R/V *Kaiyo* Cruise Report

KY18-04

Technical note for Physical and Chemical oceanographic measurements

5th December 2018 – 3rd March 2019

version 0.1 (30 Sep 2019)

Content

1. Cruise Information

2. Physical and chemical oceanographic measurements

2.1 CTDO2

2.2 Bottle salinity

2.3 Bottle oxygen

2.4 Nutrient

2.5 Carbon items

2.6 Oxygen isotope

2.7 Lowered Acoustic Doppler Curenet Profiler

2.8 Expendible CTD

3. Other measurements

Foreword

This document decribes technical details of physical and chemical oceanographic measurements carried out as part of *multidisciplinary ecosystem survey in the eastern Indian sector of the Antarctic (CCAMLR Division 58.4.1) with a focus on Antarctic frill during 2018/2019 season by the Japanese survey vessel, Kaiyo-mar*u. A preliminary report for the entire cruise has been published in Japanese and available upon request to the lead author. An excerpt in English is available as Murase *et al.* (2019)*. This document accompanies the physical and chemical oceanographic data submitted to CCHDO (CLIVAR and Carbon Hydrographic Data Office) and describes technical aspects of the measurement carried out onboard the cruise KY18-04. For questions, please contact the lead author.

K. Katsumata (Lead author, k.katsumata@jamstec.go.jp), D. Nomura, D. Hirano, S. Toyoda, D. Orui, M. Sato, Y. Koh, K. Yamazaki, M. Kiuchi, S. Aoki, and H. Murase (Principal Investigator)

*Murase, H., Abe, K., Matsukura, R., Sasaki, H., Driscoll, R., Driscoll, S., Schaafsma, F., van Regteren, M., Yang, Q., Ohshima, H., Ohshima, K., Sugioka, R., Tong, J., Yamamoto, N., Doiguchi, H., Briggs, E., Doi, K., Hirano, D., Katsumata, K., Kiuchi, M., Ko, Y., Nomura, D., Orui, M., Sato, H., Toyoda, S., Yamazaki, K., Ishihara, T., Hamabe, K., Kumagai, S., Miyashita, T., Yamada, N., Koyama, Y. and Sasaki, H. 2019. Cruise report of multidisciplinary ecosystem survey in the eastern Indian sector of the Antarctic (CCAMLR Division 58.4.1) with a focus on Antarctic krill during 2018/19 season by the Japanese survey vessel, Kaiyo-maru. WG-EMM-19/42 [available form the CCAMLR Secretariat]

1. Cruise Information

We only list information relevant to the physical and chemical oceanographic measurements. For full information, please refer to the Japanese full cruise report.

1.1. Basic Information

Cruise track:	See Fig. 1.1.1
Cruise code:	KY18-04
Expocode	Leg 1: 490S20181205 Leg 2: 490S20190121
GHPO section designation:	S04I (part)
Ship name:	R/V Kaiyo
Ports of call:	Leg 1, Fremantle, Australia – Melbourne, Australia Leg 2, Melbourne, Australia – Sydney, Australia
Cruise date:	Leg 1, 05 December 2018 – 16 January 2019 Leg 2, 21 January 2019 – 3 May 2019
Scientists onboard in charge of physical/chemical measurements	Leg 1, Katsuro Katsumata (k.katsumata@jamstec.go.jp) Leg 2, Daisuke Hirano (hirano@lowtem.hokudai.ac.jp)
Number of Stations:	Leg 1, XCTD 63 stations, CTD 24 stations Leg 2, XCTD 84 stations, CTD 77 stations
Floats and drifters deployed:	Leg 1, Deep APEX 3 floats, Deep NINJA 1 float, Navis core Argo, 2, SOCCOM BGC Argo 5 Leg 2, Deep SOLO 3, Navis core Argo 2, pCO2 surface drifter 2

Mooring recovery : none

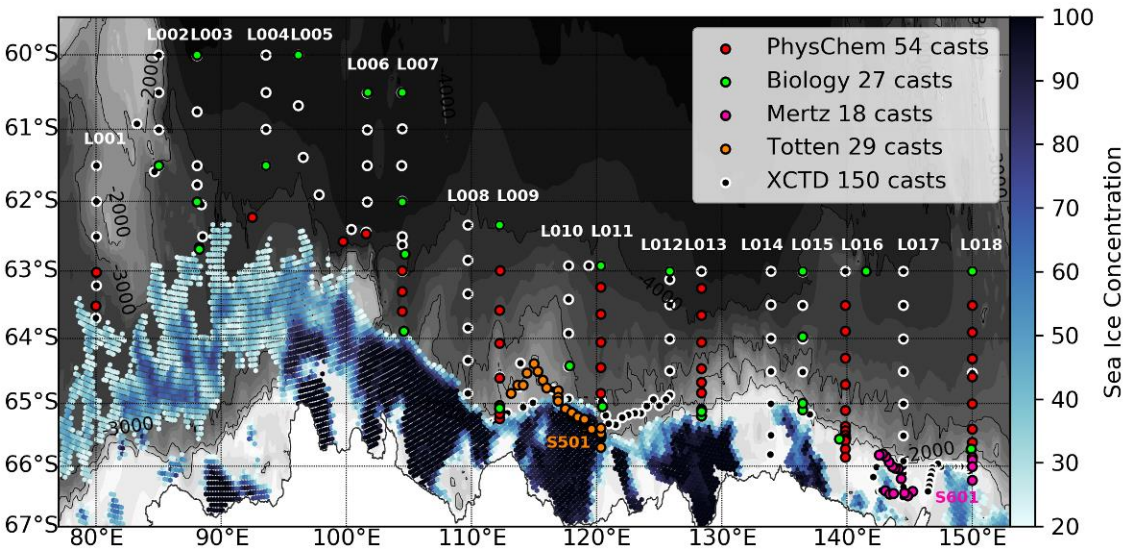


Fig. 1 The physical/chemical and biological CTD stations are denoted by red and green dots, respectively. CTD stations for the small scale oceanographic surveys in the regions off the Mertz and Totten Glaciers are denoted by pink and orange dots, respectively. The locations of XCTD casts are shown by black dots (including both XCTD-1 and XCTD-4). Total numbers for each type of CTD cast are listed in the legend. Background color expresses the bathymetry of GEBCO One Minute Grid with the isobaths of 1,000 m intervals. Sea ice concentration during the survey period estimated from the microwave remote sensing (AMSR2) is presented by bluish dots (see the color scale to the right). Reproduced from the Japanese Cruise Report Figure 15.

1.2. Cruise Participants for physical/chemical oceanographic measurements

List of Participants for leg 1

Katsuro Katsumata	CTD/Sal/XCTD	JAMSTEC
Daiki Nomura	CTD/Carbon/Nutrients/XCTD/TSG	Hokkaido University
Ken Doi	DO/XCTD	Fishery Research Agency of Japan
Masahiro Orui	DO/XCTD	Marine Works Japan
Shinsuke Toyoda	CTD/Salinity/XCTD	Marine Works Japan
Ellen M. Briggs	SOCCOM floats/Sampling	Scripps Institution of Oceanography

List of Participants for leg 2

Daisuke Hirano	CTD/Salinity/XCTD	Hokkaido University
Masaaki Kiuchi	CTD/DO/Carbon/Nutrients	Hokkaido University
Kaihei Yamazaki	CTD/Salinity/DO/XCTD	Hokkaido University
Hiroyasu Sato	DO/XCTD	Marine Works Japan
Yoichiro Koh	CTD/Salinity/DO/XCTD	Hokkaido University

We thank all people onboard volunteered to help us sampling from the Niskin bottles. Some biologists and technicians also helped us with the CTD operation. Full list of participants are found in the Japanese Cruise Report.

2. Physical and chemical oceanographic measurements

2.1 CTDO$_2$ Measurements

(1) Personnel

Katsuro Katsumata (JAMSTEC)
Daisuke Hirano (Hokkaido University)
Shinsuke Toyoda (Marine Works Japan)
Daiki Nomura (Hokkaido University)
Ken Doi (Japan Fisheries Research and Education Agency)
Hiroyasu Sato (Marine Works Japan)
Kaihei Yamazaki (Hokkaido University)
Yoichiro Ko (Hokkaido University)
Masaaki Kiuchi (Hokkaido University)
Sigeru Aoki (Hokkaido University)
Hiroto Murase (Tokyo University of Marine Science and Technology)

(2) Winch arrangements

The CTD package was deployed by using 25 kN Winch (Tsurumi-Seiki Co., Ltd., Kanagawa, Japan). Primary system components include a complete CTD Traction Winch System with up to 7000 m of 8.03 mm armored cable (TE Connectivity, Berwyn, PA, USA).

