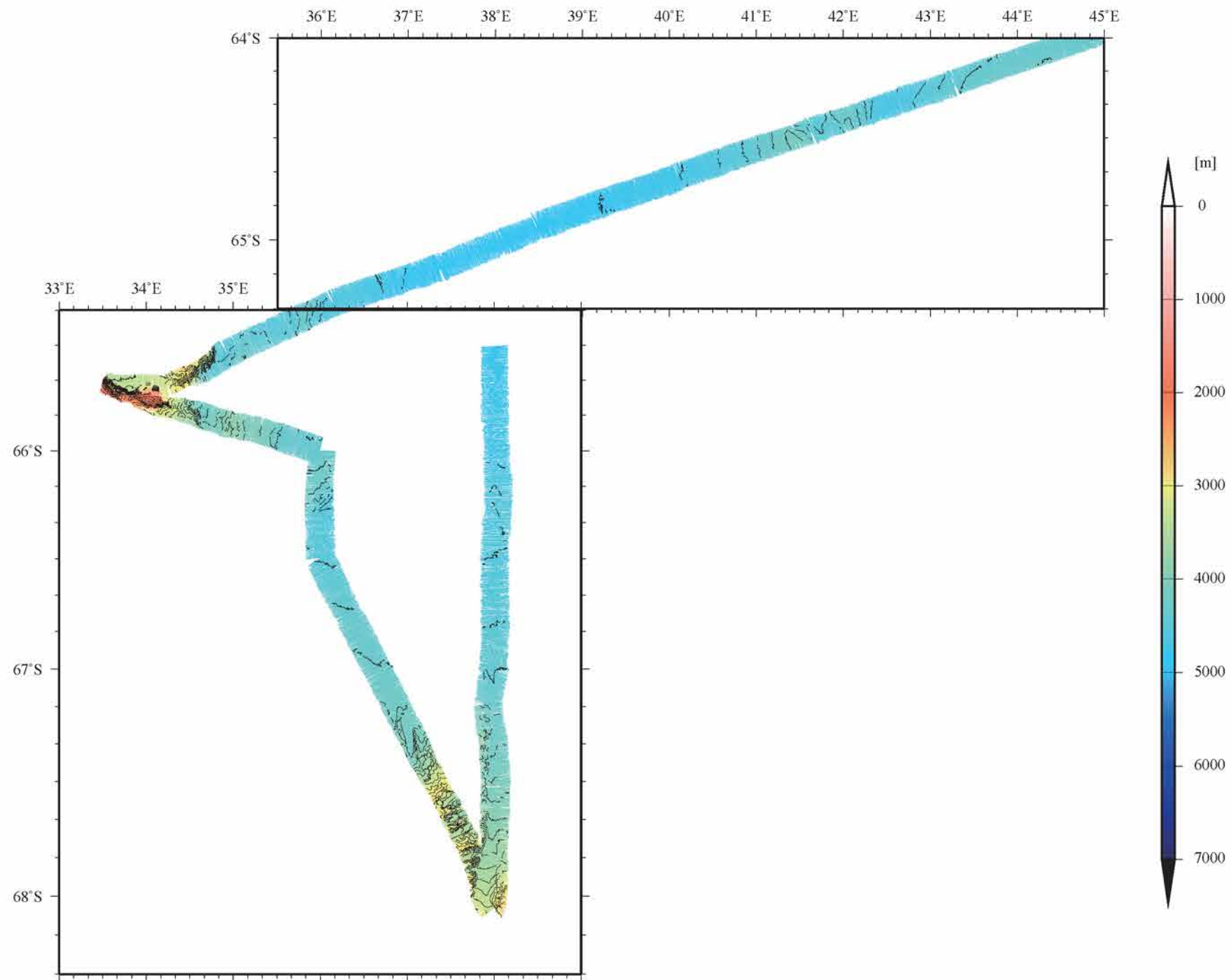
Figure 2
Continued
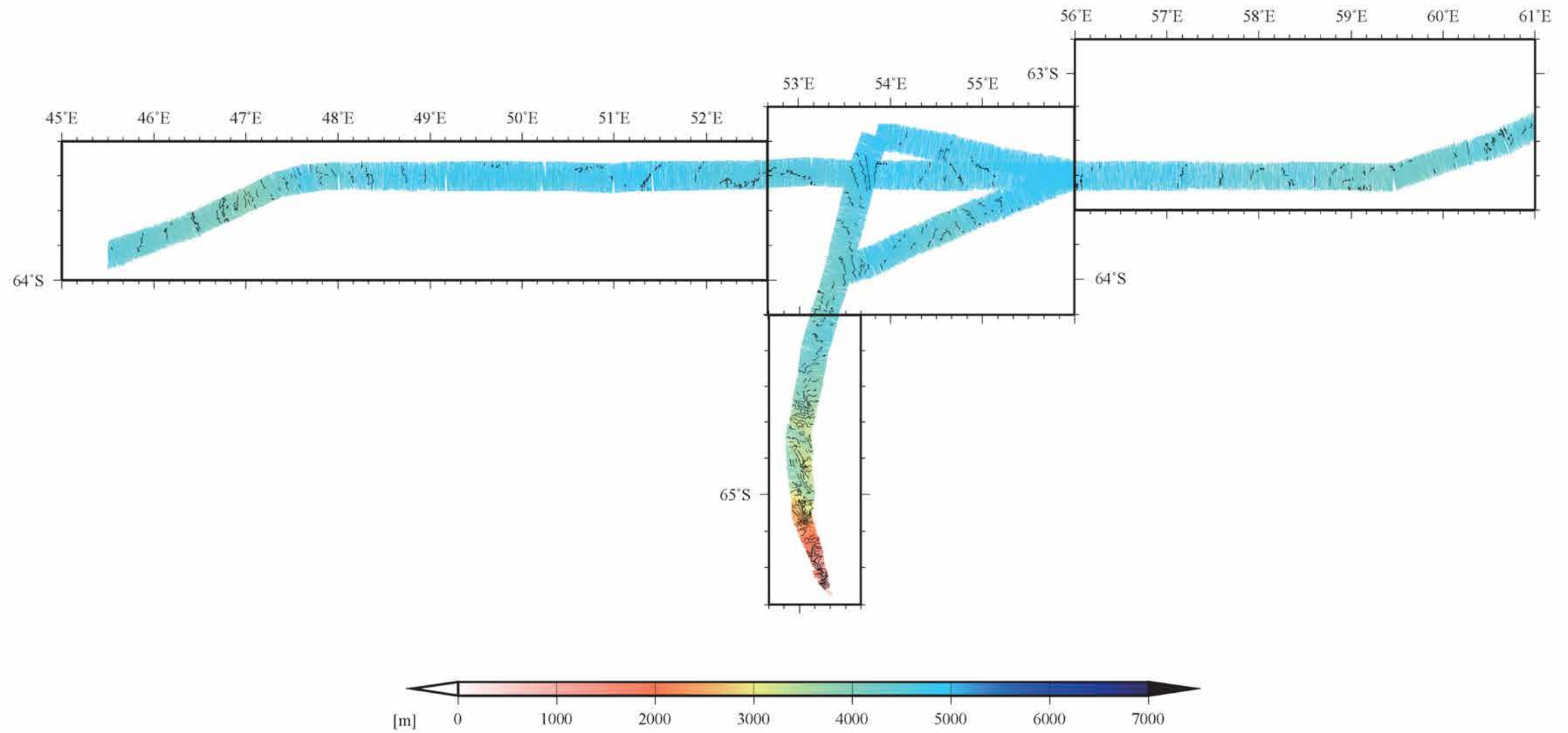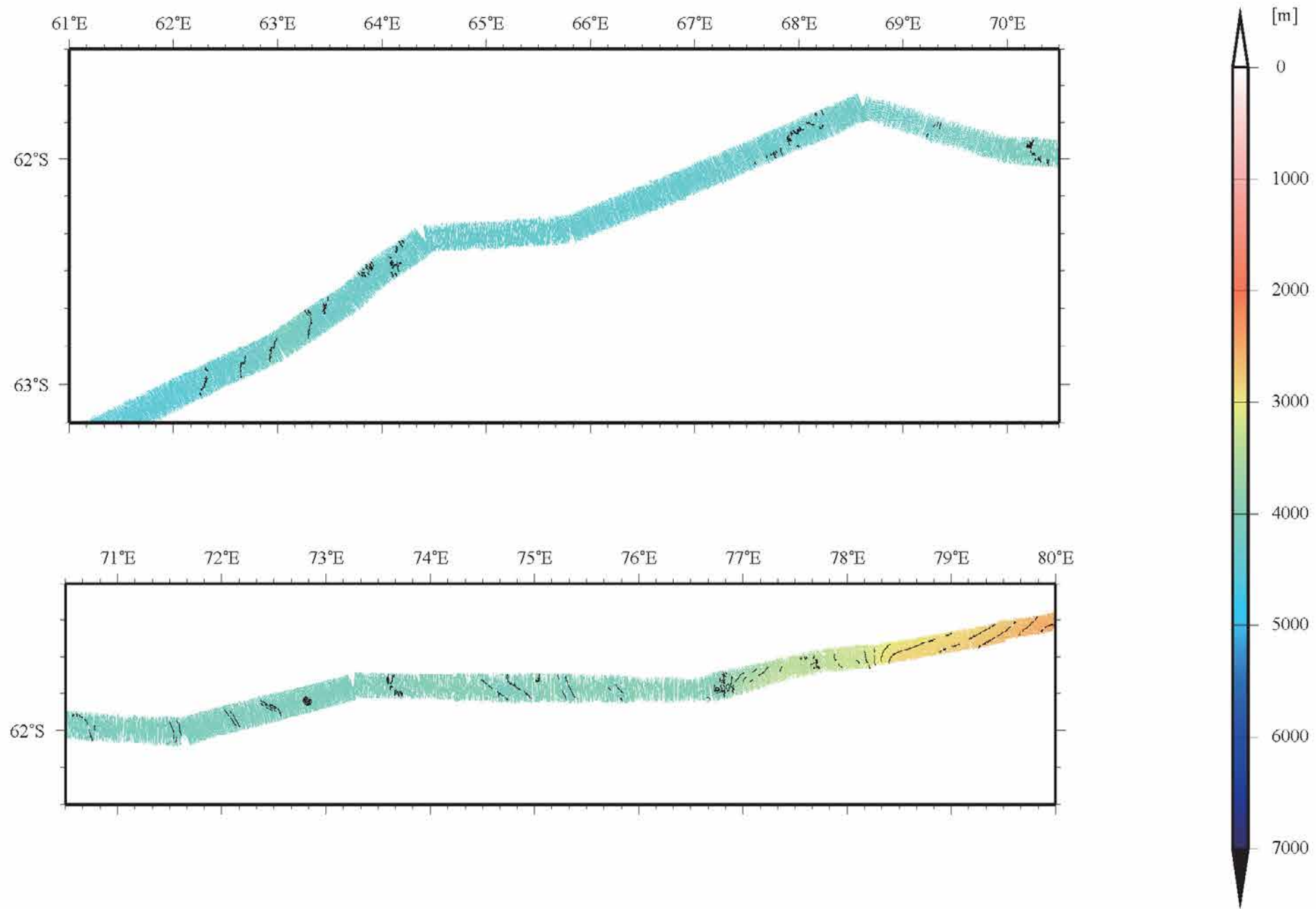
Figure 2
Continued
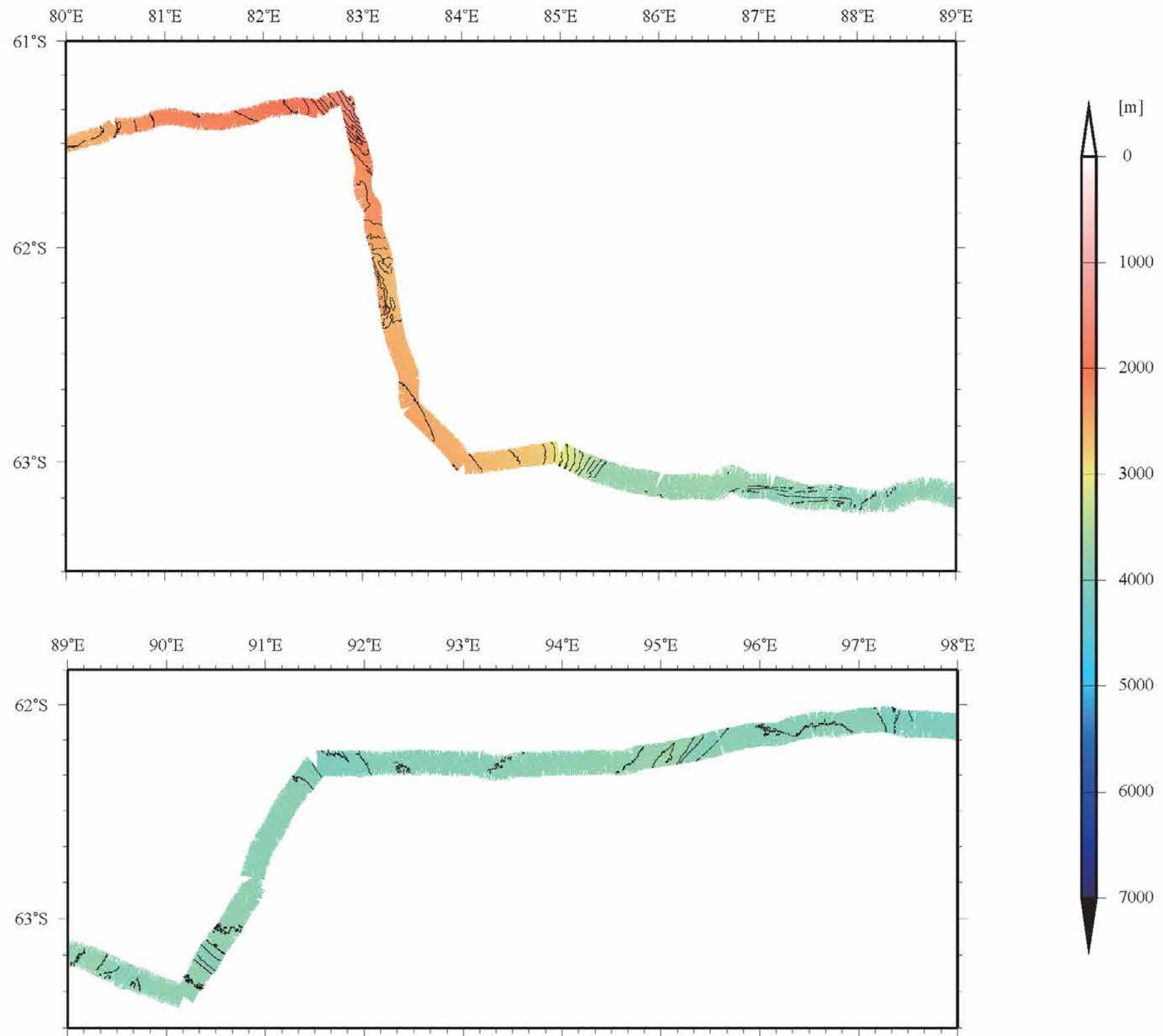
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Continued
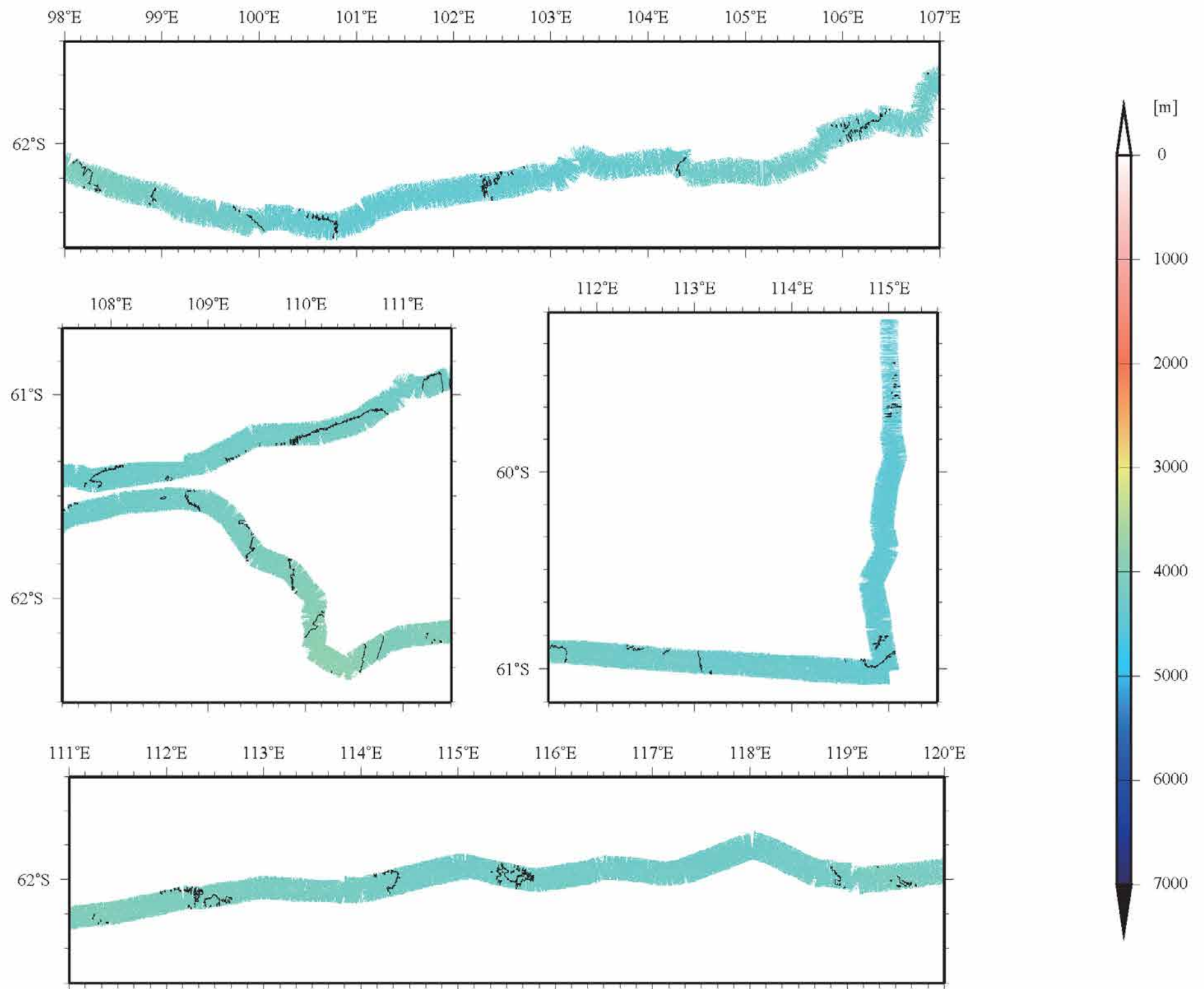
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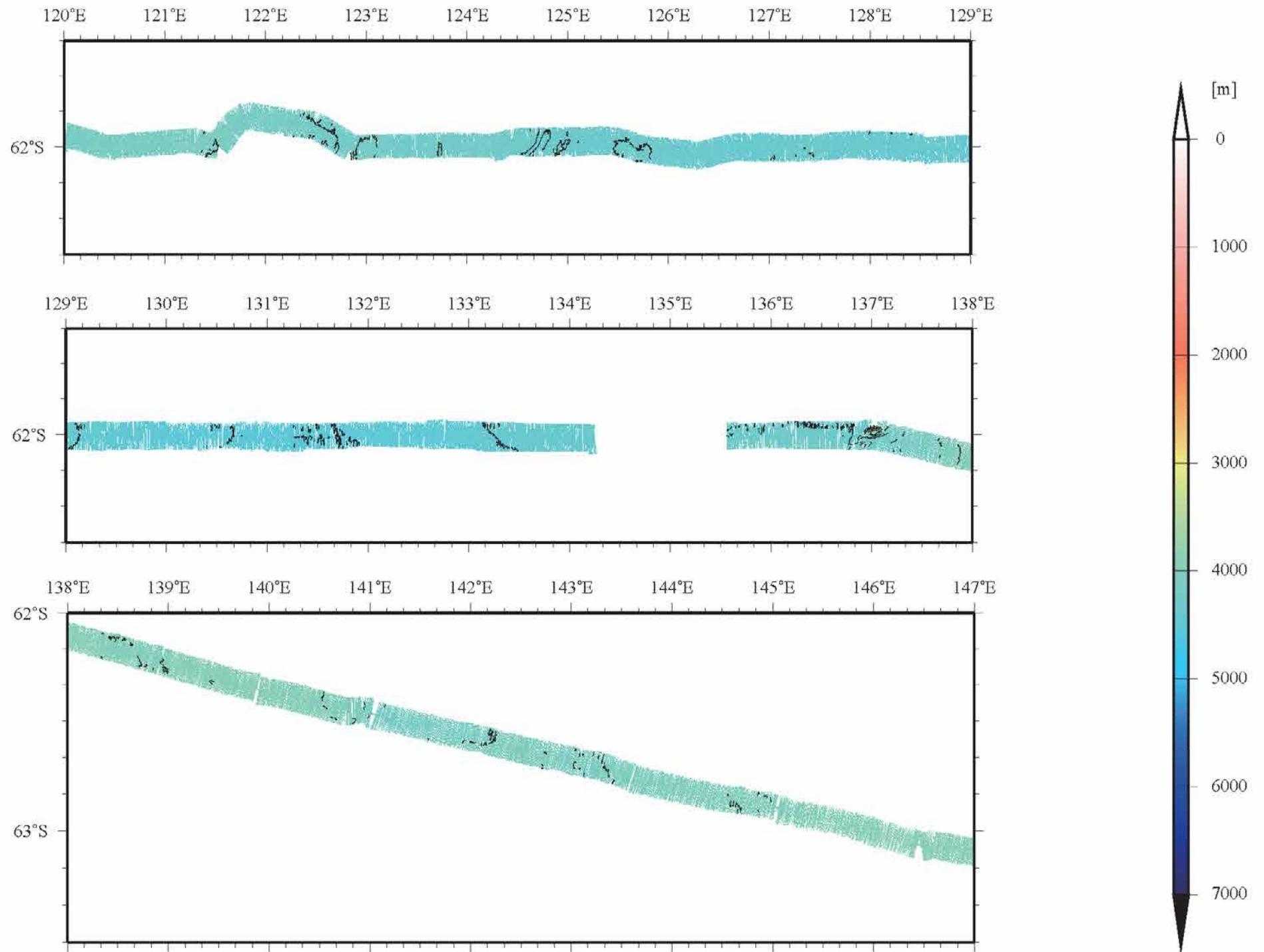
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Continued
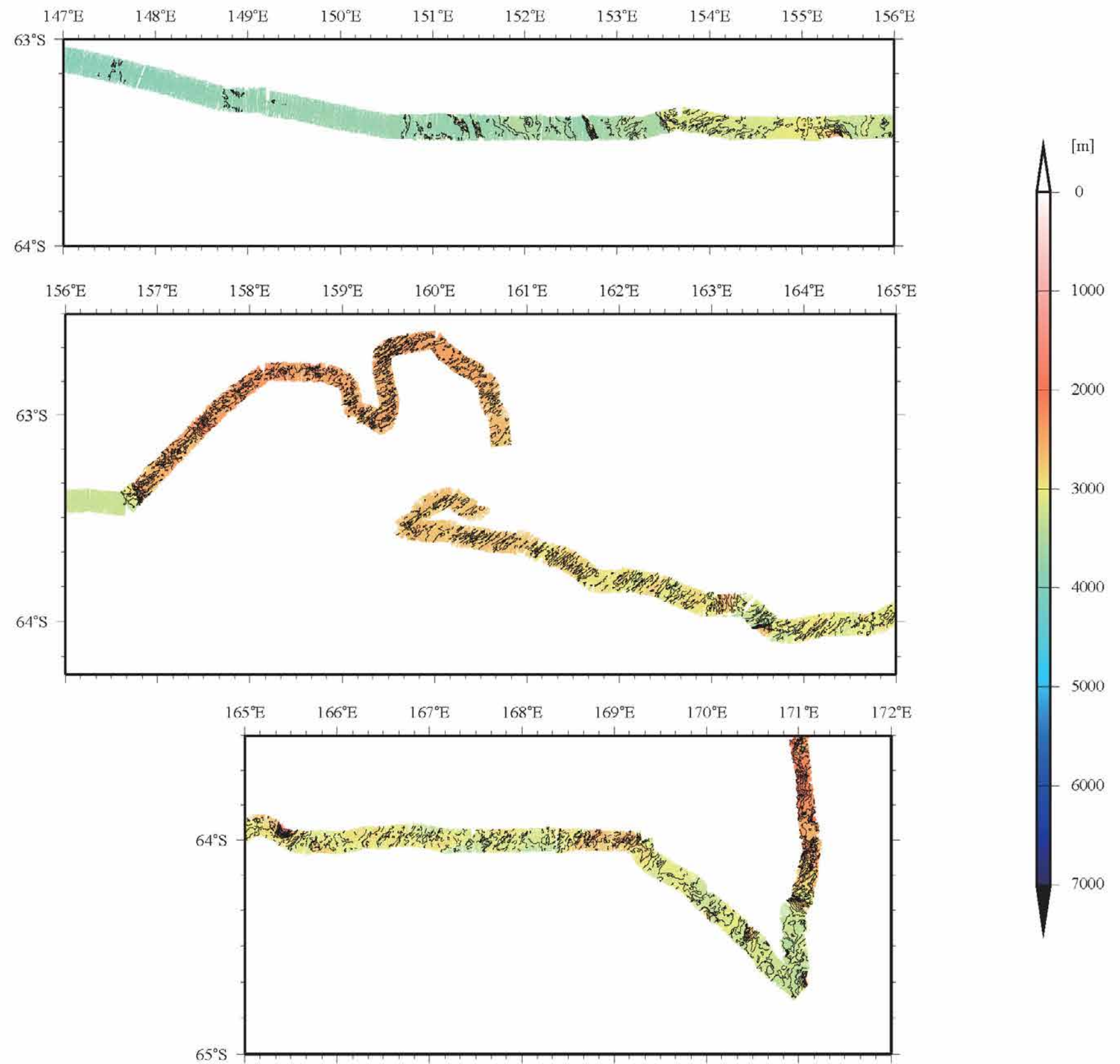
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Continued
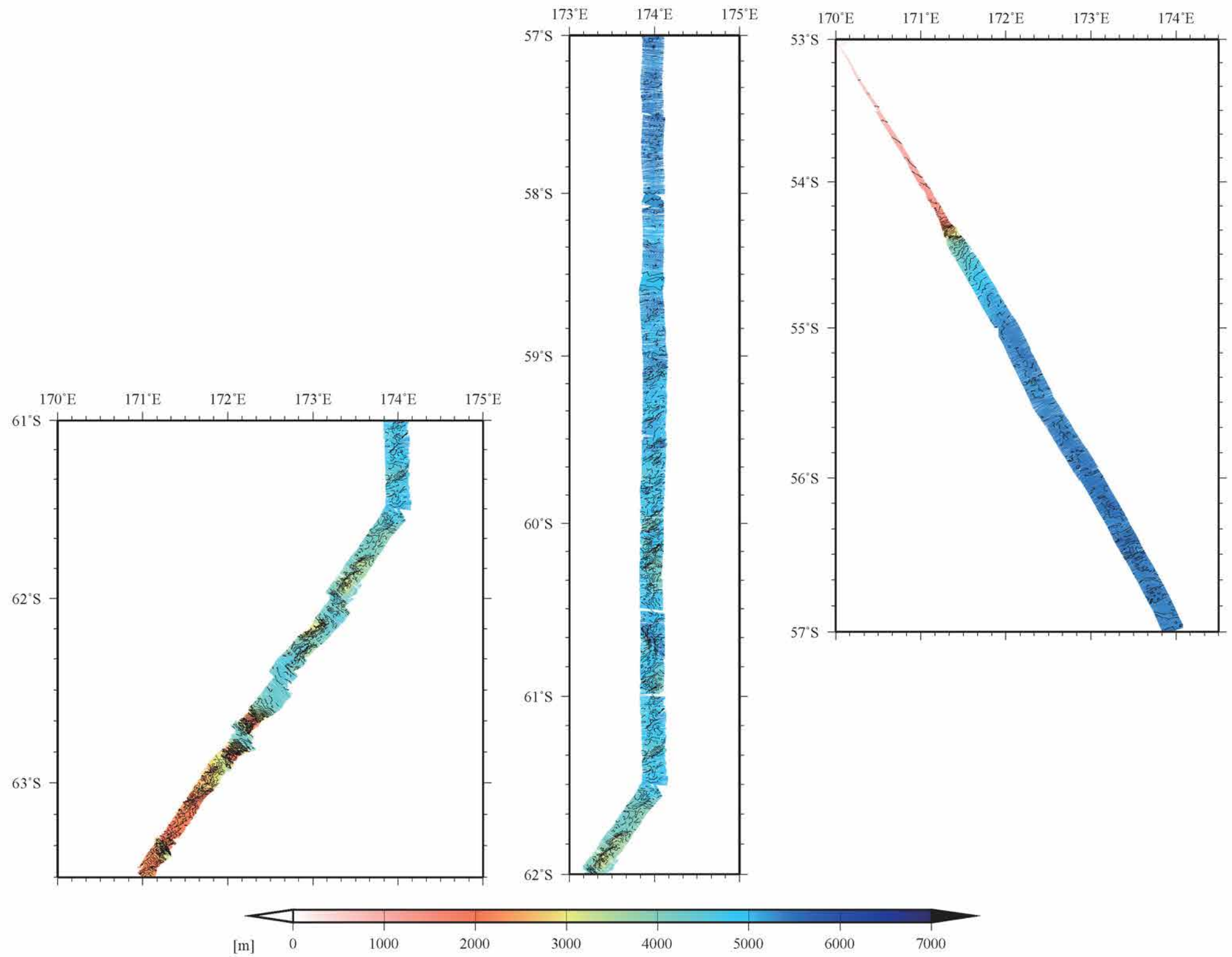
Figure 2
Continued

