doi : 10.17596/0002780

R/V Mirai Cruise Report
MR16-06 (MR16-Nishino)

Arctic Challenge for Sustainability (ArCS)

Arctic Ocean, Bering Sea, and North Pacific Ocean
22 August 2016 – 5 October 2016

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

Cruise Report ERRATA of the Nutrients part

page	Error	Correction
125	potassium nitrate CAS No. 7757-91-1	potassium nitrate CAS No. 7757-79-1
119	1N H_2SO_4	1M H_2SO_4

Contents

1. Cruise Summary

1.1. Objectives

On the basis of our previous observations and theoretical considerations, we have come to realize that the Arctic Ocean plays an important role in global climate changes. The objectives of this cruise are as follows:

a. To quantify on-going changes in ocean, atmosphere, and ecosystem, which are related to the recent Arctic warming and sea ice reduction.

b. To clarify important processes and interactions among atmosphere, ocean, and ecosystem behind Arctic changes, and their effects on human society.

c. To collect data to provide accurate projections and environmental assessments for stakeholders so that they can make appropriate decisions on the sustainable development of the Arctic region.

1.2. Overview

We conducted meteorological and hydrographic surveys including marine biogeochemical samplings in the northern Bering Sea and the Arctic Ocean on board the R/V Mirai from 22 August to 5 October 2016 under the Arctic Challenge for Sustainability (ArCS) Project.

Although the Arctic sea ice in 2016 hit the second-lowest level in recorded history, sea ice remained in the northern Chukchi Sea (Figure 1.2-1 and Photo 1.2-1) and disrupted our research plans. However, we managed to complete the observations in some focused areas where physical, chemical, and biological processes are sustaining unique marine environment and ecosystem that might be influenced by the recent Arctic warming and sea ice reduction.

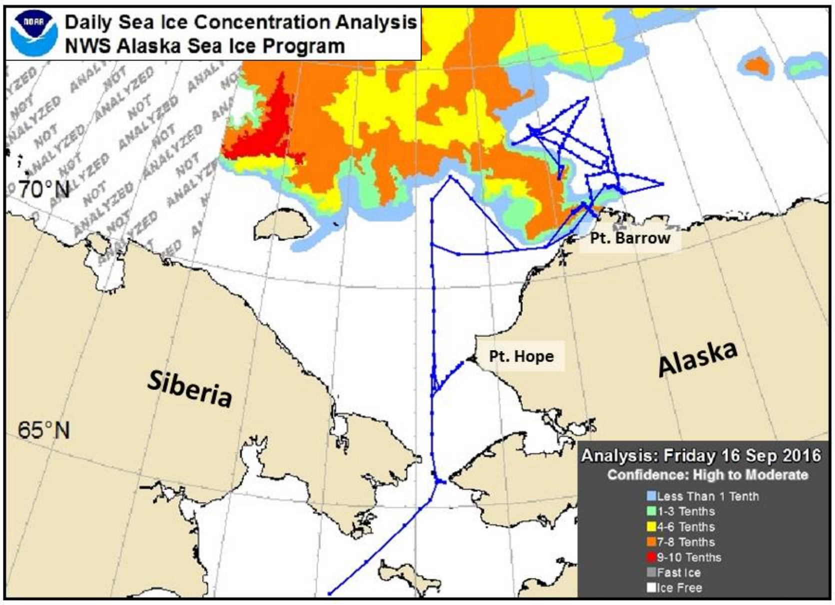


Figure 1.2-1. Colors indicate sea ice concentration on 16 September 2016. The data is obtained from Daily Sea Ice Concentration Analysis, NWS Alaska Sea Ice Program, NOAA. Blue lines represent the cruise tracks of R/V Mirai.

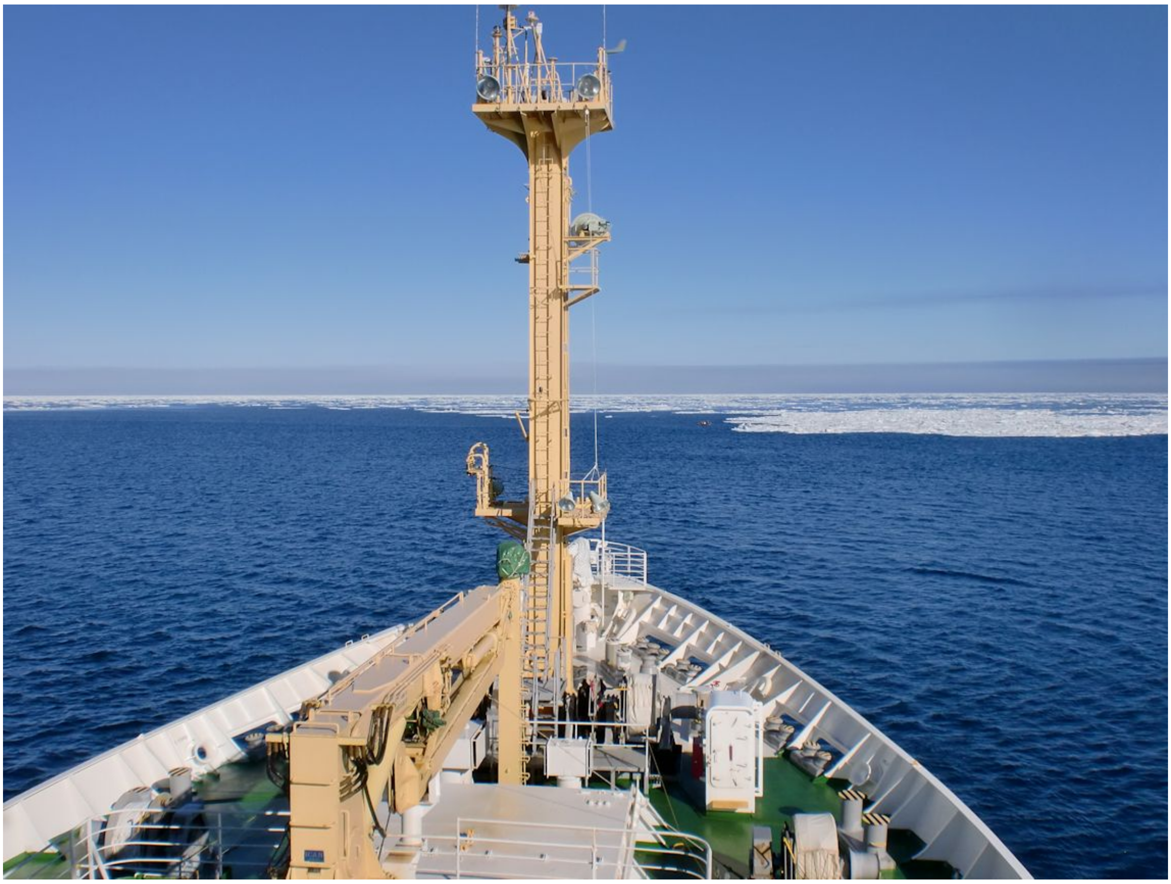


Photo 1.2-1. View of sea ice from the bow of R/V Mirai off Pt. Barrow, Alaska (71°25'N, 158°40'W).

For example, a biological hotspot in the waters off Point Hope is one of the focused areas. In this region, spring blooms are brought about by the nutrients supplied from the Bering Sea, and fall blooms are maintained by the nutrients regenerated from the organic particles accumulated at the sea floor. New instruments deployed here during Green Network of Excellence project (GRENE Arctic) indicated seasonal changes in zooplankton, and the changes might be associated with migration of sea birds. We have also reported aragonite undersaturation in the bottom water off Pt. Hope, and anthropogenic CO_2 has significant impact on the duration of undersaturation. For further studies, we carried out detailed oceanographic observations (Photo 1.2-2), bottom sediment samplings (Photo 1.2-3) and a mooring deployment (Photo 1.2-4) in this year's cruise.

Photo 1.2-2. Oceanographic observation using Conductivity-Temperature-Depth (CTD) sensors and water sampling bottles.

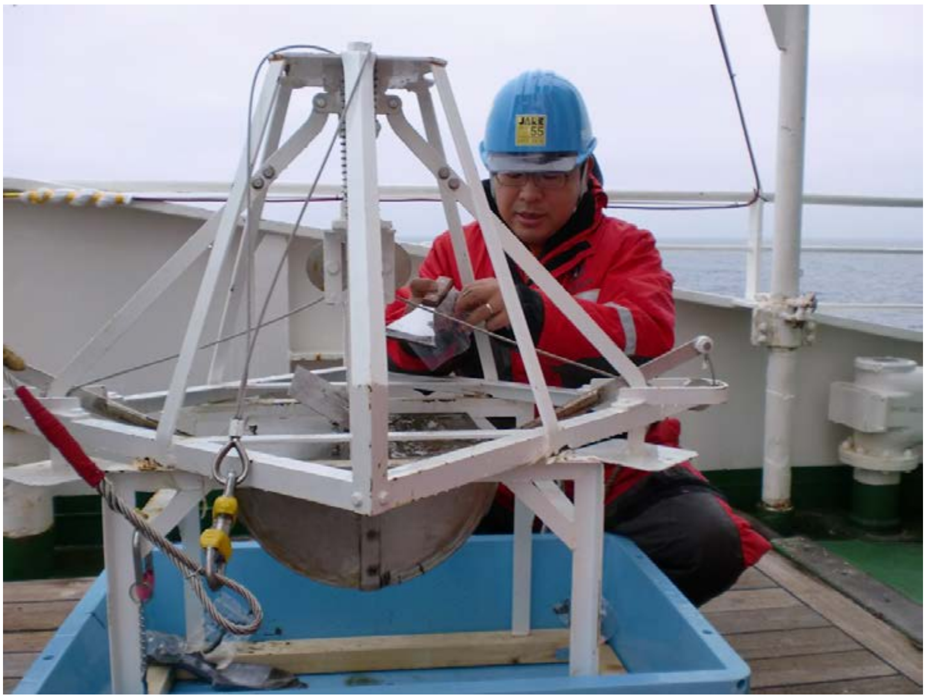


Photo 1.2-3. Bottom sediment sampling using Smith-Mcintyre grab (S&M grab).

Photo 1.2-4. Mooring deployment off Pt. Hope, Alaska (68°02'N, 168°50'W).

Another focused area is the Barrow Canyon, where we have deployed moorings to monitor the heat and freshwater fluxes of Pacific-origin water that may impact on the sea ice distribution and ecosystem in the Canada Basin. Chukchi shelf slopes and the Canada Basin are also important regions to understand the shelf-basin interaction and its impact on ecosystem in response to meteorological conditions. Thus, we set some hydrographic sections in these regions. In this cruise, we had 148 oceanographic stations including 85 water sampling sites, 68 plankton net sites, 23 sediment sampling sites, 2 sites for drifting buoy launches, 5 sites for recoveries and 8 sites for deployments of moorings and sediment traps (Figure 1.2-2). These missions were successfully completed thanks to great efforts made by the captain, ice pilot, officers, crew, and all the participants in this cruise (Photo 1.2-5). Based on the data obtained in this cruise, we will be able to shed light on the Arctic change and its controlling factors, and will contribute to the global climate change studies.

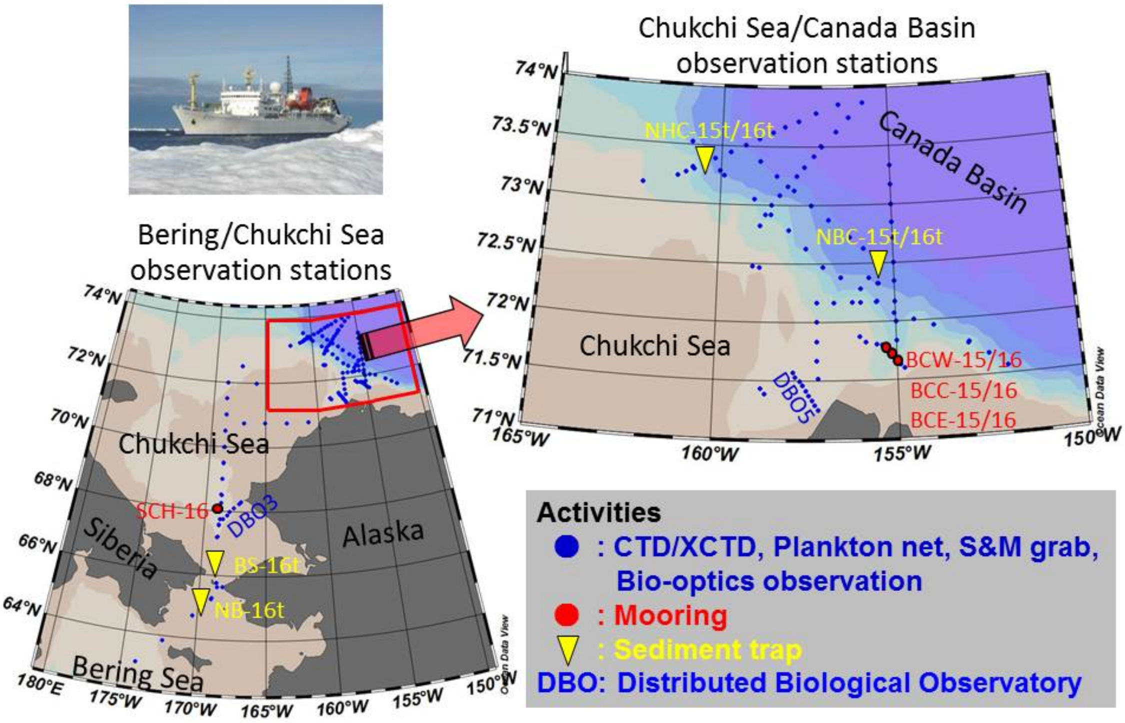


Figure 1.2-2. Map of the research area in the northern Bering Sea and the Arctic Ocean (left) and an enlarged drawing from the Chukchi shelf slope to the Canada Basin (right). Blue dots indicate stations where we conducted observations using Conductivity-Temperature-Depth (CTD) sensors with water sampling bottles, eXpendable Conductivity-Temperature-Depth (XCTD) sensors, plankton nets, Smith-Mcintyre grab (S&M grab), and bio-optics instruments. Red dots and yellow triangles represent mooring and sediment trap sites, respectively. We also carried out intensive oceanographic surveys under an international collaboration (Distributed Biological Observatory) off Pts. Hope and Barrow.

Photo 1.2-5. Commemorative photograph for the participants of R/V Mirai Arctic Ocean cruise in 2016.

This cruise included the following 11 studies:

- Studies on board

● Representative of the Science Party [Affiliation]: Jun Inoue [NIPR]

○ Title of proposal: Predictability study on weather and sea-ice forecasts linked with user engagement

● Representative of the Science Party [Affiliation]: Fumikazu Taketani [JAMSTEC]

○ Title of proposal: Ship-borne observations of trace gases/aerosols in the marine atmosphere

● Representative of the Science Party [Affiliation]: Naomi Harada [JAMSTEC]

○ Title of proposal: How plankton responses to multi stressors such as ocean warming and acidification?

● Representative of the Science Party [Affiliation]: Toru Hirawake [Hokkaido University]

○ Title of proposal: Primary production and transportation of organic materials in the northern Bering and the southern Chukchi Seas

● Representative of the Science Party [Affiliation]: Atsushi Yamaguchi [Hokkaido University]

○ Title of proposal: Comparison of zooplankton with differences in net mesh-size, and standing stock and material flux role of Appendicularia

● Representative of the Science Party [Affiliation]: Bungo Nishizawa [Hokkaido

University]
○ Title of proposal: Seasonal distribution of short-tailed shearwaters and their prey in the Bering and Chukchi Seas
● Representative of the Science Party [Affiliation]: Yasuhisa Ishihara [JAMSTEC]
○ Title of proposal: Smart float observation in the marginal ice zone
● Representative of the Science Party [Affiliation]: Kohei Mizobata [Tokyo University of marine science and technology]
○ Title of proposal: Elucidation of the variability of freshwater in the Arctic Ocean
● Representative of the Science Party [Affiliation]: Motoyo Itoh [JAMSTEC]
○ Title of proposal: Mooring observations in the Barrow Canyon and southern Chukchi Sea
● Representative of the Science Party [Affiliation]: Shigeto Nishino [JAMSTEC]
○ Title of proposal: Observational study on the variability of physical and chemical environments in the Pacific Arctic Ocean

- Studies not on board
● Representative of the Science Party [Affiliation]: Yasunori Tohjima [NIES]
○ Title of proposal: Ship-board observations of atmospheric greenhouse gases and related species in the Arctic Ocean and the western North Pacific

1.3. Basic information

Name of vessel	R/V Mirai L x B x D 118.02m x 19.0m x 13.2m Gross Tonnage: 8,706 tons Call Sign JNSR
Cruise code	MR16-06
Undertaking institute	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Chief scientist	Shigeto Nishino Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Cruise periods	22 August 2016 – 5 October 2016
Ports call	22 August 2016, Hachinohe (leave port) 23 September 2016, Off Nome (arrival and leave after an ice pilot disembarkation) 4 October 2016, Hachinohe (arrival in and leave port) 5 October 2016, Sekinehama (arrival in port)
Research areas	The North Pacific Ocean, the Bering Sea, and the Arctic Ocean

1.4. Cruise Track

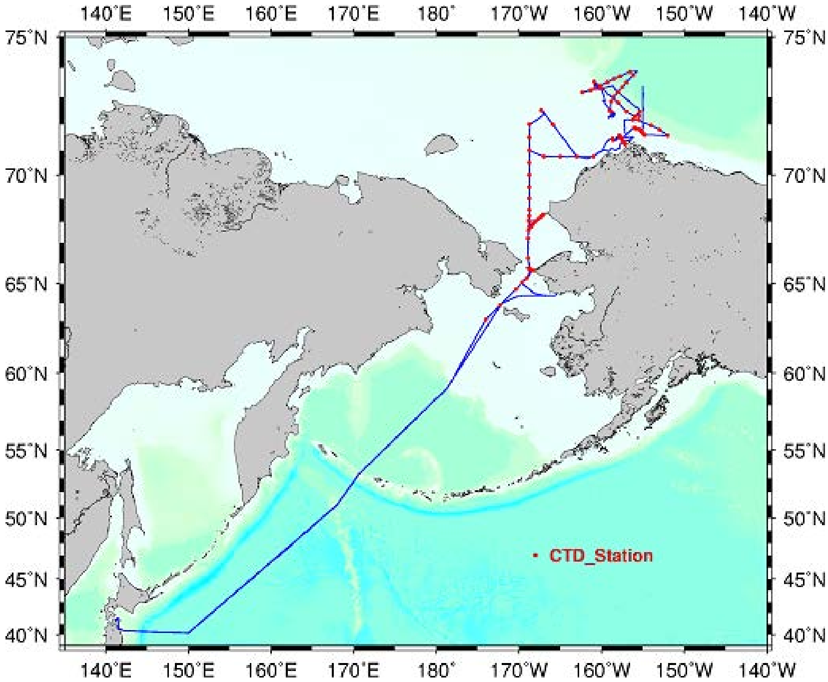


Figure 1.4-1. Cruise track and CTD stations of MR16-06.

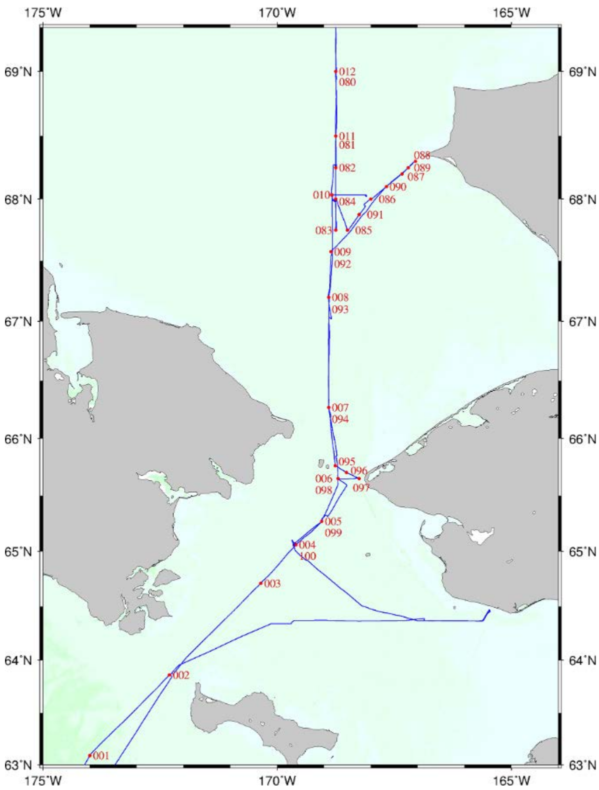


Figure 1.4-2. Cruise track and CTD Stations (63°N to 69°N).

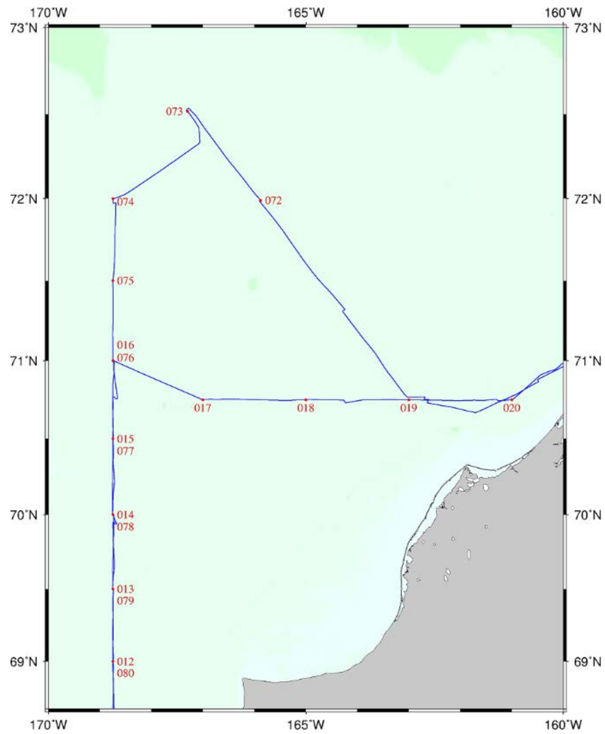


Figure 1.4-3. Cruise track and CTD Stations (69°N to 73°N).

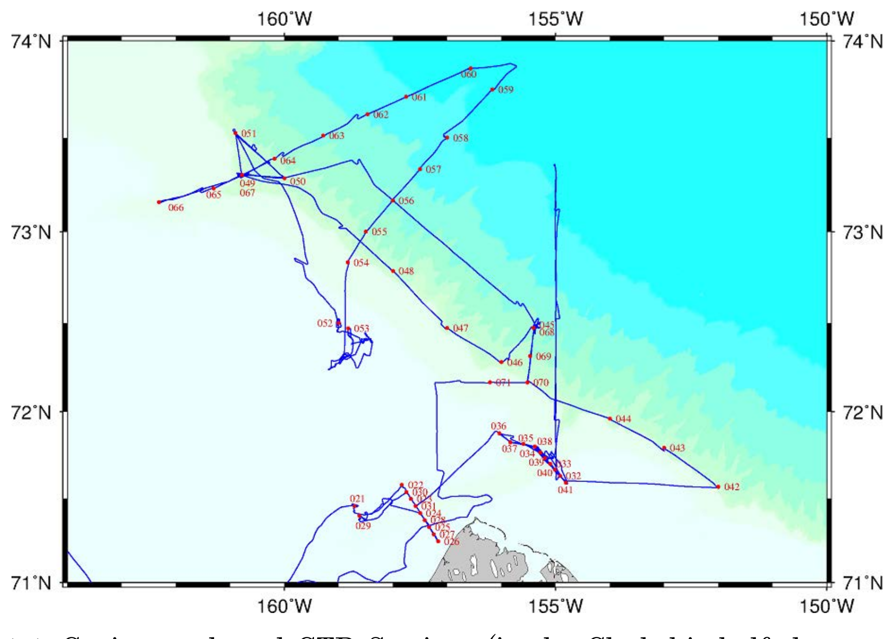


Figure 1.4-4. Cruise track and CTD Stations (in the Chukchi shelf slope and Canada Basin).

1.5. List of participants

Table 1.5-1. List of participants of MR16-06.

No.	Name	Organization	Position
1	Shigeto Nishino	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Senior Research Scientist
2	Amane Fujiwara	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Research Scientist
3	Kazutoshi Sato	National Institute of Polar Research	Project researcher
4	Akira Yamauchi	Nagasaki University	Graduate student
5	Toshihiro Ozeki	Hokkaido University of Education	Professor
6	Fumikazu Taketani	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Senior Scientist
7	Jonaotaro Onodera	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Senior Scientist
8	Koji Sugie	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Research Scientist
9	Takuhei Shiozaki	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Project Researcher
10	Makoto Sampei	Graduate school of fisheries sciences, Hokkaido university	Project assistant professor
11	Hisatomo Waga	Graduate school of fisheries sciences, Hokkaido university	Graduate student
12	Yoshiyuki Abe	Graduate school of fisheries Sciences, Hokkaido University	Post-Doctoral Researcher
13	Bungo Nishizawa	Graduate School of Fisheries Sciences, Hokkaido University	Post-Doctoral Researcher
14	Kensuke Watari	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Engineer
15	Satoshi Tsubone	Japan Agency for Marine-Earth Science and Technology	Project Engineer

		(JAMSTEC)	
16	Fumitaka Sugimoto	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Engineer
17	Hirari Sato	Toyko University of Marine Science and Technology	Graduate student
18	David Snider	Martech Polar	Ice Navigator
19	Shinya Okumura	Nippon Marine Enterprises, Ltd.	Technical Staff
20	Kazuho Yoshida	Nippon Marine Enterprises, Ltd.	Technical Staff
21	Yutaro Murakami	Nippon Marine Enterprises, Ltd.	Technical Staff
22	Hiroshi Matsunaga	Marine Works Japan Ltd.	Technical Staff
23	Keisuke Matsumoto	Marine Works Japan Ltd.	Technical Staff
24	Tatsuya Tanaka	Marine Works Japan Ltd.	Technical Staff
25	Rei Ito	Marine Works Japan Ltd.	Technical Staff
26	Sonoka Tanihara	Marine Works Japan Ltd.	Technical Staff
27	Keisuke Takeda	Marine Works Japan Ltd.	Technical Staff
28	Rio Kobayashi	Marine Works Japan Ltd.	Technical Staff
29	Minoru Kamata	Marine Works Japan Ltd.	Technical Staff
30	Shinichiro Yokogawa	Marine Works Japan Ltd.	Technical Staff
31	Yoshiko Ishikawa	Marine Works Japan Ltd.	Technical Staff
32	Yasuhiro Arii	Marine Works Japan Ltd.	Technical Staff
33	Tomonori Watai	Marine Works Japan Ltd.	Technical Staff
34	Nagisa Fujiki	Marine Works Japan Ltd.	Technical Staff
35	Emi Deguchi	Marine Works Japan Ltd.	Technical Staff
36	Atsushi Ono	Marine Works Japan Ltd.	Technical Staff
37	Masanori Enoki	Marine Works Japan Ltd.	Technical Staff
38	Hironori Sato	Marine Works Japan Ltd.	Technical Staff
39	Hiroshi Hoshino	Marine Works Japan Ltd.	Technical Staff
40	Misato Kuwahara	Marine Works Japan Ltd.	Technical Staff
41	Masahiro Orui	Marine Works Japan Ltd.	Technical Staff
42	Keitaro Matsumoto	Marine Works Japan Ltd.	Technical Staff
43	Haruka Tamada	Marine Works Japan Ltd.	Technical Staff
44	Tomohiko Sugiyama	Marine Works Japan Ltd.	Technical Staff
45	Takehiro Kanii	Marine Works Japan Ltd.	Technical Staff
46	Rui Nitahara	Marine Works Japan Ltd.	Technical Staff

2. Meteorology
2.1. GPS Radiosonde

(1) Personnel

Jun Inoue	NIPR	- PI, not on board
Kazutoshi Sato	NIPR	
Kazuhiro Oshima	JAMSTEC	- not on board
Akira Yamauchi	Nagasaki Univ.	
Shinya Okumura	Nippon Marine Enterprises Ltd. (NME)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objectives

To understand the thermodynamic structure of the boundary layer, and migratory cyclones and anticyclones, a 6-hourly radiosonde observation was conducted over the Arctic Ocean and North Pacific Oceans from 31 August through 28 September 2016 which includes 3-hourly additional radiosonde observation over the Arctic ocean. The dataset includes 12-hourly initial-observations over the Bering Sea and North Pacific Ocean during 23-30 August 2016. Obtained data will be used mainly for studies of clouds, validation of reanalysis data as well as satellite analysis, and data assimilation.

(3) Parameters

Atmospheric soundings of temperature, humidity, and wind speed/direction.

(4) Instruments and Methods

Radiosonde observations were carried out from 23 August to 28 September 2016, by using GPS radiosonde (RS41-SPG). We used software (DigiCORA III, ver.3.64), processor (SPS311), GPS antenna (GA20), UHF antenna (RB21) and balloon launcher (ASAP) made by Vaisala Oyj. Prior to launch, humidity, air temperature, and pressure sensors were calibrated by using the calibrator system (GC25 and PTB330, Vaisala). In case the relative wind to the ship is not appropriate for the launch, the handy launch was selected.

(5) Station List

Table 2.1-1 summarizes the log of upper air soundings. All data were sent to the world meteorological community by the global telecommunication system (GTS) through the Japan Meteorological Agency immediately after each observation. Raw data was recorded as binary format during ascent. ASCII data was converted from raw data.

(6) Preliminary results

Location of all radiosonde observations during the cruise is shown in Figure 2.1.1. Time-height section of observed air temperature and wind during the cruise are shown in Figure 2.1.2.

The former period is characterized by relatively weak wind near center of high pressure system over the Chukchi sea. During middle period, GPS radiosonde observation was primarily conducted under a strong pressure gradient along the outer rim of the cyclone.

On 16-18 September, we carried out radiosonde observation near the center of cyclone over the Central Arctic. During this period, we observed strong warm southwest wind in front of cyclone and cold northeast wind in back of cyclone.

During MR16-06 cruise, to obtain data exceeding 30 hPa level, we used 300g balloons which is lager than that in previous cruises. Although the balloon did not reach 10 hPa level, most of balloons reached 30 hPa levels.

(7) Data Archive

All datasets obtained in this cruise will be submitted to the Data Management Group (DMG) of JAMSTEC, and will be opened to the public via "R/V MIRAI Data Webpage" in JAMSTEC web site.

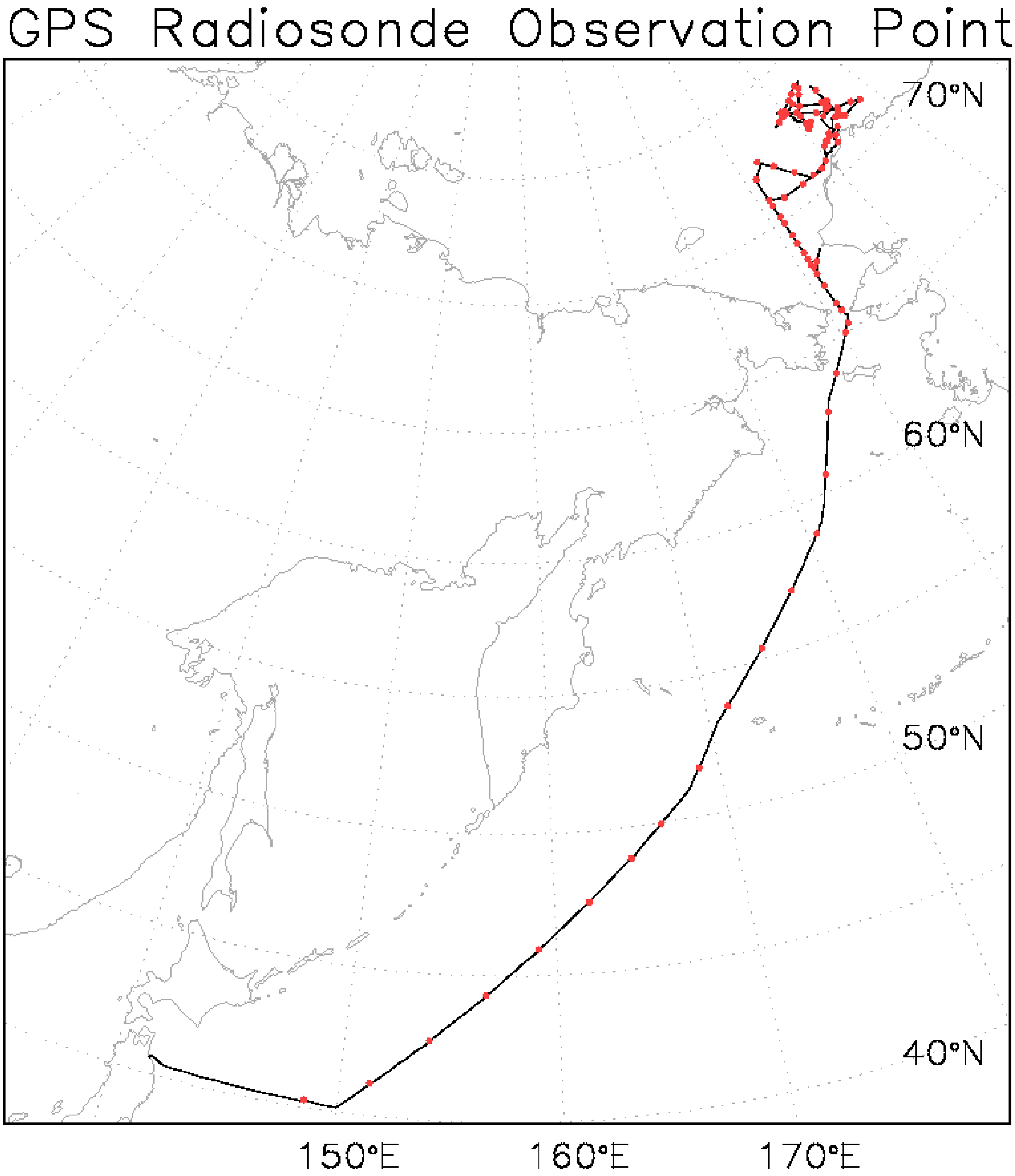


Figure 2.1-1: Sounding stations during the cruise.

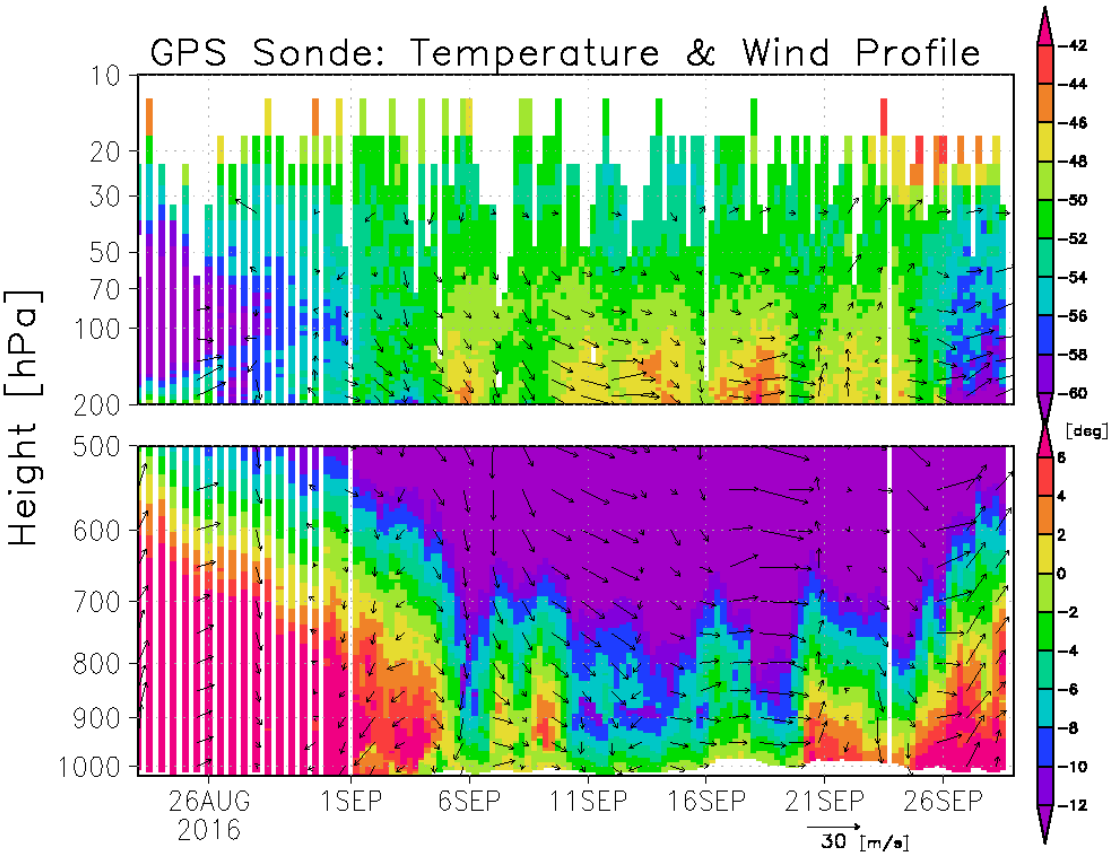


Figure 2.1-2: Time-height section of air temperature (shade) and wind (vectors).