(3) Overview of the equipment

The CTD system was SBE 911plus system (Sea-Bird Electronics, Inc., Bellevue, Washington, USA). The SBE911plus controls 24-position SBE 32 Carousel Water Sampler. The Carousel equipped with 10-litre water sample bottles (Ocean Test Equipment, Inc., Lauderdale, Florida, USA). The SBE 9plus was mounted horizontally in a 24-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 was mounted in the main housing of the underwater unit and ported to outside through the oil-filled plastic capillary tube. A modular unit of underwater housing pump (SBE 5T) flushed water through sensor tubing at a constant rate independent of the CTD's motion, and pumping rate (3000 rpm) remained nearly constant over the entire input voltage range of 12-18 volts DC. Flow speed of pumped water in standard TC duct was 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 were also used with the SBE 9plus underwater unit; an altimeter (PSA-916T; Teledyne Benthos, Inc., North Falmous, Massachusetts, USA), an oxygen optode (RINKO-III; JFE Advantech Co., Ltd, Kobe Hyogo, Japan), a 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 Inc., Halifax, Nova Scotia, Canada).

Summary of the system used in this cruise

24-position Carousel system

Deck unit:

SBE 11plus, S/N 11P13830-0408

Under water unit:

SBE 9plus, S/N 09P67356-1076 (pressure sensor S/N: 121329)

Temperature sensor:

SBE 3plus, S/N 03P2405 (primary)

SBE 3plus, S/N 03P4811 (secondary)

Conductivity sensor:

SBE 4, S/N 043969 (primary)

SBE 4, S/N 043264 (secondary)

Oxygen sensor:

SBE 43, S/N 430624

JFE Advantech RINKO III, S/N 0275 (foil batch no. 161209BA)

Pump:

SBE 5T, S/N 056321 (primary)

SBE 5T, S/N 053575 (secondary)

Altimeter:

PSA-916T, S/N 46614

Fluorometer:

Seapoint Sensors, Inc., S/N SCF-3567 (measurement range: 0-15 μg/L)

Transmissometer:

C-Star, S/N CST-1757DR

PAR:

SatPAR, S/N 1167

Carousel Water Sampler:

SBE 32, S/N 3218189-0218

Water sample bottle:

10-litre water sample bottle model 110

Deep ocean standard thermister

SBE-35, S/N 0022

(4) Pre-cruise calibration

i. Pressure

The pressure sensor was Paroscientific series 4000 Digiquartz high pressure transducer (Model 415K:

Paroscientific, Inc., Redmond, Washington, USA) with 0.01 per million of resolution over the absolute pressure range of 0 to 15000 psia (0 to 10332 dbar). 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 1076, 20 July 2018

slope = 0.99996000

offset = 0.12400

ii. Temperature (SBE 3)

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 03P2405, 04 January 2018

S/N 03P4811, 16 April 2015

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

S/N 4811, –2.7192e–7 [°C/dbar]

iii. Conductivity (SBE 4)

The SBE 4 has a nominal accuracy of 0.0003 S/m, typical stability of 0.0003 S/m/month, and resolution of 0.00004 S/m at 24 samples per second

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

S/N 043969, 11 September 2018

S/N 043264, 01 March 2012

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 430624, 14 August 2018

v. Deep Ocean Standards Thermometer

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. Since 2014, fixed-point cells traceable to NIST temperature standards is directly used in the manufacturer's calibration of the SBE 35 (Uchida et al., 2015).

S/N 0022, 4 February 2015 (slope and offset correction)

Slope = 1.000007

Offset = 0.000246

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

The PSA-916T uses the nominal speed of sound of 1500 m/s.

vii. Oxygen optode (RINKO)

RINKO model III (JFE Alec Co., Ltd) 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 = 0.0126 (for S/N 0275)

H2 = 5000 dbar

H3 = 2000 seconds

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 Tr (in %) and beam attenuation coefficient cp are calculated from the sensor output (V in volt) as follows.

$$Tr = M * volts + B$$

$$cp = -(1 / 0.25) \ln(Tr / 100)$$

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

S/N CST-1757DR, 20 November 2015

x. PAR

Photosynthetically Active Radiation (PAR) sensors (Satlantic, LP, Halifax, Nova Scotia, Canada) 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 1167, 28 August 2018

(5) Data collection and processing

i. Data collection

CTD system was powered on at least 15 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. On some stations, the stabilization time was not long enough. This will be remarked in (6)i,below.

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 the bottom. . For the up cast, the package was lifted at a rate of 1.0 m/s except for bottle firing stops. As a rule, the bottle was fired after waiting from the stop for 30 seconds to enhance exchanging the water between inside and outside of the bottle.

Water samples were collected using a 24-bottle SBE 32 Carousel Water Sampler with 10-litre sample bottles.

Data acquisition software

SEASAVE-Win32, version 7.26.7.107

ii. Data collection problems

(a) Miss trip, miss fire, and remarkable leak

Sample bottles did not trip correctly at the following stations.

Miss trip	Miss fire	Leak
none	none	001_1 #12, #18, #21
		002_1 #12, #20, #22
		802_1 #1
		804_2 #19, #21
		003_1 #10, #20, #23
		805_1 #1
		806_1 #14
		807_2 #20
		008_1 #2
		009_1 #10, #20
		010_1 #10
		011_1 #20, #22
		012_1 #20
		016_1 #15
		814_1 #14, #15
		017_1 #15
		020_1 #15
		022_1 #1, #14, #21
		817_1 #1
		027_1 #1
		607_1 #10
		608_1 #7
		609_1 #10
		034_1 #19
		035_1 #11, #19
		038_1 #1
		047_1 #19
		048_1 #11
		053_1 #9, #12, #19
		054_1, #1, #2
		501_1, #5, #9
		504_1, #2
		506_1, #7, #19
		508_1, #5, #11
		509_1, #10
		510_1, #2
		519_1, #2

521_1, #2

522_1, #19

525_1, #2

526_1, #20

527_1, #2

529_1, #9

(b) Noise in down cast data

Primary temperature data were noisy at station 806_1 (from 28 dbar) of down cast. Primary conductivity data were noisy at station 806_1 (from 28 dbar), 015_1 (from 67 dbar) of down cast.

iii. Data processing

We followed the standard data processing method recommended by SBE Data Processing software (version 7.23.2); namely;

1. DATACNV (4.4 seconds for bottle detection and 0.0 seconds for offfset)
2. TCORP
3. RINKOCOR
4. RINKOCORROS
5. BOTTLESUM (4.4 seconds average or 1 second for non-stopping fire)
6. ALIGNCTD (1.73 scan delay for conductivity; 5 second advancing for SBE-43; 1 second advancing for RINKO; 2 second advancing for transmissiometer)
7. WILDEDIT(10 standard deviation for the 1st pass, 20 standard deviation for the 2nd pass within 1000 scans)
8. CELLTM (alpha=0.03, 1/beta=7.0)
9. FILTER (0.15 seconds)
10. WFILTER (49 scan window)
11. SECTIONU
12. LOOPEDIT
13. DERIVE
14. BINAVG (1 dbar bin)
15. SPLIT

(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 15 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 (12.5 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. 2.1. 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 (0.24 dbar) from the pre-cruise calibration. The post-cruise correction of the pressure data is not necessary for the pressure sensor.

There is one cast where the pre-deployment pressure was abnormally low around day 218. This is Station 522 Cast 001. The power of the deck unit was turned on just before deployment and the pressure sensor was not stabilized. The pressure reading after deployment before the CTD pump was turn one was almost identical with the readings from Stations 521 and 523. We thus regard the pressure reading for 522 was accurate.