Figure 3

Surface wind measured at 25 m above sea level

Figure 4a
Sea surface temperature (ºC)
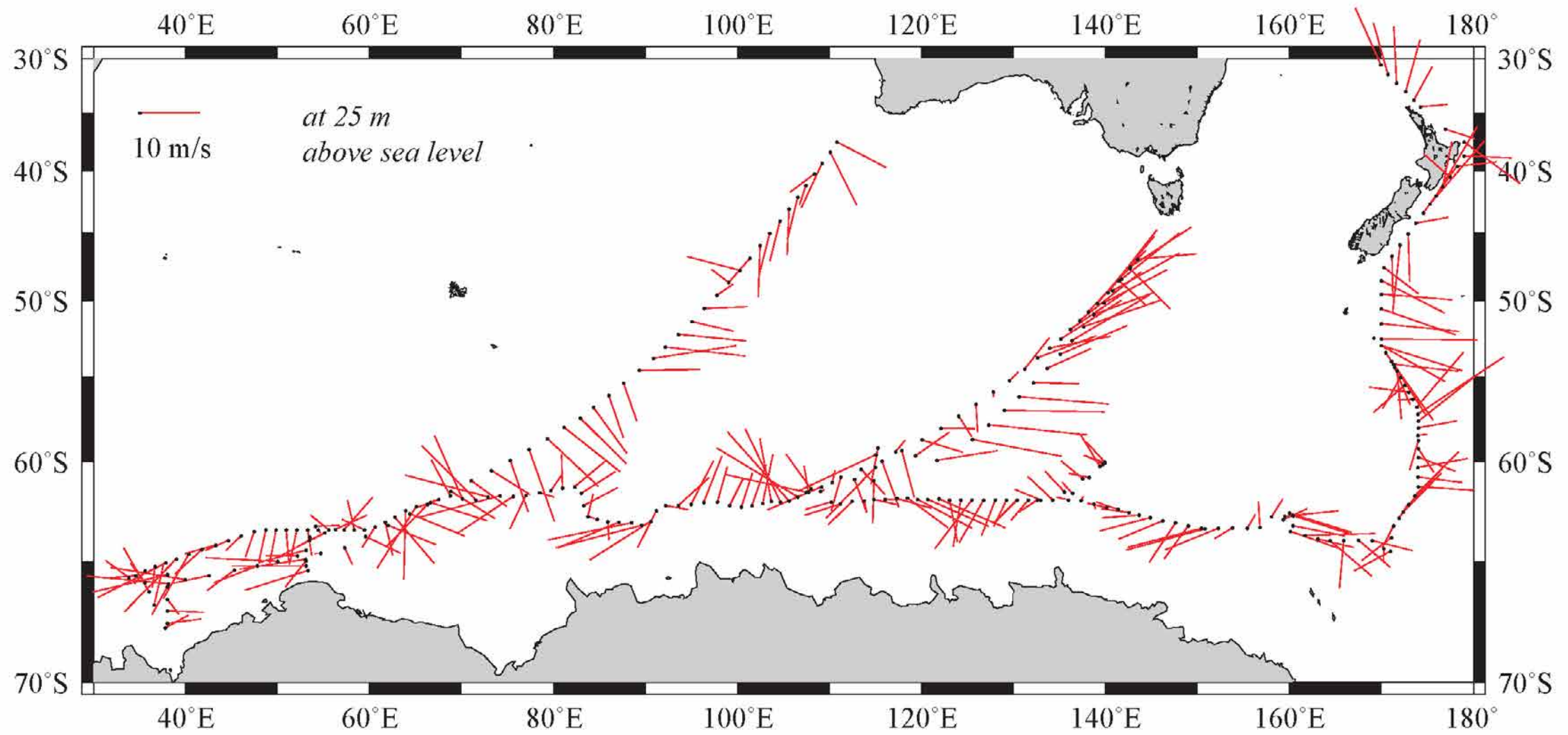
Sea Surface Temperature
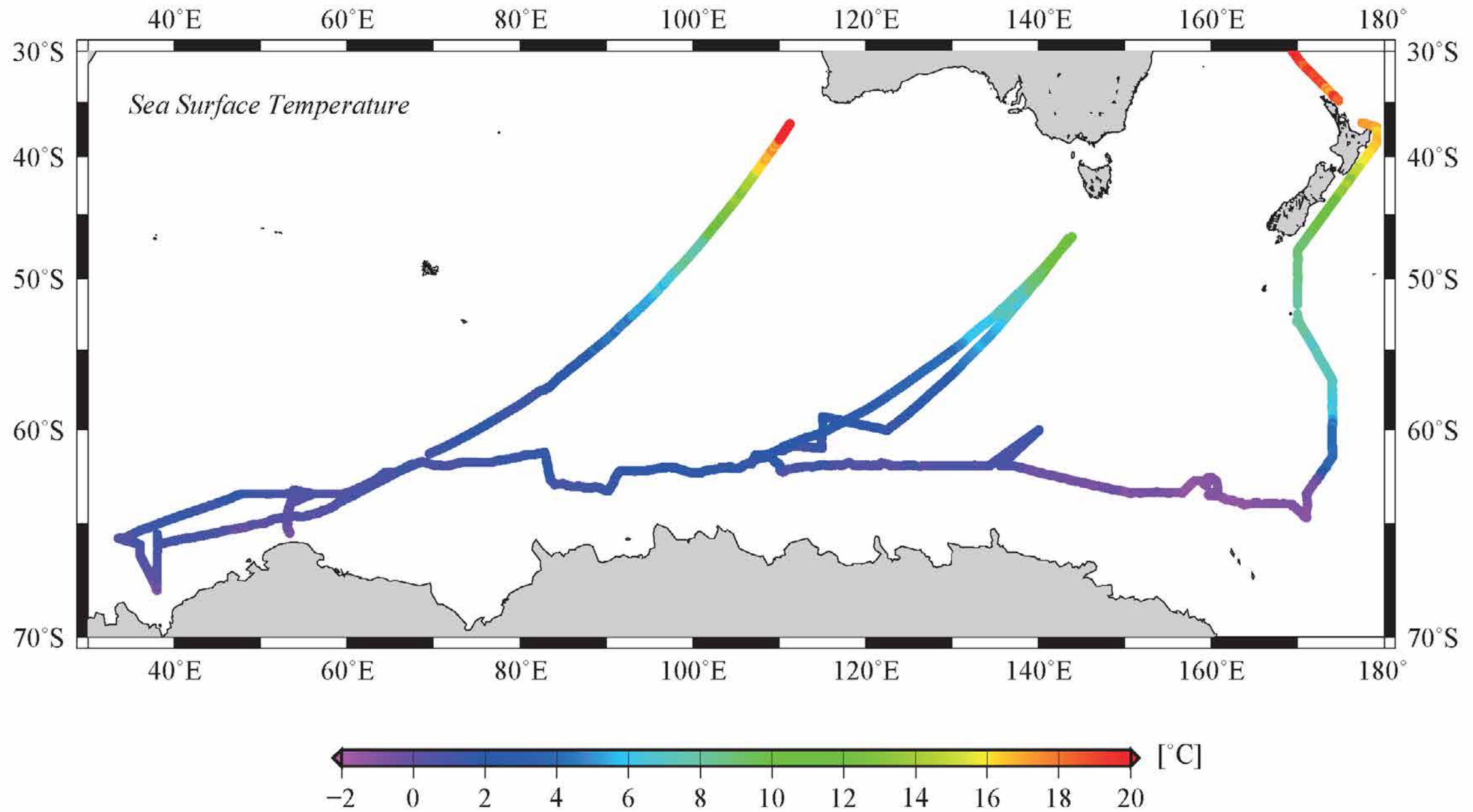
Figure 4b
Sea surface salinity (psu)

Sea Surface Salinity
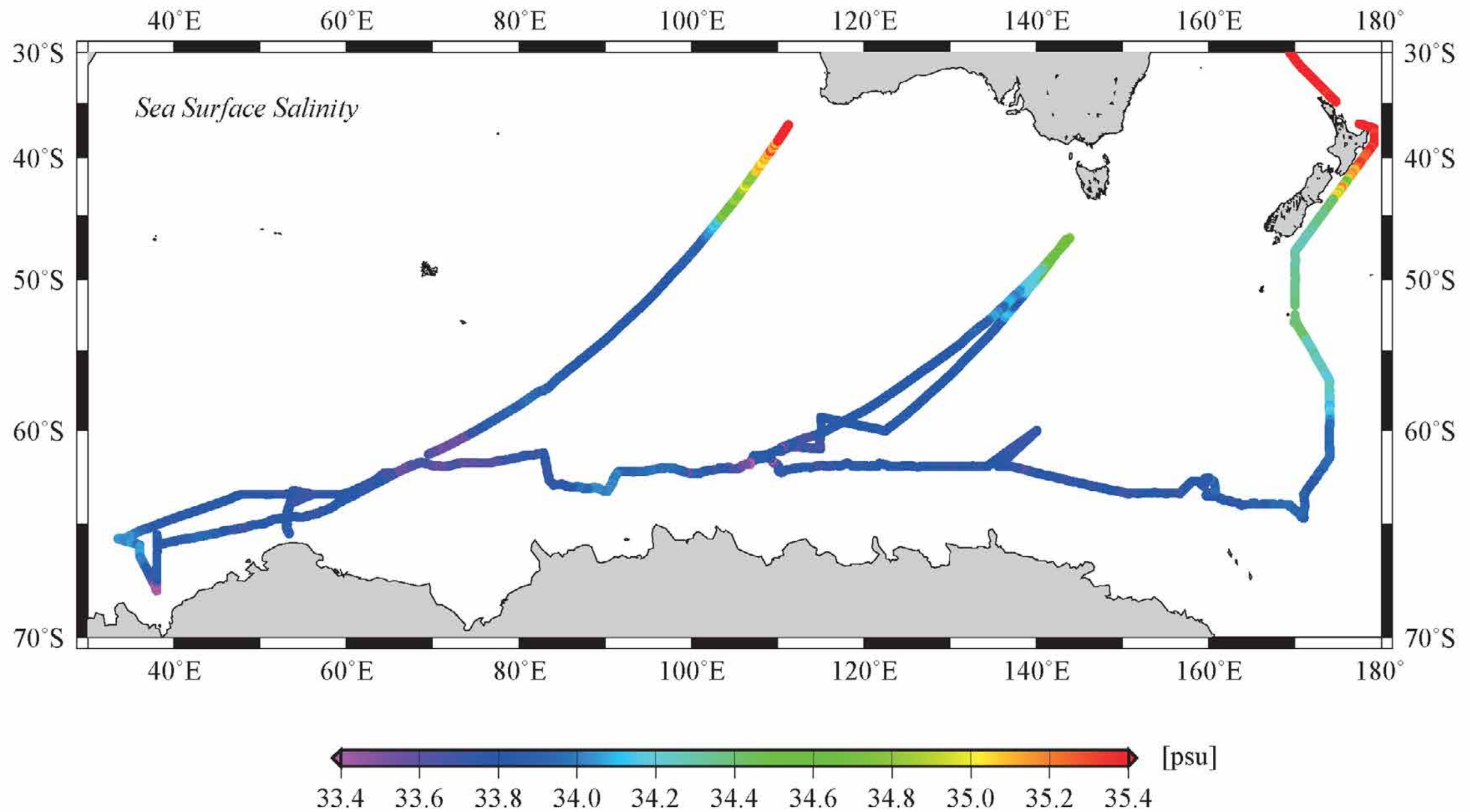
Figure 4c
Sea surface oxygen (μmol/kg)
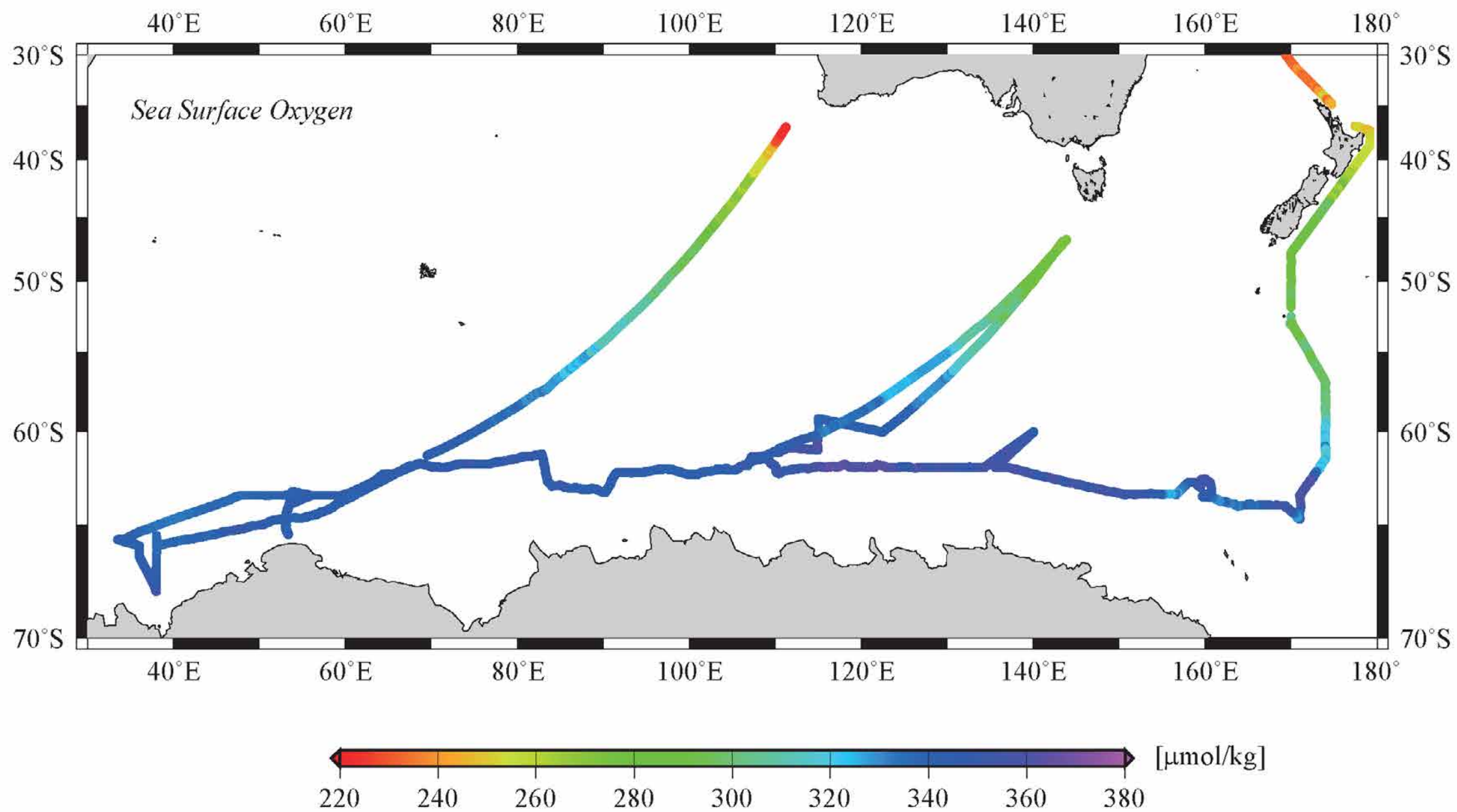
Figure 4d
Sea surface chlorophyll a (mg/m^3)
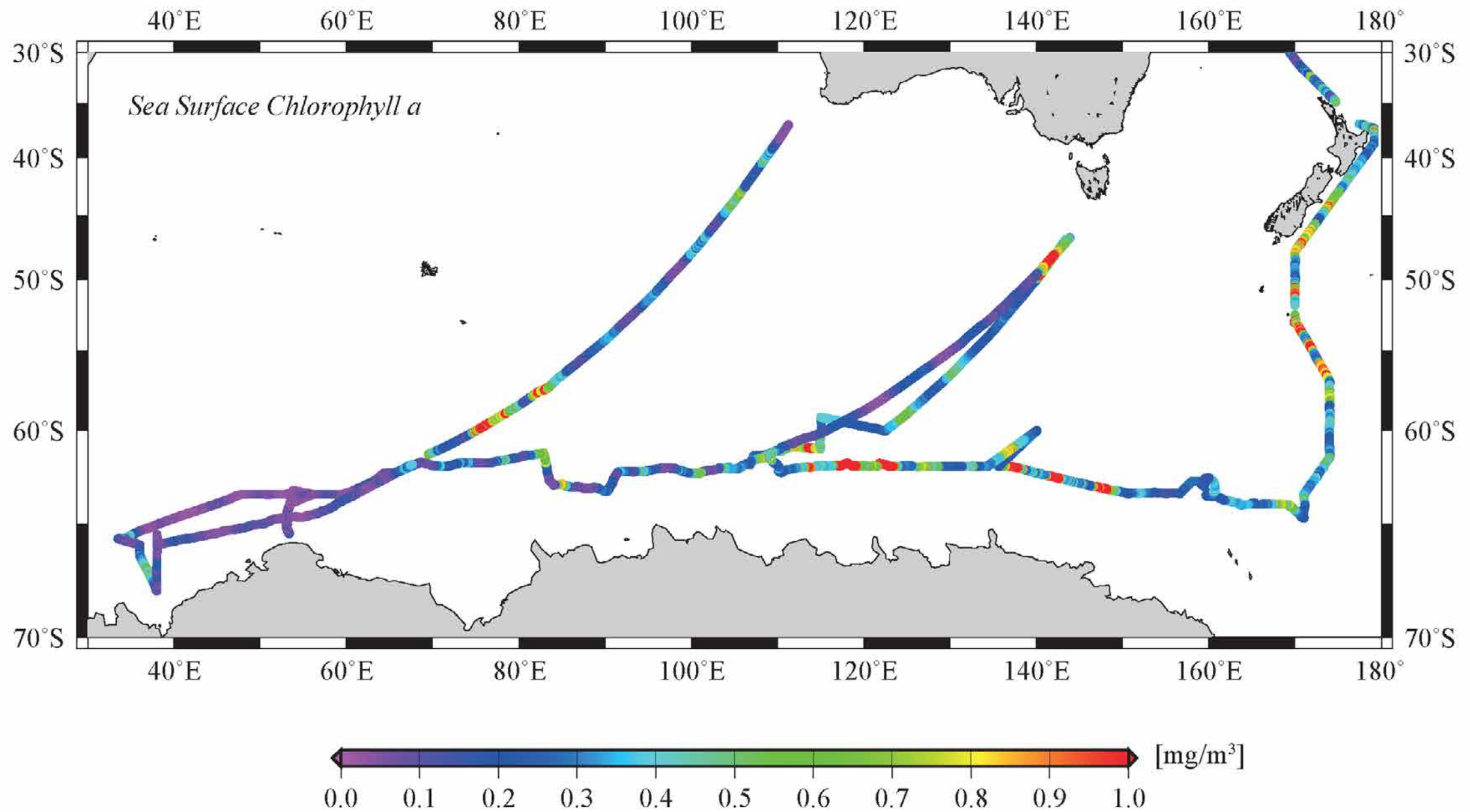
Figure 5