Table 2.1-1: Launch log

ID	Date	Latitude	Longitude	Psfc	Tsfc	RHsfc	WD	Wsp	SST	Max height			Cloud	
	YYYYMMDDHH	degN	degE	hPa	degC	%	deg	m/s	degC	hPa	m	Duration	Amount	Type
RS001	2016082300	40.209	148.482	1009.5	24.9	90	160	12.7	24.40	19.2	27073	7137	3	Cu, As
RS002	2016082312	41.010	151.285	1013.5	23.0	97	174	10.9	22.32	13.1	29662	7217	–	–
RS003	2016082400	42.618	153.822	1015.7	23.5	89	179	8.6	22.66	23.4	25804	6679	2	Sc,As
RS004	2016082412	44.263	156.455	1016.3	20.4	100	181	9.1	18.85	32.3	23761	6832	–	–
RS005	2016082500	45.838	159.016	1015.6	18.5	100	188	8.4	17.41	20.2	26849	6520	10	Sc
RS006	2016082512	47.433	161.709	1016.1	16.0	100	240	8.0	14.80	62.0	19680	5592	–	–
RS007	2016082600	48.888	164.253	1018.2	14.8	99	222	3.4	13.75	32.9	23720	6429	10	St
RS008	2016082612	49.912	166.065	1020.8	14.4	100	220	4.8	13.62	15.3	28776	6847	–	–
RS009	2016082700	51.646	168.724	1019.8	12.6	100	255	5.1	12.36	19.0	27341	6751	10	St
RS010	2016082712	53.629	171.216	1017.6	13.0	100	250	7.4	12.240	17.7	27759	7143	–	–
RS011	2016082800	55.365	174.294	1015.9	12.4	100	199	3.5	12.270	14.0	29321	6947	10	St
RS012	2016082812	57.070	177.439	1020.2	11.3	97	94	4.6	11.300	13.1	29714	6767	–	–
RS013	2016082900	58.713	179.395	1023.2	11.1	97	79	9.4	12.130	15.8	28483	6514	10	St
RS014	2016082912	60.585	−176.982	1024.4	12.0	87	110	9.4	11.830	19.6	27078	6731	–	–
RS015	2016083000	62.695	−174.488	1024.7	9.7	94	151	1.1	10.760	17.6	27788	5961	10	St
RS016	2016083012	63.862	−172.296	1023.7	7.8	93	57	6.1	9.640	13.2	29717	7273	–	–
RS017	2016083100	65.052	−169.603	1022.6	7.1	96	10	8.2	6.830	15.3	28709	6683	0	–
RS018	2016083106	65.281	−169.060	1021.0	9.1	91	9	9.5	7.430	28.3	24654	5869	0	–
RS019	2016083112	65.821	−168.732	1023.1	8.7	93	351	6.3	7.850	12.9	29770	7652	–	–
RS020	2016083118	66.169	−168.860	1023.9	6.6	98	16	7.8	6.370	46.5	21415	5252	9	fog
RS021	2016090100	66.267	−168.905	1024.4	5.5	100	344	9.7	6.770	17.8	27654	6394	10	St
RS022	2016090106	66.970	−168.892	1023.3	6.3	93	14	13.5	7.150	16.6	28091	6997	3	St
RS023	2016090112	67.570	−168.829	1022.9	4.4	98	13	11.2	5.530	12.0	30230	7349	–	–
RS024	2016090118	68.034	−168.833	1022.6	5.4	96	20	13.6	7.890	14.5	28959	7351	10	St
RS025	2016090200	68.216	−168.804	1023.1	5.4	93	23	14.6	7.800	17.5	27755	6116	10	St
RS026	2016090206	69.000	−168.747	1024.7	5.4	80	32	13.0	8.320	14.8	28836	7028	2	St
RS027	2016090212	69.914	−168.746	1027.3	5.0	86	42	9.3	6.250	25.1	25372	5645	–	–
RS028	2016090218	70.684	−168.750	1028.7	2.2	100	80	7.5	6.170	10.5	31077	7629	10	St
RS029	2016090300	70.756	−167.048	1028.4	2.4	88	80	5.2	7.100	14.4	28973	6090	0	
RS030	2016090306	70.749	−154.426	1026.6	2.4	88	53	6.0	5.100	14.6	28886	6662	1	Ci
RS031	2016090312	70.747	−161.544	1025.1	2.5	89	356	1.9	3.810	35.3	23091	6037	–	–
RS032	2016090318	71.258	−159.474	1022.0	1.2	79	313	7.1	0.570	69.1	18721	4306	0	–
RS033	2016090400	71.439	−158.721	1020.0	0.2	97	323	5.8	1.900	12.8	29694	7137	10	St
RS034	2016090406	71.578	−157.836	1017.4	−0.1	100	314	5.0	2.230	47.0	21196	4622	10	St
RS035	2016090412	71.330	−157.323	1014.9	0.7	100	337	4.8	1.580	21.8	26126	6671	–	–
RS036	2016090418	71.451	−157.940	1013.1	−1.8	98	342	5.4	2.210	107.3	14495	3960	9	St,Ci

RS037	2016090500	71.391	−158.616	1011.2	−1.5	92	340	3.9	2.250	11.6	30257	6930	10	St
RS038	2016090506	71.482	−158.016	1010.1	−0.3	96	329	4.0	2.240	26.4	24884	5580	9	St,Sc
RS039	2016090512	71.863	−155.978	1008.5	1.7	93	18	11.2	3.140	16.8	27772	6248	−	−
RS040	2016090518	71.757	−155.097	1011.0	0.8	77	22	11.8	0.410	10.9	30595	6793	7	St,SC
RS041	2016090600	71.782	−155.359	1014.1	0.5	74	3	10.4	0.400	13.3	29280	6295	6	Sc
RS042	2016090606	72.430	−154.998	1016.5	−0.3	93	20	4.7	3.010	22.0	25953	5688	5	Sc
RS043	2016090612	73.215	−154.999	1015.8	−0.6	81	267	7.5	2.910	32.6	23426	5971	−	−
RS044	2016090618	72.063	−155.013	1014.9	−0.2	89	272	8.3	3.420	30.8	23773	5618	10	Sc
RS045	2016090700	71.798	−155.326	1011.2	0.4	97	247	12.1	1.730	32.5	23436	5320	10	Sc,St
RS046	2016090703	71.695	−155.075	1009.2	1.2	99	272	10.1	1.590	72.0	18260	4123	10	Sc
RS047	2016090706	71.814	−155.604	1008.0	0.9	97	295	13.3	2.950	83.0	17327	4022	10	Sc
RS048	2016090712	71.799	−155.386	1008.4	1.9	96	316	11.0	2.910	72.4	18278	4452	−	−
RS049	2016090715	71.732	−155.211	1009.2	1.9	97	311	7.8	2.980	74.2	18296	4645	−	−
RS050	2016090718	71.631	−154.922	1010.1	1.8	100	308	8.0	1.690	50.7	20532	5512	10	St
RS051	2016090800	71.565	−151.994	1012.7	0.5	87	9	2.9	3.680	14.5	28692	6236	10	St
RS052	2016090806	71.793	−153.019	1014.6	0.3	87	48	1.6	2.620	12.6	29615	6416	10	St
RS053	2016090812	72.019	−154.561	1014.2	1.9	100	177	5.7	3.410	10.7	30686	7024	−	−
RS054	2016090818	72.448	−155.377	1010.2	−0.2	100	231	7.4	3.190	48.0	20890	4455	10	St
RS055	2016090900	72.500	−155.302	1007.5	1.1	95	239	9.1	3.360	18.9	26939	6327	10	St
RS056	2016090906	72.341	−155.817	1004.1	0.6	100	266	9.3	1.990	14.1	28873	6021	10	St
RS057	2016090912	72.468	−157.031	1003.8	0.5	100	312	8.3	2.960	15.0	28421	6795	−	−
RS058	2016090918	73.018	−158.879	1004.9	0.6	91	357	4.2	3.070	11.3	30262	6884	10	Sc
RS059	2016091000	73.295	−160.804	1006.3	0.3	99	22	4.1	3.010	44.3	21405	5280	10	Sc
RS060	2016091006	73.388	−160.005	1007.7	−0.8	87	26	8.9	2.840	20.5	26352	6265	10	Sc
RS061	2016091012	73.364	−160.611	1010.7	−1.6	80	351	7.8	2.950	20.3	26440	5354	−	−
RS062	2016091018	72.543	−159.047	1012.4	−1.7	93	316	4.3	−1.000	48.4	20795	4576	10	Sc
RS063	2016091100	72.470	−159.001	1015.7	−1.7	72	299	3.4	−1.030	48.0	20875	5145	10	Sc
RS064	2016091106	72.450	−158.996	1016.2	−2.6	82	307	4.7	−1.200	31.9	23503	5354	9	Sc
RS065	2016091112	72.399	−158.528	1016.8	−2.9	80	262	8.2	0.700	19.3	26575	6549	−	−
RS066	2016091118	72.320	−158.787	1016.3	−3.1	83	305	8.0	−0.510	12.9	29366	6563	10	Sc
RS067	2016091200	72.436	−158.828	1016.3	−2.5	93	290	8.7	−0.410	20.9	26257	6478	10	Sc
RS068	2016091206	72.408	−158.426	1015.4	−0.3	81	25	5.5	0.900	20.8	26266	5839	10	Sc
RS069	2016091212	72.400	−158.399	1014.8	−0.4	70	30	7.3	0.820	28.4	24256	5936	−	−
RS070	2016091218	72.272	−158.983	1013.6	−1.5	75	57	8.8	−0.530	52.6	20253	4422	9	Sc
RS071	2016091300	72.248	−159.144	1013.0	−1.3	74	57	10.2	−1.010	36.6	22602	4917	10	Sc
RS072	2016091306	72.831	−158.816	1014.2	−1.6	74	60	6.4	2.520	34.5	22971	5847	−	−
RS073	2016091312	73.166	−158.008	1014.9	−1.7	66	25	3.9	2.300	26.2	24735	6218	−	−
RS074	2016091318	73.454	−157.154	1014.2	−2.2	79	4	5.6	1.680	18.3	27039	6383	10	Sc
RS075	2016091400	73.618	−156.609	1013.5	−2.5	83	293	6.6	1.810	13.3	29139	7045	10	Sc
RS076	2016091406	73.860	−156.573	1011.6	−1.3	77	281	7.1	1.830	34.5	22958	5748	−	−

RS077	2016091412	73.734	−157.577	1009.9	−0.5	78	284	10.3	2.520	13.8	28838	7378	−	−
RS078	2016091418	73.614	−158.533	1008.8	−0.6	85	298	8.7	2.490	19.3	26671	5669	10	Ac,Sc
RS079	2016091500	73.440	−159.803	1009.1	−0.2	86	318	8.8	1.860	17.4	27386	6299	10	Sc
RS080	2016091506	73.230	−161.345	1009.1	−0.1	88	324	9.6	2.180	44.0	21370	5226	−	−
RS081	2015091512	73.214	−161.612	1008.0	−0.8	74	301	7.5	2.180	15.9	27930	7781	−	−
RS082	2016091518	73.309	−160.793	1003.9	−1.4	70	268	7.8	2.360	16.6	27625	6185	10	Sc
RS083	2016091600	73.299	−160.826	998.6	−0.5	68	246	12.9	2.360	159.3	12960	2730	10	Sc
RS084	2016091606	73.392	−160.400	991.3	0.4	83	230	15.6	1.850	35.6	22720	5528	−	−
RS085	2016091612	73.369	−158.922	984.7	0.5	97	230	14.2	2.080	16.8	27597	6352	−	−
RS086	2016091618	72.615	−155.697	984.0	0.0	95	222	13.6	2.130	14.6	28406	6561	10	St
RS087	2016091621	72.458	−155.379	982.9	0.6	97	225	14.5	2.400	15.4	28121	6552	10	Sc
RS088	2016091700	72.473	−155.413	982.4	0.3	92	270	11.6	2.360	17.0	27488	6086	10	Sc
RS089	2016091706	72.314	−155.469	984.6	0.0	94	264	8.0	1.970	16.6	27625	6533	−	−
RS090	2016091712	72.167	−156.444	982.8	1.0	98	221	9.4	2.350	18.7	26829	6558	−	−
RS091	2016091718	71.514	−156.675	981.7	0.2	97	250	9.6	1.550	34.5	22866	4998	10	St
RS092	2016091721	71.389	−156.657	982.6	−0.2	95	262	7.3	−0.280	25.4	24857	5313	10	St
RS093	2016091800	71.115	−157.786	985.7	−0.6	85	284	13.0	0.890	12.4	29548	7863	5	Sc
RS094	2016091806	70.917	−160.274	989.9	−0.1	76	287	13.6	0.630	31.0	23564	5742	−	−
RS095	2016091812	70.753	−162.622	995.5	0.1	88	262	11.4	3.070	43.4	21388	4927	−	−
RS096	2016091818	71.265	−164.182	996.9	0.0	68	286	14.0	2.150	19.9	26441	6457	10	Sc
RS097	2016091900	71.989	−165.891	998.8	−1.1	71	290	13.2	3.050	17.6	27264	5883	9	Sc
RS098	2016091906	72.523	−167.322	999.6	−2.2	81	281	10.9	1.240	19.5	26567	6153	−	−
RS099	2016091912	71.998	−168.750	1002.6	−0.4	79	283	11.6	3.120	24.5	25080	6373	−	−
RS100	2016091918	71.058	−168.746	1003.1	0.0	66	251	5.1	4.870	16.5	27665	5774	9	Sc
RS101	2016092000	70.300	−168.735	1000.7	1.3	69	27	1.4	4.900	19.0	26789	6345	7	Sc,Cc
RS102	2016092006	69.424	−168.749	993.0	5.3	100	77	6.9	5.720	16.1	27877	7378	−	−
RS103	2016092009	69.002	−168.746	990.0	6.3	99	140	6.4	6.050	28.5	24132	5956	−	−
RS104	2016092012	68.506	−168.754	986.8	6.6	97	127	5.8	6.340	39.1	22083	6173	−	−
RS105	2016092018	67.753	−168.746	985.0	5.3	100	197	12.8	6.640	23.7	25315	5829	10	St
RS106	2016092100	67.871	−168.254	987.8	5.7	96	191	9.6	7.030	18.5	26942	6504	8	As
RS107	2016092106	68.303	−167.059	988.5	6.2	96	203	6.3	5.620	33.0	23161	5905	−	−
RS108	2016092112	67.651	−168.658	987.2	5.2	100	197	3.5	6.430	27.5	24346	5848	−	−
RS109	2016092118	67.198	−168.897	986.0	4.5	97	1	3.6	5.700	21.7	25871	6135	10	Sc
RS110	2016092200	66.402	−168.901	986.4	5.5	99	22	5.2	6.370	15.8	28006	6667	10	Sc
RS111	2016092206	65.765	−168.771	987.4	5.9	96	53	7.4	6.000	67.6	18480	4795	−	−
RS112	2016092212	65.347	−169.965	988.7	4.9	98	24	12.5	4.660	39.2	22033	5644	−	−
RS113	2016092218	65.098	−169.676	990.3	3.8	87	16	10.6	4.270	17.1	27440	6515	8	Ac
RS114	2016092300	64.954	−169.479	990.7	4.1	76	352	9.7	4.620	15.7	28012	6658	10	Sc
RS115	2016092306	64.501	−168.174	990.6	4.5	81	348	11.2	5.580	28.4	24144	5963	−	−
RS116	2016092312	64.365	−166.678	991.3	4.6	78	338	9.6	7.900	10.7	30659	8241	−	−

RS117	2016092400	64.367	−166.669	996.2	4.3	82	342	5.9	7.650	15.7	28093	6663	10	Sc
RS118	2016092406	64.369	−169.365	998.8	3.2	86	99	3.6	5.860	14.3	28732	7382	−	−
RS119	2016092412	63.925	−172.155	1002.8	2.5	93	359	12.2	5.050	27.0	24472	6107	−	−
RS120	2016092418	62.890	−173.617	1006.8	6.0	56	311	5.2	7.300	19.9	26518	5855	5	Ac
RS121	2016092500	61.823	−175.095	1006.8	8.3	78	219	8.8	8.310	16.9	27627	6484	8	Sc
RS122	2016092506	60.911	−176.320	1005.7	8.8	83	226	9.2	9.440	36.7	22498	5186	−	−
RS123	2016092512	59.927	−177.598	1002.5	8.7	92	232	12.9	9.290	32.7	23221	5549	−	−
RS124	2016092518	58.981	−178.853	1000.4	9.4	92	236	12.2	9.900	14.5	28687	6439	10	Unknown
RS125	2016092600	58.310	179.742	1004.2	10.0	86	293	11.3	9.500	16.7	27723	6378	0	−
RS126	2016092606	57.525	178.278	1010.4	9.7	88	308	7.8	9.560	36.0	22661	5481	−	−
RS127	2016092612	56.709	176.736	1013.8	9.7	97	217	5.5	9.870	21.7	26013	6463	−	−
RS128	2016092618	55.863	175.163	1014.2	9.0	94	240	11.0	9.590	17.6	27391	6955	−	−
RS129	2016092700	55.060	173.767	1012.6	10.1	88	207	15.2	9.960	21.4	26097	6432	10	Sc
RS130	2016092706	54.414	172.585	1006.2	10.3	89	193	19.1	9.950	52.5	20255	4324	−	−
RS131	2016092712	53.957	171.796	1005.2	10.5	89	217	13.8	9.580	17.6	27371	6300	−	−
RS132	2016092718	53.366	170.776	1008.0	10.7	88	252	13.1	10.060	20.6	26316	5900	−	−
RS133	2016092800	52.571	169.802	1013.1	10.6	64	309	5.4	10.580	20.8	26262	6467	7	Ci,Cc,Sc,As
RS134	2016092806	51.651	168.747	1011.8	10.2	95	188	5.9	10.510	14.3	28759	6695	−	−
RS135	2016092812	50.745	167.544	1006.5	9.3	94	170	9.9	10.710	33.4	23211	5736	−	−

2.2. C-band Weather Radar

(1) Personnel

Jun Inoue	NIPR	- PI, not on board
Kazutoshi Sato	NIPR	
Kazuhiro Oshima	JAMSTEC	- not on board
Akira Yamauchi	Nagasaki Univ.	
Shinya Okumura	NME (Nippon Marine Enterprises Ltd.)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objectives

Low level clouds over the Arctic Ocean which usually dominate during summer have a key role for sea/ice surface heat budget. In addition, cyclones which modify the sea-ice distributions are substantially important to understand the air-ice-sea interaction. To capture the broad cloud-precipitation systems and their temporal and spatial evolution over the Arctic Ocean, three-dimensional radar echo structure and wind fields of rain/snow clouds was obtained by C-band Doppler radar observation. At the same time, scans are performed to evaluate the performance of the radar, and to develop the better strategy of the radar observation.

(3) Parameters

The C-band Weather radar observed three-dimensional radar echo structure and wind fields of rain/snow cloud.

Radar variables, which are converted from the power and phase of the backscattered signal at vertically and horizontally-polarized channels, are as follows:

Radar reflectivity:	Z
Doppler velocity:	Vr
Spectrum width of Doppler velocity:	SW
Differential reflectivity:	ZDR
Differential propagation phase:	ΦDP
Specific differential phase:	KDP
Co-polar correlation coefficients:	ρHV

(4) Instruments and methods

The C-band Weather radar on board R/V Mirai is used. The basic specification of the radar is as follows:

Frequency:	5370 MHz (C-band)
Polarimetry:	Horizontal and vertical
(simultaneously transmitted and received)	
Transmitter:	Solid-state transmitter
	(with pulse compression technique)
Output Power:	6 kW (H) + 6 kW (V)
Antenna Diameter:	4 meter
Beam Width:	1.0 degrees
INU (Inertial Navigation Unit):	PHINS (IXBLUE S.A.S.)

The antenna is controlled to point the commanded ground-relative direction, by controlling the azimuth and elevation to cancel the ship attitude (roll, pitch and yaw) detected by the INU. The Doppler velocity is also corrected by subtracting the ship motion in beam direction.

As the maintenance, internal parameters of the radar are checked and calibrated at the beginning and the end of the cruise. Meanwhile, the following parameters are checked daily; (1) frequency, (2) peak output power, (3) pulse width, and (4) PRF (pulse repetition frequency).

During the cruise, the radar was operated typically by repeating a volume scan with 17 PPIs (Plan Position Indicators) every 6-minute. A dual PRF mode with the maximum range of typically 100 km is used for the volume scan. A surveillance PPI scan is performed every 30 minutes in a single PRF mode with the maximum range of 300 km. RHI (Range Height Indicator) scans are operated whenever detailed vertical structures are necessary in certain azimuth directions. Vertical Point scans are performed due to collecting data for ZDR calibration. During this cruise, the scan strategy is kept same, as in Table 2.2-1, to provide the same data quality to highlight the temporal variation of the precipitating systems.

(5) Observation log

The radar was operated continuously from 02:18UTC 23 Aug. to 05:00UTC 02 Oct.

(6) Preliminary results

Figure 2.2-1, 2.2-2 and 2.2-3 show the PPI image, NOAA satellite image, and weather condition, i.e. SLP, wind and SAT fields, from JMA GPV for precipitating events. During the cruise, several precipitation systems passed near the R/V MIRAI. The C-band weather radar captured strong precipitation systems during MR16-06. Snowfall accompanied with the northwest wind was observed around Barrow during September 6-7 (Figure 2.2-1). The precipitation systems exceeding 30dBZ were observed during September 9-10 (Figure 2.2-2). Moreover, the cyclone center was captured by the radar during September 16-18 (Figure 2.2-3). The further detailed analyses will be performed after the cruise.

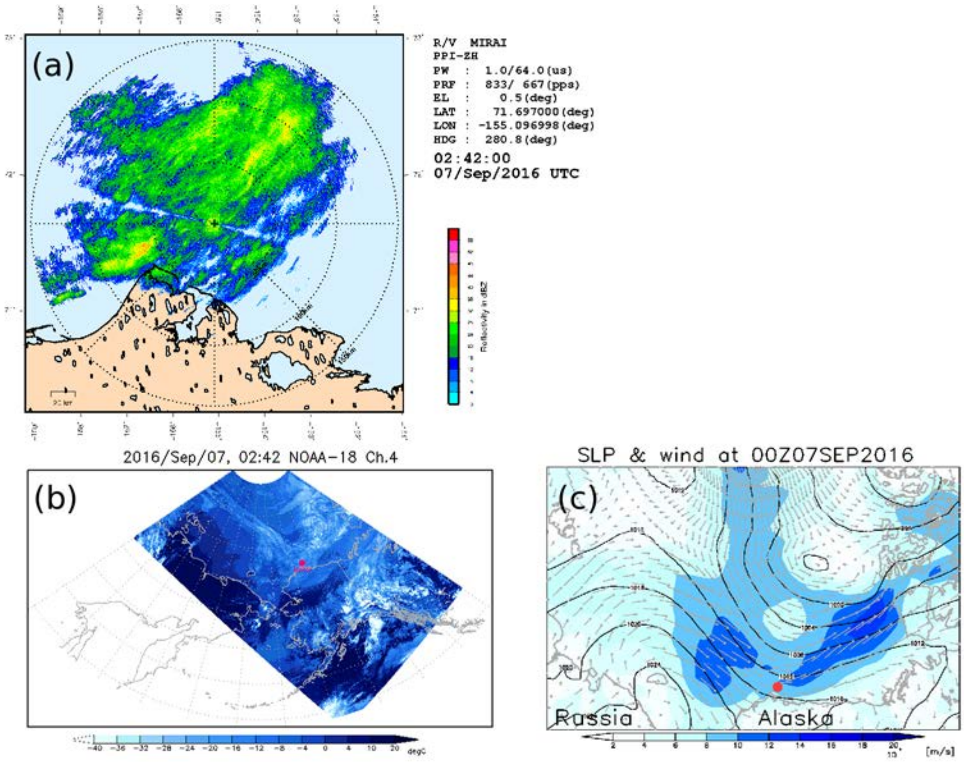


Figure 2.2-1: (a) PPI image obtained by the first volume scan at elevation angle of 0.5 degree, (b) NOAA satellite image, (c) sea level pressure (SLP, contour), wind (vector and shade) fields from JMA GPV on September 07.

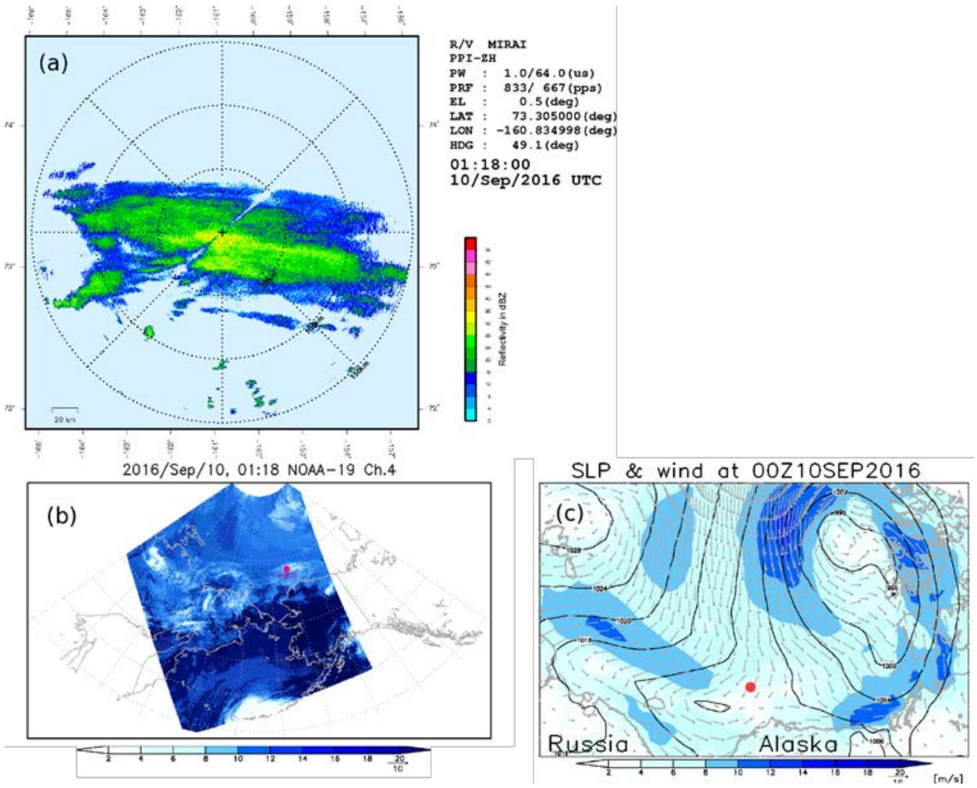


Figure 2.2-2: Same as in Figure 2.2-1, but for September 10.

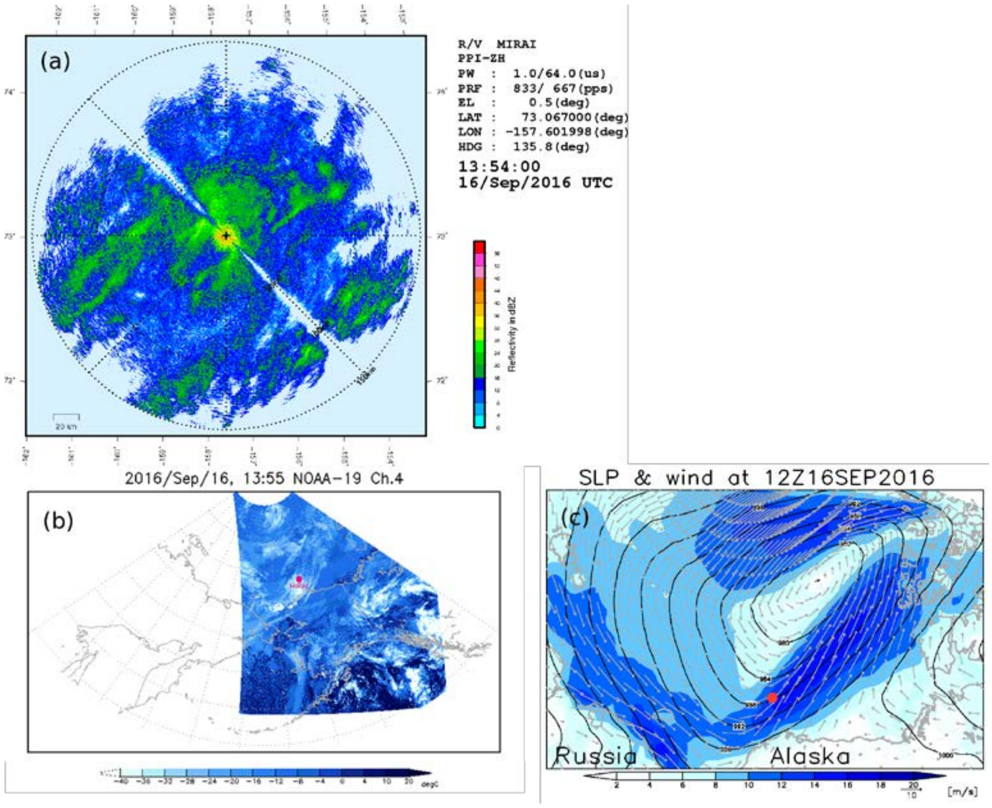


Figure 2.2-3: Same as in Figure 2.2-1, but for September 16.

(7) Data archive

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(8) Remarks (Times in UTC)

i) The following period, data acquisition was suspended due to maintenance.
04:00 28 Sep. 2016 - 04:06 28 Sep. 2016

Table 2.2-1: Parameters for scan strategy in the Arctic Ocean.

<table>
<tr><th></th><th>Surveillance PPI Scan</th><th colspan="6">Volume Scan</th><th>RHI Scan</th><th>Vertical Point Scan</th></tr>
<tr><td>Repeated Cycle (min.)</td><td>30</td><td colspan="6">6</td><td colspan="2">12</td></tr>
<tr><td>Times in One Cycle</td><td>1</td><td colspan="6">1</td><td>3</td><td>3</td></tr>
<tr><td>Pulse Width (long / short, in microsec)</td><td>200 / 2</td><td colspan="2">64 / 1</td><td colspan="2">32 / 1</td><td colspan="2">32 / 1</td><td>32 / 1</td><td>32/1</td></tr>
<tr><td>Scan Speed (deg/sec)</td><td>18</td><td colspan="2">18</td><td colspan="2">24</td><td colspan="2">36</td><td>9 (in el.)</td><td>36</td></tr>
<tr><td rowspan="2">PRF(s) (Hz)</td><td rowspan="2">400</td><td colspan="6">dual PRF (ray alternative)</td><td rowspan="2">1250</td><td rowspan="2">2000</td></tr>
<tr><td>667</td><td>833</td><td>938</td><td>1250</td><td>1333</td><td>2000</td></tr>
<tr><td>Pulses / Ray</td><td>16</td><td>26</td><td>33</td><td>27</td><td>34</td><td>37</td><td>55</td><td>32</td><td>64</td></tr>
<tr><td>Ray Spacing (deg.)</td><td>0.7</td><td colspan="2">0.7</td><td colspan="2">0.7</td><td colspan="2">1.0</td><td>0.23</td><td>1.0</td></tr>
<tr><td>Azimuth</td><td colspan="7">Full Circle</td><td>Optional</td><td>Full Circle</td></tr>
<tr><td>Bin Spacing (m)</td><td colspan="9">150</td></tr>
<tr><td>Max. Range (km)</td><td>300</td><td colspan="2">150</td><td colspan="2">100</td><td colspan="2">60</td><td>100</td><td>60</td></tr>
<tr><td>Elevation Angle(s) (deg.)</td><td>0.5</td><td colspan="2">0.5</td><td colspan="2">1.0, 1.7, 2.4, 3.1, 3.8, 4.6, 5.5, 6.5, 7.6, 8.9</td><td colspan="2">10.4, 12.0, 13.8, 16.0, 18.3, 21.0</td><td>0.0 to 60.0</td><td>90</td></tr>
</table>

2.3. Surface Meteorological Observations

(1) Personnel

Shigeto Nishino	JAMSTEC: PI
Shinya Okumura	NME (Nippon Marine Enterprises Ltd.)
Kazuho Yoshida	NME
Yutaro Murakami	NME
Masanori Murakami	MIRAI Crew

(2) Objectives

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

(3) Instruments and methods

Surface meteorological parameters were observed during this cruise. In this cruise, we used two systems for the observation.

i. MIRAI Surface Meteorological observation (SMet) system

Instruments of SMet system are listed in Table 2.3-1 and measured parameters are listed in Table 2.3-2. Data were collected and processed by KOAC-7800 weather data processor made by Koshin-Denki, Japan. The data set consists of 6-second averaged data.

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

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

a) Portable Radiation Package (PRP) designed by BNL – short and long wave downward radiation.
b) Analog meteorological data sampling with CR1000 logger manufactured by Campbell Inc. Canada – wind pressure, and rainfall (by a capacitive rain gauge) measurement.
c) Digital meteorological data sampling from individual sensors - air temperature, relative humidity and rainfall (by optical rain gauge (ORG)) measurement.
d) Photosynthetically Available Radiation (PAR) sensor manufactured by Biospherical Instruments Inc. (USA) - PAR measurement.
e) Scientific Computer System (SCS) developed by NOAA (National Oceanic

and Atmospheric Administration, USA) – centralized data acquisition and logging of all data sets.

SCS recorded PRP, air temperature and relative humidity, CR1000 and ORG data. SCS composed Event data (JamMet) from these data and ship's navigation data every 6 seconds. Instruments and their locations are listed in Table 2.3-3 and measured parameters are listed in Table 2.3-4.

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

i. Young Rain gauge (SMet and SOAR)
   Inspect of the linearity of output value from the rain gauge sensor to change Input value by adding fixed quantity of test water.
ii. Barometer (SMet and SOAR)
   Comparison with the portable barometer value, PTB220, VAISALA
iii. Thermometer (air temperature and relative humidity) (SMet and SOAR)
   Comparison with the portable thermometer value, HM70, VAISALA

(4) Observation log

22 Aug. 2016 to 05 Oct. 2016

(5) Preliminary results

Figure. 2.3-1 shows the time series of the following parameters;

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

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(7) Remarks (Times in UTC)

ii) The following periods, Sea surface temperature of SMet data was available.

08:22, 22 Aug. 2016 - 05:30, 03 Oct. 2016

iii) The following time, increasing of SMet capacitive rain gauge data were invalid due to test transmitting for MF/HF radio.

03:18, 26 Sep. 2016

iv) The following time, starboard-side temperature, dew point temperature and relative humidity data of SMet were invalid due to a sensor communication error.

01:26:24, 28 Aug. 2016

v) The following time, increasing of SMet ORG data were invalid due to water spraying of the fire drill.

01:09, 27 Sep. 2016

vi) The following periods, PRP data acquisition was suspended due to maintenance.

21:11 22 Aug. 2016 - 21:13 22 Aug. 2016
02:37 31 Aug. 2016 - 03:59 31 Aug. 2016
22:53 31 Aug. 2016 - 22:53 31 Aug. 2016
10:23 21 Sep. 2016 - 10:29 21 Sep. 2016

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

23:00 31 Aug. 2016 - 10:23 21 Sep. 2016

Table 2.3-1: Instruments and installation locations of SMet system

Sensors	Type	Manufacturer	Location(altitude from surface)
Anemometer	KE-500	Koshin Denki, Japan	foremast (24 m)
Tair/RH	HMP155	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	compass deck (21 m) starboard and port side
Thermometer: SST	RFN2-0	Koshin Denki, Japan	4th deck (-1m, inlet -5m)
Barometer	Model-370	Setra System, USA	captain deck (13 m) weather observation room
Rain gauge	50202	R. M. Young, USA	compass deck (19 m)
Optical rain gauge	ORG-815DS	Osi, USA	compass deck (19 m)
Radiometer (short wave)	MS-802	Eko Seiki, Japan	radar mast (28 m)

Radiometer (long wave)	MS-202	Eko Seiki, Japan	radar mast (28 m)
Wave height meter	WM-2	Tsurumi-seiki, Japan	bow (10 m)

Table 2.3-2: Parameters of MIRAI Surface Meteorological observation system

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

Table 2.3-3: Instruments and installation locations of SOAR system

Sensors (Meteorological)	Type	Manufacturer	Location (altitude from surface)
Anemometer	05106	R.M. Young, USA	foremast (25 m)
Barometer	PTB210	Vaisala, Finland	foremast (23 m)
with 61002 Gill pressure port, R.M. Young, USA			
Rain gauge	50202	R.M. Young, USA	foremast (24 m)
Tair/RH	HMP155	Vaisala, Finland	foremast (23 m)
with 43408 Gill aspirated radiation shield		R.M. Young, USA	foremast (23 m)
Optical rain gauge	ORG-815DR	Osi, USA	foremast (24 m)

Sensors (PRP)	Type	Manufacturer	Location (altitude from surface)
Radiometer (short wave)	PSP	Epply Labs, USA	foremast (25 m)

Radiometer (long wave)	PIR	Epply Labs, USA	foremast (25 m)
Fast rotating shadowband radiometer		Yankee, USA	foremast (25 m)

Sensor (PAR)	Type	Manufacturer	Location (altitude from surface)
PAR sensor	PUV-510	Biospherical Instruments Inc., USA	Navigation deck (18m)

Table 2.3-4: Parameters of SOAR system (JamMet)

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 SOG	knot	
4 COG	degree	
5 Relative wind speed	m/s	
6 Relative wind direction	degree	
7 Barometric pressure	hPa	
8 Air temperature	degC	
9 Relative humidity	%	
10 Rain rate (optical rain gauge)	mm/hr	
11 Precipitation (capacitive rain gauge)	mm	reset at 50 mm
12 Down welling shortwave radiation	W/m^2	
13 Down welling infra-red radiation	W/m^2	
14 Defuse irradiance	W/m^2	
15 PAR	microE/cm2/sec	

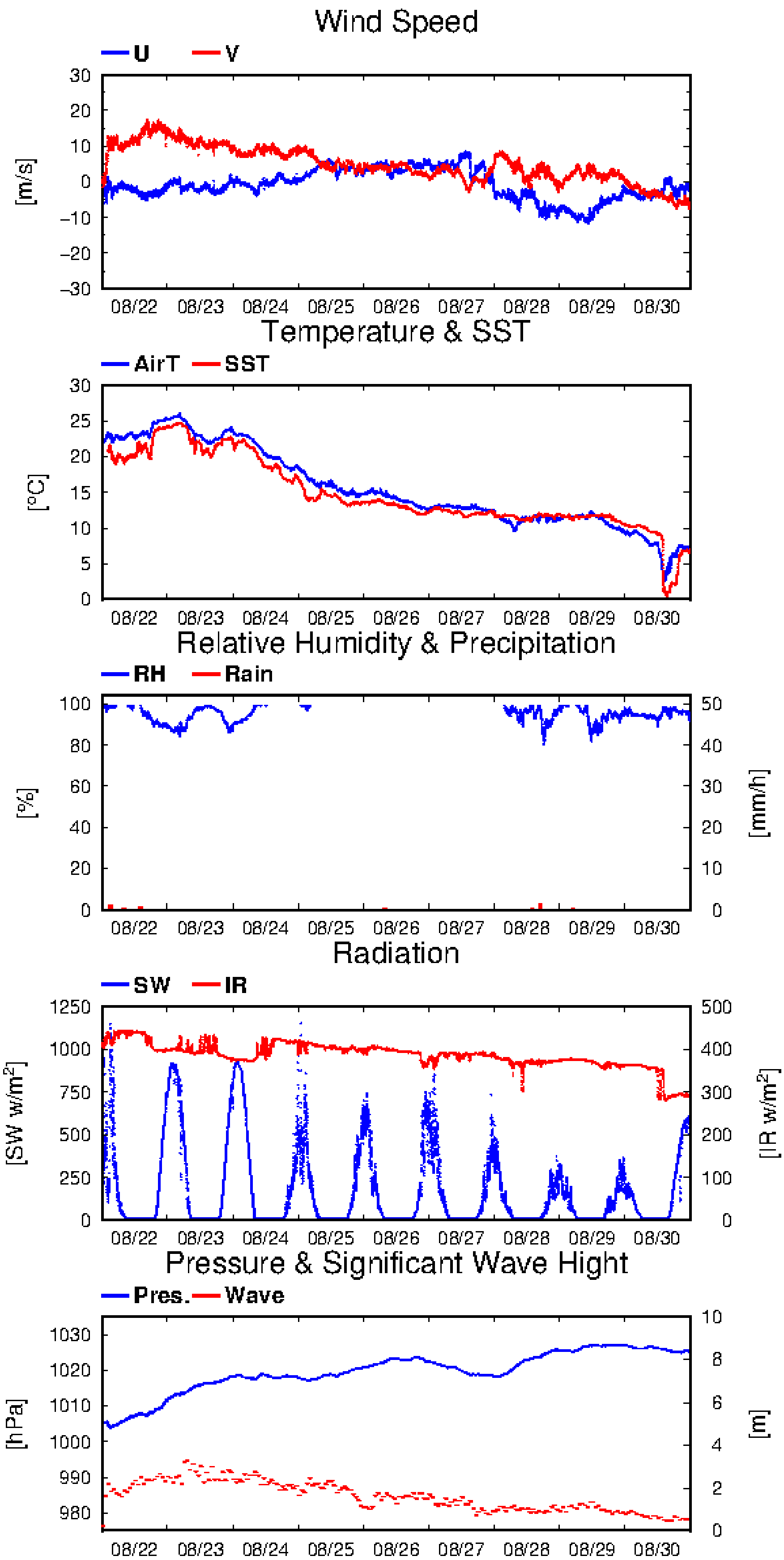


Figure 2.3-1: Time series of surface meteorological parameters during this cruise

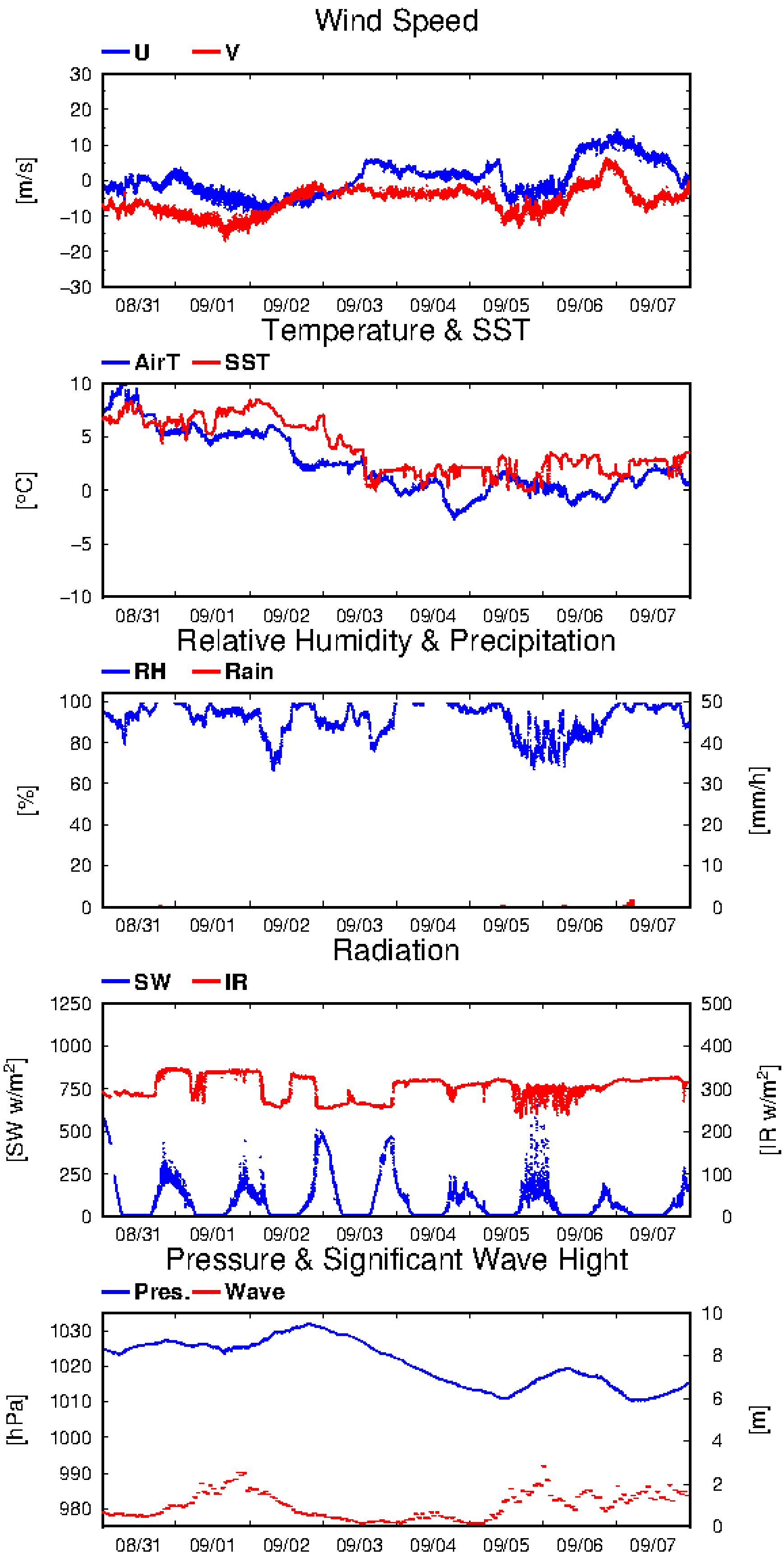


Figure 2.3-1: (Continued)

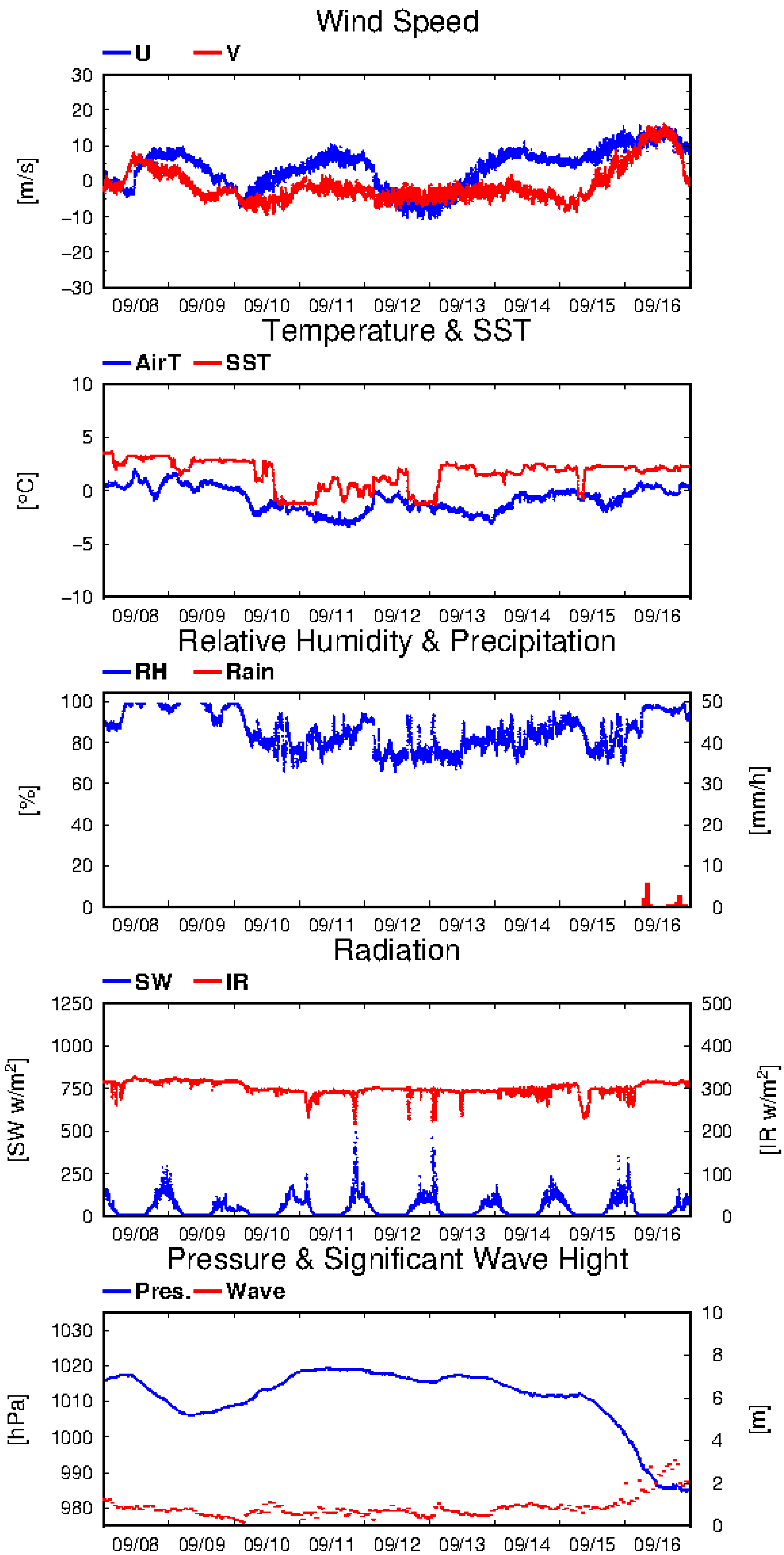


Figure 2.3-1: (Continued)