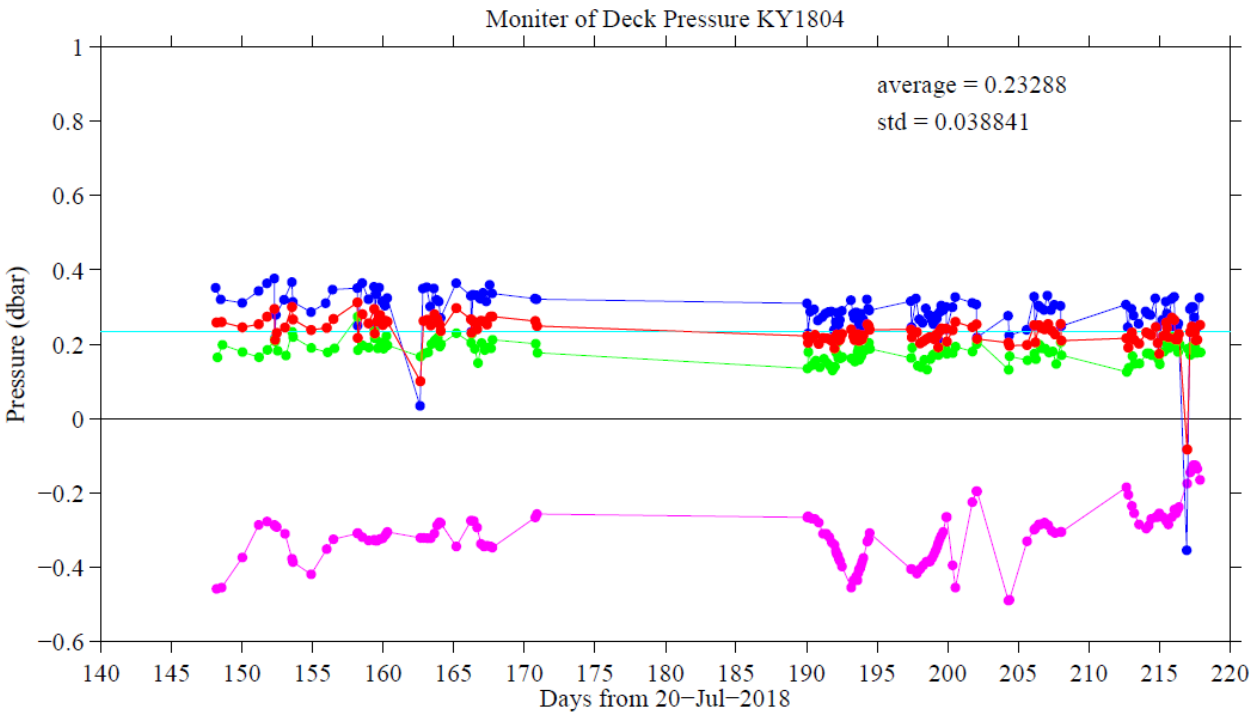


Fig. 2.1 Time series of the CTD deck pressure. Atmospheric pressure deviation (magenta dots) from a standard atmospheric pressure was subtracted from the CTD deck pressure. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dots indicate averages of the pre- and the post-cast deck pressures.

ii. Temperature

The CTD temperature sensors (SBE 3) were calibrated using a method by Uchida et al. (2007) 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.

Fig.2.2 shows the difference between SBE-3 and SBE-35. Generally both primary and secondar SBE-3 were stable. Around Day=43, the primary sensor showed unstable readings. We use the secondary reading for these stations.

The CTD temperature was preliminary calibrated as

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

where T is CTD temperature in °C, P is pressure in dbar, t is time in days from pre-cruise calibration date of the CTD temperature (=345.2028 for station 001 cast 1) and c_0, c_1, and c_2 are calibration coefficients. The coefficients were determined using the data for the depths deeper than 1950 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 2.1. The results of the post-cruise calibration for the CTD temperature are shown in Fig. 2.3.

Table 2.1 Calibration coefficients for the CTD temperature sensors.

Serial number	c_0 (°C/dbar)	c_1 (°C/day)	c_2 (°C)
4811	2.45396687e–7	2.39155e–6	–4.7818e–4
1359	–2.09739841e–7	5.01829e–7	–5.7450e–4

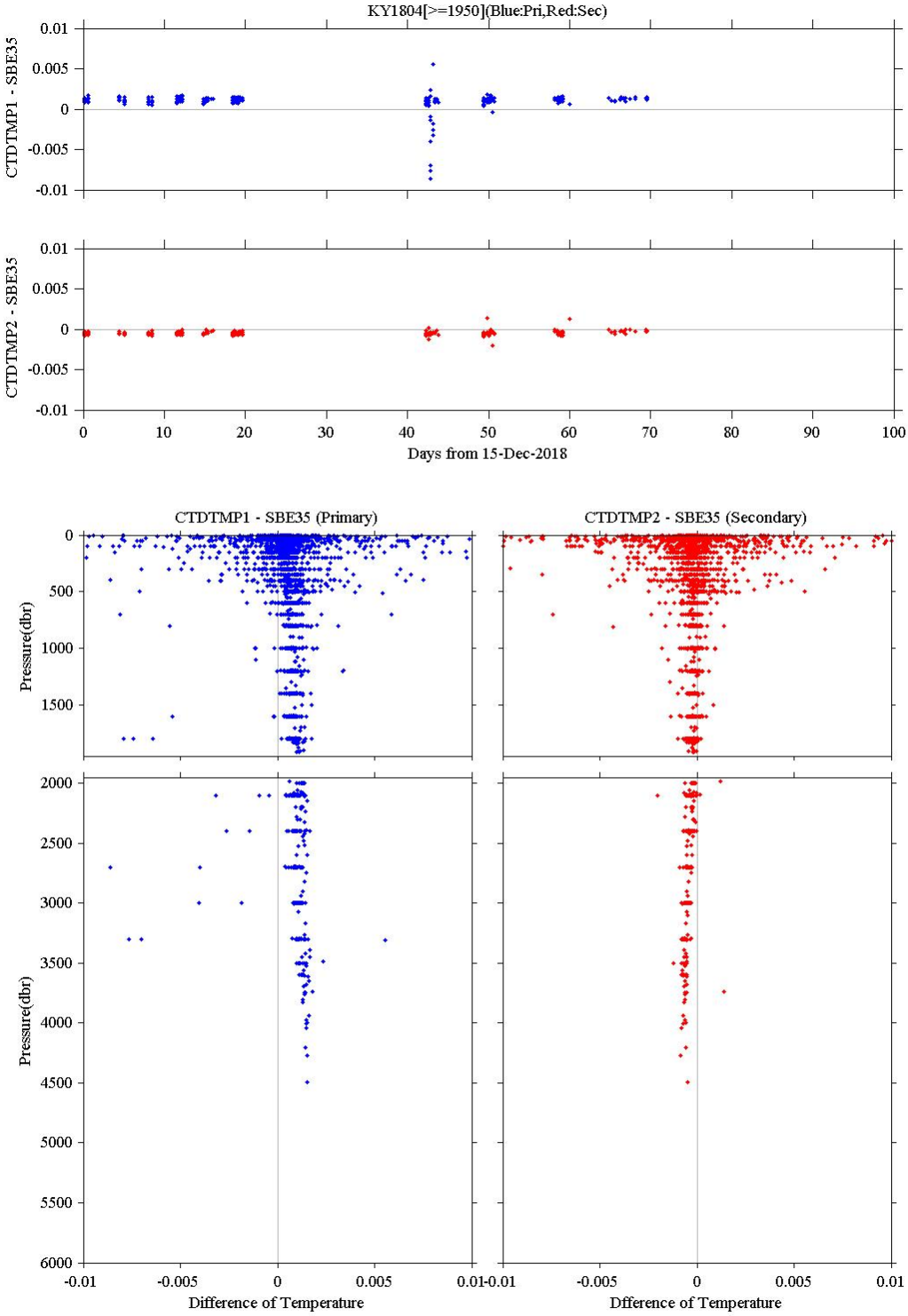


Fig. 2.2 Difference between the CTD temperature (blue:primary, red:secondary) and the SBE 35. Upper two panels show temporal development and lower two pressure dependence.