ΔpCO_2 (ppmv)
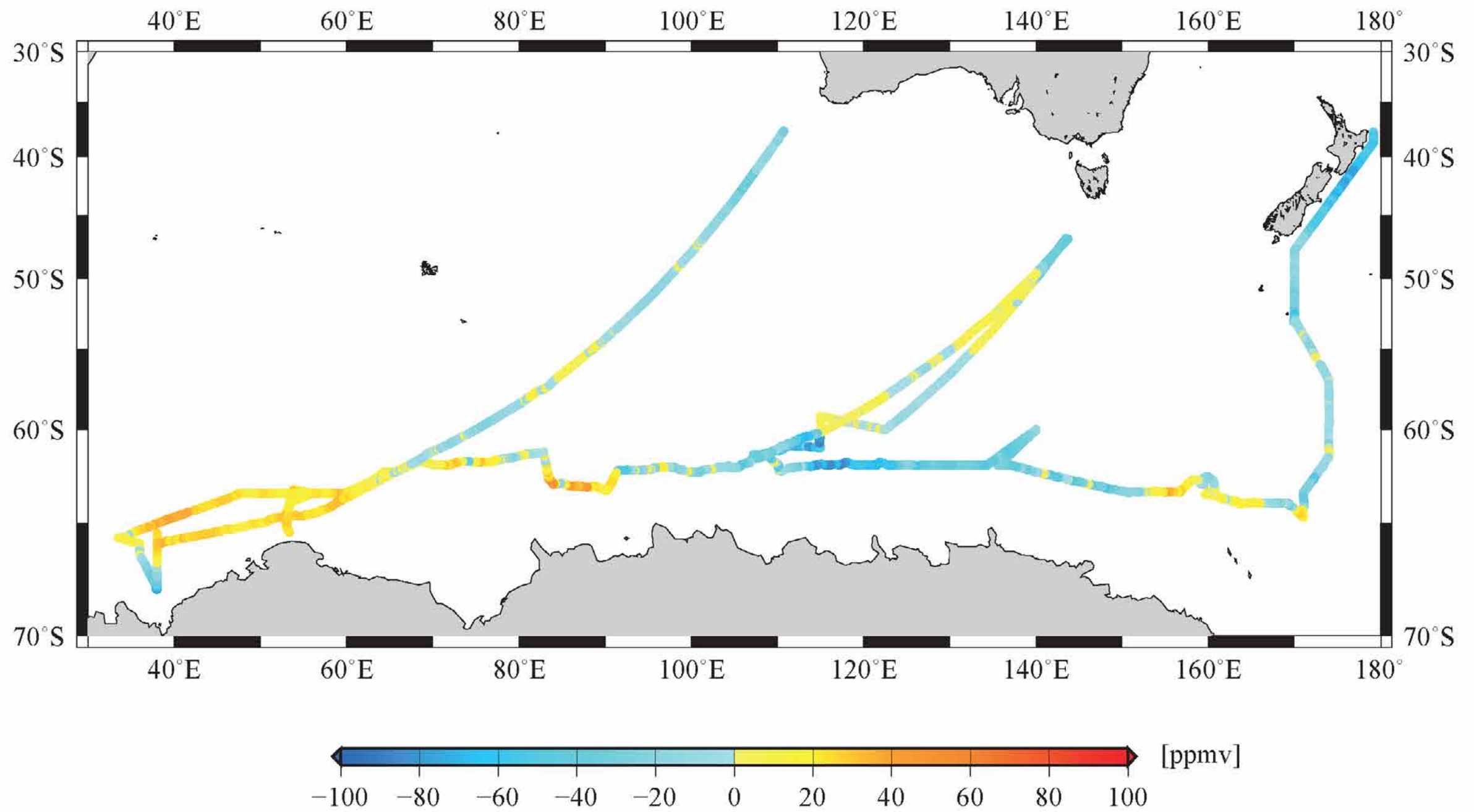
Figure 6
Surface current measured by shipboard ADCP
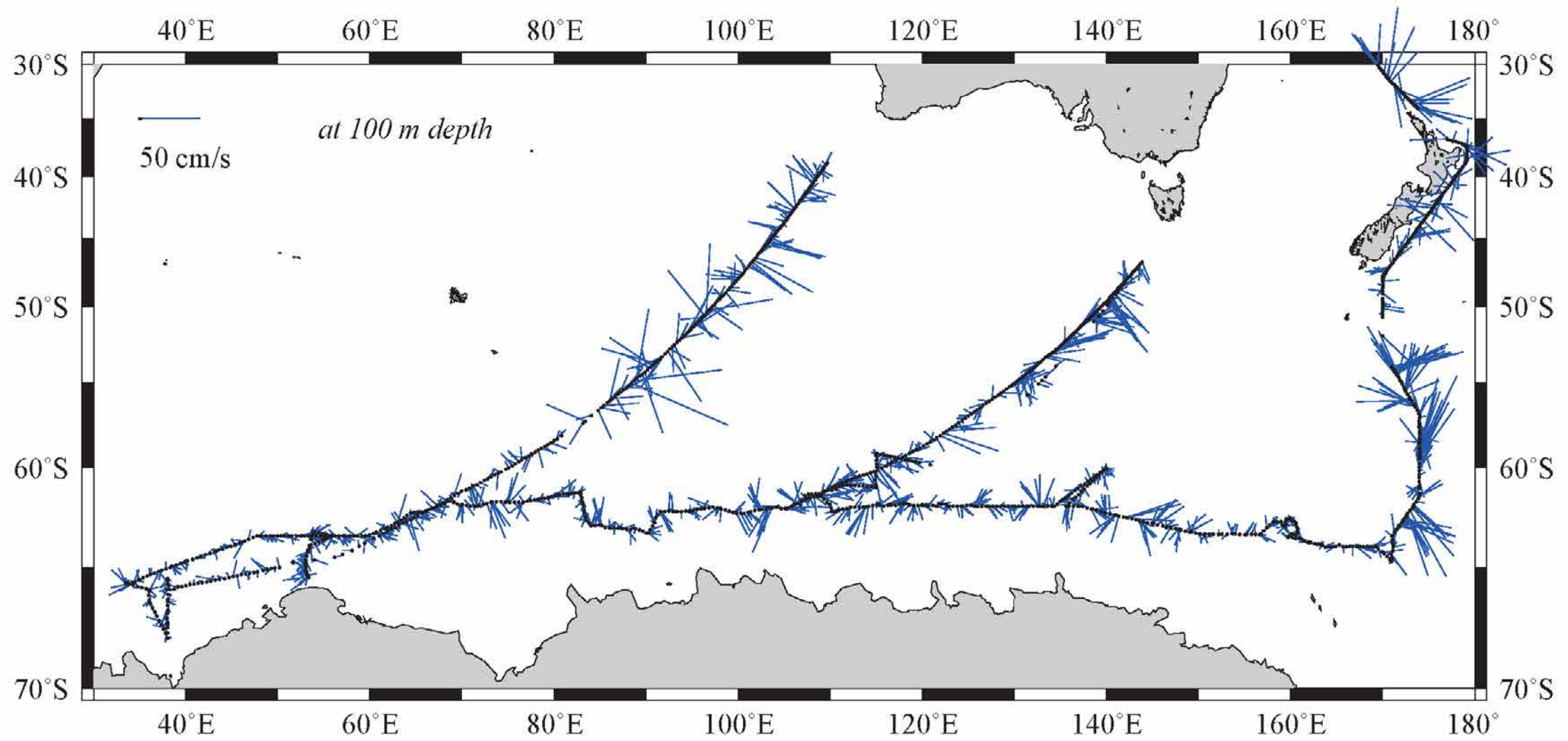
Figure 7
Potential temperature (ºC)
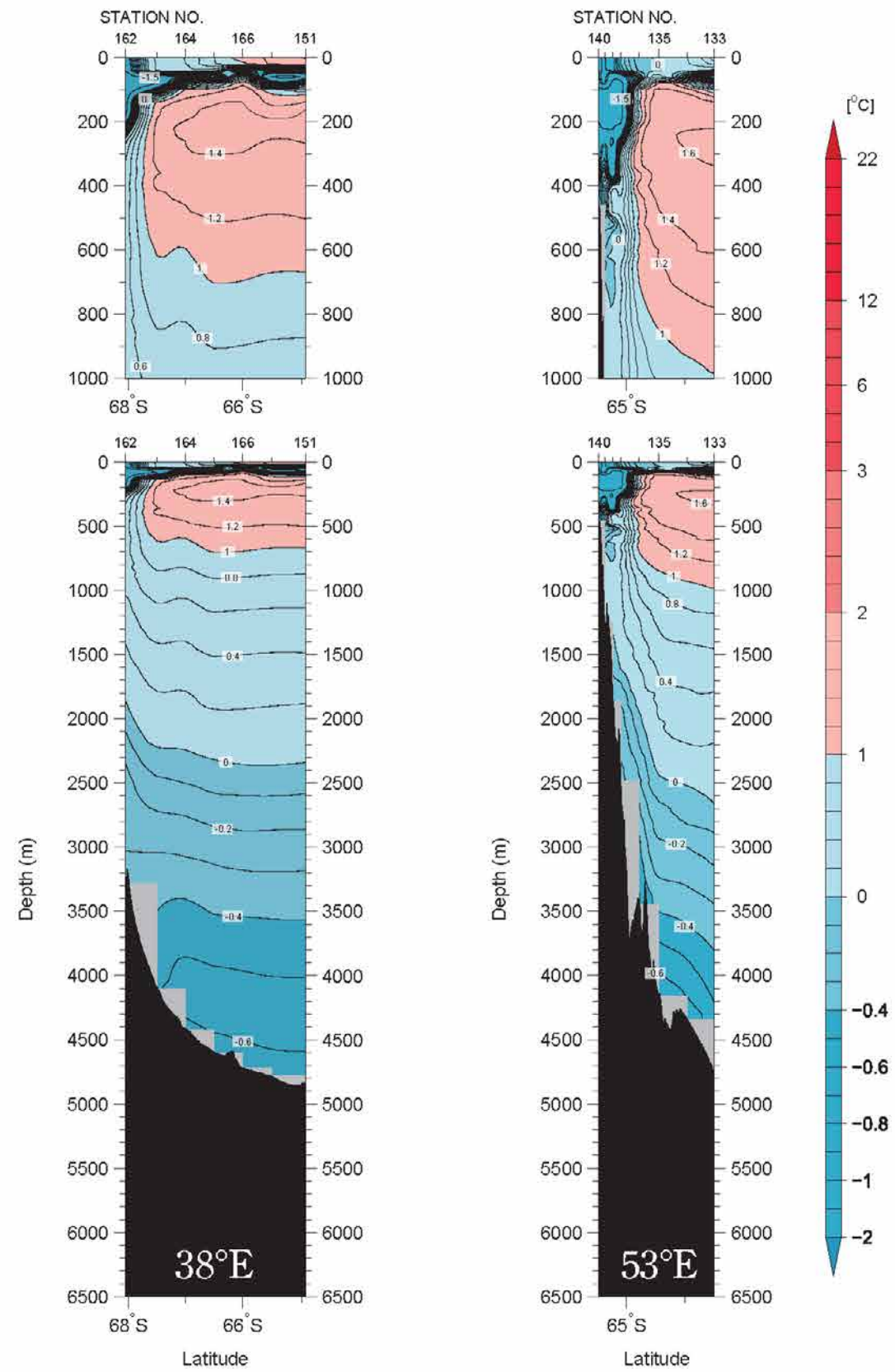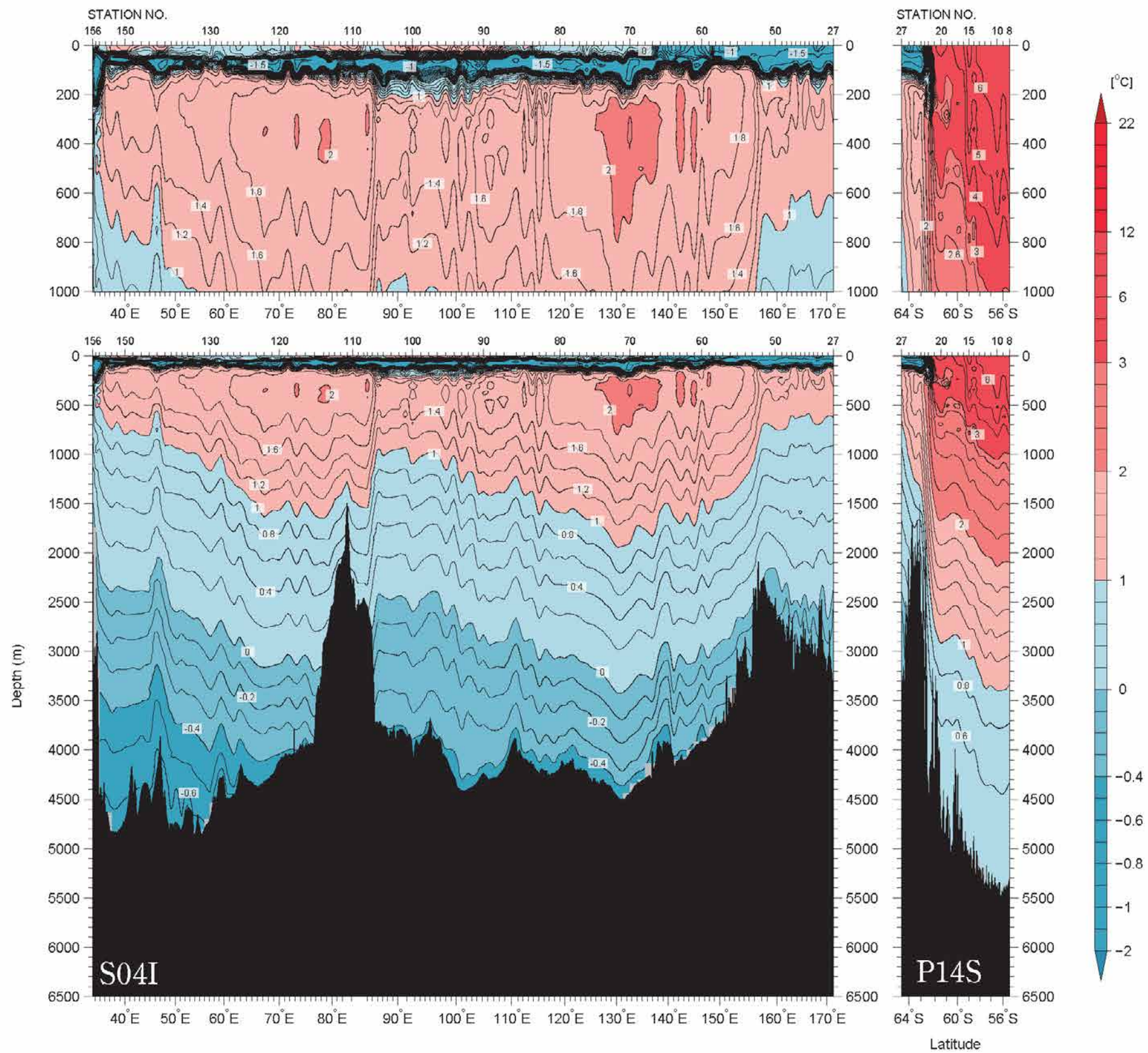
Figure 8
CTD salinity
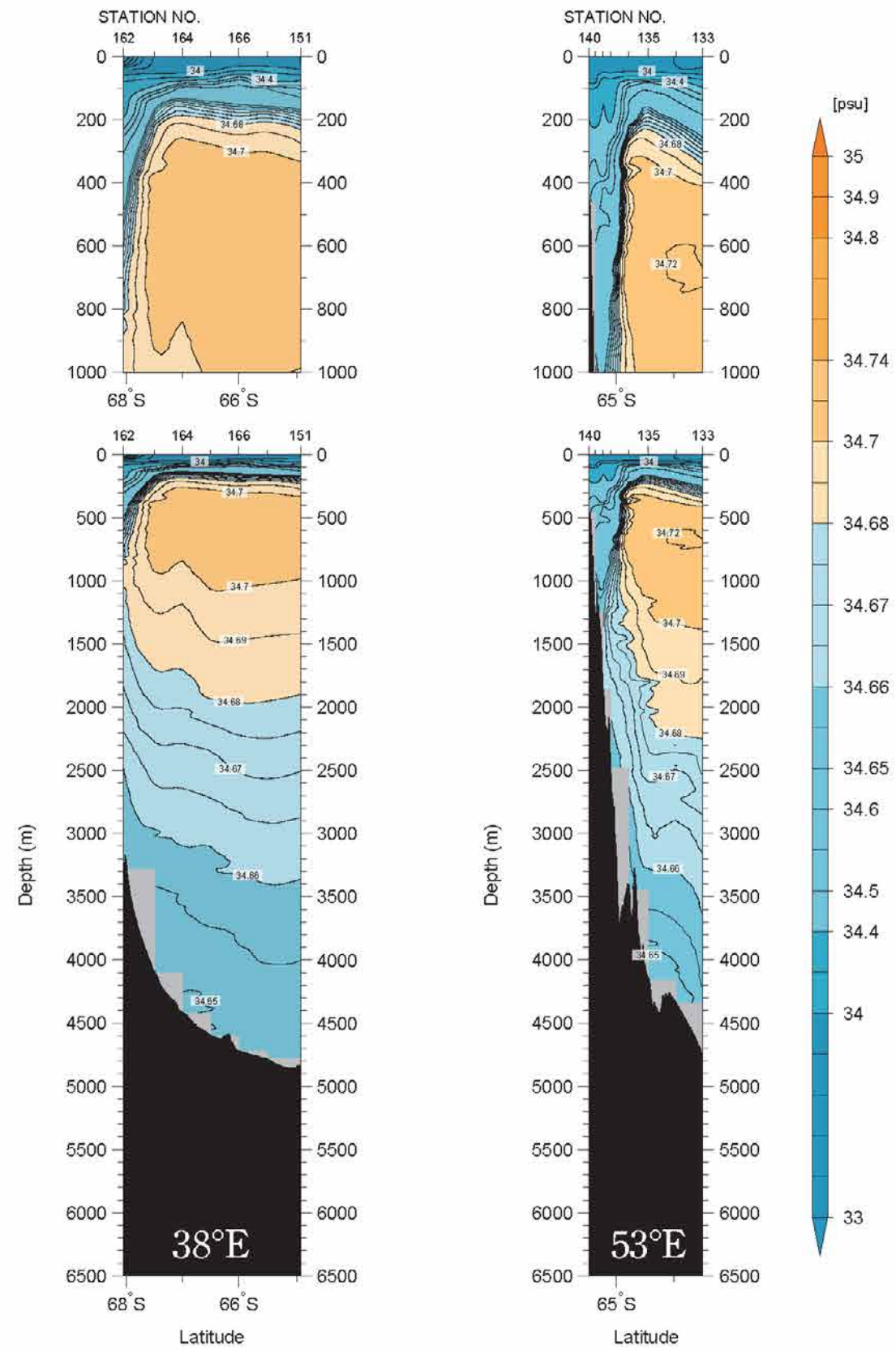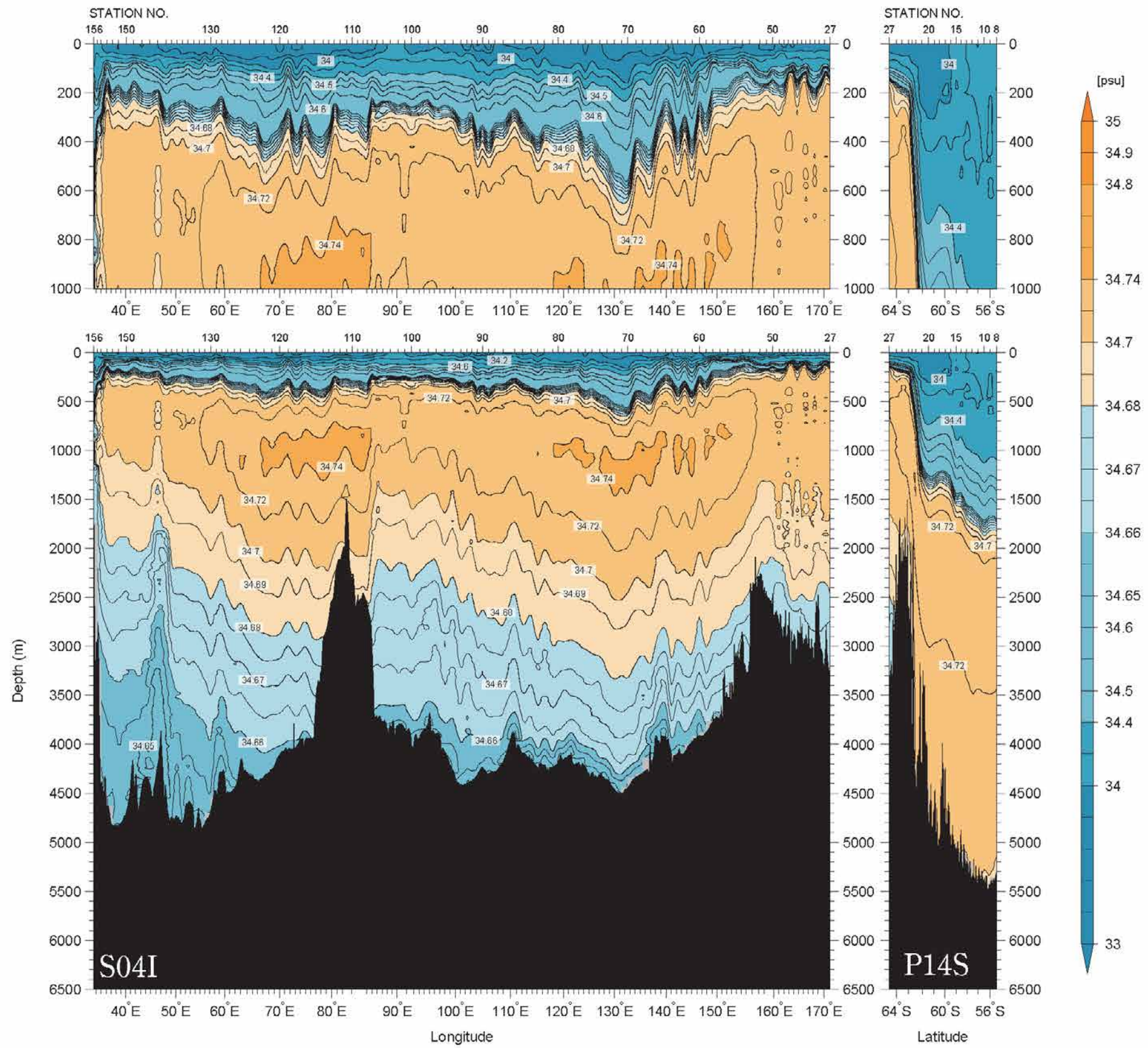
Figure 9
Absolute Salinity (g/kg)
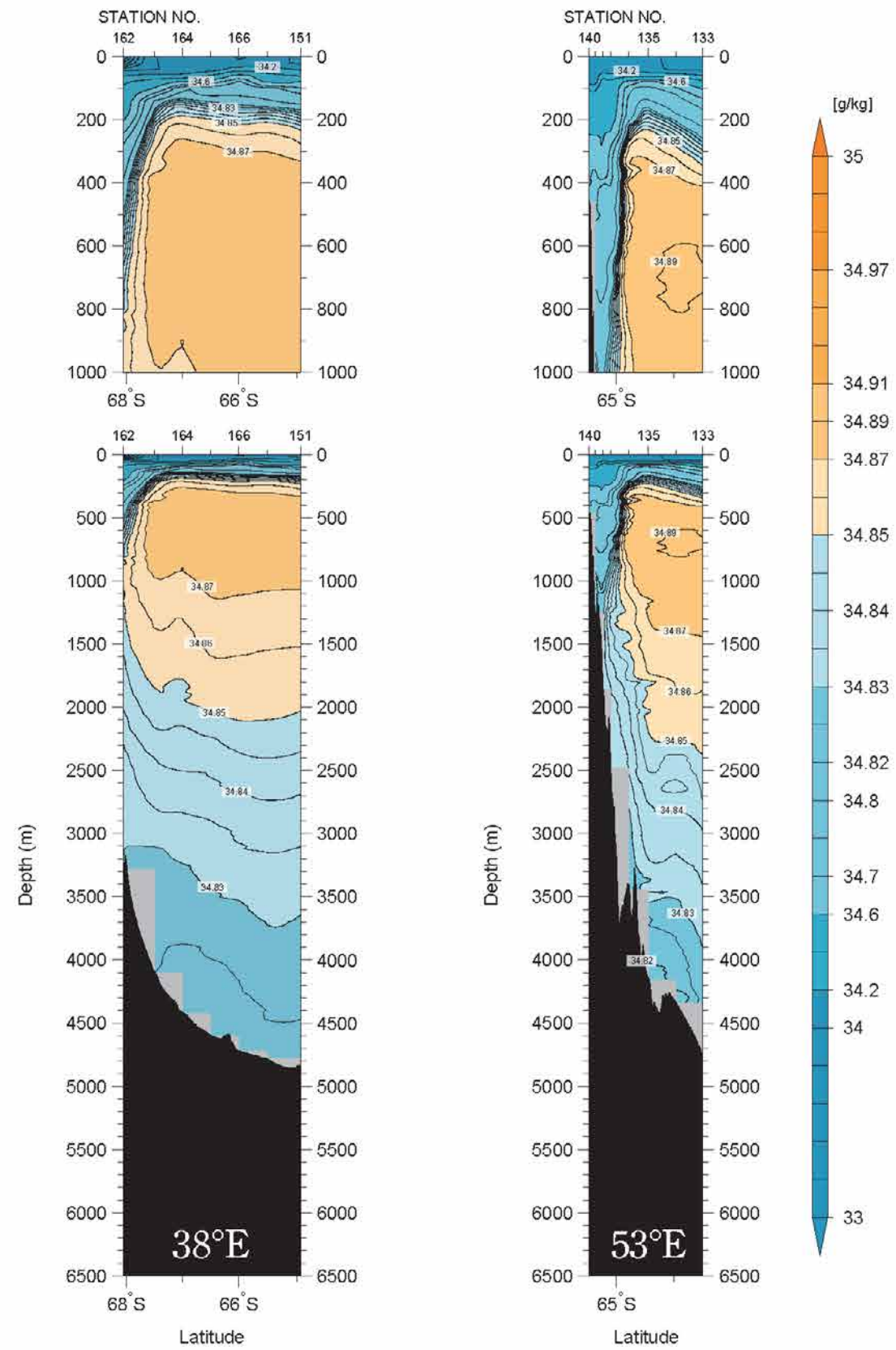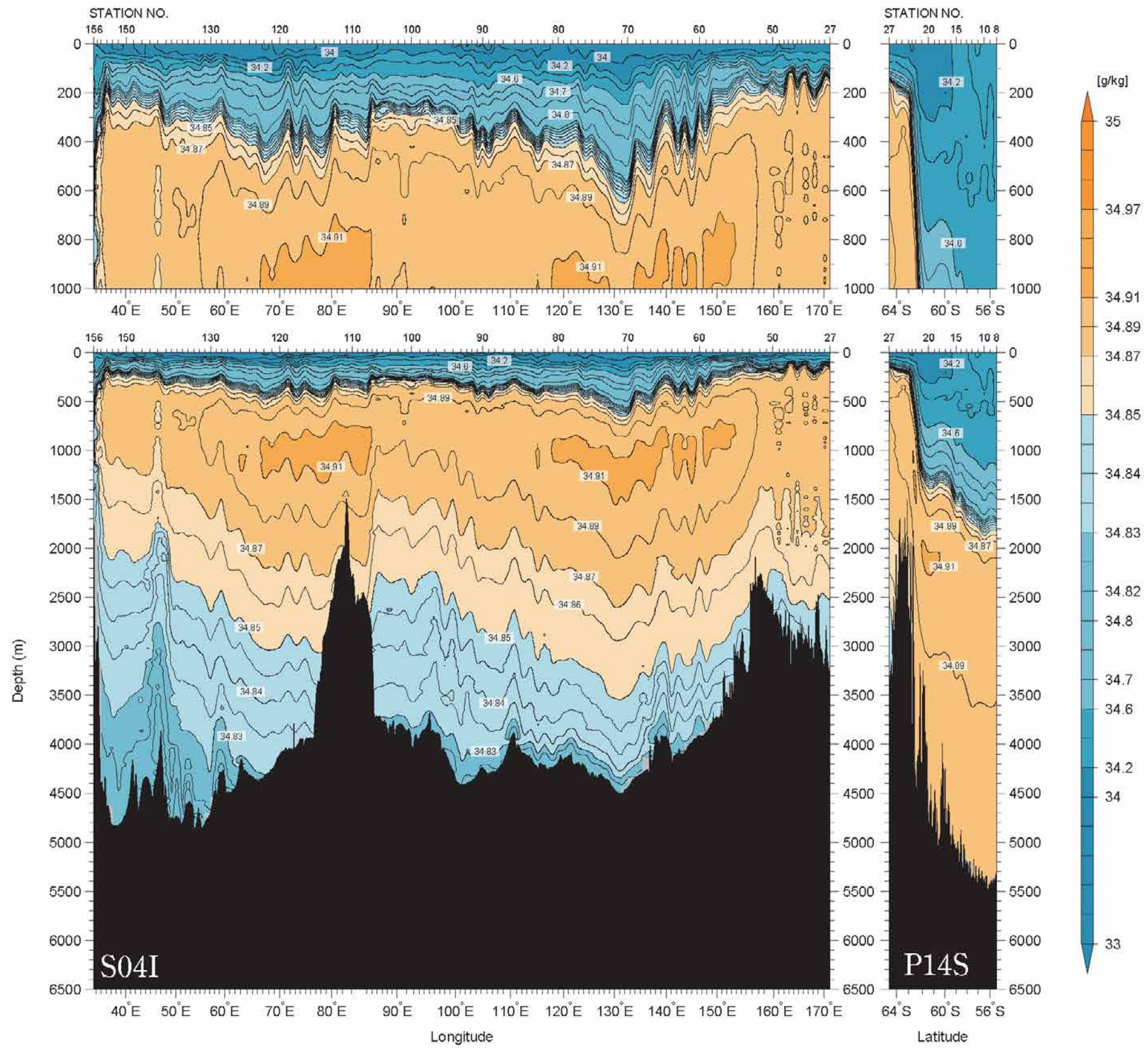
S04I

P14S

Figure 10a
Density (upper: σ_0, lower: σ_4)
(kg/m^3) (EOS-80)

S04I

P14S

143
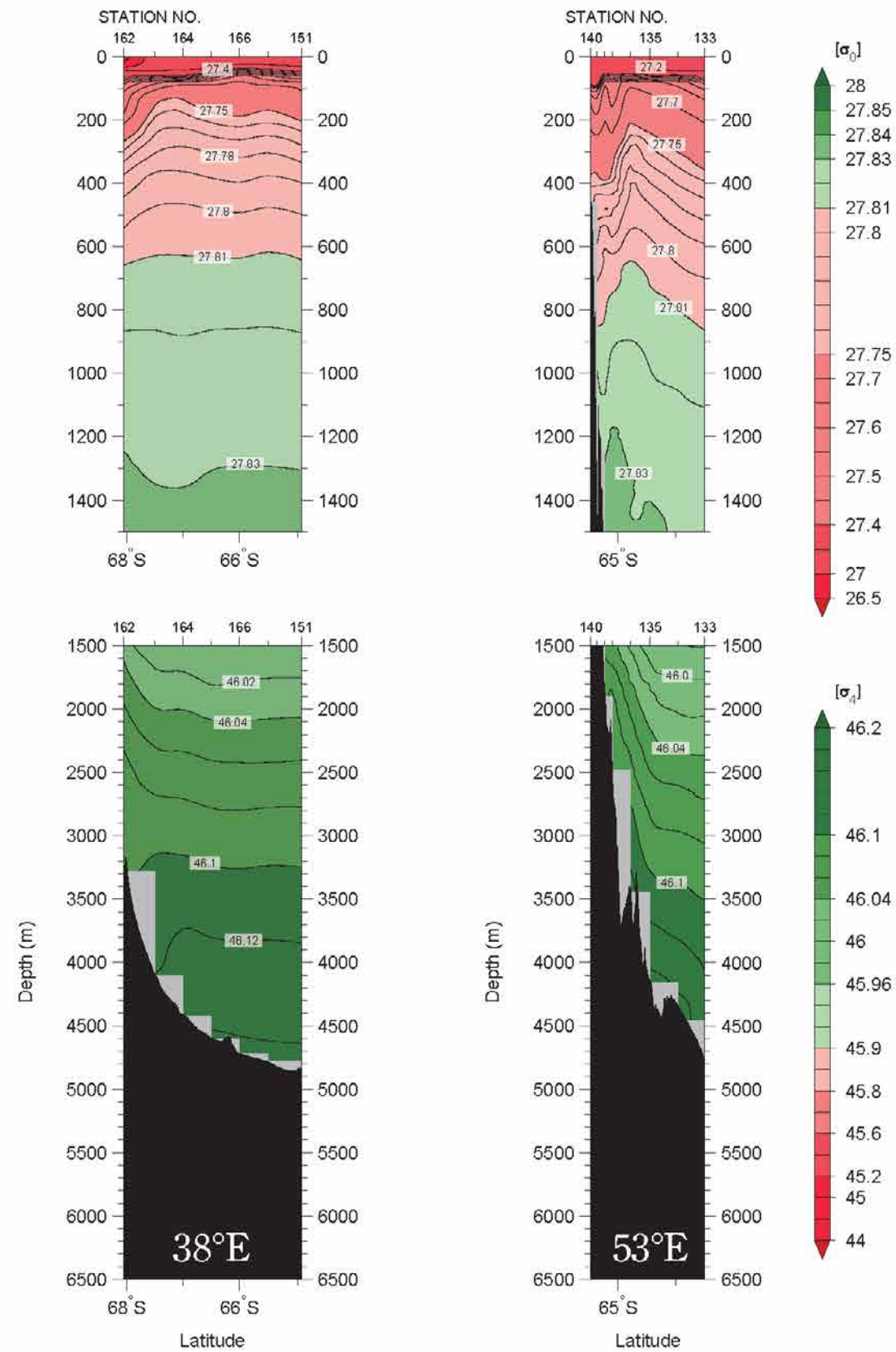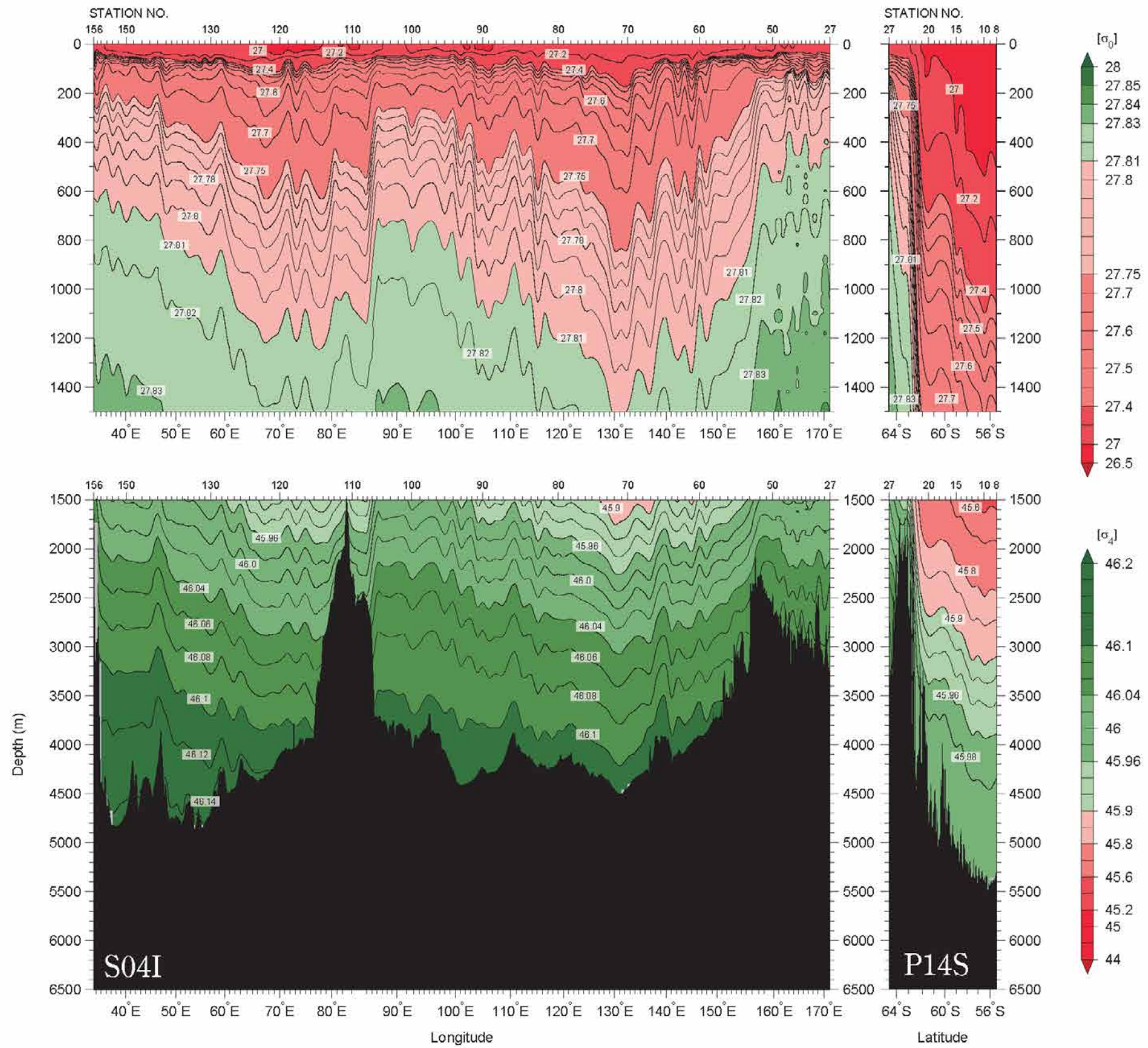
Figure 10b
Density (upper: σ_0, lower: σ_4)
(kg/m^3) (TEOS-10)