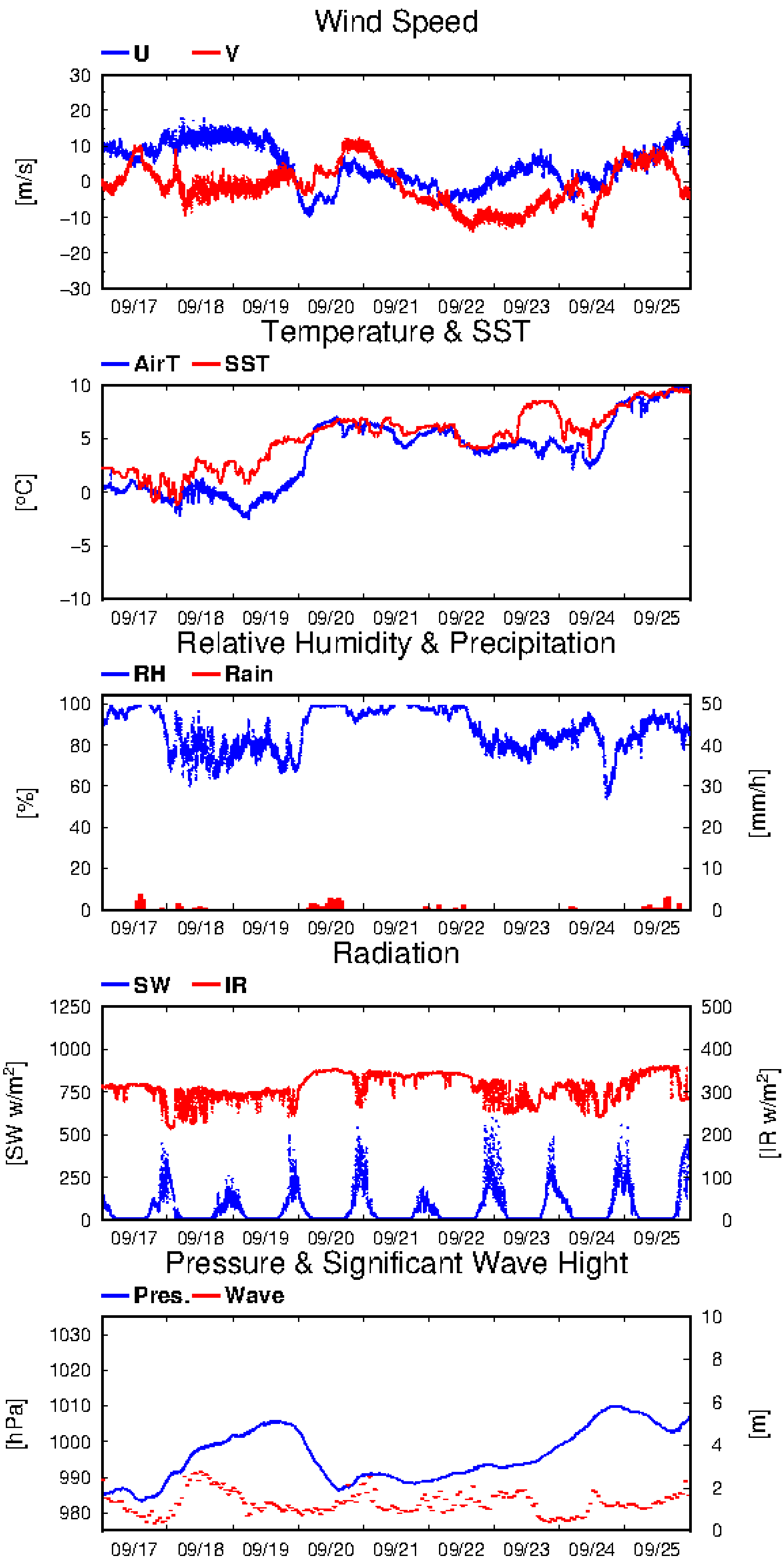


Figure 2.3-1: (Continued)

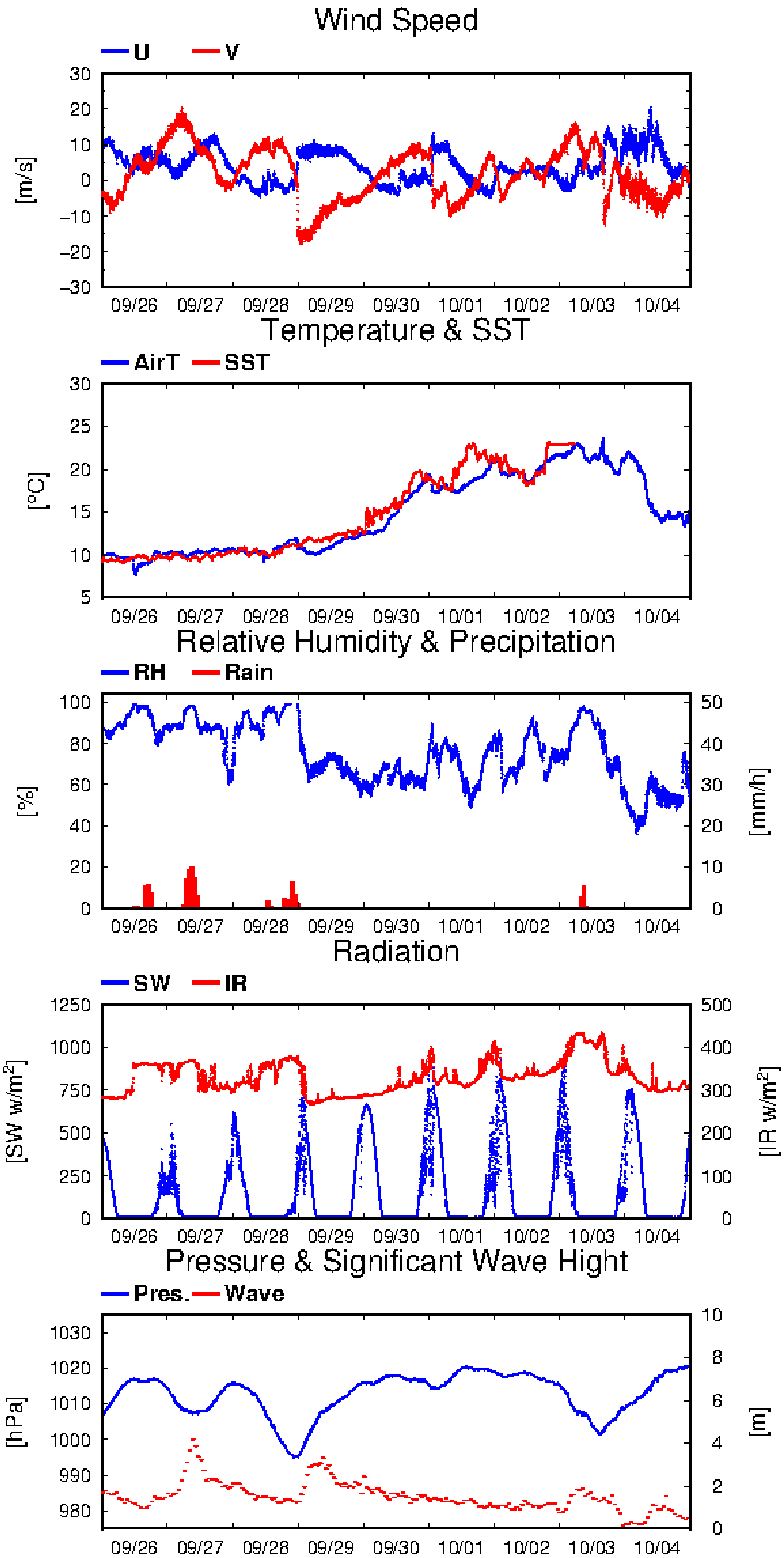


Figure 2.3-1: (Continued)

2.4. Ceilometer

(1) Personnel

Shigeto Nishino	JAMSTEC	- PI
Shinya Okumura	NME (Nippon Marine Enterprises Ltd.)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objectives

The information of cloud base height and the liquid water amount around cloud base is important to understand the process on formation of the cloud. As one of the methods to measure them, the ceilometer observation was carried out.

(3) Parameters

1. Cloud base height [m].
2. Backscatter profile, sensitivity and range normalized at 10 m resolution.
3. Estimated cloud amount [oktas] and height [m]; Sky Condition Algorithm.

(4) Instruments and methods

We measured cloud base height and backscatter profile using ceilometer (CL51, VAISALA, Finland) throughout this cruise.

Major parameters for the measurement configuration are as follows;

Laser source:	Indium Gallium Arsenide (InGaAs) Diode Laser
Transmitting center wavelength:	910±10 nm at 25 degC
Transmitting average power:	19.5 mW
Repetition rate:	6.5 kHz
Detector:	Silicon avalanche photodiode (APD)
Measurement range:	0 ~ 15 km
	0 ~ 13 km (Cloud detection)
Resolution:	10 meter in full range
Sampling rate:	36 sec
Sky Condition	0, 1, 3, 5, 7, 8 oktas (9: Vertical Visibility)
	(0: Sky Clear, 1: Few, 3: Scattered, 5-7: Broken, 8: Overcast)

On the archive dataset, cloud base height and backscatter profile are recorded with the resolution of 10 m.

(5) Observation log

22 Aug. 2016 to Oct. 05 2016

(6) Preliminary results

Figure 2.4-1 shows the time series of cloud-base heights derived from the ceilometer during this cruise.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(8) Remarks (Times in UTC)

i) Window cleaning
   22:04 26 Aug. 2016
   00:44 03 Sep. 2016
   00:35 14 Sep. 2016
   02:42 20 Sep. 2016
   00:59 26 Sep. 2016

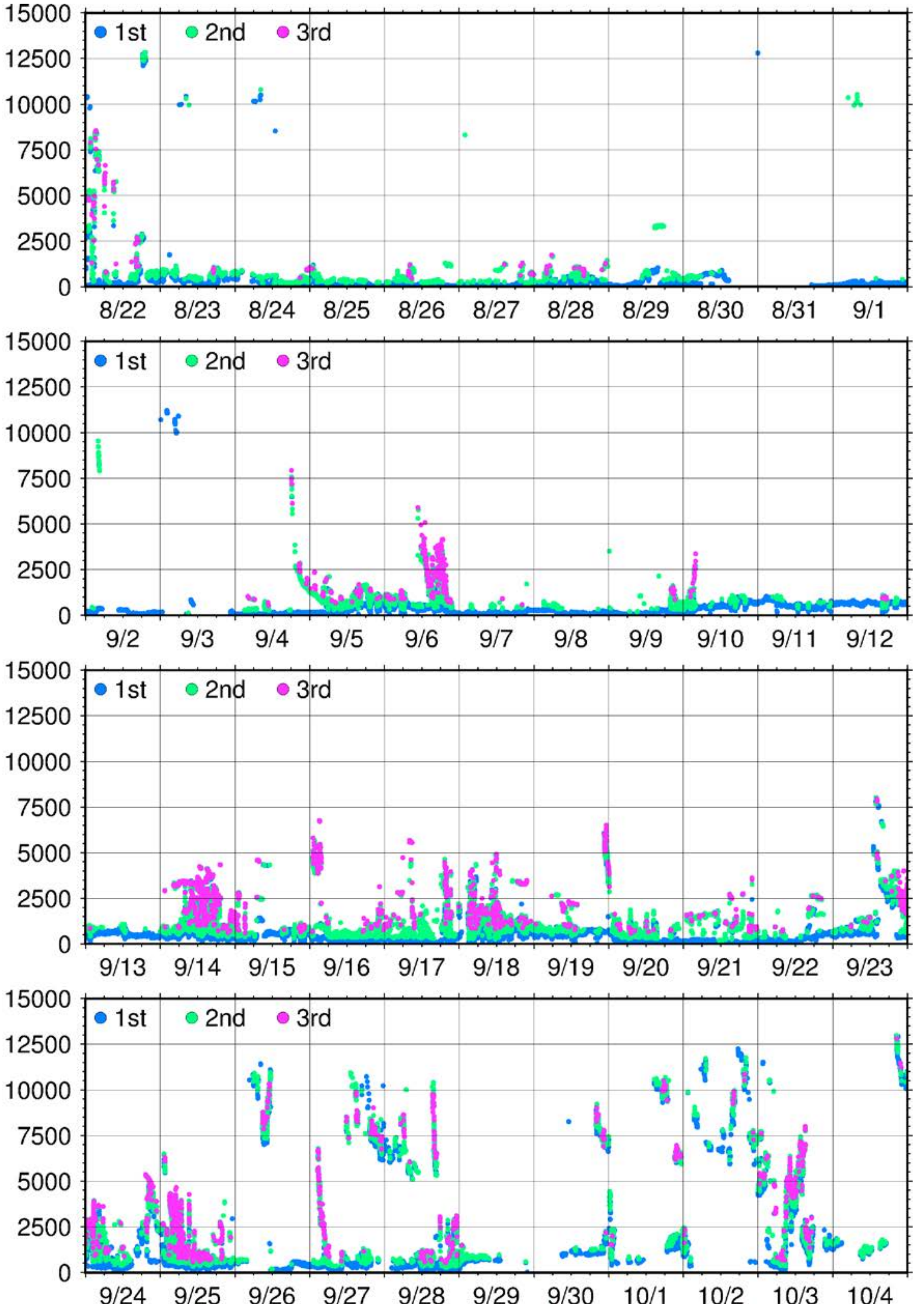


Figure 2.4-1: Time series of cloud base height during this cruise

2.5. Sea Spray

(1) Personnel

Jun Inoue	NIPR	PI
Toshihiro Ozeki	Hokkaido Univ. of Education	
Hajime Yamaguchi	University of Tokyo	
Makoto Toda	University of Tokyo	

(2) Objectives

Marine disasters caused by ship icing occur frequently in cold regions. The typical growth mechanism of sea spray icing is as follows. First, sea spray is generated from the bow of the ship. Next, the spray drifts and impinges upon the superstructure, after which there is a wet growth of ice from the brine water flow. To address icing on the ship, we focus on the impinging seawater spray. We investigated the drop size of seawater spray and made sampling of superstructure ice accretion on R/V Mirai.

(3) Parameters

Number of sea spray particles, the amount of spray impinging on ships, pitching angles and rolling angles at the bridge, and samples of sea spray ice (incl. snow and sea surface water samples).

(4) Instruments and methods

The amount of seawater spray and the size distribution of seawater particles were measured by a spray particle counter (SPC) and a marine rain gauge type spray gauge (MRS). The pitching angles and the rolling angles were measured by accelerometers (Marine Station; Weathernews).

(4.1) Spray particle counter (SPC)

The SPC, which was originally developed for the measurement of drifting snow, was improved to be a seawater spray particle counter. The flux distribution and the transport rate can be calculated as a function of particle size. The SPC (SPC-S7; Niigata Denki) consists of a sensor, data processor, and personal computer (Figure 2.5-1), and the measuring range is set from 100 to 1,000 μm in diameter. The sensing area is 25 mm wide, 3 mm high, and 0.5 mm deep, and SLD light is used as a parallel ray. The sensor measures light attenuation caused by particles that pass through the sensing area. The processor divides the particles into 32 classes depending on their diameters. The categories are shown in Table 2.5-1. The particles in each class are counted every second. The volume flux of the spray was calculated by ($4\pi r_c^3/3$) where r_c is class value of particle radius. The unit of the volume flux is millimeters [mm] per unit time, which is also the unit of precipitation.

(4.2) Marine rain gauge type spray gauge (MRS)

The marine rain gauge type spray gauge (MRS) consists of a marine rain gauge (CYG-50202, R M Young) and a cylindrical spray trap (Figure 2.5-2). The marine rain gauge was developed to measure rainfall on ships. It collects seawater spray or precipitation in a catchment funnel which has a cross sectional area of 100 cm^2. The inside diameter of the funnel is 112 mm. The cylindrical spray trap is attached above the marine rain gauge to capture the seawater spray from the horizontal direction instead of precipitation. The impinging spray particle is drained into the catchment funnel. The spray trap has a diameter of 76.3 mm, a height of 120 mm, and the projected area is 92 cm^2. The amount of seawater spray is measured every minute. The smallest measurable unit is 0.1 mm.

To reveal the positional relationship of the amount of seawater spray, observations were conducted from three different points on the deck. SPCs were installed one on center of the compass deck and one on the starboard of the bridge deck. The three MRSs were installed one on the compass deck (ch.1), one on the port (ch.2) and one on the starboard (ch.3) of the bridge deck. They were set on the bulwark behind 42 m from the bow.

(5) Station list or Observation log

The data of SPCs, MRS (ch.1) and pitching and rolling angles were obtained continuously through the cruise from Aug. 22 to Oct. 2. The data of MRSs (ch.2 and ch.3) were obtained continuously through the cruise from Aug. 22 to Sep. 4, and from Sep. 19 to Oct. 2. The sea spray ice sample was obtained on Sep. 16.

(6) Preliminary results

The SPCs were able to satisfactorily perform measurements of the particles. Figure 2.5-3 shows the size distribution of a splash which occurred on 5:23 UTC, Sep 16 (Figure 2.5-4). The two SPCs detected a large number of spray particles simultaneously. Figure 2.5-5 shows the spherical equivalent water drop volumes passing the gate of the SPC during this period.

Figure 2.5-6 shows time series of accumulated spray volume (incl. precipitation) that were detected by the MRSs during the cruse from Aug. 22 to Oct. 2. The further analyses will be done after the cruise.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.

<http://www.godac.jamstec.go.jp/darwin/e>

Table 2.5-1: Category number and class value of spray size.

Category	Class value of spray size [μm]
0	88
1	128
2	158
3	187
4	218
5	249
6	281
7	309
8	338
9	367
10	395
11	422
12	453
13	484
14	514
15	543
16	573
17	603
18	633
19	664
20	694
21	724
22	753
23	783
24	810
25	836
26	861
27	887
28	913
29	939
30	964
31	989

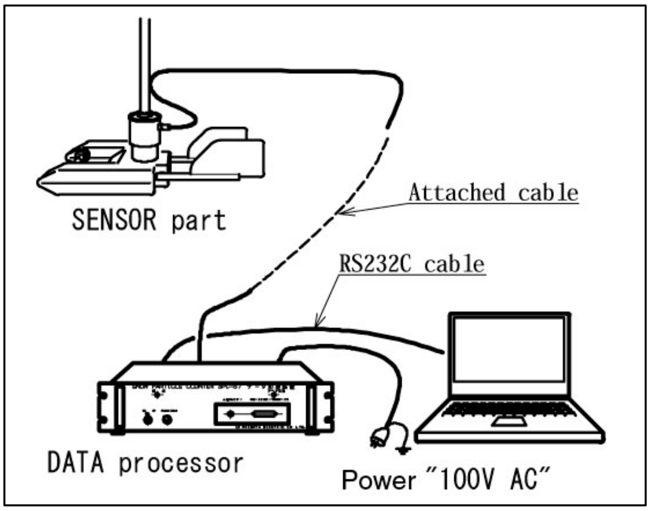


Figure 2.5-1: Schematic view of spray particle counter (SPC).

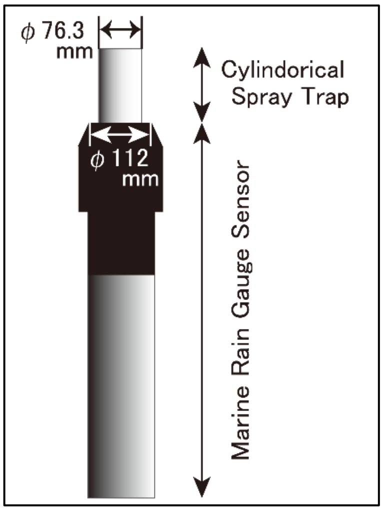


Figure 2.5-2: Schematic view of marine rain gauge type spray gauge (MRS).

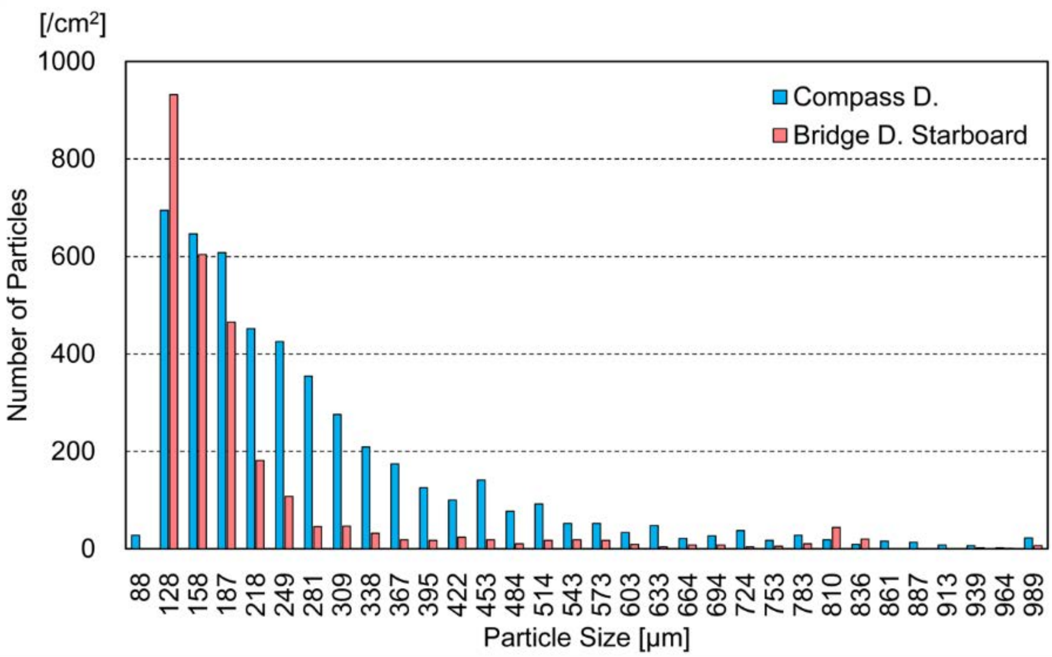


Figure 2.5-3: Spray size distribution of a splash which occurred on 5:23 UTC, Sep 16.

Figure 2.5-4: Sea spray generation at the port side on 5:23 UTC, Sep 16.

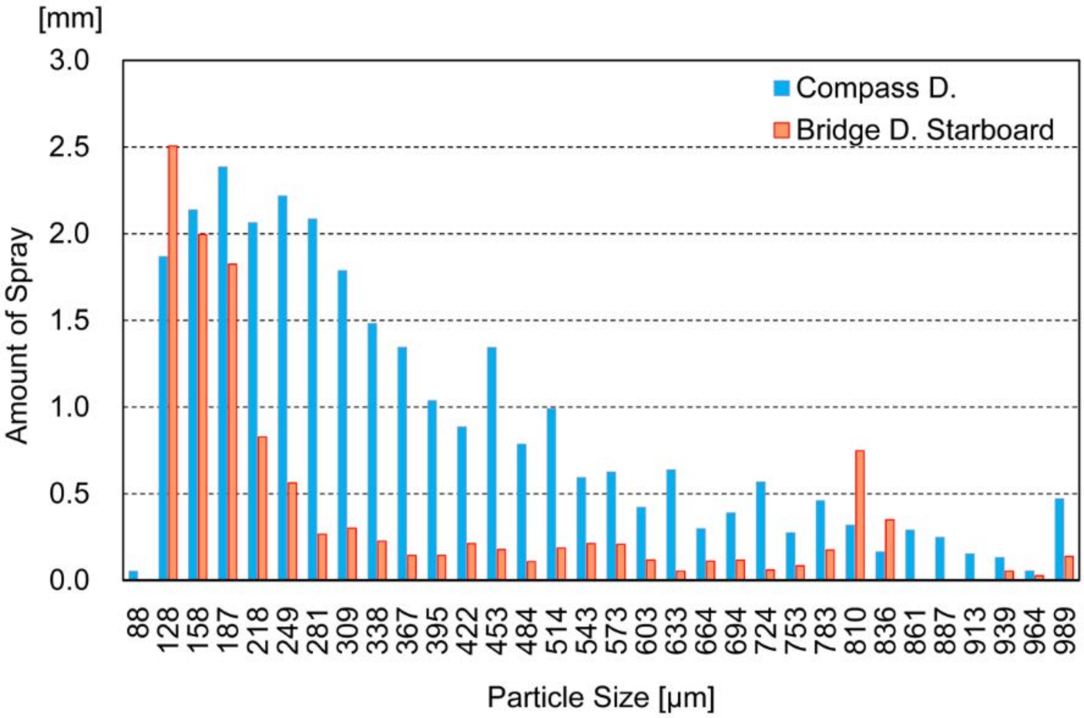


Figure 2.5-5: Amount of impinging sea spray which occurred on 5:23 UTC, Sep 16.

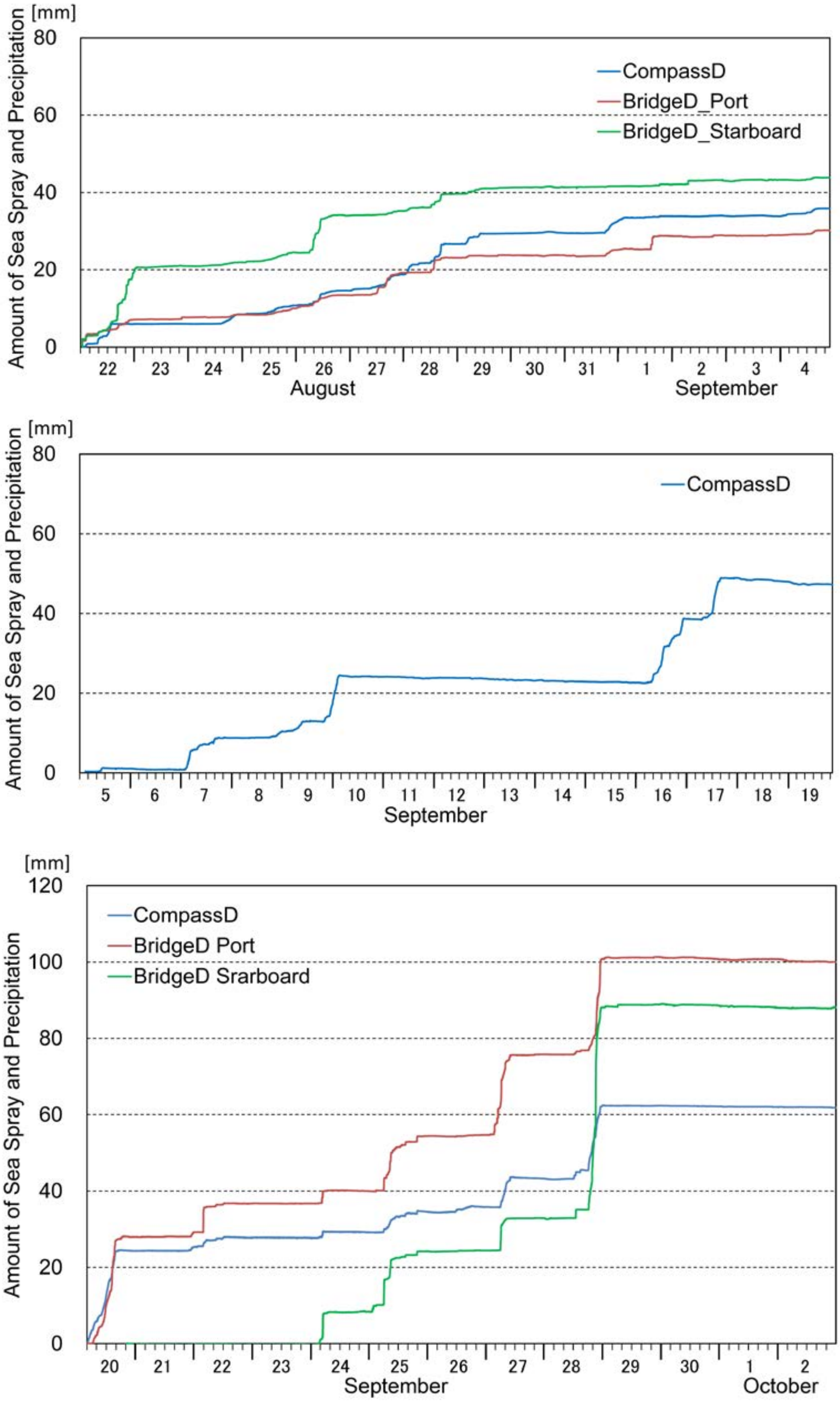


Figure 2.5-6: Time series of accumulated spray volume (incl. precipitation) that were detected by the MRSs during the cruse from Aug. 22 to Oct. 2.

2.6. Tropospheric gas and particles observation in the Arctic Marine Atmosphere

(1) Personnel

Fumikazu Taketani	JAMSTEC	- PI, on board
Yugo Kanaya	JAMSTEC	- not on board
Takuma Miyakawa	JAMSTEC	- not on board
Hisahiro Takashima	JAMSTEC/Fukuoka Univ.	- not on board
Yutaka Tobo	NIPR	- not on board
Yuichi Komazaki	JAMSTEC	- not on board
Masayuki Takigawa	JAMSTEC	- not on board
Kazuyuki Miyazaki	JAMSTEC	- not on board
Kazuhiko Miura	Tokyo Univ. of Sci.	- not on board
Kazuhiro Oshima	JAMSTEC	- not on board
Kazuyo Yamaji	JAMSTEC/Kobe Univ.	- not on board

(2) Objectives

· To investigate roles of aerosols in the marine atmosphere in relation to climate change

· To investigate processes of biogeochemical cycles between the atmosphere and the ocean.

· To investigate contribution of suspended particles to the rain, and snow

(3) Parameters

· Black carbon(BC) and fluorescent particles
· Particle size distribution
· Particle number concentration
· Composition of ambient particles
· Composition of snow, rain and sea ice
· Aerosol extinction coefficient (AEC)
· Surface ozone(O3), and carbon monoxide(CO) mixing ratios

(4) Instruments and methods

(4-1) Online aerosol observations:

(4-1-1) Particle umber concentration and size distribution

The number concentration of particles was measured by mixing condensation particle counter (MCPC) (, TSI). The size distribution of particles was measured by a scanning mobility particle sizer (SMPS) (comprising a 3080 Electrostatic Classifier with 3081 differential mobility analyzer (DMA), a condensation particle counter (CPC) model 3010, TSI), and a handheld optical particle counter (OPC, KR-12A, Rion).

(4-1-2) Black carbon (BC)

Number and mass BC concentration were measured by an instrument based on laser-induced incandescence, single particle soot photometer (SP2) (model D, Droplet Measurement Technologies). The laser-induced incandescence technique based on intracavity Nd:YVO4 laser operating at 1064 nm were used for detection of single particles of BC.

(4-1-3) Fluorescent property

Fluorescent properties of aerosol particles were measured by a single particle fluorescence sensor, Waveband Integrated bioaerosol sensor (WIBS4) (WIBS-4A, Droplet Measurement Technologies). Two pulsed xenon lamps emitting UV light (280 nm and 370 nm) were used for excitation. Fluorescence emitted from a single particle within 310–400 nm and 420–650 nm wavelength windows was recorded.

For SP2, SMPS, and MCPC instruments, the ambient air was commonly sampled from the compass deck by a 3-m-long conductive tube through the dryer to dry up the particles, and then introduced to each instrument installed at the environmental research room. WIBS4 and OPC instruments were installed at the compass deck. The ambient air was directory introduced to the instruments.

(4-2) Ambient air sampling

Ambient air samplings were carried out by air samplers installed at compass deck. Ambient particles were collected on the quartz filter (ϕ =110mm) and nuclepore membrane filter (ϕ =47mm) along cruise track to analyze their composition and ice nuclei ability using a high-volume air sampler (HVS, HV-525PM, SIBATA) and a handmade air sampler operated at flow rate of 500 L/min and 10L/min, respectively . To avoid collecting particles emitted from the funnel of the own vessel, the sampling period was controlled automatically by using a "wind-direction selection system". Coarse and fine particles separated at the diameter of 2.5 μm were collected on quartz filters, while all size particles were collected on nuclepore membrane filter. These sampling logs are listed in Tables 2.6-1 and 2.6-2. To investigate the morphology of particles by the electron microscope and biological material in particles by fluorescence detection technique, temporal samplings (5 – 60min) are carried out using air sampler (Kl-1L, PIXE INTERNATIONAL) and handmade sampler operated at flow rate of 1 L/min and 2.7L/min, respectively. These sampling logs are listed in Tables 2.6-3 and 2.6-4. All samples are going to be analyzed in laboratory.

(4-3) Snow, rain and ice sampling

Snow and rain samples were corrected using metal tray and rain sampler, respectively. Sea ices were also sampled. These sampling logs are listed in Tables 2.6-5. To investigate the interaction from aerosols to rain/snow, these samples are going to be analyzed in laboratory.

(4-4) MAX-DOAS

Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS), a passive remote sensing technique measuring spectra of scattered visible and ultraviolet (UV) solar radiation, was used for atmospheric aerosol and gas profile measurements. Our MAX-DOAS instrument consists of two main parts: an outdoor telescope unit and an indoor spectrometer (Acton SP-2358 with Princeton Instruments PIXIS-400B), connected to each other by a 14-m bundle optical fiber cable. The telescope unit was updated before the cruise; only one-axis scan for elevation angle was attained, while capability of azimuth scan was not employed. The line of sight was in the directions of the portside of the vessel and the scanned elevation angles were 1.5, 3, 5, 10, 20, 30, 90 degrees in the 30-min cycle. The roll motion of the ship was measured to autonomously compensate additional motion of the prism, employed for scanning the elevation angle. For the selected spectra recorded with elevation angles with good accuracy, DOAS spectral fitting was performed to quantify the slant column density (SCD) of NO2 (and other gases) and O4 (O2-O2, collision complex of oxygen) for each elevation angle. Then, the O4 SCDs were converted to the aerosol optical depth (AOD) and the vertical profile of aerosol extinction coefficient (AEC) using an optimal estimation inversion method with a radiative transfer model. Using derived aerosol information, retrievals of the tropospheric vertical column/profile of NO2 and other gases were made.

(4-5) CO and O3

Ambient air was continuously sampled on the compass deck and drawn through ~20-m-long Teflon tubes connected to a gas filter correlation CO analyzer (Model 48C, Thermo Fisher Scientific) and a UV photometric ozone analyzer (Model 49C, Thermo Fisher Scientific), located in the Research Information Center. The data will be used for characterizing air mass origins.

(5) Station list or Observation log

Table 2.6-1: Logs of ambient particles sampling on the quartz filter

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1606-HV-001	2016	08	23	1:36	UTC	40	12.5800	N	149	5.3	E
MR1606-HV-002	2016	08	24	23:43	UTC	45	57.3900	N	159	09.282	E
MR1606-HV-003	2016	08	26	21:49	UTC	51	45.3181	N	168	51.1661	E
MR1606-HV-004	2016	08	27	22:58	UTC	55	27.0996	N	174	24.7067	E
MR1606-HV-005	2016	08	28	23:58	UTC	58	38.3750	N	179	32.0428	W
MR1606-HV-006	2016	08	29	23:44	UTC	62	45.3200	N	174	25.5348	W
MR1606-HV-007	2016	09	01	1:41	UTC	66	18.8440	N	168	53.7834	W
MR1606-HV-008	2016	09	04	3:26	UTC	71	29.6475	N	158	3.6164	W
MR1606-HV-009	2016	09	07	21:11	UTC	71	34.6852	N	152	57.3655	W
MR1606-HV-010	2016	09	10	20:35	UTC	72	29.7263	N	159	01.1846	W
MR1606-HV-011	2016	09	12	23:35	UTC	72	14.8244	N	159	8.8654	W
MR1606-HV-012	2016	09	14	22:20	UTC	73	30.4546	N	159	17.3246	W
MR1606-HV-013	2016	09	17	19:40	UTC	71	26.1774	N	156	33.0959	W
MR1606-HV-014	2016	09	19	21:35	UTC	70	29.7833	N	168	44.5328	W
MR1606-HV-015	2016	09	21	20:40	UTC	66	52.0475	N	168	54.1556	W
MR1606-HV-016	2016	09	24	20:05	UTC	62	22.7145	N	174	10.6697	W
MR1606-HV-017	2016	09	26	21:00	UTC	55	19.7797	N	174	13.0685	E
MR1606-HV-018	2016	09	27	21:00	UTC	52	36.7638	N	169	50.9038	E
MR1606-HV-019	2016	09	29	23:19	UTC	46	03.1747	N	159	19.0799	E
MR1606-HV-020	2016	10	01	1:35	UTC	42	38.3706	N	153	47.4419	E

Table 2.6-2: Logs of ambient particles sampling on the nuclepore membrane filter

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1606-IN-001	2016	08	23	1:36	UTC	40	12.5800	N	149	5.3	E
MR1606-IN-002	2016	08	24	23:43	UTC	45	57.3900	N	159	09.282	E
MR1606-IN-003	2016	08	26	21:49	UTC	51	45.3181	N	168	51.1661	E
MR1606-IN-004	2016	08	27	22:58	UTC	55	27.0996	N	174	24.7067	E
MR1606-IN-005	2016	08	28	23:58	UTC	58	38.3750	N	179	32.0428	W
MR1606-IN-006	2016	08	29	23:44	UTC	62	45.3200	N	174	25.5348	W
MR1606-IN-007	2016	09	01	1:41	UTC	66	18.8440	N	168	53.7834	W
MR1606-IN-008	2016	09	04	3:26	UTC	71	29.6475	N	158	3.6164	W
MR1606-IN-009	2016	09	07	21:11	UTC	71	34.6852	N	152	57.3655	W
MR1606-IN-010	2016	09	10	20:35	UTC	72	29.7263	N	159	01.1846	W
MR1606-IN-011	2016	09	12	23:35	UTC	72	14.8244	N	159	8.8654	W
MR1606-IN-012	2016	09	14	22:20	UTC	73	30.4546	N	159	17.3246	W
MR1606-IN-013	2016	09	17	19:40	UTC	71	26.1774	N	156	33.0959	W
MR1606-IN-014	2016	09	19	21:35	UTC	70	29.7833	N	168	44.5328	W
MR1606-IN-015	2016	09	21	20:40	UTC	66	52.0475	N	168	54.1556	W
MR1606-IN-016	2016	09	24	20:05	UTC	62	22.7145	N	174	10.6697	W
MR1606-IN-017	2016	09	26	21:00	UTC	55	19.7797	N	174	13.0685	E
MR1606-IN-018	2016	09	27	21:00	UTC	52	36.7638	N	169	50.9038	E
MR1606-IN-019	2016	09	29	23:19	UTC	46	03.1747	N	159	19.0799	E
MR1606-IN-020	2016	10	01	1:35	UTC	42	38.3706	N	153	47.4419	E

Table 2.6-3: Logs of ambient particles sampling for the electron microscope

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1606-Tel-001	2016	08	23	4:10	UTC	40	10.0000	N	149	56	E
MR1606-Tel-002	2016	08	24	3:08	UTC	43	12.0000	N	154	10	E
MR1606-Tel-003	2016	08	25	3:55	UTC	46	31.4700	N	160	07.81	E
MR1606-Tel-004	2016	08	25	21:45	UTC	48	53.3920	N	164	14.163	E
MR1606-Tel-005	2016	08	26	21:09	UTC	51	22.8000	N	168	25.9050	E
MR1606-Tel-006	2016	08	27	22:11	UTC	55	16.0580	N	174	07.7040	E
MR1606-Tel-007	2016	08	27	22:39	UTC	55	19.4510	N	174	13.46	E
MR1606-Tel-008	2016	08	28	20:58	UTC	58	26.1970	N	179	56.2772	W
MR1606-Tel-009	2016	08	29	20:25	UTC	62	14.1130	N	174	02.175	W
MR1606-Tel-010	2016	08	30	20:18	UTC	64	57.5668	N	169	48.92	W
MR1606-Tel-011	2016	09	01	20:42	UTC	68	02.0780	N	168	50.178	W
MR1606-Tel-012	2016	09	02	20:33	UTC	70	58.0680	N	168	31.974	W
MR1606-Tel-013	2016	09	03	0:31	UTC	70	45.2409	N	166	36.4	W
MR1606-Tel-014	2016	09	04	1:15	UTC	71	25.3778	N	158	43.9651	W
MR1606-Tel-015	2016	09	04	22:17	UTC	71	23.2170	N	158	36.6502	W
MR1606-Tel-016	2016	09	07	2:22	UTC	71	41.9938	N	155	05.6618	W
MR1606-Tel-017	2016	09	08	2:55	UTC	71	35.6618	N	152	07.0001	W
MR1606-Tel-018	2016	09	08	20:33	UTC	72	29.4846	N	155	20.7671	W
MR1606-Tel-019	2016	09	10	19:52	UTC	72	29.6800	N	159	01.2666	W
MR1606-Tel-020	2016	09	11	20:06	UTC	72	28.0510	N	158	49.1779	W
MR1606-Tel-021	2016	09	13	19:47	UTC	73	30.0365	N	157	00.9285	W
MR1606-Tel-022	2016	09	14	19:57	UTC	73	30.4546	N	159	17.3246	W
MR1606-Tel-023	2016	09	16	21:58	UTC	72	28.5626	N	155	25.22153	W
MR1606-Tel-024	2016	09	17	22:48	UTC	72	28.4718	N	155	18.0691	W
MR1606-Tel-025	2016	09	18	23:34	UTC	71	59.3639	N	165	52.6528	W
MR1606-Tel-026	2016	09	19	19:13	UTC	70	47.6838	N	168	44.8441	W
MR1606-Tel-027	2016	09	20	20:04	UTC	67	57.4610	N	168	42.1045	W
MR1606-Tel-028	2016	09	22	0:12	UTC	66	16.2526	N	168	53.5846	W
MR1606-Tel-029	2016	09	22	19:05	UTC	65	03.0994	N	169	37.7063	W
MR1606-Tel-030	2016	09	22	20:27	UTC	65	03.0994	N	169	37.7063	W
MR1606-Tel-031	2016	09	23	2:22	UTC	64	41.2392	N	168	42.6308	W
MR1606-Tel-032	2016	09	24	0:20	UTC	64	22.1572	N	167	15.7412	W
MR1606-Tel-033	2016	09	24	21:52	UTC	62	03.7675	N	174	45.6556	W
MR1606-Tel-034	2016	09	25	20:56	UTC	58	30.2093	N	179	49.5903	W
MR1606-Tel-035	2016	09	26	1:12	UTC	58	02.3553	N	179	17.0511	W
MR1606-Tel-036	2016	09	26	21:00	UTC	55	19.7797	N	174	13.0685	E
MR1606-Tel-037	2016	09	28	2:13	UTC	52	05.2892	N	169	13.7420	E
MR1606-Tel-038	2016	09	28	23:16	UTC	49	08.0530	N	164	38.3433	E
MR1606-Tel-039	2016	09	29	23:19	UTC	46	03.1747	N	159	19.0799	E
MR1606-Tel-040	2016	09	30	22:39	UTC	43	00.8735	N	154	24.3252	E
MR1606-Tel-041	2016	10	02	0:03	UTC	42	12.1217	N	149	07.3454	E

