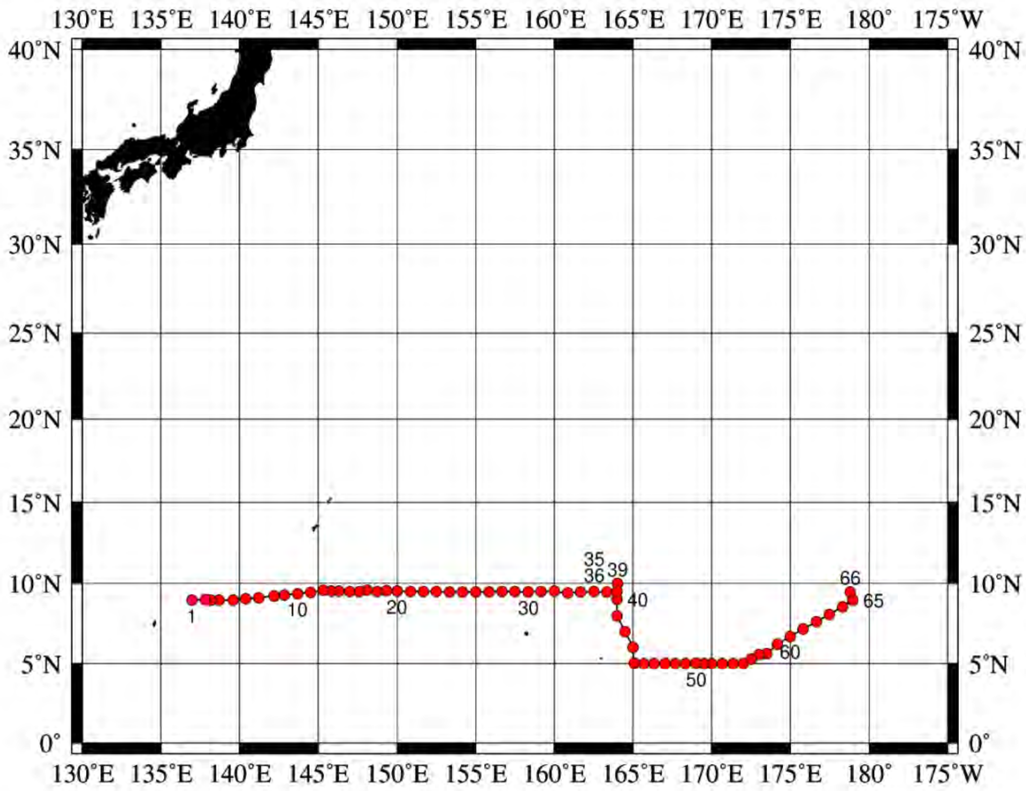
CRUISE REPORT: P04W

(Updated JUN 2021)



HIGHLIGHTS

Cruise Summary Information

Section Designation	**P04W** (AKA RF15-07)
Expedition designation (ExpoCodes)	**49UP20150724**
Chief Scientists	**Keizo SHUTTA / JMA**
Dates	**2015 JUL 24 - 2015 AUG 15**
Ship	*Ryofu Maru*
Ports of call	Leg 1: Tokyo – Pohnpei, Leg 2: Pohnpei–Tokyo
Geographic Boundaries	10° 2.41' N 136° 59.66' E 178° 59.82' E 4° 59.45' N
Stations	66
Floats and drifters deployed	2 floats deployed
Moorings deployed or recovered	0

Contact Information:

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Final report assembly by Jerry Kappa, SIO/UCSD

A. CRUISE NARRATIVE

1. Highlights

Cruise designation: RF15-07 (WHP-P04W revisit)

a. EXPOCODE: 49UP20150724

b. Chief scientist: Keizo SHUTTA (shutta.kei@met.kishou.go.jp)
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c. Ship name: R/V Ryofu Maru

d. Ports of call: Leg 1: Tokyo – Pohnpei, Leg 2: Pohnpei–Tokyo

e. Cruise dates: Leg 1: 24 July 2015–18 August 2015
Leg 2: 22 August 2015–15 September 2015

f. Floats and drifters deployed: 2 Floats

Cruise Summary Information

RF15-07 cruise was carried out during the period from July 24 to September 15, 2015. The cruise started from Japan, and sailed towards southeast to the first station. Hydrographic observation started near Marshal Islands followed by sailing towards west along latitude approximately 10°N. This line was observed by Woods Hole Oceanographic Institution in 1989 as 'WHP-P04', which is a part of WOCE (World Ocean Circulation Experiment) Hydrographic Programme.

A total of 66 stations was occupied using a Sea-Bird Electronics (SBE) 36 position carousel equipped with 10-liter Niskin water sample bottles, a CTD system (SBE911plus) equipped with SBE35 deep ocean standards thermometer, JFE Advantech oxygen sensor (RINKO III), Teledyne Benthos altimeter (PSA-916D), and Teledyne RD Instruments L-ADCP (300kHz). To examine consistency of data, we carried out the observation twice at 9°30'N, 162°30'E (Stn.35 and 36). Cruise track and station location are shown in Figure 1.

At each station, full-depth $CTDO_2$ (temperature, conductivity (salinity) and dissolved oxygen) profile and up to 36 water samples were taken and analyzed. Water samples were obtained from 10 dbar to approximately 10 m above the bottom. In addition, surface water was sampled using a stainless steel bucket at each station. Sampling layer is designed as so-called staggered mesh as shown in Table 1 (*Swift*, 2010). The bottle depth diagram is shown in Figure 2.

Water samples were analyzed for salinity, dissolved oxygen, nutrients, dissolved inorganic carbon (DIC), total alkalinity (TA), pH, CFC-11, CFC-12 and phytopigment (chlorophyll-a and phaeopigments). Underway measurements of partial pressure of carbon dioxide ($p CO_2$), temperature, salinity, chlorophyll-a, subsurface current, bathymetry and meteorological parameters were conducted along the cruise track.

R/V Ryofu Maru departed Tokyo (Japan) on July 24, 2015. Before the observation at the first station, all watch standers were drilled in the method of sample drawing and CTD operations near Izu-Oshima (34°42'N, 139°51'E). The hydrographic cast of $CTDO_2$ was started at the first station (Stn.66 (9°30'N, 178°48'E; RF5486)) on August 2, 2015. Leg 1 consisted of 31 stations from Stn.66 to Stn.36 (9°30'N, 162°31'E; RF5516). She called for Pohnpei (Federated States of Micronesia) on August 18 (Leg 1). She left Pohnpei on August 22, 2015 for Tokyo (Japan) and arrived on September 15, 2015 (Leg 2). Leg 2 consisted of 35 stations from Stn.35 (9°29'N, 162°29'E; RF5517) to Stn.1 (9°N, 137°E; RF5551). Location data of stations is shown in Table 2.

Two Argo floats were deployed along the cruise track. The information of deployed the floats are listed in Table 3.

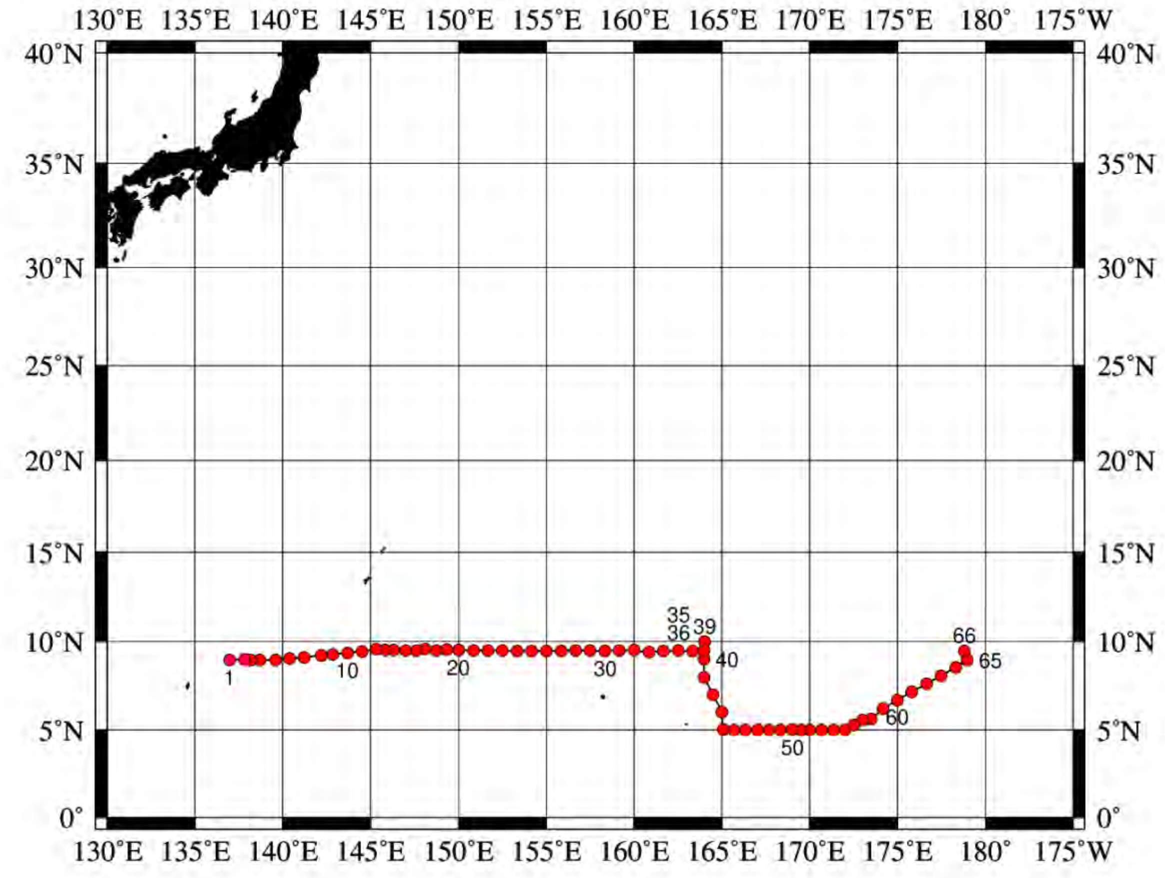

Figure 1: Cruise track of RF15-07.

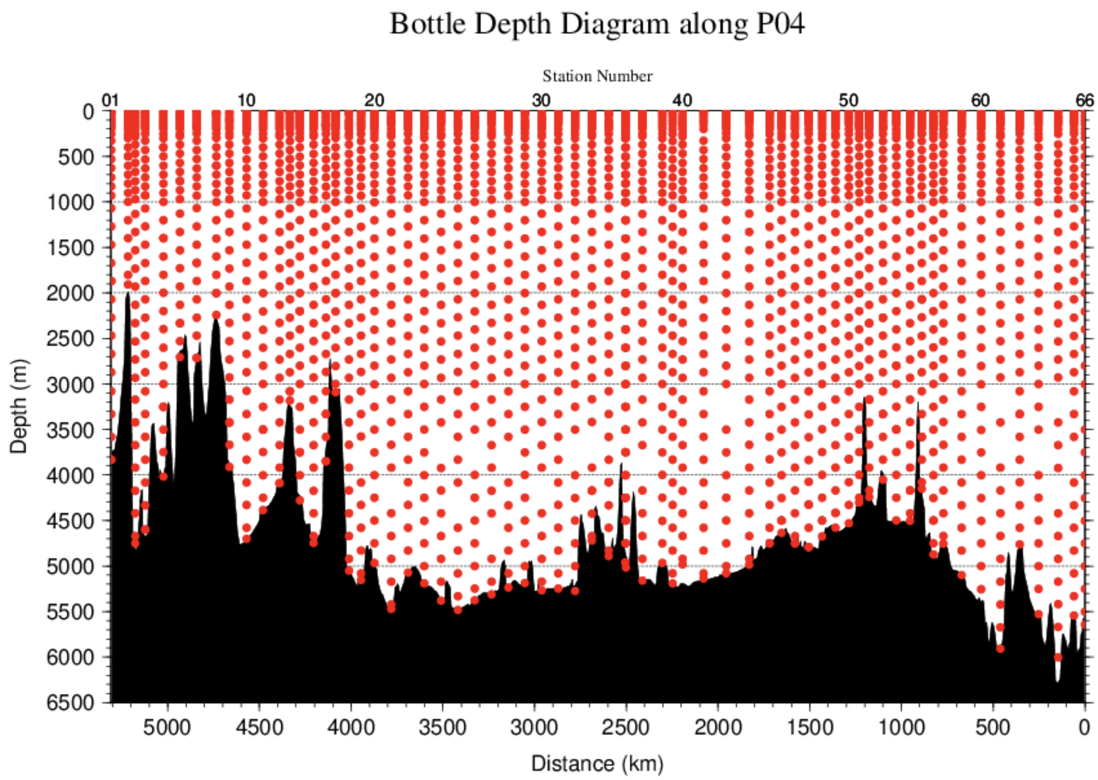

Figure 2: The bottle depth diagram for WHP-P04 revisit.

Table 1. The scheme of sampling layer in meters.

9 °N (Stn.1 - Stn.66)				9 °N (Stn.1 - Stn.66)			
Bottle count	*Scheme1*	*Scheme2*	*Scheme3*	*Bottle count*	*Scheme1*	*Scheme2*	*Scheme3*
1	10	10	10	21	1600	1670	1530
2	25	25	25	22	1800	1870	1730
3	50	50	50	23	2000	2070	1930
4	75	75	75	24	2200	2270	2130
5	100	100	100	25	2400	2470	2330
6	125	125	125	26	2600	2670	2530
7	150	150	150	27	2800	2870	2730
8	175	175	175	28	3000	3080	2930
9	200	200	200	29	3250	3330	3170
10	250	250	250	30	3500	3580	3420
11	300	330	280	31	3750	3830	3670
12	400	430	370	32	4000	4080	3920
13	500	530	470	33	4250	4330	4170
14	600	630	570	34	4500	4580	4420
15	700	730	670	35	4750	4830	4670
16	800	830	770	36	5000	5080	4920
17	900	930	870	37	5250	5330	5170
18	1000	1070	970	38	5500	5580	5420
19	1200	1270	1130	39	5750	5830	5670
20	1400	1470	1330	40	6000	6000	6000

Table 2: Station data of RF15-07 cruise. The 'RF' column indicates the JMA station identification number.

Leg	*Station*		*Position*	
	Stn	*RF*	*Latitude*	*Longitude*
2	1	5551	8-59.51 N	136-59.79 E
2	2	5550	9-00.35 N	137-49.10 E
2	3	5549	8-59.33 N	138-11.38 E
2	4	5548	8-59.23 N	138-41.11 E
2	5	5547	8-59.36 N	139-35.34 E
2	6	5546	9-04.38 N	140-23.73 E
2	7	5545	9-07.51 N	141-13.56 E
2	8	5544	9-14.43 N	142-12.20 E
2	9	5543	9-17.02 N	142-51.00 E
2	10	5542	9-22.65 N	143-42.11 E
2	11	5541	9-27.78 N	144-30.22 E
2	12	5540	9-35.18 N	145-19.27 E
2	13	5539	9-31.20 N	145-50.19 E
2	14	5538	9-31.00 N	146-19.11 E
2	15	5537	9-30.88 N	147-00.57 E
2	16	5536	9-30.48 N	147-37.58 E
2	17	5535	9-35.25 N	148-05.82 E
2	18	5534	9-30.33 N	148-45.85 E
2	19	5533	9-33.77 N	149-20.78 E
2	20	5532	9-31.01 N	150-01.31 E
2	21	5531	9-30.61 N	150-51.12 E
2	22	5530	9-30.80 N	151-41.26 E
2	23	5529	9-30.04 N	152-29.82 E
2	24	5528	9-29.59 N	153-20.15 E
2	25	5527	9-29.59 N	154-10.33 E
2	26	5526	9-29.81 N	155-00.36 E
2	27	5525	9-29.74 N	155-51.13 E
2	28	5524	9-30.69 N	156-41.11 E
2	29	5523	9-30.28 N	157-30.43 E
2	30	5522	9-29.44 N	158-20.83 E
2	31	5521	9-30.38 N	159-10.14 E
2	32	5520	9-31.15 N	160-00.25 E
2	33	5519	9-25.17 N	160-50.30 E
2	34	5518	9-29.53 N	161-40.02 E
2	35	5517	9-29.05 N	162-29.27 E

Leg	*Station*		*Position*	
	Stn.	*RF*	*Latitude*	*Longitude*
1	36	5516	9-30.02 N	162-30.74 E
1	37	5515	9-29.80 N	163-20.14 E
1	38	5514	10-01.06 N	164-01.07 E
1	39	5513	9-30.66 N	163-59.35 E
1	40	5512	9-01.16 N	163-59.54 E
1	41	5511	7-59.93 N	163-58.52 E
1	42	5510	7-00.40 N	164-29.95 E
1	43	5509	6-01.10 N	165-00.94 E
1	44	5508	5-01.27 N	165-05.64 E
1	45	5507	5-00.67 N	165-40.86 E
1	46	5506	5-00.86 N	166-20.43 E
1	47	5505	5-00.73 N	167-01.30 E
1	48	5504	5-00.53 N	167-41.10 E
1	49	5503	5-00.01 N	168-20.87 E
1	50	5502	5-01.17 N	169-00.67 E
1	51	5501	5-00.69 N	169-30.60 E
1	52	5500	4-59.45 N	170-00.27 E
1	53	5499	5-00.96 N	170-40.84 E
1	54	5498	5-00.84 N	171-20.15 E
1	55	5497	4-59.86 N	172-00.93 E
1	56	5496	5-17.28 N	172-31.21 E
1	57	5495	5-34.83 N	173-00.08 E
1	58	5494	5-37.67 N	173-30.23 E
1	59	5493	6-12.87 N	174-10.65 E
1	60	5492	6-42.43 N	175-00.03 E
1	61	5491	7-10.53 N	175-49.42 E
1	62	5490	7-38.81 N	176-39.10 E
1	63	5489	8-04.76 N	177-29.13 E
1	64	5488	8-33.21 N	178-19.33 E
1	65	5487	8-59.18 N	178-58.44 E
1	66	5486	9-29.57 N	178-47.96 E

Table 3: Information of deployed float.

Float WMO number	*Date and Time of deployment (UTC)*	*Position of deployment*		*PI*	
		Latitude	*Longitude*		
5904990	2015 July 28 10:59	20-23.55 N	156-44.18 E	JAMSTEC	ARVOR
2902959	2015 Sep. 9 02:00	24-58.68 N	138-42.79 E	JMA	APEX

ARVOR: nke Instrumentation (France)
APEX: Teledyne Webb Research (USA)

List of Principal Investigators for all Measurements

The principal investigator (PI) and the person in charge responsible for major parameters measured on the cruise are listed in Table 4.

Table 4: List of principal investigators and the person in charge on the ship for RF15-07.

Item	Principal Investigator（PI）	Person in charge on the ship
Hydrography		
$CTDO_2$ / LADCP	Toshiya NAKANO	Nobumi KATO
Salinity	Toshiya NAKANO	Koichi WADA
Dissolve oxygen	Toshiya NAKANO	Chihiro KAWAMURA
Nutrients	Toshiya NAKANO	Takahiro KITAGAWA
Phytopigment	Toshiya NAKANO	Takahiro KITAGAWA
DIC	Toshiya NAKANO	Shu SAITO
Total Alkalinity	Toshiya NAKANO	Shu SAITO
pH	Toshiya NAKANO	Shu SAITO
CFCs	Toshiya NAKANO	Kazutaka ENYO
Underway		
Meteorology	Toshiya NAKANO	Keizo SHUTTA
Thermo-Salinograph	Toshiya NAKANO	Shu SAITO
pCO_2	Toshiya NAKANO	Shu SAITO
Chlorophyll-a	Toshiya NAKANO	Takahiro KITAGAWA
ADCP	Toshiya NAKANO	Nobumi KATO
Bathymetry	Toshiya NAKANO	Nobumi KATO
Floats		
Argo float (JMA)	Kazuhiro NEMOTO	Keizo SHUTTA
Argo float (JAMSTEC)	Shigeki HOSODA	Keizo SHUTTA

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Reference

Swift, J.H. (2010): Reference-quality water sample data: Notes on acquisition, record keeping, and evaluation. *IOCCP Report No.**14**, ICPO Pub. 134, 2010 ver.1*

B. HYDROGRAPHIC MEASUREMENT TECHNIQUES AND CALIBRATION

1. CTDO$_2$ MEASUREMENTS

Updated 5 March 2020

1.1 Personnel

Nobumi KATO (GEMD/JMA)
Koichi WADA (GEMD/JMA)
Yutaka KOBASHIGAWA (GEMD/JMA)
Jinya MIURA (GEMD/JMA)
Toshiyuki AMAZAWA (GEMD/JMA)

1.2 CTDO$_2$ measurement system

(*Software* : SEASAVEwin32 ver7.23.2)

Deck unit	***Serial Number***	***Station***
SBE 11plus (SBE)	0683	RF5486 – 5551
Under water unit	***Serial Number***	***Station***
SBE 9plus (SBE)	69709 (Pressure: 1103)	RF5486 – 5551
Temperature	***Serial Number***	***Station***
SBE 3plus (SBE)	4321 (primary)	RF5486 – 5551
	5511 (secondary)	RF5486 – 5551
SBE 35 (SBE)	0069	RF5486 – 5551
Conductivity	***Serial Number***	***Station***
SBE 4C (SBE)	2988 (primary)	RF5486 – 5551
	4316 (secondary)	RF5486 – 5551
Pump	***Serial Number***	***Station***
SBE 5T (SBE)	5420 (primary)	RF5486 – 5551
	5501 (secondary)	RF5486 – 5551
Oxygen	***Serial Number***	***Station***
RINKO III (JFE)	025 (foil number:141303B)	RF5486 – 5551
	008 (foil numner:141304B)	RF5486 – 5551
Water sampler (36 position)	***Serial Number***	***Station***
SBE 32 (SBE)	0734	RF5486 – 5551
Altimeter	***Serial Number***	***Station***
PSA-916D (TB)	47830	RF5486 – 5538
	43854	RF5539 – 5551
Water Sampling Bottle		***Station***
Niskin Bottle (GO)		RF5486 – 5551

SBE: Sea- Bird Electronics, Inc., USA
TB: Teledyne Benthos, Inc., USA
JFE: JFE Advantech Co., Ltd., Japan
GO: General Oceanics, Inc., USA

1.3 Pre-cruise calibration

(1.3.1) Pressure

S/N 1103, 04 May 2015

c_1	=	–4.282684e+004	t_1	=	3.006702e+001
c_2	=	5.097742e–001	t_2	=	–8.607997e–005
c_3	=	1.312000e–002	t_3	=	3.727820e–006
d_1	=	3.583800e–002	t_4	=	3.699030e–009
d_2	=	0.000000e+000	t_5	=	0.000000e+000

Formula:

$$c = c_1 + c_2 \times U + c_3 \times U^2$$
$$d = d_1 + d_2 \times U$$
$$t_0 = t_1 + t_2 \times U + t_3 \times U^2 + t_4 \times U^3 + t_5 \times U^4$$

U (*degrees Celsius*) = *M* × (*12-bit pressure temperature compensation word*) + *B*

U: temperature in degrees Celsius

S/N 1103 coefficients in SEASOFT (configuration sheet dated on 04 *May 2015)*

M = 1.28040e–002, B = –9.31868e+000

Finally, pressure is computed as

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

t: pressure period (μsec)

The drift–corrected pressure is computed as

$$Drift corrected\ pressure(dbar) = slope \times (computed\ pressure\ in\ dbar) + offset$$

Slope = 1.00004, Offset = 0.0463

(1.3.2) Temperature (ITS-90): SBE 3plus

S/N 4321(primary), 01 May 2015

g	=	4.39121739e–003	j	=	1.97139836e–006
h	=	6.47466739e–004	f_0	=	1000.0
i	=	2.31450429e–005			

S/N 5511(secondary), 24 Jan. 2015

g	=	4.36821681e–003	j	=	1.35703648e–006
h	=	6.31058826e–004	f_0	=	1000.0
i	=	1.95507287e–005			

Formula:

$$Temperature(ITS-90) = \frac{1}{g + h \times \ln(f_0/f) + i \times \ln^2(f_0/f) + j \times \ln^3(f_0/f)} - 273.15$$

f: Instrument freq.[Hz]

(1.3.3) Deep Ocean Standards Thermometer Temperature (ITS-90): SBE 35

S/N 0069, 23 Oct. 2006

a_0	=	4.96812728e–003	a_3	=	–1.14827915e–005
a_1	=	–1.39341438e–003	a_4	=	2.44200422e–007
a_2	=	2.06596098e–004			

Formula:

$$Linearized\ temperature(ITS-90) = 1/\{a_0 + a_1 \times \ln(n) + a_2 \times \ln^2(n) + a_3 \times \ln^3(n) + a_4 \times \ln^4(n)\} - 273.15$$

n: instrument output

The slow time drift of the SBE 35

S/N 0069, 17 Oct. 2014 (2nd step: fixed point calibration)

Slope = 1.000012, Offset = –0.000550

Formula:

$$Temperature(ITS-90) = slope \times (Linearized\ temperature) + offset$$

(1.3.4) Conductivity: SBE 4C

S/N 2988(primary), 01 May 2015

g	=	–9.85278832e+000	j	=	4.34181802e–005
h	=	1.34626692e+000	CP_{cor}	=	–9.5700e–008
i	=	3.51383646e–004	CT_{cor}	=	3.2500e–006

S/N 4316(secondary), 01 May 2015

g	=	–9.87013372e+000	j	=	2.39767065e–004
h	=	1.29110437e+000	CP_{cor}	=	–9.5700e–008
i	=	–2.58121723e–003	CT_{cor}	=	3.2500e–006

Conductivity of a fluid in the cell is expressed as:

$$C(S/m) = (g + h \times f^2 + i \times f^3 + j \times f^4) / \{10 \times (1 + CT_{cor} \times t + CP_{cor} \times p)\}$$

f: instrument frequency (kHz)

t: water temperature (degrees Celsius)

p: water pressure (dbar).