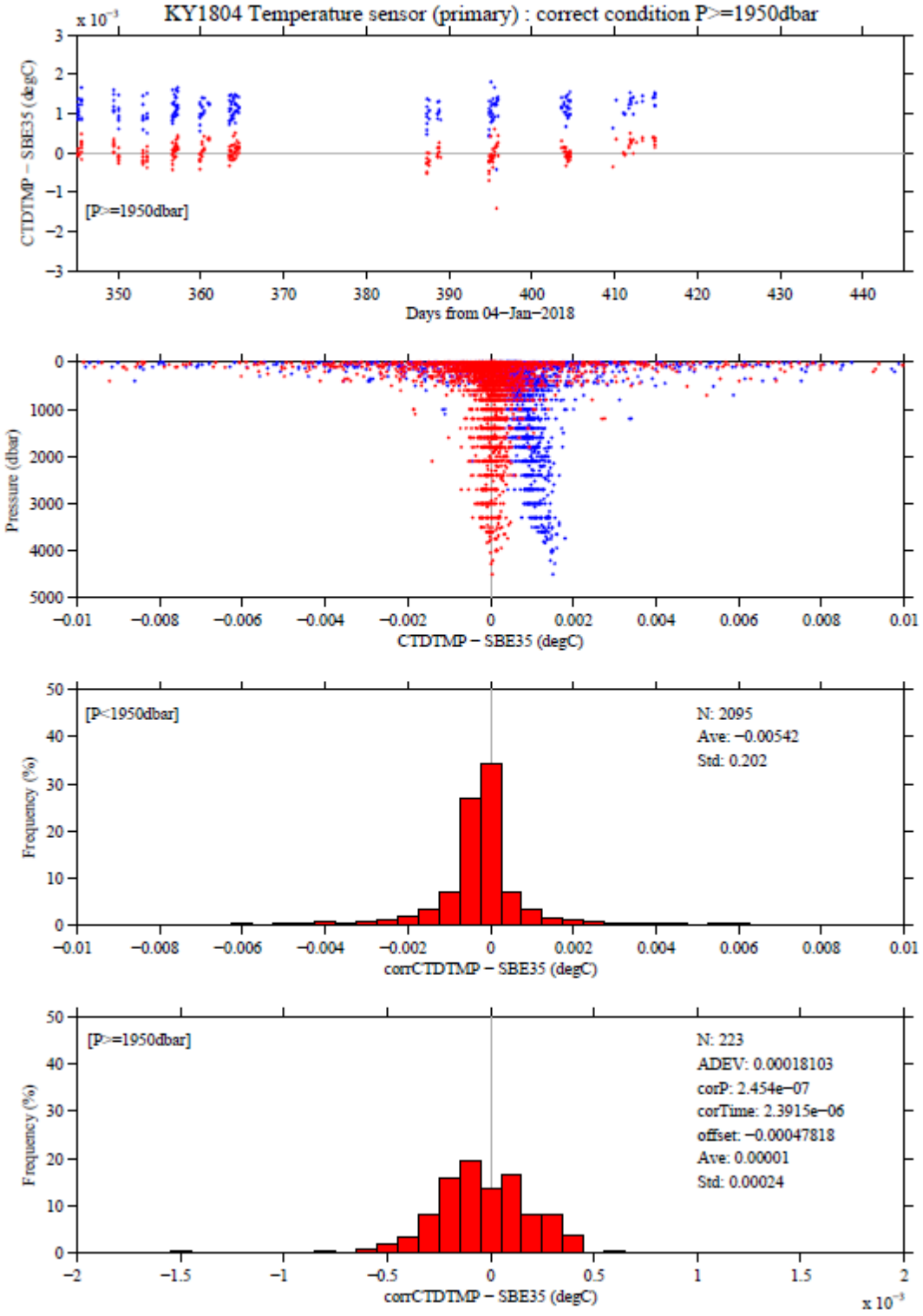


Fig 2.3: Calibration for the primary temperature sensor. Blue is uncalibrated, red is calibrated for the top panel (time development) and the second panel (depth dependence). The lower two panels show the histgram of the difference for shallow (< 1950 dbar) and deep (>= 1950 dbar) data.

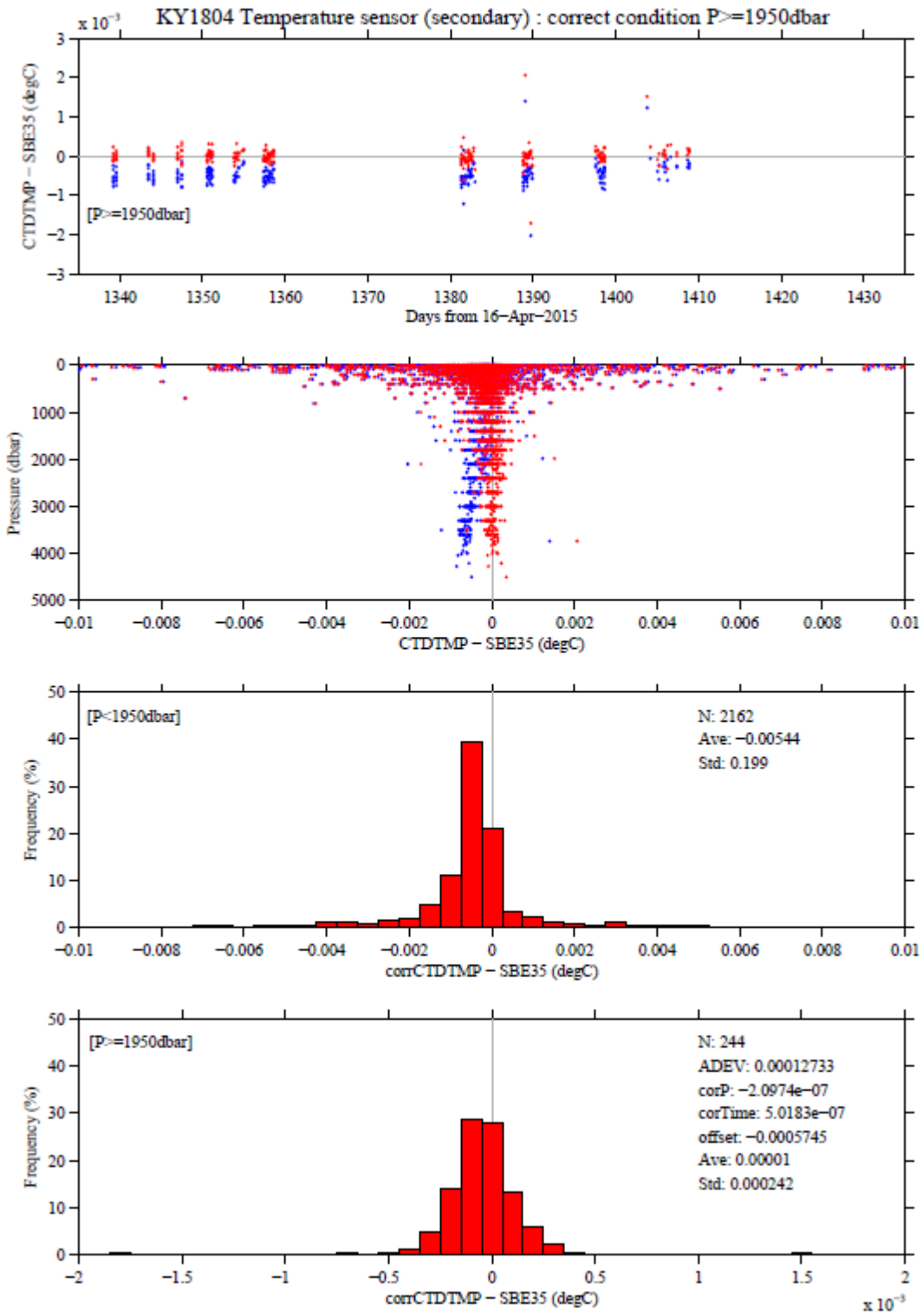


Fig 2.4: Calibration for the secondary temperature sensor. Blue is uncalibrated, red is calibrated for the top panel (time development) and the second panel (depth dependence). The lower two panels show the histgram of the difference for shallow (< 1950 dbar) and deep (>= 1950 dbar) data.

iii. Salinity

Fig 2.5 shows the differnce between the CTD conductivity and bottle salinity. The primary sensor was generally stable during Leg 1 but drifted towards low values during Leg 2. Around DAY=43, the reading for the primary was unstable, possibly linked to the similar situation for the temperature sensor (Fig.2.2). We use the reading from the secondary for these stations. We regard the secondary as drifting with time towards lower values.

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

$$\text{Calibrated conductivity} = C - (c_0 \times C + c_1 \times P + c_2 \times C \times P + c_3 \times C^2 + c4 \times t + c_{5)}$$

where C is CTD conductivity in S/m, P is pressure in dbar, t is time in days (t=0 at the start of the first cast on each leg), and c_0, c_1, c_2, c_3, c_4, and c_5 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 used after the post-cruise calibration for the temperature data. The calibration coefficients are listed in Table 2.3. The results of the post-cruise calibration for the CTD salinity are shown in Fig. 2.6.

Table 2.3 Calibration coefficients for the conductivity sensors. The first 2 lines for Leg 1 (t=0 at station 1 cast 1), the following 2 lines for Leg 2 first part (t=0 at station 818 cast 1), the last 2 lines for Leg 2 second part (t=0 at station 506 cast 1).