Table 2.6-4: Logs of ambient particles sampling for the fluorescence detection technique

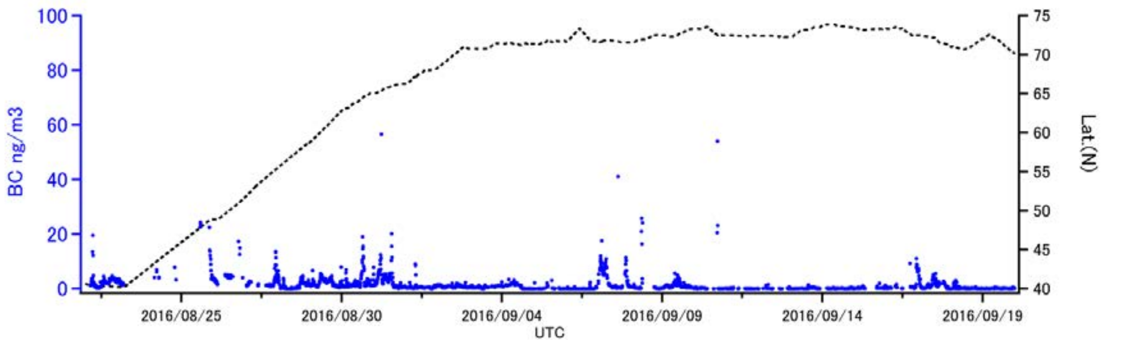
On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1606-Bio-001	2016	08	24	3:32	UTC	43	17.8275	N	154	49.96	E
MR1606-Bio-002	2016	08	25	22:33	UTC	48	53.3288	N	164	14.7195	E
MR1606-Bio-003	2016	08	26	21:38	UTC	51	25.5600	N	168	28.87	E
MR1606-Bio-005	2016	08	28	1:12	UTC	55	40.7453	N	174	50.0181	E
MR1606-Bio-006	2016	08	29	0:41	UTC	58	51.2330	N	179	05.759	W
MR1606-Bio-007	2016	08	30	1:07	UTC	63	01.6737	N	174	04.6133	W
MR1606-Bio-008	2016	08	30	20:18	UTC	64	57.5568	N	169	48.92	W
MR1606-Bio-009	2016	08	31	1:02	UTC	65	03.8856	N	169	38.2332	W
MR1606-Bio-010	2016	09	01	1:26	UTC	66	16.3030	N	168	54.3853	W
MR1606-Bio-011	2016	09	01	20:55	UTC	68	02.0000	N	168	50.686	W
MR1606-Bio-012	2016	09	02	20:33	UTC	70	58.0680	N	168	31.0947	W
MR1606-Bio-013	2016	09	03	0:31	UTC	70	45.2409	N	166	36.4	W
MR1606-Bio-014	2016	09	05	0:09	UTC	71	23.0980	N	158	36.441	W
MR1606-Bio-016	2016	09	05	20:08	UTC	71	44.0555	N	155	8.2837	W
MR1606-Bio-017	2016	09	06	19:18	UTC	71	43.8582	N	155	7.1617	W
MR1606-Bio-019	2016	09	07	2:28	UTC	71	41.9938	N	155	05.6618	W
MR1606-Bio-020	2016	09	08	2:55	UTC	71	35.6618	N	152	07.0001	W
MR1606-Bio-021	2016	09	08	20:33	UTC	72	29.4846	N	155	20.7671	W
MR1606-Bio-023	2016	09	09	21:19	UTC	73	16.4181	N	160	27.6488	W
MR1606-Bio-025	2016	09	08	20:33	UTC	73	18.3729	N	160	50.8353	W
MR1606-Bio-026	2016	09	10	23:45	UTC	72	27.9422	N	159	01.0543	W
MR1606-Bio-027	2016	09	11	0:26	UTC	72	27.5354	N	159	01.4714	W
MR1606-Bio-028	2016	09	11	1:44	UTC	72	27.0429	N	159	00.9489	W
MR1606-Bio-029	2016	09	11	20:06	UTC	72	28.0510	N	158	49.1779	W
MR1606-Bio-030	2016	09	12	23:35	UTC	72	14.6602	N	159	09.3886	W
MR1606-Bio-031	2016	09	13	1:00	UTC	72	15.9600	N	159	08.4090	W
MR1606-Bio-032	2016	09	13	19:57	UTC	73	30.0365	N	157	00.9285	W
MR1606-Bio-033	2016	09	14	19:58	UTC	73	30.0365	N	157	00.9285	W
MR1606-Bio-034	2016	09	14	22:20	UTC	73	30.0365	N	157	00.9285	W
MR1606-Bio-035	2016	09	15	21:45	UTC	73	18.3340	N	160	48.0391	W
MR1606-Bio-036	2016	09	16	1:58	UTC	73	17.9674	N	160	46.8111	W
MR1606-Bio-037	2016	09	16	22:00	UTC	72	28.5626	N	155	25.22153	W
MR1606-Bio-038	2016	09	17	0:33	UTC	72	28.4718	N	155	18.0691	W
MR1606-Bio-041	2016	09	18	0:46	UTC	71	01.4602	N	158	29.8529	W
MR1606-Bio-043	2016	09	18	23:34	UTC	71	59.3639	N	165	52.6528	W
MR1606-Bio-044	2016	09	19	19:13	UTC	70	47.6838	N	168	44.8441	W
MR1606-Bio-045	2016	09	19	21:39	UTC	70	29.5286	N	168	44.6611	W
MR1606-Bio-046	2016	09	20	18:55	UTC	68	00.4123	N	168	45.0968	W
MR1606-Bio-047	2016	09	20	20:04	UTC	67	57.4610	N	168	42.1045	W
MR1606-Bio-048	2016	09	21	4:22	UTC	68	18.0936	N	167	03.2818	W
MR1606-Bio-049	2016	09	22	0:12	UTC	66	16.2526	N	168	53.5846	W
MR1606-Bio-050	2016	09	22	19:05	UTC	65	03.0994	N	169	37.7063	W
MR1606-Bio-051	2016	09	22	20:27	UTC	65	03.0994	N	169	37.7063	W
MR1606-Bio-052	2016	09	23	2:23	UTC	64	41.2392	N	168	42.6308	W
MR1606-Bio-053	2016	09	23	21:05	UTC	64	21.7649	N	165	43.1016	W
MR1606-Bio-054	2016	09	24	0:20	UTC	64	22.1572	N	167	15.7412	W
MR1606-Bio-055	2016	09	24	20:05	UTC	62	22.7145	N	174	19.5452	W
MR1606-Bio-056	2016	09	24	21:52	UTC	62	03.7675	N	174	45.6556	W
MR1606-Bio-057	2016	09	25	0:32	UTC	61	39.0001	N	175	21.0661	W
MR1606-Bio-058	2016	09	25	1:34	UTC	61	28.0207	N	175	33.5248	W
MR1606-Bio-059	2016	09	25	21:05	UTC	58	30.0452	N	179	51.4322	W
MR1606-Bio-060	2016	09	25	21:34	UTC	58	29.6575	N	179	54.8241	W
MR1606-Bio-061	2016	09	26	1:12	UTC	58	02.3553	N	179	17.0511	W
MR1606-Bio-062	2016	09	26	1:20	UTC	58	01.3338	N	179	15.1761	E
MR1606-Bio-063	2016	09	26	21:00	UTC	55	19.7797	N	174	13.0685	E
MR1606-Bio-064	2016	09	27	1:06	UTC	54	48.8620	N	173	17.5821	E
MR1606-Bio-065	2016	09	27	21:38	UTC	52	36.7638	N	169	50.9038	E
MR1606-Bio-066	2016	09	28	2:13	UTC	52	05.2892	N	169	13.7420	E
MR1606-Bio-067	2016	09	29	23:19	UTC	46	03.1747	N	159	19.0799	E
MR1606-Bio-068	2016	09	30	22:39	UTC	43	00.8735	N	154	24.3252	E
MR1606-Bio-069	2016	10	01	3:36	UTC	42	20.5537	N	153	20.3791	E
MR1606-Bio-069	2016	10	02	0:03	UTC	42	12.1217	N	149	07.3454	E

Table 2.6-5: List of snow, rain, and sea ice sampling

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1606-OK-001	2016	08	23	4:52	UTC	40	10.0000	N	150	0	E
MR1606-OK-002	2016	08	26	21:49	UTC	51	45.3181	N	168	51.1661	E
MR1606-OK-003	2016	08	30	1:58	UTC	63	06.0000	N	174	58.51	W
MR1606-OK-004	2016	09	06	20:36	UTC	71	43.9659	N	155	08.2872	W
MR1606-OK-005	2016	09	07	2:40	UTC	71	41.8129	N	155	05.7492	W
MR1606-OK-006	2016	09	07	5:40	UTC	71	51.7375	N	155	48.4552	W
MR1606-OK-007	2016	09	07	20:50	UTC	71	35.0271	N	153	12.0804	W
MR1606-OK-008	2016	09	09	20:30	UTC	73	15.7245	N	160	14.9544	W
MR1606-OK-009	2016	09	09	22:50	UTC	73	17.7080	N	160	48.6272	W
MR1606-OK-010	2016	09	10	1:00	UTC	73	18.2487	N	160	49.6985	W
MR1606-OK-011	2016	09	11	1:40	UTC	72	27.4280	N	158	59.74	W
MR1606-OK-012	2016	09	15	0:20	UTC	73	30.0365	N	157	00.9285	W
MR1606-OK-013	2016	09	16	1:30	UTC	73	17.8265	N	160	47.3963	W
MR1606-OK-014	2016	09	16	21:46	UTC	72	28.6347	N	155	25.3155	W
MR1606-OK-015	2016	09	17	0:45	UTC	72	28.4700	N	155	18.0961	W
MR1606-OK-016	2016	09	17	19:40	UTC	71	27.0001	N	156	30.8299	W
MR1606-OK-017	2016	09	17	22:30	UTC	71	07.7011	N	157	47.6706	W
MR1606-OK-018	2016	09	18	5*35	UTC	70	51.7084	N	160	30.3442	W
MR1606-OK-019	2016	09	18	19:45	UTC	71	35.3114	N	164	57.5523	W
MR1606-OK-020	2016	09	20	4:55	UTC	69	25.8776	N	168	44.9248	W
MR1606-OK-021	2016	09	20	19:00	UTC	68	00.4123	N	168	45.0968	W
MR1606-OK-022	2016	09	22	3:30	UTC	65	51.0613	N	168	47.0244	W
MR1606-OK-023	2016	09	22	20:10	UTC	65	03.0994	N	169	37.7063	W
MR1606-OK-024	2016	09	24	5:30	UTC	64	20.3343	N	169	42.3974	W
MR1606-OK-025	2016	09	25	21:10	UTC	58	30.0452	N	179	51.4332	W
MR1606-OK-026	2016	09	27	21:40	UTC	52	36.7638	N	169	50.9038	E
MR1606-OK-027	2016	09	27	23:20	UTC	49	08.0530	N	164	38.3433	E
MR1606-ICE-001	2016	09	03	11:30	UTC	71	25.5532	N	158	43.2475	W
MR1606-ICE-002	2016	09	10	23:45	UTC	72	27.9422	N	159	01.0543	W
MR1606-ICE-003	2016	09	11	0:26	UTC	72	27.5354	N	159	01.4714	W
MR1606-snow-001	2016	09	09	20:00	UTC	73	15.4713	N	160	07.4181	W
MR1606-snow-002	2016	09	10	0:34	UTC	73	18.1995	N	160	49.1168	W
MR1606-snow-003	2016	09	10	0:34	UTC	73	18.1995	N	160	49.1168	W
MR1606-snow-004	2016	09	17	22:30	UTC	71	07.7011	N	157	47.6706	W
MR1606-snow-005	2016	09	18	5*35	UTC	70	51.7084	N	160	30.3442	W
MR1606-snow-006	2016	09	18	19:45	UTC	71	35.3114	N	164	57.5523	W
MR1606-rain-007	2016	09	20	4:55	UTC	69	25.8776	N	168	44.9248	W
MR1606-rain-008	2016	09	20	19:00	UTC	68	00.4123	N	168	45.0968	W

(6) Preliminary results

Figure 2.6-1: temporal variation of BC mass concentration



(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

2.7. Greenhouse gasses observation

(1) Personnel

Yasunori Tohjima	NIES	-PI, not on board
Shigeyuki Ishidoya	AIST	-not on board
Fumikazu Taketani	JAMSTEC	-on board
Shinji Morimoto	Tohoku Univ.	-not on board
Shuji Aoki	Tohoku Univ.	-not on board
Ryo Fujita	Tohoku Univ.	-not on board
Keiichi Katsumata	NIES	-not on board
Daisuke Goto	NIPR	-not on board
Kentaro Ishijima	JAMSTEC	-not on board
Prabir Patra	JAMSTEC	-not on board
Hiroshi Uchida	JAMSTEC	-not on board
Shohei Murayama	AIST	-not on board

(2) Objective

(2-1) Continuous observations of CO_2, CH_4 and CO mixing ratios

The Arctic region is considered to be vulnerable to the global warming, which would potentially enhance emissions of the greenhouse gases including CO_2 and CH_4 from the carbon pools in the Arctic regions into the atmosphere. The objective of this study is to detect the increases in the atmospheric greenhouse gas levels associated with the ongoing global warming in the Arctic region in the early stage. The continuous observations of the atmospheric CO_2 and CH_4 mixing ratios during this MR16-06 cruise would allow us to detect the enhanced mixing ratios associated with the regional emissions and to estimate the distribution of the regional emission sources. The atmospheric CO mixing ratios, which were also observed at the same time, can be used as an indicator of the anthropogenic emissions associated with the combustion processes.

(2-2) Discrete flask sampling

In order to clarify spatial variations and air-sea exchanges of the greenhouse gases at northern high latitude, whole air samples were corrected into 40 stainless-steel flasks on-board R/V MIRAI (MR16-06). The collected air samples will be analyzed for the mixing ratios of CO_2, O_2, Ar, CH_4, CO, N_2O and SF_6 and the stable isotope ratios of CO_2 and CH_4.

(3) Parameters

(3-1) Continuous observations of CO_2, CH_4 and CO mixing ratios

Mixing ratios of atmospheric CO_2, CH_4, and CO.

(3-2) Discrete flask sampling

Mixing ratios of atmospheric CO_2, O_2 (O_2/N_2 ratio), Ar (Ar/N_2 ratio), CH_4, CO, N_2O and SF_6, $\delta^{13}C$ and $\delta^{18}O$ of CO_2, $\delta^{13}C$ and δD of CH_4.

(4) Instruments and Methods

(4-1) Continuous observations of CO_2, CH_4 and CO mixing ratios

Atmospheric CO_2, CH_4, and CO mixing ratios were measured by a wavelength-scanned cavity ring-down spectrometer (WS-CRDS, Picarro, G2401). An air intake, capped with an inverted stainless steel beaker covered with stainless steel mesh, was placed on the right-side of the upper deck. A diaphragm pump (GAST, MOA-P108) was used to draw in the outside air at a flow rate of ~8 L min^{-1}. Water vapor in the sample air was removed to a dew pint of about 2°C and about -35°C by passing it through a thermoelectric dehumidifier (KELK, DH-109) and a Nafion drier (PERMA PURE, PD-50T-24), respectively. Then, the dried sample air was introduced into the WS-CRDS at a flow rate of 100 ml min^{-1}. The WS-CRDS were automatically calibrated every 25 hour by introducing 3 standard airs with known CO_2, CH_4 and CO mixing ratios. The analytical precisions for CO_2, CH_4 and CO mixing ratios are about 0.02 ppm, 0.3 ppb and 3 ppb, respectively.

(4-2) Discrete flask sampling

The air sampling equipment consisted of an air intake, a piston pump (GAST LOA), a water trap, solenoid valves (CKD), an ethanol bath as refrigerant, a flow meter and an immersion cooler (EYELA ECS-80). Ambient air was pumped using a piston pump from an air intake, dried cryogenically and filled into a 1 L stainless-steel flask at a pressure of 0.55 MPa.

(5) Station list or Observation log

The continuous observations of CO_2, CH_4 and CO mixing ratios were conducted during the entire cruise. Sampling logs of the discrete flask sampling are listed in Table 2.7-1.

Tabel 2.7-1 : List of logs of the discrete flask sampling

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1606-Flask_Gas_001	2016	08	23	9:37	UTC	40	49.169	N	150	58.816	E
MR1606-Flask_Gas_002	2016	08	24	8:24	UTC	43	53.0925	N	155	49.0918	E
MR1606-Flask_Gas_003	2016	08	25	8:12	UTC	47	04.1943	N	161	2.5080	E
MR1606-Flask_Gas_004	2016	08	26	13:27	UTC	48	52.2320	N	164	17.6971	E
MR1606-Flask_Gas_005	2016	08	27	6:04	UTC	51	51.2220	N	170	06.1812	E
MR1606-Flask_Gas_006	2016	08	28	6:09	UTC	56	22.2190	N	176	07.4533	E
MR1606-Flask_Gas_007	2016	08	29	6:15	UTC	59	46.5100	N	177	51.8409	W
MR1606-Flask_Gas_008	2016	08	30	2:47	UTC	63	05.9170	N	173	58.9815	W
MR1606-Flask_Gas_009	2016	08	31	3;51	UTC	65	16.2052	N	169	03.3740	W
MR1606-Flask_Gas_010	2016	09	01	2:02	UTC	66	22.9438	N	168	53.9834	W
MR1606-Flask_Gas_011	2016	09	01	22:12	UTC	68	04.2297	N	168	50.3751	W
MR1606-Flask_Gas_012	2016	09	03	2:24	UTC	70	44.8335	N	165	31.5337	W
MR1606-Flask_Gas_013	2016	09	04	0:47	UTC	71	25.5532	N	158	43.2475	W
MR1606-Flask_Gas_014	2016	09	05	3:38	UTC	71	22.6856	N	158	37.5291	W
MR1606-Flask_Gas_015	2016	09	06	3:40	UTC	72	10.7581	N	155	00.0192	W
MR1606-Flask_Gas_016	2016	09	07	3:09	UTC	71	44.2740	N	155	12.5010	W
MR1606-Flask_Gas_017	2016	09	08	3:42	UTC	71	40.6696	N	152	28.7447	W
MR1606-Flask_Gas_018	2016	09	09	2:09	UTC	72	28.6387	N	155	24.6434	W
MR1606-Flask_Gas_019	2016	09	10	3:35	UTC	73	18.1516	N	160	35.5822	W
MR1606-Flask_Gas_020	2016	09	11	4:43	UTC	72	27.0470	N	158	59.7326	W
MR1606-Flask_Gas_021	2016	09	12	3:48	UTC	72	24.5986	N	158	27.1432	W
MR1606-Flask_Gas_022	2016	09	13	1:57	UTC	72	18.9617	N	158	55.0247	W
MR1606-Flask_Gas_023	2016	09	14	3:58	UTC	73	52.0466	N	156	10.9524	W
MR1606-Flask_Gas_024	2016	09	15	1:35	UTC	73	23.1519	N	160	13.1688	W
MR1606-Flask_Gas_025	2016	09	16	0:58	UTC	73	18.4700	N	160	44.0635	W
MR1606-Flask_Gas_026	2016	09	17	1:21	UTC	72	28.4076	N	155	19.7498	W
MR1606-Flask_Gas_027	2016	09	18	1:15	UTC	71	03.2706	N	158	38.6753	W
MR1606-Flask_Gas_028	2016	09	19	0:08	UTC	71	59.2442	N	165	53.5707	W
MR1606-Flask_Gas_029	2016	09	20	4:04	UTC	69	29.9847	N	168	44.6925	W
MR1606-Flask_Gas_030	2016	09	21	2:38	UTC	68	12.1775	N	167	20.1248	W
MR1606-Flask_Gas_031	2016	09	22	0:42	UTC	66	16.3242	N	168	53.5760	W
MR1606-Flask_Gas_032	2016	09	22	21:24	UTC	65	02.9636	N	169	39.7344	W
MR1606-Flask_Gas_033	2016	09	24	1:53	UTC	64	21.8061	N	167	59.2905	W
MR1606-Flask_Gas_034	2016	09	25	0:52	UTC	61	35.9200	N	175	24.5098	W
MR1606-Flask_Gas_035	2016	09	26	1:38	UTC	57	59.3282	N	179	11.2951	E
MR1606-Flask_Gas_036	2016	09	27	2:16	UTC	54	41.3540	N	173	04.3527	E
MR1606-Flask_Gas_037	2016	09	28	2:25	UTC	52	03.6667	N	169	11.9503	E
MR1606-Flask_Gas_038	2016	09	29	6:22	UTC	48	11.3125	N	163	01.3857	E
MR1606-Flask_Gas_039	2016	09	29	3:58	UTC	45	26.3050	N	158	20.3259	E
MR1606-Flask_Gas_040	2016	10	01	4:37	UTC	42	14.1610	N	153	11.0105	E
MR1606-Flask_Gas_041	2016	10	01	1:12	UTC	42	14.4520	N	149	00	E

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group (DMG) of JAMSTEC, and will opened to the public via “R/V Mirai Data Web Page” in JAMSTEC home page.

3. Physical Oceanography

3.1. CTD cast and water samplings

(1) Personnel

Shigeto Nishino	(JAMSTEC): Principal Investigator
Tatsuya Tanaka	(MWJ): Operation Leader
Hiroshi Matsunaga	(MWJ)
Rei Ito	(MWJ)
Keisuke Takeda	(MWJ)

(2) Objectives

Investigation of oceanic structure and water sampling.

(3) Parameters

Temperature
Conductivity
Pressure
Dissolved Oxygen voltage
Dissolved Oxygen
Transmission %, beam attenuation coefficient and voltage
Turbidity
Fluorescence
Photosynthetically Active Radiation (PAR)
Nitrate
Altimeter

(4) Instruments and methods

CTD/Carousel Water Sampling System, which is 36-position Carousel water sampler (CWS) with Sea-Bird Electronics, Inc. CTD (SBE9plus), was used during this cruise. 12-litter sample bottles were used for sampling seawater. The sensors attached on the CTD were temperature (Primary and Secondary), conductivity (Primary and Secondary), pressure, dissolved oxygen voltage (RINKO III), dissolved oxygen (SBE43), transmission, turbidity, fluorescence, PAR, nitrate, deep ocean standards thermometer and altimeter. The Practical Salinity was calculated by measured values of pressure, conductivity and temperature. The CTD/CWS was deployed from starboard on working deck.

The CTD raw data were acquired on real time using the Seasave-Win32 (ver.7.23.2) provided by Sea-Bird Electronics, Inc. and stored on the hard disk of the personal computer. Seawater was sampled during the up cast by sending fire commands from the personal computer. We stop at each layer for 1 minute above thermo cline or 30 seconds below thermo cline to stabilize then fire. 104 casts of CTD measurements were conducted (Table 3.1-1). Data processing procedures and used utilities of SBE Data Processing-Win32 (ver.7.23.2.) and SEASOFT were as follows:

DATCNV: Convert the binary raw data to engineering unit data. DATCNV also extracts bottle information where scans were marked with the bottle confirm bit during acquisition. The duration was set to 4.4 seconds, and the offset was set to 0.0 seconds.

TCORP (original module): Corrected the pressure sensitivity of the primary temperature (SBE3) sensor.

S/N 031359: -1.8386e-007 (degC/dbar)

RINKOCOR (original module): Corrected the time dependent, pressure induced effect (hysteresis) of the RINKO for both profile data.

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

BOTTLESUM: Create a summary of the bottle data. The data were averaged over 4.4 seconds.

ALIGNCTD: Convert the time-sequence of sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. Dissolved oxygen (SBE43) data are systematically delayed with respect to depth mainly because of the long time constant of the dissolved oxygen sensors and of an additional delay from the transit time of water in the pumped pluming line. This delay was compensated by 6 seconds advancing dissolved oxygen sensors output (dissolved oxygen voltage) relative to the temperature data. RINKO-III voltage, transmission data and voltage are also delayed by slightly slow response time to the sensor. RINKO-III voltage was compensated by 1 second, and transmission data was compensated by 3 seconds advancing.

WILDEDIT: Mark extreme outliers in the data files. The first pass of WILDEDIT obtained an accurate estimate of the true standard deviation of the data. The data were read in blocks of 1000 scans. Data greater than 10 standard deviations were flagged. The second pass computed a standard deviation over the same 1000 scans excluding the flagged values. Values greater than 20 standard deviations were marked bad. This process was applied to pressure, depth, temperature, conductivity and dissolved oxygen (RINKO III and SBE43) voltage.

CELLTM: Remove conductivity cell thermal mass effects from the measured conductivity. Typical values used were thermal anomaly amplitude alpha = 0.03 and the time constant 1/beta = 7.0.

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

WFILTER: Perform a median filter to remove spikes in the transmission data, voltage, fluorescence, turbidity and nitrate data. A median value was determined by 49 scans of the window.

SECTIONU (original module of SECTION): Select a time span of data based on scan number in order to reduce a file size. The minimum number was set to be the starting time when the CTD package was beneath the sea-surface after activation of the pump. The maximum number was set to be the end time when the package came up from the surface.

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

DESPIKE (original module): Remove spikes of the data. A median and mean absolute deviation was calculated in 1-dbar pressure bins for both down and up cast, excluding the flagged values. Values greater than 4 mean absolute deviations from the median were marked bad for each bin. This process was performed twice for temperature, conductivity and dissolved oxygen (RINKO III and SBE43) voltage.

DERIVE: Compute dissolved oxygen (SBE43).

BINAVG: Average the data into 1-dbar pressure bins.

BOTTOMCUT (original module): Deletes discontinuous scan bottom data, if it's created by BINAVG.

DERIVE: Compute salinity, potential temperature, and sigma-theta.

SPLIT: Separate the data from an input .cnv file into down cast and up cast files.

Configuration file

MR1606B.xmlcon: 001M001 - 031M001, 072M001 - 099M001
MR1606C.xmlcon: 032M001 - 071M001

Specifications of the sensors are listed below.

CTD: SBE911plus CTD system

Under water unit: SBE9plus (S/N 09P54451-1027, Sea-Bird Electronics, Inc.)
Pressure sensor: Digiquartz pressure sensor (S/N 117457)
Calibrated Date: 16 Jun. 2016
Temperature sensors:
Primary: SBE03-04/F (S/N 031359, Sea-Bird Electronics, Inc.)
Calibrated Date: 01 Jun. 2016
Secondary: SBE03-04/F (S/N 031525, Sea-Bird Electronics, Inc.)
Calibrated Date: 07 May 2016
Conductivity sensors:
Primary: SBE04C (S/N 042435 Sea-Bird Electronics, Inc.)
Calibrated Date: 12 May 2016
Secondary: SBE04C (S/N 042854, Sea-Bird Electronics, Inc.)
Calibrated Date: 12 May 2016
Dissolved Oxygen sensors:
RINKO III (S/N 0024 (144002A), JFE Advantech Co., Ltd.)
Calibrated Date: 21 Jan. 2016
SBE43 (S/N 430575, Sea-Bird Electronics, Inc.)
Calibrated Date: 07 May 2016
Transmission meter:
C-Star (S/N CST-1726DR, WET Labs, Inc.)
Calibrated Date: 26 May 2015
Turbidity Meter:
Seapoint Turbidity Meter (S/N 14953, Seapoint Sensors, Inc.)
Chlorophyll Fluorometer:
Seapoint Chlorophyll Fluorometer (S/N 3618, Seapoint Sensors, Inc.)
Photosynthetically Active Radiation (PAR) sensor:
PAR-Log ICSW (S/N 1025, Satlantic Inc.)
Calibrated Date: 06 Jul. 2015
UV Nitrate sensor:
Deep SUNA (Submersible Ultraviolet Nitrate Analyzer),
(S/N 385, Satlantic Inc.)
Calibrated Date: 02 Jul. 2015
Altimeter:

Benthos PSA-916T (S/N 1157, Teledyne Benthos, Inc.)

Deep Ocean Standards Thermometer:
SBE35 (S/N 0053, Sea-Bird Electronics, Inc.)
Calibrated Date: 11 May 2016
Carousel water sampler:
SBE32 (S/N 3254451-0826, Sea-Bird Electronics, Inc.)
Submersible Pump:
Primary: SBE5T (S/N 055816, Sea-Bird Electronics, Inc.)
Secondary: SBE5T (S/N 054598, Sea-Bird Electronics, Inc.)
Bottom contact switch: (Sea-Bird Electronics, Inc.)

Deck unit: SBE11plus (S/N 11P54451-0872, Sea-Bird Electronics, Inc.)

(5) Station list

During this cruise, 104 casts of CTD observation were carried out. Date, time and locations of the CTD casts are listed in Table 3.1-1. In some cast, we used a bottom contact sensor also.

(6) Preliminary results

During this cruise, we judged noise, spike or shift in the data of some cast. These were as follows.

001M001: Primary conductivity
down 21 dbar: spike
Secondary conductivity
down 21 dbar: spike
Turbidity
down 3 and 36 dbar: negative value
006M001: Secondary conductivity
down 16 dbar: spike
008M001: Turbidity
up 4 dbar: spike
012M001: Primary temperature
up 30 dbar : shift
Primary conductivity
up 30 dbar - surface : shift
Secondary conductivity
up 10 - surface : shift
Dissolved oxygen (SBE43)

up 30 dbar : shift

up 30 dbar - surface : shift (questionable)

013M001: Primary conductivity

down 38 dbar: spike

014M001: Primary conductivity

down 27 dbar: spike

018M001: Primary temperature and conductivity

down 24 dbar - 26dbar: shift

022M001: Turbidity

down 28 dbar: negative value

032M001: Secondary conductivity

down 33 dbar: spike

034M001: Turbidity

down 182 dbar: negative value

035M001: Turbidity

down 5 and 29dbar: negative value

037M001: Turbidity

down 25 and 31 dbar: negative value

Nitrate

up 50 dbar - surface: shift

038M001: Nitrate

surface - bottom and bottom - surface: shift

Turbidity

down 10 and 32 dbar: negative value

042M001: Turbidity

down 204 dbar: negative value

043M001: Primary conductivity

down 380 dbar - bottom and bottom - up 219 dbar: shift

Turbidity

down 141 and 157 dbar: negative value

044M001: Turbidity

down 91, 114 and 167 dbar: negative value

045M001: Turbidity

down 217 dbar: negative value

047M001: Turbidity

down 39, 137, 283 and 473 dbar: negative value

049M001: Nitrate

up 59 dbar - surface: shift

Turbidity

down 172 dbar: negative value

050M001: Nitrate

surface - bottom and bottom - surface: shift

051M001: Nitrate

surface - bottom and bottom - surface: shift

059M001: Dissolved oxygen (SBE43)

down 3686 dbar - bottom: shift

064M001: Turbidity

down 205 and 211 dbar: negative value

065M001: Turbidity

down 137 dbar: negative value

067M001: Turbidity

down 80 dbar: negative value

068M001: Turbidity

down 63, 165, 188, 193 and 209 dbar: negative value

069M001: Turbidity

down 39, 129, 196 and 447 dbar: negative value

072M001: Primary conductivity

down 18 dbar: spike

Turbidity

down 27 dbar: spike

down 28 dbar: negative value

up 27, 10 and 5 dbar: shift

073M001: Turbidity

up 40, 33, 30 and 20 dbar: shift

074M001: Turbidity

up 43, 40, 30, 20, 10 and 5 dbar: shift

079M001: Turbidity

up 36 and 30 dbar: shift

081M001: Turbidity

up 40, 30, 20, 18, 10 and 5 dbar: shift

082M001: Turbidity

up 40, 35 and 30 dbar: shift

083M001: Primary conductivity

up 7 dbar - surface: shift

084M001: Primary temperature and conductivity

up 44 dbar - up 35 dbar: shift (questionable)

Turbidity

up 13 dbar: spike

085M001: Secondary conductivity

up 42 dbar - surface: shift

086M001: Primary conductivity
up 20 dbar - up 5 dbar: shift
Secondary temperature and conductivity
surface - bottom and bottom - surface: shift
Dissolved oxygen (SBE43)
up 20 dbar - surface: shift

087M001: Primary temperature and conductivity
up 23 dbar - up 5 dbar: shift
Secondary temperature and conductivity
surface - bottom and bottom - surface: shift
Dissolved oxygen (SBE43)
up 23 dbar - up 5 dbar: shift

089M001: Primary conductivity
down 36 dbar - bottom: shift
Dissolved oxygen (SBE43)
down 36 dbar - bottom: shift

094M001: Primary conductivity
down 47 dbar - bottom and bottom - up 30 dbar: shift

(7) Data archive

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

Table 3.1-1 MR16-06 CTD cast table

Stnnbr	Castno	Date(UTC) (mmddyy)	Time(UTC) Start	End	BottomPosition Latitude	Longitude	Depth	Wire Out	HT Above Bottom	Max Depth	Max Pressure	CTD Filename	Remark
001	1	083016	02:16	02:50	63-05.66N	173-59.09W	75.7	67.4	4.4	70.3	71.0	001M001	
002	1	083016	09:41	10:13	63-51.59N	172-18.21W	54.6	46.5	4.8	49.5	50.0	002M001	
003	1	083016	17:31	17:55	64-42.65N	170-20.92W	47.4	37.5	6.1	41.6	42.0	003M001	
004	1	083016	21:41	22:11	65-03.58N	169-36.35W	50.6	42.3	6.3	44.6	45.0	004M001	P.P. cast
005	1	083116	03:48	04:13	65-16.20N	169-03.37W	53.5	44.7	5.1	48.5	49.0	005M001	
006	1	083116	07:51	08:18	65-38.95N	168-42.10W	49.1	41.0	5.8	43.6	44.0	006M001	
007	1	083116	19:30	20:04	66-16.16N	168-54.83W	56.4	47.6	5.0	51.5	52.0	007M001	P.P. cast
007	2	083116	22:08	22:17	66-16.34N	168-53.64W	55.9	44.5	8.8	47.5	48.0	007M002	Clean cast
007	3	083116	23:08	23:22	66-16.03N	168-54.30W	56.3	43.0	9.9	46.5	47.0	007M003	Clean cast
008	1	090116	06:41	07:02	67-11.94N	168-54.10W	48.3	38.4	5.0	43.6	44.0	008M001	
009	1	090116	10:08	10:32	67-33.96N	168-49.32W	50.2	40.4	6.4	43.6	44.0	009M001	
010	1	090116	19:30	20:03	68-02.09N	168-49.89W	58.1	47.2	5.9	52.5	53.0	010M001	P.P. cast
011	1	090216	01:09	01:30	68-30.01N	168-44.32W	53.7	39.3	9.2	44.6	45.0	011M001	
012	1	090216	04:42	05:05	68-59.97N	168-44.51W	52.4	43.2	4.8	47.5	48.0	012M001	
013	1	090216	08:31	08:54	69-29.94N	168-44.67W	51.3	41.9	5.6	45.5	46.0	013M001	
014	1	090216	12:06	12:24	69-59.97N	168-44.58W	40.5	31.6	4.7	35.6	36.0	014M001	
015	1	090216	15:40	15:58	70-30.06N	168-44.82W	38.5	29.6	5.8	32.7	33.0	015M001	
016	1	090216	19:20	19:45	70-59.77N	168-44.62W	44.4	35.8	5.5	38.6	39.0	016M001	P.P. cast
017	1	090216	23:30	23:48	70-45.10N	167-00.16W	47.9	39.1	6.4	41.6	42.0	017M001	

018	1	090316	03:28	03:47	70-45.01N	164-59.94W	41.7	32.9	5.7	35.6	36.0	018M001	
019	1	090316	07:49	08:10	70-44.94N	162-59.99W	44.1	52.0	5.1	38.6	39.0	019M001	
020	1	090316	12:29	12:47	70-44.97N	161-00.09W	43.5	36.0	4.9	38.6	39.0	020M001	
021	1	090416	00:30	00:52	71-25.65N	158-42.98W	58.2	50.3	5.4	52.5	53.0	021M001	
022	1	090416	04:26	04:52	71-34.75N	157-49.64W	64.1	55.5	5.2	58.4	59.0	022M001	
023	1	090416	06:50	07:21	71-29.72N	157-40.09W	85.0	76.3	5.4	78.2	79.0	023M001	
024	1	090416	08:59	09:29	71-24.85N	157-29.92W	122.5	111.2	10.4	112.8	114.0	024M001	
025	1	090416	11:35	12:05	71-19.80N	157-19.41W	89.3	82.5	5.5	84.1	85.0	025M001	
026	1	090416	13:34	13:51	71-14.67N	157-09.72W	45.1	36.8	5.3	39.6	40.0	026M001	
027	1	090416	14:50	14:56	71-17.33N	157-15.02W	57.4	49.1	4.3	52.5	53.0	027M001	no water sampling
028	1	090416	15:54	16:04	71-22.43N	157-24.84W	111.0	103.6	6.1	105.9	107.0	028M001	no water sampling
029	1	090516	01:09	01:48	71-23.10N	158-36.45W	63.7	56.6	5.0	58.4	59.0	029M001	P.P. cast
030	1	090516	06:04	06:11	71-32.11N	157-45.15W	70.9	62.1	5.4	65.3	66.0	030M001	no water sampling
031	1	090516	07:04	07:11	71-27.29N	157-34.53W	109.5	100.1	9.9	101.9	103.0	031M001	no water sampling
032	1	090716	01:34	01:40	71-37.71N	154-54.66W	54.0	44.5	6.4	47.5	48.0	032M001	no water sampling
033	1	090716	02:31	02:40	71-41.88N	155-05.83W	172.2	160.6	9.5	162.3	164.0	033M001	no water sampling
034	1	090716	03:34	03:46	71-45.90N	155-16.95W	204.1	192.9	10.2	194.9	197.0	034M001	no water sampling
035	1	090716	04:43	04:50	71-48.83N	155-35.67W	115.8	101.8	10.2	105.9	107.0	035M001	no water sampling
036	1	090716	06:14	06:38	71-52.54N	156-02.26W	80.1	69.8	6.1	75.2	76.0	036M001	
037	1	090716	08:30	09:04	71-49.34N	155-50.03W	88.5	81.8	4.9	85.1	86.0	037M001	
038	1	090716	10:47	11:30	71-47.96N	155-23.15W	146.1	134.7	10.2	137.5	139.0	038M001	
039	1	090716	13:38	14:31	71-44.13N	155-12.67W	303.4	294.2	9.9	295.7	299.0	039M001	
040	1	090716	15:48	16:16	71-39.87N	155-00.93W	102.0	87.8	9.8	92.0	93.0	040M001	
041	1	090716	17:34	17:52	71-35.83N	154-47.82W	40.4	30.7	4.6	34.6	35.0	041M001	
042	1	090716	23:24	00:25	71-34.01N	152-00.19W	474.0	463.6	9.5	464.7	470.0	042M001	P.P. cast

043	1	090816	05:24	06:26	71-47.20N	153-00.44W	378.0	377.1	9.7	376.8	381.0	043M001	
044	1	090816	08:43	09:51	71-57.51N	154-00.13W	708.0	701.9	6.9	697.6	706.0	044M001	
045	1	090816	19:42	21:35	72-29.48N	155-21.13W	2178.0	1980.5	-	1972.0	2002.0	045M001	P.P. cast
046	1	090916	05:58	07:10	72-16.79N	156-00.03W	708.0	689.5	11.2	690.7	699.0	046M001	
047	1	090916	10:07	11:06	72-28.13N	157-00.56W	564.0	550.0	10.0	550.5	557.0	047M001	
048	1	090916	13:45	14:55	72-47.31N	158-00.46W	792.0	751.2	9.2	749.8	759.0	048M001	
049	1	091016	02:11	02:59	73-18.53N	160-51.80W	385.0	373.2	9.0	374.8	379.0	049M001	
050	1	091016	04:48	06:21	73-17.37N	160-00.62W	1220.0	1232.1	7.6	1215.7	1232.0	050M001	
051	1	091016	09:01	09:54	73-31.46N	160-54.16W	485.0	472.6	9.7	472.5	478.0	051M001	
052	1	091016	21:55	22:22	72-28.57N	159-00.10W	52.4	43.7	5.7	46.5	47.0	052M001	P.P. cast
053	1	091116	20:31	20:52	72-27.96N	158-48.78W	53.3	45.4	4.8	48.5	49.0	053M001	
054	1	091316	04:46	05:34	72-49.84N	158-48.84W	277.0	259.5	10.0	262.1	265.0	054M001	
055	1	091316	07:40	09:06	72-59.82N	158-29.91W	1267.0	1251.4	8.9	1249.2	1266.0	055M001	
056	1	091316	10:41	12:40	73-09.98N	158-00.57W	2388.0	2378.2	8.8	2373.5	2412.0	056M001	
057	1	091316	14:32	16:05	73-19.95N	157-30.71W	2958.0	2947.6	8.6	2943.2	2995.0	057M001	no water sampling
058	1	091316	18:03	20:25	73-29.98N	157-00.50W	3238.0	3231.2	9.4	3225.0	3284.0	058M001	
058	2	091316	21:40	22:07	73-30.46N	157-02.97W	3189.0	113.2	-	115.8	117.0	058M002	P.P. cast
059	1	091416	00:12	02:18	73-45.08N	156-09.07W	3694.0	3689.3	9.3	3678.7	3750.0	059M001	no water sampling
060	1	091416	04:43	07:24	73-51.56N	156-34.84W	3841.0	3838.5	9.2	3824.5	3900.0	060M001	
061	1	091416	11:29	13:15	73-42.64N	157-45.48W	3453.0	3450.4	9.9	3443.2	3508.0	061M001	no water sampling
062	1	091416	14:49	17:06	73-37.31N	158-28.03W	2927.0	2914.6	9.2	2909.0	2960.0	062M001	
063	1	091416	19:44	21:40	73-30.44N	159-17.49W	2372.0	2365.9	8.8	2358.8	2397.0	063M001	P.P. cast
064	1	091516	00:22	01:47	73-23.23N	160-12.24W	1355.0	1353.0	9.5	1346.5	1365.0	064M001	
065	1	091516	03:48	04:38	73-13.86N	161-18.79W	311.0	304.3	6.9	305.6	309.0	065M001	
066	1	091516	07:21	08:04	73-09.53N	162-18.98W	203.0	184.7	10.3	186.0	188.0	066M001	

067	1	091516	21:46	22:46	73-18.31N	160-48.13W	417.0	407.4	9.7	408.3	413.0	067M001	P.P. cast
067	2	091616	02:05	02:20	73-17.93N	160-46.99W	423.0	97.8	-	100.9	102.0	067M002	Clean cast
067	3	091616	03:26	03:39	73-17.71N	160-49.39W	418.0	96.3	-	99.9	101.0	067M003	Clean cast
068	1	091616	21:27	23:18	72-28.57N	155-25.25W	2008.0	1999.3	9.9	1996.5	2027.0	068M001	P.P. cast
069	1	091716	04:58	06:27	72-18.90N	155-27.92W	1394.0	1378.9	10.2	1377.1	1396.0	069M001	
070	1	091716	07:36	08:26	72-09.98N	155-31.13W	378.0	358.3	9.0	360.0	364.0	070M001	
071	1	091716	09:51	10:33	72-10.03N	156-12.80W	233.0	221.2	7.9	225.6	228.0	071M001	
072	1	091816	23:25	23:52	71-59.43N	165-52.77W	45.4	31.1	7.2	37.6	38.0	072M001	P.P. cast
073	1	091916	05:09	05:32	72-31.16N	167-18.68W	51.0	41.3	6.0	44.5	45.0	073M001	
074	1	091916	10:48	11:13	71-59.93N	168-45.10W	50.9	39.5	8.0	42.6	43.0	074M001	
075	1	091916	14:13	14:32	71-30.01N	168-44.89W	48.6	35.3	7.5	40.6	41.0	075M001	
076	1	091916	17:27	17:44	70-59.88N	168-44.94W	44.7	33.8	6.6	37.6	38.0	076M001	
077	1	091916	21:14	21:39	70-29.95N	168-44.62W	38.8	29.2	5.8	32.7	33.0	077M001	P.P. cast
078	1	092016	01:00	01:16	69-59.88N	168-44.80W	41.1	33.1	5.2	35.6	36.0	078M001	
079	1	092016	04:11	04:31	69-30.08N	168-44.66W	51.4	41.2	5.8	45.5	46.0	079M001	
080	1	092016	07:29	07:54	69-00.04N	168-44.88W	53.3	43.9	5.0	47.5	48.0	080M001	
081	1	092016	11:15	11:36	68-30.12N	168-44.93W	54.3	45.4	4.9	48.5	49.0	081M001	
082	1	092016	13:16	13:39	68-15.09N	168-45.02W	57.3	48.3	5.1	51.5	52.0	082M001	
083	1	092016	16:41	16:59	67-45.08N	168-45.14W	50.6	39.0	5.4	44.6	45.0	083M001	
084	1	092016	18:55	19:23	68-00.46N	168-45.09W	59.2	45.0	8.1	50.5	51.0	084M001	P.P. cast
085	1	092016	21:47	22:07	67-45.02N	168-30.04W	50.4	37.1	7.1	42.6	43.0	085M001	
086	1	092116	00:05	00:26	68-00.07N	167-59.71W	54.2	45.6	4.6	49.5	50.0	086M001	
087	1	092116	02:47	03:14	68-12.26N	167-19.91W	48.4	39.0	5.2	42.6	43.0	087M001	
088	1	092116	04:23	04:40	68-18.12N	167-03.27W	39.4	28.8	5.3	33.7	34.0	088M001	
089	1	092116	05:50	05:55	68-14.95N	167-11.90W	45.7	36.6	5.7	39.6	40.0	089M001	no water sampling

090	1	092116	07:26	07:31	68-06.05N	167-40.04W	53.0	44.3	6.0	46.5	47.0	090M001	no water sampling
091	1	092116	09:22	09:26	67-52.56N	168-10.05W	60.0	48.9	7.7	51.5	52.0	091M001	no water sampling
092	1	092116	11:50	12:09	67-34.43N	168-50.76W	50.5	42.4	5.4	44.6	45.0	092M001	
093	1	092116	18:28	19:00	67-11.81N	168-53.26W	48.9	39.3	4.8	43.6	44.0	093M001	P.P. cast
094	1	092116	23:52	00:14	66-16.25N	168-53.55W	56.9	48.5	5.2	51.5	52.0	094M001	
095	1	092216	04:16	04:35	65-45.83N	168-45.57W	52.5	42.4	5.5	46.5	47.0	095M001	
096	1	092216	06:34	06:52	65-39.14N	168-14.91W	42.8	34.4	4.5	37.6	38.0	096M001	
097	1	092216	08:24	08:43	65-39.01N	168-41.79W	49.7	41.2	5.7	43.6	44.0	097M001	
098	1	092216	11:43	12:09	65-15.96N	169-03.07W	53.6	45.2	5.9	47.5	48.0	098M001	
099	1	092216	18:29	18:54	65-03.14N	169-37.11W	51.0	39.9	5.3	45.5	46.0	099M001	P.P. cast

3.2. XCTD/UCTD

3.2.1. XCTD

(1) Personnel

Shigeto Nishino	JAMSTEC:	PI
Shinya Okumura	NME (Nippon Marine Enterprises Ltd.)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objective

To obtain vertical profiles of sea water temperature and salinity (calculated by the function of temperature, pressure (depth), and conductivity).