(1.3.5) Oxygen (RINKO III)

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

RINKOIII output is expressed in voltage from 0 to 5 V.

1.4 Data correction and Post-cruise calibration

(1.4.1) Temporal change of deck pressure and Post-cruise calibration

The drift–corrected pressure of post-cruise is computed as

$$Driftcorrected\ pressure(dbar) = slope \times (computed\ pressure\ in\ dbar) + offset$$

S/N 1103, 16 Oct. 2015

Slope = 1.00003, Offset = 0.0239

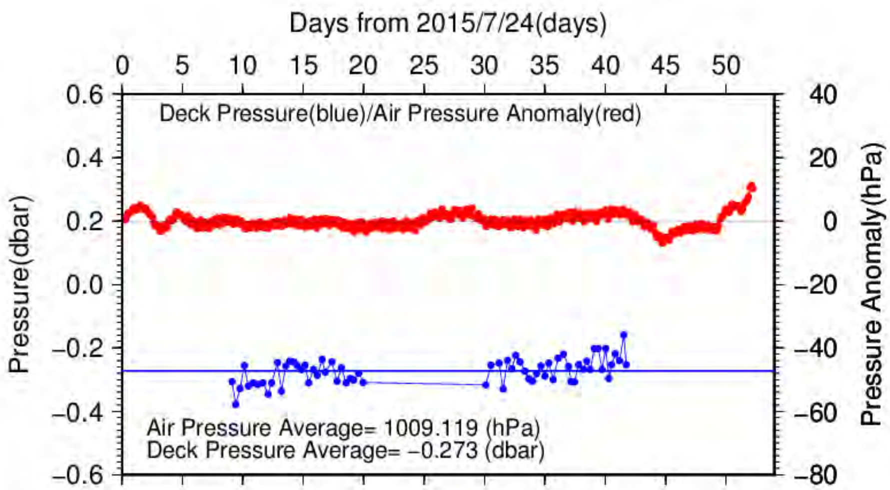

Figure C.1.1: Time series of the CTD deck pressure. Red line indicates atmospheric pressure anomaly. Blue line and dots indicate pre-cast deck pressure and average.

(1.4.2) Temperature sensor (SBE 3plus)

The practical corrections for CTD temperature data can be made by using a SBE 35, correcting the SBE 3plus to agree with the SBE 35 (*McTaggart et al., 2010*; *Uchida et al., 2007*).

CTD temperature is corrected as

$$Corrected\ temperature = T - (c_0 + c_1 \times P + c_2 \times P^2)$$

T : the CTD temperature (degrees Celsius), P: pressure (dbar) and c_0, c_1, c_2 : coefficients

Table C.1.1: Temperature correction summary (Pressure ≥ 2000dbar). (Bold : selected sensor)

S/N	*Num*	$c_0(K)$	$c_1(K/dbar)$	$C_2(K/dbar^2)$	*Stations*
4321	433	2.3754287e–4	7.1430481e–8	0.0000000e+0	RF5486 – 5516
4321	416	2.6076840e–4	5.5049546e–8	0.0000000e+0	RF5517 – 5551
5511	**435**	**-3.1366487e–6**	**-2.4213192e–7**	**3.4909460e-11**	**RF5486 – 5516**
5511	**416**	**3.3597151e–4**	**-4.7346361e–7**	**6.2970873e-11**	**RF5517 – 5551**

Table C.1.2: Temperature correction summary for S/N 4321.

Stations	Pressure < 2000dbar			Pressure ≥ 2000dbar		
	Num	Average (K)	Std (K)	Num	Average (K)	Std (K)
RF5517 – 5551	680	–0.0018	0.0132	433	0.0000	0.0002
RF5486 – 5516	793	–0.0006	0.0145	416	0.0000	0.0002

Table C.1.3: Temperature correction summary for S/N 5511.

Stations	Pressure < 2000dbar			Pressure ≥ 2000 dbar		
	Num	Average (K)	Std (K)	Num	Average (K)	Std (K)
RF5486 – 5516	680	–0.0006	0.0175	435	0.0000	0.0002
RF5517 – 5551	793	–0.0010	0.0165	416	0.0000	0.0002

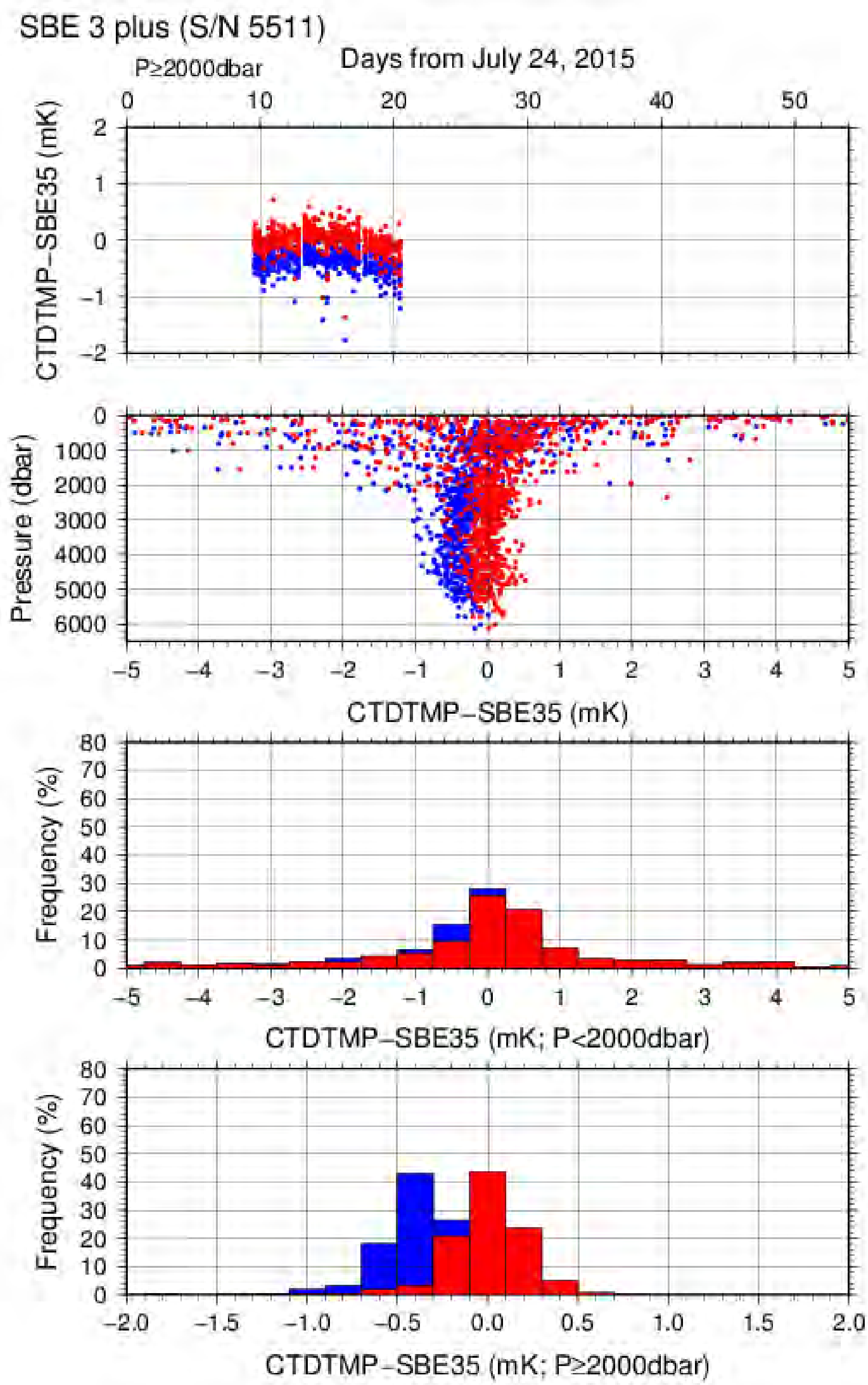

Figure C.1.2**:** Difference between the CTD temperature (*S/N 5511*) and the Deep Ocean Standards thermometer (SBE 35) at Leg 1. Blue and red dots indicate before and after the correction using SBE 35 data respectively. Lower two panels show histogram of the difference after correction.

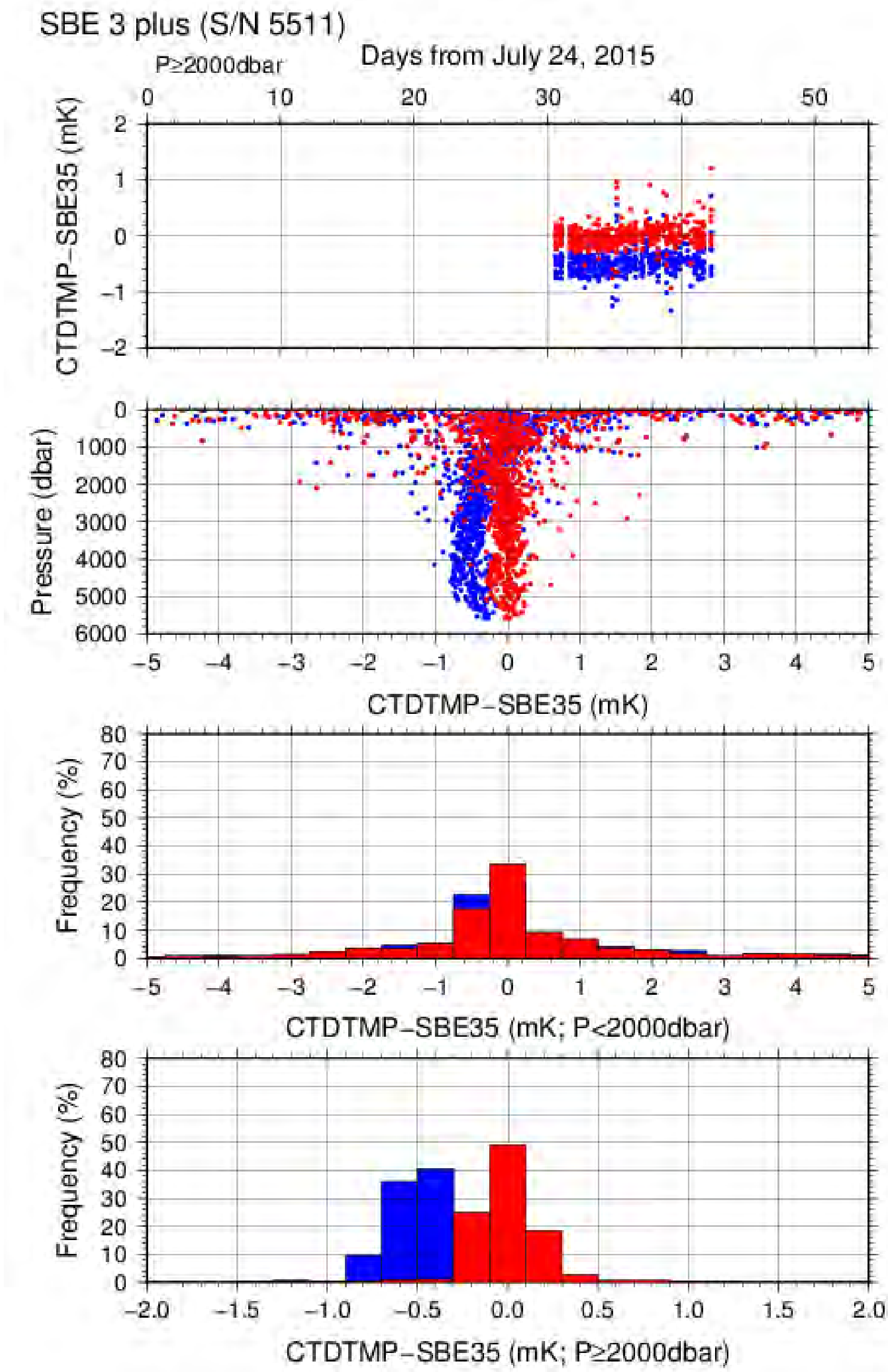

Figure C.1.3: Difference between the CTD temperature (*S/N 5511*) and the Deep Ocean Standards thermometer (SBE 35) at Leg 2. Blue and red dots indicate before and after the correction using SBE 35 data respectively. Lower two panels show histogram of the difference after correction.

Post–cruise sensor calibration for the SBE 3plus

S/N 4321(primary), 16 Oct. 2015

g	=	4.39122630e–003	j	=	1.97996371e–006
h	=	6.47501491e–004	f_0	=	1000.0
i	=	2.31753528e–005			

S/N 5511(secondary), 16 Oct. 2015

g	=	4.36816775e–003	j	=	1.34328201e–006
h	=	6.30960365e–004	f_0	=	1000.0
i	=	1.94873151e–005			

Formula:

$$Temperature(ITS-90) = \frac{1}{g + h \times \ln(f_0/f) + i \times \ln^2(f_0/f) + j \times \ln^3(f_0/f)} - 273.15$$

f: Instrument freq.[Hz]

Post–cruise sensor calibration for the SBE 35

S/N 0069, 22 Oct. 2015 (2nd step: fixed point calibration)

Slope = 1.000004, Offset = 0.000683

Formula:

$$Temperature(ITS-90) = slope \times (Linearized\ temperature) + offset$$

(1.4.3) Conductivity sensor (SBE 4C)

The practical corrections for CTD conductivity data can be made by using a bottle salinity data, correcting the SBE 4C to agree with measured conductivity (*McTaggart et al., 2010*).

CTD conductivity is corrected

$$Corrected\ Conductivity = C - \left(\sum_{i=0}^{I} c_i \times C^i + \sum_{j=1}^{J} p_j \times P^j\right)$$

C: CTD conductivity, c_i and p_j : calibration coefficients

i, j: determined by referring to AIC (*Akaike*, 1974). According to *McTaggart et al.* (2010), maximum of I and J are 2.

Table C.1.4: Conductivity correction coefficient summary. (Bold : selected sensor)

S/N	*Num*	c_0*(S/m)*	c_1	c_2*(m/S)*	*Stations*
			p_1*(S/m/dbar)*	p_2*(S/m/dbar^2)*	
2988	1142	1.6861e–4	0.0000e+0	0.0000e+0	RF5486 – 5516
			8.6189e–8	–8.7748e–12	
2988	1318	1.9913e–4	5.0992e–5	0.0000e+0	RF5517 – 5551
			3.3650e–8	0.0000e–0	
4316	**1144**	**4.2129e–4**	**-1.2155e–4**	**0.0000e+0**	**RF5486 – 5516**
			8.9017e–8	**–5.2210e–12**	
4316	**1315**	**1.7825e–6**	**0.0000e–0**	**0.0000e+0**	**RF5517 – 5551**
			1.2325e–7	**–1.0345e–11**	

Table C.1.5: Conductivity correction and salinity correction summary for S/N 2988.

Stations	Pressure < 1900dbar					
	Conductivity			Salinity		
	Num	Average (S/m)	Std (S/m)	Num	Average	Std
RF5486 – 5516	672	0.0000	0.0003	672	0.0001	0.0024
RF5517 – 5551	841	0.0000	0.0005	841	0.0000	0.0041
Stations	Pressure ≥ 1900 dbar					
	Conductivity			Salinity		
	Num	Average (S/m)	Std (S/m)	Num	Average	Std
RF5486 – 5516	470	0.0000	0.0000	470	0.0000	0.0005
RF5517 – 5551	477	0.0000	0.0001	477	0.0001	0.0007

Table C.1.6: Conductivity correction and salinity correction summary for S/N 4316.

Stations	Pressure < 1900dbar					
	Conductivity			Salinity		
	Num	Average (S/m)	Std (S/m)	Num	Average	Std
RF5486 – 5516	669	0.0000	0.0003	669	0.0000	0.0024
RF5517 – 5551	839	0.0000	0.0005	839	0.0000	0.0040
Stations	Pressure ≥ 1900 dbar					
	Conductivity			Salinity		
	Num	Average (S/m)	Std (S/m)	Num	Average	Std
RF5486 – 5516	475	0.0000	0.0000	475	0.0000	0.0005
RF5517 – 5551	476	0.0000	0.0000	476	0.0000	0.0005

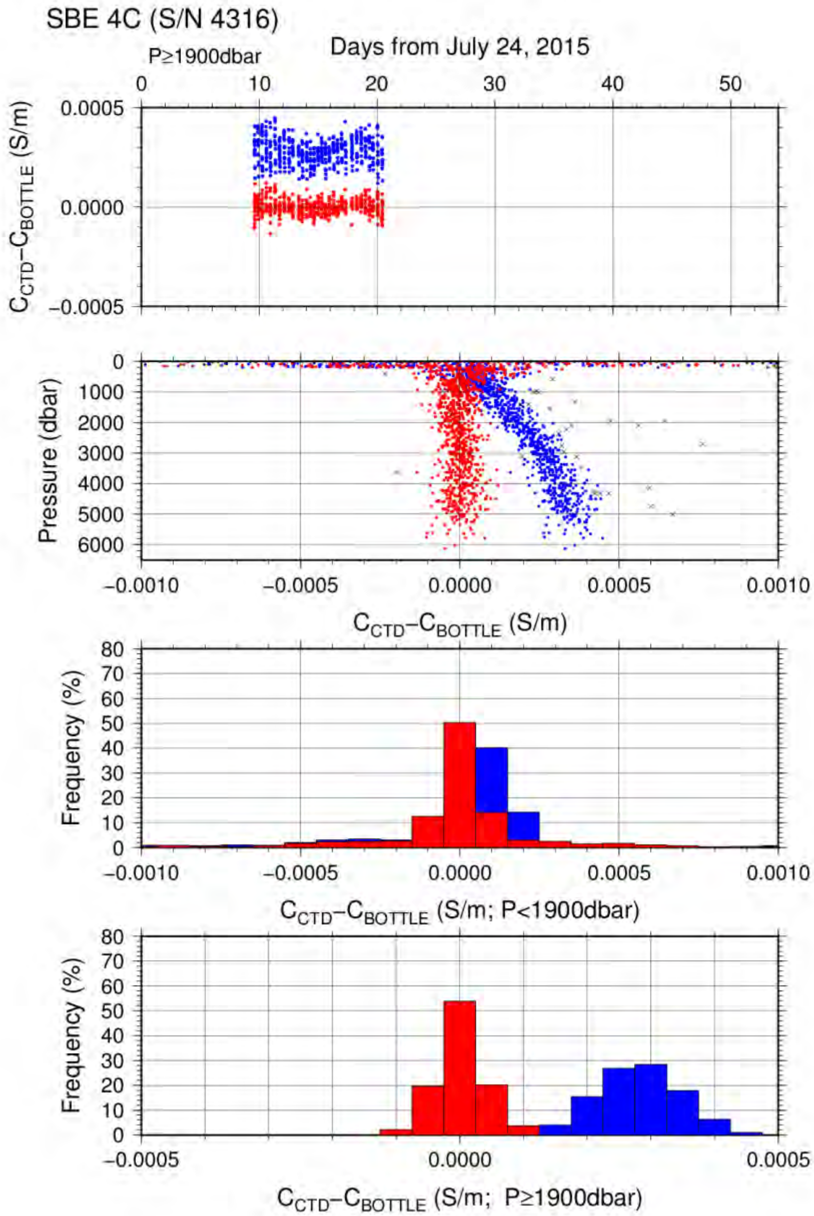

Figure C.1.4: Difference between the CTD conductivity (*S/N 4316*) and the bottle conductivity at Leg 1. Blue and red dots indicate before and after the calibration using bottle data respectively. Lower two panels show histogram of the difference before and after calibration.

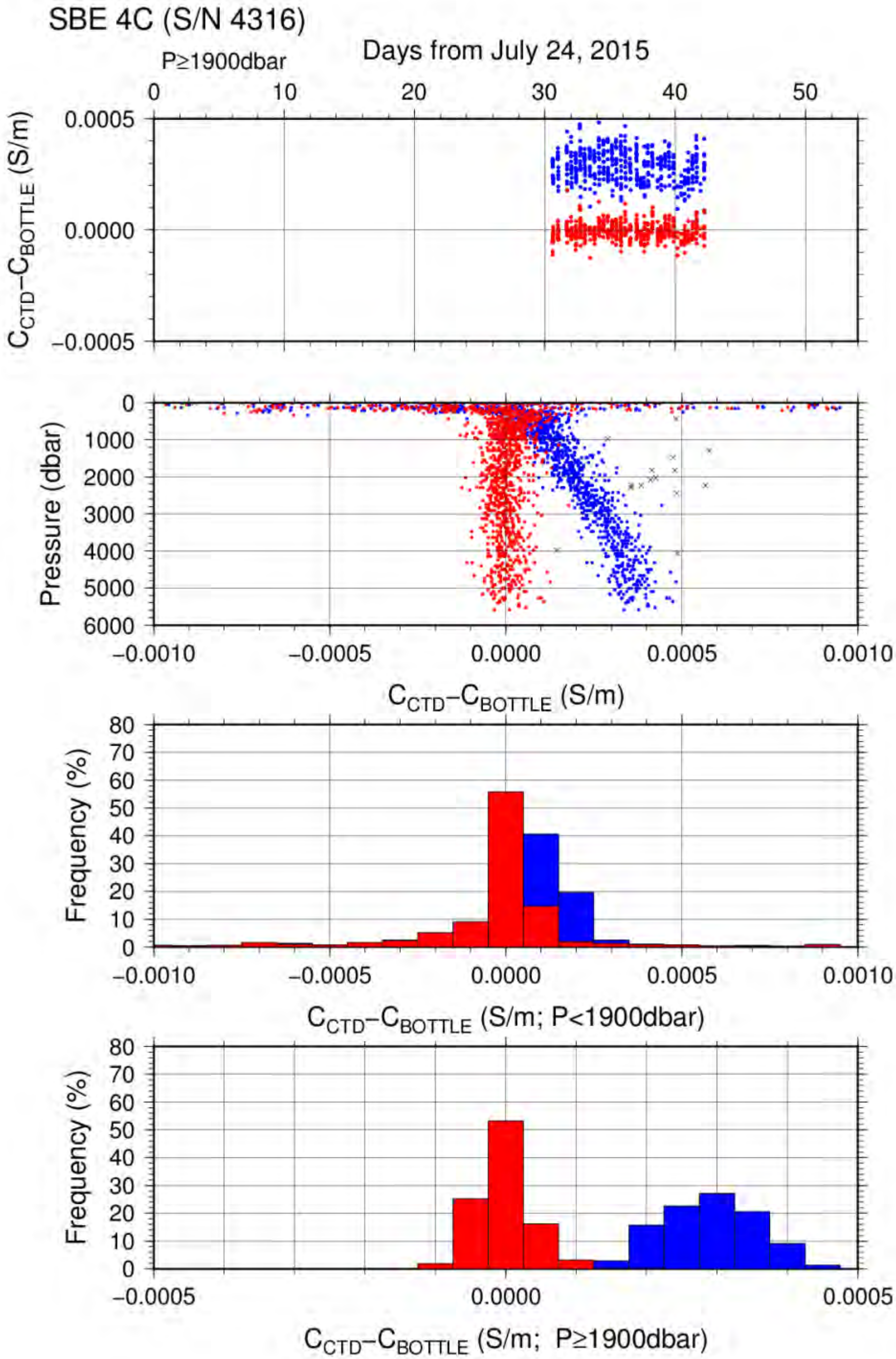

Figure C.1.5: Difference between the CTD conductivity (*S/N 4316*) and the bottle conductivity at Leg 2. Blue and red dots indicate before and after the calibration using bottle data respectively. Lower two panels show histogram of the difference before and after calibration.