Figure 11
Density (γ^n) (kg/m^3)

146
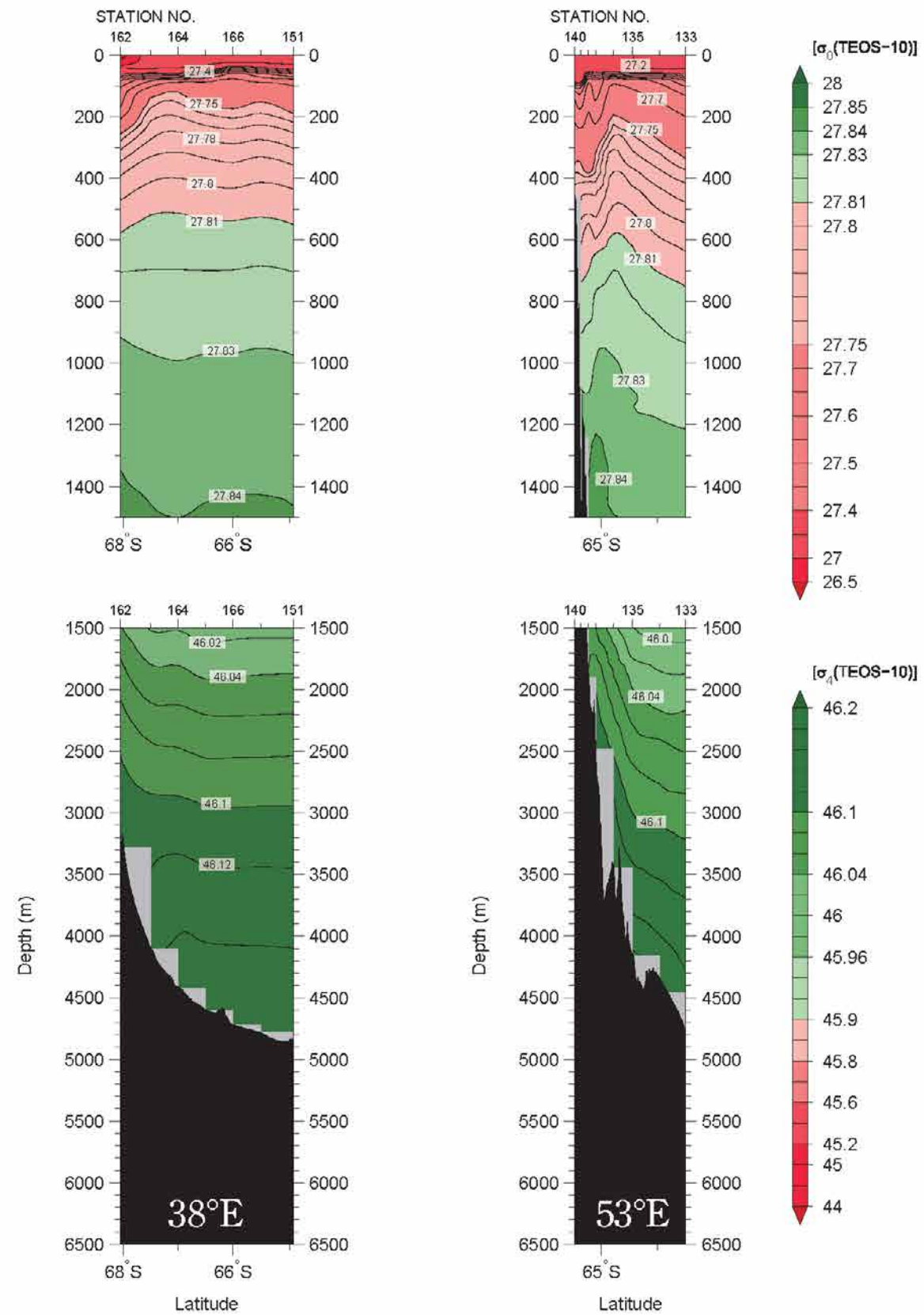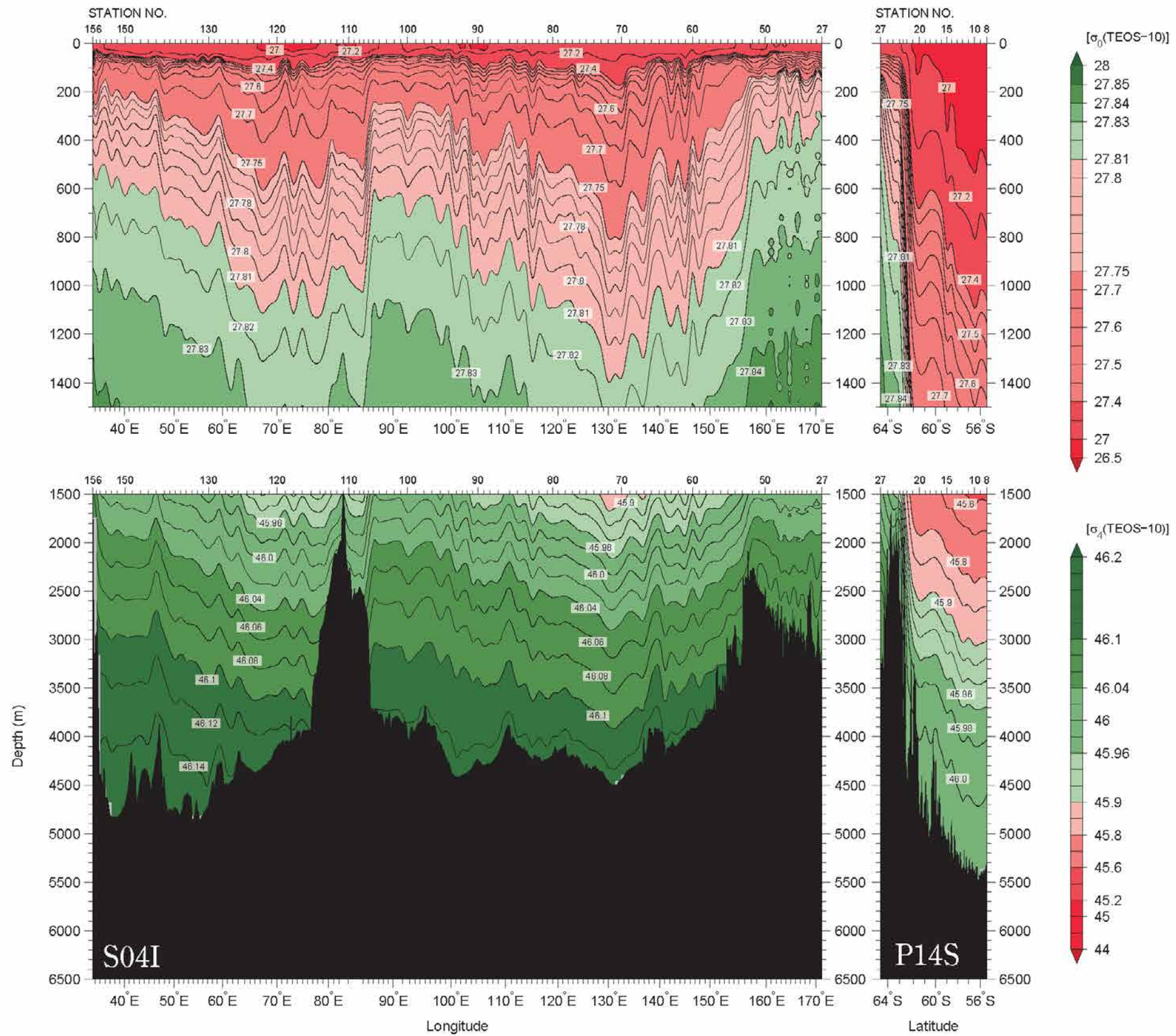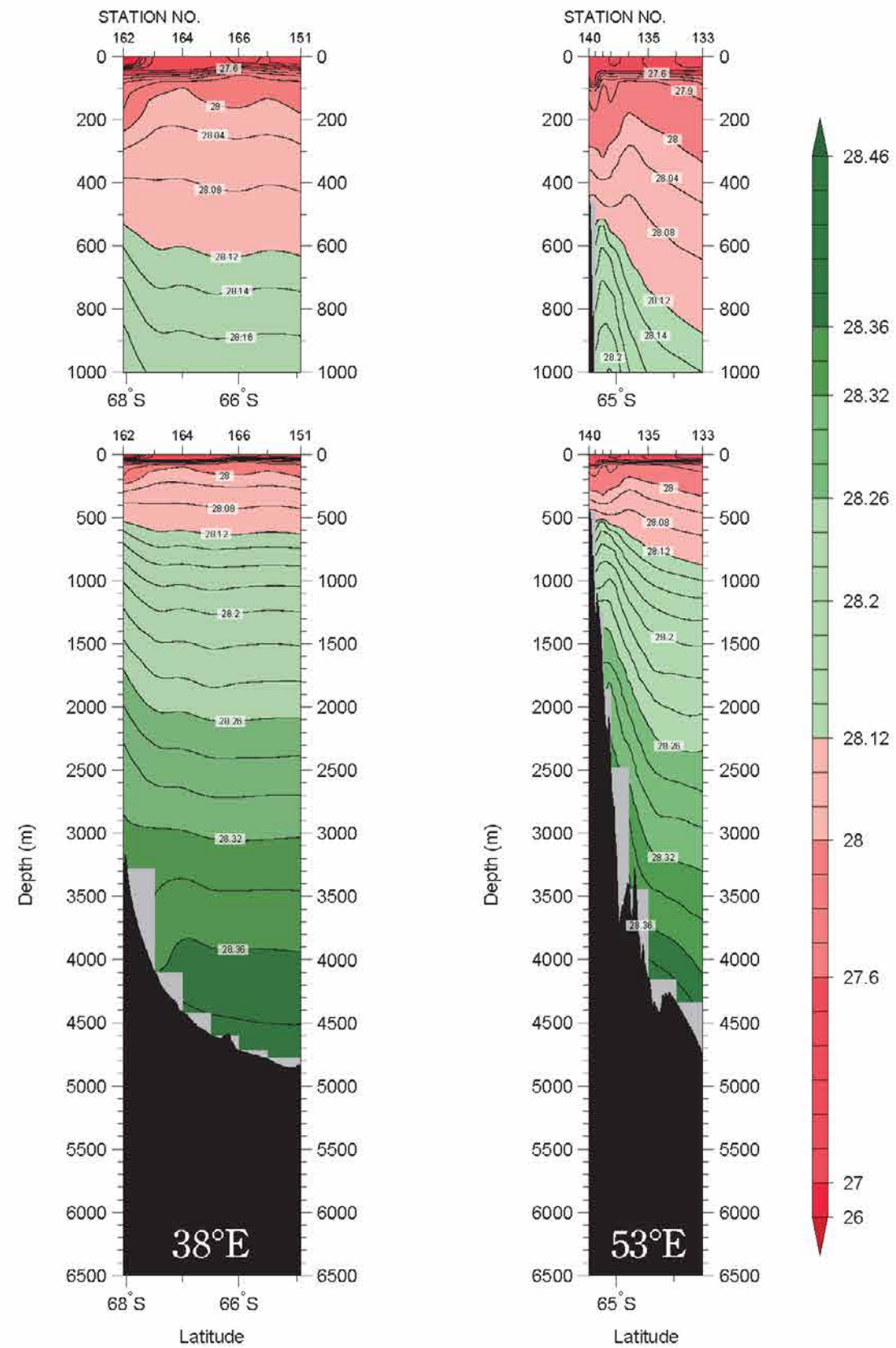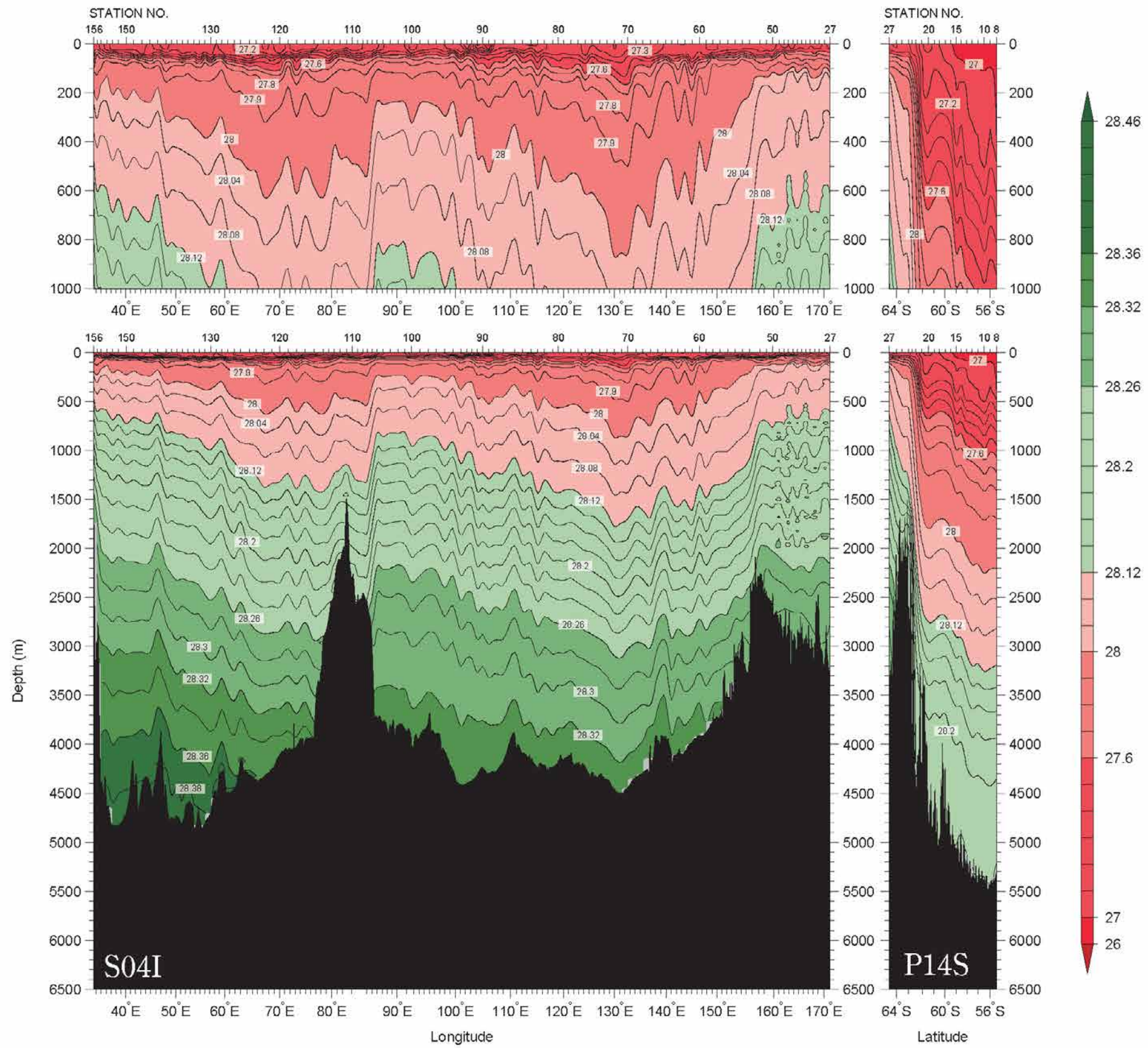
Figure 12
CTD oxygen (μmol/kg)
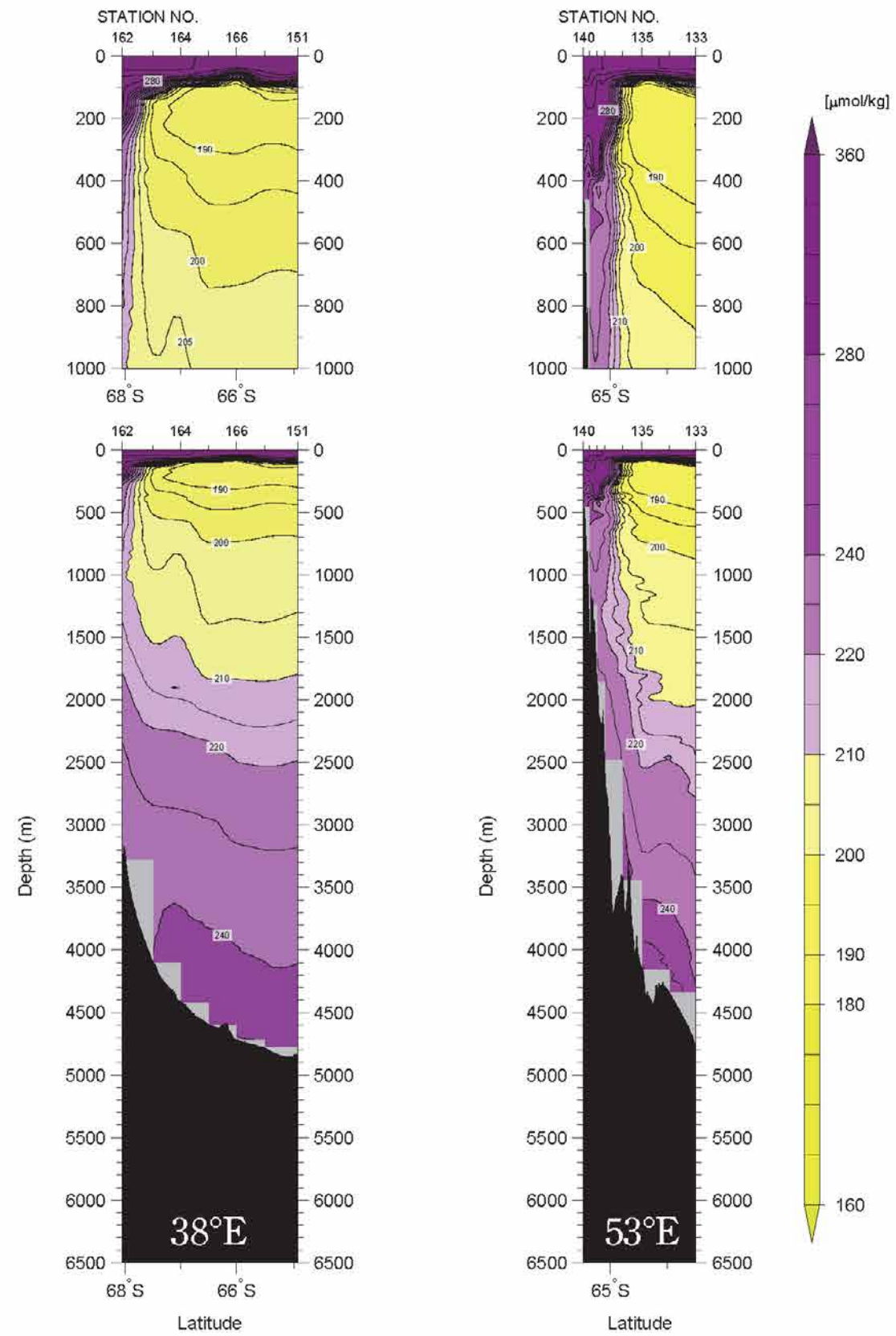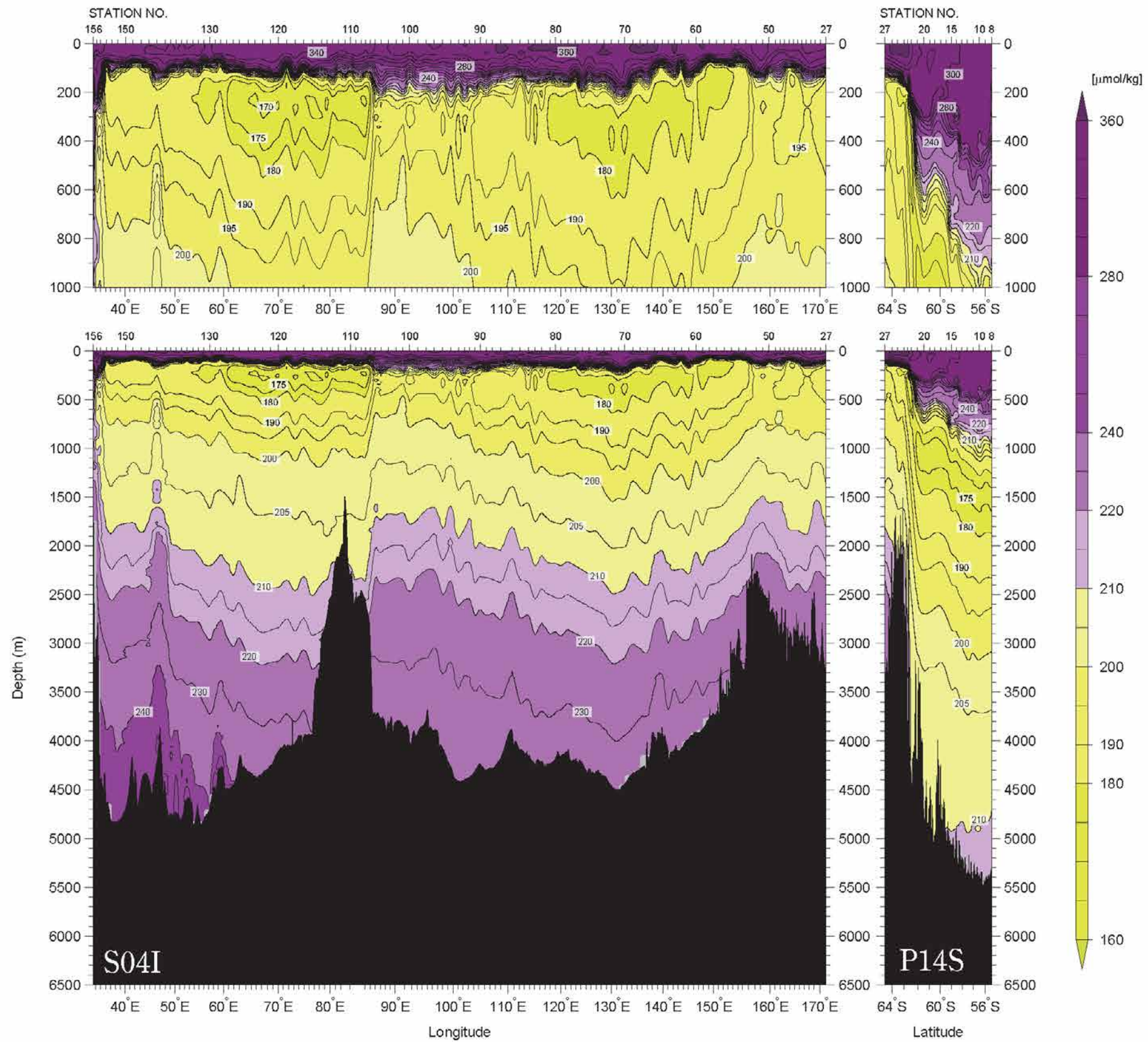
Figure 13
CTD chlorophyll *a* (mg/m³)

38°E   53°E
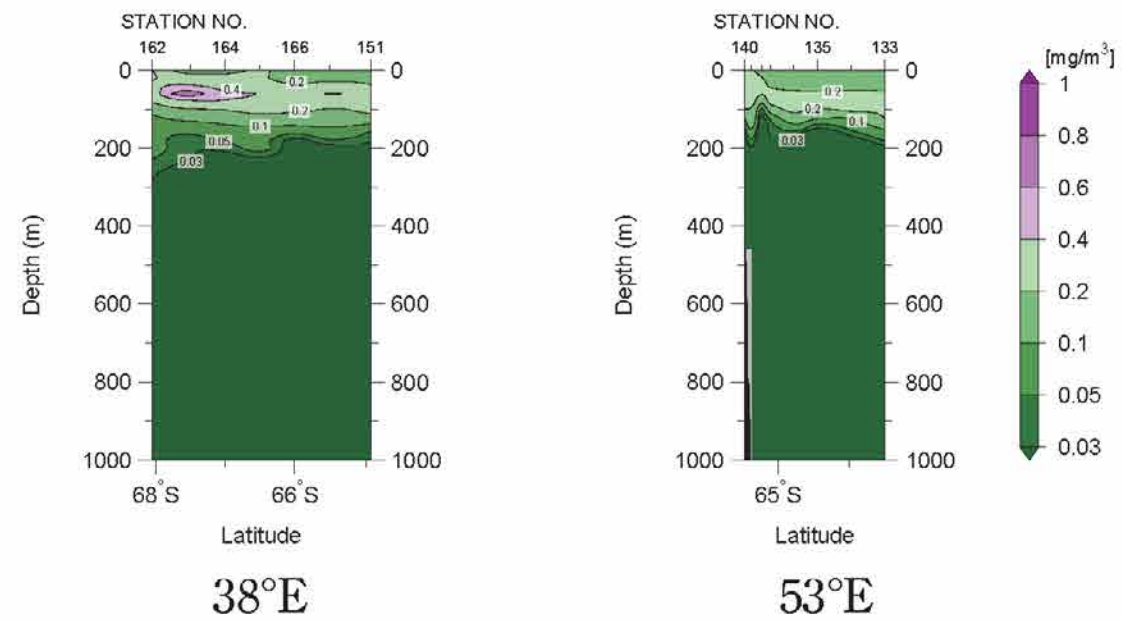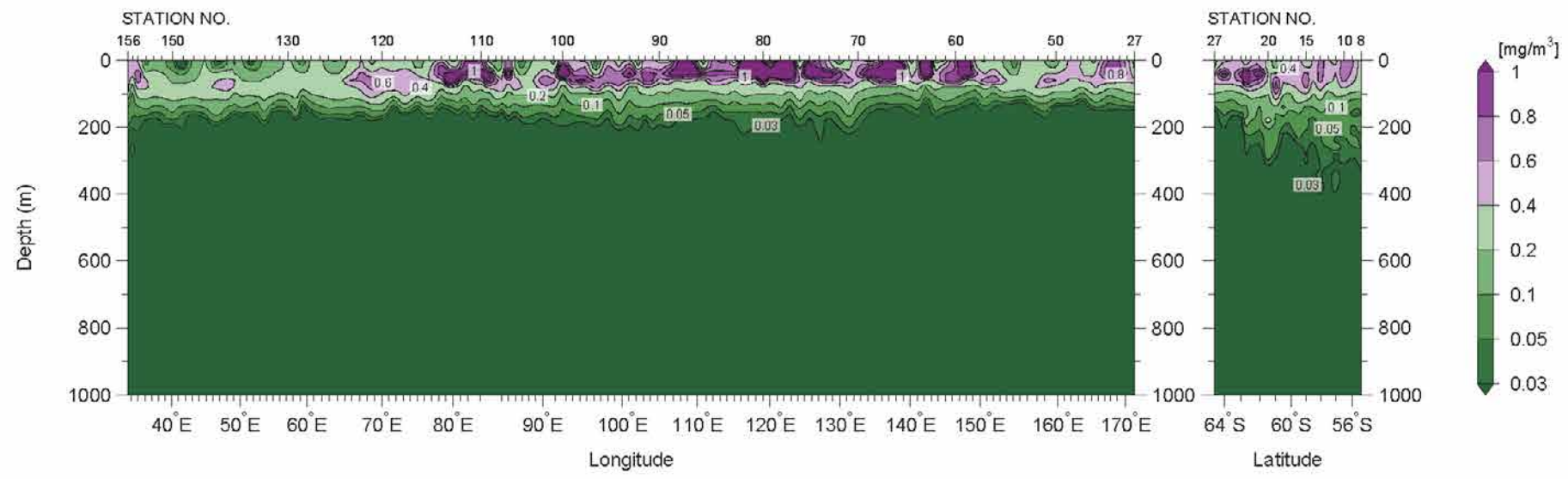
S04I