(3) Parameters

The range and accuracy of parameters measured by the XCTD (eXpendable Conductivity, Temperature & Depth profiler) are as follows;

Parameter	Range	Accuracy
Conductivity	0 ~ 60 [mS/cm]	+/- 0.03 [mS/cm]
Temperature	-2 ~ 35 [deg-C]	+/- 0.02 [deg-C]
Depth	0 ~ 1000 [m]	5 [m] or 2 [%] (either of them is major)

(4) Instruments and Methods

We observed the vertical profiles of the sea water temperature and conductivity measured by XCTD-1 manufactured by Tsurumi-Seiki Co.(TSK). The signal was converted by MK-150N(TSK), and was recorded by AL-12B software (Ver.1.1.4, TSK). We launched 51 probes (XCTD-01 – XCTD-51) by using the automatic launcher or the hand launcher. The summary of XCTD observation log is shown in Table 3.2.1-1.

(5) Observation log

Table 3.2.1-1: XCTD observation log

No.	Statio No.	Date [YYYY/MM/DD]	Time [hh:mm]	Latitude [degN]	Logitude [degW]	Depth [m]	SST [deg-C]	SSS [PSU]	Probe S/N
1	XCTD-01	2016/09/06	01:50	71-49.9914	155-00.0014	282	0.895	27.212	15073001
2	XCTD-02	2016/09/06	02:43	71-59.9984	154-59.9460	329	3.583	27.067	15073002
3	XCTD-03	2016/09/06	03:36	72-09.9960	154-59.9726	999	3.431	27.130	15073010
4	XCTD-04	2016/09/06	04:28	72-20.0003	154-59.9134	1978	3.223	27.413	15073007
5	XCTD-04re	2016/09/06	04:30	72-20.4988	154-59.9322	1961	3.220	27.408	15073003
6	XCTD-05	2016/09/06	05:18	72-30.0051	154-59.7930	2475	2.759	27.463	15073011
7	XCTD-06	2016/09/06	06:34	72-42.6270	154-59.8833	2855	3.457	26.870	15073018
8	XCTD-07	2016/09/06	07:20	72-50.9966	154-59.9457	3251	3.480	27.176	15073013
9	XCTD-08	2016/09/06	08:09	73-00.0047	155-00.4945	3459	3.000	26.952	15073012
10	XCTD-09	2016/09/06	09:02	73-10.0002	155-00.0210	3615	2.894	26.646	15073008
11	XCTD-10	2016/09/06	09:57	73-20.0083	155-00.1700	3672	2.411	26.919	15073005
12	XCTD-11	2016/09/08	03:45	71-40.9849	152-30.0298	440	2.767	27.404	15073009

No.	Statio No.	Date [YYYY/MM/DD]	Time [hh:mm]	Latitude [degN]	Logitude [degW]	Depth [m]	SST [deg-C]	SSS [PSU]	Probe S/N
13	XCTD-12	2016/09/08	07:34	71-46.8833	153-01.8614	388	2.785	27.823	15073021
14	XCTD-13	2016/09/08	11:14	72-00.7269	154-30.2209	705	3.469	26.720	15073019
15	XCTD-14	2016/09/08	12:16	72-04.0246	155-00.0868	403	3.298	27.135	15073014
16	XCTD-14re	2016/09/08	12:21	72-04.2555	155-02.4718	388	3.279	27.149	15073022
17	XCTD-15	2016/09/08	14:09	72-10.4422	155-29.9692	395	3.009	27.241	15073015
18	XCTD-16	2016/09/08	15:44	72-19.3698	155-27.1315	1442	3.224	27.168	15073016
19	XCTD-17	2016/09/09	04:50	72-22.5276	155-42.2131	1272	1.740	27.029	15073017
20	XCTD-18	2016/09/09	08:36	72-22.6753	156-30.0836	446	2.921	26.998	16017196
21	XCTD-19	2016/09/09	12:25	72-37.6473	157-29.9394	348	2.777	27.304	16017193
22	XCTD-20	2016/09/09	16:26	72-55.1756	158-29.9251	1024	3.017	27.256	15073004
23	XCTD-21	2016/09/09	17:47	73-03.1025	158-59.9464	773	3.075	27.104	15073023
24	XCTD-22	2016/09/09	19:44	73-14.8951	159-54.8473	642	2.758	27.278	16017199
25	XCTD-23	2016/09/10	07:35	73-24.2591	160-27.0662	1180	2.781	27.127	15073020
26	XCTD-24	2016/09/13	06:34	72-55.0035	158-39.9747	782	2.731	26.896	16017195
27	XCTD-25	2016/09/13	09:52	73-05.0055	158-14.9381	2034	2.391	26.896	16017197
28	XCTD-26	2016/09/13	13:45	73-14.9825	157-45.2545	2741	2.263	26.803	16017191
29	XCTD-27	2016/09/13	16:48	73-25.0186	157-14.9061	3246	2.157	26.588	16017198
30	XCTD-28	2016/09/13	23:09	73-37.5637	156-34.9584	3619	1.627	26.640	16027268
31	XCTD-29	2016/09/14	03:20	73-52.5134	155-45.3692	3823	1.000	26.621	16017194
32	XCTD-30	2016/09/14	10:13	73-47.1395	157-10.6464	3764	1.963	26.687	16027270
33	XCTD-31	2016/09/14	13:57	73-40.0407	158-06.3433	3260	2.154	26.719	16027271
34	XCTD-32	2016/09/14	18:33	73-33.9740	158-52.7208	2742	2.273	26.952	16017200
35	XCTD-33	2016/09/14	22:56	73-26.9453	159-43.9621	1934	1.857	26.839	16027272
36	XCTD-34	2016/09/15	02:18	73-20.7431	160-28.7988	943	2.191	26.759	16017192
37	XCTD-35	2016/09/15	14:23	73-16.0040	161-03.2341	340	2.379	27.077	16027269
38	XCTD-36	2016/09/16	11:06	73-22.5271	158-49.9781	2106	2.207	27.008	16027273
39	XCTD-37	2016/09/16	12:27	73-14.8851	158-19.9658	2142	2.277	26.916	16027282
40	XCTD-38	2016/09/16	13:26	73-07.5336	157-49.9990	2264	2.264	27.173	16027281
41	XCTD-39	2016/09/16	14:26	72-59.9491	157-19.9384	2368	2.287	27.190	16027274
42	XCTD-40	2016/09/16	15:26	72-52.4849	156-50.0190	2340	2.148	27.220	16027278
43	XCTD-41	2016/09/16	16:38	72-43.5284	156-14.1554	2409	1.943	27.271	16027291
44	XCTD-42	2016/09/16	17:24	72-37.5645	155-50.5547	2140	1.970	27.278	16027292
45	XCTD-43	2016/09/17	09:15	72-09.9442	155-57.6610	251	1.926	22.248	16027290
46	XCTD-44	2016/09/17	11:25	72-10.0249	156-41.9721	186	2.308	27.035	16027286
47	XCTD-45	2016/09/17	12:12	72-10.0082	157-11.3759	114	2.289	27.278	16027288
48	XCTD-46	2016/09/17	13:09	72-00.0022	157-11.4207	87	1.890	27.330	16027289
49	XCTD-47	2016/09/17	14:03	71-50.0117	157-11.3525	66	0.752	27.296	16027317
50	XCTD-48	2016/09/17	14:59	71-40.1327	157-11.0794	62	0.895	27.544	16027318
51	XCTD-49	2016/09/17	16:01	71-31.1055	157-09.3127	115	1.371	27.536	16027319

SST : Sea Surface Temperature [deg-C] measured by TSG (ThermoSalinoGraph).

SSS : Sea Surface Salinity [PSU] measured by TSG.

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

3.2.2. UCTD

(1) Personnel

Shigeto Nishino	(JAMSTEC): Principal investigator
Rei Ito	(MWJ): Operation leader
Hiroshi Matsunaga	(MWJ)
Keisuke Matsumoto	(MWJ)
Keisuke Takeda	(MWJ)
Sonoka Tanihara	(MWJ)
Rio Kobayashi	(MWJ)

(2) Objectives

The "Underway CTD" (UCTD) system measures vertical profiles of temperature, conductivity and pressure like traditional CTD system. The advantage of the UCTD system is to obtain good-quality CTD profiles from moving vessels with repeatable operation. In addition, the UCTD data are more accurate than those from XCTD because the sensor of the UCTD is basically same as that used in the traditional CTD system.

The purpose of UCTD observation in this cruise is to operate test at the Bering Sea.

(3) Methods

The UCTD system, manufactured by Oceanscience Group, was utilized in this cruise. The system consists of the probe unit and on-deck unit with the winch and the rewinder, as in Figure 3.2.2-1. After spooling the line for certain length onto the probe unit (in "tail spool" part), the probe unit is released from the vessels in to the ocean, and then measure temperature, conductivity, and pressure during its free-fall with speed of roughly 4 m/s in the ocean. The probe unit is physically connected to the winch on the vessel by line. Releasing the line from the tail spool ensure the probe unit to be fall without physical forcing by the movement of vessel. After the probe unit reaches the deepest layer for observation, it is recovered by using the winch on the vessel. The observed data are stored in the memory within the probe unit. The dataset can be downloaded into PCs via Bluetooth communication on the deck.

The specifications of the sensors are listed in Table 3.2.2-1. The UCTD system used in this cruise can observe temperature, conductivity and pressure from surface to 500 m depth with 16 Hz sampling rate.

During the profiling, the vessel can be cruised (straight line recommended). The manufacturer recommends the maximum speed of the vessel during the profiling as in Table 3.2.2-2.

Table 3.2.2-1:Specification of the sensors of the UCTD system in this cruise.

Parameter	Accuracy	Resolution	Range
Temperature (deg.C)	0.004	0.002	-5 to 43
Conductivity (S/m)	0.0003	0.0005	0 to 9
Pressure (dbar)	1.0	0.5	0 to 2000

Table 3.2.2-2:Maximum depth and speed of the vessel during profile.

Maximum depth to profile	Maximum ship speed (knot)
0 to 350 m	13
350 to 400 m	12
400 to 450 m	11
450 to 500 m	10
500 to 550 m	8
550 to 600 m	6
600 to 650 m	4
650 to 1000 m	2

Figure 3.2.2-1:UCTD system installed and operated on R/V Mirai.

(4) Preliminary results

During this cruise, 2 casts of UCTD observation were carried out. Date, time and locations of the CTD casts are listed in Table 3.2.2-3.

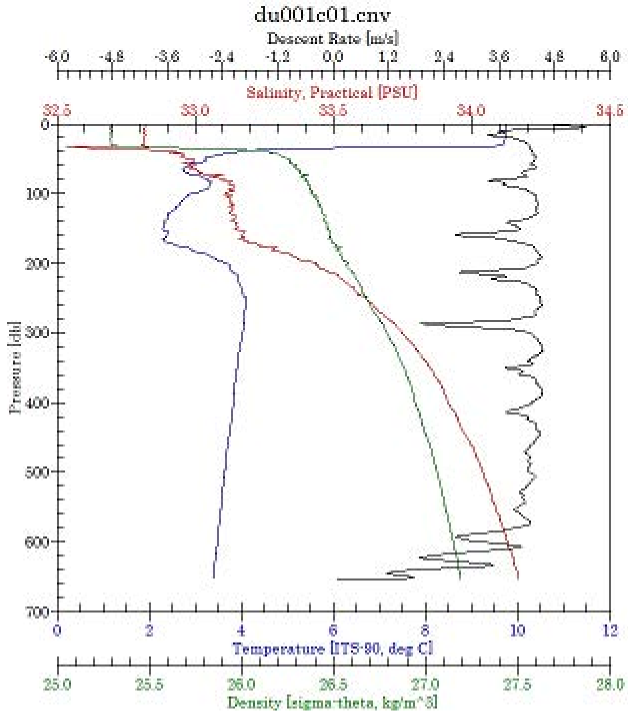
Vertical profiles (down cast) of temperature, salinity, Density with descent rate are shown in Figure 3.2.2-2.

(5) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

Table 3.2.2-3: List of UCTD stations during MR16-06 cruise.

Station Number	Cast Number	Time Towed (UTC)	Position Towed		Max Depth and Pressure		S/N of sensor	Remarks
			Latitude	Longitude	Depth (m)	Pressure (dbar)		
u001	01	25 Sep. 2016 20:57	58 - 30.20 N	179 - 49.65 W	646.9	654.0	0247	
u002	02	25 Sep. 2016 21:24	58 - 29.81 N	179 - 53.50 W	658.7	666.0	0249	



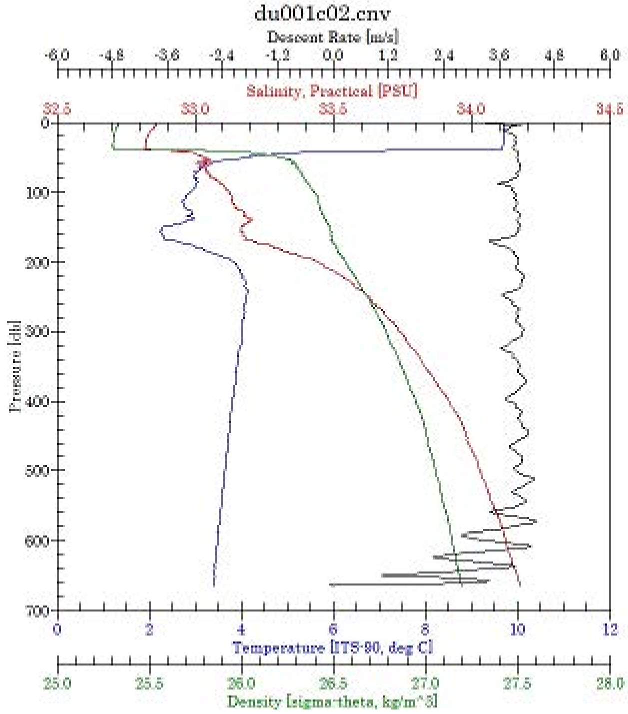


Figure 3.2.2-2: UCTD profiles of temperature (blue line), salinity (red line), density (green line), and descent rate (black line) at the station of u001c01 and u001c02.

3.3. Shipboard ADCP

(1) Personnel

Shigeto Nishino	JAMSTEC	-PI
Shinya Okumura	NME(Nippon Marine Enterprise Ltd.)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objectives

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

(3) Parameters

Major parameters for the measurement, Direct Command, are shown in Table 3.3-1.

Table 3.3-1: Major parameters

Bottom-Track Commands	
BP = 001	Pings per Ensemble (almost less than 1,200m depth)
Environmental Sensor Commands	
EA = 04500	Heading Alignment (1/100 deg)
ED = 00065	Transducer Depth (0 - 65535 dm)
EF = +001	Pitch/Roll Divisor/Multiplier (pos/neg) [1/99 - 99]
EH = 00000	Heading (1/100 deg)
ES = 35	Salinity (0-40 pp thousand)
EX = 00000	Coordinate Transform (Xform:Type; Tilts; 3Bm; Map)
EZ = 10200010	Sensor Source (C; D; H; P; R; S; T; U)
	C (1): Sound velocity calculates using ED, ES, ET (temp.)
	D (0): Manual ED
	H (2): External synchro
	P (0), R (0): Manual EP, ER (0 degree)
	S (0): Manual ES
	T (1): Internal transducer sensor
	U (0): Manual EU
EV = 0	Heading Bias(1/100 deg)
Timing Commands	
TE = 00:00:02.00	Time per Ensemble (hrs:min:sec.sec/100)
TP = 00:02.00	Time per Ping (min:sec.sec/100)
Water-Track Commands	
WA = 255	False Target Threshold (Max) (0-255 count)
WC = 120	Low Correlation Threshold (0-255)
WD = 111 100 000	Data Out (V; C; A; PG; St; Vsum; Vsum^2; #G; P0)
WE = 1000	Error Velocity Threshold (0-5000 mm/s)

WF = 0800	Blank After Transmit (cm)
WN = 100	Number of depth cells (1-128)
WP = 00001	Pings per Ensemble (0-16384)
WS = 800	Depth Cell Size (cm)
WV = 0390	Mode 1 Ambiguity Velocity (cm/s radial)

(4) Instruments and methods

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

1. R/V MIRAI has installed the Ocean Surveyor for vessel-mount ADCP (frequency 76.8 kHz; Teledyne RD Instruments, USA). It has a phased-array transducer with single ceramic assembly and creates 4 acoustic beams electronically. We mounted the transducer head rotated to a ship-relative angle of 45 degrees azimuth from the keel.
2. For heading source, we use ship's gyro compass (Tokyo Keiki, Japan), continuously providing heading to the ADCP system directory. Additionally, we have Inertial Navigation System (Phins, Ixblue, France) which provide high-precision heading, attitude information, pitch and roll. They are stored in ".N2R" data files with a time stamp.
3. Differential GNSS system (MultiFix, Fugro, Netherlands) providing precise ship's position.
4. We used VmDas software version 1.46.5 (TRDI) for data acquisition.
5. To synchronize time stamp of ping with Computer time, the clock of the logging computer is adjusted to GPS time server every 1 minute.
6. Fresh water is charged in the sea chest to prevent bio fouling at transducer face.
7. The sound speed at the transducer does affect the vertical bin mapping and vertical velocity measurement, and that is calculated from temperature, salinity (constant value; 35.0 PSU) and depth (6.5 m; transducer depth) by equation in Medwin (1975).

Data was configured for "8 m" layer intervals starting about 23m below sea surface, and recorded every ping as raw ensemble data (.ENR). Additionally, 15, 60 seconds averaged data were recorded as short-term average (.STA). 300 seconds averaged data were long-term average (.LTA), respectively.

(5)Observation Period

23 Aug. 2016 – 5 Oct. 2016 (UTC)

(6)Remarks

We changed measurement parameters from default settings (WS800, WN100 or 25, WF800) for performance test. Changed parameters are shown in Table 3.3-2.

Table 3.3-2: Measurement parameters

DATE	TIME	WS	WN	WF
8/25	13:58 – 14:08	400	64	800
	14:09 – 14:17	400	32	800
8/26	09:41 – 10:05	800	64	200
	10:06 – 10:23	800	32	200
	10:31 – 10:48	600	32	200
	10:48 – 11:11	600	64	200
	11:12 – 11:33	400	64	200
	11:33 – 11:48	400	64	400
	11:48 – 12:05	400	32	200
	12:06 – 12:18	400	32	400
	12:18 – 12:30	600	32	400
	12:31 – 12:46	600	64	400
	12:47 – 12:59	800	32	400
	12:59 – 13:15	800	64	400
	13:16 – 13:32	800	64	800
	13:33 – 13:48	600	64	800
	13:49 – 14:01	800	32	800
	14:01 - 14:13	600	32	800
	14:13 – 14:25	400	32	800
	14:25 – 14:40	400	64	800
9/2	01:18 – 08:23	400	24	200
	08:24 – 08:40	400	24	400
	08:41 – 08:45	400	24	300
	08:57 – 12:12	400	24	300
	12:13 – 19:43	400	24	400
9/2 – 9/3	19:44 – 03:27	600	16	300
	03:28 – 07:51	600	16	300
	07:51 – 12:04	600	16	400
9/18 – 9/20	23:54 – 07:32	400	18	200
	18:42 – 23:46	400	18	200
9/22 – 9/24	20:58 – 12:25	400	18	200
9/24 – 9/25	12:25 – 00:55	400	24	200

(7)Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via “Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)” in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

3.4. Surface wave measurement by drifting wave buoys

(1) Personnel

Jun Inoue	NIPR	- PI, not on board
Kazutoshi Sato	NIPR	
Takuji Waseda	The University of Tokyo	- not on board
Adrean Webb	The University of Tokyo	- not on board

(2) Objectives

The objective of this research is to observe ocean waves in the ice-free ocean and validate the numerical wave model which is under development.

(3) Parameters

Wave parameters (wave height and period), air and water temperature, and GPS position.

(4) Instruments and methods

Waves in Ice buoy (WII buoy) is a drifting type surface wave buoy purchased from an Australian company. The basic system was developed in cooperation with P. A. S. Consultants, Australia, and A. Kohout of NIWA. A similar system was used in the past to be placed on a floating ice in the Antarctica. For the Arctic measurement, we have developed a floating type buoy. The motion of the floating buoy will be measured by 9-axis motion sensor, and the onboard processing unit will analyze the data on the fly. The data acquisition is 40 minutes long. The sampling interval is typically set to 3 hours, and during an event, is switched to 1 hour. The analyzed data (statistical quantities and power spectral density) and metadata are transferred by Iridium satellite link to the server maintained by P. A. S. Consultants. Further analyzed data is accessible by a user-friendly wave page. The raw data is stored in the SD card.

Currently, there is no plan to retrieve the buoy. The battery is charged by the solar cell. When the battery voltage drops due to reduced solar radiation during winter, the system will switch to an energy save mode, and only the GPS position will be reported.

(5) Station list or Observation log

Buoy NO	Deployment		
	Date (YYYYMMDD)	Longitude (deg W)	Latitude (deg N)
1	20160910 UTC	155.2819	72.6212
2	20160910 UTC	155.3115	72.6219

(6) Preliminary results

Preliminary analysis results are shown below for records from Sep.10 to Oct.2 (Figure 3.4-1). Both buoys followed almost the same trajectories until it started to separate. The drifting speed is relatively slow, and both buoys are still in the same area. Significant wave height is shown in Figure 3.4-2. Because of the relatively low energy, the signal to noise level is relatively low, and therefore, the analysis were made with different cutoff wave periods. During the storm around 9/19, the significant wave height exceeded 4 m, which is quite rare in the Arctic. Detailed analysis is needed. Various moment wave periods were estimated (Figure 3.4-3). In general, the wave periods are around 5 to 7 s. Except for the storm period, these waves are most likely swells propagating from distant storms.

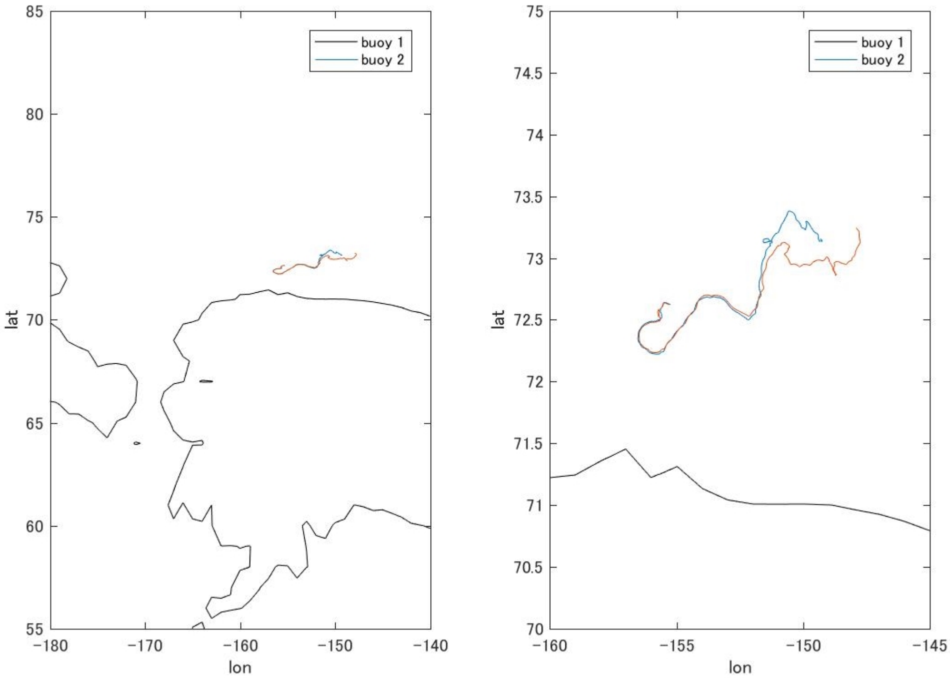


Figure 3.4-1: Trajectories of the buoys, from 9/10 to 10/2. The right figure is the close up of the trajectories.

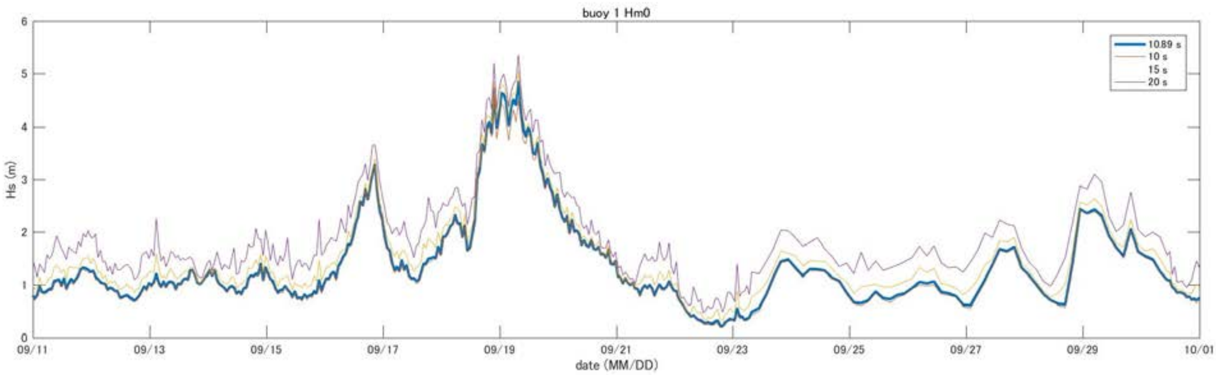
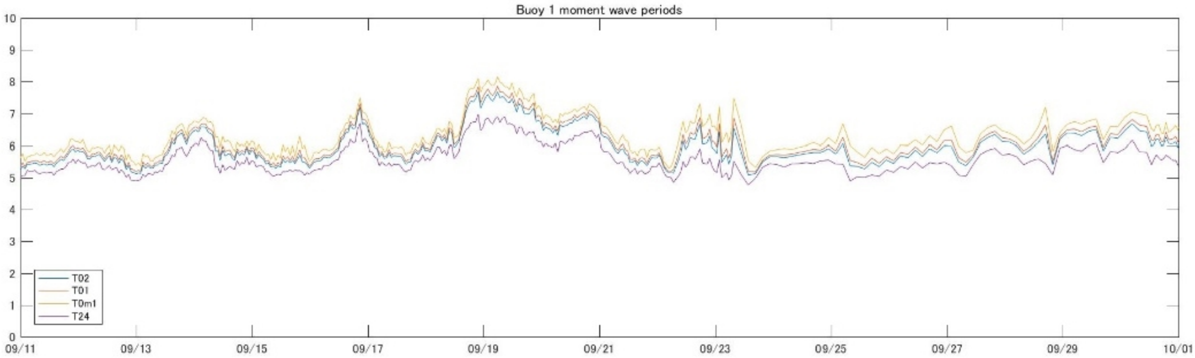


Figure 3.4-2: Significant wave height from 9/10 to 10/2. The thick blue line is applying the high-pass filter at cutoff period of 10.89 s, while the others are for 10 s, 15 s and 20 s



cutoff periods.

Figure 3.4-3: Moment periods from 9/10 to 10/2.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

NOTE: Because of some incorrect parameter settings of the analysis program, the data submitted directly from the buoy does not represent the correct physical values. The data requires post-processing. Therefore, the data needs to be quality controlled before it is released.

3.5. Salinity measurements

(1)Personnel

Shigeto Nishino (JAMSTEC): Principal investigator
Sonoka Tanihara (MWJ)

(2)Objectives

To understand the spatial and temporal variation of salinity and to provide calibrations for the measurements of salinity collected from CTD and TSG (Underway surface water monitoring).

(3)Parameters

The specifications of the AUTOSAL salinometer are shown as follows ;

Salinometer (Model 8400B "AUTOSAL" ; Guildline Instruments Ltd.)
Measurement Range : 0.005 to 42 (PSU)
Accuracy : Better than ±0.002 (PSU) over 24 hours without re-standardization
Maximum Resolution : Better than ±0.0002 (PSU) at 35 (PSU)

(4) Instruments and methods

a. Salinity Sample Collection

Seawater samples were collected with 12 liter Niskin-X bottles, bucket, and TSG. The salinity sample bottle of 250ml brown glass with screw cap was used for collecting the sample water. Each bottle was rinsed 3 times with the sample water, and was filled with sample water to the bottle shoulder. All of sample bottles for TSG were sealed with a plastic insert thimble and a screw cap because we took into consideration the possibility of storage for about a month. The thimble was rinsed 3 times with the sample water before use. The bottle was stored for more than 24 hours in the laboratory before the salinity measurement.

Types and numbers (n) of the samples are shown in Table 3.5-1.

Table 3.5-1 Types and numbers (n) of samples

Types	N
Samples for CTD and bucket	1245
Samples for TSG	42
Total	1287

b. Instruments and method

The salinity analysis was carried out on R/V MIRAI during the cruise of MR16-06 using the salinometer (Model 8400B "AUTOSAL" ; Guildline Instruments Ltd.: S/N 62556) with an additional peristaltic-type intake pump (Ocean Scientific International, Ltd.).

One pair of precision digital thermometers (Model 9540 ; Guildline Instruments Ltd.) were used. The thermometer monitored the ambient temperature and the other monitored the bath temperature.

The specifications of the thermometer are shown as follows ;

Thermometer (Model 9540 ; Guildline Instruments Ltd.)
Measurement Range : -40 to +180 deg C
Resolution : 0.001
Limits of error ±deg C : 0.01 (24 hours @ 23 deg C ±1 deg C)
Repeatability : ±2 least significant digits

The measurement system was almost the same as Aoyama *et al.* (2002). The salinometer was operated in the air-conditioned ship's laboratory at a bath temperature of 21 deg C. The ambient temperature varied from approximately 18.8 deg C to 21.1 deg C, while the bath temperature was very stable and varied within +/- 0.002 deg C (S/N 62556) on rare occasion.

The measurement for each sample was done with a double conductivity ratio and defined as the median of 31 readings of the salinometer. Data collection was started 10 seconds after filling the cell with the sample and it took about 15 seconds to collect 31 readings by the personal computer. Data were taken for the sixth and seventh filling of the cell after rinsing 5 times. In the case of the difference between the double conductivity ratio of these two fillings being smaller than 0.00002, the average value of the double conductivity ratio was used to calculate the bottle salinity with the algorithm for the practical salinity scale, 1978 (UNESCO, 1981). If the difference was greater than or equal to 0.00003, an eighth filling of the cell was done. In the case of the difference between the double conductivity ratio of these two fillings being smaller than 0.00002, the average value of the double conductivity ratio was used to calculate the bottle salinity. In the case of the double conductivity ratio of eighth filling did not satisfy the criteria above, the operator measured a ninth or tenth filling of the cell and calculated the bottle salinity above. The cell was cleaned with detergent after the measurement of the day.

(5) Station list

Table.3.5-1 shows the sampling locations for the salinity analysis in this cruise.

Table. 3.5-1 List of sampling locations of the salinity samples collected from CTD

Stnnbr	Castno	Date(UTC)	BottomPosition		Depth
		(mmddyy)	Latitude	Longitude	
001	1	083016	63-05.66N	173-59.09W	75.7
002	1	083016	63-51.59N	172-18.21W	54.6
003	1	083016	64-42.65N	170-20.92W	47.4
004	1	083016	65-03.58N	169-36.35W	50.6
005	1	083116	65-16.20N	169-03.37W	53.5
006	1	083116	65-38.95N	168-42.10W	49.1
007	1	083116	66-16.16N	168-54.83W	56.4
008	1	090116	67-11.94N	168-54.10W	48.3
009	1	090116	67-33.96N	168-49.32W	50.2
010	1	090116	68-02.09N	168-49.89W	58.1
011	1	090216	68-30.01N	168-44.32W	53.7
012	1	090216	68-59.97N	168-44.51W	52.4
013	1	090216	69-29.94N	168-44.67W	51.3
014	1	090216	69-59.97N	168-44.58W	40.5
015	1	090216	70-30.06N	168-44.82W	38.5
016	1	090216	70-59.77N	168-44.62W	44.4
017	1	090216	70-45.10N	167-00.16W	47.9
018	1	090316	70-45.01N	164-59.94W	41.7
019	1	090316	70-44.94N	162-59.99W	44.1
020	1	090316	70-44.97N	161-00.09W	43.5
021	1	090416	71-25.65N	158-42.98W	58.2
022	1	090416	71-34.75N	157-49.64W	64.1
023	1	090416	71-29.72N	157-40.09W	85.0
024	1	090416	71-24.85N	157-29.92W	122.5
025	1	090416	71-19.80N	157-19.41W	89.3
026	1	090416	71-14.67N	157-09.72W	45.1
029	1	090516	71-23.10N	158-36.45W	63.7
036	1	090716	71-52.54N	156-02.26W	80.1
037	1	090716	71-49.34N	155-50.03W	88.5
038	1	090716	71-47.96N	155-23.15W	146.1
039	1	090716	71-44.13N	155-12.67W	303.4
040	1	090716	71-39.87N	155-00.93W	102.0
041	1	090716	71-35.83N	154-47.82W	40.4

042	1	090716	71-34.01N	152-00.19W	474.0
043	1	090816	71-47.20N	153-00.44W	378.0
044	1	090816	71-57.51N	154-00.13W	708.0
045	1	090816	72-29.48N	155-21.13W	2178.0
046	1	090916	72-16.79N	156-00.03W	708.0
047	1	090916	72-28.13N	157-00.56W	564.0
048	1	090916	72-47.31N	158-00.46W	792.0
049	1	091016	73-18.53N	160-51.80W	385.0
050	1	091016	73-17.37N	160-00.62W	1220.0
051	1	091016	73-31.46N	160-54.16W	485.0
052	1	091016	72-28.57N	159-00.10W	52.4
053	1	091116	72-27.96N	158-48.78W	53.3
054	1	091316	72-49.84N	158-48.84W	277.0
055	1	091316	72-59.82N	158-29.91W	1267.0
056	1	091316	73-09.98N	158-00.57W	2388.0
058	1	091316	73-29.98N	157-00.50W	3238.0
060	1	091416	73-51.56N	156-34.84W	3841.0
062	1	091416	73-37.31N	158-28.03W	2927.0
063	1	091416	73-30.44N	159-17.49W	2372.0
064	1	091516	73-23.23N	160-12.24W	1355.0
065	1	091516	73-13.86N	161-18.79W	311.0
066	1	091516	73-09.53N	162-18.98W	203.0
067	1	091516	73-18.31N	160-48.13W	417.0
068	1	091616	72-28.57N	155-25.25W	2008.0
069	1	091716	72-18.90N	155-27.92W	1394.0
070	1	091716	72-09.98N	155-31.13W	378.0
071	1	091716	72-10.03N	156-12.80W	233.0
072	1	091816	71-59.43N	165-52.77W	45.4
073	1	091916	72-31.16N	167-18.68W	51.0
074	1	091916	71-59.93N	168-45.10W	50.9
075	1	091916	71-30.01N	168-44.89W	48.6
076	1	091916	70-59.88N	168-44.94W	44.7
077	1	091916	70-29.95N	168-44.62W	38.8
078	1	092016	69-59.88N	168-44.80W	41.1
079	1	092016	69-30.08N	168-44.66W	51.4
080	1	092016	69-00.04N	168-44.88W	53.3
081	1	092016	68-30.12N	168-44.93W	54.3
082	1	092016	68-15.09N	168-45.02W	57.3

083	1	092016	67-45.08N	168-45.14W	50.6
084	1	092016	68-00.46N	168-45.09W	59.2
085	1	092016	67-45.02N	168-30.04W	50.4
086	1	092116	68-00.07N	167-59.71W	54.2
087	1	092116	68-12.26N	167-19.91W	48.4
088	1	092116	68-18.12N	167-03.27W	39.4
092	1	092116	67-34.43N	168-50.76W	50.5
093	1	092116	67-11.81N	168-53.26W	48.9
094	1	092116	66-16.25N	168-53.55W	56.9
095	1	092216	65-45.83N	168-45.57W	52.5
096	1	092216	65-39.14N	168-14.91W	42.8
097	1	092216	65-39.01N	168-41.79W	49.7
098	1	092216	65-15.96N	169-03.07W	53.6
099	1	092216	65-03.14N	169-37.11W	51.0

(6) Preliminary results

a. Standard Seawater (SSW)

The specifications of SSW used in this cruise are shown as follows ;

Batch

: P159

conductivity ratio : 0.99988

double conductivity ratio : 1.99976

salinity : 34.995

expiration date : 15th Dec 2018

Standardization control of the salinometer S/N 62556 was set to 560 (30th Aug.) and 23 measurements were carried out at this setting. The value of STANDBY was 5102 +/- 0001 and that of ZERO was 0.0-0000 +/- 0001. 65 bottles of SSW were measured in this period.

Figure 3.5-1 shows the history of the double conductivity ratio of the Standard Seawater batch P159 before correction in the salinometer S/N 62556. The average of the double conductivity ratio in 65 bottles of SSW was 1.99971 and the standard deviation was 0.00002, which is equivalent to 0.0005 in salinity.

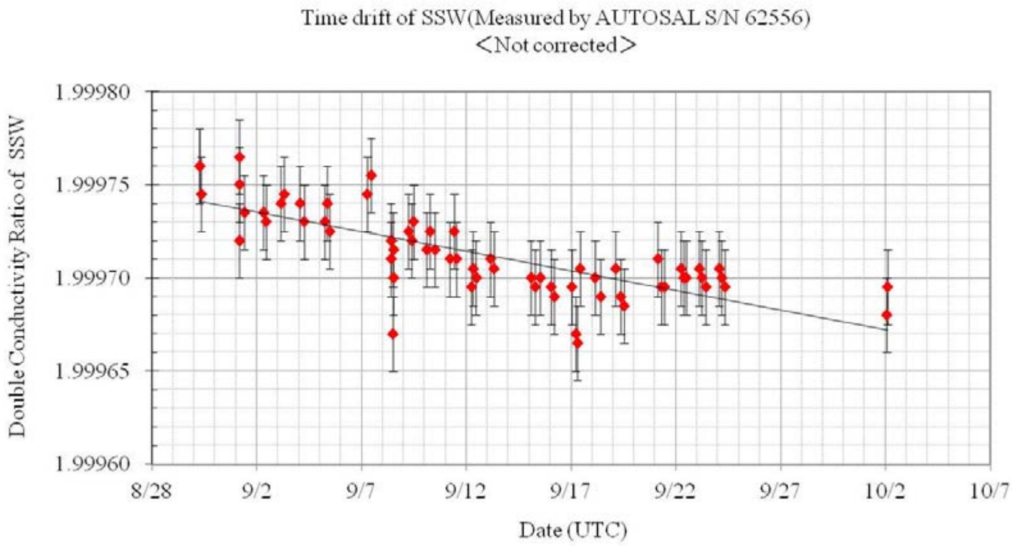


Figure 3.5-1 History of double conductivity ratio for the Standard Seawater batch P159 in the salinometer S/N 62556 (before correction)

Figure 3.5-2 shows the history of the double conductivity ratio of the Standard Seawater batch P159 after correction in the salinometer S/N 62556. The average of the double conductivity ratio in 65 bottles of SSW after correction was 1.99976 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity.