Serial number	c0 ()	c1 (S/(m dbar))	c2 (1/dbar)	c3 (m/S)	c4 (S/(m day))	c5 (S/m)
043969	1.284357e–3	3.163250e–6	–1.018073e–6	–1.492625e–5	4.956134e–6	–3.622195e–3
043264	4.090534e–4	2.181403e–6	–7.086326e–7	1.325711e–4	–1.444536e–5	–2.343661e–3
043969	–1.524666e–3	1.012093e–6	–3.024394e–7	2.678404e–4	–6.008872e–6	2.386300e–3
043264	–4.039886e–3	1.233949e–6	–3.973485e–7	7.094685e–4	–6.442122e–6	5.514836e–3
043969	–3.227557e–3	2.152767e–6	–6.930300e–7	5.959293e–4	–4.273015e–5	4.142508e–3
043264	–1.947506e–3	2.025779e–6	–6.683331e–7	3.573764e–4	–3.141508e–5	1.983786e–3

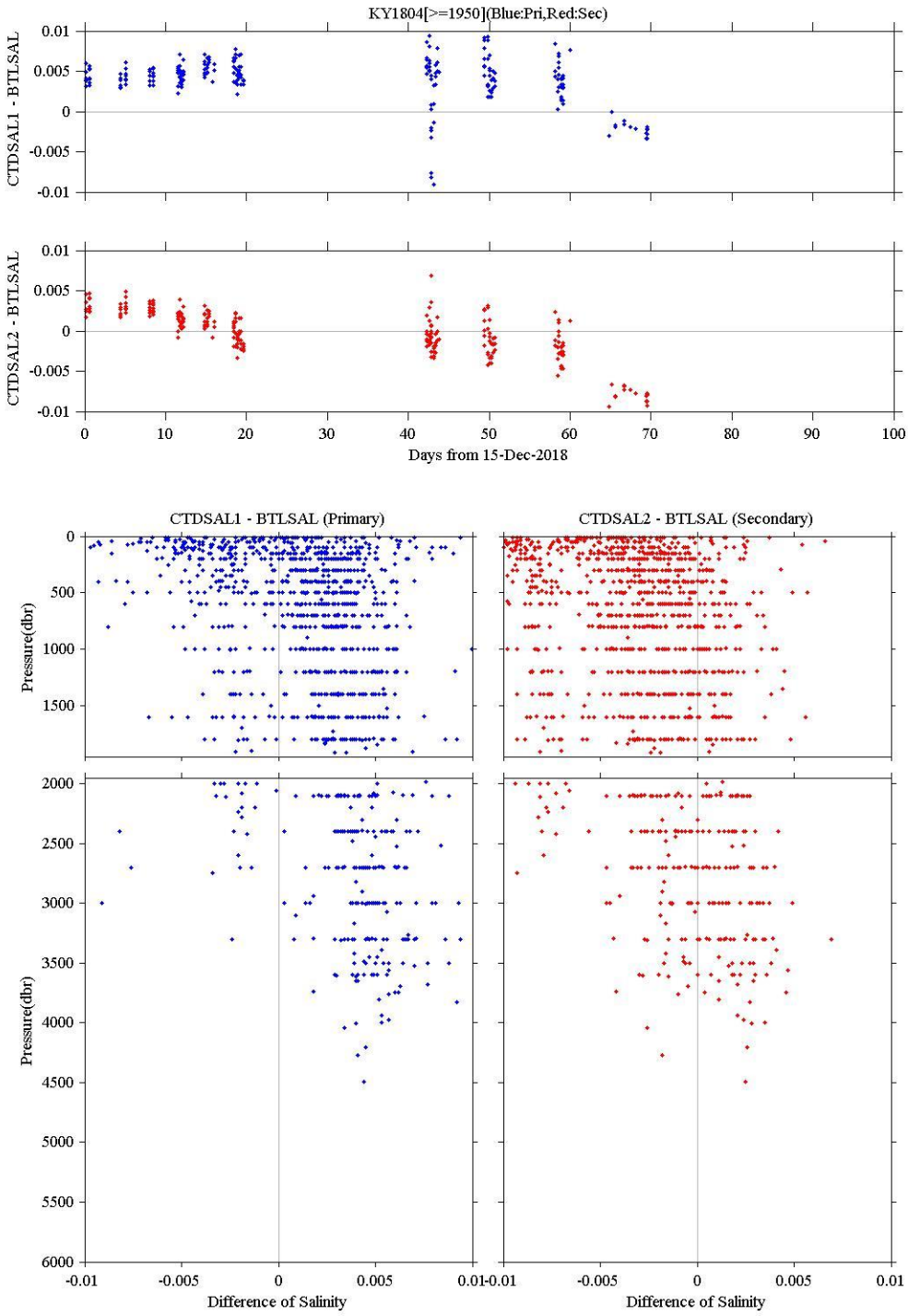


Fig. 2.5 Difference between the CTD salinity (blue:primary, red:secondary) and the bottle salinity. Upper two panels show temporal development and lower two pressure dependence.

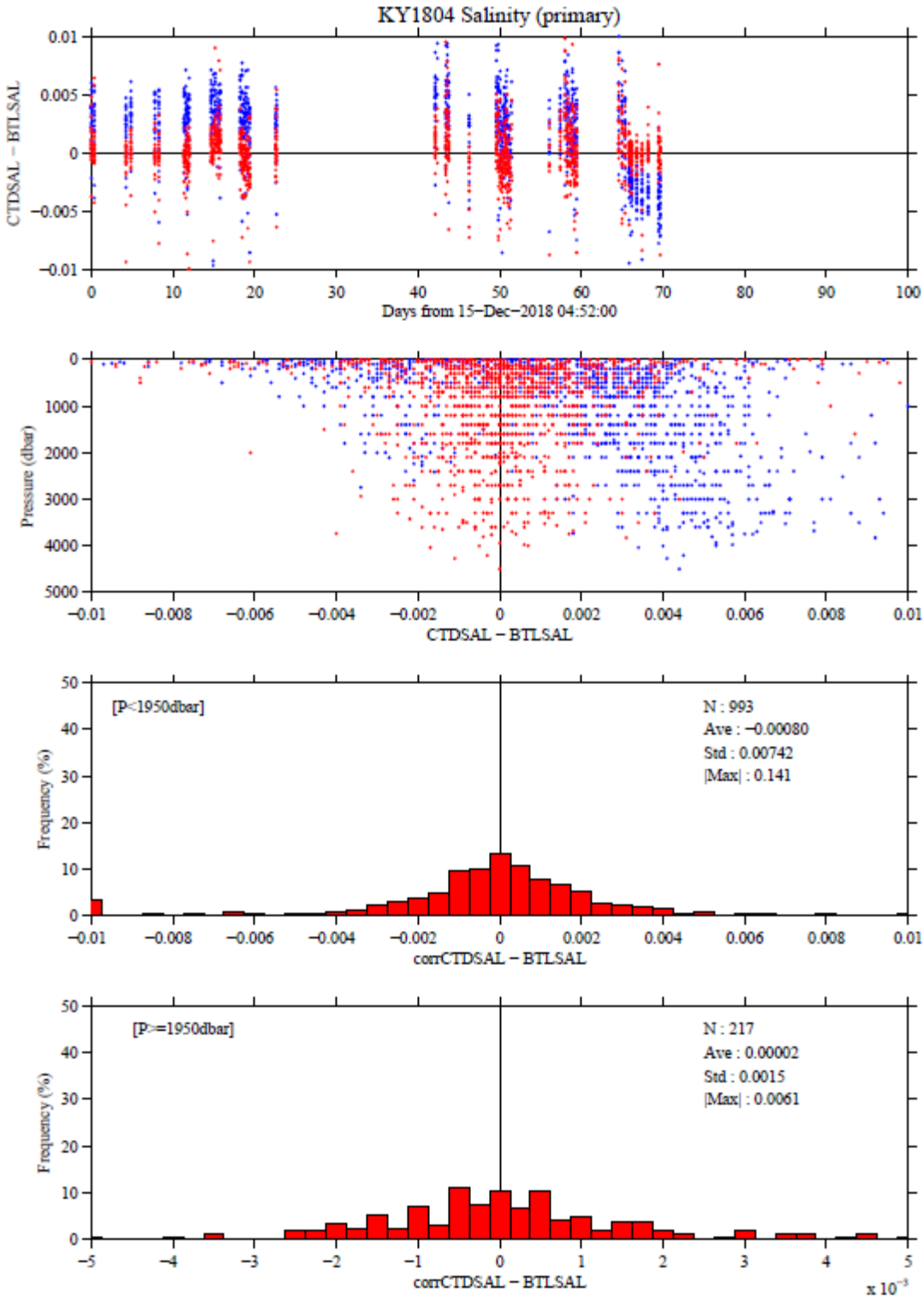


Fig. 2.6 Calibration for the primary conductivity sensor. Blue is uncalibrated, red is calibrated for the top panel (time development) and the second panel (depth dependence). The lower two panels show the histgram of the difference for shallow (< 1950 dbar) and deep (>= 1950 dbar) data.