P14S

Figure 14
CTD beam attenuation coefficient (m^{-1})
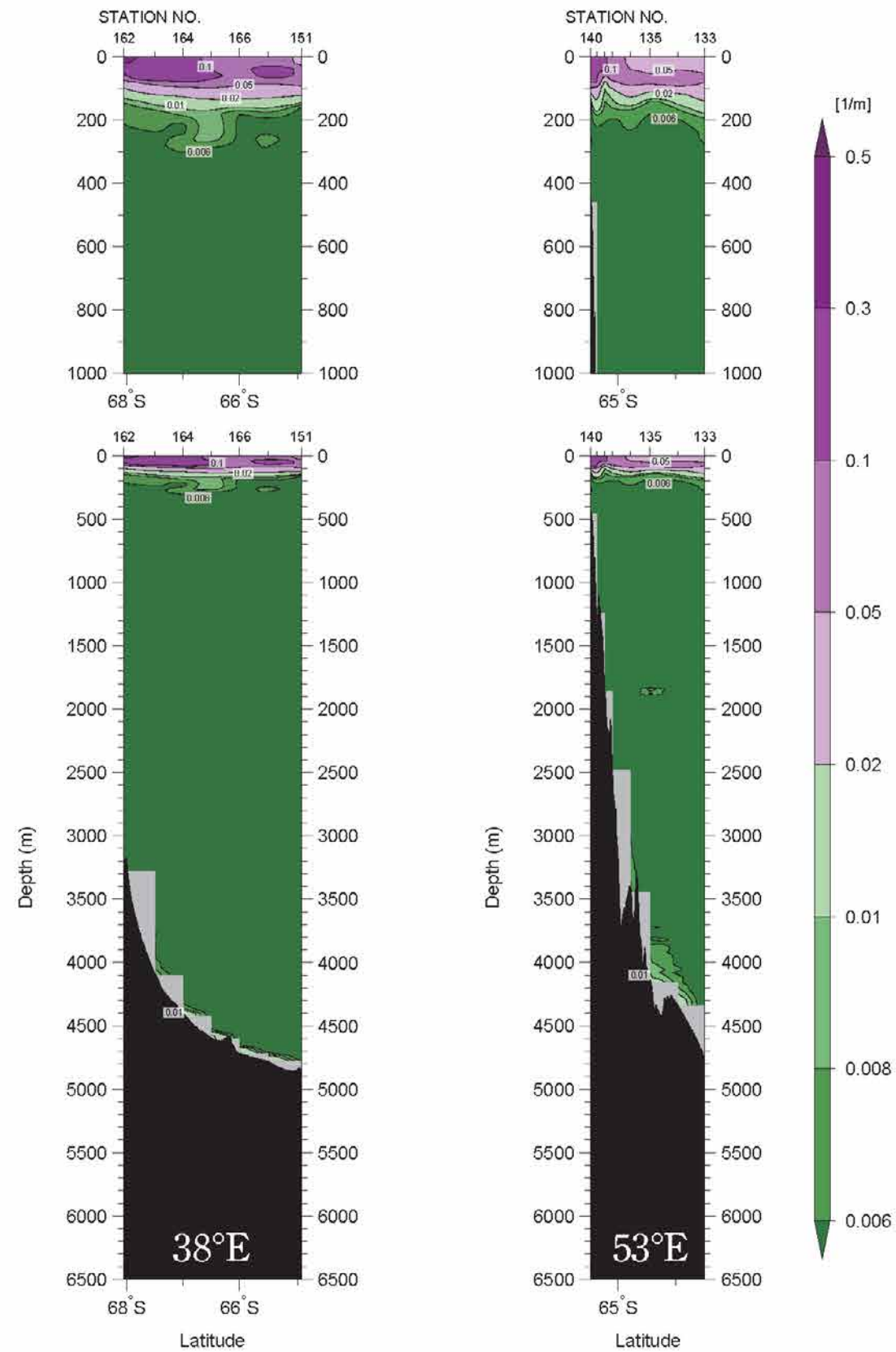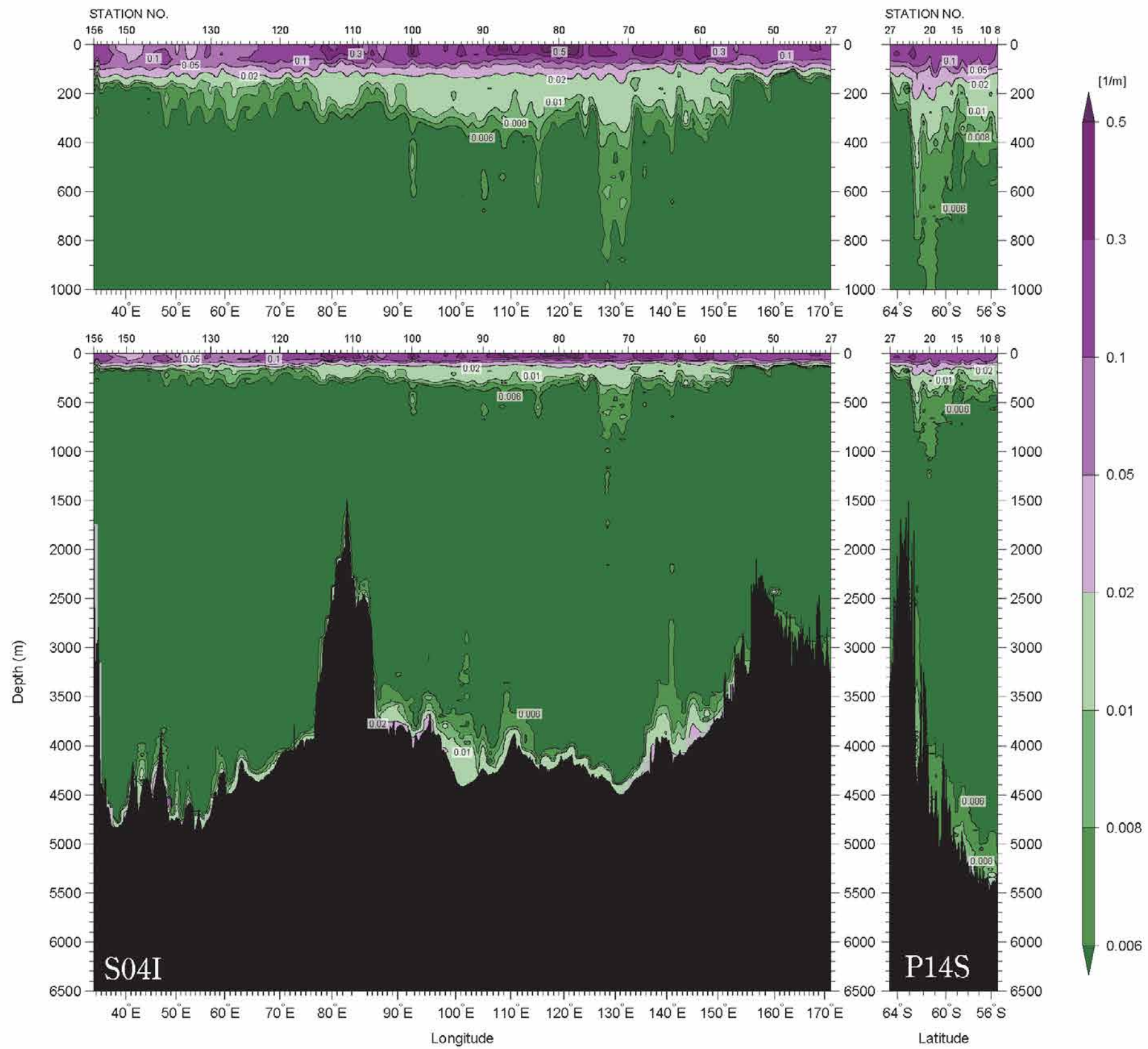
153

Figure 15

Bottle sampled dissolved oxygen (µmol/kg)

154

Figure 16
Silicate (μmol/kg)

STATION NO.

156 150 130 120 110 100 90 80 70 60 50 27

STATION NO.

27 20 15 10 8

[μmol/kg]

140
130
126
120

100

60

40

10

0

Depth (m)

S04I

P14S

Longitude

Latitude

Figure 17
Nitrate (μmol/kg)

STATION NO.
156 150 130 120 110 100 90 80 70 60 50 27

STATION NO.
27 20 15 10 8

[μmol/kg]

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Depth (m)

Longitude

Latitude

159
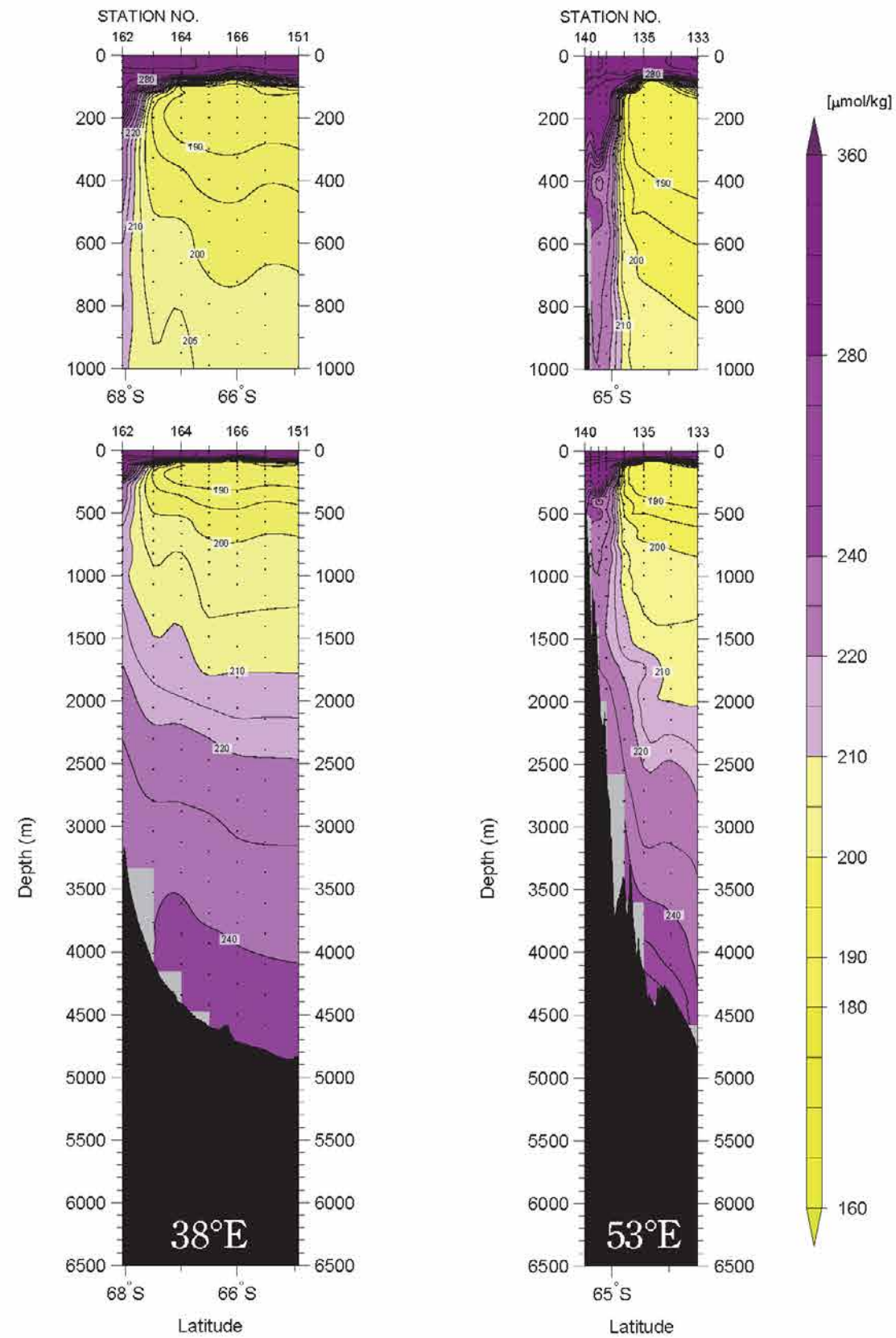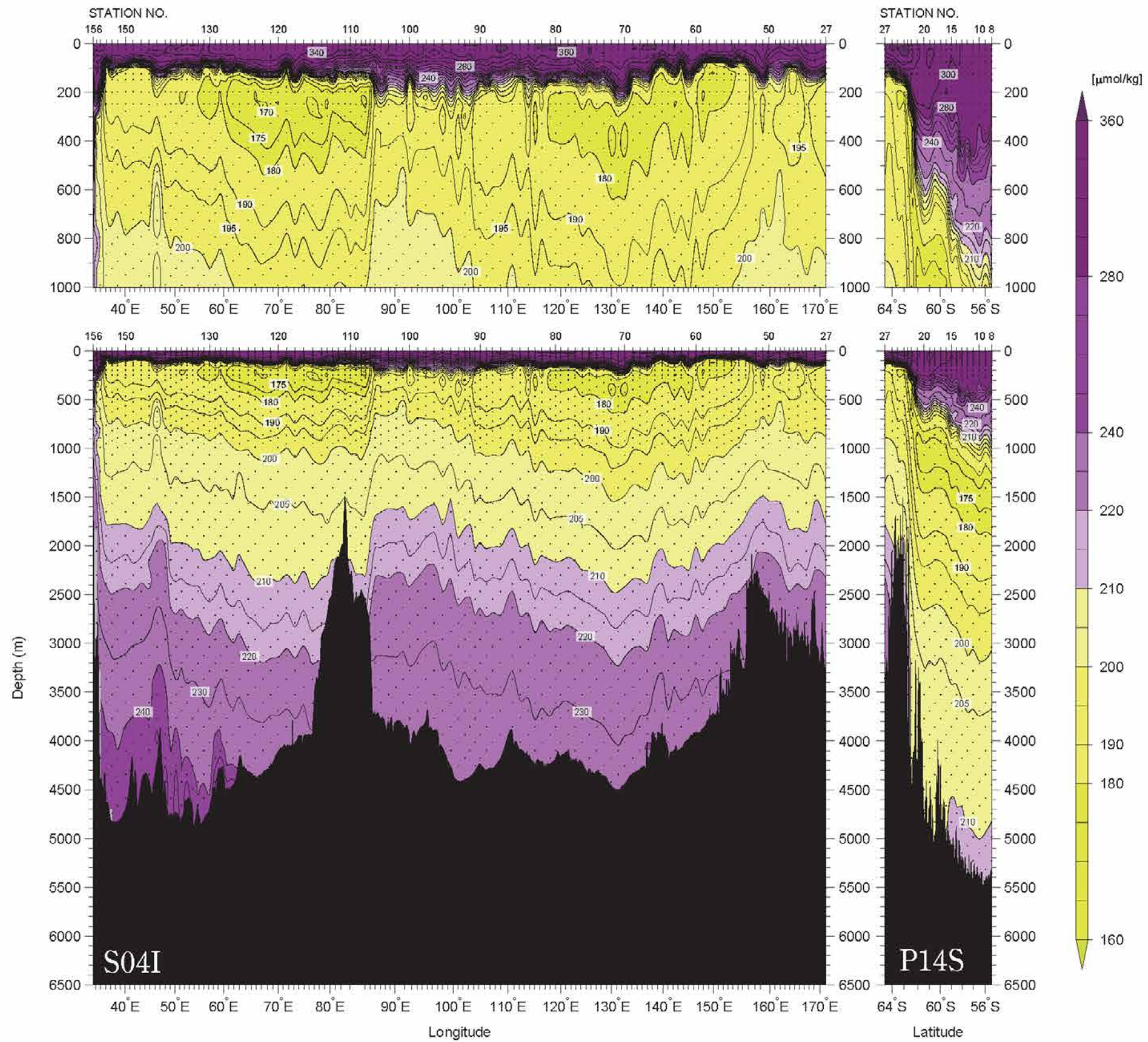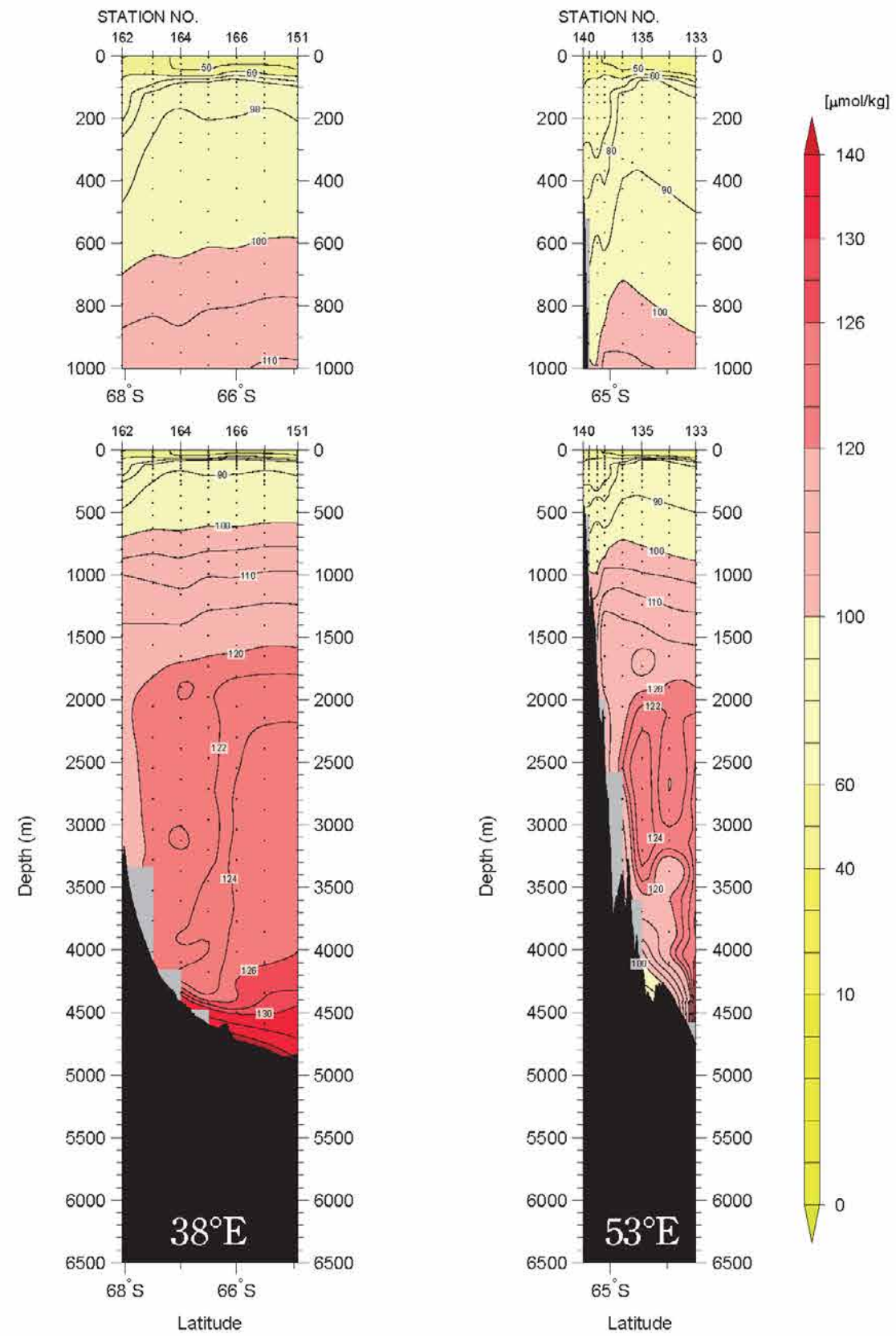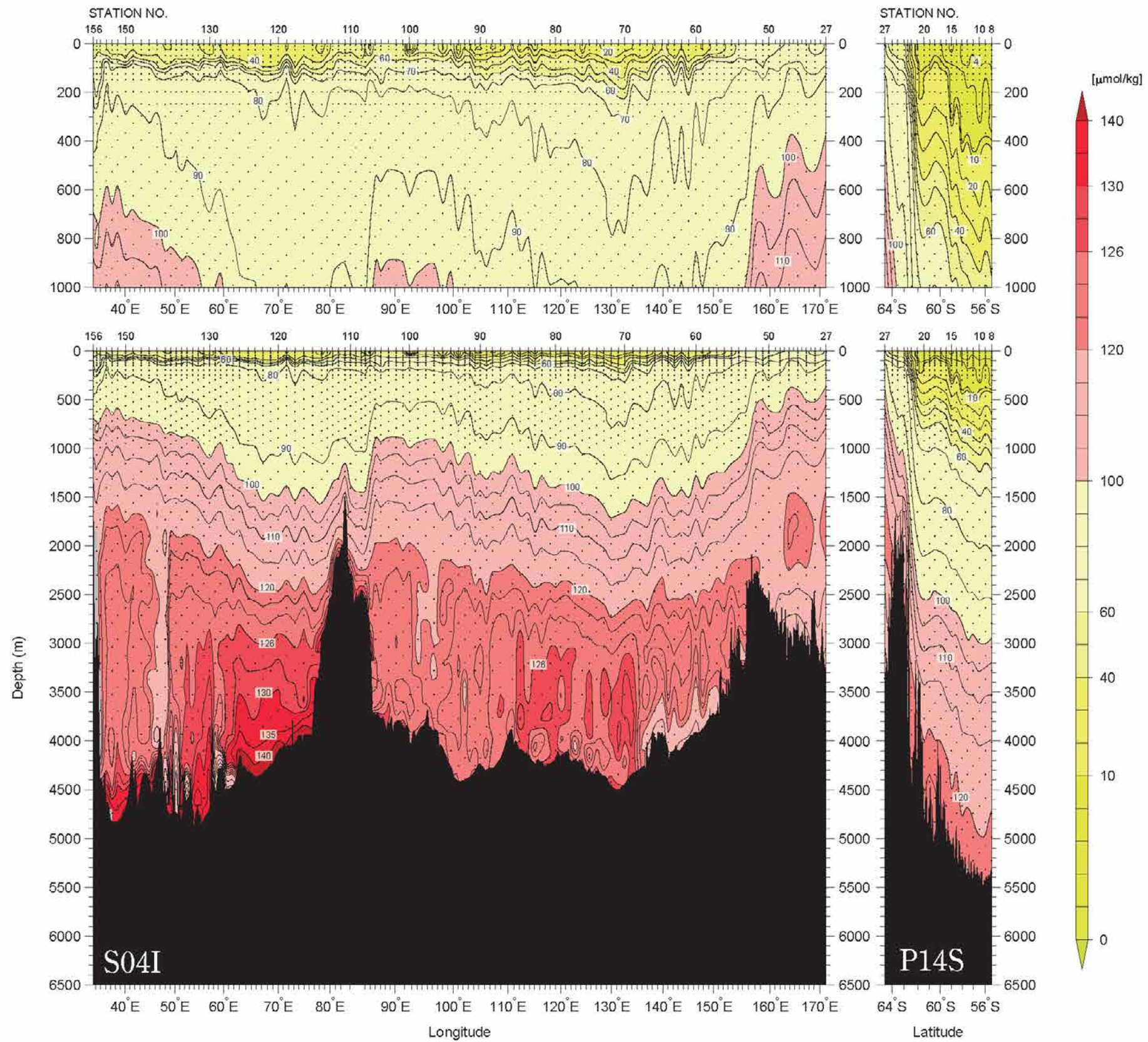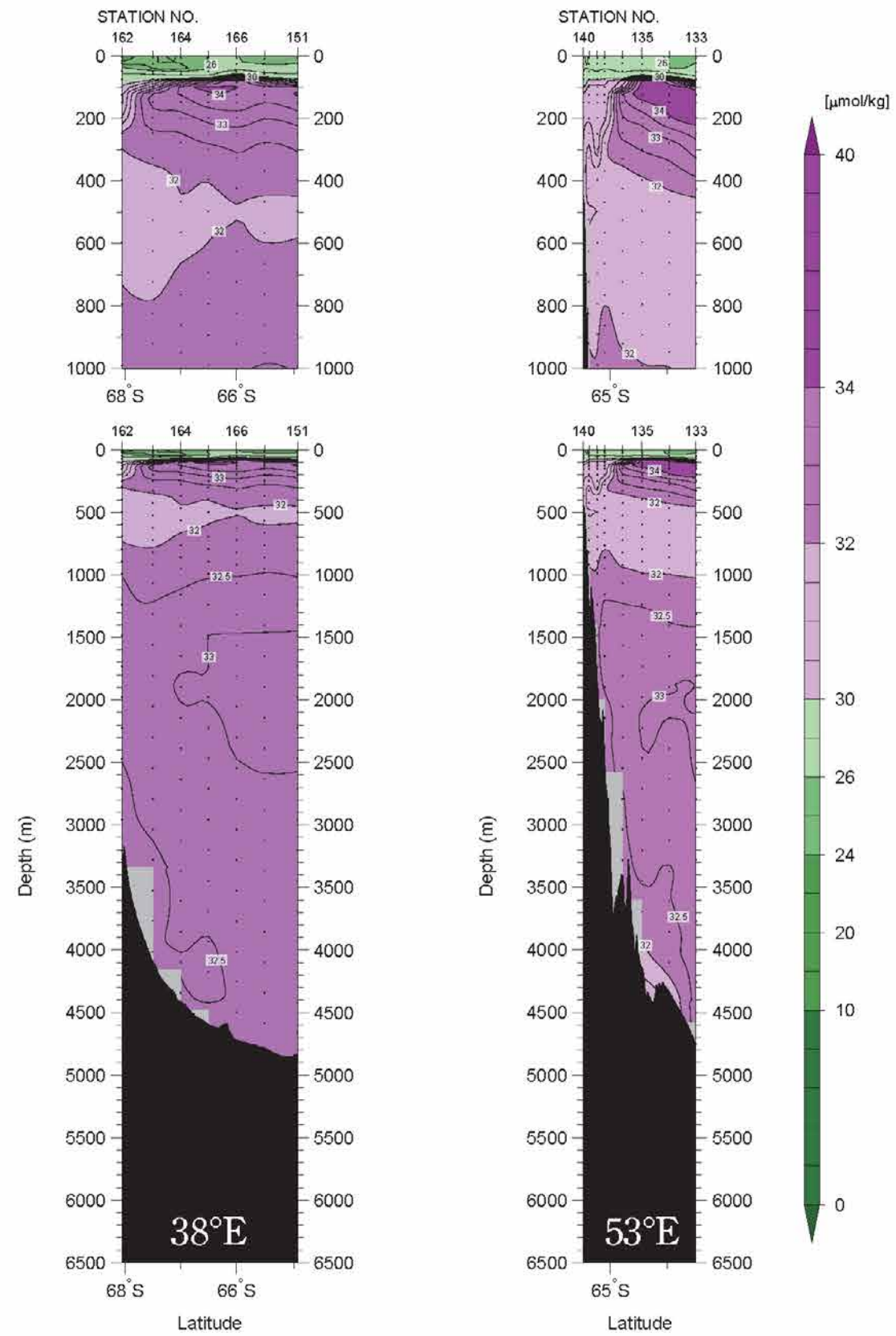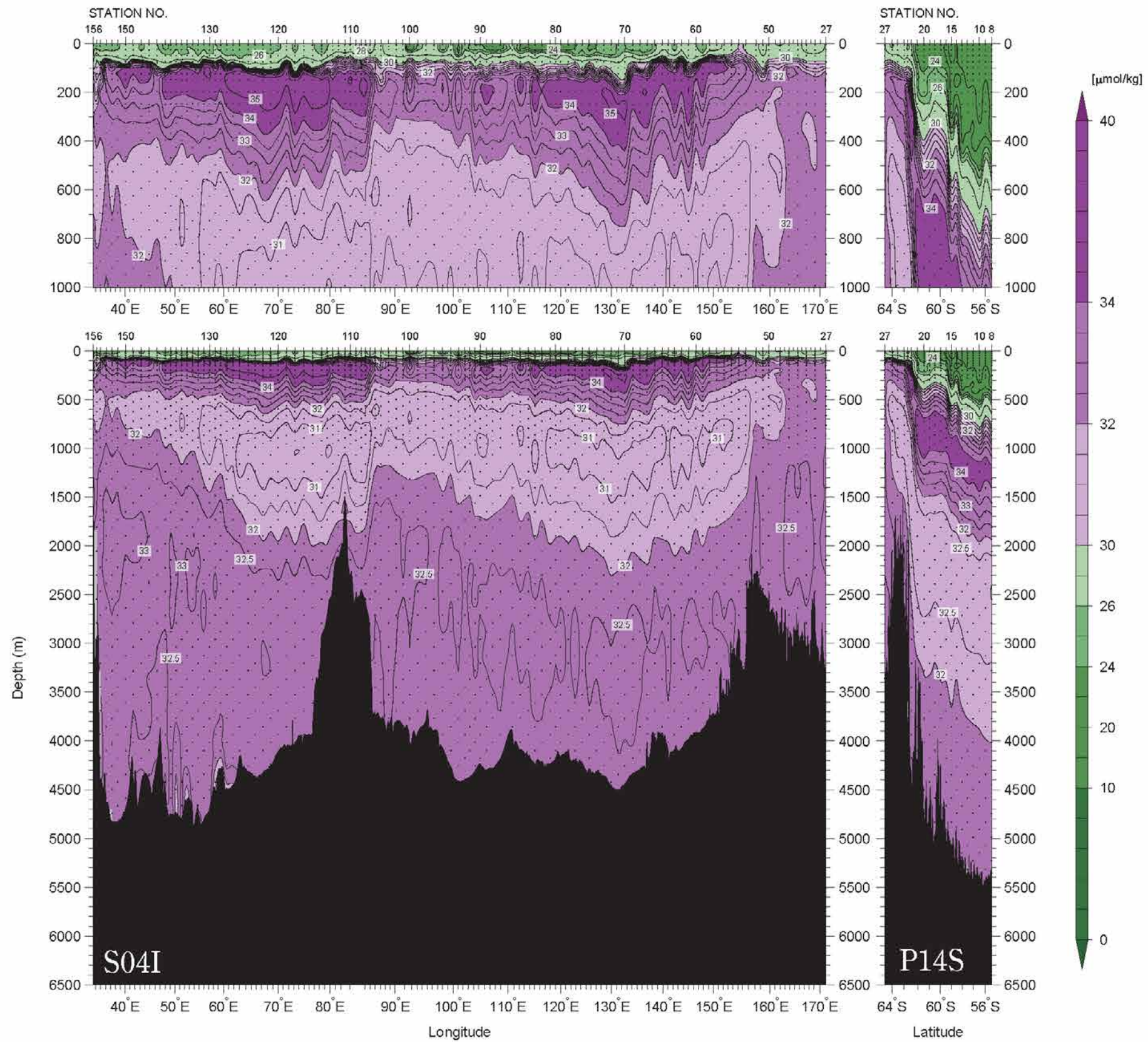
Figure 18
Nitrite (μmol/kg)
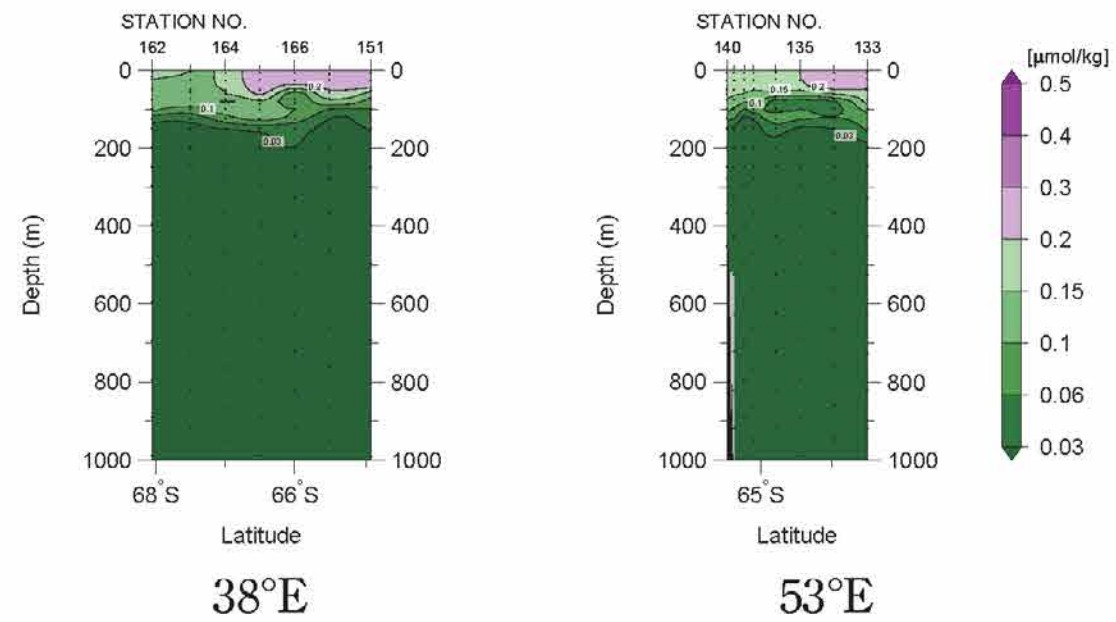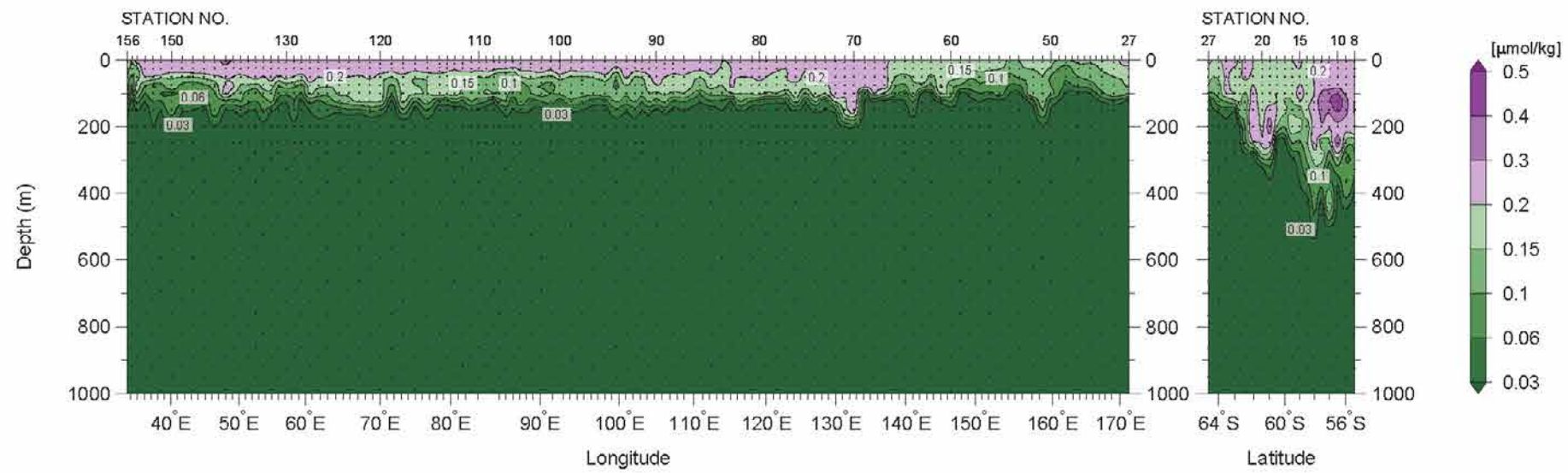
S04I