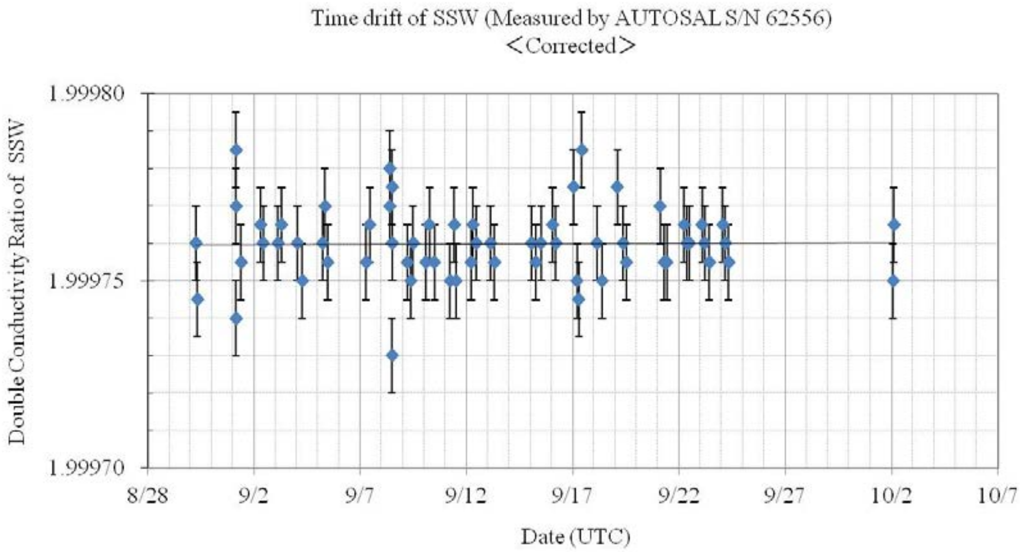


Figure 3.5-2 History of double conductivity ratio for the Standard Seawater batch P159 in the salinometer S/N 62556 (after correction)

b. Sub-Standard Seawater

Sub-standard seawater was made from surface-sea water (poor in nutrient) filtered by a pore size of 0.45 micrometer and stored in a 20 liter container made of polyethylene and stirred for at least 24 hours before measuring. It was measured between every station in order to check for the possible sudden drifts of the salinometer.

c. Replicate Samples

We estimated the precision of this method using 211 pairs of replicate samples taken from the same Niskin bottle.

Figure 3.5-5 shows the histogram of the absolute difference between each pair of all replicate samples. The average and the standard deviation of absolute difference among 211 pairs were 0.0011 and 0.0038 in salinity, respectively.

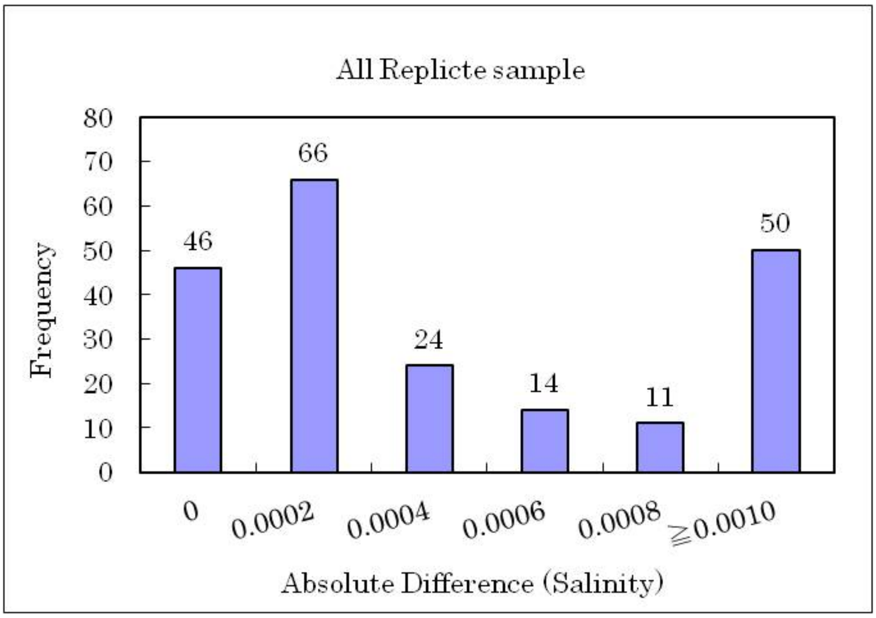


Figure 3.5-5 Histogram of the Absolute Difference of all Replicate Samples

145 pairs of replicate samples were to estimate the precision of shallow (<200dbar) samples. Figure 3.5-6 shows the histogram of the absolute difference between each pair of shallow (<200dbar) replicate samples. The average and the standard deviation of absolute difference among 145 pairs were 0.0009 and 0.0015 in salinity, respectively.

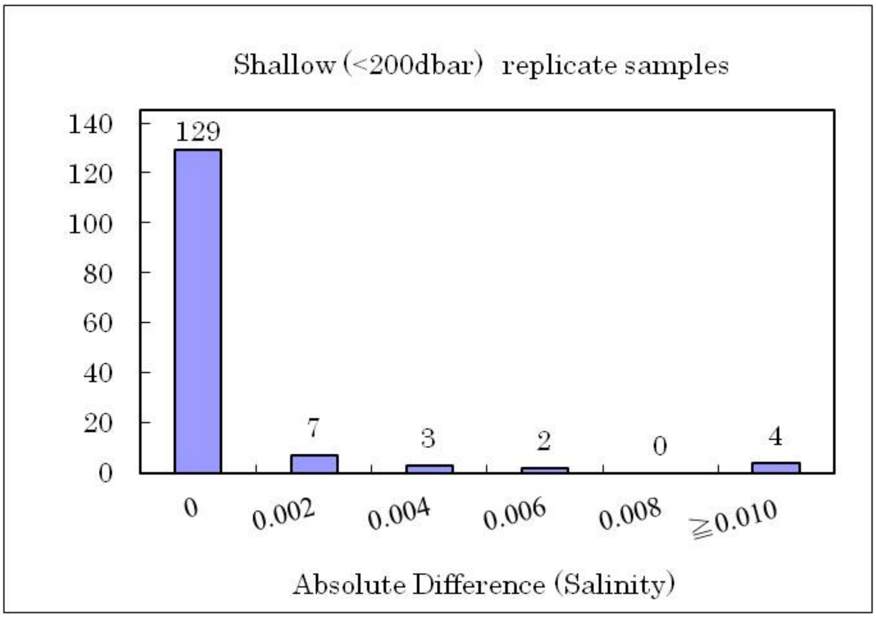


Figure 3.5-6 Histogram of the Absolute Difference between Shallow (<200dbar) Replicate Samples

66 pairs of replicate samples were to estimate the precision of deep (>=200dbar) samples. Figure 3.5-7 shows the histogram of the absolute difference between each pair of deep (>=200dbar) replicate samples. The average and the standard deviation of absolute difference among 65 pairs were 0.0004 and 0.0004 in salinity, respectively.

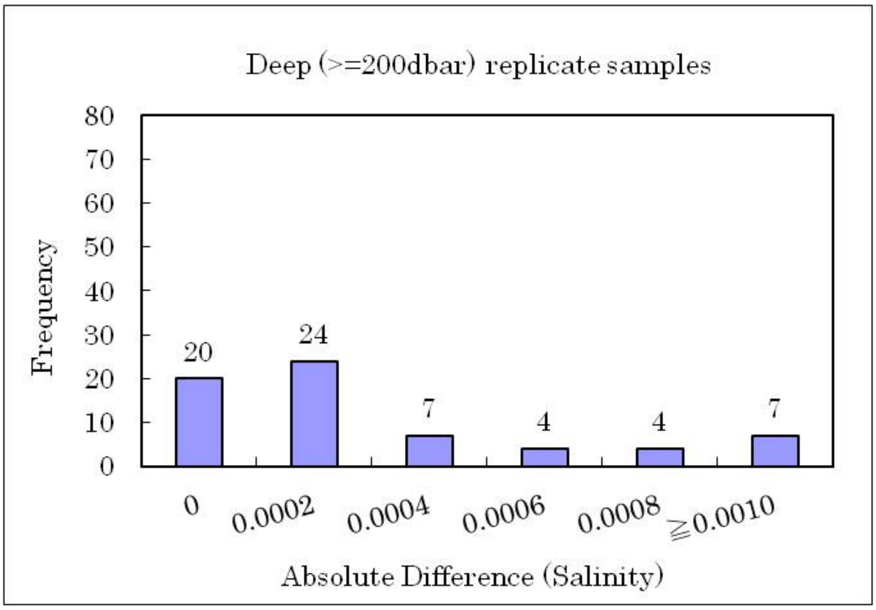


Figure 3.5-7 Histogram of the Absolute Difference between Deep (>=200dbar) Replicate Samples

d. Data Correction for Samples

All data were corrected according to the result of the offset correction for SSW.

(7) Data archives

a. Data Policy

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

b. Citation

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

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

3.6. Vector network analyzer

(1) Personnel

Kohei Mizobata (TUMSAT): Principal Investigator (not-onboard)

Hillary Sato (TUMSAT)

TUMSAT:Tokyo University of Marine Science and Technology

(2) Objectives

Changes of amount and spatial distribution of Fresh water due to ice melting have impacts on the ocean acidification and thermohaline circulation in the Arctic Ocean. Therefore, information about fresh water is needed to be elucidated. ESA and NASA launched satellites, the SAC-D and SMOS, carrying the L-band (1.4GHz) microwave radiometer, which estimates sea surface salinity (SSS). The utilization of SSS can be used as a proxy of freshwater distribution. Sea surface radiance at L-band, which is observed by microwave sensor, is the function of SSS and sea surface temperature (SST). The fundamental relationship among SSS, SST and radiance have been revealed by laboratory experiments, but that relationship in the cold area like the Arctic Ocean is not validated. The objective of this study is to observe sea surface radiance by using Vector network analyzer for estimating sea surface salinity, and validate/calibrate (if possible) satellite SSS retrieval with SSS measured by salinometer.

(3) Parameters

- Frequency (MHz)
- Calibration short amplitude (dB)
- Calibration short phase (deg)
- Calibration release amplitude (dB)
- Calibration release phase (deg)
- Standard sample’s amplitude (dB)
- Standard sample’s phase (deg)
- Sample’s amplitude (dB)
- Sample’s phase (deg)
- Real part of dielectric constant
- Imaginary part of dielectric constant
- Dielectric loss tangent

(4) Instruments and methods

Seawater's dielectric constant and dielectric loss tangent was measured by Vector network analyzer, collected by bucket at 49 stations as CTD casting.

(5) Station list or Observation log

Sea surface microwave were collected at 45 stations. (Figure 3.6-1).

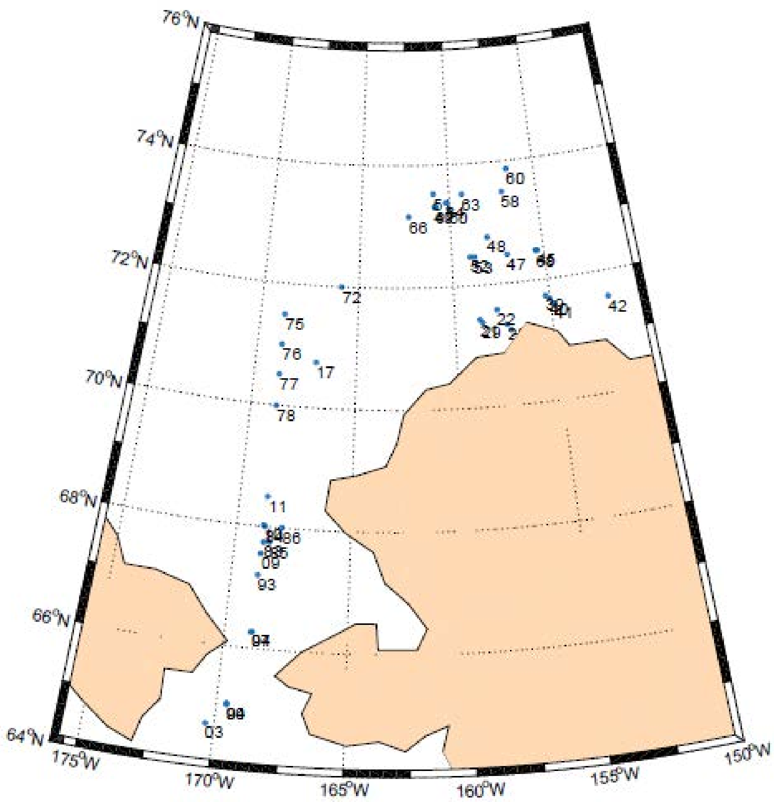


Figure3.6-1 Map of observing station.

(6) Preliminary results

Observation shows L-band microwave radiance has significant errors at Bering Strait (Figure3.6-2). On the other hand, small errors can be found in the north of Chukchi Sea. The area where large errors seems like the area where is easily affected by turbid coastal water, indicating that turbidity may have an impact on dielectric constant of sea water. After this cruise, we will investigate whether turbidity can be used as a quality flag for SSS retrieval using ocean color images derived from satellite ocean color sensors (e.g., MODIS).

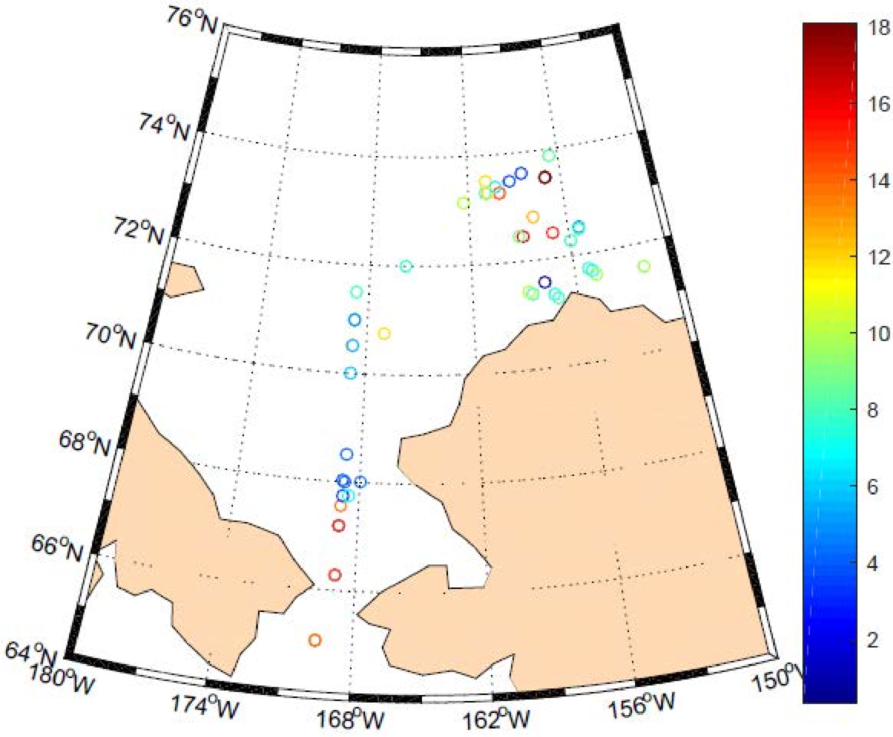


Figure3.6-2 Map of observing station. Color indicates the absolute difference of real part of dielectric constant between VNA observation and ideal value.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

3.7. Density

(1) Personnel

Hiroshi Uchida (JAMSTEC) (Principal investigator)
Shigeto Nishino (JAMSTEC)
Amane Fujiwara (JAMSTEC)
Masanori Enoki (MWJ)

(2) Objectives

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

(3) Materials and methods

Seawater densities were measured during the cruise with an oscillation-type density meter (DMA 5000M, serial no. 81661961, Anton-Paar GmbH, Graz, Austria) with a sample changer (Xsample 122, serial no. 81683390, Anton-Paar GmbH). The sample changer was used to load samples automatically from up to ninety-six 12-mL glass vials.

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

Time drift of the density meter was monitored by periodically measuring the density of ultra-pure water (Milli-Q water, Millipore, Billerica, Massachusetts, USA) prepared from Yokosuka (Japan) tap water in October 2012. The true density at 20 °C of the Milli-Q water was estimated to be 998.2042 kg m^{-3} from the isotopic composition ($\delta D = -8.76$ ‰, $\delta^{18}O = -56.86$ ‰) and International Association for the Properties of Water and Steam (IAPWS)-95 standard. An offset correction was applied to the measured density by using the Milli-Q water measurements ($\rho_{Milli\text{-}Q}$) with a slight modification of the density dependency (Uchida et al., 2011). The offset (ρ_{offset}) of the measured density (ρ) was evaluated in September 2016 as follows:

$$\rho_{offset} = (\rho_{Milli\text{-}Q} - 998.2042) - (\rho - 998.2042) \times 0.000277 \text{ [kg m}^{-3}\text{]}.$$

The offset correction was verified by measuring Reference Material for Density in Seawater (prototype Dn-RM1 and PRE18) produced by Kanso Technos Co., Ltd., Osaka, Japan, along with the Milli-Q water.

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

(4) Results

Results of density measurements of the Reference Material for Density in Seawater (Dn-RM1 and PRE18) were shown in Table 3.7.1.

A total of 19 pairs of replicate samples were measured. The root-mean square of the absolute difference of replicate samples was 0.0009 g/kg excluding for 2 pairs of bad or questionable measurements.

The measured density salinity anomalies (δS_A) are shown in Figure 3.7.1. The measured δS_A agree with calculated δS_A from Pawlowicz et al. (2011) which exploits the correlation between δS_A and nutrient concentrations and carbonate system parameters based on mathematical investigation using a model relating composition, conductivity and density of arbitrary seawaters, except for depths between 1500 and 3000 dbar.

(5) References

IOC, SCOR and IAPSO (2010): The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, United Nations Educational, Scientific and Cultural Organization (English), 196 pp.

Pawlowicz, R., D. G. Wright and F. J. Millero (2011): The effects of biogeochemical processes on ocean conductivity/salinity/density relationships and the characterization of real seawater. *Ocean Science*, 7, 363–387.

Uchida, H., T. Kawano, M. Aoyama and A. Murata (2011): Absolute salinity measurements of standard seawaters for conductivity and nutrients. *La mer*, 49, 237–244.

Table 3.7-1. Result of density measurements of the Reference Material for Density in Seawater (prototype Dn-RM1 and PRE18). Number in parentheses shows standard deviation.

Date	Stations	Mean density of Dn-RM1 (kg/m^3)	Mean density of PRE18 (kg/m^3)
2016/11/10-11/12	1,62,63,64,65,42, 43,44,46	1024.2646(5)	1024.2236(8)
2016/11/13-11/15	46,47,48,49,50,51, 54,55	1024.2652(1)	1024.2234(6)
2016/11/15-11/16	55,56,58,60,62,63, 64,65,66	1024.2621(7)	1024.2227(6)
Average:		1024.2640(16)	1024.2232(5)

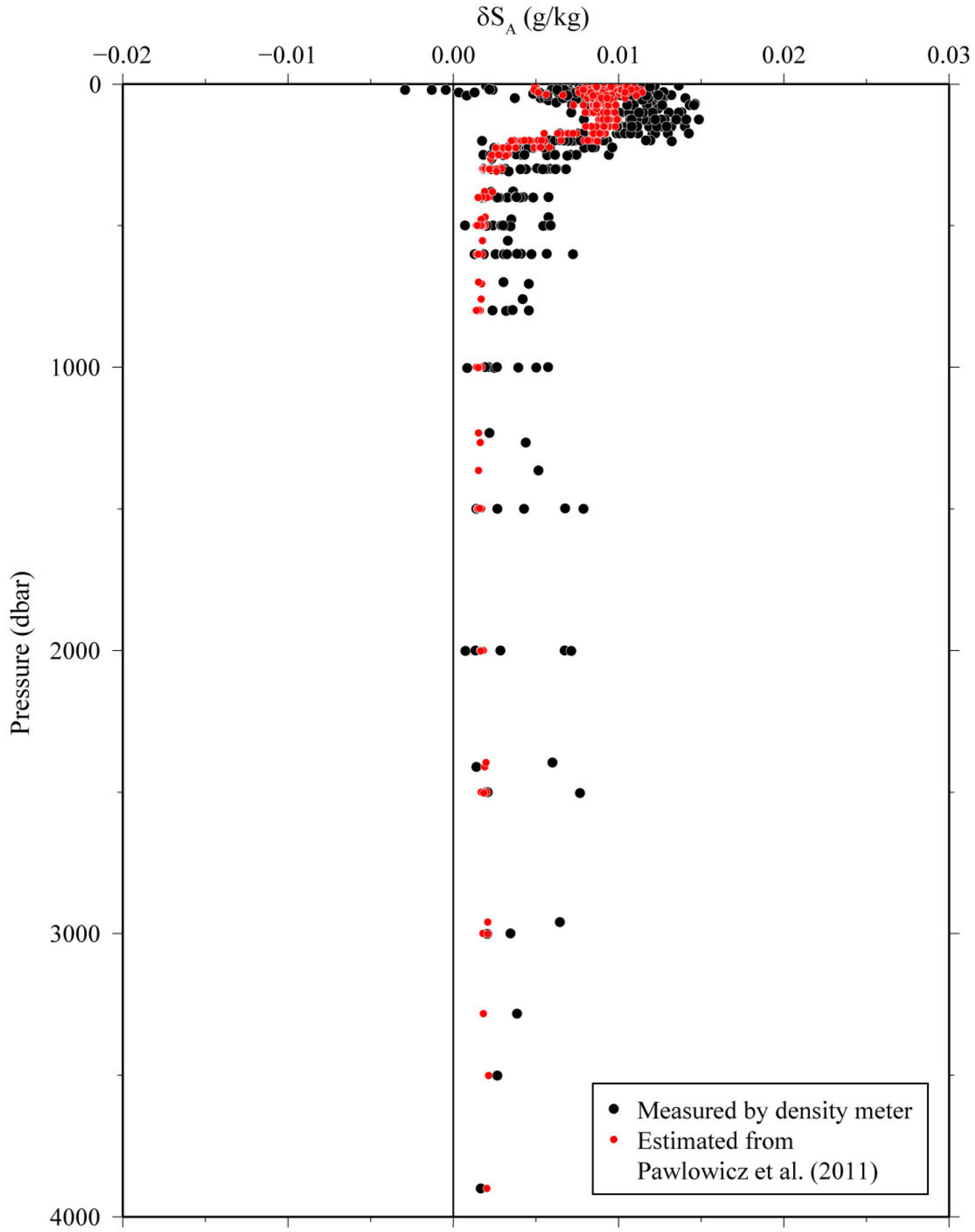


Figure 3.7-1. Vertical distribution of density salinity anomaly measured by the density meter. Absolute Salinity anomaly estimated from nutrients and carbonate parameters (Pawlowicz et al., 2011) are also shown for comparison.

3.8. Moorings

We recovered five moorings (BCE-15, BCC-15, BCW-15 NHC-15t and NBC-15t) .

We deployed six moorings. One mooring was deployed in the Southern Chukchi sea (SCH-16). Three moorings were deployed in the Barrow Canyon (BCE-16, BCC-16, BCW-16) at the locations which are almost the same as those of the deployed mooring. In addition, two sediment trap moorings were deployed in the North of Barrow Canyon (NBC-16t) and North of Hanna Canyon (NHC-16t) at the locations which are almost the same as those of the deployed mooring. Detail of the sediment trap mooring is described in section 4.16.1 (PI: Naomi Harada, JAMSTEC).

(1) Personnel

Shigeto Nishino	(JAMSTEC)	Principal Investigator
Motoyo Ito	(JAMSTEC not on board)	
Jonaotaro Onodera	(JAMSTEC)	
Amane Fujiwara	(JAMSTEC)	
Keisuke Matsumoto	(MWJ)	Operation leader
Rei Ito	(MWJ)	Technical staff
Keisuke Takeda	(MWJ)	Technical Staff

(2) Objectives

The purpose of mooring measurements at the Barrow Canyon (BCE-16, BCC-16, BCW-16) is to monitor the variations of volume, heat and fresh water fluxes of Pacific Water. The purpose of mooring measurements at the Southern Chukchi sea (SCH-16) where the biological activity is extremely high and is called a biological hot spot is to understand the ocean environment and its annual changes maintaining the hot spot. Components of these moorings are depicted in Figure 3.8-1, 3.8-2.

(3)Parameters

- Oceanic velocities
- Echo intensity, bottom tracking range and velocities for sea ice measurements
- Pressure, Temperature and Conductivity
- Dissolved oxygen
- pH
- Chlorophyll-a and turbidity

(4) Instruments and methods

1) CTD or CT sensors

SBE37-SM (Sea-Bird Electronics Inc.)

A7CT-USB (JFE Advantech)

2) Current meters
Workhorse ADCP 300 kHz SC Sentinel (Teledyne RD Instruments, Inc.)
Aquadopp Current Meter 2MHz (NORTEK AS)
S4 current meter (InterOcean systems, Inc.)

3) Dissolved oxygen sensor
AROW-USB (JFE Advantech)

4) Chlorophyll-a and turbidity sensor
ACLW-USB (JFE Advantech)
MFL50W-USB (JFE Advantech)

5) pH sensor
Hybrid pH (JAMSTEC)

6) Acoustic transponder
XT-6000-10 (Teledyne Benthos, Inc.)
XT-6001-13 (Teledyne Benthos, Inc.)

7) Acoustic releaser
Model L-Ti (Nichiyu giken kogyo co., LTD)
Model L-BL (Nichiyu giken kogyo co., LTD)
8242XS (ORE offshore /EdgeTech)

(5) Station list

Table 3.8-1: Station of deployed mooring

Mooring ID	Deployment Date [UTC]	Latitude [N]	Longitude [W]	Bottom depth [m]
SCH-16	2016/09/01	68-01.9805	168-50.1210	58.4
BCE-16	2016/09/07	71-40.3657	155-00.0516	106.7
BCC-16	2016/09/09	71-44.0273	155-09.6939	283
BCW-16	2016/09/06	71-47.7577	155-20.7304	169.4
NBC-16t	2016/09/17	72-28.3208	155-24.5086	1,995
NHC-16t	2016/09/16	73-18.1658	160-46.9514	425

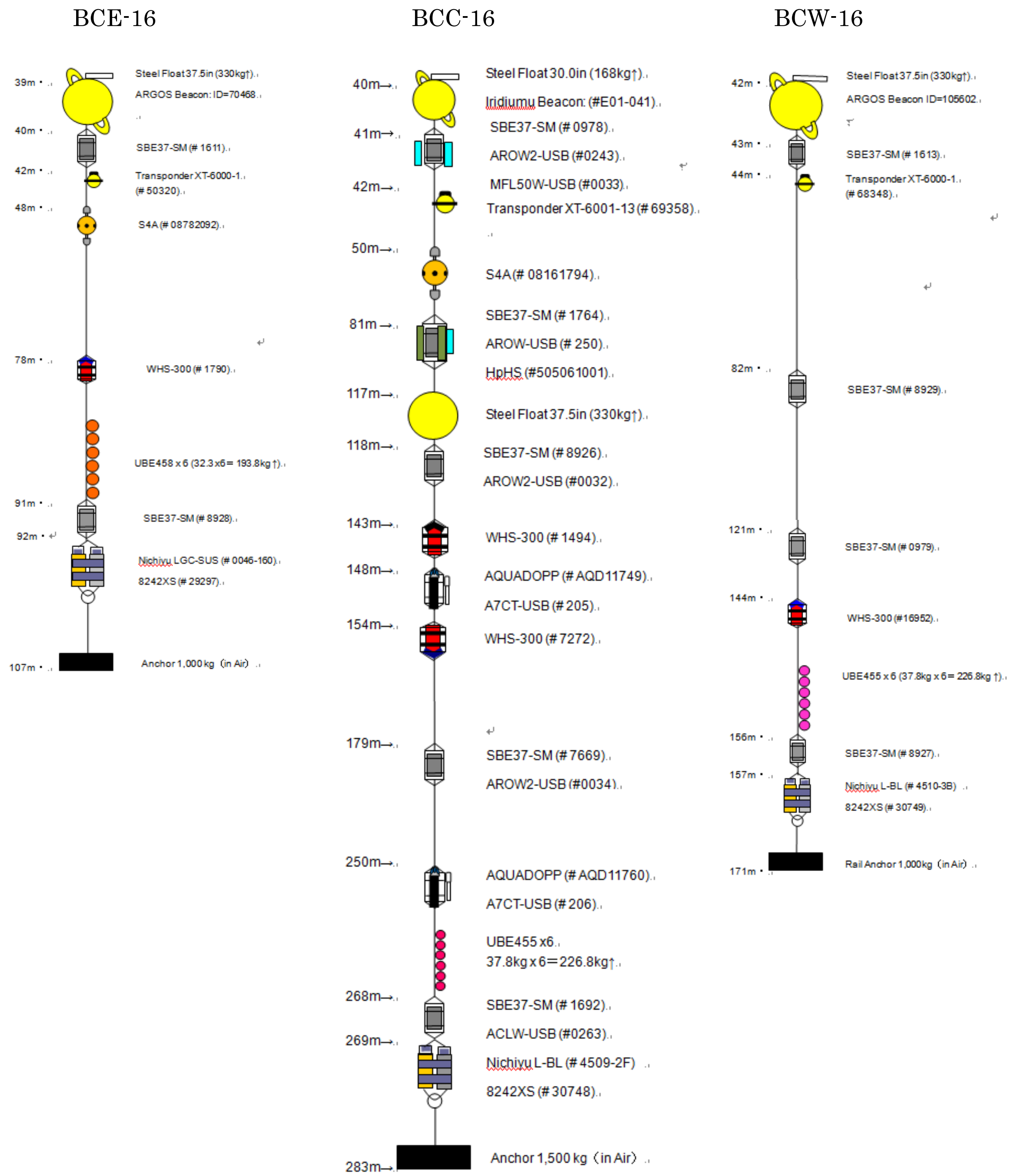


Figure 3.8-1: Mooring diagram of Deployment moorings (BCE-16, BCC-16, BCW-16)

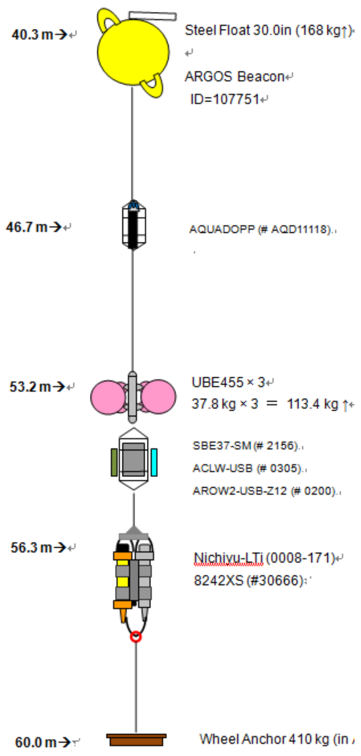


Figure 3.8-2: Mooring diagram of Deployment moorings (SCH-16)

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

3.9. Smart Float Operation

(1) Personnel

Kensuke Watari (JAMSTEC): PI
Fumitaka Sugimoto (JAMSTEC)
Satoshi Tsubone (JAMSTEC)
Tomohiko Sugiyama (MWJ)

(2) Objectives

Smart Float in the Arctic, is a device that has been developed in order to observe under the ice. In this cruise, the following experiment was carried out.

① Smart Float has a built-in video camera. In this video camera, shoot under the sea ice, it was experimental for getting the video data to recover the smart Float.

② Smart Flaot have a CTD sensor which is developed by the JAMSTEC. Using this sensor, it was CTD observation under the ice. At the same time, do the CTD observation on the ship, to confirm the certainty of the observed value.

③ A long time to dive a smart Float, was confirmed during the motion control function.

④ Comparing the orientation of the geomagnetic sensor and GPS compass of smart Float, to correct the deviation of the value.

(3) Parameters

Diving time
Diving depth
Diving direction
Geomagnetic
CTD

(4) Instruments and methods

①Smart Float

Smart float has been developed by JAMSTEC, it is a small AUV for observing the under sea ice. CTD sensors, cameras, etc., are equipped with a variety of observation equipment. In this experiment, it was used five smart floats No.3 ~. 7.

Figure 3.9-1: Smart Float No.6

②Calibration for Geomagnetic Sensor

In this experiment with the sensor using the following were detected deviation of the magnetic north and true North.

(4) Observation log

Table 3.9-1: Smart Float operation point

Dive No	Body No	Date (UTC-11)	Deploy Point	Recover Point
1	3	2016/9/3	71.27.20N 158.42.61W	Same point of deploy
2	7	2016/9/4	71.23.3137N 158.36.4195W	71.22.9924N 158.37.6726W
3	4	2016/9/10	72.29.61N 159.01.93W	72.28.1061N 159.00.4545W
4	5	2016/9/10	72.28.1061N 159.00.4545W	LOST
5	6	2016/9/10	72.27.8872N 159.01.0734W	72.25.5991N 158.56.6944,W
6	7	2016/9/10	72.27.4212N 159.02.0294W	LOST
7	4	2016/9/11	72.26.47N 158.49.94W	72.26.96N 158.49.38W
8	3	2016/9/11	72.26.26N 158.47.98W	Same point of deploy

(5) Preliminary results

①Photo under sea ice

Smart floats have a video camera. They can record the movie under sea ice.

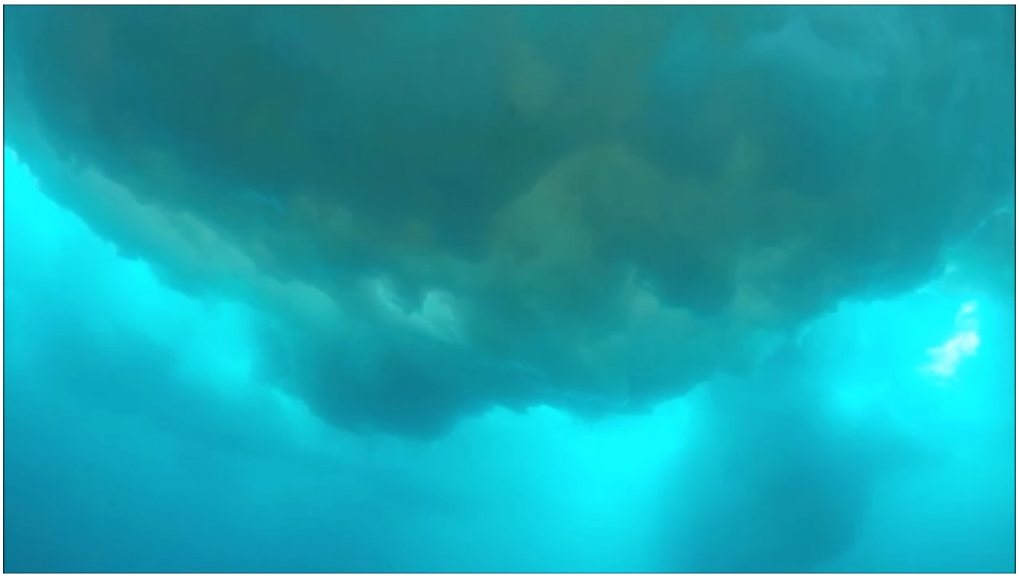
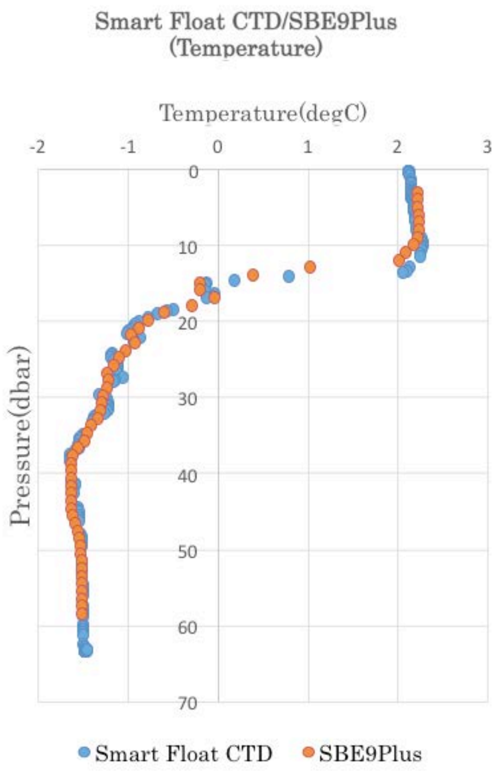
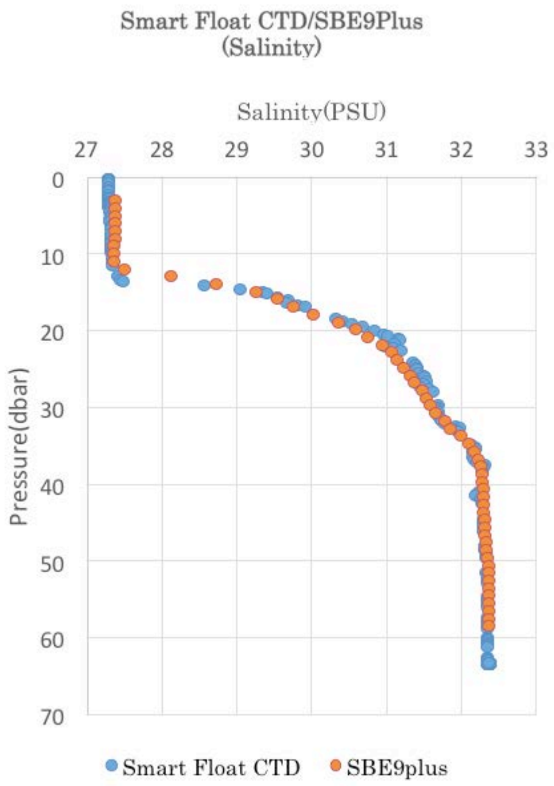


Figure 3.9-2: Photo taken by Smart float in the sea

②Comparison of the CTD sensor

Smart floats have a CTD sensor. We compare with observation value.





(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via “Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)” in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

3.10. Sound velocity

(1) Personnel

Hiroshi Uchida (JAMSTEC) (Principal investigator)
Shigeto Nishino (JAMSTEC)
Tatsuya Tanaka (MWJ)
Hiroshi Matsunaga (MWJ)
Rei Ito (MWJ)
Keisuke Takeda (MWJ)

(2) Objectives

The objective of this study is to estimate Absolute Salinity (also called "density salinity") from sound velocity data with temperature and pressure data from CTD, and to evaluate an algorithm to estimate absolute salinity provided along with TEOS-10 (the International Thermodynamic Equation of Seawater 2010) (IOC et al., 2010).

(3) Materials and methods

Sound velocity profiles were measured at the CTD casts by using a velocimeter (MiniSVP, serial no. 49618, Valeport Ltd., Devon, United Kingdom). The sound velocity sensing elements are a ceramic transducer (signal sound pulse of 2.5 MHz frequency), a signal reflector, and spacer rods to control the sound path length (10 cm), providing a measurement at depths up to 6000 m. The velocimeter was attached to the CTD frame and level of the sound path of the velocimeter was same as that of the CTD temperature sensor, just next to the primary temperature sensor (Fig. 3.10.1). Although temperature and pressure data were also measured by the velocimeter, only sound velocity data measured at a sampling rate of 8 Hz will be combined with the CTD temperature and pressure data measured at a sampling rate of 24 Hz to estimate Absolute Salinity.

The CTD casts obtained the sound velocity data were listed in Table 3.10.1. The estimated Absolute Salinity profiles will be calibrated in situ referred to the Absolute Salinity data measured by a density meter for water samples (see Section 3.7).

Fig. 3.10.1. Photos of the velocimeter attached to the CTD frame.

(4) Reference

IOC, SCOR and IAPSO (2010): The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, United Nations Educational, Scientific and Cultural Organization (English), 196 pp.

Table 3.10.1. CTD casts (STNNBR_CASTNO) obtained sound velocity data.

CTD cast with density measurements	CTD cast without density measurements
001_001	032_001
042_001	033_001
043_001	034_001
044_001	035_001
046_001	036_001
047_001	037_001
048_001	038_001
049_001	039_001
050_001	040_001
051_001	041_001
055_001	052_001
056_001	053_001
060_001	057_001
062_001	058_001
063_001	058_002
064_001	059_001
065_001	067_001
066_001	067_002
	068_001
	069_001
	070_001
	071_001

4. Chemical and Biological Oceanography
4.1. Dissolved Oxygen

(1) Personnel
Shigeto NISHINO (JAMSTEC): Principal Investigator
Haruka TAMADA (Marine Works Japan Co. Ltd): Operation Leader
Misato Kuwahara (Marine Works Japan Co. Ltd)
Rui Nitahara (Marine Works Japan Co. Ltd)

(2) Objective
Determination of dissolved oxygen in seawater by Winkler titration.

(3) Parameters
Dissolved Oxygen

(4) Instruments and Methods
Following procedure is based on an analytical method, entitled by "Determination of dissolved oxygen in sea water by Winkler titration", in the WHP Operations and Methods (Dickson, 1996).

a. Instruments
Burette for sodium thiosulfate and potassium iodate;
APB-510 / APB-620 manufactured by Kyoto Electronic Co. Ltd. / 10 cm^3 of titration vessel
Detector;
Automatic photometric titrator (DOT-01X) manufactured by Kimoto Electronic Co. Ltd.
Software;
DOT_Terminal Ver. 1.2.0

b. Reagents
Pickling Reagent I: Manganese chloride solution (3 mol dm^{-3})
Pickling Reagent II:
Sodium hydroxide (8 mol dm^{-3}) / sodium iodide solution (4 mol dm^{-3})
Sulfuric acid solution (5 mol dm^{-3})
Sodium thiosulfate (0.025 mol dm^{-3})
Potassium iodate (0.001667 mol dm^{-3})

CSK standard of potassium iodate:

Lot KPG6393, Wako Pure Chemical Industries Ltd., 0.0100N

c. Sampling

Seawater samples were collected with Niskin bottle attached to the CTD-system and surface bucket sampler. Seawater for oxygen measurement was transferred from sampler to a volume calibrated flask (ca. 100 cm^3). Three times volume of the flask of seawater was overflowed. Temperature was measured by digital thermometer during the overflowing. Then two reagent solutions (Reagent I and II) of 1 cm^3 each were added immediately into the sample flask and the stopper was inserted carefully into the flask. The sample flask was then shaken vigorously to mix the contents and to disperse the precipitate finely throughout. After the precipitate has settled at least halfway down the flask, the flask was shaken again vigorously to disperse the precipitate. The sample flasks containing pickled samples were stored in a laboratory until they were titrated.

d. Sample measurement

At least two hours after the re-shaking, the pickled samples were measured on board. 1 cm^3 sulfuric acid solution and a magnetic stirrer bar were added into the sample flask and stirring began. Samples were titrated by sodium thiosulfate solution whose morality was determined by potassium iodate solution. Temperature of sodium thiosulfate during titration was recorded by a digital thermometer. During this cruise, we measured dissolved oxygen concentration using 2 sets of the titration apparatus. Dissolved oxygen concentration (μmol kg^{-1}) was calculated by sample temperature during seawater sampling,salinity of the bottle sampling, flask volume, and titrated volume of sodium thiosulfate solution without the blank.

e. Standardization and determination of the blank

Concentration of sodium thiosulfate titrant was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130°C. 1.7835g potassium iodate weighed out accurately was dissolved in deionized water and diluted to final volume of 5 dm^3 in a calibrated volumetric flask (0.001667 mol dm^{-3}). 10 cm^3 of the standard potassium iodate solution was added to a flask using a volume-calibrated dispenser. Then 90 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 1 cm^3 of pickling reagent solution II and I were added into the flask in order. Amount of titrated volume of sodium thiosulfate (usually 5 times measurements average) gave the morality of sodium thiosulfate titrant.