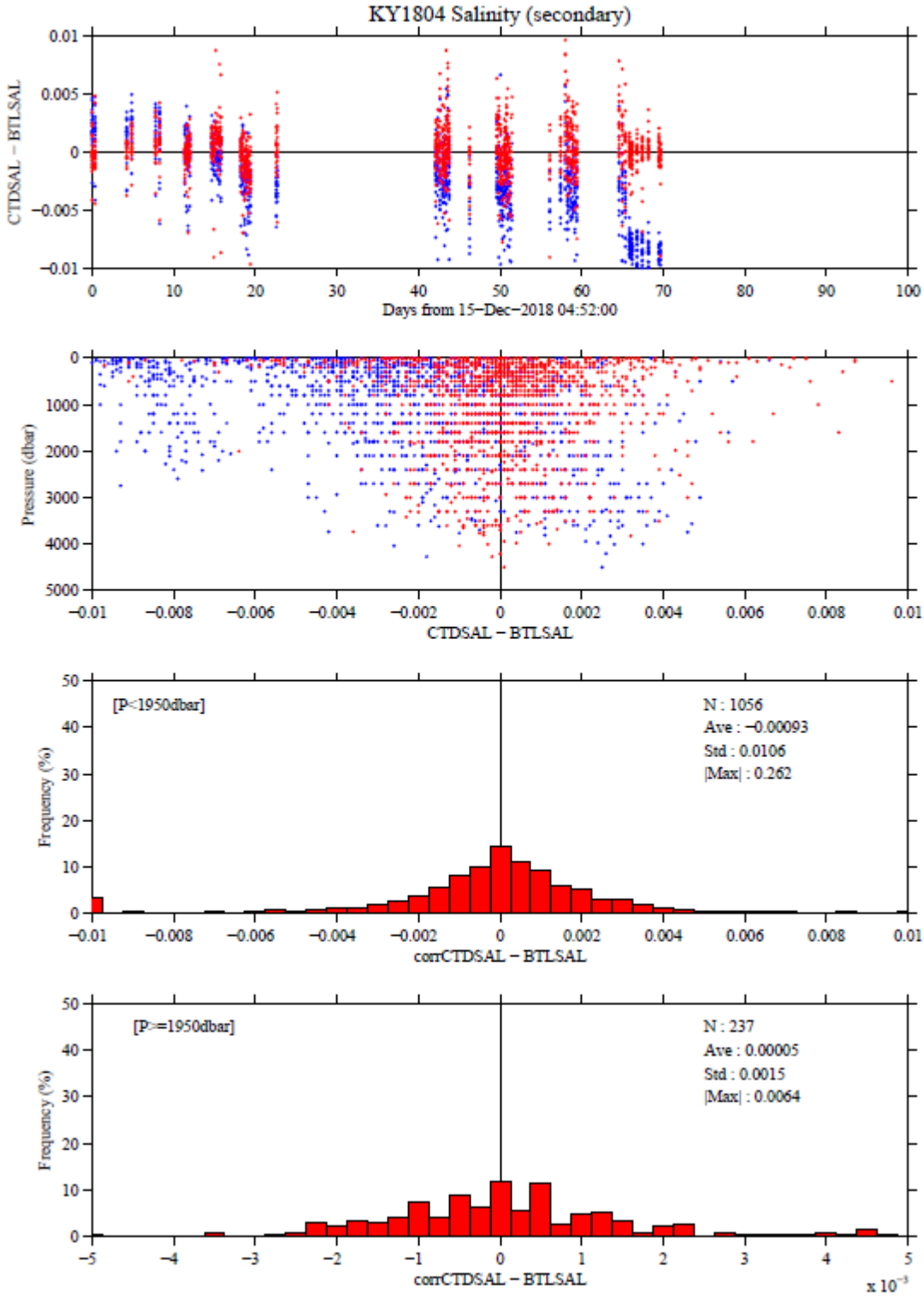


Fig. 2.7 Calibration for the secondary conductivity sensor. Blue is uncalibrated, red is calibrated for the top panel (time development) and the second panel (depth dependence). The lower two panels show the histgram of the difference for shallow (< 1950 dbar) and deep (>= 1950 dbar) data.

iv. Oxygen

We use the RINKO oxygen optode as our primary sensor due to its fast response time. The difference between the RINKO reading and the bottle oxygen is shown on Fig.2.8 along with that for SBE-43. The RINKO sensor drifted during Leg 1 but stabilized during Leg 2.

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

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

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

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

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

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

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, t is workikg time (days) integrated from the first CTD cast.. 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.

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

where p is CTD pressure (dbar) and C_p 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 (Garcia and Gordon, 1992).

B0 = -6.24523e-3

B1 = -7.37614e-3

B2 = -1.03410e-2

B3 = -8.17083e-3

C0 = -4.88682e-7

ts = log((298.15 - T) / (273.15 + T))

$$f = \exp(s \times (B0 + B1 \times ts + B2 \times ts^2 + B3 \times ts^3) + C0 \times S^2);$$

Garcia and Gordon (1992)

ox = ox * f

where V_b is the RINKO output (voltage), V_0 is voltage in the absence of oxygen, P is CTD pressure reading, T is CTD temperature in °C, S is CTD salinity, and t is working time (days) integrated from the first CTD cast. 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 estimate the

coefficients.

The post-cruise calibrated temperature and salinity data were used for the calibration. The calibration coefficients are listed in Table 2.4. The results of the post-cruise calibration for the RINKO oxygen are shown in Fig. 2.9.

Table 2.4 Calibration coefficients for the RINKO oxygen sensors.

Coefficient	Leg 1	Leg 2
c_0	7.561820e–2	2.679721e–2
c_1	1.559016e–4	–1.612003e–3
c_2	–7.196132e–5	–5.875572e–5
c_3	–3.185731e–2	–6.727683e–2
c_4	–5.172026e–2	–8.044962e–2
c_5	8.884524e–2	1.610701e–1
c_6	–7.383176e–4	–4.476357e–4
c_7	6.595850e–5	2.447884e–4
C_p	0.027	0.025

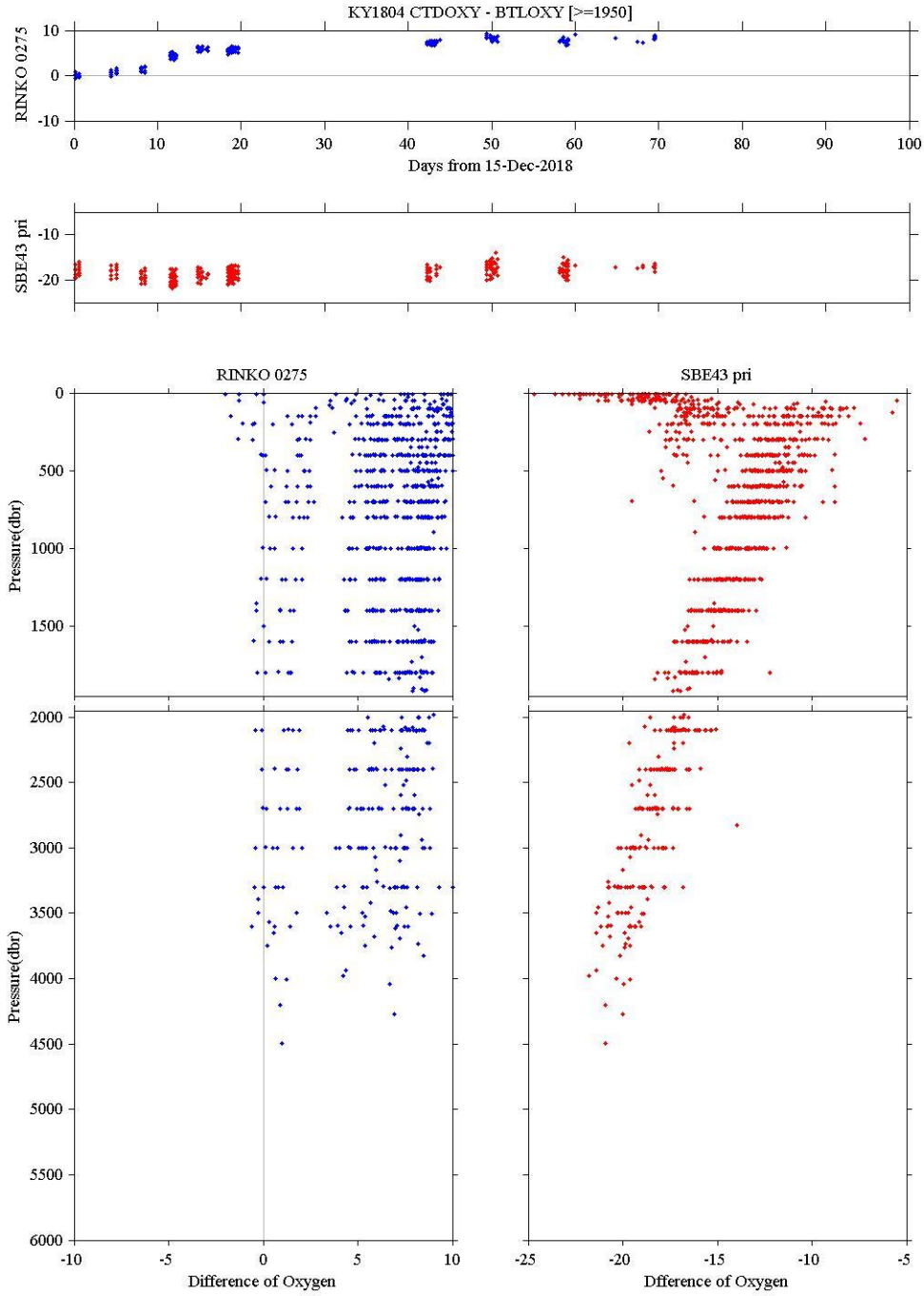


Fig. 2.8. Difference between the CTD oxygen (blue:RINKO, red:SBE-43) and the bottle salinity. Upper two panels show temporal development and lower two pressure dependence.