Post–cruise sensor calibration for the SBE 4C

S/N 2988(primary), 16 Oct. 2015

g	=	–9.85203889e+000	j	=	4.61136788e–005
h	=	1.34620761e+000	CP_{cor}	=	–9.5700e–008
i	=	3.29757340e–004	CT_{cor}	=	3.2500e–006

S/N 4316(secondary), 16 Oct. 2015

g	=	–9.87076057e+000	j	=	2.45401575e–004
h	=	1.29126815e+000	CP_{cor}	=	–9.5700e–008
i	=	–2.63568263e–003	CT_{cor}	=	3.2500e–006

Conductivity of a fluid in the cell is expressed as:

$$C(S/m) = \left(g + h \times f^2 + i \times f^3 + j \times f^4\right) / \left\{10 \times \left(1 + CT_{cor} \times t + CP_{cor} \times p\right)\right\}$$

f: instrument frequency (kHz)
t: water temperature (degrees Celsius)
p: water pressure (dbar).

(1.4.4) Oxygen sensor (RINKO III)

The CTD oxygen is calculated using RINKO III output (voltage) by the Stern-Volmer equation, according to a method by *Uchida et al. (2008)* and *Uchida et al. (2010)*. The pressure hysteresis for the RINKO III output (voltage) is corrected according to a method by *Sea-bird Electornics (2009)* and *Uchida et al. (2010)*. The formulas are as follows:

$$P_0 = 1.0 + c_4 \times t$$

$$P_c = c_5 + c_6 \times v + c_7 \times T + c_8 \times T \times v$$

$$K_{sv} = c_1 + c_2 \times t + c_3 \times t^2$$

$$coef = (1.0 + c_9 \times P/1000)^{1/3}$$

$$[O_2] = O_2^{sat} \times \{(P_0/P_c - 1.0)/K_{sv} \times coef\}$$

P: pressure (dbar), t: potential temperature, v: RINKO output voltage (volt)

T: elapsed time of the sensor from the beginning of first station in calculation group in day

O_2^{sat}: dissolved oxygen saturation by *Garcìa and Gordon* (1992) (μmol/kg)

$[O_2]$: dissolved oxygen concentration (μmol/kg)

c_1–c_9: determined by minimizing difference between CTD oxygen and bottle dissolved oxygen by quasi-newton method (*Shanno, 1970*).

Table C.1.7: Dissolved oxygen correction coefficient summary. (Bold : selected sensor)

S/N	*Stations*	c_1 / c_6	c_2 / c_7	c_3 / c_8	c_4 / c_9	c_5
025	**RF5521 – 5551**	**1.77941e+0**	**2.30304e–2**	**1.20674e–4**	**–1.17375e–3**	**–1.18870e–1**
		3.03798e–1	**2.58797e–4**	**5.18761e–4**	**9.91309e–2**	
025	**RF5486 – 5520**	**1.78556e+0**	**2.89718e–2**	**2.21929e–4**	**–1.84584e–4**	**–1.33767e–1**
		3.08384e–1	**–4.86350e–4**	**7.43793e–4**	**8.31758e–2**	
008	RF5521 – 5551	1.80537e+0	2.37545e–2	1.39951e–4	–8.37342e–4	–1.24338e–1
		2.84432e–1	2.32233e–4	7.58759e–4	1.07596e–1	
008	RF5486 – 5520	1.81772e+0	3.16183e–2	2.80953e–4	4.88528e–4	–1.46188e–1
		2.90917e–1	–4.48620e–4	9.04550e–4	8.80134e–2	

Table C.1.8: Dissolved oxygen correction summary for S/N 025.

Stations	Pressure < 950dbar			Pressure ≥ 950dbar		
	Num	Average (µmol/kg)	Std (µmol/kg)	Num	Average (µmol/kg)	Std (µmol/kg)
RF5521 – 5551	510	0.11	1.33	566	–0.01	0.33
RF5486 – 5520	598	0.03	1.02	593	0.00	0.22

Table C.1.9: Dissolved oxygen correction summary for S/N 008.

Stations	Pressure < 950dbar			Pressure ≥ 950dbar		
	Num	Average (µmol/kg)	Std (µmol/kg)	Num	Average (µmol/kg)	Std (µmol/kg)
RF5521 – 5551	510	0.09	1.31	566	–0.01	0.35
RF5486 – 5520	598	0.00	1.03	593	0.00	0.22

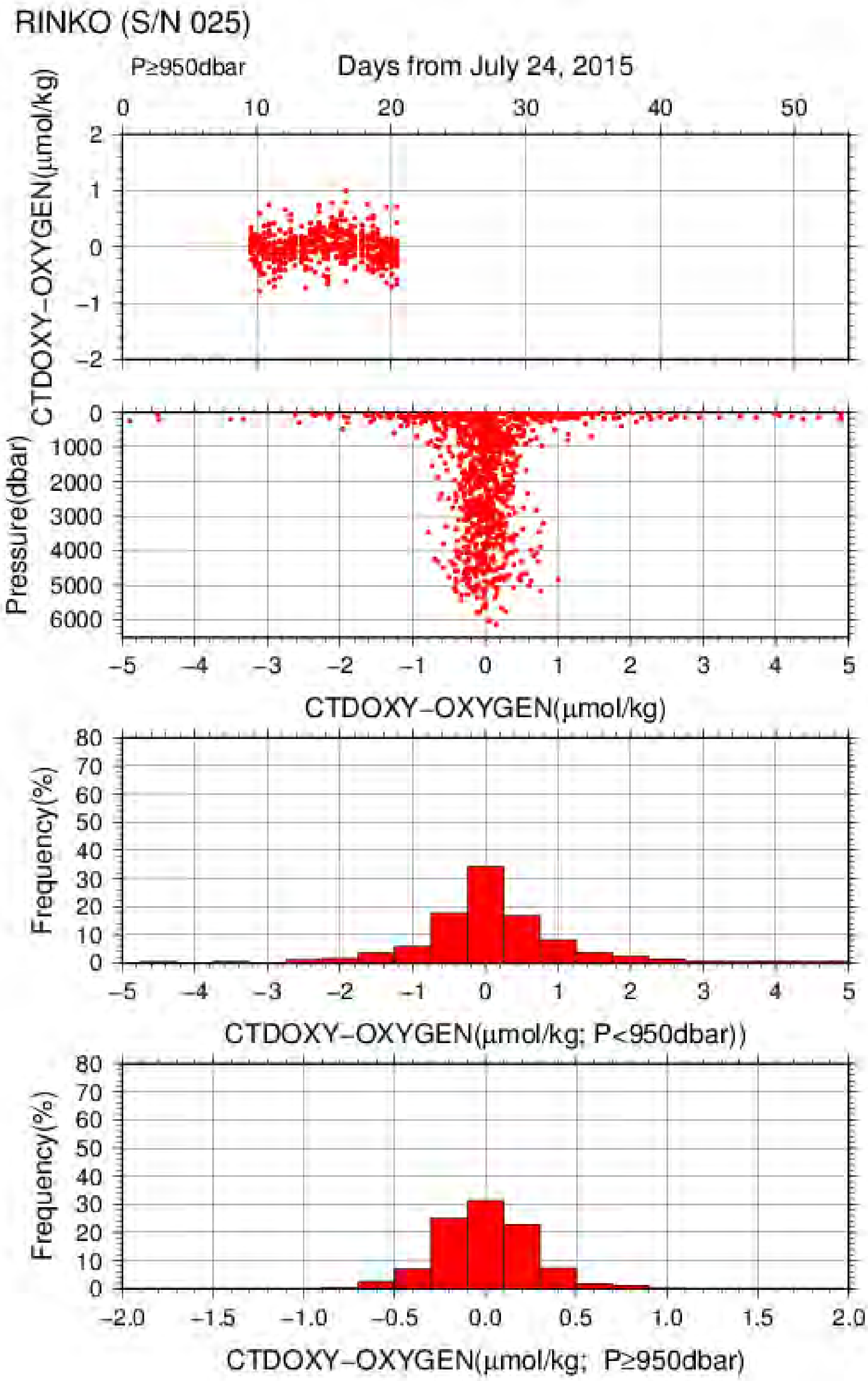

Figure C.1.6: Difference between the CTD oxygen (*S/N 025*) and bottle dissolved oxygen at Leg 1. Red dots in upper two panels indicate the result of calibration. Lower two panels show histogram of the difference between calibrated oxygen and bottle oxygen.

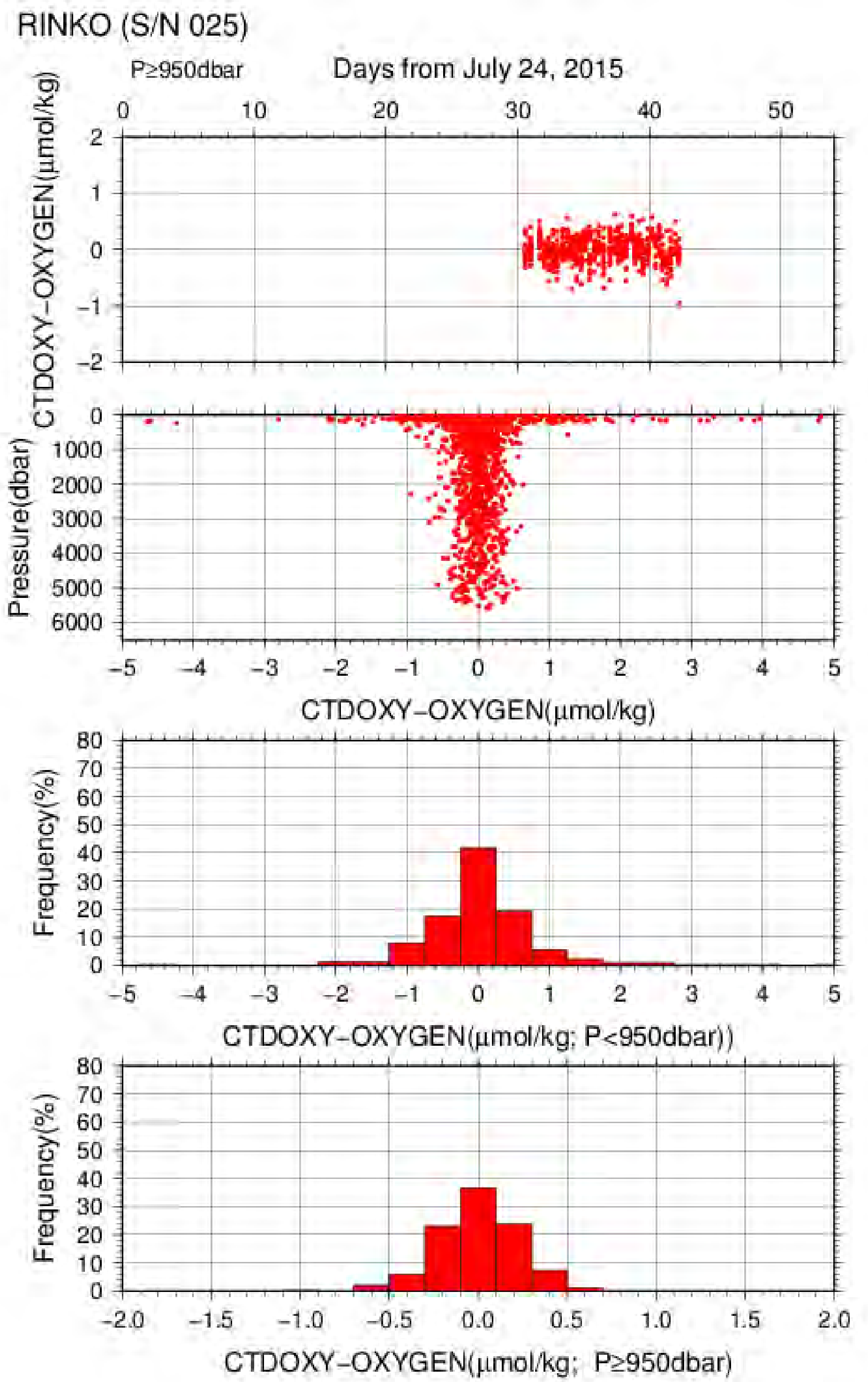

Figure C.1.7**:** Difference between the CTD oxygen (*S/N 025*) and bottle dissolved oxygen at Leg 2. Red dots in upper two panels indicate the result of calibration. Lower two panels show histogram of the difference between calibrated oxygen and bottle oxygen.

(1.4.5) Results of detection of sea floor by the altimeter (PSA-916D)

The altimeter detected the sea floor at 58 of 66 stations, the average distance of beginning detecting the sea floor was 35.0m, and that of final detection of sea floor was 12.9m. The summary of detection of PSA-916D was shown in Figure C.1.8.

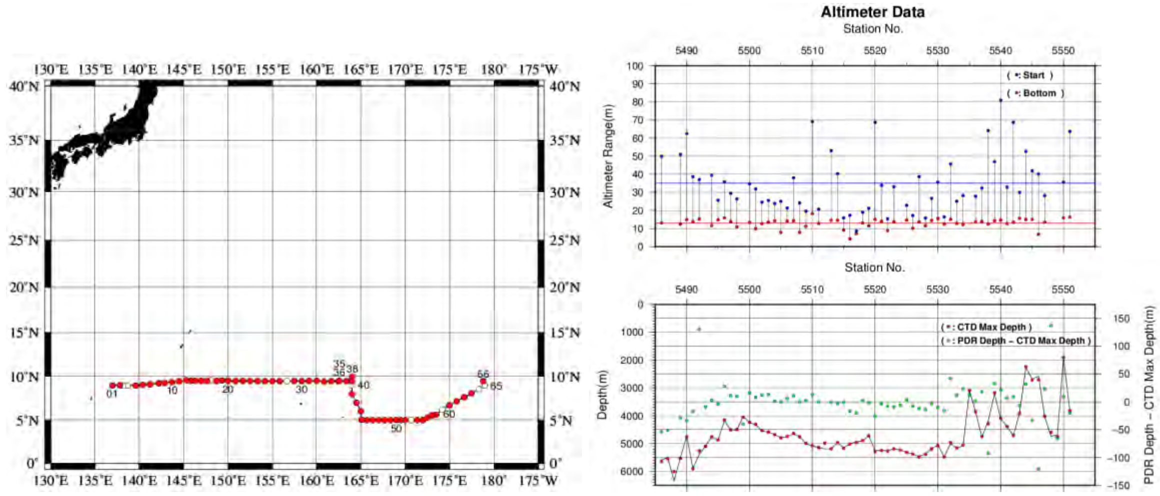

Figure C.1.8: The summary of detection of PSA-916D. The left panel shows the stations of detection, the right panel shows the relationship among PSA-916D, bathymetry and CTD depth. In the left panel, closed and open circles indicate react and no-react stations, respectively.

References

Akaike, H. (1974): A new look at the statistical model identification. *IEEE Transactions on Automatic Control, **19**:716–722.*

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

McTaggart, K. E., G. C. Johnson, M. C. Johnson, F. M. Delahoyde, and J. H. Swift (2010): The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and guidelines. IOCCP Report No ***14***, ICPO Publication Series No. 134, version 1, 2010.

Sea-Bird Electronics (2009): SBE 43 dissolved oxygen (DO) sensor – hysteresis corrections, *Application note no. 64-3, 7 pp.*

Shanno, David F. (1970): Conditioning of quasi-Newton methods for function minimization. *Math. Comput.* ***24****, 647–656. MR 42 #8905.*

Uchida, H., G. C. Johnson, McTaggart, K. E. (2010): CTD oxygen sensor calibration procedures. In: The GO-SHIP repeat hydrography manual: A Collection of Expert Reports and guidelines. IOCCP Report No ***14***, ICPO Publication Series No. 134, version 1, 2010.

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.*

Uchida, H., T. Kawano, I. Kaneko, and M. Fukasawa (2008): In-situ calibration of optode-based oxygen sensors. *J. Atmos. Oceanic Technol., **25**, 2271–2281*.

C. HYDROGRAPHIC MEASUREMENTS

1. BOTTLE SALINITY

1 November 2019

1.1 Personnel

Nobumi KATO (GEMD/JMA)
Koichi WADA (GEMD/JMA)
Yutaka KOBASHIGAWA (GEMD/JMA)
Jinya MIURA (GEMD/JMA)
Toshiyuki AMAZAWA (GEMD/JMA)

1.2 Salinity measurement

Salinometer: AUTOSAL 8400B (S/N696774; Guildline Instruments Ltd., Canada)
Thermometer: Guildline platinum thermometers model 9450 (to monitor an ambient temperature and bath temperature)
IAPSO Standard Sea Water: P157 (K15=0.99985)

1.3 Sampling and measurement

The measurement system was almost same as *Kawano* (2010).
Algorithm for practical salinity scale, 1978 (*UNESCO*, 1981) was employed to convert the conductivity ratios to salinities.

1.4 Stations occupied

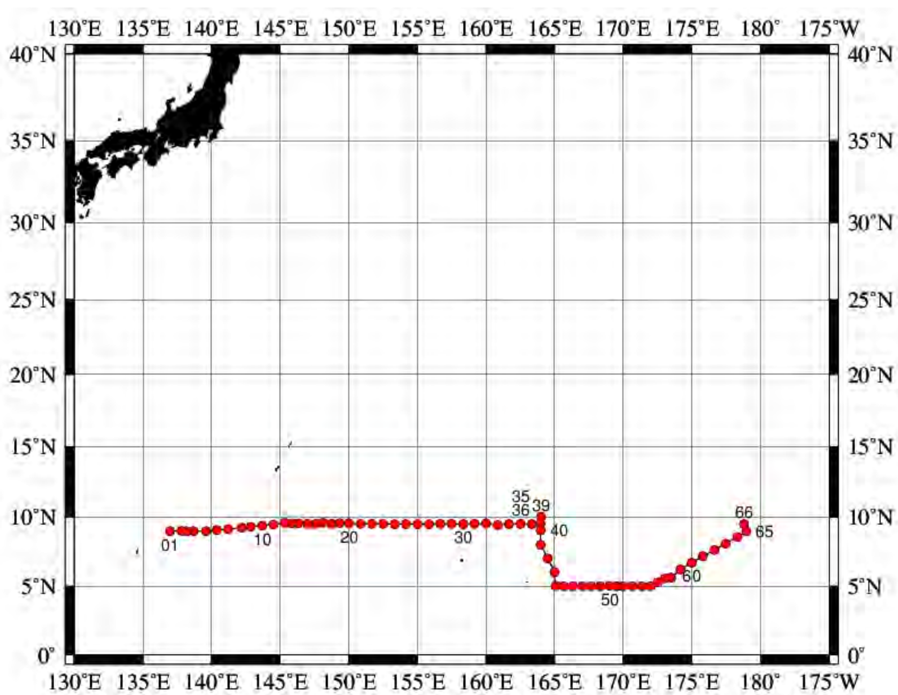

Figure C.2.1: Location of observation stations of bottle salinity. Closed and open circles indicate sampling and no-sampling station, respectively.

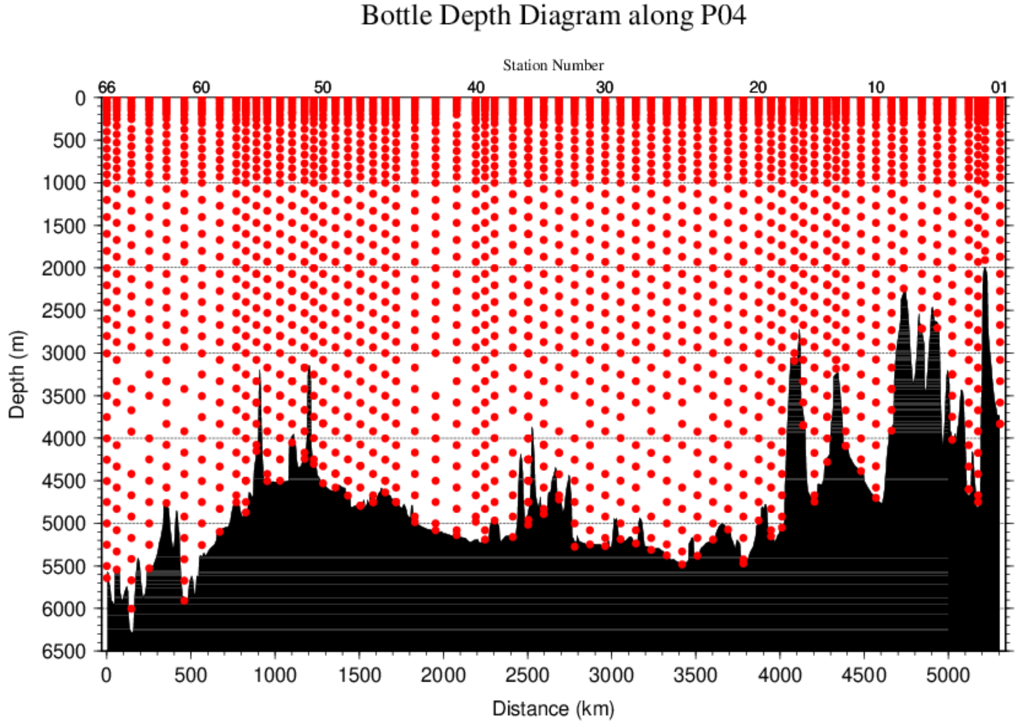

Figure C.2.2: Distance-depth distribution of sampling layers of bottle salinity.