The oxygen in the pickling reagents I (1 cm^3) and II (1 cm^3) was assumed to be 3.8 x

10^{-8} mol (Murray *et al.*, 1968). The blank due to other than oxygen was determined as follows.1 and 2 cm^3 of the standard potassium iodate solution were added to two flasks respectively using a calibrated dispenser. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 1 cm^3 of pickling reagent solution II and I each were added into the flask in order. The blank was determined by difference between the first (1 cm^3 of KIO_3) titrated volume of the sodium thiosulfate and the second (2 cm^3 of KIO_3) one. The results of 3 times blank determinations were averaged.

(5) Observation log

a. Standardization and determination of the blank

Table 4.1-1 shows results of the standardization and the blank determination during this cruise.

Table 4.1-1 Results of the standardization and the blank determinations during cruise.

Date	KIO_3 ID	$Na_2S_2O_3$	DOT-01X(No.7)		DOT-01X(No.8)		Stations
			E.P.	Blank	E.P.	Blank	
2016/08/23	K1605A01	T1606A	3.961	0.001	3.961	0.000	
2016/08/23	CSK_KPG6393	T1606A	3.963	0.001	3.964	0.000	
2016/08/29	K1605A02	T1606A	3.961	0.002	3.960	0.001	001, 002, 003, 004, 005, 006, 007, 008, 009, 010, 011, 012, 013, 014, 015, 016, 017, 018, 019, 020, 021, 022, 023, 024, 025, 026, 029
2016/09/05	K1605A03	T1606A	3.966	0.005	3.964	0.004	
2016/9/05	K1605A03	T1606B	3.966	0.005	3.960	0.004	036, 037, 038, 039, 040, 041, 042, 043, 044, 045, 046, 047, 048, 049, 050, 051, 052, 053
2016/09/12	K1605A04	T1606B	3.961	0.008	3.959	0.007	
2016/09/12	K1605A04	T1606C	3.963	0.006	3.961	0.005	054, 055, 056, 058, 060, 062, 063, 064, 065, 066, 067, 068, 069, 070, 071
2016/9/18	K1605A05	T1606C	3.966	0.008	3.961	0.008	
2016/9/18	K1605A05	T1606D	3.960	0.003	3.958	0.003	072, 073, 074, 075, 076, 077, 078, 079, 080, 081,

							082, 083, 084, 085, 086, 087, 088, 092, 093, 094, 095, 096, 097, 098, 099
2015/9/23	K1605A06	T1606 D	3.965	0.004	3.962	0.007	

b. Repeatability of sample measurement

Replicate samples were taken at every CTD casts. Total amount of the replicate sample pairs of good measurement was 134. The standard deviation of the replicate measurement was 0.26 μmol kg^{-1} that was calculated by a procedure in Guide to best practices for ocean CO_2 measurements Chapter4 SOP23 Ver.3.0 (2007). Results of replicate samples were shown in Table 4.1-2and this diagram shown in Figure 4.1-1.

Table 4.1-2 Results of the replicate sample measurements

Layer	Number of replicate sample pairs	Oxygen concentration (μmol kg^{-1}) Standard Deviation.
200m>	110	0.28
>=200m	24	0.10
All	134	0.26

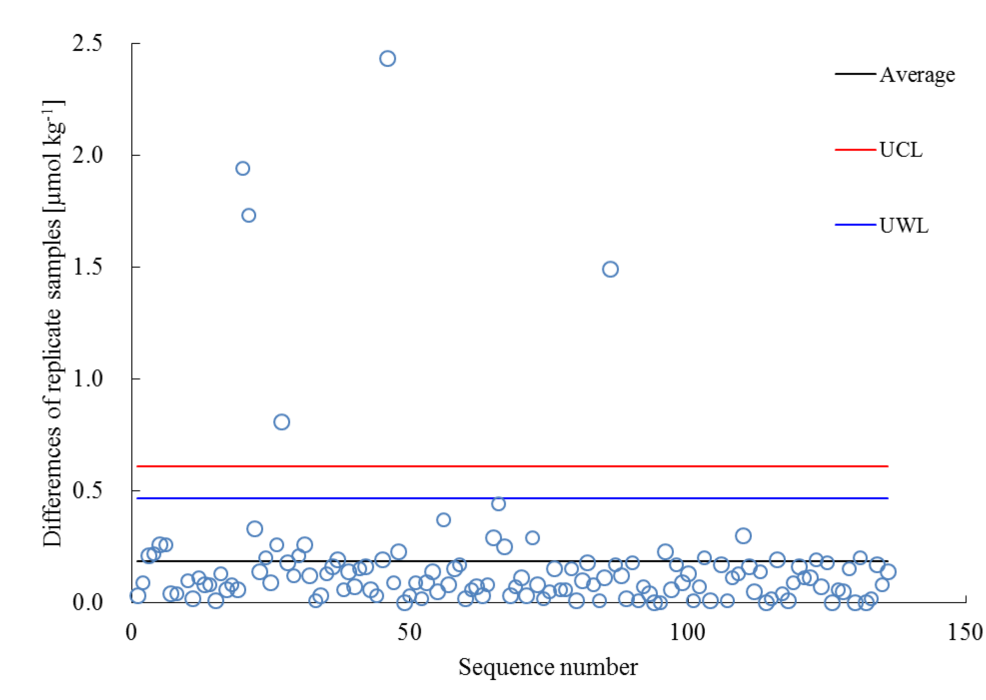


Figure 4.1-1 Differences of replicate samples against sequence number

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.

<http://www.godac.jamstec.go.jp/darwin/e>

(7) References

Dickson, A.G., Determination of dissolved oxygen in sea water by Winkler titration. (1996)

Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.), Guide to best practices for ocean CO2 measurements. (2007)

Culberson, C.H., WHP Operations and Methods July-1991 "Dissolved Oxygen", (1991)

Japan Meteorological Agency, Oceanographic research guidelines (Part 1). (1999)

KIMOTO electric CO. LTD., Automatic photometric titrator DOT-01 Instruction manual

4.2. Nutrients

(1) Personnel

Michio AOYAMA (JAMSTEC/Fukushima Univ.): Principal Investigator
Shigeto NISHINO (JAMSTEC)
Yasuhiro ARII (MWJ): Operation leader
Shinichiro YOKOGWA (MWJ)
Takehiro KANII (MWJ)
Yoshiko ISHIKAWA (MWJ)

(2) Objectives

The objectives of nutrients analyses during the R/V Mirai MR16-06 cruise in the Arctic Ocean, of which EXPOCODE is 49NZ20160822, is as follows:

- Describe the present status of nutrients concentration with excellent comparability using certified reference material of nutrient in seawater.

(3) Parameters

The determinants are nitrate, nitrite, silicate, phosphate and ammonia in the Arctic Ocean.

(4) Instruments and methods

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

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

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

The phosphate analysis is a modification of the procedure of Murphy and Riley

(1962). Molybdic acid is added to the seawater sample to form phosphomolybdic acid which is in turn reduced to phosphomolybdous acid using L-ascorbic acid as the reductant.

The ammonia in seawater is mixed with an alkaline containing EDTA, ammonia as gas state is formed from seawater. The ammonia (gas) is absorbed in sulfuric acid by way of 0.5 μm pore size membrane filter (ADVANTEC PTFE) at the dialyzer attached to analytical system. The ammonia absorbed in sulfuric acid is determined by coupling with phenol and hypochlorite to form indophenols blue. Wavelength using ammonia analysis is 630 nm, which is absorbance of indophenols blue.

The flow diagrams and reagents for each parameter are shown in Figures 4.2-1 to 4.2-5.

(4.2) Nitrate + Nitrite Reagents

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

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

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

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

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

Dissolve 1 g NED, $C_{10}H_7NHCH_2CH_2NH_2 \cdot 2HCl$, in 1000 ml of DIW and add 10 ml concentrated HCl. After mixing, 1 ml Triton™X-100 (50 % solution in ethanol) is added. This reagent is stored in a dark bottle.

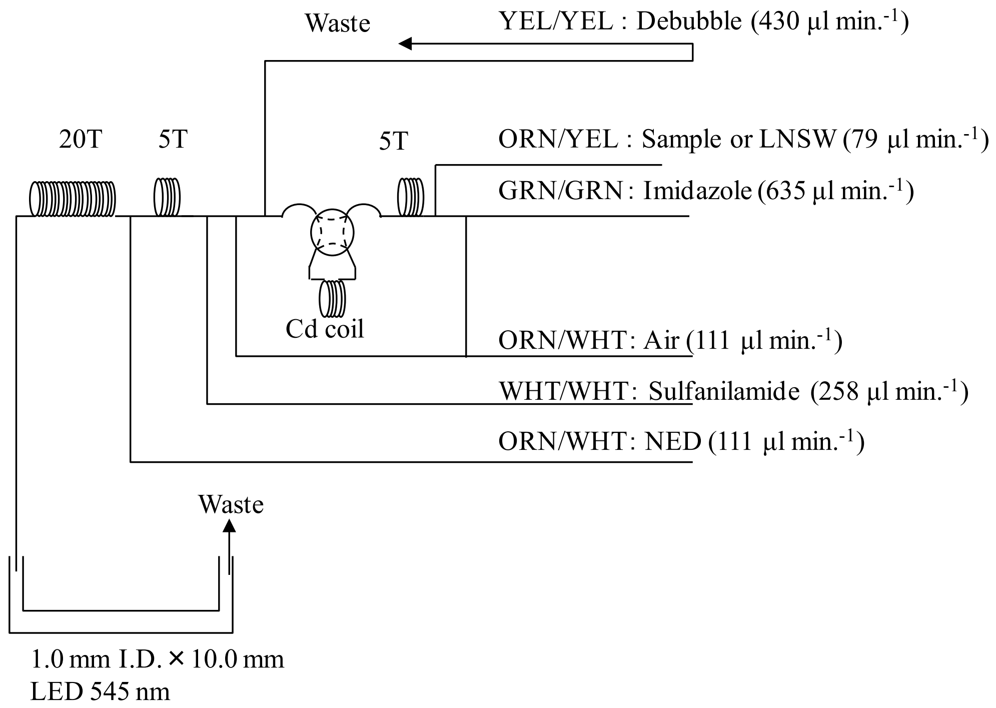


Figure 4.2-1 NO_3+NO_2 (1ch.) Flow diagram.

(4.3) Nitrite Reagents

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

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

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

Dissolve 1 g NED, $C_{10}H_7NHCH_2CH_2NH_2 \cdot 2HCl$, in 1000 ml of DIW and add 10 ml concentrated HCl. After mixing, 1 ml Triton™X-100 (50 % solution in ethanol) is added. This reagent is stored in a dark bottle.

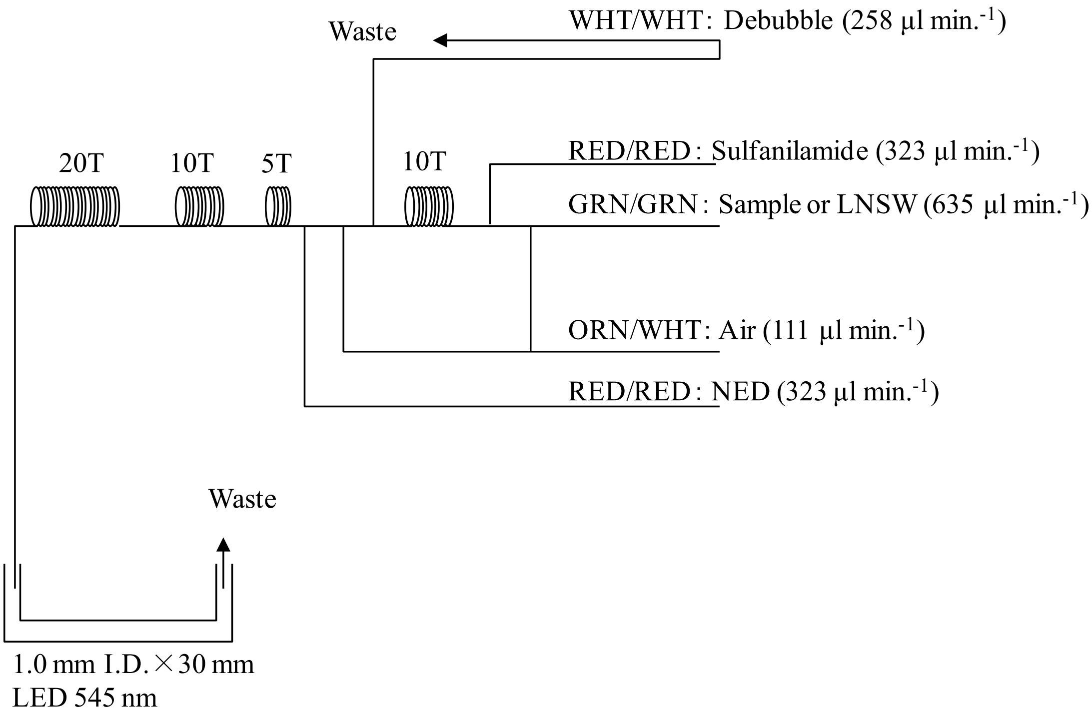


Figure 4.2-2 NO_2 (2ch.) Flow diagram.

(4.4) Silicate Reagents

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

Dissolve 15 g disodium molybdate(VI) dihydrate, $Na_2MoO_4 \cdot 2H_2O$, in 980 ml DIW, add 8 ml concentrated H_2SO_4. After mixing, 20 ml sodium dodecyl sulphate (15 % solution in water) is added.

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

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

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

Dissolve 2.5 g L (+)-ascorbic acid, $C_6H_8O_6$, in 100 ml of DIW. This reagent was freshly prepared at every day.

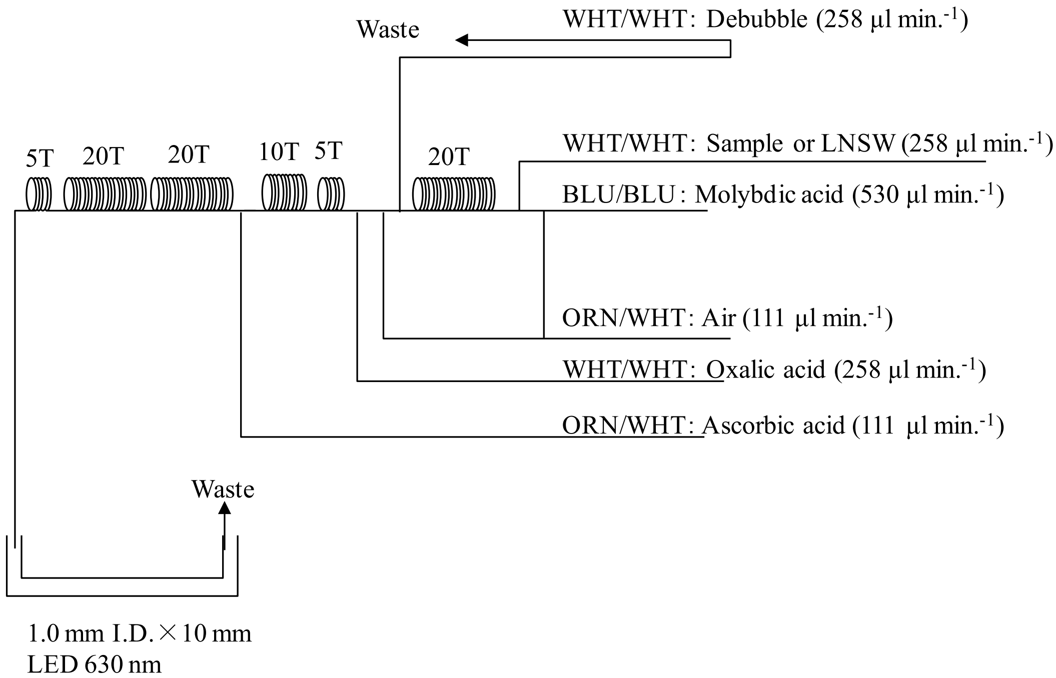


Figure 4.2-3 SiO_2 (3ch.) Flow diagram.

(4.5) Phosphate Reagents

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

Dissolve 8 g disodium molybdate(VI) dihydrate, $Na_2MoO_4 \cdot 2H_2O$, and 0.17 g antimony potassium tartrate, $C_8H_4K_2O_{12}Sb_2 \cdot 3H_2O$, in 950 ml of DIW and add 50 ml concentrated H_2SO_4.

Mixed Reagent

Dissolve 1.2 g L (+)-ascorbic acid, $C_6H_8O_6$, in 150 ml of stock molybdate solution. After mixing, 3 ml sodium dodecyl sulphate (15 % solution in water) is added. This reagent was freshly prepared before every measurement.

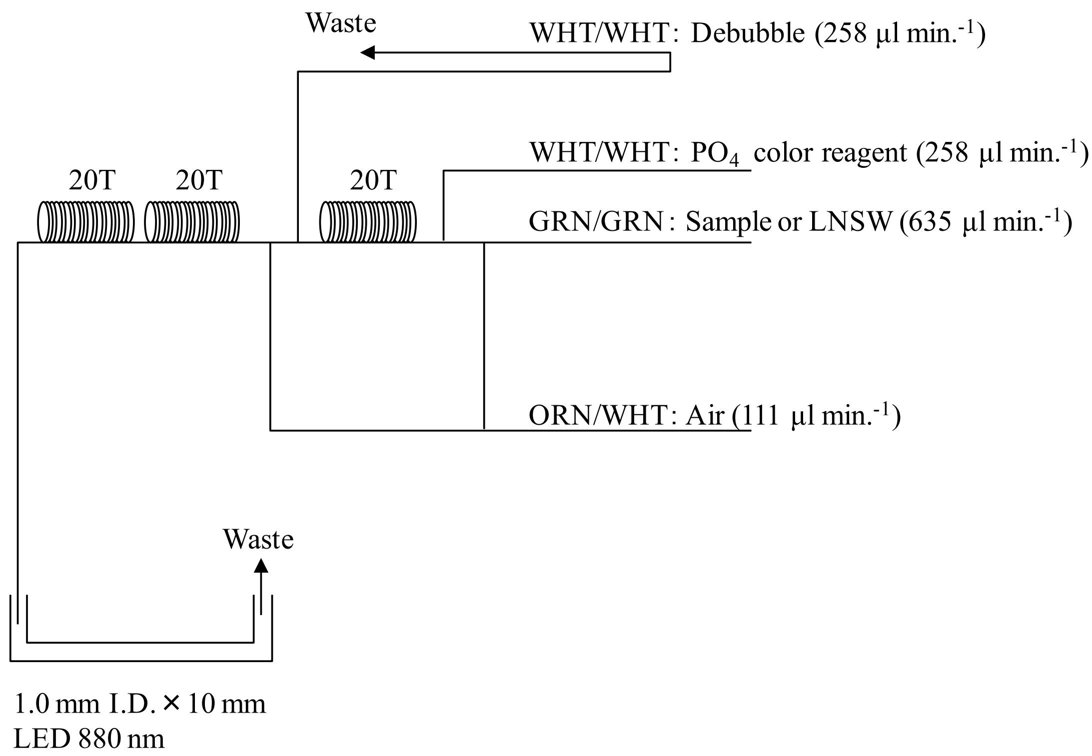


Figure 4.2-4 PO_4 (4ch.) Flow diagram.

(4.6) Ammonia Reagents

EDTA

Dissolve 41 g EDTA (ethylenediaminetetraacetatic acid tetrasodium salt), $C_{10}H_{12}N_2O_8Na_4 \cdot 4H_2O$, and 2 g boric acid, H_3BO_3, in 200 ml of DIW. After mixing, 1 ml Triton™X-100 (30 % solution in DIW) is added. This reagent is prepared at a week about.

NaOH

Dissolve 5 g sodium hydroxide, NaOH, and 16 g EDTA in 100 ml of DIW. This reagent is prepared at a week about.

Stock Nitroprusside

Dissolved 0.25 g sodium pentacyanonitrosylferrate(II), $Na_2[Fe(CN)_5NO]$, in 100 ml of DIW and add 0.2 ml 1N H_2SO_4. Stored in a dark bottle and prepared at a month about.

Nitroprusside solution

Mixed 4 ml stock nitroprusside and 5 ml 1N H_2SO_4 in 500 ml of DIW. After mixing, 2 ml Triton™X-100 (30 % solution in DIW) is added. This reagent is stored in a dark bottle and prepared at every 2 or 3 days.

Alkaline phenol

Dissolved 10 g phenol, C_6H_5OH, 5 g sodium hydroxide and 2 g citric acid, $C_6H_8O_7$, in 200 ml DIW. Stored in a dark bottle and prepared at a week about.

NaClO solution

Mixed 3 ml sodium hypochlorite solution, NaClO, in 47 ml DIW. Stored in a dark bottle and fleshly prepared before every measurement. This reagent is prepared 0.3% available chlorine.

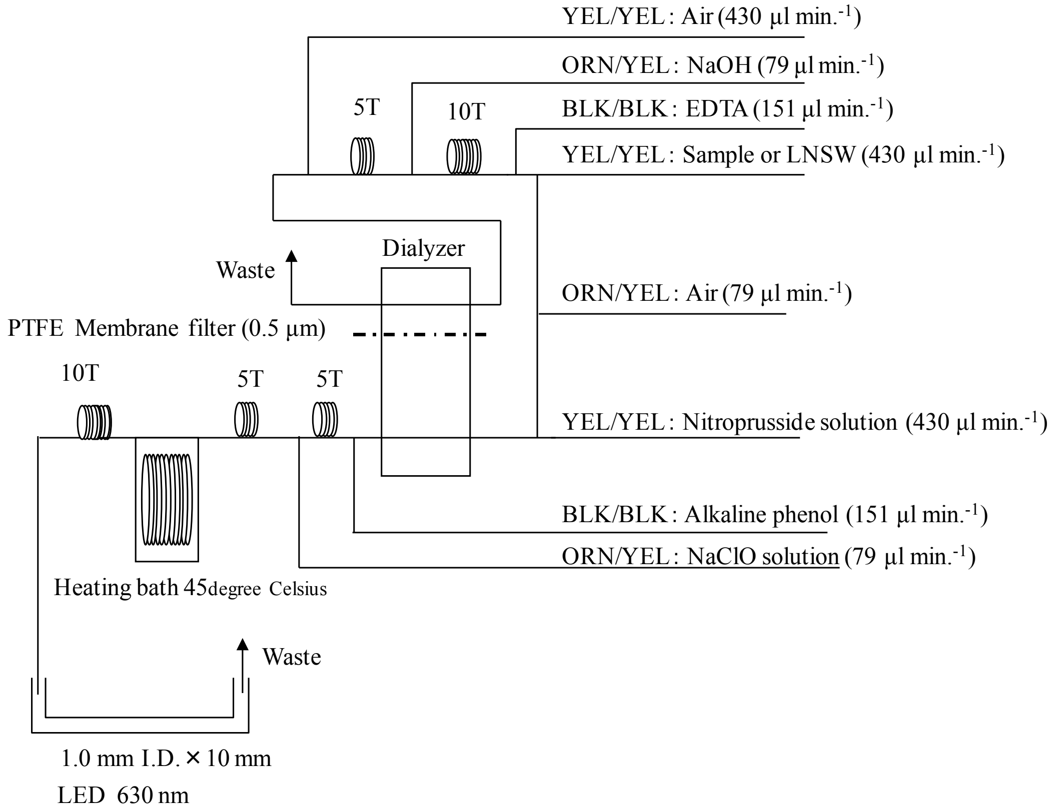


Figure 4.2-5 NH_4 (5ch.) Flow diagram.

(4.7) Sampling procedures

Sampling of nutrients followed that oxygen, salinity and trace gases. Samples were drawn into a virgin 10 ml polyacrylates vials without sample drawing tubes. These were rinsed three times before filling and vials were capped immediately after the drawing. The vials are put into water bath adjusted to ambient temperature, 23 ± 1.0 degree Celsius, in about 30 minutes before use to stabilize the temperature of samples.

No transfer was made and the vials were set an auto sampler tray directly. Samples were analyzed after collection within 24 hours, samples collected at station 53 were however analyzed after 36 hours.

(4.8) Data processing

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

- Check baseline shift.
- Check the shape of each peak and positions of peak values taken, and then change the positions of peak values taken if necessary.
- Carry-over correction and baseline drift correction were applied to peak heights of each samples followed by sensitivity correction.
- Baseline correction and sensitivity correction were done basically using liner regression.
- Load pressure and salinity from uncalibrate CTD data to calculate density of seawater tentatively. To calculate the final nutrients concentration we used salinity obtained bottle samples for 1025 samples and salinity from uncalibrate CTD data for 82 samples.
- Calibration curves to get nutrients concentration were assumed second order equations.

(4.9) Summary of nutrients analysis

We made 38 QuAAtro runs for the water columns sample collected by 86 casts at 85 stations as shown in Table 4.2-1 during MR16-06. The total amount of layers of the seawater sample reached to 1107. We made basically duplicate measurement. The station locations for nutrients measurement is shown in Figure 4.2-6.

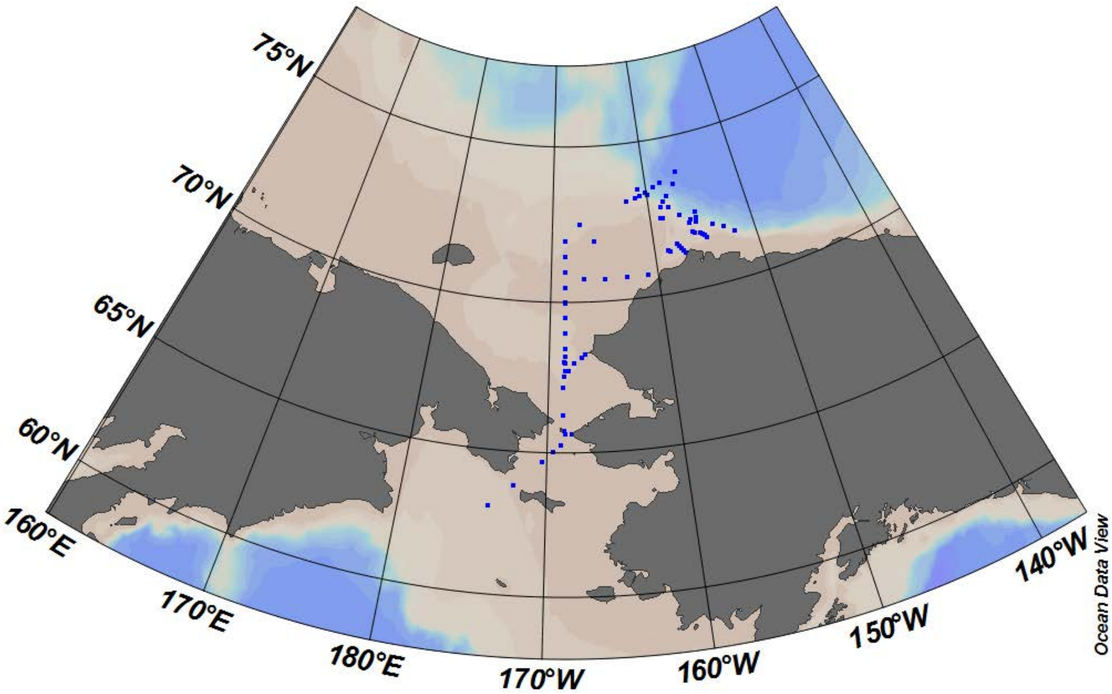


Figure 4.2-6 Sampling positions of nutrients sample.

(5) Station list

The sampling station list for nutrients is shown in Table 4.2-1.

Table 4.2-1 List of stations

Station	Cast	Date (UTC)	Position*		Depth (dbar)
		(mmddyy)	Latitude	Longitude	
001	1	083016	63-05.66N	173-59.09W	75.7
002	1	083016	63-51.59N	172-18.21W	54.6
003	1	083016	64-42.65N	170-20.92W	47.4
004	1	083016	65-03.58N	169-36.35W	50.6
005	1	083116	65-16.20N	169-03.37W	53.5
006	1	083116	65-38.95N	168-42.10W	49.1
007	1	083116	66-16.16N	168-54.83W	56.4
008	1	090116	67-11.94N	168-54.10W	48.3
009	1	090116	67-33.96N	168-49.32W	50.2
010	1	090116	68-02.09N	168-49.89W	58.1
011	1	090216	68-30.01N	168-44.32W	53.7
012	1	090216	68-59.97N	168-44.51W	52.4
013	1	090216	69-29.94N	168-44.67W	51.3
014	1	090216	69-59.97N	168-44.58W	40.5
015	1	090216	70-30.06N	168-44.82W	38.5
016	1	090216	70-59.77N	168-44.62W	44.4
017	1	090216	70-45.10N	167-00.16W	47.9
018	1	090316	70-45.01N	164-59.94W	41.7
019	1	090316	70-44.94N	162-59.99W	44.1
020	1	090316	70-44.97N	161-00.09W	43.5
021	1	090416	71-25.65N	158-42.98W	58.2
022	1	090416	71-34.75N	157-49.64W	64.1
023	1	090416	71-29.72N	157-40.09W	85.0
024	1	090416	71-24.85N	157-29.92W	122.5
025	1	090416	71-19.80N	157-19.41W	89.3
026	1	090416	71-14.67N	157-09.72W	45.1
029	1	090516	71-23.10N	158-36.45W	63.7
036	1	090716	71-52.54N	156-02.26W	80.1
037	1	090716	71-49.34N	155-50.03W	88.5
038	1	090716	71-47.96N	155-23.15W	146.1
039	1	090716	71-44.13N	155-12.67W	303.4
040	1	090716	71-39.87N	155-00.93W	102.0
041	1	090716	71-35.83N	154-47.82W	40.4

042	1	090716	71-34.01N	152-00.19W	474.0
043	1	090816	71-47.20N	153-00.44W	378.0
044	1	090816	71-57.51N	154-00.13W	708.0
045	1	090816	72-29.48N	155-21.13W	2178.0
046	1	090916	72-16.79N	156-00.03W	708.0
047	1	090916	72-28.13N	157-00.56W	564.0
048	1	090916	72-47.31N	158-00.46W	792.0
049	1	091016	73-18.53N	160-51.80W	385.0
050	1	091016	73-17.37N	160-00.62W	1220.0
051	1	091016	73-31.46N	160-54.16W	485.0
052	1	091016	72-28.57N	159-00.10W	52.4
053	1	091116	72-27.96N	158-48.78W	53.3
054	1	091316	72-49.84N	158-48.84W	277.0
055	1	091316	72-59.82N	158-29.91W	1267.0
056	1	091316	73-09.98N	158-00.57W	2388.0
058	1	091316	73-29.98N	157-00.50W	3238.0
058	2	091316	73-30.46N	157-02.97W	3189.0
060	1	091416	73-51.56N	156-34.84W	3841.0
062	1	091416	73-37.31N	158-28.03W	2927.0
063	1	091416	73-30.44N	159-17.49W	2372.0
064	1	091516	73-23.23N	160-12.24W	1355.0
065	1	091516	73-13.86N	161-18.79W	311.0
066	1	091516	73-09.53N	162-18.98W	203.0
067	1	091516	73-18.31N	160-48.13W	417.0
068	1	091616	72-28.57N	155-25.25W	2008.0
069	1	091716	72-18.90N	155-27.92W	1394.0
070	1	091716	72-09.98N	155-31.13W	378.0
071	1	091716	72-10.03N	156-12.80W	233.0
072	1	091816	71-59.43N	165-52.77W	45.4
073	1	091916	72-31.16N	167-18.68W	51.0
074	1	091916	71-59.93N	168-45.10W	50.9
075	1	091916	71-30.01N	168-44.89W	48.6
076	1	091916	70-59.88N	168-44.94W	44.7
077	1	091916	70-29.95N	168-44.62W	38.8
078	1	092016	69-59.88N	168-44.80W	41.1
079	1	092016	69-30.08N	168-44.66W	51.4
080	1	092016	69-00.04N	168-44.88W	53.3
081	1	092016	68-30.12N	168-44.93W	54.3
082	1	092016	68-15.09N	168-45.02W	57.3

083	1	092016	67-45.08N	168-45.14W	50.6
084	1	092016	68-00.46N	168-45.09W	59.2
085	1	092016	67-45.02N	168-30.04W	50.4
086	1	092116	68-00.07N	167-59.71W	54.2
087	1	092116	68-12.26N	167-19.91W	48.4
088	1	092116	68-18.12N	167-03.27W	39.4
092	1	092116	67-34.43N	168-50.76W	50.5
093	1	092116	67-11.81N	168-53.26W	48.9
094	1	092116	66-16.25N	168-53.55W	56.9
095	1	092216	65-45.83N	168-45.57W	52.5
096	1	092216	65-39.14N	168-14.91W	42.8
097	1	092216	65-39.01N	168-41.79W	49.7
098	1	092216	65-15.96N	169-03.07W	53.6
099	1	092216	65-03.14N	169-37.11W	51.0
001	1	083016	63-05.66N	173-59.09W	75.7
002	1	083016	63-51.59N	172-18.21W	54.6
003	1	083016	64-42.65N	170-20.92W	47.4
004	1	083016	65-03.58N	169-36.35W	50.6
005	1	083116	65-16.20N	169-03.37W	53.5
006	1	083116	65-38.95N	168-42.10W	49.1
007	1	083116	66-16.16N	168-54.83W	56.4
008	1	090116	67-11.94N	168-54.10W	48.3
009	1	090116	67-33.96N	168-49.32W	50.2

*: Position indicates latitude and longitude where CTD reached maximum depth at the cast.

(6) Nutrients standards

(6.1) Volumetric laboratory ware of in-house standards

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

(6.1.1) Volumetric flasks

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

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

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

(6.1.2) Pipettes and pipettors

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

(6.2) Reagents, general considerations

(6.2.1) Specifications

For nitrate standard, "potassium nitrate 99.995 suprapur®" provided by Merck, Lot. B0771365211, CAS No.: 7757-91-1, was used.

For nitrite standard solution, we used "nitrous acid iron standard solution (NO_2^- 1000) provided by Wako, Lot ECP4122, Code. No. 140-06451." This standard solution was certified by Wako using Ion chromatograph method. Calibration result is 999 mg L^{-1} at 20 degree Celsius. Expanded uncertainty of calibration (k=2) is 0.7 % for the calibration result.

For phosphate standard, "potassium dihydrogen phosphate anhydrous 99.995 suprapur®" provided by Merck, Lot. B1144508528, CAS No.: 7778-77-0, was used.

For the silicate standard, we use "Silicon standard solution SiO_2 in NaOH 0.5 mol/l CertiPUR®" provided by Merck, CAS No.: 1310-73-2, of which lot number is HC54715536 are used. The silicate concentration is certified by NIST-SRM3150 with the uncertainty of 0.7 %. HC54715536 is certified as 1005 mg L^{-1}.

For ammonia standard, "ammonium Chloride" provided by NMIJ. We used NMIJ CRM 3011-a. The purity of this standard was greater than 99.9 %. Expanded uncertainty of calibration (k=2) is 0.065 %.

(6.2.2) Ultra-pure water

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

(6.2.3) Low nutrients seawater (LNSW)

Surface water having low nutrient concentration was taken and filtered using 0.20 μm pore capsule cartridge filter at MR15-05 cruise on January, 2016. This water is stored in 20 liter cubitainer with paper box.

LNSW concentrations were assigned to August, 2016 on MR16-06 cruise.

(6.2.4) Concentrations of nutrients for A, D, B and C standards

Concentrations of nutrients for A, D, B and C standards are set as shown in Table 4.2-2. The C standard is prepared according recipes as shown in Table 4.2-3. All volumetric laboratory tools were calibrated prior the cruise as stated in chapter (6.1) Then the actual concentration of nutrients in each fresh standard was calculated based on the ambient, solution temperature and determined factors of volumetric laboratory wares.

The calibration curves for each run were obtained using 4 levels, C-1, C-2, C-3 and C-4. We used 4 levels calibration curve.

Table 4.2-2 Nominal concentrations of nutrients for A, D, B and C standards.

	A	D	B	C-1	C-2	C-3	C-4
NO_3 (μM)	22500	900	670	0	14	28	42
NO_2 (μM)	21700	870	26	0	0.5	1.0	1.6
SiO_2 (μM)	35800		1430	0	29	57	85
PO_4 (μM)	3000		60	0	1.2	2.4	3.6
NH_4 (μM)	4000		320	0	3.2	6.4	9.6

Table 4.2-3 Working calibration standard recipes.

C Std.	B-1 Std.	B-2 Std.	B-3 Std.	DIW
C-1	0 ml	0 ml	0 ml	75 ml
C-2	10 ml	10 ml	5 ml	50 ml
C-3	20 ml	20 ml	10 ml	25 ml
C-4	30 ml	30 ml	15 ml	0 ml

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

B-2 Std.: Nitrite

B-3 Std.: Ammonia

(6.2.5) Renewal of in-house standard solutions

In-house standard solutions as stated in paragraph (6.2) were renewed as shown in Table 4.2-4(a) to (c).

Table 4.2-4(a) Timing of renewal of in-house standards.

NO_3, NO_2, SiO_2, PO_4, NH_4	Renewal
A-1 Std. (NO_3)	maximum a month
A-2 Std. (NO_2)	commercial prepared solution
A-3 Std. (SiO_2)	commercial prepared solution
A-4 Std. (PO_4)	maximum a month

A-5 Std. (NH_4)	maximum a month
D-1 Std.	maximum 8 days
D-2 Std.	maximum 8 days
B-1 Std. (mixture of A-1, A-3 and A-4 std.)	maximum 8 days
B-2 Std. (dilute D-2 std.)	maximum 8 days
B-3 Std. (dilute A-5 std.)	maximum 8 days

Table 4.2-4(b) Timing of renewal of working calibration standards.

Working standards	Renewal
C Std. (mixture of B-1 , B-2 and B-3 Std.)	every 24 hours

Table 4.2-4(c) Timing of renewal of in-house standards for reduction estimation.

Reduction estimation	Renewal
36 µM NO_3	when C Std. renewed
35 µM NO_2	when C Std. renewed

(7) Certified Reference Material of nutrients in seawater

To get the more accurate and high quality nutrients data to achieve the objectives stated above, huge numbers of the bottles of the Certified Reference Material of nutrients in seawater (hereafter CRM), which were recently certify by JAMSTEC and KANSO, are prepared (Aoyama et al., 2006, 2007, 2008, 2009, 2012, 2014, 2016). In the previous worldwide expeditions, such as WOCE cruises, the higher reproducibility and precision of nutrients measurements were required (Joyce and Corry, 1994). Since no standards were available for the measurement of nutrients in seawater at that time, the requirements were described in term of reproducibility. The required reproducibility was 1 %, 1 to 2 %, 1 to 3 % for nitrate, phosphate and silicate, respectively. Although nutrient data from the WOCE one-time survey was of unprecedented quality and coverage due to much care in sampling and measurements, the differences of nutrients concentration at crossover points are still found among the expeditions (Aoyama and Joyce, 1996, Mordy et al., 2000, Gouretski and Jancke, 2001). For instance, the mean offset of nitrate concentration at deep waters was 0.5 µmol kg^{-1} for 345 crossovers at world oceans, though the maximum was 1.7 µmol kg^{-1} (Gouretski and Jancke, 2001). At the 31 crossover points in the Pacific WHP one-time lines, the WOCE standard of reproducibility for nitrate of 1 % was fulfilled at about half of the crossover points and the maximum difference was 7 % at deeper layers below 1.6 degree Celsius in potential temperature (Aoyama and Joyce, 1996).

(7.1) CRM for this cruise

CRM lots BY, BU, CA and BW, which almost cover range of nutrients concentrations in the Arctic Ocean are prepared 28 sets.

These CRM assignments were completely done based on random number. The CRM bottles were stored at a room in the ship, REAGENT STORE, where the temperature was maintained around 14.5 - 22.5 degree Celsius.

(7.2) CRM concentration

We used nutrients concentrations for CRM lots BY, BU, CA and BW as shown in Table 4.2-5.

Table 4.2-5 Certified concentration and uncertainty (k=2) of CRMs.

unit: µmol kg^{-1}

Lot	Nitrate	Nitrite	Phosphate	Silicate	Ammonia*
BY	0.02 ± 0.02	0.02 ± 0.01	0.039 ± 0.010	1.76 ± 0.06	0.90
BU	3.94 ± 0.05	0.07 ± 0.01	0.345 ± 0.009	20.92 ± 0.49	0.99
CA	19.66 ± 0.15	0.06 ± 0.01	1.407 ± 0.014	36.58 ± 0.22	0.67
BW	24.59 ± 0.20	0.07 ± 0.01	1.541 ± 0.014	60.01 ± 0.42	0.93

*For ammonia values are references

(8) Quality control

(8.1) Precision of nutrients analyses during the cruise

Precision of nutrients analyses during this cruise was evaluated based on the 6 to 12 measurements, which are measured every 7 to 14 samples, during a run at the concentration of C-4 std. Summary of precisions are shown as shown in Table 4.2-6 and Figures 4.2-7 to 4.2-11, Analytical precisions previously evaluated were 0.08 % for nitrate, 0.10 % for phosphate and 0.07 % for silicate in CLIVAR P21 revisited cruise of MR09-01 cruise in 2009, respectively. During in this cruise, analytical precisions were 0.17 % for nitrate, 0.17 % for nitrite, 0.13 % for silicate, 0.14 % for phosphate and 0.38 % for ammonia in terms of median of precision, respectively. Then we can conclude that the analytical precisions for nitrate, nitrite, silicate, phosphate and ammonia were maintained throughout this cruise.

Table 4.2-6 Summary of precision based on the replicate analyses.