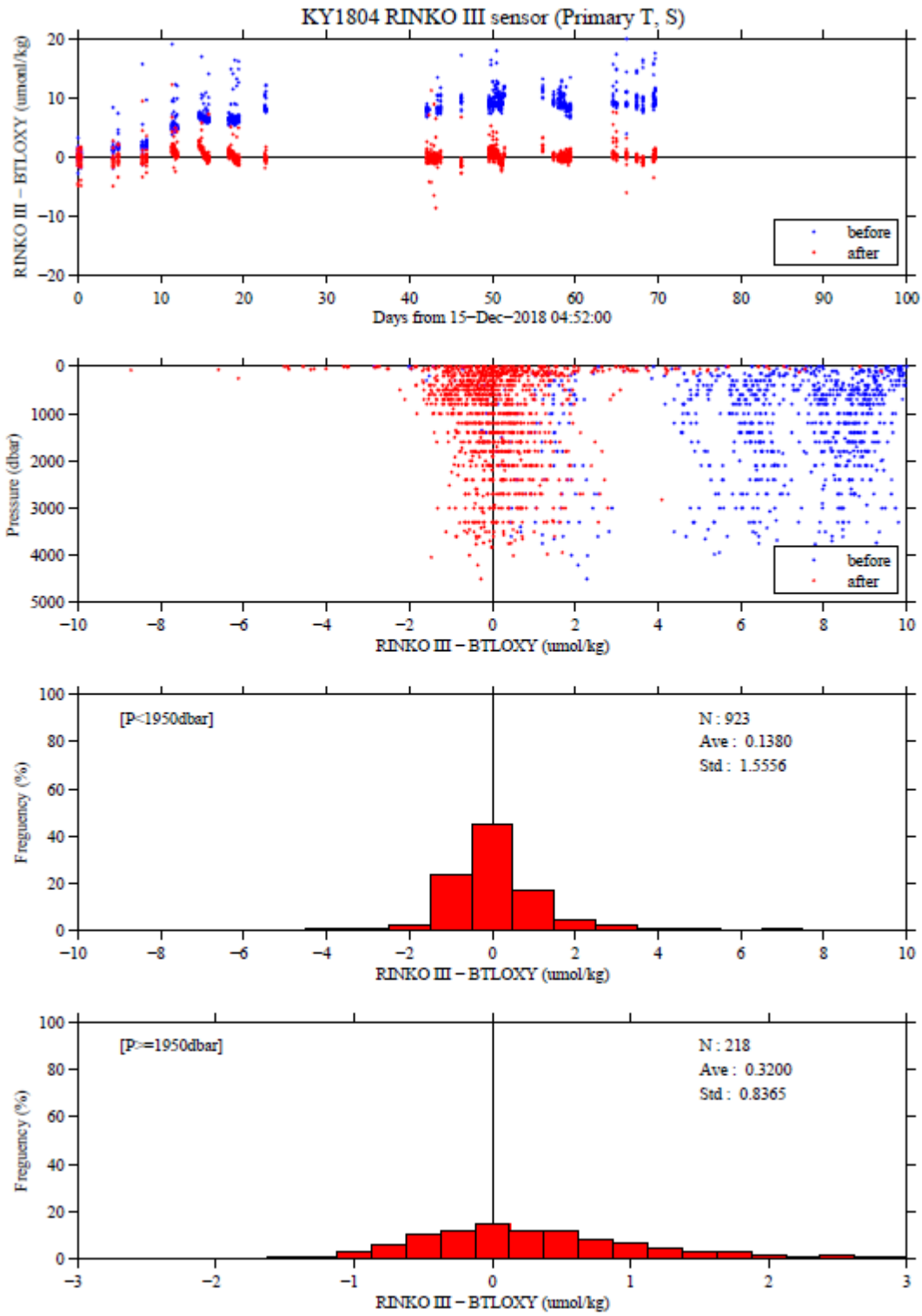


Fig. 2.9 Calibration for the RINKO dissolved oxygen sensor. Blue is uncalibrated, red is calibrated for the top panel (time development) and the second panel (depth dependence). The lower two panels show the histgram of the difference for shallow (< 1950 dbar) and deep (>= 1950 dbar) data.

v. Remarks for products

For the following entries in the SEAFILE output, a shift in the primary temperature and primary conductivity were found and values from the secondary temperature and secondary conductivity were used in the output fo temperature, salinity, oxygen, potential temperature, and potential density.

Station 026 Cast 1

Station 207 Cast 1

Station 028 Cast 1

Station 029 Cast 1

The following files for the EXCHANGE output, the secondary temperature and conductivity were used due to the shifts in the primary sensor;

Station 207 Cast 1

Station 028 Cast 1

Station 029 Cast 1.

vi. Fluorometer, transmissioneter, PAR

These optical sensors have not been calibrated after the cruise. Bottle HPLC data have been collected at 5 stations and are available at /

(7) References

Edwards, B., D. Murphy, C. Janzen and N. Larson (2010): Calibration, response, and hysteresis in deep-sea dissolved oxygen measurements, *J. Atmos. Oceanic Technol.*, 27, 920–931.

García, H. E. and L. I. Gordon (1992): Oxygen solubility in seawater: Better fitting equations. *Limnol. Oceanogr.*, 37 (6), 1307–1312.

Uchida, H., G. C. Johnson, and K. E. McTaggart (2010): CTD oxygen sensor calibration procedures, The GO-SHIP Repeat Hydrography Manual: A collection of expert reports and guidelines, IOCCP Rep., No. 14, ICPO Pub. Ser. No. 134.

Uchida, H., T. Nakano, J. Tamba, J. V. Widiatmo, K. Yamazawa, S. Ozawa and T. Kawano (2015): Deep ocean temperature measurement with an uncertainty of 0.7 mK, J. Atmos. Oceanic Technol., 32, 2199–2210.

Uchida, H., K. Ohyama, S. Ozawa, and M. Fukasawa (2007): In situ calibration of the Sea-Bird 9plus CTD thermometer, *J. Atmos. Oceanic Technol.*, 24, 1961–1967.

2.2 Bottle Salinity

September 30, 2019

(1) Personnel

Katsuro Katsumata (JAMSTEC)
Daisuke Hirano (Hokkaido University)
Shinsuke Toyoda (Marine Works Japan)
Daiki Nomura (Hokkaido University)
Ken Doi (Japan Fisheries Research and Education Agency)
Hiroyasu Sato (Marine Works Japan)
Kaihei Yamazaki (Hokkaido University)
Yoichiro Ko (Hokkaido University)
Masaaki Kiuchi (Hokkaido University)
Sigeru Aoki (Hokkaido University)
Hiroto Murase (Tokyo University of Marine Science and Technology)

(2) Objectives

Bottle salinities were measured to calibrate CTD salinity data.

(3) Instrument and Method

Salinity measurement was conducted following the method by Kawano (2010).

i. Salinity Sample Collection

The bottles in which the salinity samples were collected and stored were 250 ml brown borosilicate glass bottles with inner caps and screw caps (PTFE packing). Each bottle was rinsed three times with sample water and was filled to the shoulder of the bottle. The inner 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 a salinometer (Autosal model 8400B; Guildline Instruments Ltd., Ontario, Canada; S/N 71758), which was modified by adding an peristaltic-type intake pump (Ocean Scientific International Ltd., Hampshire, UK) and two platinum thermometers (FLUKE Corporation, Model 1502A). 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 the same as that described in Aoyama et al. (2002). The salinometer was operated in the air-conditioned laboratory of the shipwitht a bath temperature of 24 °C.

The ambient temperature varied from approximately 22.0 to 24.0 °C, while the bath temperature was stable and varied within ±0.004 °C. A measure of a double conductivity ratio of a sample was taken as a median of 11

readings. Data collection was started after 30 seconds and it took about 11 seconds to collect 11 readings by a personal computer. Data were sampled for the sixth, seventh and eighth filling of the cell. The average value of the three double conductivity ratios was used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981).

The cell was cleaned with soap (50 times diluted solution of S-CLEAN WO-23 [Neutral], Sasaki Chemical Co. Ltd., Kyoto, Japan) after the measurement for each day.

(4) Results

i. Standard Seawater

Standardization control was set to 472 (Leg1) and 478 (Leg2). The value of STANDBY was 5959 or 5960±0001 (Leg1), 5965±0001 (Leg2) and that of ZERO was from -0.00000 to -0.00004. We used IAPSO Standard Seawater batch P162 whose conductivity ratio is 0.99983 (double conductivity ratio is 1.99966) as the standard for salinity measurement.