1.5 Results

(1.5.1) Ambient temperature, bath temperature and SSW measurements

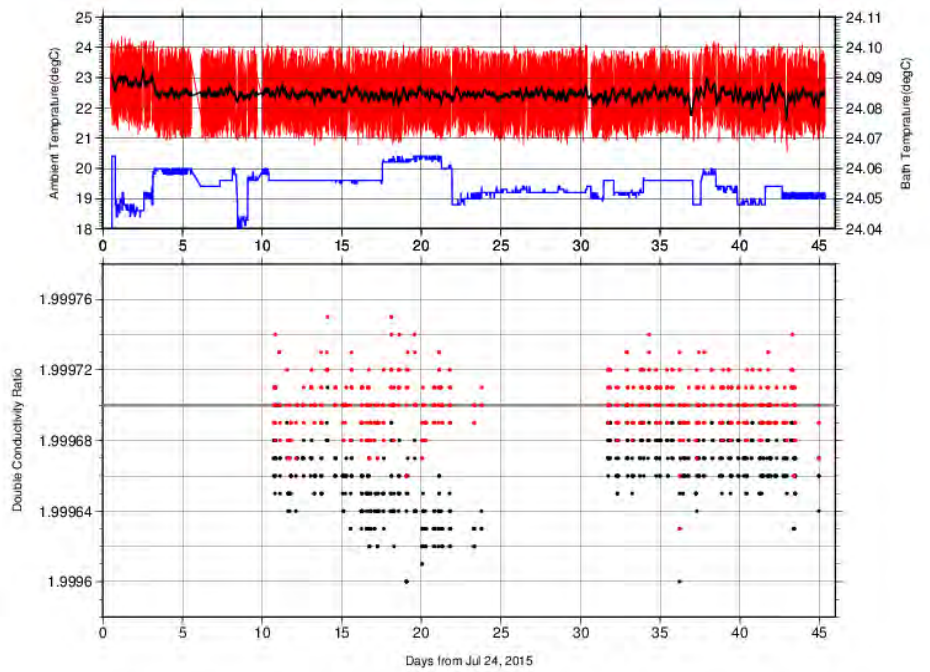

Figure C.2.3: The upper panel, red line, black line and blue line indicate time-series of ambient temperature, ambient temperature average and bath temperature during cruise. The lower panel, black dots and red dots indicate raw and corrected time-series of the double conductivity ratio of the standard sea water (P157).

(1.5.2) Replicate and Duplicate Samples

We took replicate (pair of water samples taken from a single Niskin bottle) and duplicate (pair of water samples taken from different Niskin bottles closed at the same depth) samples of bottle salinity through the cruise. Results of the analyses are summarized in Table C.2.1. Detailed results of them are shown in Figure C.2.4. The calculation of the standard deviation from the difference of sets was based on a procedure (SOP 23) in *DOE* (1994).

Table C.2.1: Summary of replicate and duplicate analyses.

Measurement	Ave. ± S.D.
Replicate	0.0003±0.0004 (N=267)
Duplicate	0.0007±0.0012 (N=64)

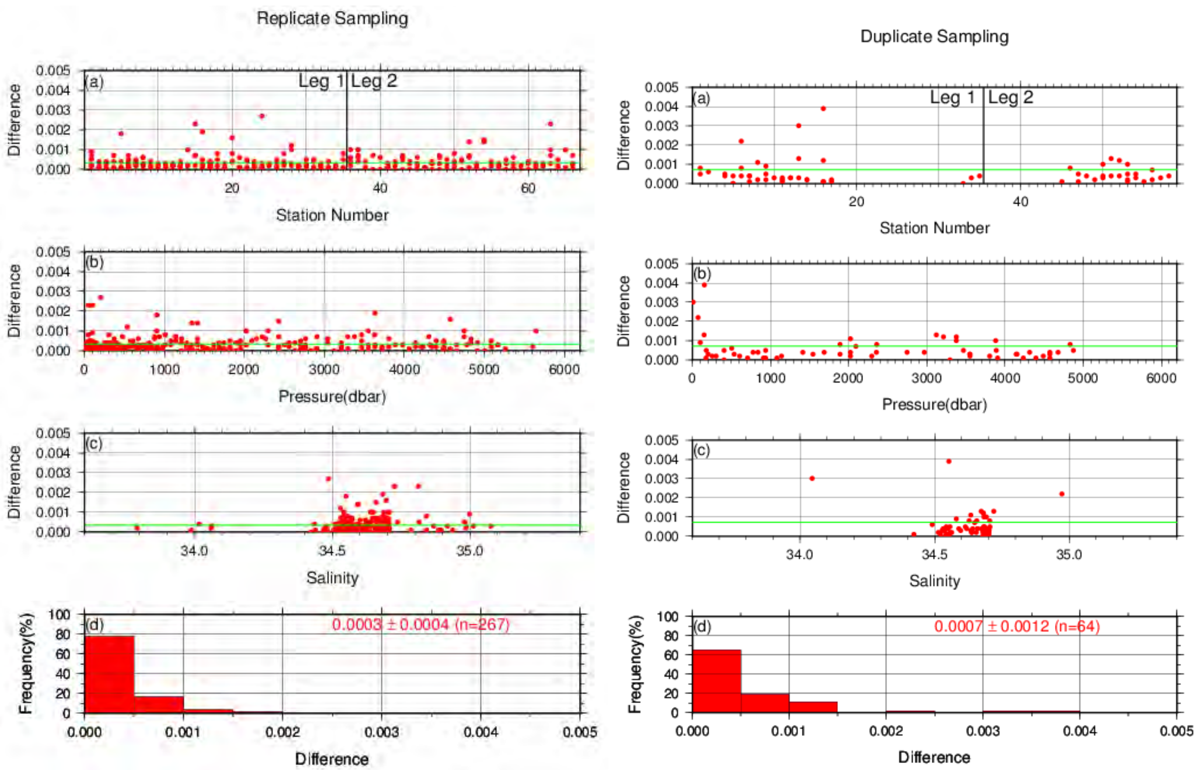

Figure C.2.4: Result of (left) replicate and (right) duplicate analyses during the cruise against (a) station number, (b) pressure and (c) salinity, and (d) histogram of the measurements. Green line indicates the mean of the differences of salinity of replicate/duplicate.

(1.5.3) Summary of assigned quality control flags

Table C.2.2: Summary of assigned quality control flags

Flag	Definition	Salinity
2	Good	1944
3	Questionable	0
4	Bad (Faulty)	138
6	Replicate measurements	271
Total number of samples		2353

References

DOE (1994), Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. *A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74.*

Kawano (2010), 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. BOTTLE OXYGEN

1 November 2019

2.1 Personnel

Chihiro KAWAMURA (GEMD/JMA)
Atsushi KOJIMA (GEMD/JMA)
Misaki YAKAWA (GEMD/JMA)

2.2 Station occupied

A total of 66 stations (Leg 1: 31, Leg 2: 35) were occupied for dissolved oxygen measurements. Station location and sampling layers of bottle oxygen are shown in Figures C.3.1 and C.3.2, respectively.

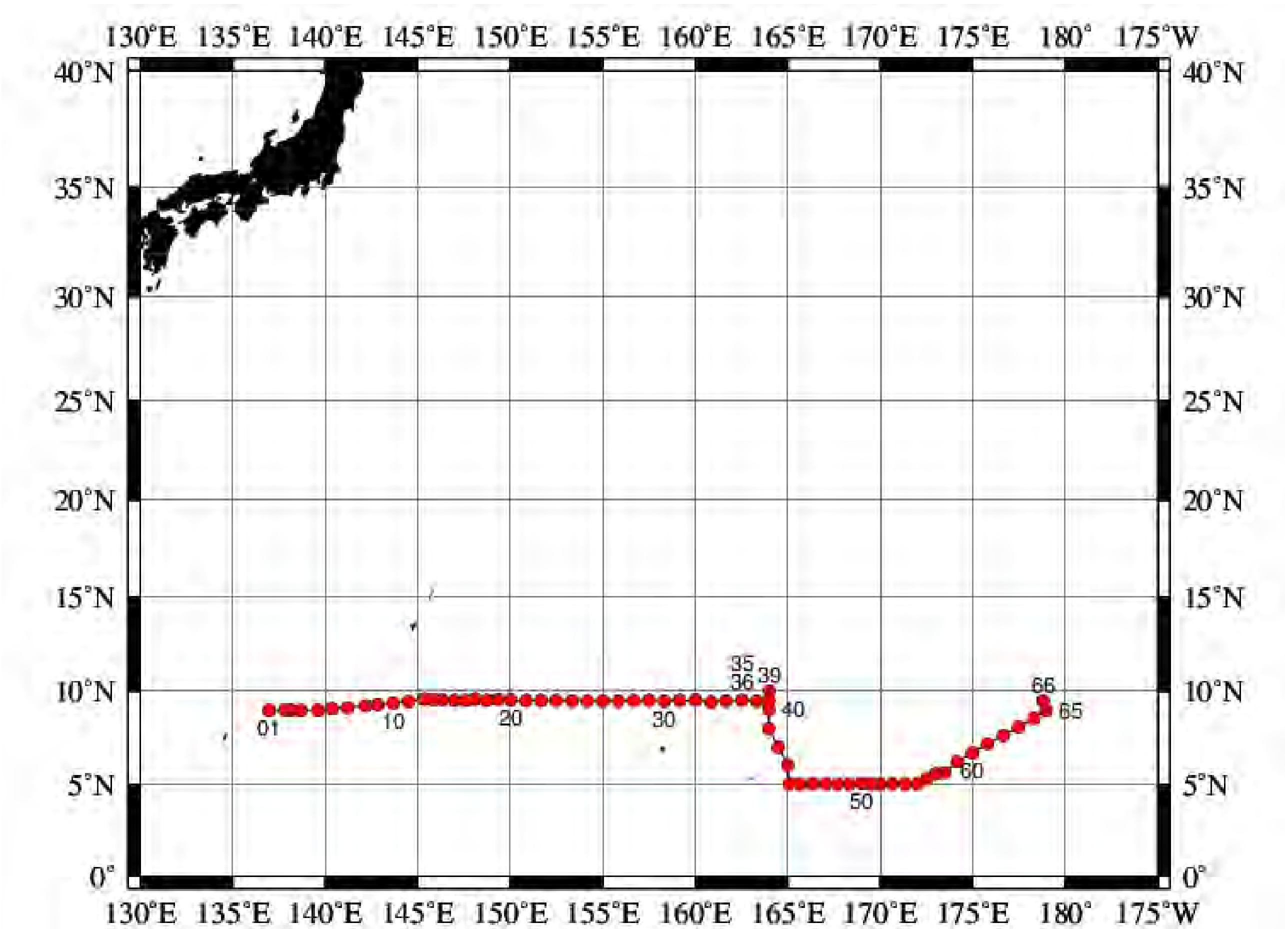

Figure C.3.1: Location of observation stations of bottle oxygen. Closed and open circles indicate sampling and no-sampling stations, respectively.

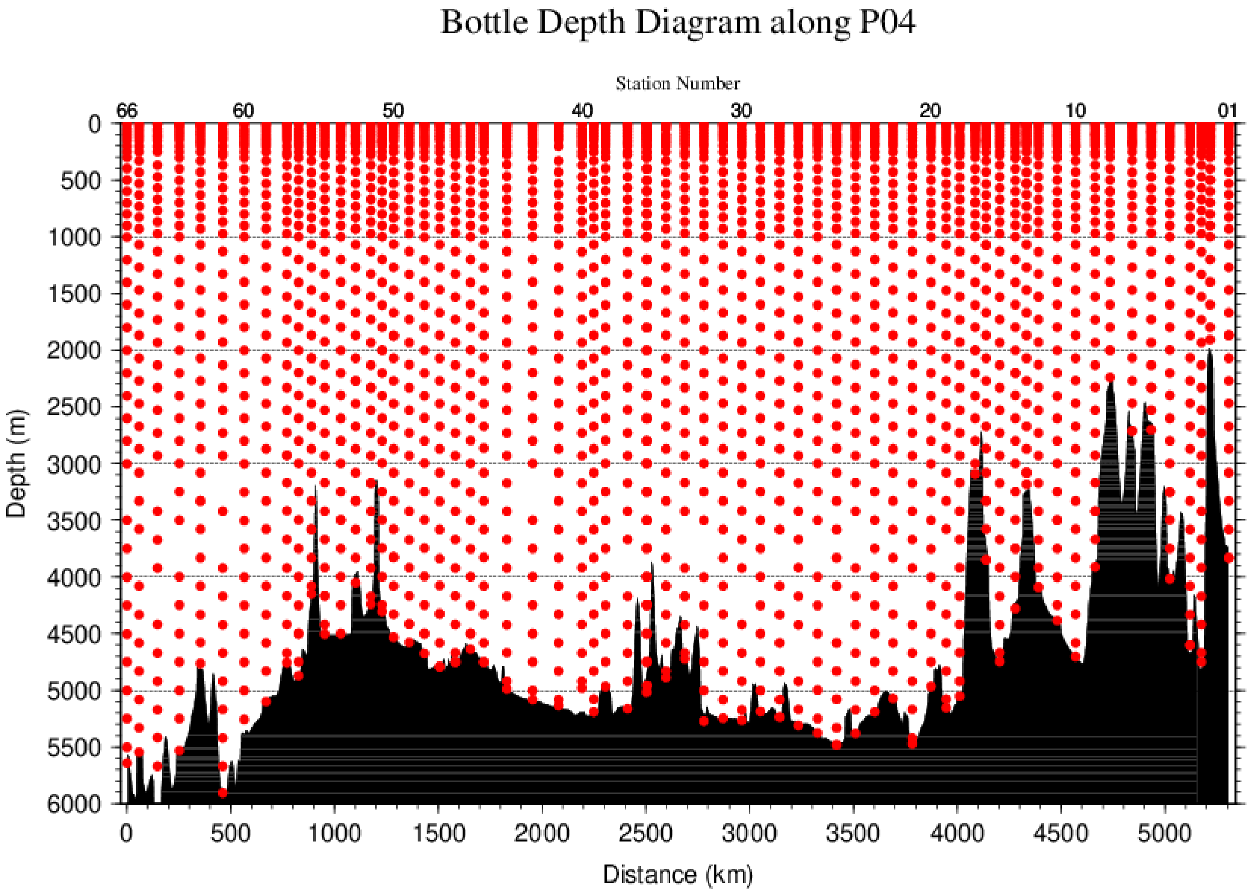

Figure C.3.2: Distance-depth distribution of sampling layers of bottle oxygen.

2.3 Instrument

Detector: DOT-01X (Kimoto Electronic, Japan)
Burette: APB-510 (Kyoto Electronic, Japan)

2.4 Sampling and measurement

Methods of seawater sampling, measurement, and calculation of dissolved oxygen concentration were based on IOCCP Report (Langdon, 2010). Details of the methods are shown in Appendix A1.

The reagents for the measurement were prepared according to recipes described in Appendix A2. It is noted that standard KIO_3 solutions were prepared gravimetrically using the highest purity standard substance KIO_3 (Lot. No. TLG0272, Wako Pure Chemical, Japan). Batch list of prepared standard KIO_3 solutions is shown in Table C.3.1.

Table C.3.1: Batch list of the standard KIO_3 solutions.

KIO_3 batch	Concentration and uncertainty (k=2) at 20 °C. Unit is normality (N).	Purpose of use
20150501-2	0.010003±0.000004	Standardization (main use)
20150611-2	0.010000±0.000004	Mutual comparison

2.5 Standardization

Concentration of $Na_2S_2O_3$ titrant was determined with the standard KIO_3 solution "20150501-2", based on the methods of IOCCP Report (Langdon, 2010). The results of standardization during the cruise are shown in Figure C.3.3. Standard deviation of its concentration at 20 °C determined through standardization was used in calculation of an uncertainty.

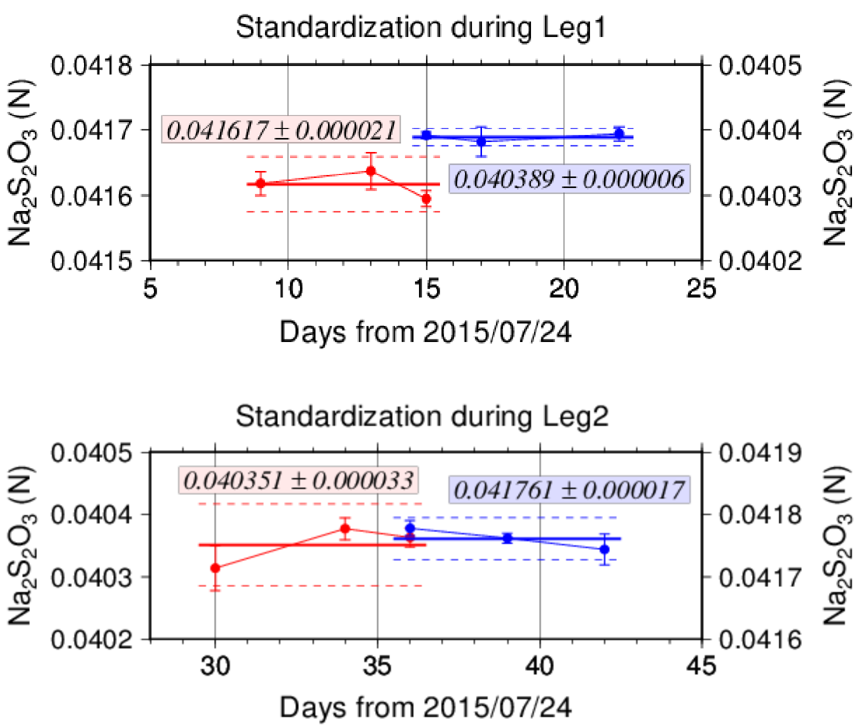

Figure C.3.3: Calculated concentration of $Na_2S_2O_3$ solution at 20 °C in standardization during Leg 1 (top) and Leg 2 (bottom). Different colors of plots indicate different batches of $Na_2S_2O_3$ solution; red (blue) plots correspond to the left (right) y-axis. Error bars of plots show standard deviation of concentration of $Na_2S_2O_3$ in the measurement. Thick and dashed lines denote the mean and 2 times of standard deviations for the batch measurements, respectively.

2.6 Blank

(2.6.1) Reagent blank

Blank in oxygen measurement (reagent blank; $V_{blk,\ dw}$) can be represented as follows;

$$V_{blk,\ dw} = V_{blk,\ ep} + V_{blk,\ reg} \quad (C3.1)$$

where $V_{blk,\ ep}$ represents a blank due to differences between the measured end-point and the equivalence point, and $V_{blk,\ reg}$ a blank associated with oxidants or reductants in the reagent. The reagent blank $V_{blk,\ dw}$ was determined by the methods described in IOCCP Report (Langdon, 2010). Because we used two sets (set A and B) of pickling reagent-I and -II, the blanks in each set were determined (Figure C.3.4).

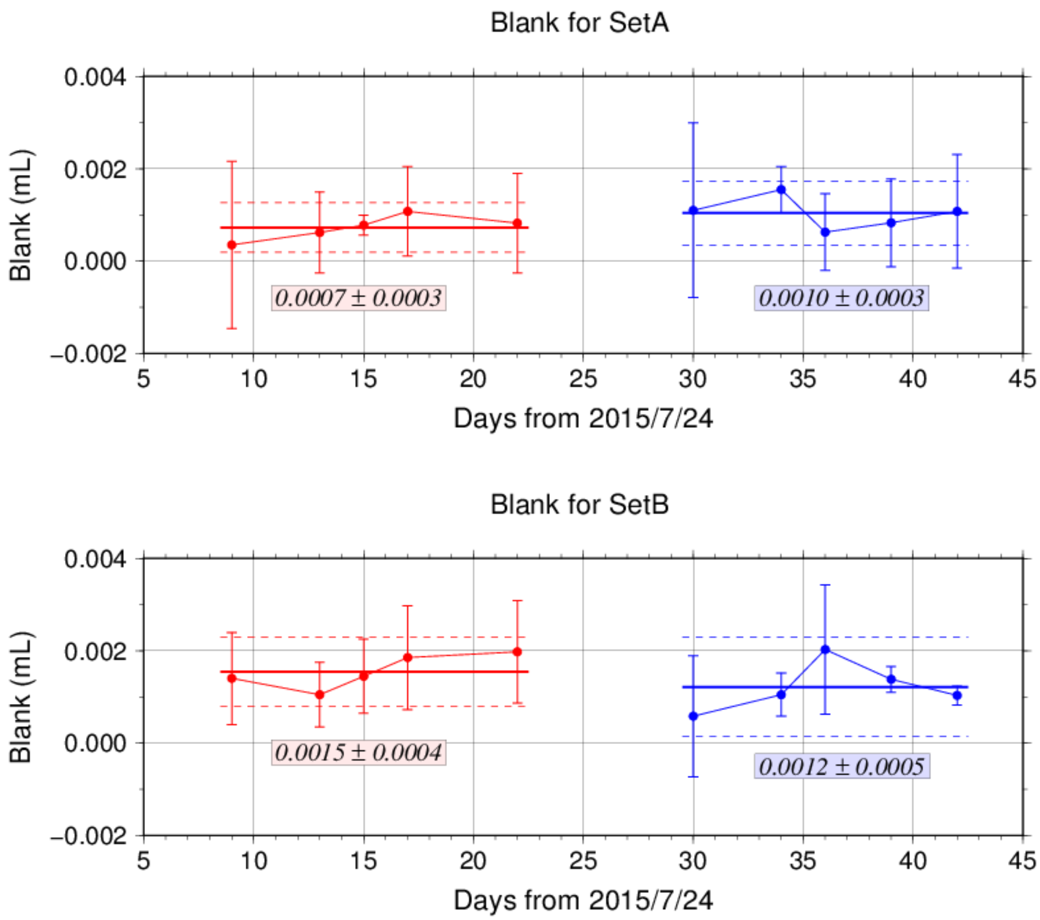

Figure C.3.4. Reagent blank ($V_{blk,\ dw}$) determination for set A (top) and set B (bottom). Error bars of plots show standard deviation of the measurement. Thick and dashed lines denote the mean and 2 times of standard deviations for the batch measurement, respectively.

(2.6.2) Other blanks

We also determined two other blanks related to oxygen measurement; the blank $V_{blk,\ reg}$ and the seawater blank ($V_{blk,\ sw}$). Details are described in Appendix A3.

2.7 Quality Control

2.7.1 Replicate and duplicate analyses

We took replicate (pair of water samples taken from a single Niskin bottle) and duplicate (pair of water samples taken from different Niskin bottles closed at the same depth) samples of dissolved oxygen through the cruise. Results of the analyses are summarized in Table C.3.2. Detailed results of them are shown in Figure C.3.5. The calculation of the standard deviation from the difference of sets was based on a procedure (SOP 23) in DOE (1994).

Table C.3.2: Summary of replicate and duplicate measurements.

Measurement	Ave. ± S.D. ($\mu mol\ kg^{-1}$)
Replicate	0.16±0.15 (N=251)
Duplicate	0.21±0.19 (N=71)

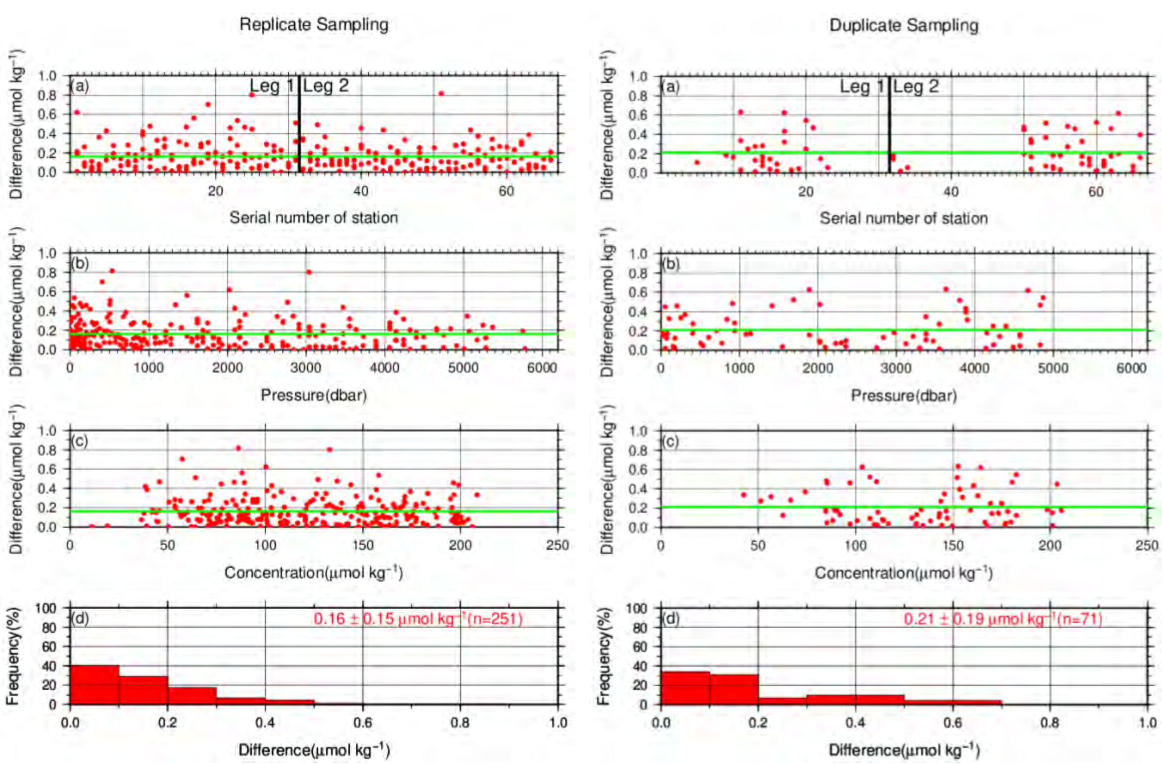

Figure C.3.5: Results of (left) replicate and (right) duplicate measurements during the cruise against (a) station number, (b) pressure and (c) concentration of dissolved oxygen. Green line denotes the average of the measurements. Bottom panels (d) show histogram of the measurements.