P14S

Figure 19
Phosphate (μmol/kg)
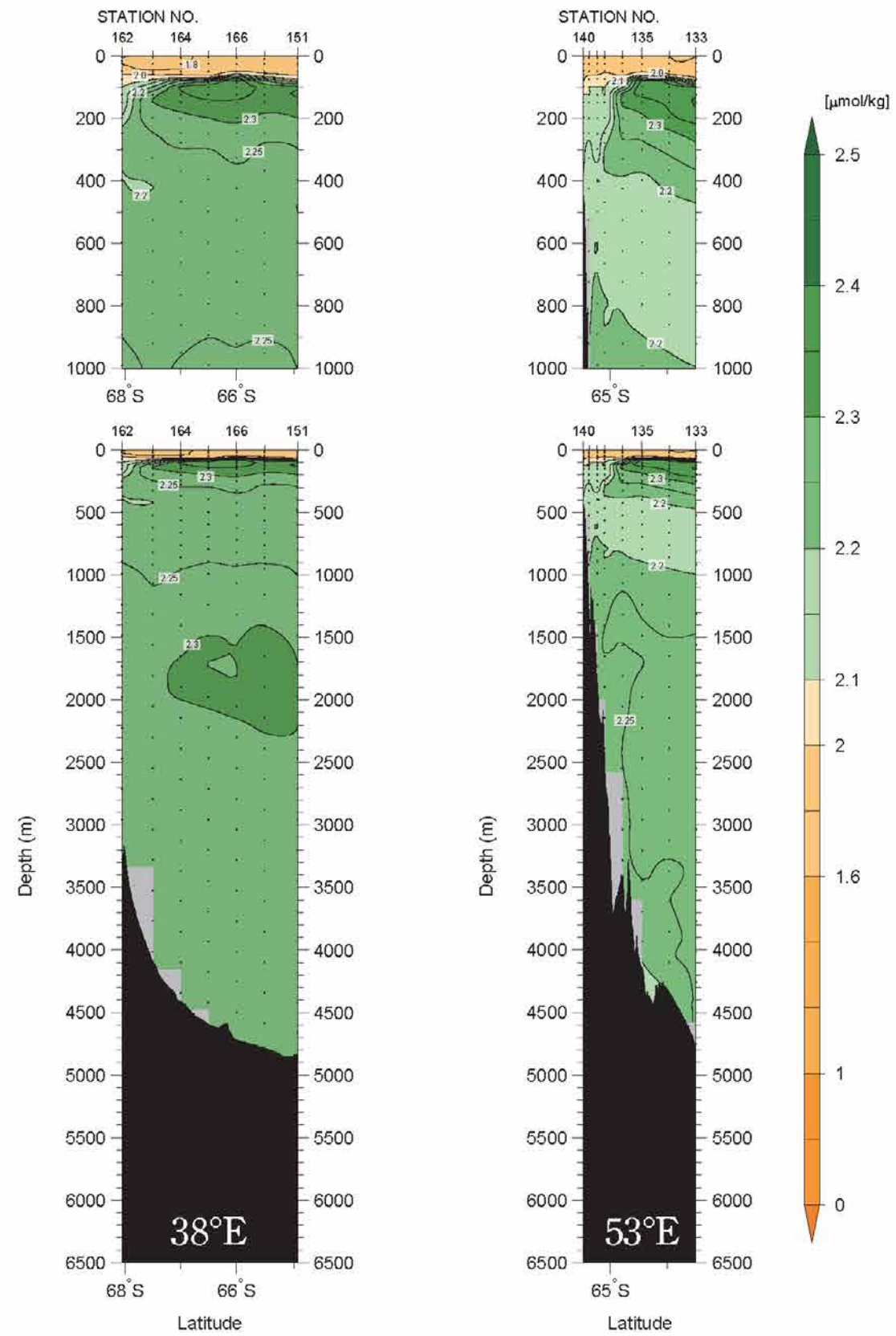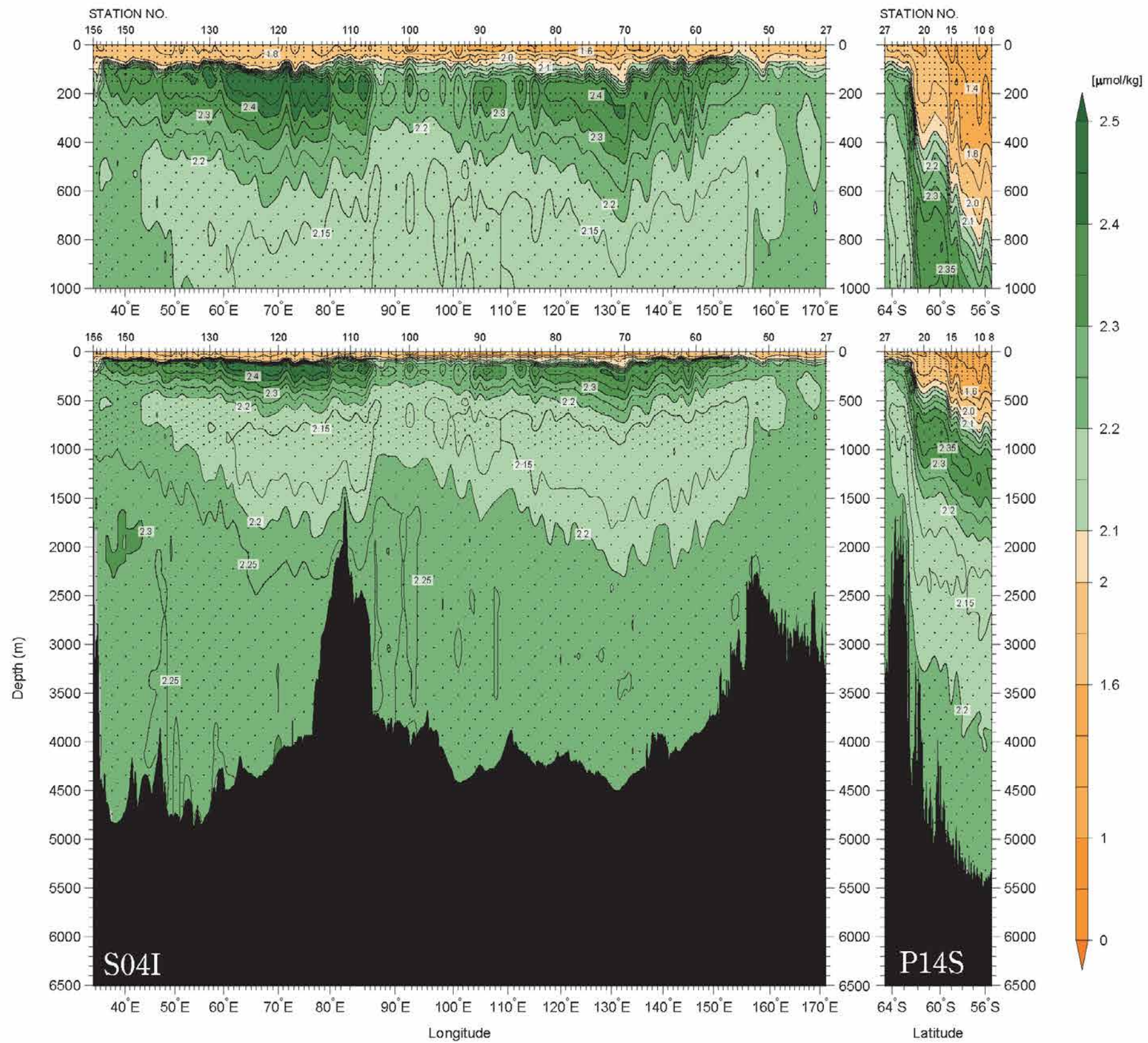
Figure 20
Dissolved inorganic carbon
(C_T) (μmol/kg)

Figure 21
Total alkalinity (A_T) (μmol/kg)

STATION NO.
156 150   130   120   110   100   90   80   70   60   50   27

STATION NO.
27   20   15   10 8

[μmol/kg]

2430
2410
2380
2370
2360
2350
2320
2260
2200

Depth (m)

S04I

P14S

Longitude

Latitude

167

Figure 22
pH (pH$_T$)

STATION NO.
156 150   130   120   110   100   90   80   70   60   50   27

STATION NO.
27   20   15   10 8

S04I

P14S

Depth (m)

Longitude

Latitude

169
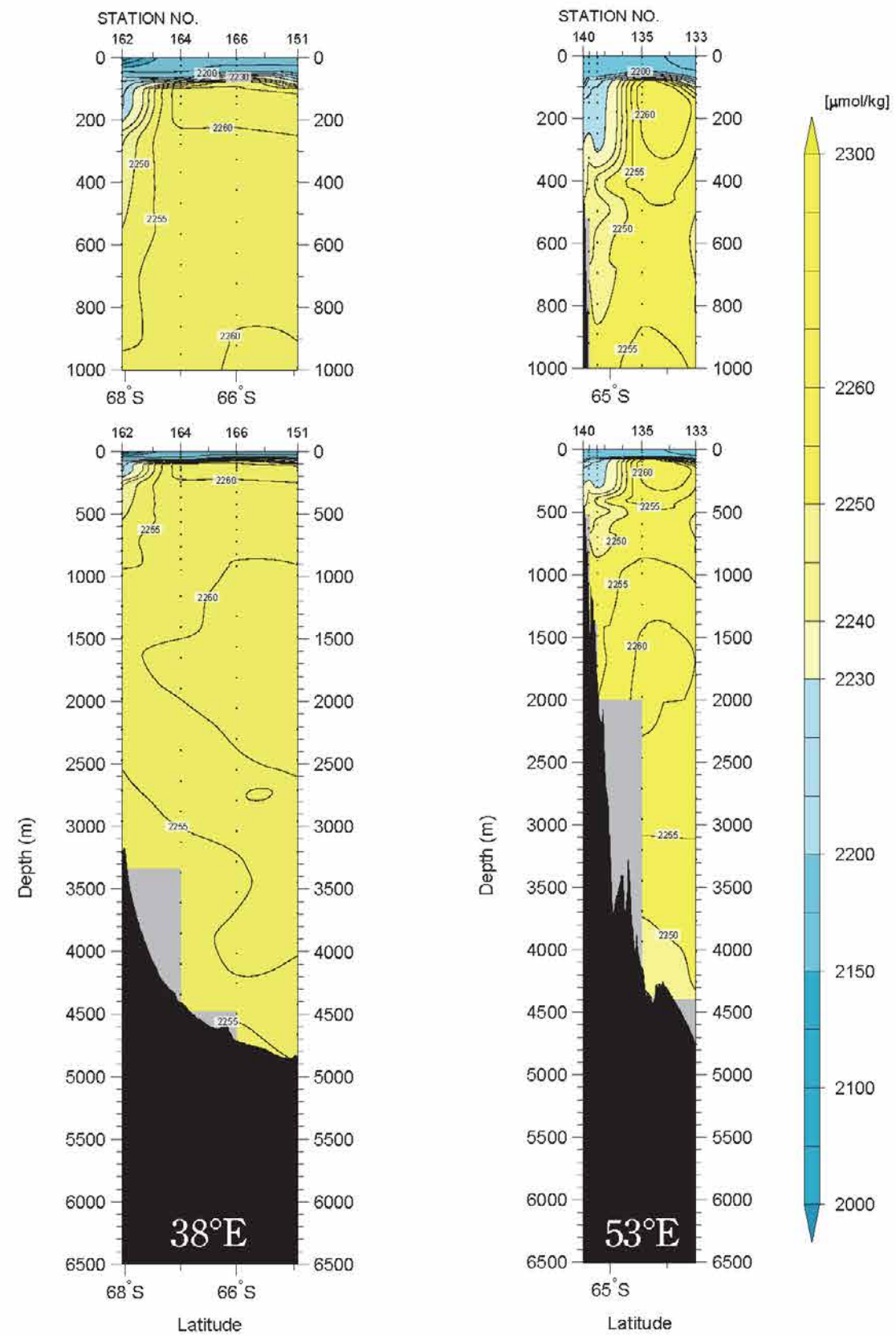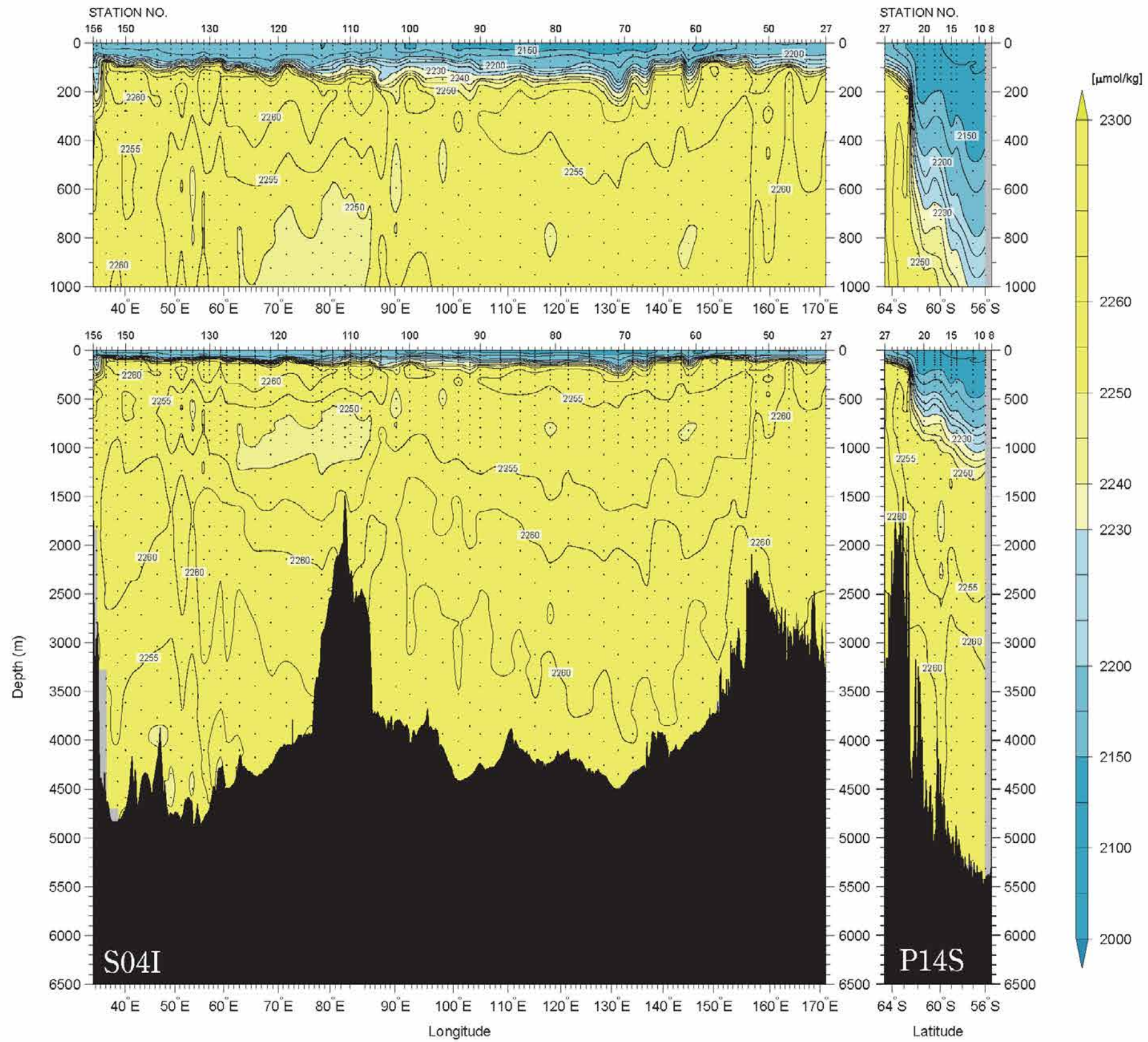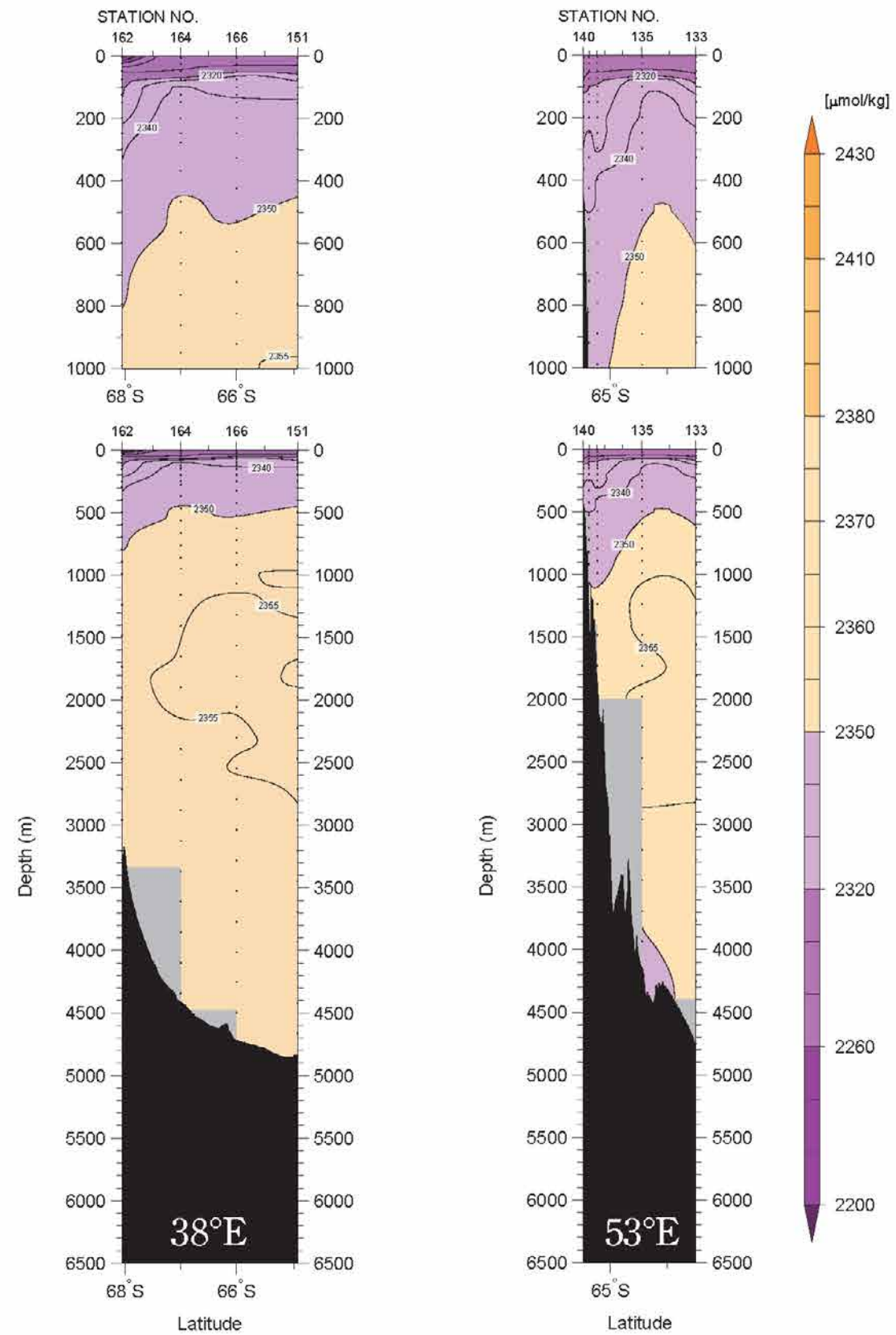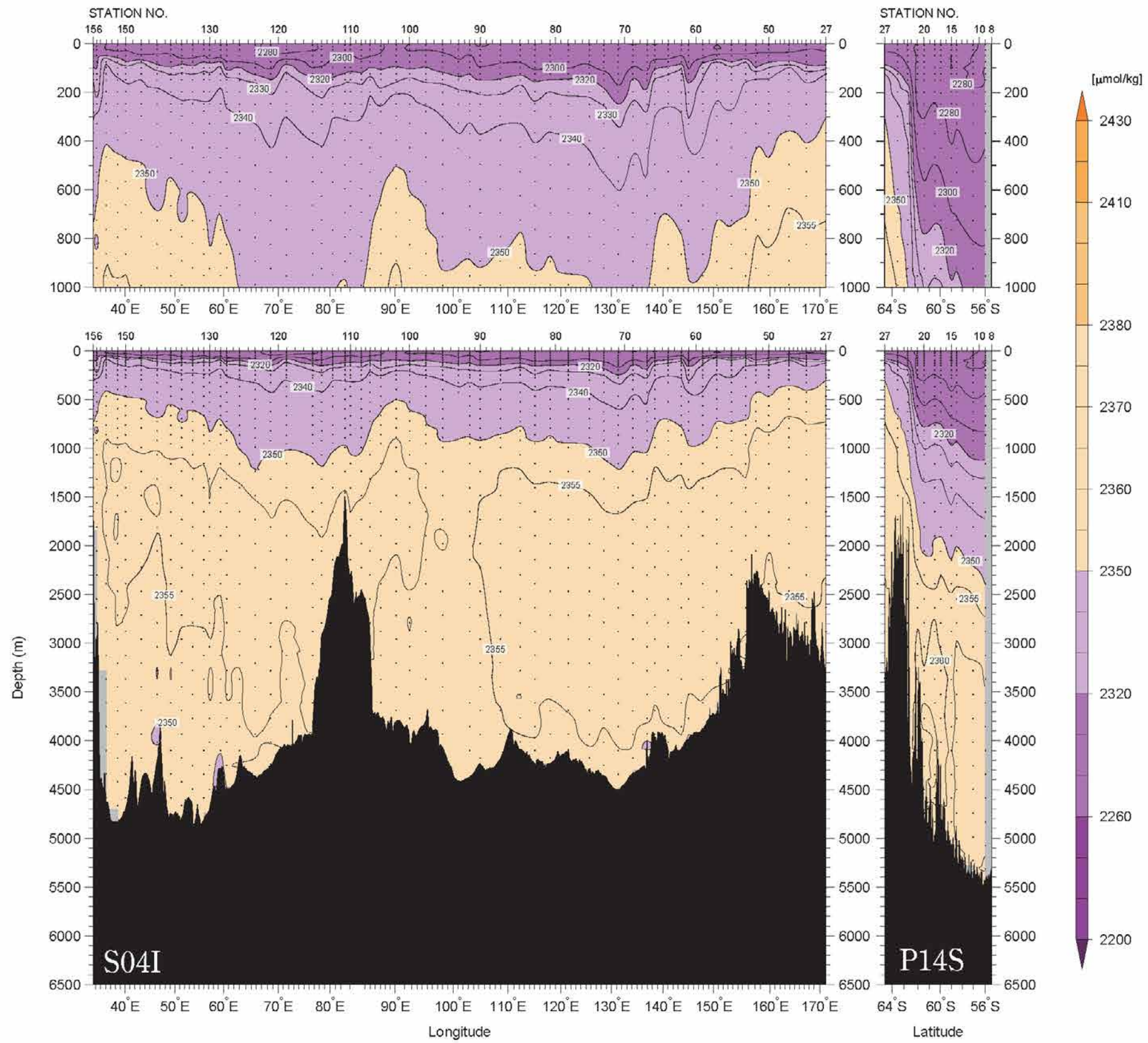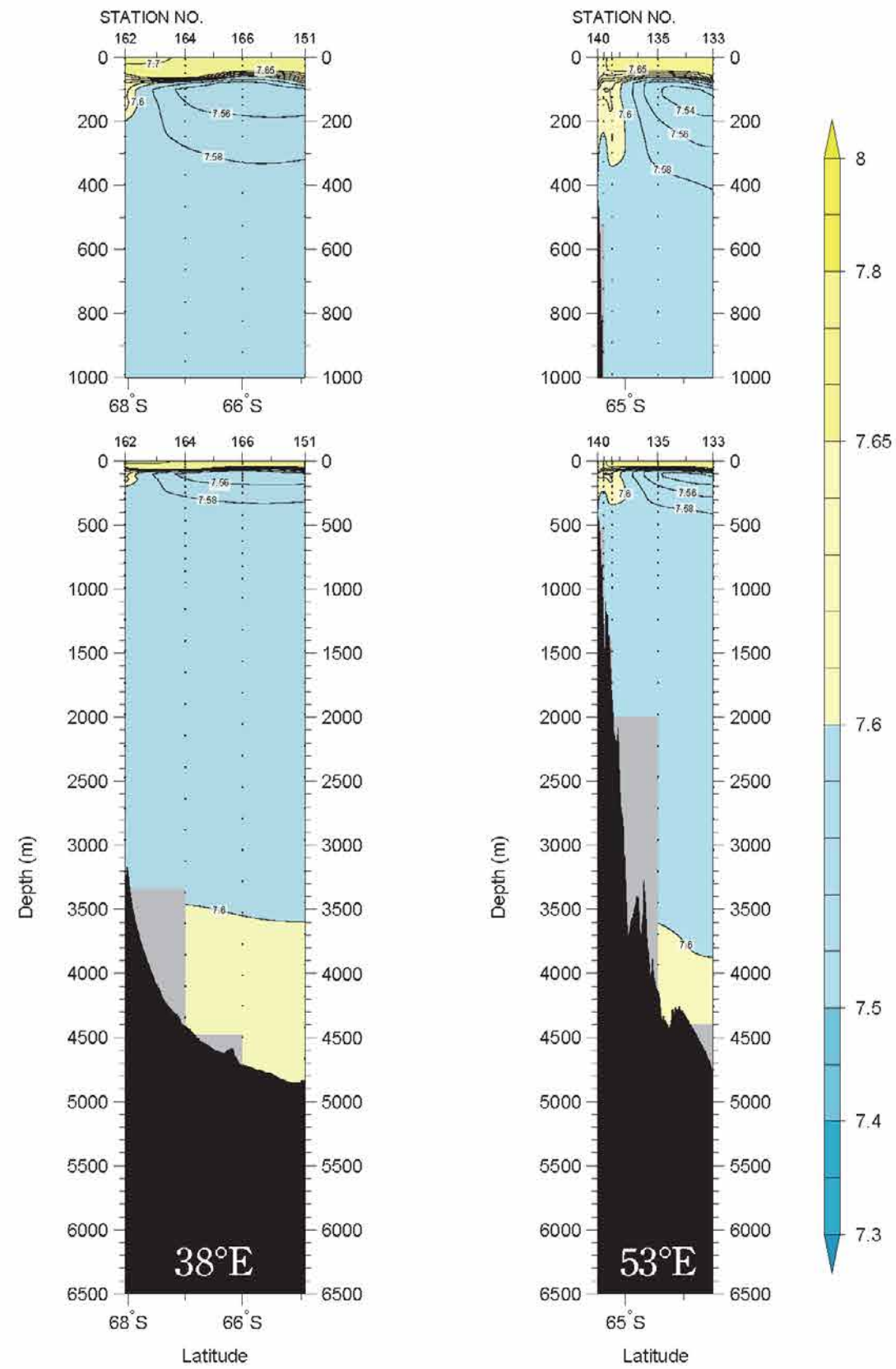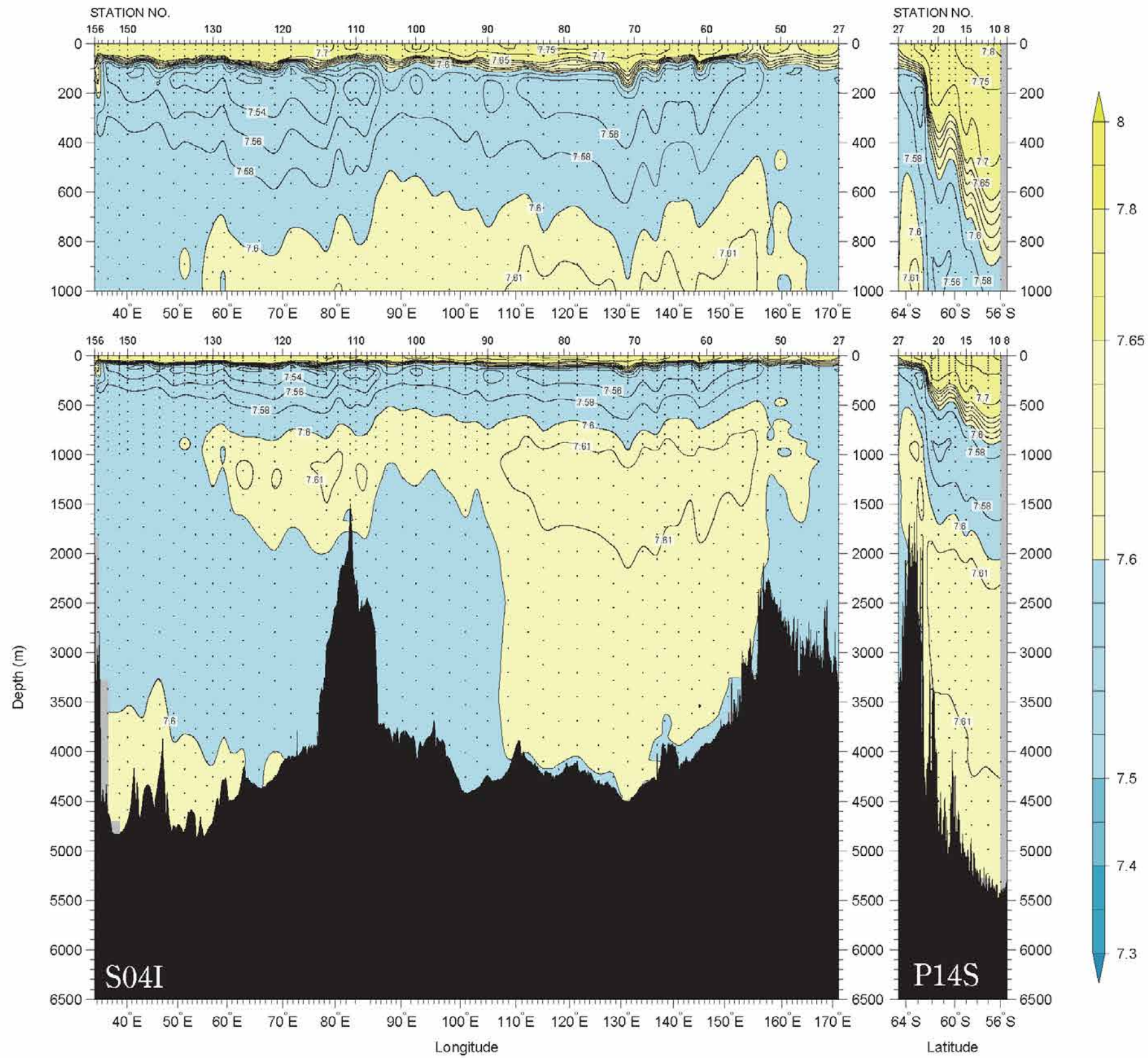
Figure 23
CFC-11 (pmol/kg)