Time drift of the salinometer was corrected by using the Standard Seawater measurements. The average of double conductivity ratio was 1.99966 and the standard deviation was 0.00002, which is equivalent to 0.0004 in salinity.

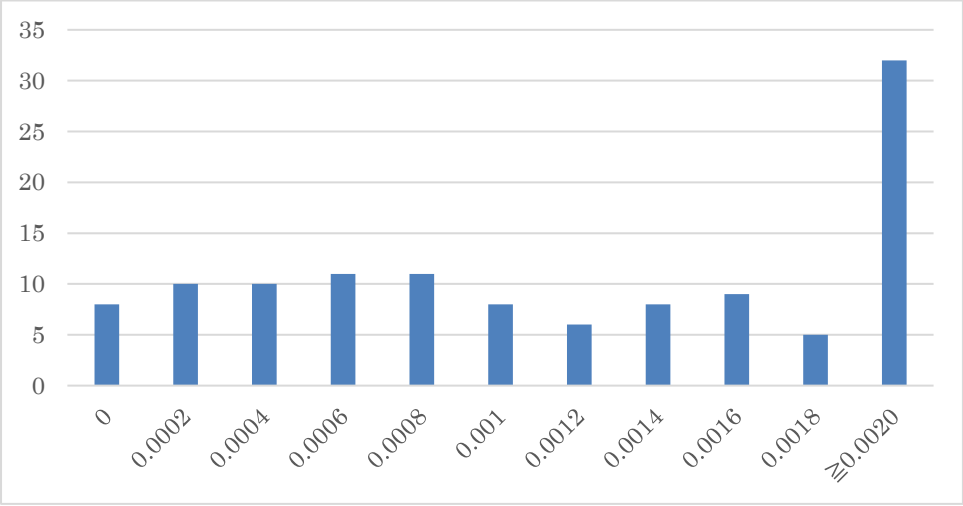
The average of the Standard Seawater measurement (N=107) was 34.9925 with a standard deviation of 0.0009. After the correction, the average was 34.9933 and the standard deviation 0.0004.

ii. Sub-Standard Seawater

We also used sub-standard seawater which was deep-sea water filtered and stored in a 20 liter cubitainer made of polyethylene and stirred for at least 24 hours before measuring. It was measured every 7 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 some pairs of replicate samples collected from the same Sample bottle. For all the pairs (N=118), the average difference is 0.00150 and the standard deviation of the difference is 0.00138, both converted to salinity. The histgram is shown below.



(5)References

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

Kawano (2010): Salinity. The GO-SHIP Repeat Hydrography Manual: A collection of Expert Reports and Guidelines, IOCCP Report No. 14, ICPO Publication Series No. 134, Version 1.

UNESCO (1981): Tenth report of the Joint Panel on Oceanographic Tables and Standards. UNESCO Tech. Papers in Mar. Sci., 36, 25 pp.

2.3 Bottle Oxygen

(1) Personnel

Katsuro Katsumata (JAMSTEC)
Daisuke Hirano (Hokkaido University)
Shinsuke Toyoda (Marine Works Japan)
Daiki Nomura (Hokkaido University)
Ken Doi (Japan Fisheries Research and Education Agency)
Hiroyasu Sato (Marine Works Japan)
Kaihei Yamazaki (Hokkaido University)
Yoichiro Ko (Hokkaido University)
Masaaki Kiuchi (Hokkaido University)
Sigeru Aoki (Hokkaido University)
Hiroto Murase (Tokyo University of Marine Science and Technology)

(2) Objectives

Bottle oxygen was measured to calibrate the electrical dissolved oxygen sensors on the CTD system.

(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): NMIJ CRM 3006-a No.061, Mass fraction: 99.973 ± 0.018 % (expanded uncertainty)
CSK standard of potassium iodate: Lot KPG6393, Wako Pure Chemical Industries Ltd., 0.0100N

(4) Instruments

Burette for sodium thiosulfate and potassium iodate;
APB-620 (S/N:00640377 and 00600198) manufactured by Kyoto Electronic Co. Ltd. / 10 cm^3 of titration vessel
Detector;
Automatic photometric titrator, DOT-15X (S/N:800161002) manufactured by Kimoto Electronic Co. Ltd.

(5) Seawater sampling

We followed the WOCE manual for sampling (Dickson, 1996). Seawater samples were collected from 10L Niskin sampler bottles attached to the CTD-system. Seawater for bottle oxygen measurement was transferred from the Niskin sampler bottle to a volume calibrated PYREX glass flask (ca. 100 cm^3) through silicone tube with a PFA tip at the end. Three times volume of the flask of seawater was overflowed. Sample temperature was measured using a thermometer. 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 shaken.After about 30 minuits to 1 hour, the flask was shaken

again to disperse the precipitate. The sample flasks containing pickled samples were stored in a laboratory until titration.

(6) Sample measurement

At least two hours after re-shaking (but before 48 hours after sampling), the pickled samples were measured on board following the WOCE manual. All necessary volumes of containers have been measured and temperature-compensated .

(7) Standardization and determination of blank

Concentration of sodium thiosulfate titrant (ca. 0.025M) was standarized against potassium iodate solution. The blank from the presence of redox species other than oxygen was determined with deionized water. The standarization and blank determination were performed on 12 Dec, 18 Dec, 24 Dec, 29 Dec, 5 Jan, 8 Jan during Leg 1 with the mean and standard deviation of the end point as shown below. Similarly, the standarization was perfomed on 24 Jan, 28 Jan, 2 Feb, 5 Feb, 9 Feb, 14 Feb, 16 Feb, 20 Feb, 24 Feb during Leg 2.

Leg1: 3.933±0.001 mL (N=10)

Leg2:3.984±0.002 mL (N=11)

(8) Replicate sample measurement

From a routine CTD cast at all the stations, a pair of replicate samples was collected at two depths.The standard deviation of the replicate measurement was 0.21 μ mol kg^{-1} with a sample size of N=108.

(9) Quality control flag assignment

Quality flag values were assigned to oxygen measurements using the code defined in Table 0.2 of WHP Oifice 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) 9 (not sampled) have been assigned.

(10) Notes

Table 1: The samples below have bottle salinity with FLAG=3 because the density was calculated based on either from the CTD salinity primary (CTDSAL) or secondary (CTDSAL_1).

station	cast	Niskin number	
017	001	11	CTDSAL
019	001	10	CTDSAL
027	001	3	CTDSAL_1
502	001	24	CTDSAL

Table 2: The samples below have FLAG=3 because the diference from electrical sensors are relatively large.

station	cast	Niskin num.-sample (if dup)
021	001	14
033	001	13-1
034	001	3-1
035	001	3-2
037	001	9
052	001	13-2

Table 3: On the log sheet, the samples below lacked the negative sign in front of the temperature measured during DO sampling. These data were identified by a scatter plot of sampling temperature and CTD temperature. Temperature for these samples were accordingly corrected.

station	cast	Niskin number
002	001	23
005	001	23
009	001	21
009	001	22
009	001	23
010	001	23
012	001	23
013	001	23
016	001	22
016	001	23
016	001	24
030	001	2
030	001	22
032	001	2
032	001	20
032	001	21
032	001	22
032	001	23
037	001	20
037	001	21
037	001	22

Staion 019, cast 001, Niskin number 4: The automatic titration failed, but manual calculation was possible and FLAG=3 was given.

Station 033, cast 001, Ninkin number 18: It was found out during the titration that the tip of the burett had not been correctly inserted into the sample such that FLAG=3.

Station 032, cast 001, Niskin number 23: Many bubbles were found during the titration and the curve was not stable. Dubious points were manually removed with FLAG=3.

Station 054, cast 001, Niskin number 3: Irregular titration curve. Manually removed dubious points and recalculated with FLAG=4.

Station 002, cast 001, Niskin number 16
Station 011, cast 001, Niskin number 1: Samples from these two bottles were not properly treated and FLAG=5.

Station 012, cast 001, Niskin number 2: The titrator malfunctioned. Flag=5.

References

Dickson, A. (1996) Determination of dissolved oxygen in sea water by Winkler titration, in WHPO Pub. 91-1 Rev. 1, November 1994, Woods Hole, Mass., USA.

2.4 Nutrients

2.5 Carbon items

2.6 Stable isotope of oxygen

2.7 Lowered Acoustic Doppler Current Profiler

2.8.XCTD

3. Other measurements

We list some of the measurements performed during the cruise. The data are not in general publicly available at the time of writing but if the reader is intrested in possible collaboration, please contact the lead author of the present report. We do not attempt to cover biological measurements.

- Shipboard ADCP
- Shallow CTD casts for biological measurements
- continuous sampling of pumped water near the surface (pCO2 and EPCS)