(2.7.2) Mutual comparison between each standard KIO_3 solution

During the cruise, mutual comparison between different lots of standard KIO_3 solution was performed to confirm the accuracy of our oxygen measurement and the bias of a standard KIO_3 solution. A concentration of the standard KIO_3 solution “20150501-2” was determined using $Na_2S_2O_3$ solution standardized with the KIO_3 solution “20150611-2”, and the difference between measurement value and theoretical one. A good agreement among two standards confirmed that there was no systematic shift in our oxygen measurements during the cruise (Figure C.3.6).

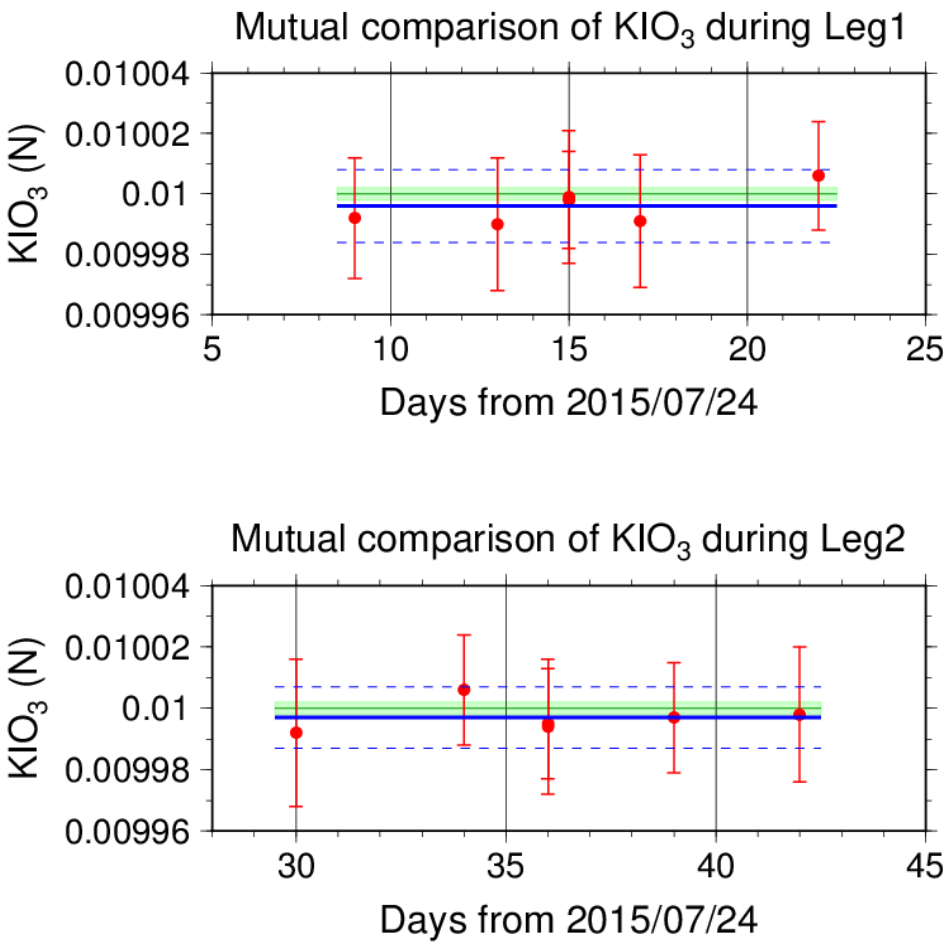

Figure C.3.6: Result of mutual comparison of standard KIO_3 solutions. Circles and error bars show mean of the measurement value and its uncertainty (k=2), respectively. Thick and dashed lines in blue denote the mean and 2 times of standard deviations, respectively, for the measurement through the leg. Green thin line and light green thick line denote nominal concentration and its uncertainty (k=2) of standard KIO_3 solution “20150501-2”.

(2.7.3) Quality control flag assignment

Quality flag value was assigned to oxygen measurements as shown in Table C.3.3, using the code defined in IOCCP Report No.14 (Swift, 2010).

Table C.3.3. Summary of assigned quality control flags.

Flag	Definition	Number of samples
2	Good	2120
3	Questionable	11
4	Bad (Faulty)	10
5	Not reported	0
6	Replicate measurements	251
	Total number of samples	2392

2.8 Uncertainty

Oxygen measurement involves various uncertainties; determination of glass bottles volume, repeatability and systematic error of burette discharge, repeatability of pickling reagents discharge, determination of reagent blank, standardization of $Na_2S_2O_3$ solution, and uncertainty of KIO_3 concentration. Considering evaluable uncertainties as above, expanded uncertainty of bottle oxygen concentration (T=20, S=34.5) was estimated as shown in Table C.3.4. However, it is difficult to determine a strict uncertainty for oxygen concentration because there is no reference material for oxygen measurement.

Table C.3.4 Expanded uncertainty (k=2) of bottle oxygen in the cruise.

O_2 conc. (μmol kg^{-1})	Uncertainty (μmol kg^{-1})
20	0.35
30	0.36
50	0.38
70	0.40
100	0.45
150	0.55
200	0.67
250	0.80
300	0.93
400	1.20

Appendix

A1. Methods

(A1.1) Seawater sampling

Following procedure is based on a determination method in IOCCP Report (Langdon, 2010). Seawater samples were collected from 10-liters Niskin bottles attached the CTD-system and a stainless steel bucket for the surface. Seawater for bottle oxygen measurement was transferred from the Niskin bottle and a stainless steel bucket to a volumetrically calibrated dry glass bottles. At least three times the glass volume water was overflowed. Then, pickling reagent-I 1 mL and reagent-II 1mL were added immediately, and sample temperature was measured using a thermometer. After a stopper was inserted carefully into the glass, it was shaken vigorously to mix the content and to disperse the precipitate finely. After the precipitate has settled at least halfway down the glass, the glass was shaken again. The sample glasses containing pickled samples were stored in a laboratory until they were titrated. To prevent air from entering the glass, deionized water (DW) was added to its neck after sampling.

(A1.2) Sample measurement

At least 15 minutes after the re-shaking, the samples were measured on board. Added 1 mL H_2SO_4 solution and a magnetic stirrer bar into the sample glass, samples were titrated with $Na_2S_2O_3$ solution whose molarity was determined with KIO_3 solution. During the titration, the absorbance of iodine in the solution was monitored using a detector. Also, temperature of $Na_2S_2O_3$ solution during the titration was recorded using a thermometer. Dissolved oxygen concentration (μmol kg^{-1}) was calculated from sample temperature at the fixation, CTD salinity, glass volume, and titrated volume of the $Na_2S_2O_3$ solution, and oxygen in the pickling reagents-I (1 mL) and II (1 mL) (7.6×10^{-8} mol; Murray *et al.*, 1968).

A2. Reagents recipes

Pickling reagent-I; Manganous chloride solution (3 mol L^{-1})

Dissolve 600 g of $MnCl_2 \cdot 4H_2O$ in DW, then dilute the solution with DW to a final volume of 1 L.

Pickling reagent-II; Sodium hydroxide (8 mol L^{-1}) / sodium iodide solution (4 mol L^{-1})

Dissolve 320 g of NaOH in about 500 mL of DW, allow to cool, then add 600 g NaI and dilute with DW to a final volume of 1 L.

H_2SO_4 solution; Sulfuric acid solution (5 mol L^{-1})

Slowly add 280 mL concentrated H_2SO_4 to roughly 500 mL of DW. After cooling the final volume should be 1 L.

$Na_2S_2O_3$ solution; Sodium thiosulfate solution (0.04 mol L^{-1})

Dissolve 50 g of $Na_2S_2O_3 \cdot 5H_2O$ and 0.4 g of Na_2CO_3 in DW, then dilute the solution with DW to a final volume of 5 L.

KIO_3 solution; Potassium iodate solution (0.001667 mol L^{-1})

Dry high purity KIO_3 for two hours in an oven at 130 °C. After weight out accurately KIO_3, dissolve it in DW in a 5 L flask. Concentration of potassium iodate is determined by a gravimetric method.

A3. Other blanks in oxygen measurement

(A3.1) Blank associated with oxidants or reductants in the reagents

The blank $V_{blk,\ reg}$, associated with oxidants or reductants in the reagent, was determined as follows. Using a calibrated pipette, 1 mL of the standard KIO_3 solution and 100 mL of DW were added to two glasses each. Then, 1 mL H_2SO_4 solution, 1 mL of pickling reagent-II and 1 mL reagent-I were added in sequence into the first glass. Next, added two times volume of the reagents (2 mL of H_2SO_4 solution, pickling reagent-II and I each) into the second one. After that, the sample was titrated to the end-point with $Na_2S_2O_3$ solution. $V_{blk,\ reg}$ was determined with difference of titrated volume of $Na_2S_2O_3$ between the first (total reagents volume is 3 mL) and the second (total reagents volume is 6 mL) one, also, experiments for three times and four times volume of them were carried out. The results are shown in Figure C.3.A1.

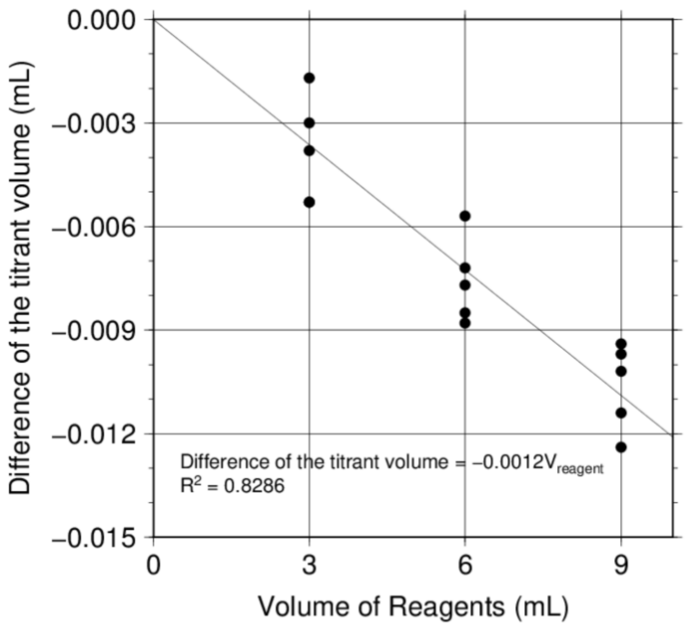

Figure C.3.A1: Blank (mL) due to redox species other than oxygen in the reagents.

The relation between difference of the titrant volume and the reagents of the volume (V_{reg}) is expressed as follows:

$$\text{Difference of the titrant volume} = -0.0012\ V_{reg}. \qquad (C3.A1)$$

Therefore, $V_{blk,\ reg}$ was estimated to be +0.004 mL.

(A3.2) Sample blank ($V_{blk,\ spl}$)

Blank due to redox species other than oxygen in the sample ($V_{blk,\ spl}$) can be a potential source of measurement error. Total blank during seawater measurement, seawater blank ($V_{blk,\ sw}$), can be represented as follows;

$$V_{blk,\ sw} = V_{blk,\ spl} + V_{blk,\ dw}. \qquad (C3.A2)$$

If the $V_{blk,\ dw}$ determined in eq. (C3.1) is identical both in seawater and in pure water, the difference between the seawater and reagent blanks gives the $V_{blk,\ spl}$.

Here, $V_{blk,\ spl}$ was determined by following procedure. Seawater was collected in the calibrated volumetric glass without the pickling solution. Then 1 mL of the standard KIO_3 solution, H_2SO_4 solution, and reagent solution-II and I each were added in sequence into the glass. After that, the sample was titrated to the end-point by $Na_2S_2O_3$ solution. Similarly, a glass contained 100 mL of DW added with 1 mL of the standard KIO_3 solution, H_2SO_4 solution, pickling reagent solution-II and I were titrated with $Na_2S_2O_3$ solution. The difference of the titrant volume of the seawater and DW glasses gave $V_{blk,\ spl}$.

The sample blank has been reported from 0.4 to 0.8 μmol kg^{-1} in the previous study (Culberson *et al.*, 1991). Additionally, these errors are expected to be the same to all investigators and not to affect the comparison of results from different investigators (Culberson, 1994). However, the magnitude and variability of the seawater blank have not yet been documented. We believe that understanding of the magnitude and variability may be important to evaluate comparability of computed oxygen concentrations with other groups. The determined sample blanks are shown in Table C.3.A1.

Table C.3.A1. Results of the sample blank determinations.

Station: RF5487 9°-00′N/137°-00′E		Station: RF5495 8°-59′N/139°-35′E		Station: RF5547 5°-35′N/173°-00′E		Station: RF5551 8°-59′N/178°-58′E	
Pres. (dbar)	Blank (μmol kg^{-1})	Pres. (dbar)	Blank (μmol kg^{-1})	Pres. (dbar)	Blank (μmol kg^{-1})	Pres. (dbar)	Blank (μmol kg^{-1})
2.6	0.42	25.6	0.95	50.8	0.41	10.8	0.61
10.6	0.29	78.3	1.21	75.4	0.38	50.1	0.50
25.1	0.38	78.3	0.80	100.7	0.48	50.1	0.41
50.9	0.42	252.1	0.70	100.7	0.50	125.2	0.58
77.9	0.50	806.8	0.62	126.1	0.84	251.9	0.68
77.9	0.49	1412.5	1.44	151.7	0.48	534.3	0.72
102.0	0.55	2021.4	0.65	176.9	0.55	736.3	0.78
151.8	0.71	2427.0	0.91	202.8	0.67	1080.9	0.72
201.7	0.72	2835.4	0.65	606.3	0.58	2297.1	0.81
433.3	0.71	3295.6	0.69	1211.2	0.50	3375.6	0.58
938.3	0.63	3295.6	0.72	1818.0	0.61	3375.6	0.72
1484.3	0.66	4077.6	0.54	2631.1	0.53	4913.8	0.76
2296.0	0.76			3293.4	0.56		
2907.1	0.65			4061.6	0.62		
3889.4	0.71			4955.6	0.68		
3889.4	0.71			4955.6	0.84		

Reference

Culberson, A.H. (1994) Dissolved oxygen, in WHPO Pub. 91-1 Rev. 1, November 1994, Woods Hole, Mass., USA.

Culberson, A.H., G. Knapp, M.C. Stalcup, R.T. Williams, and F. Zemlyak (1991) A comparison of methods for the determination of dissolved oxygen in seawater, WHPO Pub. 91-2, August 1991, Woods Hole, Mass., USA.

DOE (1994), Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. *A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74*.

Langdon, C. (2010), Determination of dissolved oxygen in seawater by Winkler titration using the amperometric technique, *IOCCP Report No.14, ICPO Pub. 134, 2010 ver.1*

Murray, C. N., J. P. Riley and T. R. S. Wilson (1968), The solubility of oxygen in Winkler reagents used for the determination of dissolved oxygen. *Deep-Sea Res*. 15, 237–238.

Swift, J. H. (2010), Reference-quality water sample data: Notes on acquisition, record keeping, and evaluation. *IOCCP Report No.14, ICPO Pub. 134, 2010 ver.1*.

3. NUTRIENTS

Updated 10 June 2020

3.1 Personnel

Takahiro KITAGAWA (GEMD/JMA)
Kei KONDO (GEMD/JMA)
Ryoma SUZUKI (GEMD/JMA)

3.2 Station occupied

A total of 66 stations (Leg 1: 31, Leg 2: 35) were occupied for nutrients measurements. Station location and sampling layers of nutrients are shown in Figures C.4.1 and C.4.2.

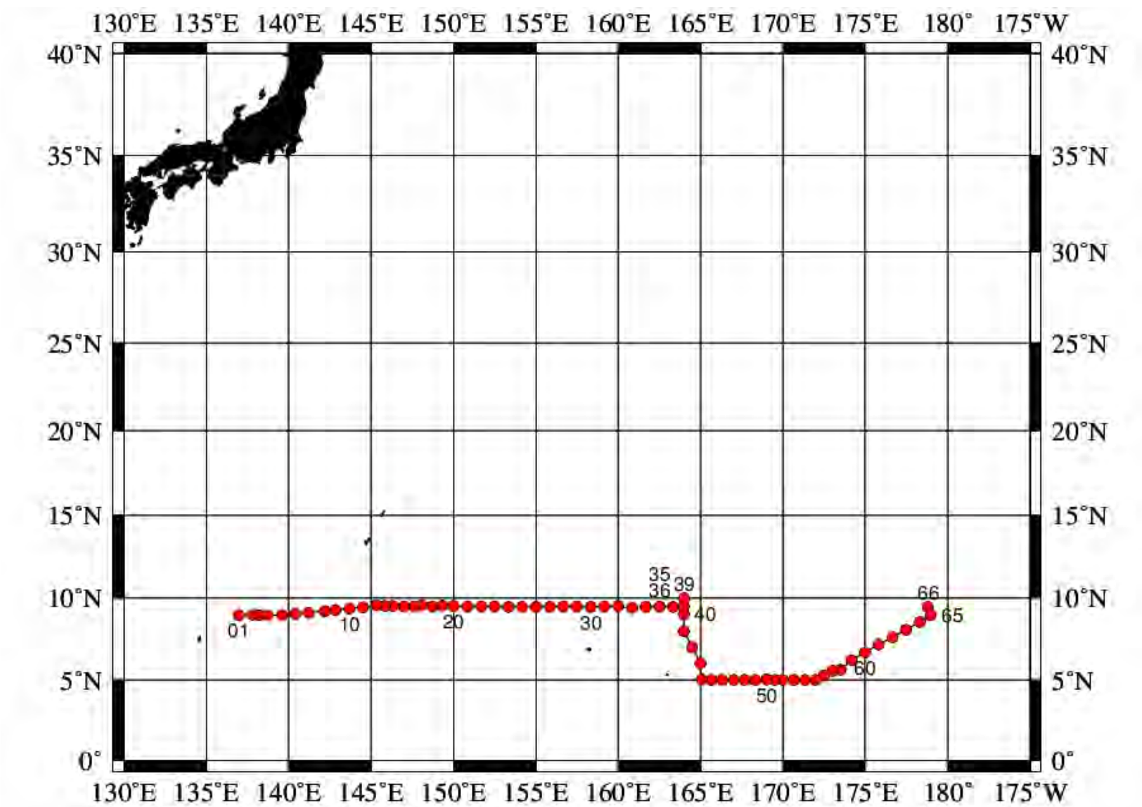

Figure C.4.1: Location of observation stations of nutrients. Closed and open circles indicate sampling and no-sampling stations, respectively.

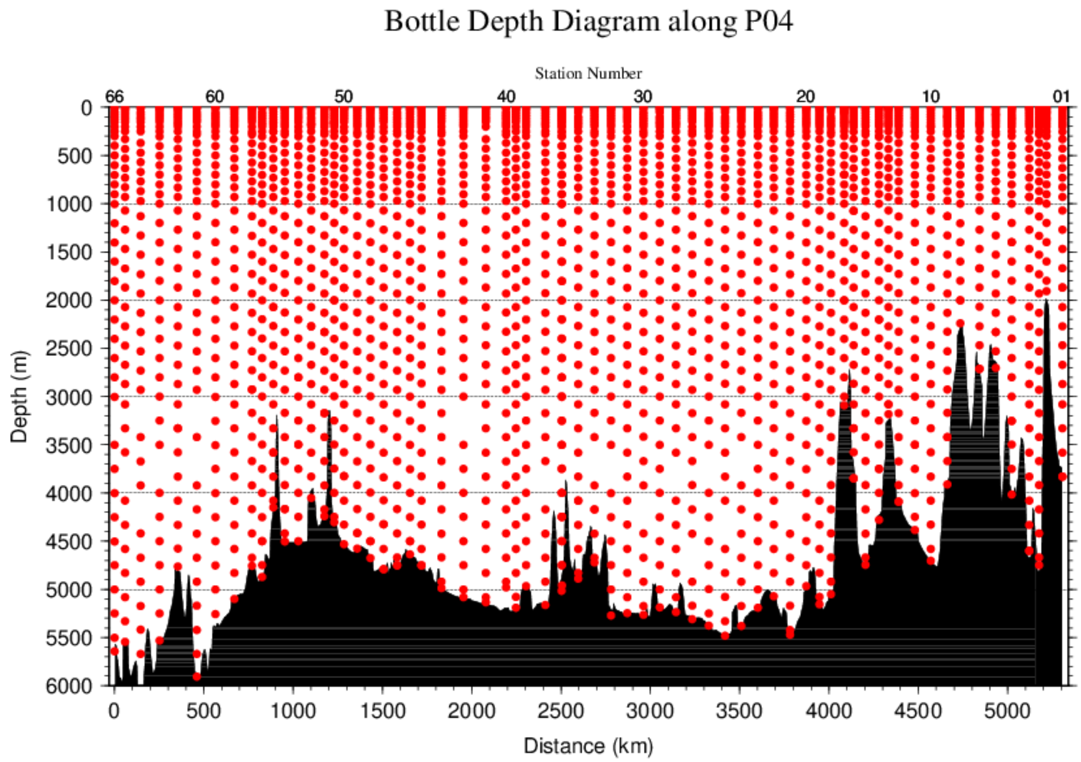

Figure C.4.2: Distance-depth distributions of sampling layers of nutrients.

3.3 Instrument

The nutrients analysis was carried out on 4-channel Auto Analyzer III (BL TEC K.K., Japan) for 4 parameters; nitrate+nitrite, nitrite, phosphate, and silicate.

3.4 Sampling and measurement

Methods of seawater sampling, measurement, and data processing of nutrient concentration were described in Appendixes A1, A2, and A3, respectively. The reagents for the measurement were prepared according to recipes shown in Appendix A4.

3.5 Nutrients standards

(3.5.1) Volumetric laboratory ware of in-house standards

All volumetric wares were gravimetrically calibrated. The weights obtained in the calibration weighing were corrected for the density of water and for air buoyancy. Polymethylpenten volumetric flasks were gravimetrically calibrated at the temperature of use within 4–6 °C. 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.

(3.5.2) Reagents of standard

The batches of the reagents used for standard are listed in Table C.4.1.

Table C.4.1. List of reagents of standard used in the cruise.

	Name	CAS No	Lot. No	Industries
Nitrate	potassium nitrate 99.995 suprapur®	7757-79-1	B0771365	Merck KGaA
Nitrite	sodium nitrite GR for analysis ACS, Reag. Ph Eur	7632-00-0	A0723349	Merck KGaA
Phosphate	potassium dihydrogen phosphate anhydrous 99.995 suprapur®	7778-77-0	B1122808	Merck KGaA
Silicate	Silicon standard solution 1000 mg/l Si*	-	HC382250	Merck KGaA

* Traceable to NIST-SRM3150

(3.5.3) Low nutrient seawater (LNSW)

Surface water with sufficiently low nutrient concentration was taken and filtered using 10 µm pore size membrane filter in our previous cruise. This water was stored in 20 liter flexible container with paper box.