Figure 24
CFC-12 (pmol/kg)

STATION NO.
156 150 130 120 110 100 90 80 70 60 50 27

STATION NO.
27 20 15 10 8

[pmol/kg]

S04I

P14S

Depth (m)

Longitude

Latitude

173

Figure 25
CFC-113 (pmol/kg)

174

Figure 26

SF₆ (fmol/kg)

STATION NO.
156 150 130 120 110 100 90 80 70 60 50 27

STATION NO.
27 20 15 10 8

[fmol/kg]

S04I

P14S

Depth (m)

Longitude

Latitude

177
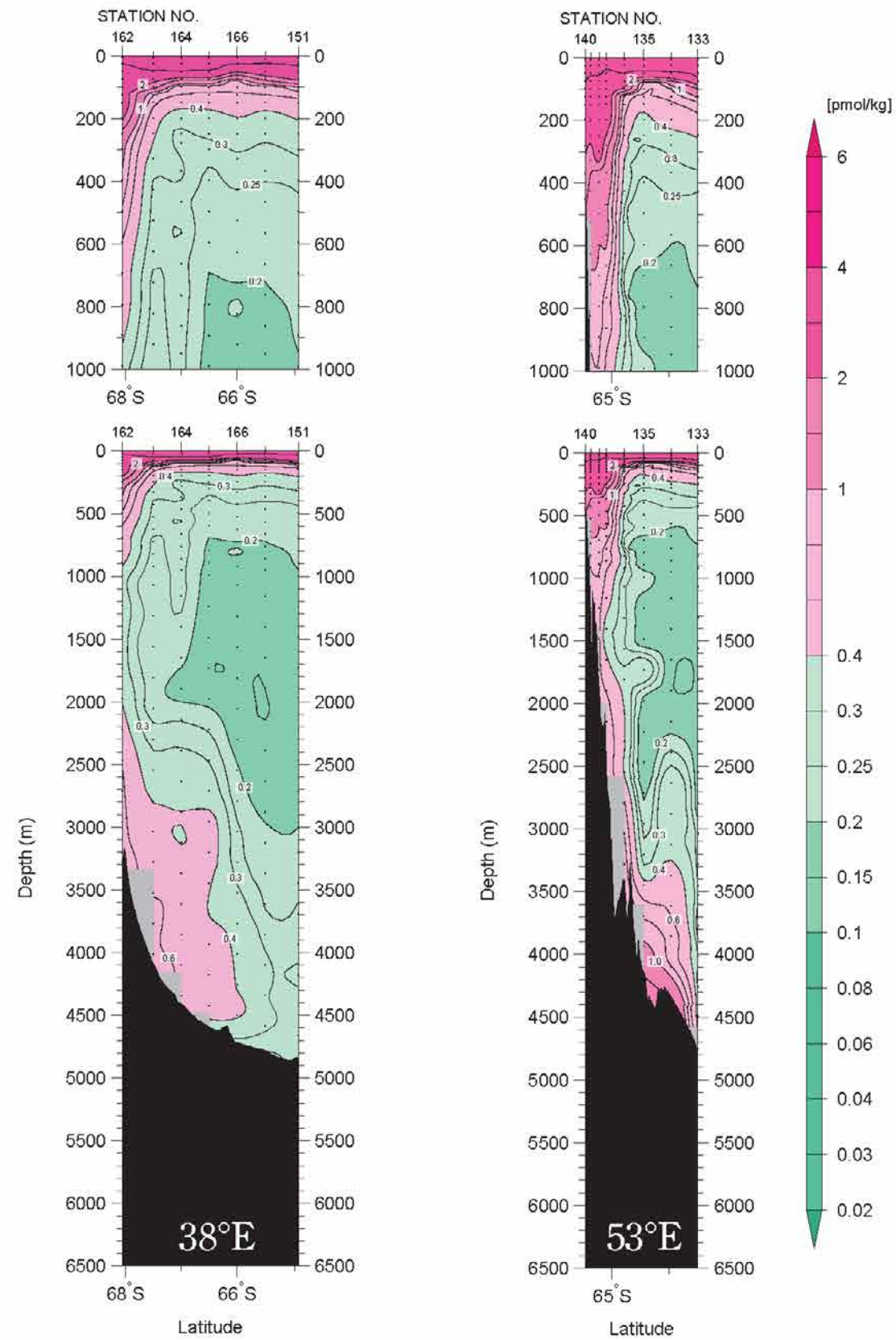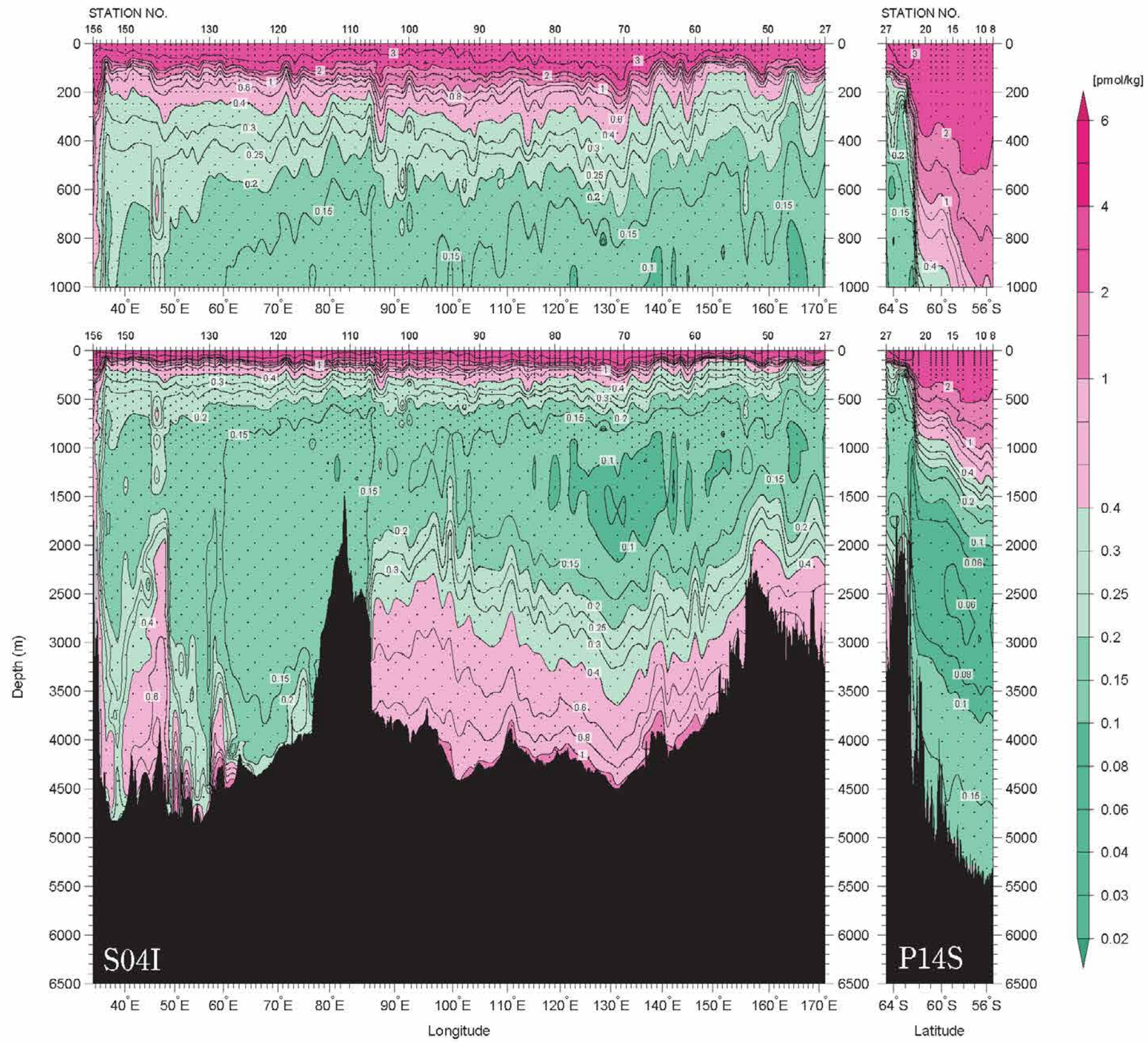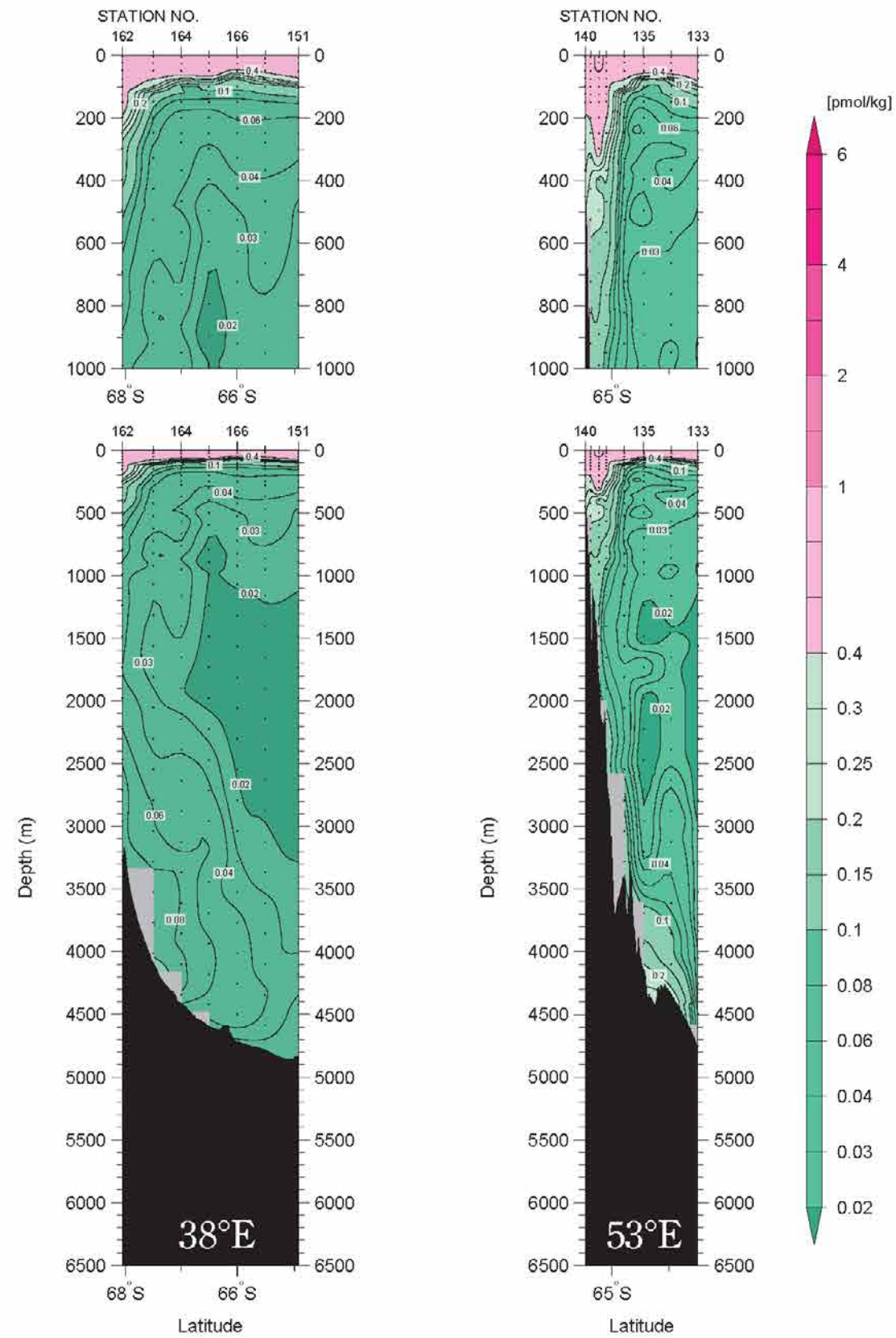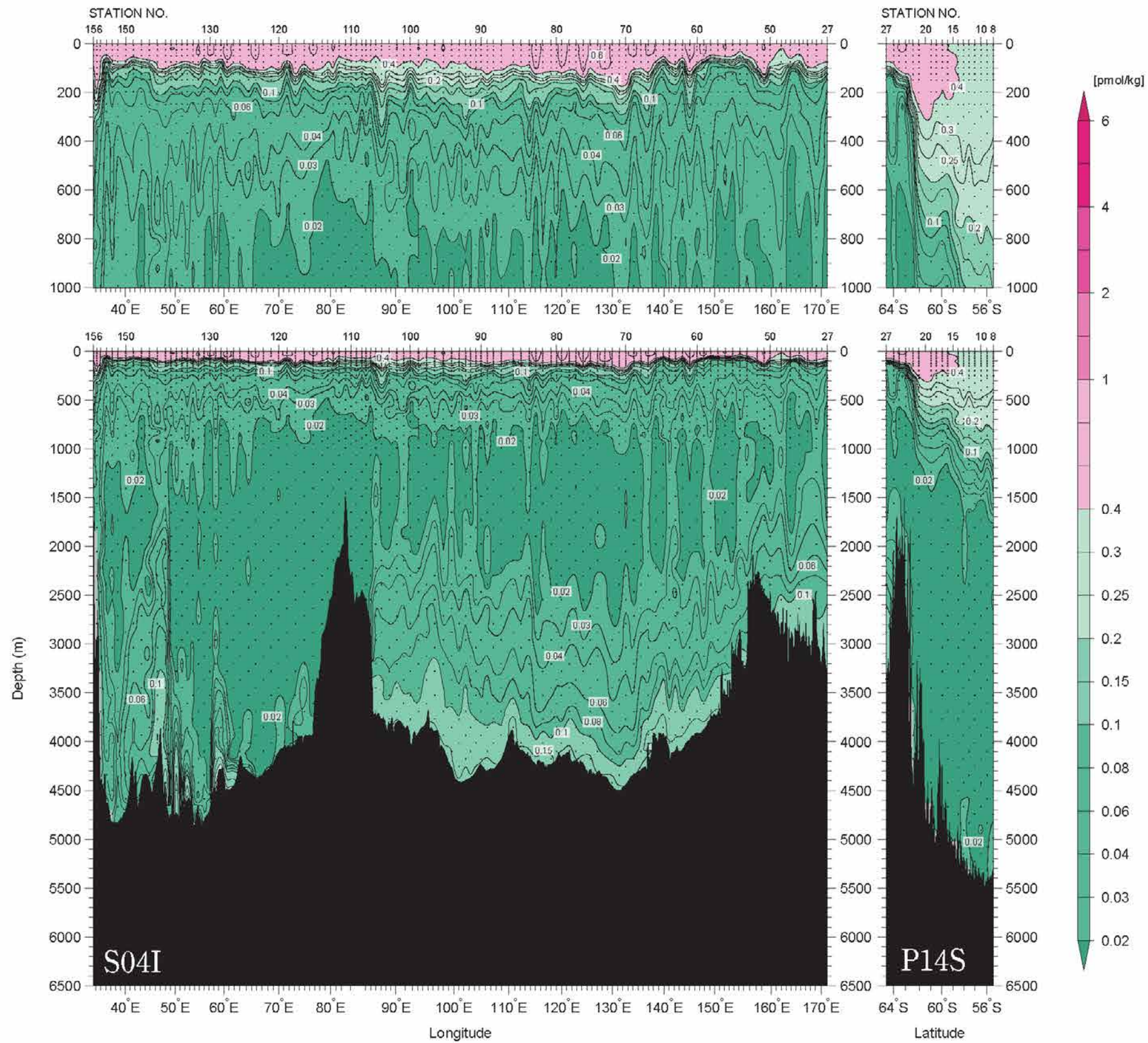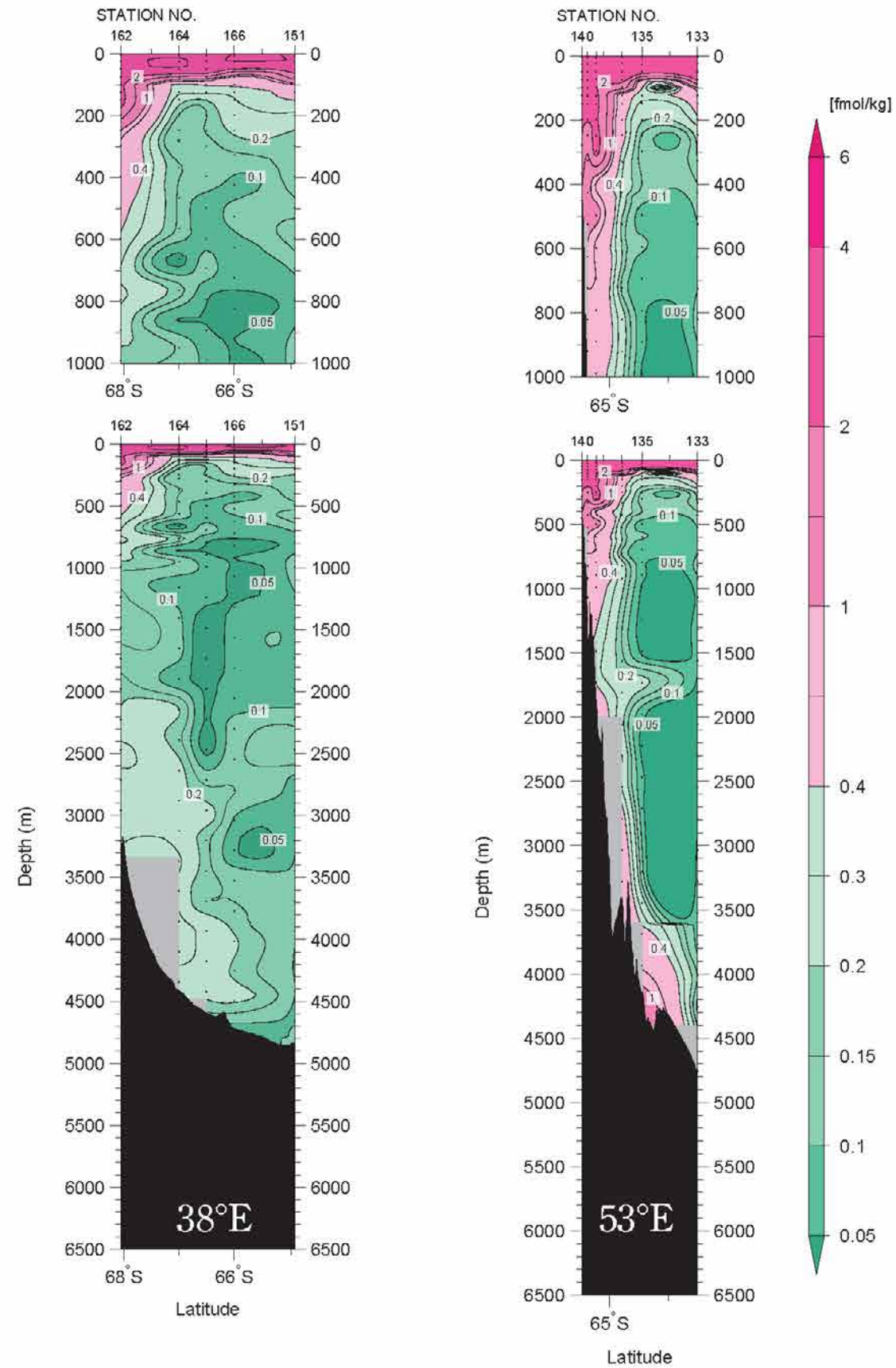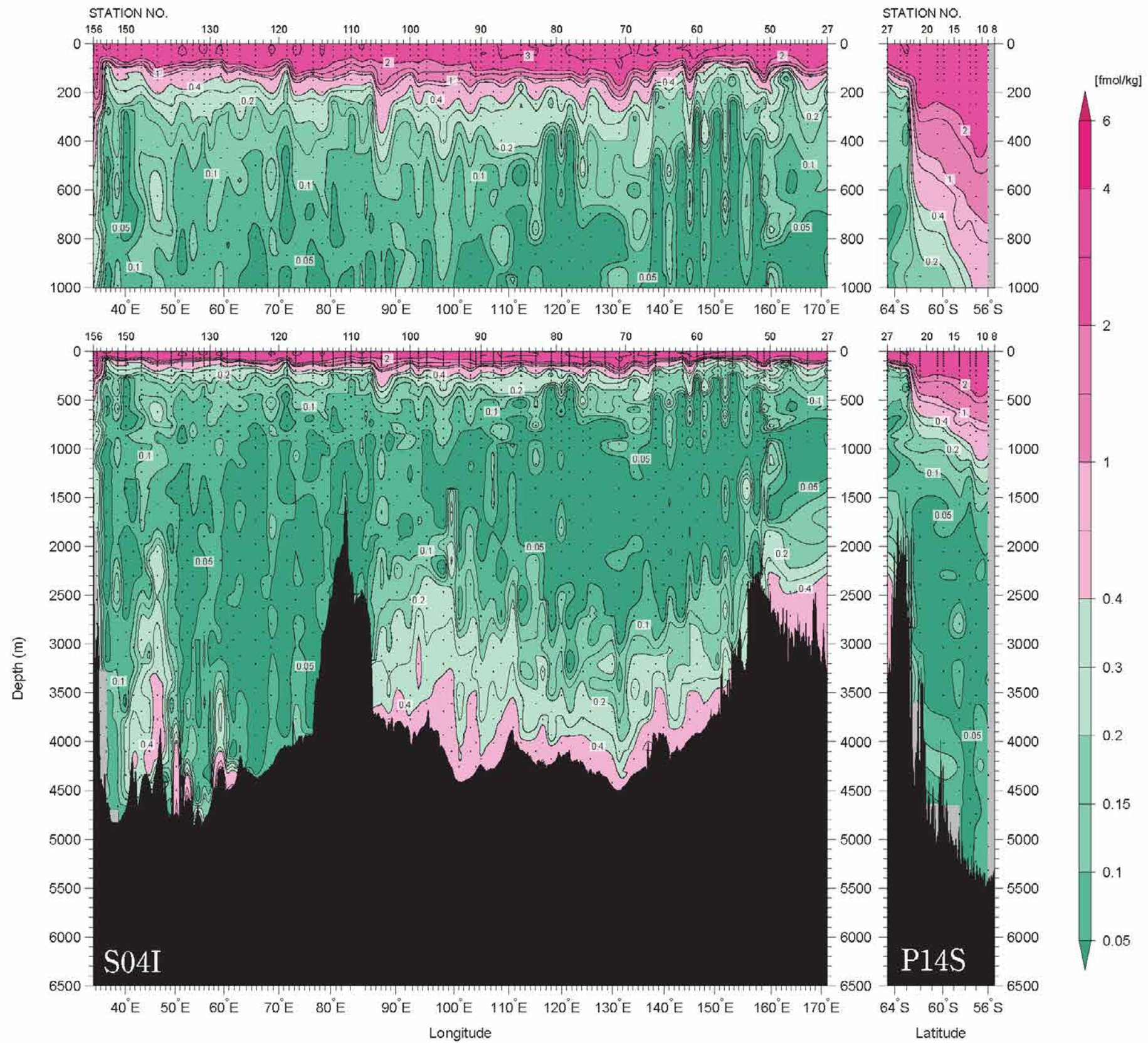
Figure 27