(3.5.4) In-house standard solutions

Nutrient concentrations for A, B and C standards were set as shown in Table C.4.2. A and B standards were prepared with deionized water (DW). C standard (full scale of working standard) was mixture of B-1 and B-2 standards, and was prepared with LNSW. C-1 standard, whose concentrations of nutrient were nearly zero, was prepared as LNSW slightly added with DW to be equal with mixing ratio of LNSW and DW in C standard. The C-2 to -5 standards were prepared with mixture of C-1 and C standards in stages as 1/4, 2/4, 3/4, and 4/4 (i.e., pure "C standard") concentration for full scale, respectively. The actual concentration of nutrients in each standard was calculated based on the solution temperature and factors of volumetric laboratory wares calibrated prior to use. Nominal zero concentration of nutrient was determined in measurement of DW after refraction error correction. The calibration curves for each run were obtained using 5 levels of C-1 to -5 standards. These standard solutions were periodically renewed as shown in Table C.4.3.

Table C.4.2: Nominal concentrations of nutrients for A, B, and C standards at 20 °C. Unit is μmol L^{-1}.

	A	B	C
Nitrate	26250	524	43.6
Nitrite	12510	250	2.0
Phosphate	2030	40.5	3.38
Silicate	35640	2134	170

Table C.4.3. Schedule of renewal of in-house standards.

Standard	Renewal
A-1 std. (NO_3)	No renewal
A-2 std. (NO_2)	No renewal
A-3 std. (PO_4)	No renewal
A-4 std. (Si)	Commercial prepared solution
B-1 std. (mixture of A-1, A-3, and A-4 stds.)	Maximum 8 days
B-2 std. (diluted A-2 std.)	Maximum 15 days
C-std. (mixture of B-1 and B-2 stds.)	Every measurement
C-1 to -5 stds.	Every measurement

3.6 Certified reference material

Certified reference material for nutrients in seawater (hereafter CRM), which was prepared by the General Environmental Technos (KANSO Technos, Japan), was used every analysis at each hydrographic station. Using CRMs for the analysis of seawater, stable comparability and uncertainty of our data are secured.

CRMs used in the cruise are shown in Table C.4.4.

Table C.4.4. Certified concentration and uncertainty (k=2) of CRMs. Unit is μmol kg^{-1}.

	Nitrate	Nitrite	Phosphate	Silicate
CRM-BY	0.024±0.019*	0.019±0.0085*	0.039±0.010*	1.763±0.063
CRM-BW	24.59±0.20	0.067±0.010	1.541±0.014	60.01±0.42
CRM-BV	35.36±0.35	0.047±0.0073	2.498±0.023	102.2±1.1
CRM-BZ	43.35±0.33	0.215±0.011	3.056±0.033	161.0±0.93

* Reference value because concentration is under limit of quantitation

The CRM-BY and -BV were analyzed every runs using newly opened CRM bottle at each hydrographic station. The CRM-BW and -BZ were also analyzed every runs but were newly opened every 2 or 3 runs. Although this usage of CRM might be less common, we have confirmed a stability of the opened CRM bottles to be tolerance in our observation. The CRM bottles were stored at a laboratory in the ship, where the temperature was maintained around 25 °C.

It is noted that nutrient data in our report are calibrated not on CRM but on in-house standard solutions. Therefore, to calculate data based on CRM, it is necessary that values of nutrient concentration in our report are correlated with CRM values measured in the same analysis run. The result of CRM measurements is attached as 49UP20150724_P04W_nut_CRM_measurement.csv.

3.7 Quality Control

(3.7.1) Replicate and duplicate analyses

We took replicate (pair of water samples taken from a single Niskin bottle) and duplicate (pair of water samples taken from different Niskin bottles closed at the same depth) samples of nutrient through the cruise. Results of the analyses are summarized in Table C.4.5. Detailed results of them are shown in Figures C.4.3–C.4.5. The calculation of the standard deviation from the difference of sets was based on a procedure (SOP 23) in DOE (1994).

Table C.4.5: Average and standard deviation of difference of replicate and duplicate measurements through the cruise. Unit is μmol kg^{-1}.

Measurement	Nitrate+nitrite	Phosphate	Silicate
Replicate	0.026±0.024 (N=255)	0.002±0.002 (N=253)	0.078±0.077 (N=251)
Duplicate	0.037±0.033 (N=70)	0.004±0.004 (N=70)	0.138±0.125 (N=69)

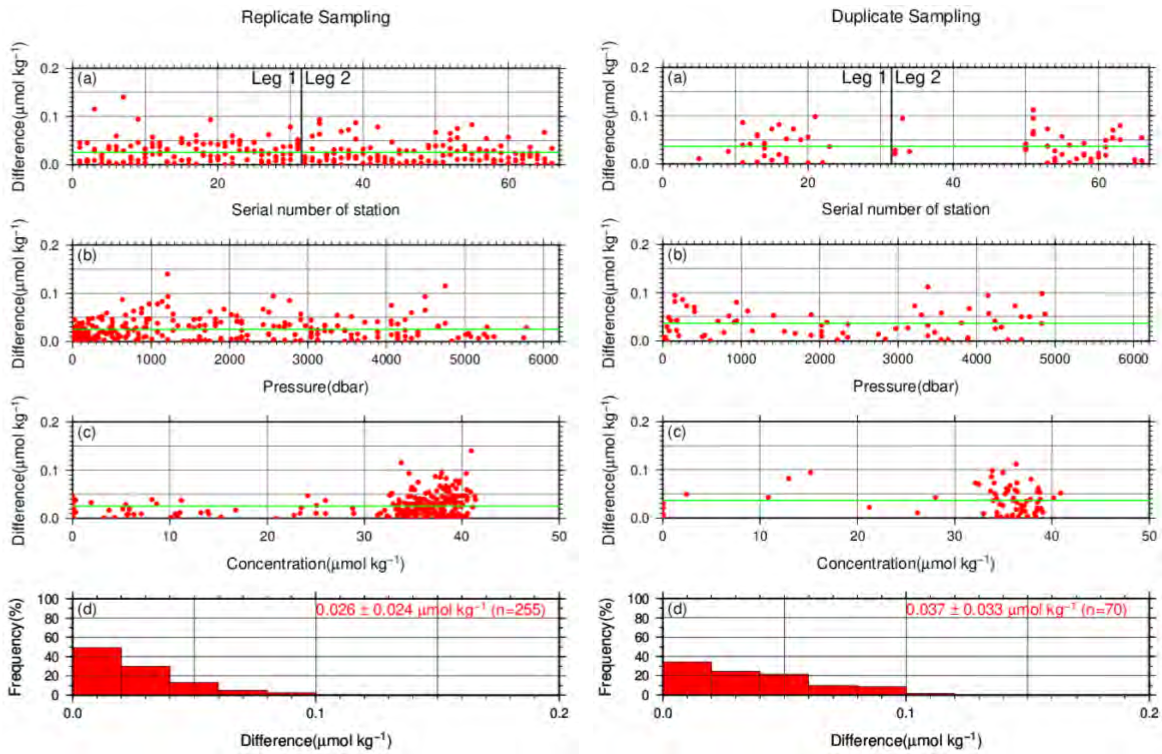

Figure C.4.3: Result of (left) replicate and (right) duplicate measurements of nitrate+nitrite through the cruise versus (a) station number, (b) sampling pressure, (c) concentration, and (d) histogram of the measurements. Green line indicates the mean of the differences of concentration of replicate/duplicate analyses.

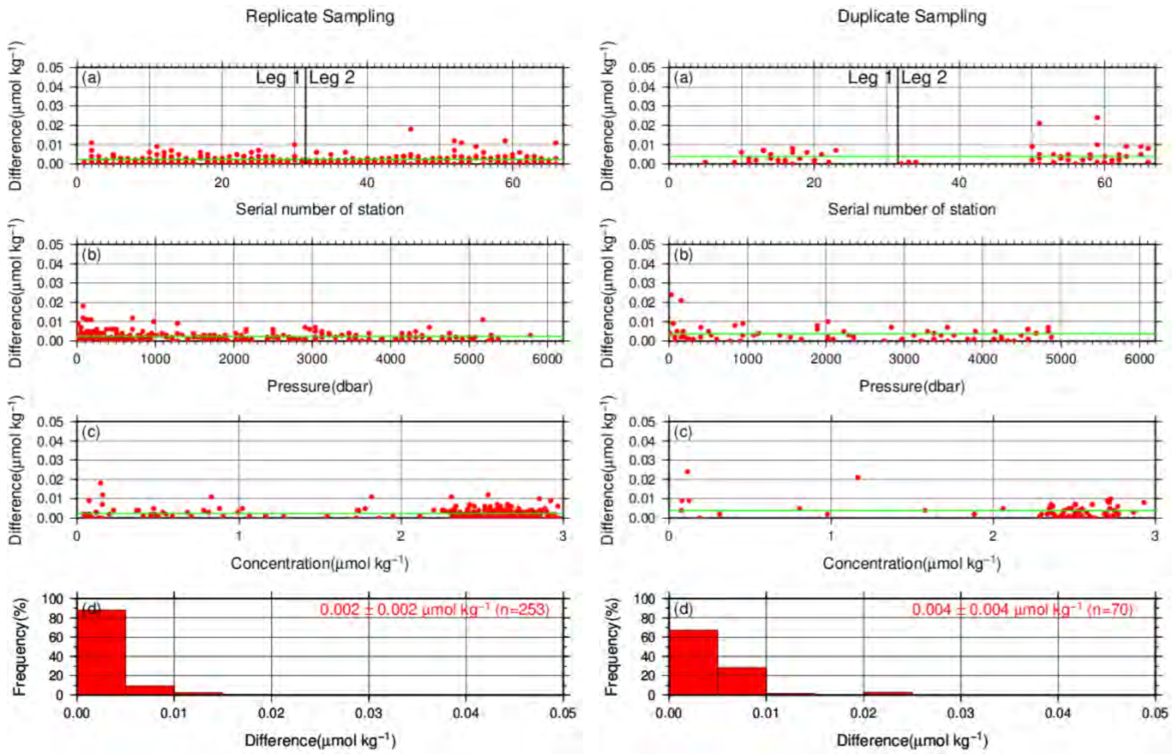

Figure C.4.4: Same as Figure C.4.3 but for phosphate.

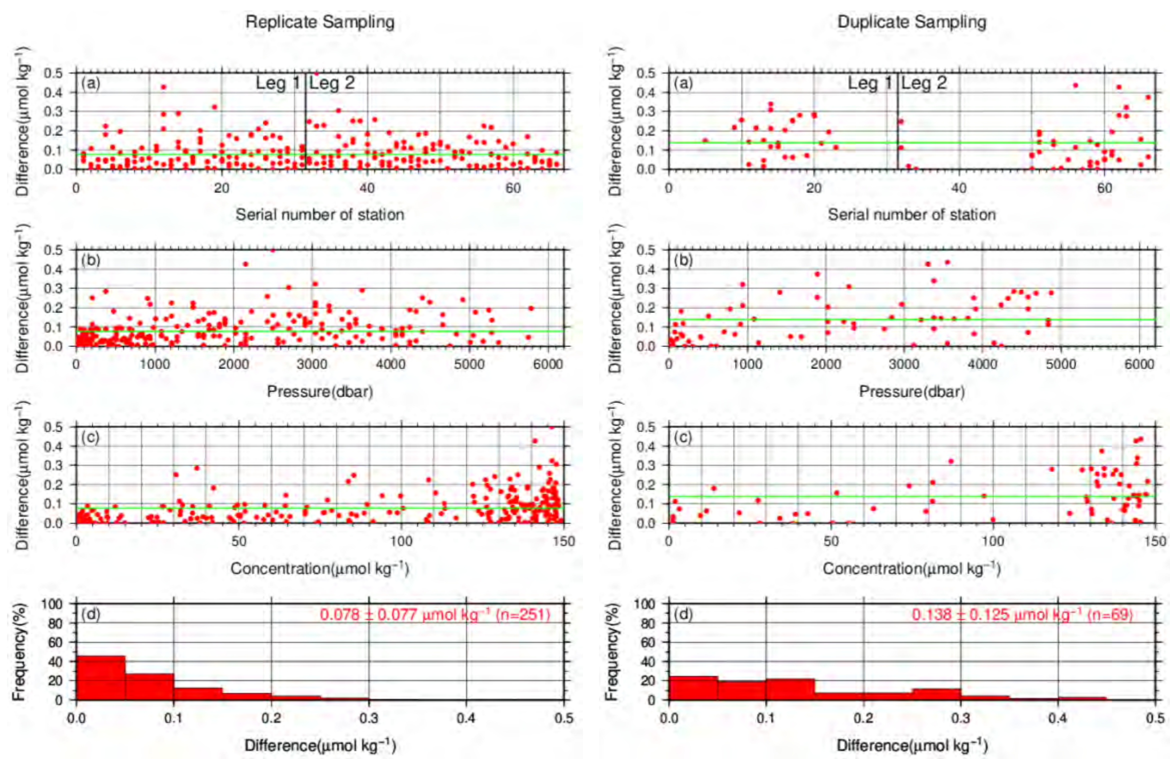

Figure C.4.5: Same as Figure C.4.3 but for silicate.

(3.7.2) Measurement of CRMs

CRM measurements during the cruise are summarized in Table C.4.6, whose concentrations were assigned with in-house standard solutions. The measured concentrations of CRM-BZ through the cruise are shown in Figures C.4.6–C.4.9.

Table C.4.6: Summary of (upper) mean concentration and its standard deviation (unit: μmol kg^{-1}), (middle) coefficient of variation (%), and (lower) total number of CRMs measurements through the cruise.

	Nitrate+nitrite	Nitrite	Phosphate	Silicate
CRM-BY	0.095±0.023 24.30% (N=132)	0.022±0.002 10.66% (N=132)	0.035±0.004 12.03% (N=132)	1.68±0.05 2.76% (N=131)
CRM-BW	24.70±0.05 0.20% (N=99)	0.073±0.002 2.10% (N=99)	1.54±0.01 0.53% (N=99)	59.93±0.13 0.22% (N=95)
CRM-BV	35.41±0.06 0.17% (N=132)	0.049±0.001 2.86% (N=132)	2.49±0.01 0.26% (N=130)	102.27±0.17 0.16% (N=128)
CRM-BZ	43.61±0.06 0.15% (N=99)	0.216±0.003 1.52% (N=99)	3.05±0.01 0.19% (N=99)	160.95±0.26 0.16% (N=96)

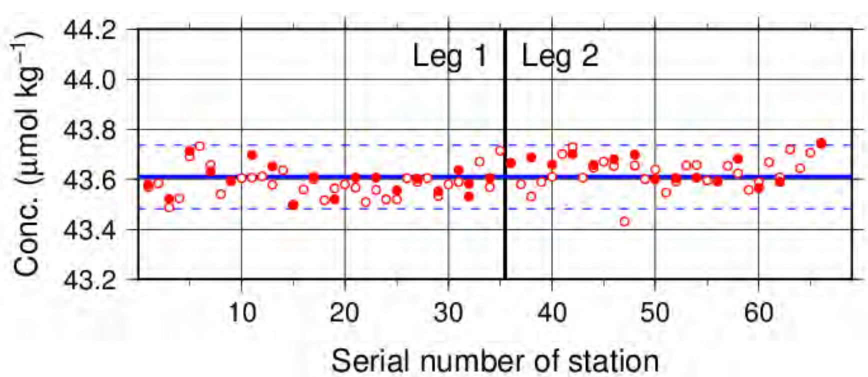

Figure C.4.6: Time-series of measured concentration of nitrate+nitrite of CRM-BZ through the cruise. Closed and open circles indicate the newly and previously opened bottle, respectively. Thick and dashed lines denote the mean and 2 times of standard deviations of the measurements through the cruise, respectively.

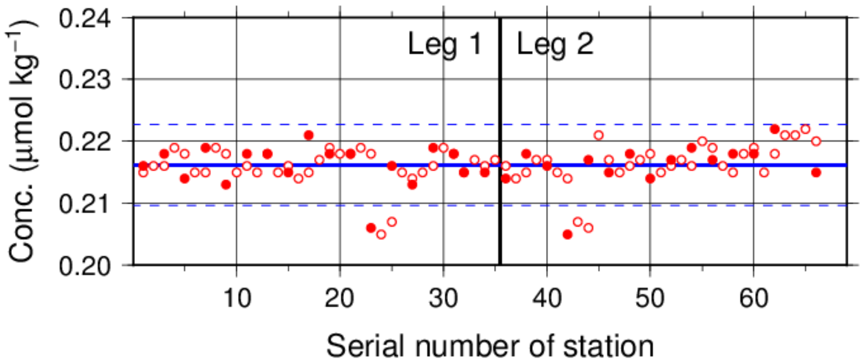

Figure C.4.7: Same as Figure C.4.6 but for nitrite.

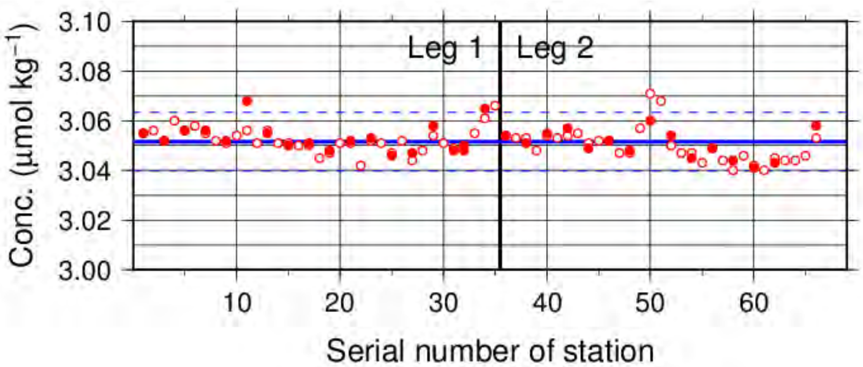

Figure C.4.8. Same as Figure C.4.6 but for phosphate.

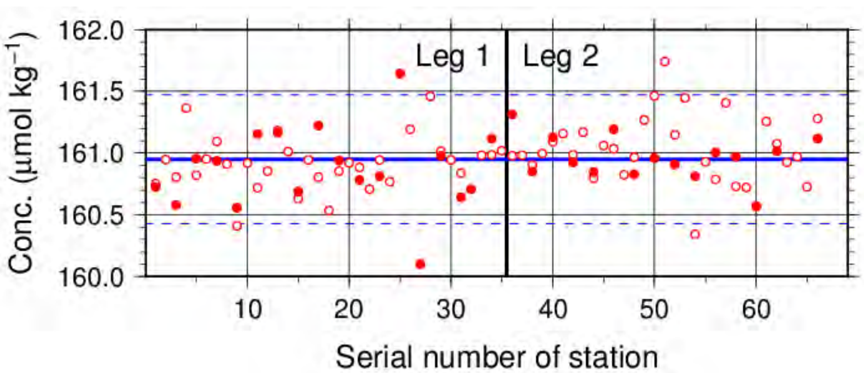

Figure C.4.9. Same as Figure C.4.6 but for silicate.

(3.7.3) Precision of analysis in a run

To monitor precision of analysis, the same samples were repeatedly measured in a sample array in a run. For this, C-5 standard solutions were randomly arrayed in every 2–10 samples as "check standard" (the number of the standard is about 8–9) in the run. The precision was estimated as coefficient of variation of the measurements. The results are summarized in Table C.4.7. The time series are shown in Figures C.4.10–C.4.13.

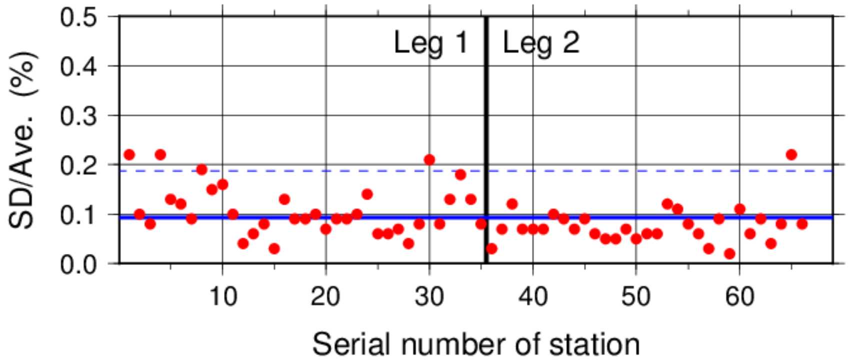

Figure C.4.10: Time-series of coefficient of variation of "check standard" measurement of nitrate+nitrite through the cruise. Thick and dashed lines denote the mean and 2 times of standard deviations of the measurements through the cruise, respectively.

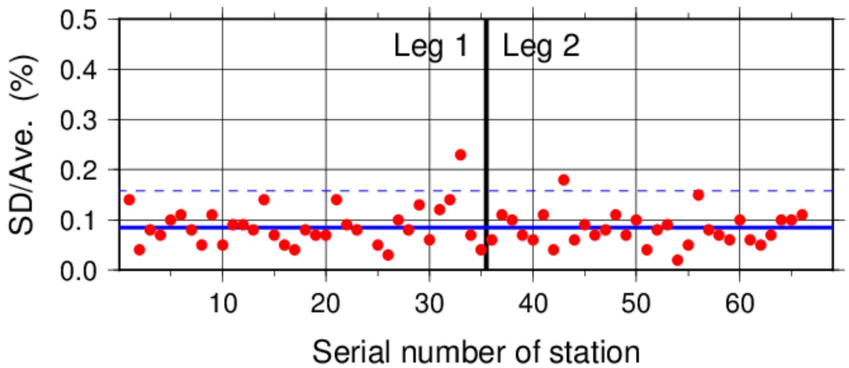

Figure C.4.11: Same as Figure C.4.10 but for nitrite.

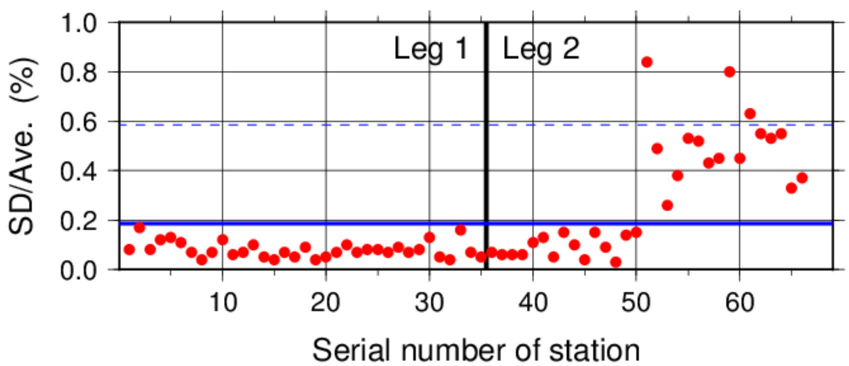

Figure C.4.12: Same as Figure C.4.10 but for phosphate.

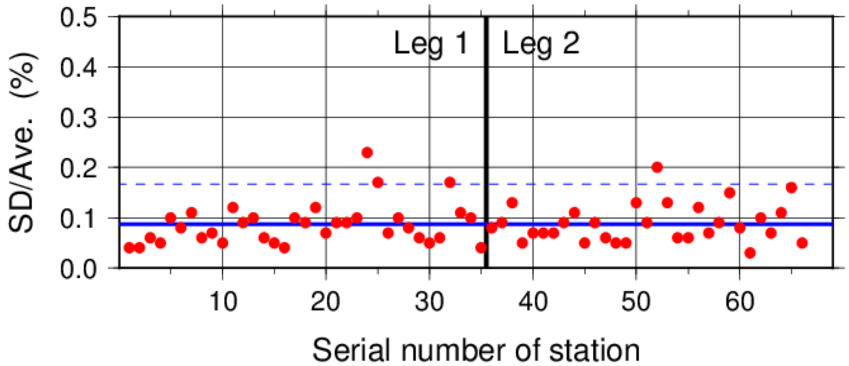

Figure C.4.13: Same as Figure C.4.10 but for silicate.

Table C.4.7: Summary of precisions during the cruise.

	Nitrate+nitrite	Nitrite	Phosphate	Silicate
Median	0.08%	0.08%	0.09%	0.08%
Mean	0.09%	0.08%	0.19%	0.09%
Minimum	0.02%	0.02%	0.03%	0.03%
Maximum	0.22%	0.23%	0.84%	0.23%
Number	66	65	66	66

(3.7.4) Carryover

Carryover coefficients were determined in each analysis run, using C-5 standard (high standard) followed by two C-1 standards (low standard). Time series of the carryover coefficients are shown in Figures C.4.14–17.

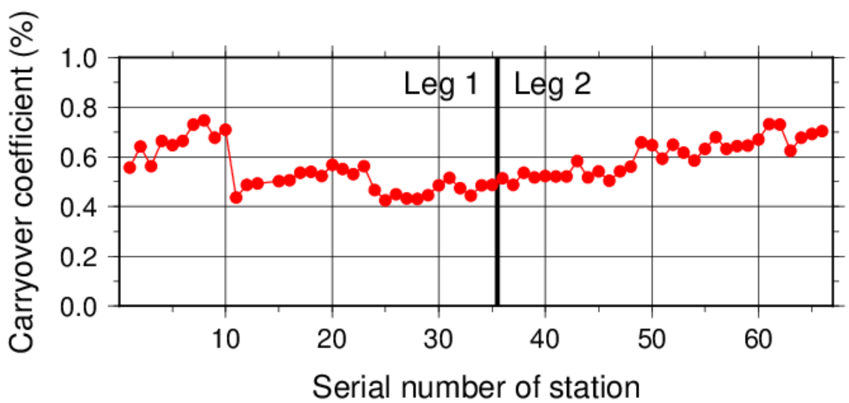

Figure C.4.14: Time-series of carryover coefficients in measurement of nitrate+nitrite through the cruise.

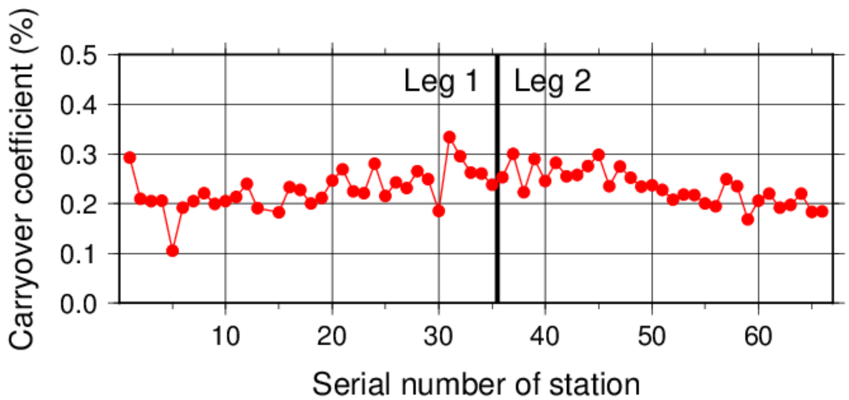

Figure C.4.15: Same as Figure C.4.14 but for nitrite.

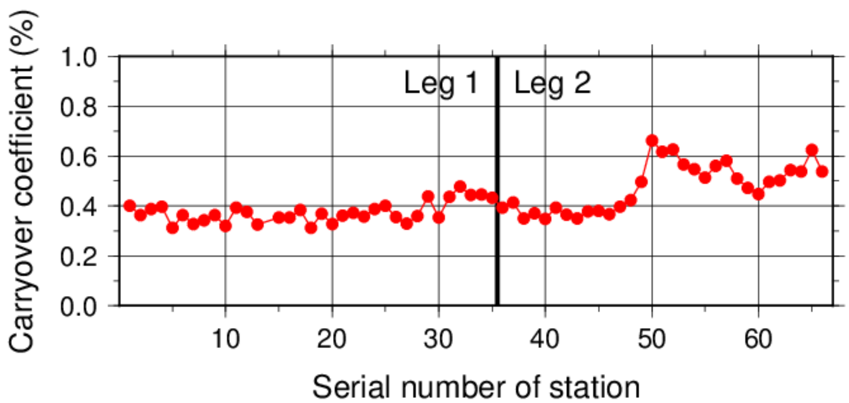

Figure C.4.16: Same as Figure C.4.14 but for phosphate.

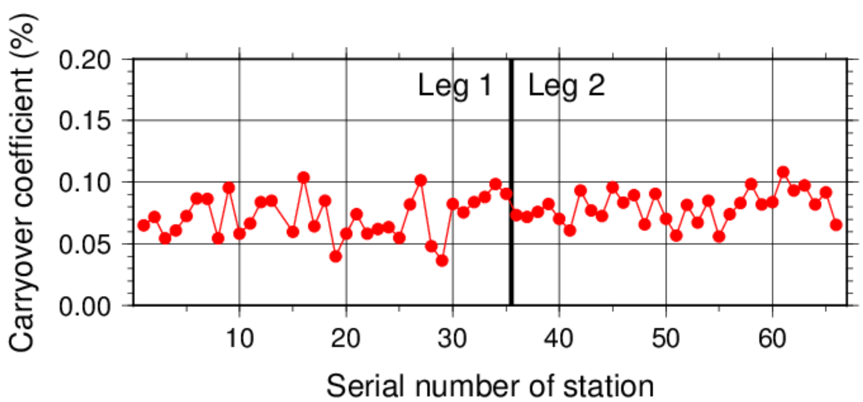

Figure C.4.17: Same as Figure C.4.14 but for silicate.

(3.7.5) Limit of detection/quantitation of measurement

Limit of detection (LOD) and quantitation (LOQ) of nutrient measurement were estimated from standard deviation (σ) of repeated measurements of nutrients concentration in C-1 standard as 3σ and 10σ, respectively. Summary of LOD and LOQ are shown in Table C.4.8.

Table C.4.8. Limit of detection (LOD) and quantitation (LOQ) of nutrient measurement in the cruise. Unit is μmol kg^{-1}.

	LOD	LOQ
Nitrate+nitrite	0.029	0.090
Nitrite	0.015	0.066
Phosphate	0.016	0.068
Silicate	0.033	0.097

(3.7.6) Quality control flag assignment

Quality flag value was assigned to nutriment measurements as shown in Table C.4.9, using the code defined in IOCCP Report No.14 (Swift, 2010).

Table C.4.9. Summary of assigned quality control flags.

Flag	Definition	Nitrate+nitrite	Nitrite	Phosphate	Silicate
2	Good	2126	2127	2123	2116
3	Questionable	1	0	7	7
4	Bad (Faulty)	10	9	9	18
5	Not reported	0	0	0	0
6	Replicate measurements	255	256	253	251
Total number of samples		2392	2392	2392	2392

3.8 Uncertainty

(3.8.1) Uncertainty associated with concentration level: U_c

Generally, an uncertainty of nutrient measurement is expressed as a function of its concentration level which reflects that some components of uncertainty are relatively large in low concentration. Empirically, the uncertainty associated with concentrations level (U_c) can be expressed as follows;

$$U_c\,(\%) = a + b \cdot (1/C_x) + c \cdot (1/C_x)^2, \qquad \text{(C4.1)}$$

where C_x is the concentration of sample for parameter X.

Using the coefficients of variation of the CRM measurements throughout the cruise, uncertainty associated with concentrations of nitrate+nitrite, phosphate, and silicate were determined as follows:

$$U_{c\text{-}no3}\,(\%) = 0.080 + 3.026 \times (1/C_n) - 0.069 \times (1/C_n)^2 \qquad \text{(C4.2)}$$

$$U_{c\text{-}po4}\,(\%) = -0.091 + 0.978 \times (1/C_p) - 0.019 \times (1/C_p)^2 \qquad \text{(C4.3)}$$

$$U_{c\text{-}sil}\,(\%) = 0.123 + 5.400 \times (1/C_s) - 1.605 \times (1/C_s)^2, \qquad \text{(C4.4)}$$

where C_n, C_p, and C_s represent concentrations of nitrate+nitrite, phosphate, and silicate, respectively, in μmol kg^{-1}. Figures C.4.18–C.4.20 show the calculated uncertainty graphically.

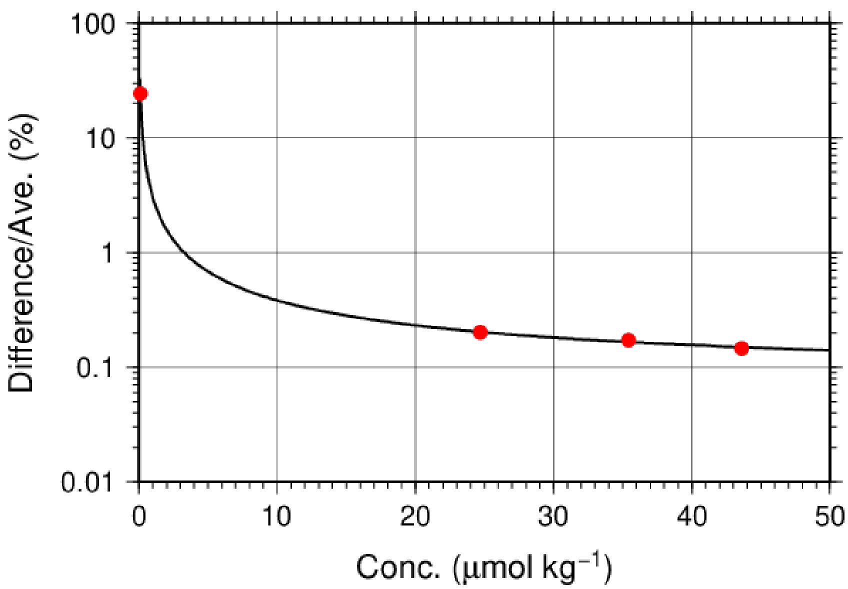

Figure C.4.18: Uncertainty of nitrate+nitrite associated with concentration level.

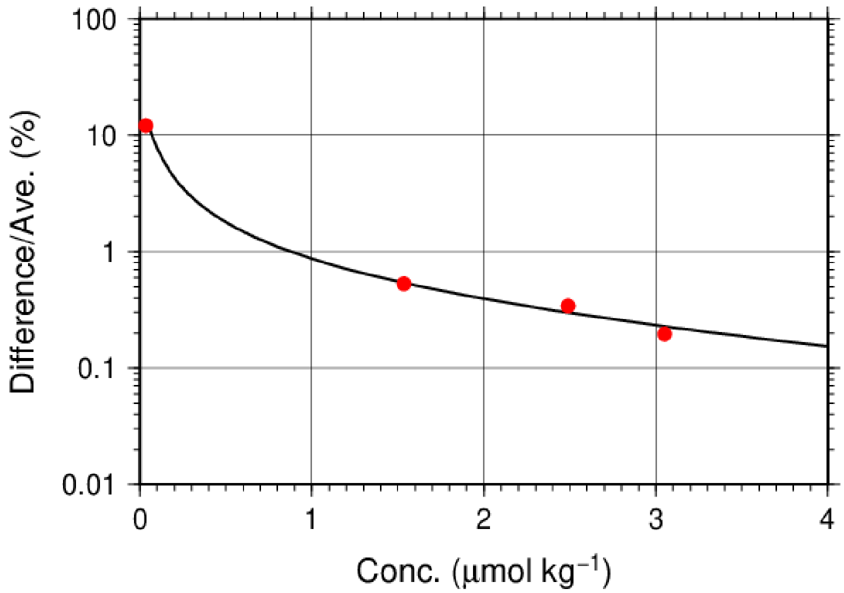

Figure C.4.19: Same as Figure C.4.18 but for phosphate.

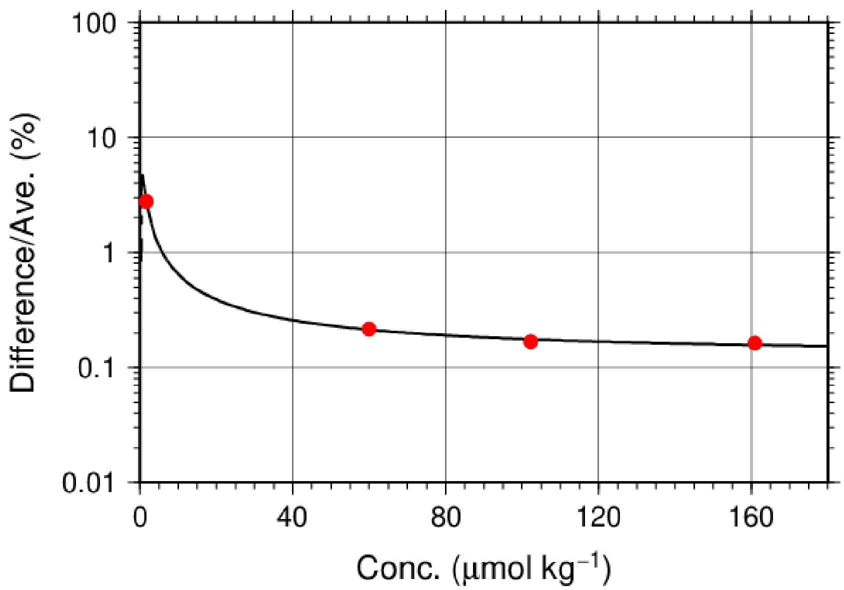

Figure C.4.20: Same as Figure C.4.18 but for silicate.

(3.8.2) Uncertainty of analysis between runs: U_s

Uncertainty of analysis among runs (U_s) was evaluated based on the coefficient of variation of measured concentrations of CRM-BZ with high concentration among the CRM lots throughout the cruise, as shown in subsection (7.2). The reason for using the CRM lot BZ to state $\underline{U_s}$ is to exclude the effect of uncertainty associated with lower concentration described previously. As is clear from the definition of U_c, U_s is equal to U_c at nutrients concentrations of lot BZ. It is important to note that U_s includes all of uncertainties during the measurements throughout stations, namely uncertainties of concentrations of in-house standard solutions prepared for each run, uncertainties of slopes and intercepts of the calibration curve in each run if first order calibration curve applied, precision of measurement in a run (U_a), and between-bottle homogeneity of the CRM.

(3.8.3) Uncertainty of analysis in a run: U_a

Uncertainty of analysis in a run (U_a) was evaluated based on the coefficient of variation of repeated measurements of the "check standard" solution, as shown in subsection (7.3). The U_a reflects the conditions associated with chemistry of colorimetric measurement of nutrients, and stability of electronic and optical parts of the instrument throughout a run. Under a well-controlled condition of the measurements, U_a might show Poisson distribution with a mean as shown in Figures C.4.10–C.4.13 and Table C.4.7 and treated as a precision of measurement. U_a is a part of U_c at the concentration as stated in a previous section for U_c.

However, U_a may show larger value which was not expected from Poisson distribution of U_a due to the malfunction of the instruments, larger ambient temperature change, human errors in handling samples and chemistries and contaminations of samples in a run. In the cruise, we observed that U_a of our measurement was usually small and well-controlled in most runs as shown in Figures C.4.10–C.4.13 and Table C.4.7. However, in a few runs, U_a showed high values which were over the mean ± twice the standard deviations of U_a, suggesting that the measurement system might have some problems.

(3.8.4) Uncertainty of CRM concentration: U_r

In the certification of CRM, the uncertainty of CRM concentrations (U_r) was stated by the manufacturer (Table C.4.4) as expanded uncertainty at k=2. This expanded uncertainty reflects the uncertainty of the Japan Calibration Service System (JCSS) solutions, characterization in assignment, between-bottle homogeneity, and long-term stability. We have ensured comparability between cruises by ensuring that at least two lots of CRMs overlap between cruises. In comparison of nutrient concentrations between cruises using KANSO CRMs in an organization, it was not necessary to include U_r in the conclusive uncertainty of concentration of measured samples because comparability of measurements was ensured in an organization as stated previously.

(3.8.5) Conclusive uncertainty of nutrient measurements of samples: U

To determine the conclusive uncertainty of nutrient measurements of samples (U), we use two functions depending on U_a value acquired at each run as follows:
When U_a was small and measurement was well-controlled condition, the conclusive uncertainty of nutrient measurements of samples, U, might be as below:

$$U = U_c. \qquad \text{(C4.5)}$$

When U_a was relative large and the measurement might have some problems, the conclusive uncertainty of nutrient measurements of samples, U, can be expanded as below:

$$U = \sqrt{U_c^2 + U_a^2}. \qquad \text{(C4.6)}$$

When U_a was relative large and the measurement might have some problems, the equation of U is defined as to include U_a to evaluate U, although U_a partly overlaps with U_c. It means that the equation overestimates the conclusive uncertainty of samples. On the other hand, for low concentration there is a possibility that the equation not only overestimates but also underestimates the conclusive uncertainty because the functional shape of U_c in lower concentration might not be the same and cannot be verified. However, we believe that the applying the above function might be better way to evaluate the conclusive uncertainty of nutrient measurements of samples because we can do realistic evaluation of uncertainties of nutrient concentrations of samples which were obtained under relatively unstable conditions, larger U_a as well as the evaluation of them under normal and good conditions of measurements of nutrients.

Appendix

A1. Seawater sampling

Seawater samples were collected from 10-liters Niskin bottle attached CTD-system and a stainless steel bucket for the surface. Samples were drawn into 10 mL polymethylpenten vials using sample drawing tubes. The vials were rinsed three times before water filling and were capped immediately after the drawing.

No transfer was made and the vials were set on an auto sampler tray directly. Samples were analyzed immediately after collection.

A2. Measurement

(A2.1) General

Auto Analyzer III is based on Continuous Flow Analysis method and consists of sampler, pump, manifolds, and colorimeters. As a baseline, we used artificial seawater (ASW).

(A2.2) Nitrate+nitrite and nitrite

Nitrate+nitrite and nitrite were analyzed according to the modification method of Armstrong (1967). The sample nitrate was reduced to nitrite in a glass tube which was filled with granular cadmium coated with copper. The sample stream with its equivalent nitrite was treated with an acidic, sulfanilamide reagent and the nitrite forms nitrous acid which reacts with the sulfanilamide to produce a diazonium ion. N-1-naphthylethylene-diamine was added to the sample stream then coupled with the diazonium ion to produce a red, azo dye. With reduction of the nitrate to nitrite, sum of nitrate and nitrite were measured; without reduction, only nitrite was measured. Thus, for the nitrite analysis, no reduction was performed and the alkaline buffer was not necessary. The flow diagrams for each parameter are shown in Figures C.4.A1 and C.4.A2. If the reduction efficiency of the cadmium column became lower than 95 %, the column was replaced.

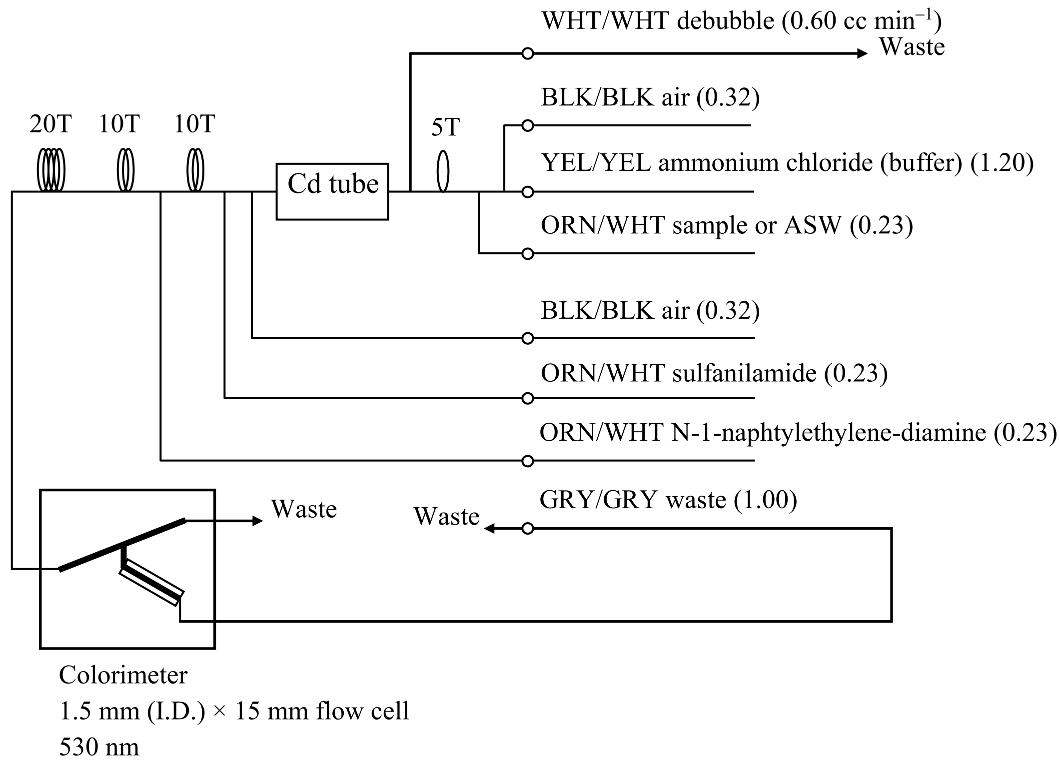

Figure C.4.A1: Nitrate+nitrite (1ch.) flow diagram.

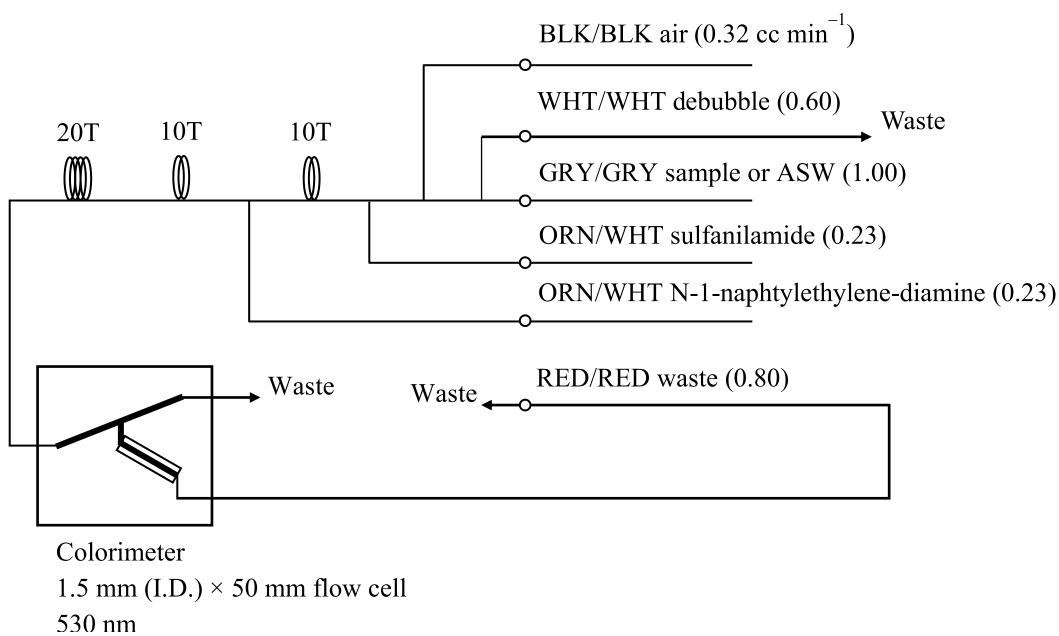

Figure C.4.A2: Nitrite (2ch.) flow diagram.

(A2.3) Phosphate

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 flow diagram for phosphate is shown in Figure C.4.A3.