Current velocity (cm/s) normal to the cruise track measured By LADCP (eastward or northward is positive)
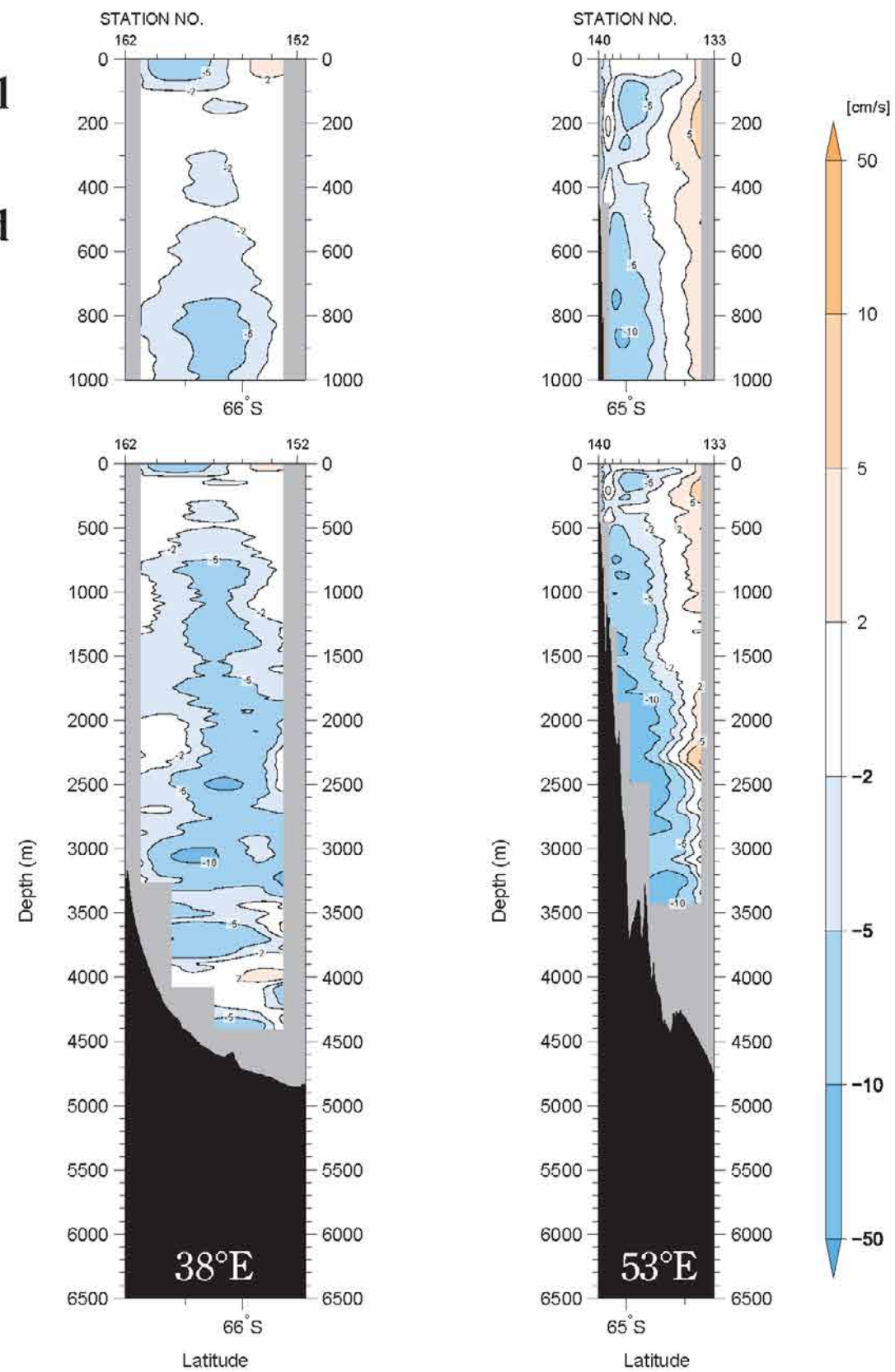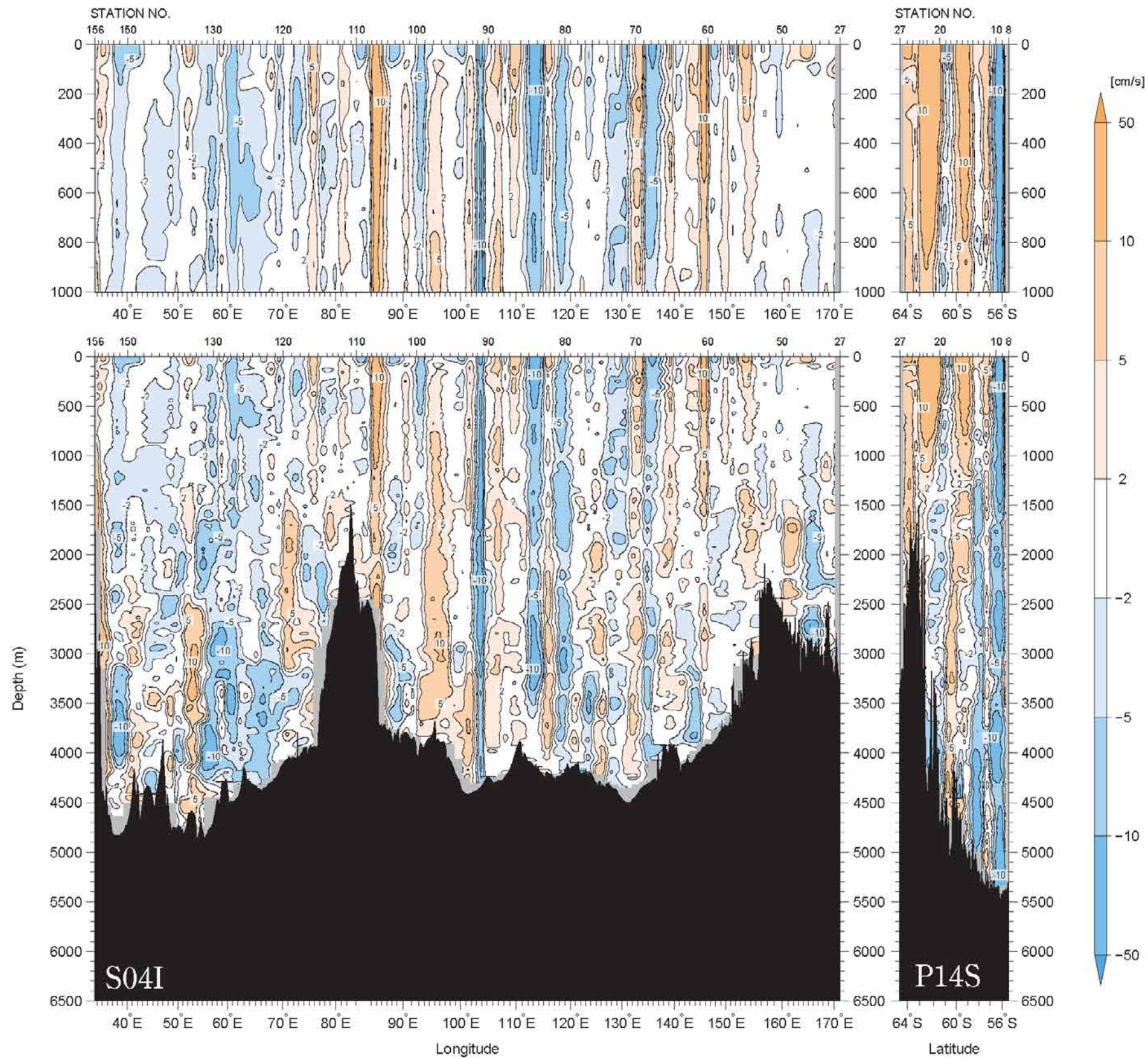
Figure 28

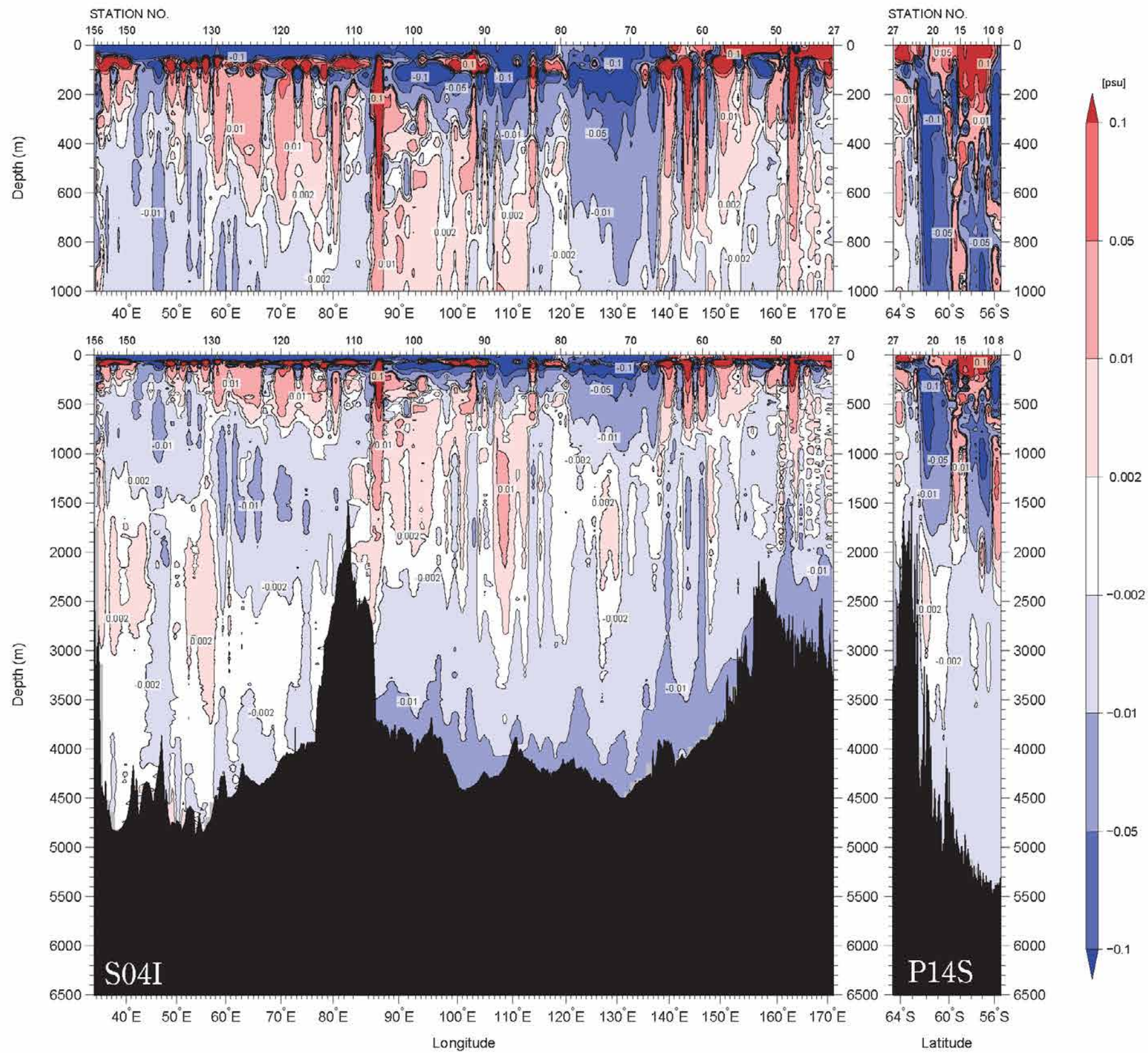## Difference in potential temperature (°C) between results from WOCE in 1995/96 and the revisit in 2012/13
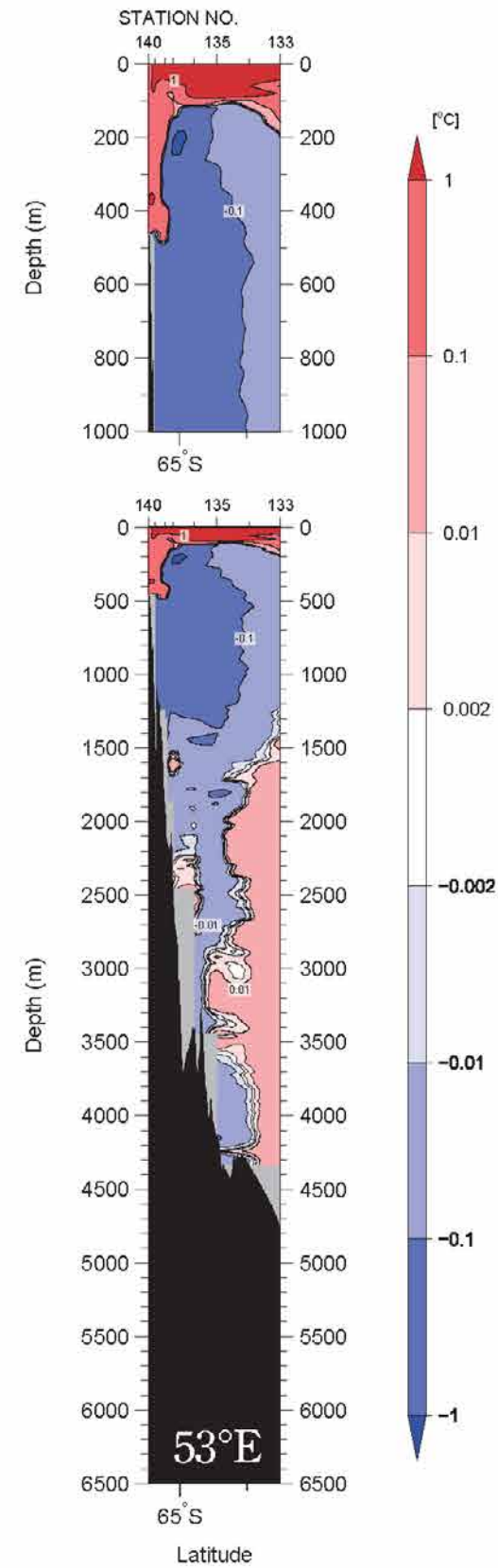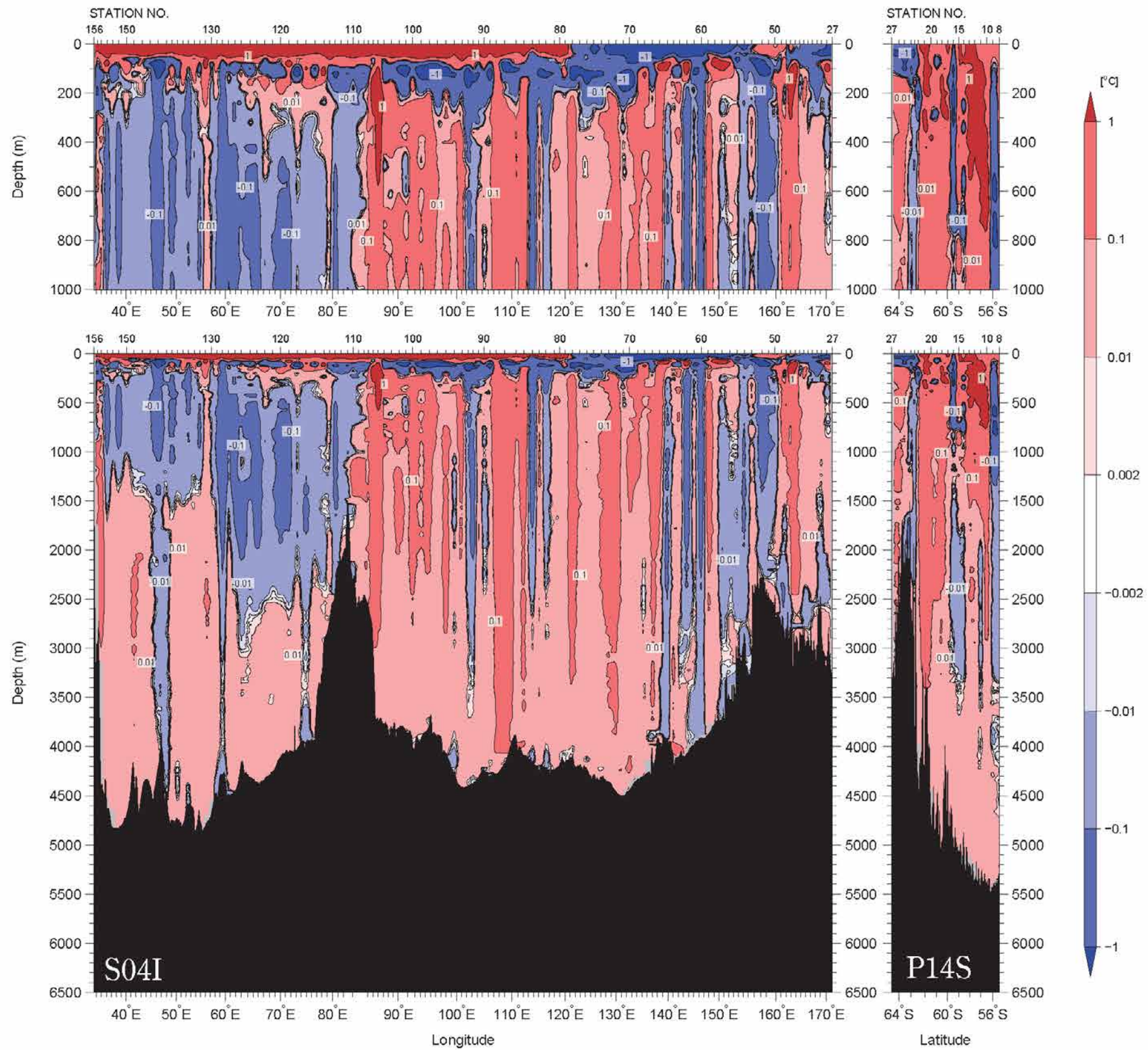
Figure 29

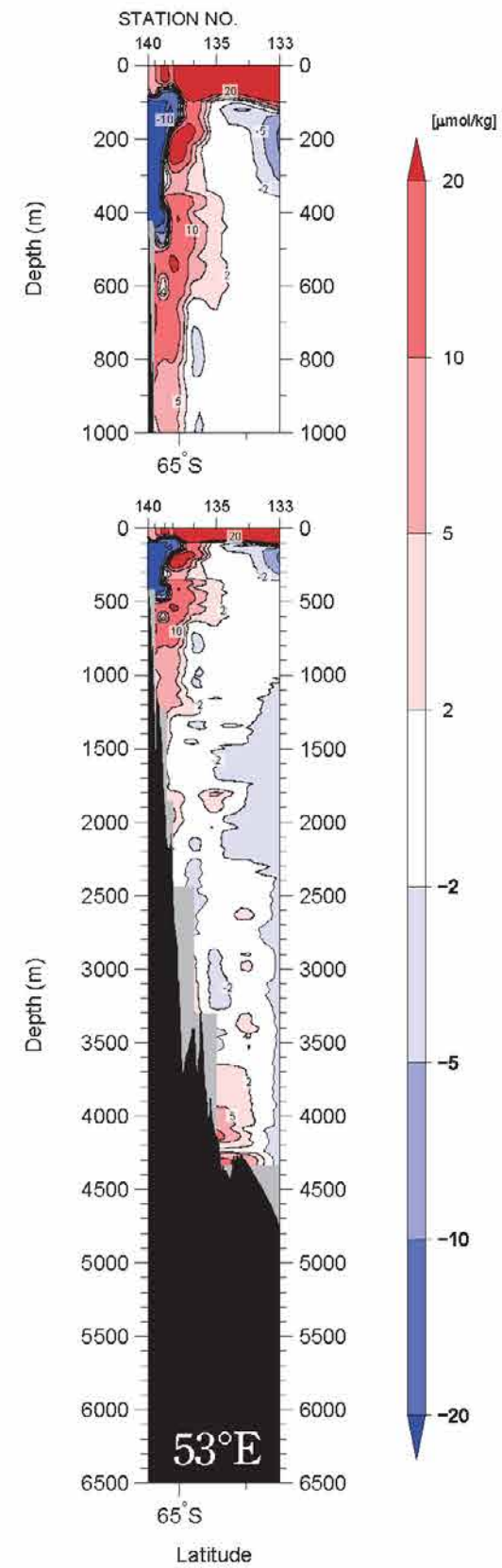## Difference in CTD salinity between results from WOCE in 1995/96 and the revisit in 2012/13

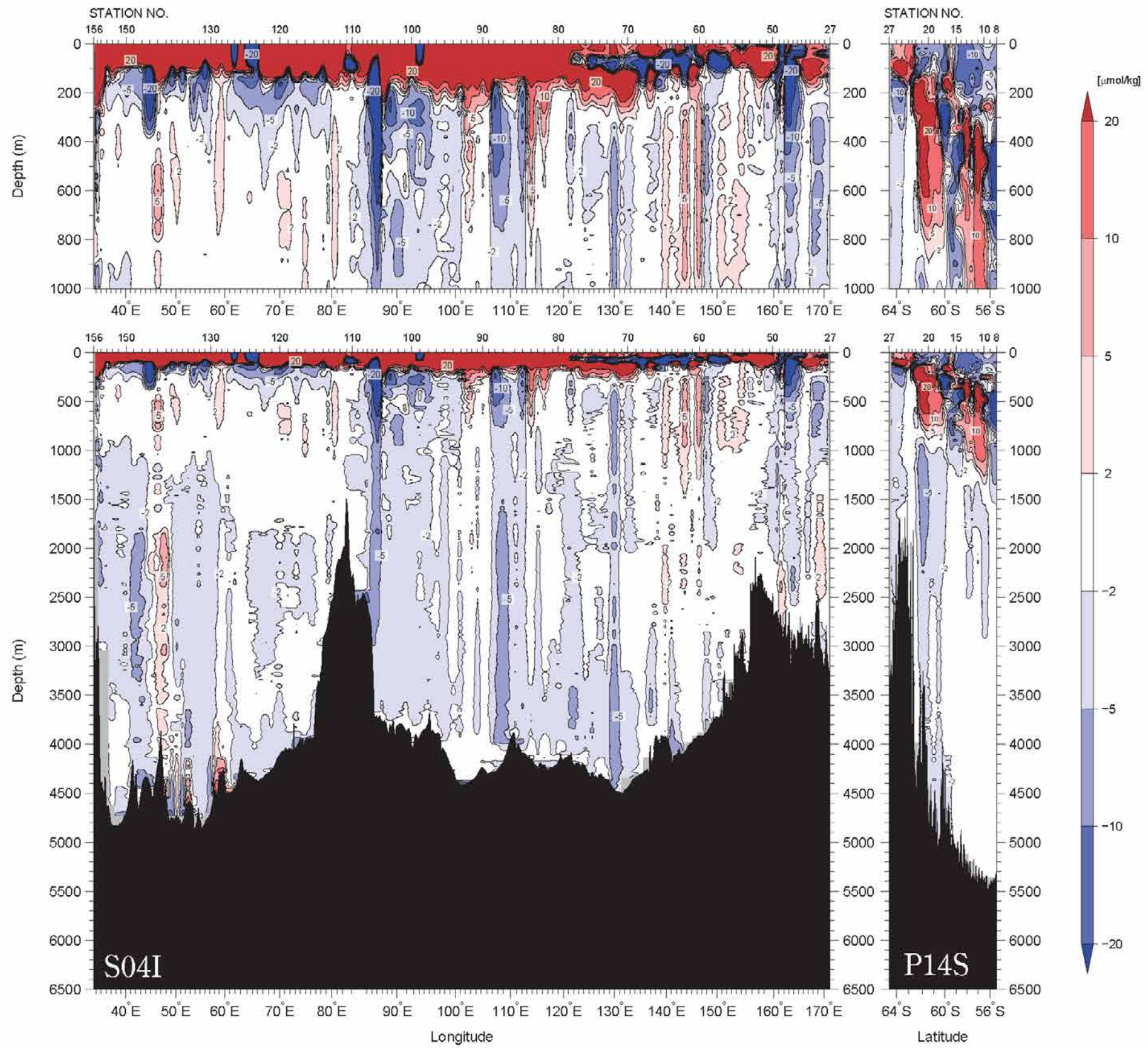STATION NO.

S04I

P14S

Depth (m)

Longitude

Latitude

[psu]

183
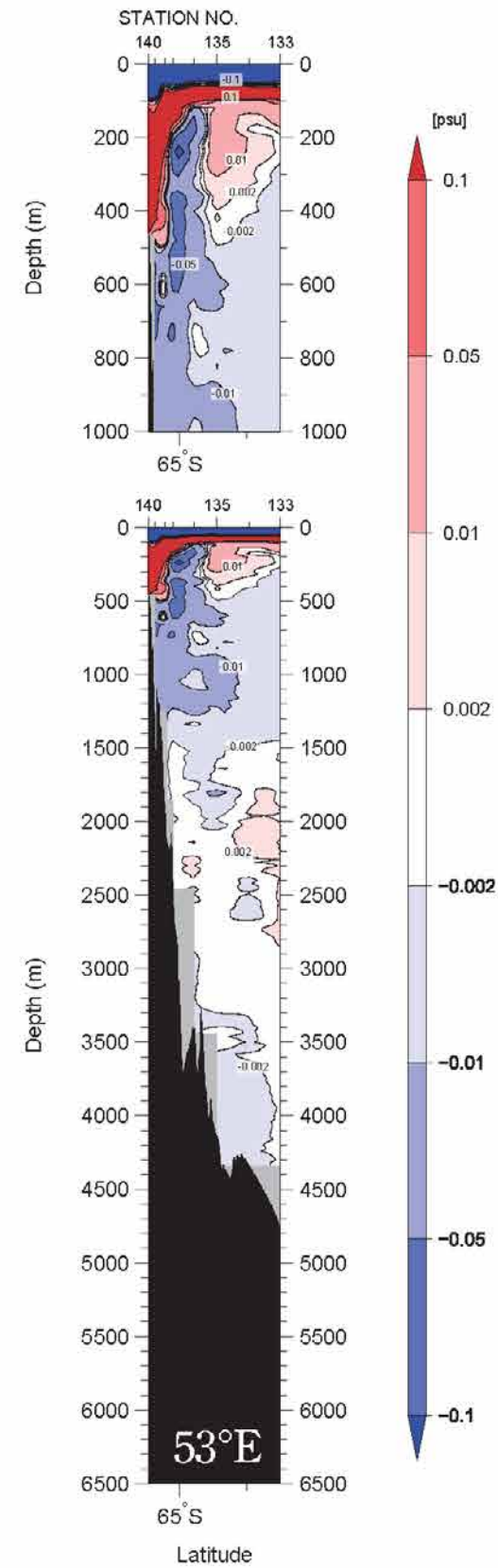
Figure 30

Difference in CTD oxygen (μmol/kg) between results from WOCE in 1995/96 and the revisit in 2012/13

Figure 31

Difference in bottle sampled dissolved oxygen (μmol/kg) between results from WOCE in 1995/96 and the revisit in 2012/13