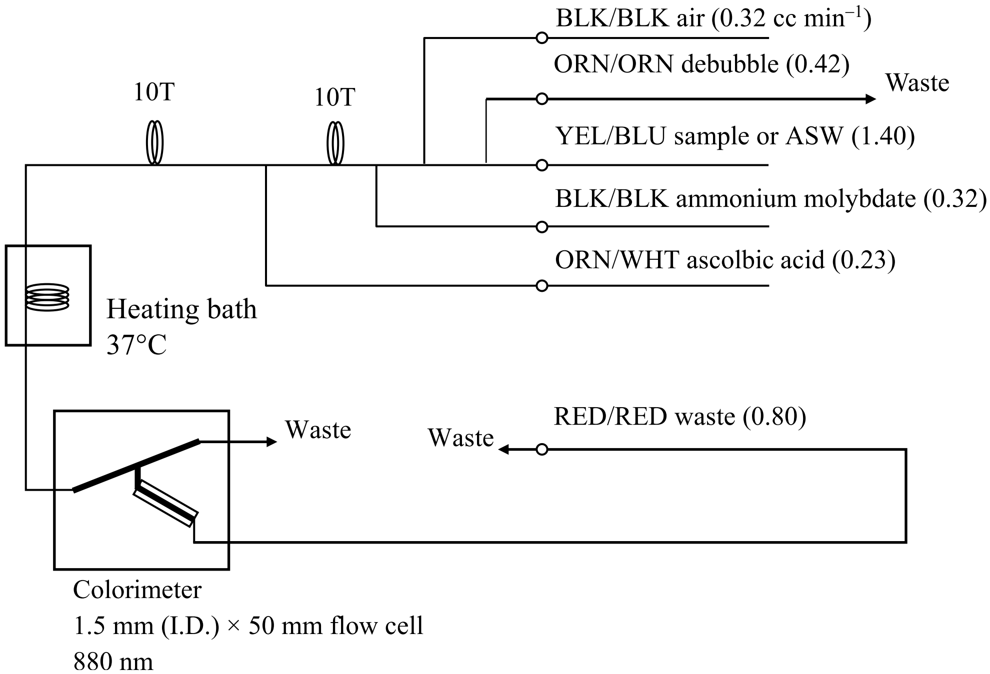

Figure C.4.A3. Phosphate (3ch.) flow diagram.

(A2.4) Silicate

The silicate was analyzed according to the modification method 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 L-ascorbic acid as the reductant. The flow diagram for silicate is shown in Figure C.4.A4.

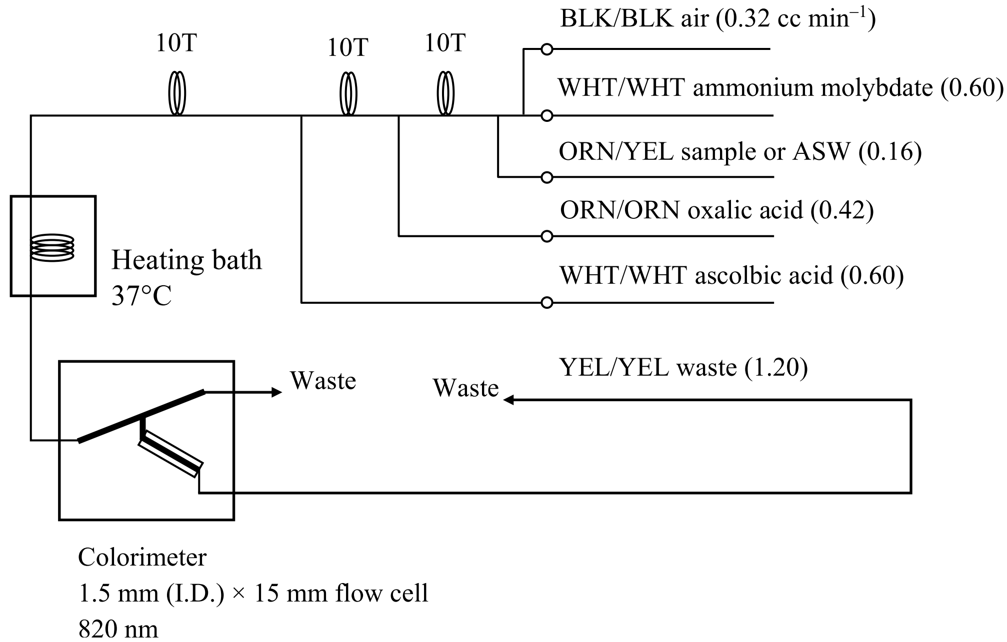

Figure C.4.A4. Silicate (4ch.) flow diagram.

A3. Data processing

Raw data from Auto Analyzer III were recorded at 1-second interval and were treated as follows;

a. Check the shape of each peak and position of peak values taken, and then change the positions of peak values taken if necessary.
b. Baseline correction was done basically using liner regression.
c. Reagent blank correction was done basically using liner regression.
d. Carryover correction was applied to peak heights of each sample.
e. Sensitivity correction was applied to peak heights of each sample.
f. Refraction error correction was applied to peak heights of each seawater sample.
g. Calibration curves to get nutrients concentration were assumed quadratic expression.
h. Concentrations were converted from μmol L^{-1} to μmol kg^{-1} using seawater density.

A4. Reagents recipes

(A4.1) Nitrate+nitrite

Ammonium chloride (buffer), 0.7 µmol L^{-1} (0.04 % w/v);

Dissolve 190 g ammonium chloride, NH_4Cl, in ca. 5 L of DW, add about 5 mL ammonia(aq) to adjust pH of 8.2–8.5.

Sulfanilamide, 0.06 µmol L^{-1} (1 % w/v);

Dissolve 5 g sulfanilamide, 4-$NH_2C_6H_4SO_3H$, in 430 mL DW, add 70 mL concentrated HCl. After mixing, add 1 mL Brij-35 (22 % w/w).

N-1-naphtylethylene-diamine dihydrochloride (NEDA), 0.004 µmol L^{-1} (0.1 % w/v);

Dissolve 0.5 g NEDA, $C_{10}H_7NH_2CH_2CH_2NH_2 \cdot 2HCl$, in 500 mL DW.

(A4.2) Nitrite

Sulfanilamide, 0.06 µmol L^{-1} (1 % w/v); Shared from nitrate reagent.

N-1-naphtylethylene-diamine dihydrochloride (NEDA), 0.004 µmol L^{-1} (0.1 % w/v); Shared from nitrate reagent.

(A4.3) Phosphate

Ammonium molybdate, 0.005 µmol L^{-1} (0.6 % w/v);

Dissolve 3 g ammonium molybdate(VI) tetrahydrate, $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$, and 0.05 g potassium antimonyl tartrate, $C_8H_4K_2O_{12}Sb_2 \cdot 3H_2O$, in 400 mL DW and add 40 mL concentrated H_2SO_4. After mixing, dilute the solution with DW to final volume of 500 mL and add 2 mL sodium dodecyl sulfate (15 % solution in water).

L(+)-ascorbic acid, 0.08 µmol L^{-1} (1.5 % w/v);

Dissolve 4.5 g L(+)-ascorbic acid, $C_6H_8O_6$, in 300 mL DW. After mixing, add 10 mL acetone. This reagent was freshly prepared before every measurement.

(A4.4) Silicate

Ammonium molydate, 0.005 µmol L^{-1} (0.6 % w/v);

Dissolve 3 g ammonium molybdate(VI) tetrahydrate, $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$, in 500 mL DW and added concentrated 2 mL H_2SO_4. After mixing, add 2 mL sodium dodecyl sulfate (15 % solution in water).

Oxalic acid, 0.4 µmol L^{-1} (5 % w/v);

Dissolve 25 g oxalic acid dihydrate, $(COOH)_2 \cdot 2H_2O$, in 500 mL DW.

L(+)-ascorbic acid, 0.08 µmol L^{-1} (1.5 % w/v); Shared from phosphate reagent.

(A4.5) Baseline

Artificial seawater (salinity is ~34.7);

Dissolve 160.6 g sodium chloride, NaCl, 35.6 g magnesium sulfate heptahydrate, $MgSO_4 \cdot 7H_2O$, and 0.84 g sodium hydrogen carbonate, $NaHCO_3$, in 5 L DW.

References

Armstrong, F. A. J., C. R. Stearns and J. D. H. Strickland (1967), The measurement of upwelling and subsequent biological processes by means of the Technicon TM Autoanalyzer TM and associated equipment, *Deep-Sea Res.*, 14(3), 381–389.

DOE (1994), Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. *A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74*.

Grasshoff, K., Ehrhardt, M., Kremling K. et al. (1983), Methods of seawater analysis. 2nd rev, *Weinheim: Verlag Chemie, Germany, West.*

Murphy, J. and Riley, J.P. (1962), Analytica chimica *Acta*, *27, 31-36.*

Swift, J. H. (2010), Reference-quality water sample data: Notes on acquisition, record keeping, and evaluation. *IOCCP Report No.14, ICPO Pub. 134, 2010 ver.1*.

4. PHYTOPIGMENTS (CHLOROPHYLL-A AND PHAEOPIGMENT)

1 November 2019

4.1 Personnel

Takahiro KITAGAWA (GEMD/JMA)
Kei KONDO (GEMD/JMA)

4.2 Station occupied

A total of 29 stations (Leg 1: 15, Leg 2: 14) were occupied for phytopigment measurements. Station location and sampling layers of phytopigment are shown in Figures C.5.1 and C.5.2.

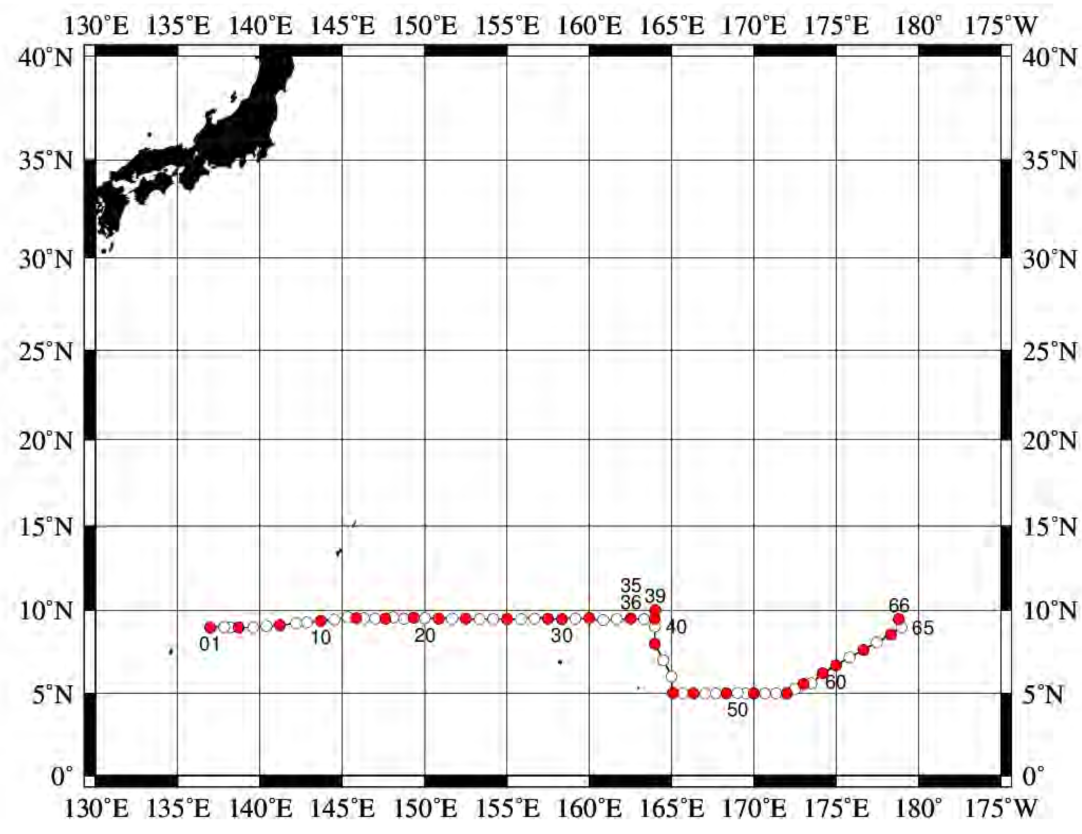

Figure C.5.1: Location of observation stations of chlorophyll-*a*. Closed and open circles indicate sampling and no-sampling stations, respectively.

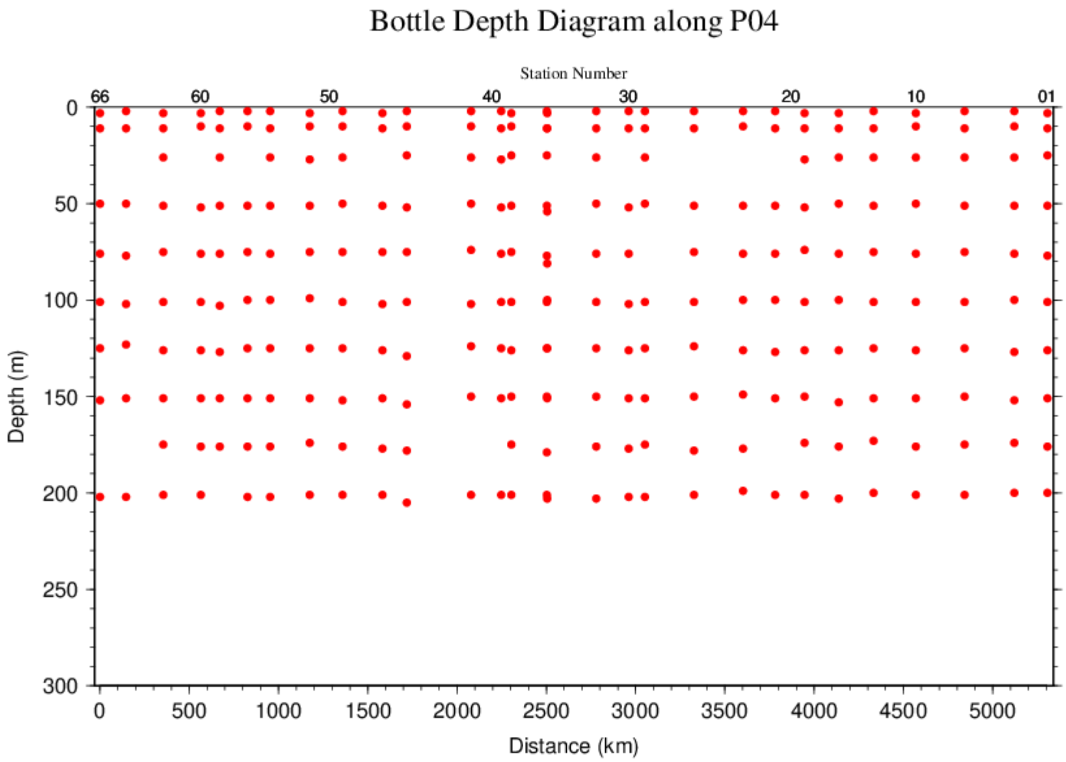

Figure C.5.2: Distance-depth distribution of sampling layers of chlorophyll-*a*.

4.3 Reagents

N,N-dimethylformamide (DMF)
Hydrochloric acid (HCl), 0.5 mol L^{-1}
Chlorophyll-*a* standard from *Anacystis nidulans* algae (Sigma-Aldrich, United States)
Rhodamine WT (Turner Designs, United States)

4.4 Instruments

Fluorometer: 10-AU (Turner Designs, United States)
Spectrophotometer: UV-1800 (Shimadzu, Japan)

4.5 Standardization

(4.5.1) Determination of chlorophyll-a concentration of standard solution

To prepare the pure chlorophyll-*a* standard solution, reagent powder of chlorophyll-*a* standard was dissolved in DMF. A concentration of the chlorophyll-*a* solution was determined with the spectrophotometer as follows:

$$\text{chl } a \text{ concentration } (\mu\text{g mL}^{-1}) = A_{chl} / a^{*}_{phy} \qquad \text{(C5.1)}$$

where A_{chl} is the difference between absorbance at 663.8 nm and 750 nm, and a^{*}_{phy} is specific absorption coefficient (UNESCO, 1994). The specific absorption coefficient is 88.74 L g^{-1} cm^{-1} (Porra *et al.*, 1989).

(4.5.2) Determination of R and f_{ph}

Before measurements, sensitivity of the fluorometer was calibrated with pure DMF and a rhodamine 1 ppm solution (diluted with deionized water).

The chlorophyll-*a* standard solution, whose concentration was precisely determined in subsection (5.1), was measured with the fluorometer, and after acidified with 1–2 drops 0.5 mol L^{-1} HCl the solution was also measured. The acidification coefficient (R) of the fluorometer was also calculated as the ratio of the unacidified and acidified readings of chlorophyll-*a* standard solution. The linear calibration factor (f_{ph}) of the fluorometer was calculated as the slope of the acidified reading against chlorophyll-*a* concentration. The R and f_{ph} in the cruise are shown in Table C.5.1.

Table C.5.1. R and f_{ph} in the cruise.

Acidification coefficient (R)	1.857
Linear calibration factor (f_{ph})	6.3099

4.6 Seawater sampling and measurement

Water samples were collected from 10-liters Niskin bottle attached the CTD-system and a stainless steel bucket for the surface. A 200 mL seawater sample was immediately filtered through 25 mm GF/F filters by low vacuum pressure below 15 cmHg, the particulate matter collected on the filter. Phytopigments were extracted in vial with 9 mL of DMF. The extracts were stored for 24 hours in the refrigerator at −30 °C until analysis.

After the extracts were put on the room temperature for at least one hour in the dark, the extracts were decanted from the vial to the cuvette. Fluorometer readings for each cuvette were taken before and after acidification with 1–2 drops 0.5 mol L^{-1} HCl. Chlorophyll-*a* and phaeopigment concentrations (μg mL^{-1}) in the sample are calculated as follows:

$$\text{chl } a \text{ conc.} = \frac{F_0 - F_a}{f_{ph} \cdot (R-1)} \cdot \frac{v}{V} \qquad \text{(C5.2)}$$

$$\text{phaeo.conc.} = \frac{R \cdot F_0 - F_a}{f_{ph} \cdot (R-1)} \cdot \frac{v}{V} \qquad \text{(C5.3)}$$

F_0: reading before acidification
F_a: reading after acidification
R: acidification coefficient (F_0/F_a) for pure chlorophyll-*a*
f_{ph}: linear calibration factor
v: extraction volume
V: sample volume.

4.7 Quality control flag assignment

Quality flag value was assigned to oxygen measurements as shown in Table C.5.2, using the code defined in IOCCP Report No.14 (Swift, 2010).

Table C.5.2: Summary of assigned quality control flags.

Flag	Definition	Chl *a*	Phaeo.
2	Good	271	271
3	Questionable	0	0
4	Bad (Faulty)	1	1
5	Not reported	0	0
	Total number	272	272

REFERENCES

Porra, R. J., W. A. Thompson and P. E. Kriedemann (1989), Determination of accurate coefficients and simultaneous equations for assaying chlorophylls *a* and *b* extracted with four different solvents: verification of the concentration of chlorophyll standards by atomic absotption spectroscopy. *Biochem. Biophy. Acta,* 975, 384-394.

Swift, J. H. (2010), Reference-quality water sample data: Notes on acquisition, record keeping, and evaluation. *IOCCP Report No.14, ICPO Pub. 134, 2010 ver.1*.

UNESCO (1994), Protocols for the joint global ocean flux study (JGOFS) core measurements: Measurement of chlorophyll *a* and phaeopigments by fluorometric analysis, *IOC manuals and guides 29, Chapter 14.*

CCHDO DATA PROCESSING HISTORY

Updated 2021-04-22

- **File Online Andrew Barna**

49UP20150724_ctd.nc (download) #78459
Date: 2021-03-13
Current Status: dataset
Notes
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- **File Online Jerry Kappa**

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Date: 2020-12-03
Current Status: unprocessed

- **File Online Jerry Kappa**

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Date: 2020-12-03
Current Status: unprocessed

- **File Submission Daisuke SASANO**

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- **File Submission Daisuke SASANO**

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- **File Online Carolina Berys**

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Date: 2020-04-20
Current Status: unprocessed

- **File Online** **Carolina Berys**

2015_C_hydrographic_merged_20191017.docx (download) #88dc7
Date: 2020-04-20
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- **File Submission** **Daisuke Sasano**

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- **File Submission** **Daisuke Sasano**

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Date: 2019-11-01
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- **File Merge** **CCHSIO**

ct1.zip (download) #6b173
Date: 2019-01-16
Current Status: merged

- **Processed "As Received" into "Dataset"** **CCHSIO**

Date: 2019-01-16
Data Type: CTD
Action: Website Update
Note:

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    2015 49UP20150724 processing - CTD/merge - CTDPRS,CTDTMP,CTDSAL,CTDOXY

2019-01-16

CCHSIO

Submission

filename   submitted by    date       id
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ct1.zip    Toshiya NAKANO  2018-05-12 14015
```

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Changes
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ct1.zip
        - added units comments
        - added cruise information as commented header
        - Renamed files to match EXCHANGE standard. Put original file name in file
          as a comment.
        - removed trailing characters "_2" and "_1" from EXPOCODE.  Added comment
          to document the change.

Conversion
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file                    converted from       software
----------------------- -------------------- -----------------------
49UP20150724_nc_ctd.zip 49UP20150724_ct1.zip hydro 0.8.2-48-g594e1cb


Updated Files Manifest
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file                    stamp
----------------------- --------------
49UP20150724_ct1.zip    20190116CCHSIO
49UP20150724_nc_ctd.zip 20190116CCHSIO

:Updated parameters: CTDPRS,CTDTMP,CTDSAL,CTDOXY

opened in JOA 5.2.1 with no apparent problems:
     49UP20150724_ct1.zip
     49UP20150724_nc_ctd.zip

opened in ODV with no apparent problems:
     49UP20150724_ct1.zip
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- **File Merge Jerry Kappa**

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Date: 2018-08-01
Current Status: dataset

- **File Merge Jerry Kappa**

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Date: 2018-08-01
Current Status: dataset

- **File Submission** **Jerry Kappa**

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Date: 2018-07-11
Current Status: dataset
Notes
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The pdf and text versions of this cruise report are ready to be placed in the
dataset.
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- **File Submission** **Jerry Kappa**

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Date: 2018-07-11
Current Status: dataset
Notes
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The pdf and text versions of this cruise report are ready to be placed in the
dataset.
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Date: 2018-06-08
Current Status: unprocessed

- **File Online** **Carolina Berys**

ct1.zip (download) #6b173
Date: 2018-06-08
Current Status: merged

- **File Online** **Carolina Berys**

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Date: 2018-06-08
Current Status: unprocessed

- **File Online** **Carolina Berys**

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Date: 2018-06-08
Current Status: unprocessed

- **File Submission** **Toshiya NAKANO**

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Date: 2018-05-12
Current Status: unprocessed
Notes

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Section: P04-W (RF15-07)
Cruise date:
RF15-07 : 24 July 2015-15 September 2015
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- **File Submission** **Toshiya NAKANO**

p04_hy1.csv (download) #3b911
Date: 2018-05-12
Current Status: unprocessed
Notes

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Ship Name: Ryofu Maru (Japan Meteorological Agency)
Section: P04-W (RF15-07)
Cruise date:
RF15-07 : 24 July 2015-15 September 2015
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- **File Submission** **Toshiya NAKANO**

ct1.zip (download) #6b173
Date: 2018-05-12
Current Status: merged
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Section: P04-W (RF15-07)
Cruise date:
RF15-07 : 24 July 2015-15 September 2015
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- **File Submission Toshiya NAKANO**

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Date: 2018-05-12
Current Status: unprocessed
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Section: P04-W (RF15-07)
Cruise date:
RF15-07 : 24 July 2015-15 September 2015
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- **File Online CCHDO System**

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Current Status: dataset
Notes
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Files migrated to new CCHDO backend, there is not enough information to know where
this file should go in the timeline.
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- **File Online CCHDO System**

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Date: 2015-04-23
Current Status: dataset
Notes
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this file should go in the timeline.
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