	Nitrate	Nitrite	Silicate	Phosphate	Ammonia
	CV %	CV %	CV %	CV %	CV%
Median	0.17	0.17	0.13	0.14	0.38
Mean	0.17	0.19	0.15	0.16	0.42
Maximum	0.32	0.53	0.33	0.31	1.07
Minimum	0.03	0.07	0.06	0.05	0.16
N	38	38	38	38	38

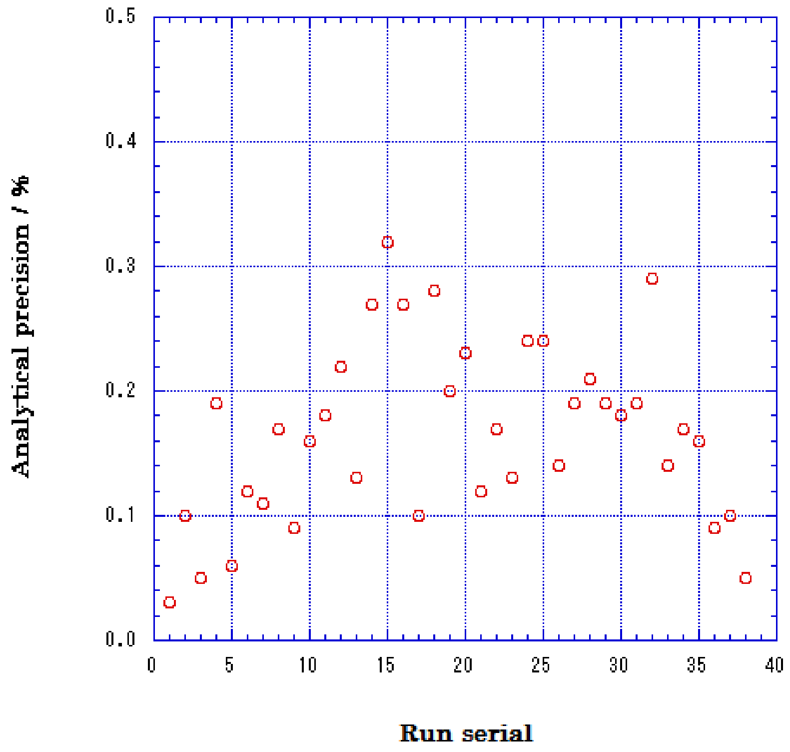


Figure 4.2-7 Time series of precision of nitrate in MR16-06

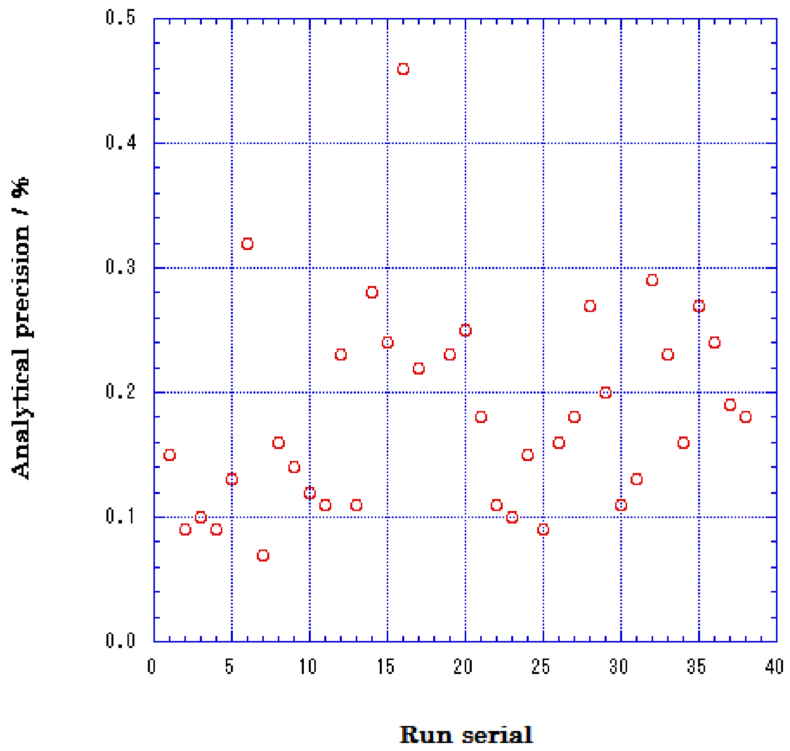


Figure 4.2-8 Time series of precision of nitrite in MR16-06.

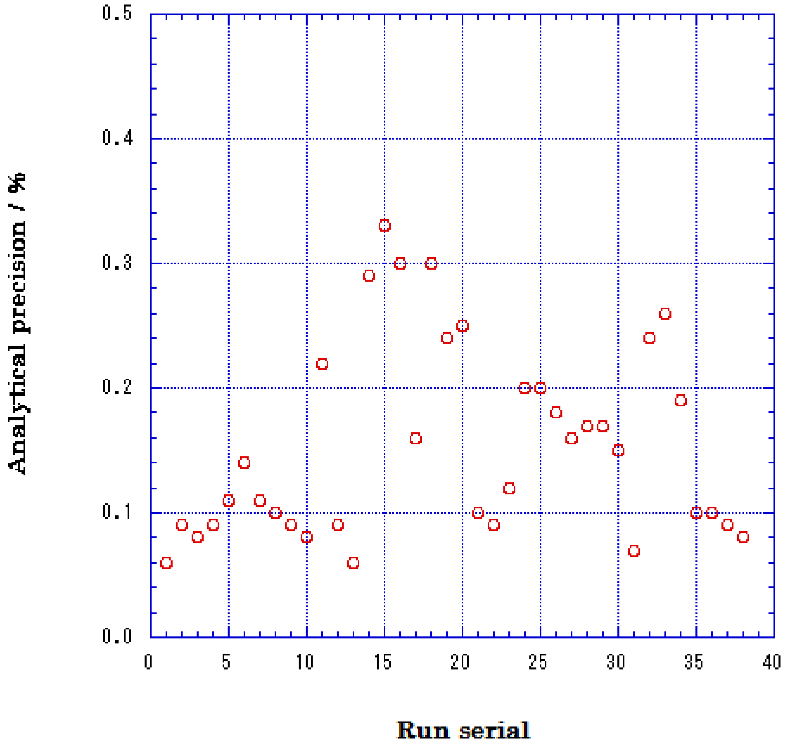


Figure 4.2-9 Time series of precision of silicate in MR16-06.

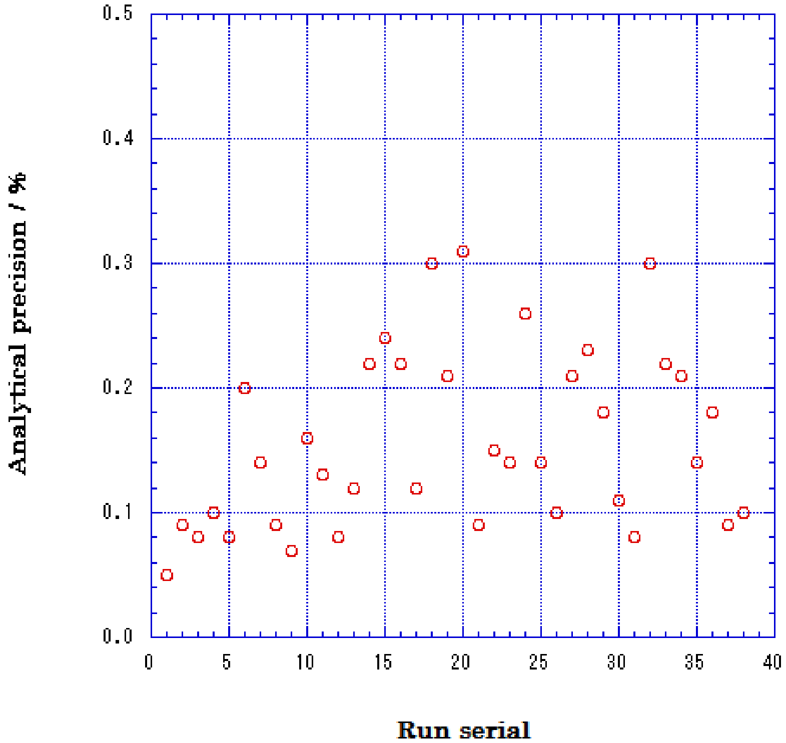


Figure 4.2-10 Time series of precision of phosphate in MR16-06.

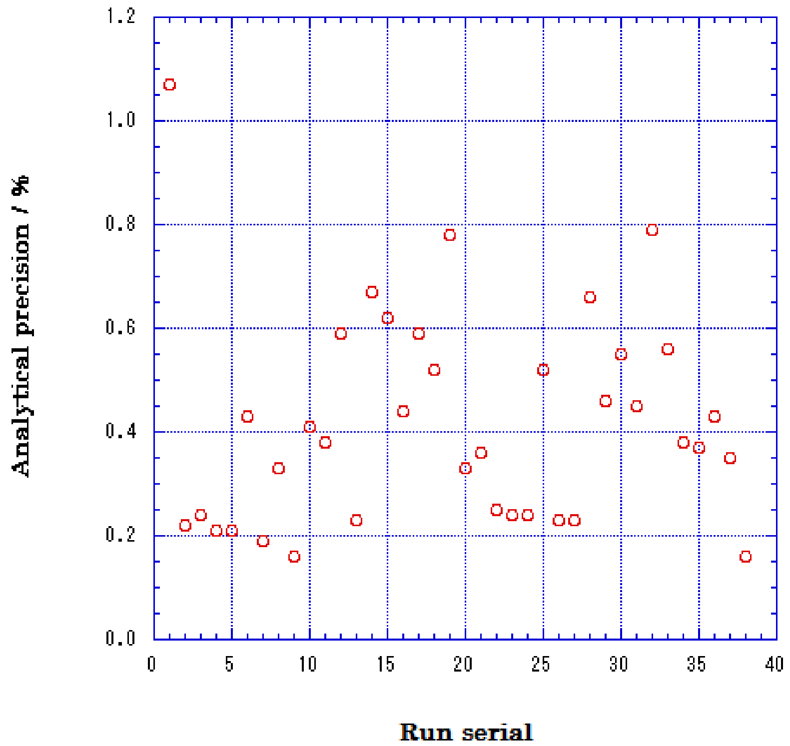


Figure 4.2-11 Time series of precision of ammonia in MR16-06.

(8.2) CRM lot. BW measurement during this cruise

CRM lot. BW was measured every run to keep the comparability. The results of lot. BW during this cruise are shown as Figures 4.2-12 to 4.2-16.

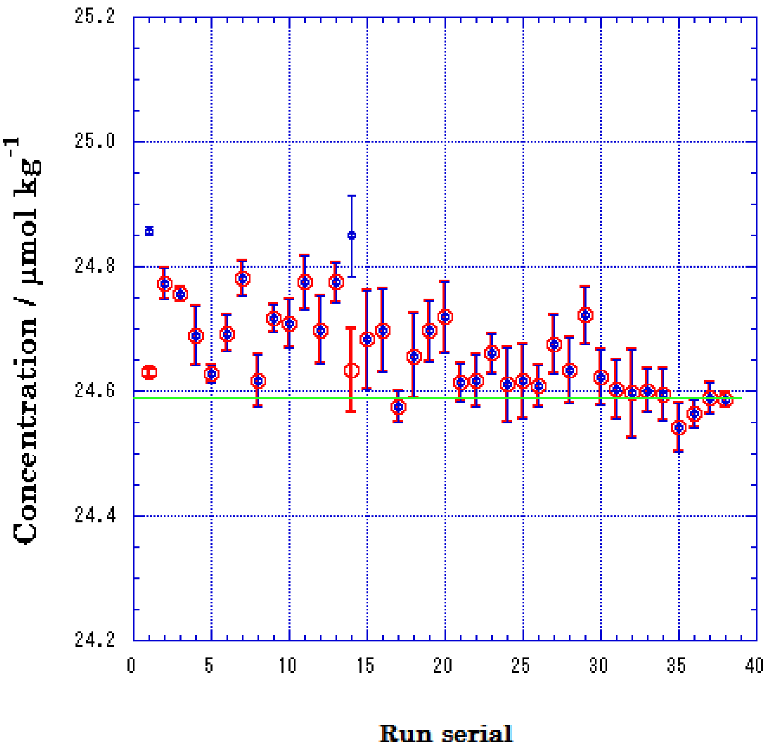


Figure 4.2-12 Time series of CRM-BW of nitrate in MR16-06. Green line is certified nitrate concentration of CRM, blue dots are no-corrrect values, red dots are corrected values.

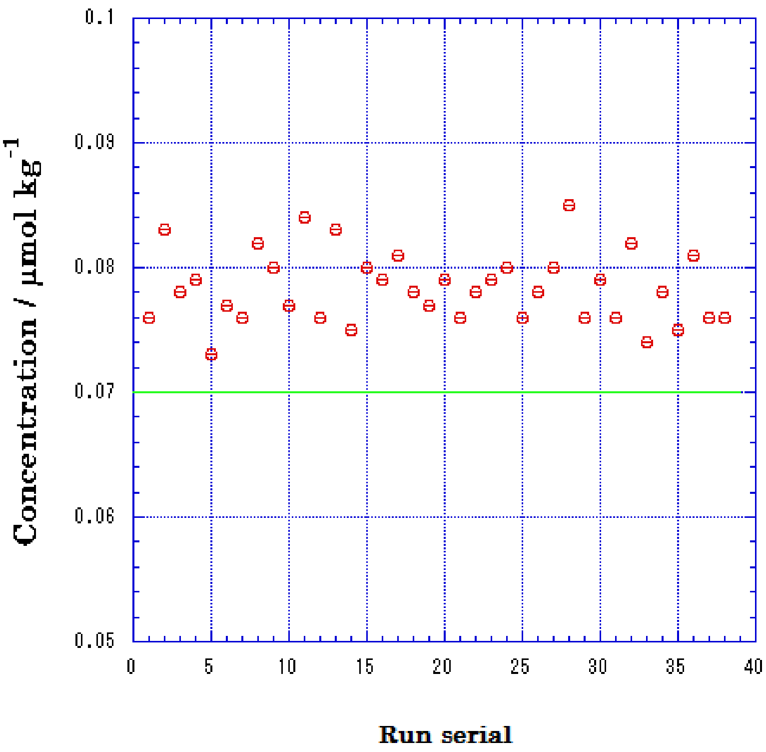


Figure 4.2-13 Time series of CRM-BW of nitrite in MR16-06.

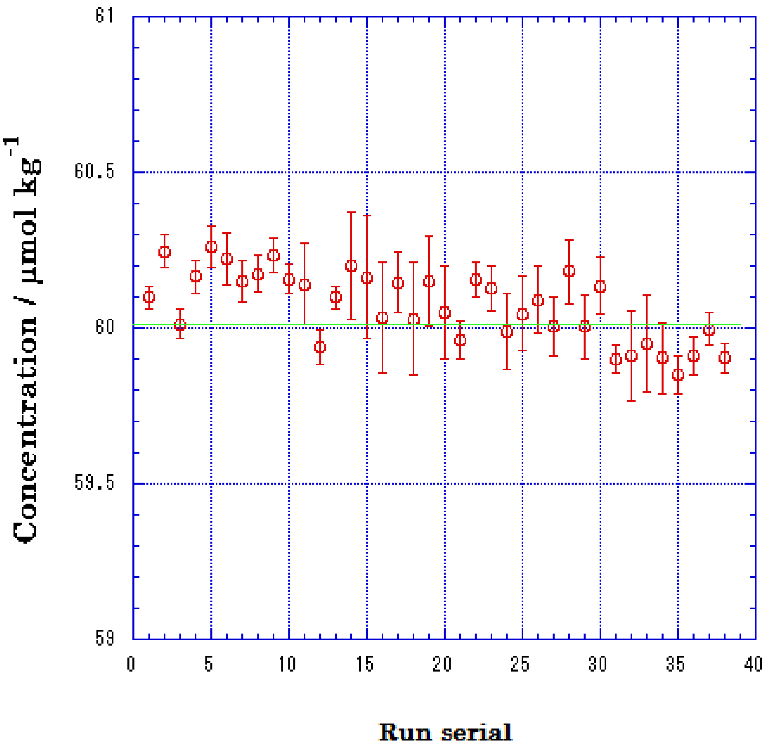


Figure 4.2-14 Time series of CRM-BW of silicate in MR16-06.

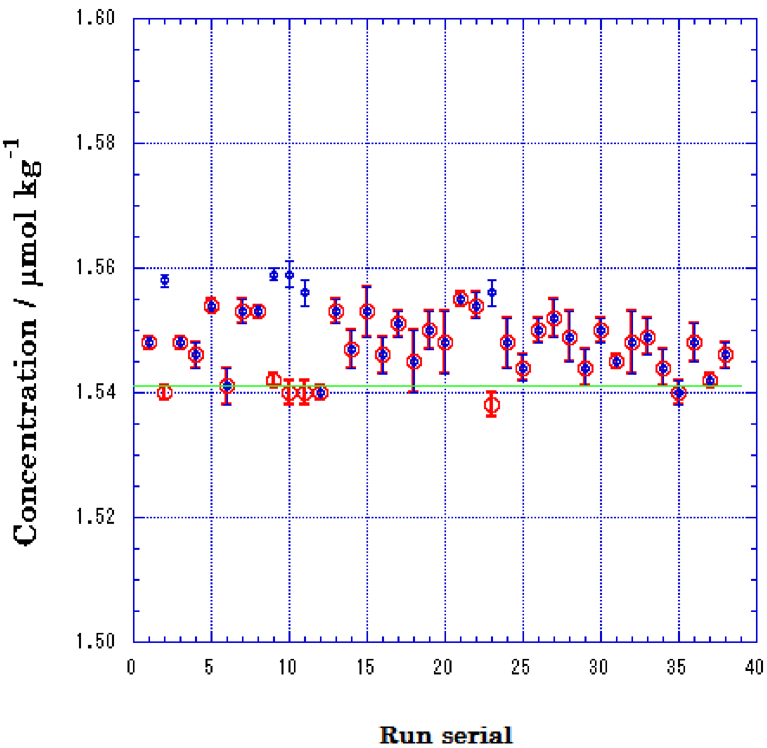


Figure 4.2-15 Time series of CRM-BW of phosphate in MR16-06. Green line is certified phosphate concentration of CRM, blue dots are no-corrrect values, red dots are corrected

values.

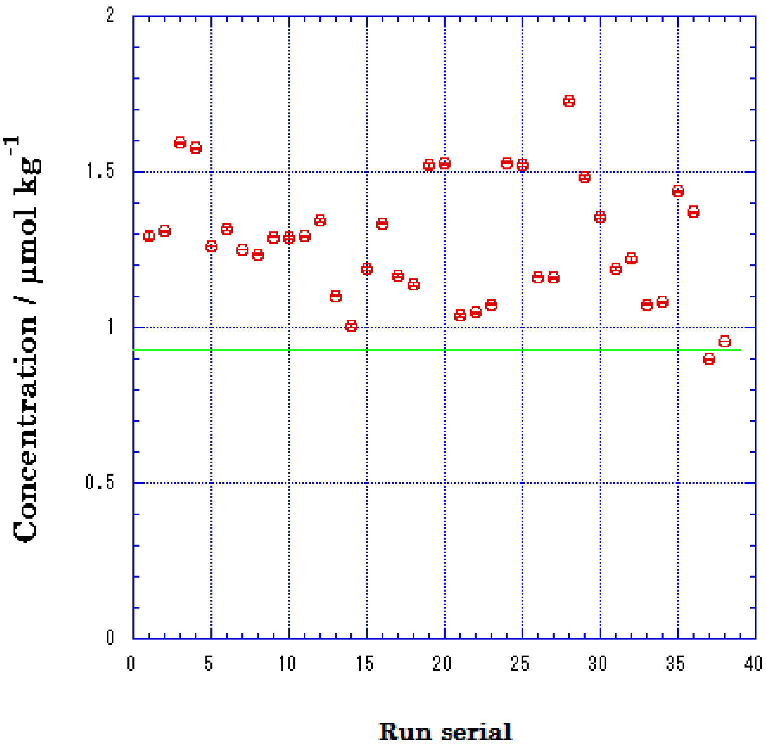


Figure 4.2-16 Time series of CRM-BW of ammonia in MR16-06.

(8.3) Carry over

We can also summarize the magnitudes of carry over throughout the cruise. These are small enough within acceptable levels as shown in Table 4.2-7 and Figure 4.2-17 to 4.2-21.

Table 4.2-7 Summary of carry over throughout MR16-06.

	Nitrate	Nitrite	Silicate	Phosphate	Ammonia
	%	%	%	%	%
Median	0.17	0.09	0.22	0.18	0.59
Mean	0.17	0.08	0.22	0.17	0.59
Maximum	0.24	0.16	0.27	0.24	0.88
Minimum	0.12	0.00	0.17	0.06	0.28
N	38	38	38	38	38

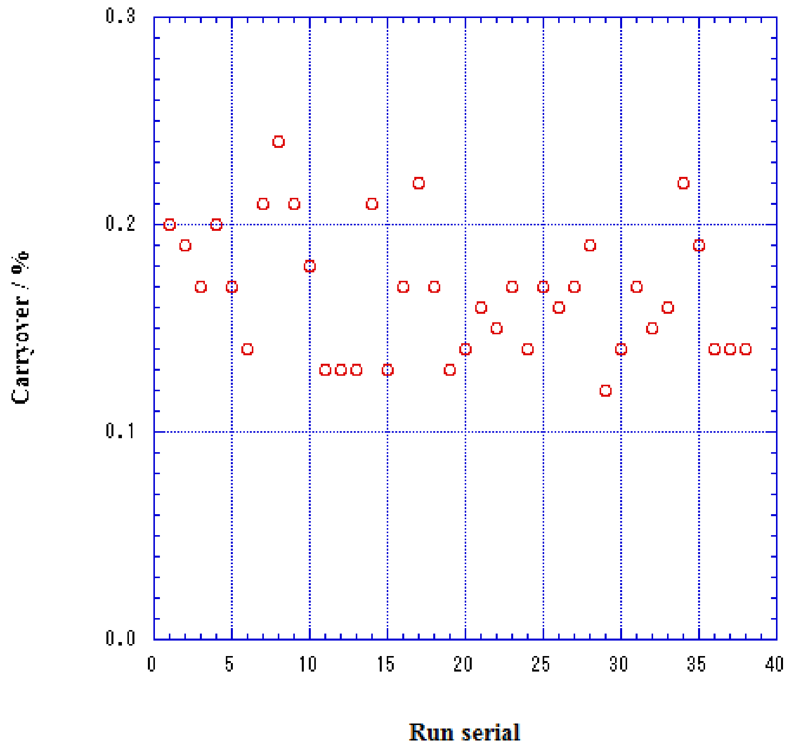


Figure 4.2-17 Time series of carry over of nitrate in MR16-06.

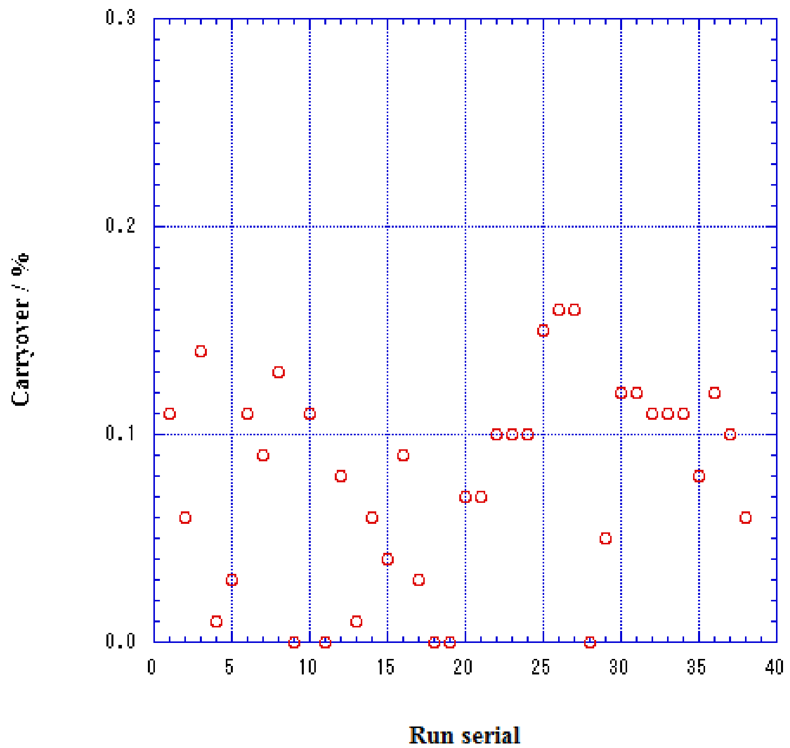


Figure 4.2-18 Time series of carry over of nitrite in MR16-06.

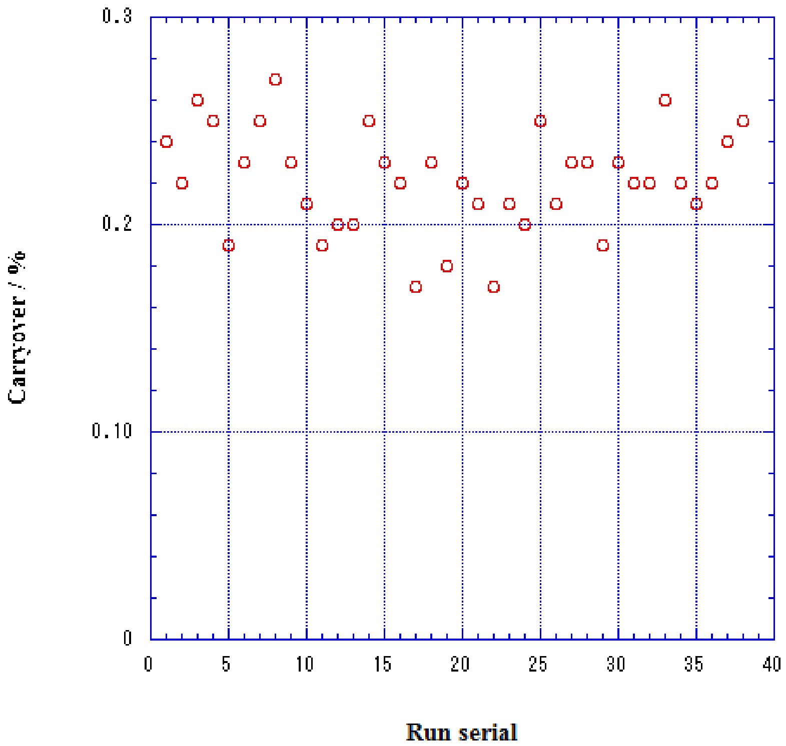


Figure 4.2-19 Time series of carry over of silicate in MR16-06.

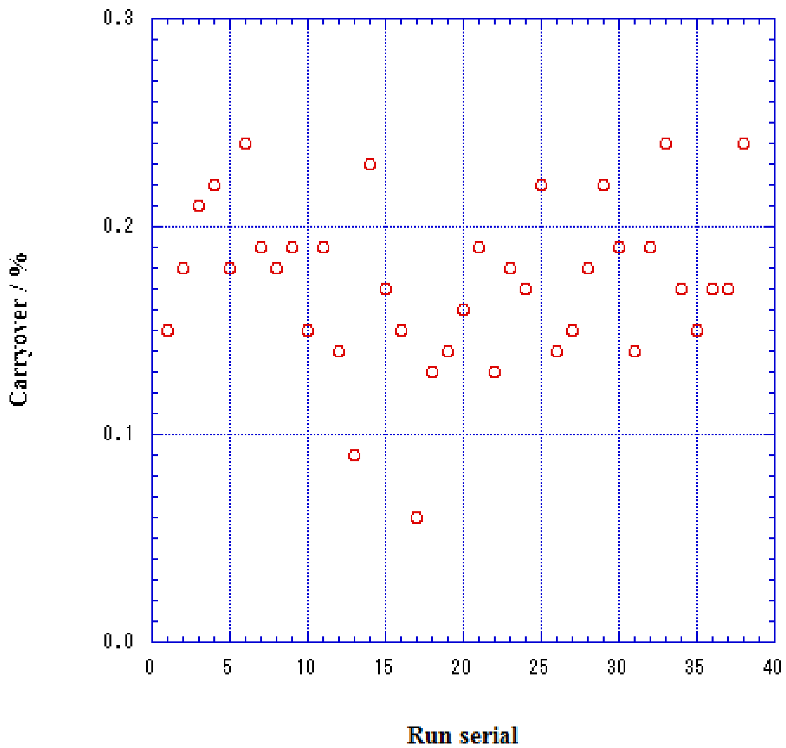


Figure 4.2-20 Time series of carry over of phosphate in MR16-06.

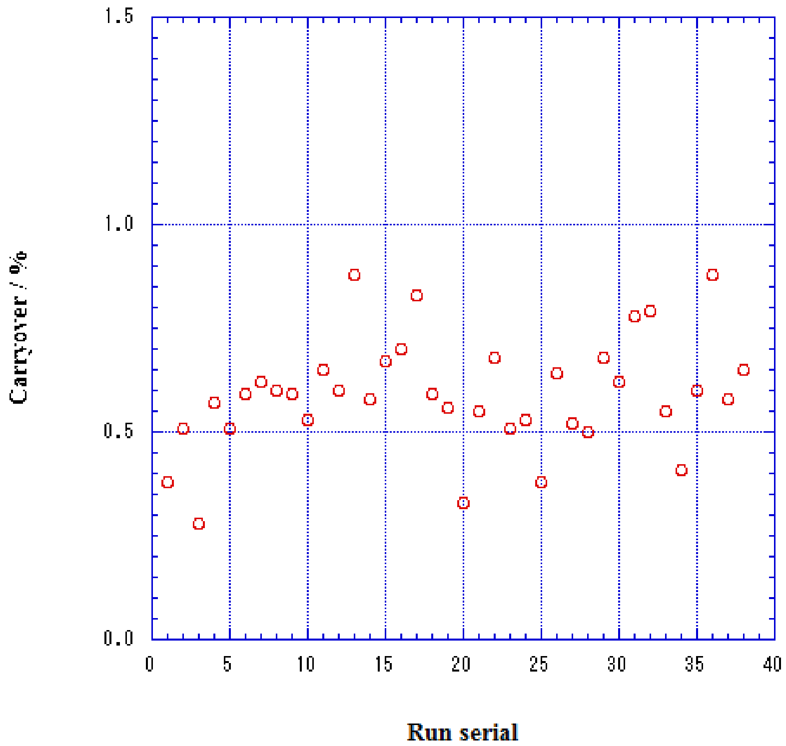


Figure 4.2-21 Time series of carry over of ammonia in MR16-06.

(8.4) Estimation of uncertainty of phosphate, nitrate and silicate concentrations

Empirical equations, eq. (1), (2) and (3) to estimate uncertainty of measurement of nitrate, silicate and phosphate are used based on measurements of 20 sets of CRMs during this cruise. These empirical equations are as follows, respectively.

Nitrate Concentration C_{NO3} in µmol kg^{-1}:
Uncertainty of measurement of nitrate (%) =
$0.15737 + 1.7606 * (1 / C_{NO3})$ --- (1)
where C_{NO3} is nitrate concentration of sample.

Silicate Concentration C_{Si} in µmol kg^{-1}:
Uncertainty of measurement of silicate (%) =
$0.075163 + 6.6583 * (1/ C_{Si})$ --- (2)
where C_{Si} is silicate concentration of sample.

Phosphate Concentration C_{PO4} in µmol kg^{-1}:
Uncertainty of measurement of phosphate (%) =
$-0.082114 + 0.53183 * (1/ C_{PO4})$ --- (3)
where C_{PO4} is phosphate concentration of sample.

Empirical equations, eq. (4) and (5) to estimate uncertainty of measurement of nitrite and ammonia are used based on duplicate measurements of the samples.

Nitrate Concentration C_{NO2} in µmol kg^{-1}:
Uncertainty of measurement of nitrite (%) =
$-0.14113 + 0.23741 * (1 / C_{NO2})$ --- (4)
where C_{NO2} is nitrite concentration of sample.

Ammonia Concentration C_{NH4} in µmol kg^{-1}:
Uncertainty of measurement of ammonia (%) =
$0.1305 + 2.3269 * (1 / C_{NH4})$ --- (5)
where C_{NH4} is ammonia concentration of sample.

(9) Problems / improvements occurred and solutions.
(9.1) centrifuged samples

When we found the value of Xmiss of the sample was less than 80% or doubtful for the particles in the sample, we carried out centrifuging for the samples by using the centrifuge (type:CN-820, AZONE). The centrifuged sample list for nutrients is shown in Table 4.2-8.

Table 4.2-8 List of centrifuged samples.

Station	Cast	Bottle	Depth (dbar)	Trans. (%)
4	1	20	40	81.4
4	1	1	45.2	77.7
5	1	0	0	-
5	1	24	5	85.4
5	1	23	10	88.3
5	1	22	20	92.3
5	1	21	29.8	86.6
5	1	25	35.1	82.4
5	1	20	40	80.1
5	1	1	49	75.3
6	1	0	0	-
6	1	24	4.6	77.5
6	1	25	7.8	83.9
6	1	23	10	78.6
6	1	22	20.3	92.9
6	1	21	29.9	88.5

6	1	20	40.4	91.8
6	1	1	44.2	86.1
7	1	0	0	-
7	1	8	3.4	79.8
7	1	24	5	79.7
7	1	7	6.9	87.5
7	1	25	6.9	87.2
7	1	6	9.2	90.6
7	1	23	10.2	91.1
7	1	5	11.2	90.1
7	1	4	15.2	90
7	1	22	20.2	90.3
7	1	3	24.9	89.9
7	1	21	30.3	91.8
7	1	20	40	90.4
7	1	19	50.1	86.2
7	1	1	51.5	85.7
8	1	0	0	-
8	1	24	4.5	87.5
8	1	23	10.1	86.6
8	1	25	14.3	83.2
8	1	22	19.6	88.3
8	1	21	29.7	83.2
8	1	20	40.1	82.8
8	1	1	43.3	82.4
9	1	0	0	-
9	1	24	5.3	79.6
9	1	23	10.4	79.6
9	1	25	16.7	79.4
9	1	22	20.8	88.2
9	1	21	30.2	74.7
9	1	20	40	77.2
9	1	1	44.2	72.7
10	1	20	40.4	84.2
10	1	3	48.2	72
10	1	19	50.6	67.9
10	1	1	52.3	62.1
15	1	25	22.1	76.3
15	1	21	30.3	70.3

15	1	1	33.3	70.6
16	1	6	27.2	83.6
16	1	5	30	82
16	1	21	30.1	82.2
16	1	25	33.2	80.6
16	1	4	39.2	73.3
16	1	1	39.2	73.2
17	1	20	39.9	85.7
17	1	1	42.3	81.6
18	1	0	0	-
18	1	24	5.1	95.1
18	1	23	10	95.2
18	1	22	19.9	92.1
18	1	25	23.8	91.8
18	1	21	29.8	97.5
18	1	1	36.3	73.3
19	1	0	0	-
19	1	24	5.1	95.7
19	1	23	10.3	95.6
19	1	22	20.2	94.5
19	1	21	29.7	90.8
19	1	25	31.9	82.9
19	1	1	38.8	77.7
20	1	0	0	-
20	1	24	4.9	96.2
20	1	23	10	96.2
20	1	22	19.8	94.6
20	1	25	26	89
20	1	21	30.3	82.7
20	1	1	38.8	82.3
21	1	25	29.9	85.5
21	1	21	29.9	79
21	1	20	39.9	88
21	1	19	49.8	86.1
21	1	1	53.3	83.9
41	1	22	20.2	88.6
41	1	21	30.2	66.1
41	1	1	34.4	61.1
12	1	0	0	-

12	1	24	5.3	90.8
12	1	23	10.1	91
12	1	22	20	91.4
12	1	25	22.8	91.5
12	1	21	30.2	96.9
12	1	20	39.8	72.3
12	1	1	47.5	71.8
13	1	0	0	-
13	1	24	5.7	94.9
13	1	23	10.2	95
13	1	22	20.3	95.3
13	1	21	30.3	96.3
13	1	25	36	94.1
13	1	20	39.9	86.1
13	1	1	46	75.2
14	1	0	0	-
14	1	24	5	98.1
14	1	23	10.1	98.2
14	1	22	19.2	98
14	1	25	29.9	77.8
14	1	21	29.9	77.5
14	1	1	35.7	77.6
43	1	25	12.5	86.3
43	1	22	20.3	86.7
43	1	21	30.1	89.7
23	1	0	0	-
23	1	24	5.4	96.7
23	1	23	10	96.8
23	1	22	20.1	96.9
23	1	25	27.6	95.4
23	1	21	30.1	89.1
23	1	20	40.1	86.7
23	1	19	50	87.3
23	1	18	74.9	92.1
23	1	1	79	90.4
24	1	0	0	-
24	1	24	4.9	94.9
24	1	23	9.8	95.3
24	1	22	19.7	97.6

24	1	25	28	95.3
24	1	21	30	90.6
24	1	20	39.8	90.4
24	1	19	50	89.5
24	1	18	74.7	88.3
24	1	17	99.9	89.9
24	1	1	114.2	92.9
25	1	0	0	-
25	1	24	5	95.2
25	1	23	10.4	93.4
25	1	22	20	95.1
25	1	25	21.8	94.6
25	1	21	30.3	92.9
25	1	20	40	92.4
25	1	19	50.2	91.3
25	1	18	74.9	90.3
25	1	1	85.2	89.8
26	1	0	0	-
26	1	24	5.1	92.2
26	1	23	10	92.3
26	1	25	18.2	88.7
26	1	22	19.9	88.4
26	1	21	30.2	87.4
26	1	1	40.1	82.3
29	1	19	49.9	88.8
29	1	1	59.2	87.4
52	1	5	36.1	74.3
52	1	20	40.1	71.1
52	1	4	40.1	71.2
52	1	3	47.3	69.3
52	1	1	47.3	69.2
39	1	1	299.1	86.1
53	1	20	40	71.3
53	1	1	48.7	69.9
54	1	18	75.1	84.7
54	1	1	264.5	89.7
69	1	25	24.1	87.8
71	1	1	227.6	88.3
72	1	5	36.3	64.3

72	1	4	37.6	63.1
72	1	1	37.5	62.6
73	1	20	40	84.5
73	1	1	45.4	71
74	1	20	40	77.3
74	1	1	43.4	74.6
75	1	20	40.1	63.9
75	1	1	41.2	55.7
76	1	25	27.7	79.2
76	1	21	30.1	72.4
76	1	1	38.3	67.7
77	1	1	33	50.3
78	1	21	29.9	85.6
78	1	25	32	70.7
78	1	1	35.8	70.1
79	1	1	45.7	51.9
80	1	1	47.5	79.2
81	1	20	40	69.4
81	1	1	48.7	67.8
82	1	19	50	61.9
82	1	1	51.7	61.2
83	1	1	44.4	79.2
84	1	1	48.6	55.5
85	1	25	38.3	48.9
85	1	20	40.4	51.6
85	1	1	42.8	50
86	1	1	50	59.3
87	1	20	39.9	65.4
87	1	1	42.7	63.5
84	1	3	47	73.2
88	1	21	30.1	63.5
88	1	1	33.6	61.3
92	1	20	40.1	52.2
92	1	1	44.8	46.3
93	1	21	29.9	92
93	1	20	39.8	53.8
93	1	1	43.6	53.1
94	1	0	0	-
94	1	24	5	90

94	1	23	9.9	89.9
94	1	25	12.8	90.2
94	1	22	20	90.8
94	1	21	30	91.2
94	1	20	40.1	90.3
94	1	19	49.9	89.2
94	1	1	51.5	88.7
95	1	0	0	-
95	1	24	5.2	92.4
95	1	23	10	91.1
95	1	22	20.1	91.1
95	1	25	22.6	91
95	1	21	30.1	90.1
95	1	20	40	85.3
95	1	1	47.1	84.6
96	1	0	0	-
96	1	24	4.7	70.2
96	1	25	7.8	69.9
96	1	23	9.9	70.7
96	1	22	20.5	71.1
96	1	21	30.3	70.1
96	1	1	37.4	69.4
97	1	0	0	-
97	1	24	5	84.4
97	1	25	7.3	84.3
97	1	23	10.1	84.3
97	1	22	20	85
97	1	21	30.3	78.1
97	1	20	40	78
97	1	1	44.2	78
98	1	0	0	-
98	1	24	5.1	88
98	1	23	10.1	88.8
98	1	25	13.5	88.9
98	1	22	20.3	90.6
98	1	21	30.3	95.6
98	1	20	40.2	91.6
98	1	1	48.2	76.3
99	1	0	0	-

99	1	24	5.1	93.7
99	1	23	10.4	93.7
99	1	22	20	93.6
99	1	25	24.1	94
99	1	21	29.8	93.5
99	1	20	39.9	92.6
99	1	1	46.3	71.7
99	1	8	5	93.9
99	1	7	10.3	94.1
99	1	6	14.2	93.7
99	1	5	17.8	93.8
99	1	4	25	93.5
99	1	3	32	93.9

Table 4.2-9. Experimental results of condition of centrifugation

Trans. (%)	absorbance	speed	time (min.)		NO_3 (μmol L^{-1})	NO_2 (μmol L^{-1})	SiO_2 (μmol L^{-1})	PO_4 (μmol L^{-1})	NH_4 (μmol L^{-1})
50	0.301	0	0	untreated	4.929	0.584	69.916	2.371	14.573
		2	10		4.973	0.453	68.804	2.112	14.601
		3	10		4.937	0.444	68.477	2.098	14.576
		4	10		4.961	0.443	68.750	2.110	14.591
		4	10	let stand for 30 min.	4.968	0.443	68.880	2.111	14.504
		4	7		4.944	0.443	68.699	2.108	14.544
		4	5		4.949	0.443	68.556	2.105	14.496
		4	3		4.956	0.446	68.674	2.111	14.637
76	0.119	0	0	untreated	11.946	0.218	35.836	2.141	6.643
		4	10		11.915	0.187	35.616	2.075	6.641
				difference	**-0.031**	**-0.031**	**-0.220**	**-0.066**	**-0.002**
85	0.071	0	0	untreated	15.418	0.225	44.004	2.353	7.349
		4	10		15.443	0.199	43.732	2.301	7.340
				difference	**0.025**	**-0.026**	**-0.272**	**-0.052**	**-0.009**
88	0.056	0	0	untreated	2.303	0.055	42.425	1.045	2.707
		4	10		2.246	0.052	42.347	1.036	2.733
				difference	**-0.057**	**-0.003**	**-0.078**	**-0.009**	**0.026**
90	0.046	0	0	untreated	4.100	0.079	10.723	1.166	3.146
		4	10		4.106	0.071	10.688	1.162	3.135
				difference	**0.006**	**-0.008**	**-0.035**	**-0.004**	**-0.011**
93	0.032	0	0	untreated	3.476	0.069	8.968	0.877	1.833
		4	10		3.461	0.065	8.969	0.859	1.802
				difference	**-0.015**	**-0.004**	**0.001**	**-0.018**	**-0.031**
98	0.009	0	0	untreated	0.195	0.023	7.699	0.727	1.181
		4	10		0.188	0.017	7.683	0.717	1.213
				difference	**-0.007**	**-0.006**	**-0.016**	**-0.010**	**0.032**

To decide condition of centrifugation, we did an experiment as shown in Table 4.2-9.

We adopted to set a speed at 4 (about 1500 rpm) and duration for 10 minutes, for the samples listed in Table 4.2-8. We observed increase of sample solution temperature about 3 K.

(9.2) Correction for concentration of Nitrate and phosphate using CRMs

During MR16-06 cruise, we found the difference between certified value and measured value of nitrate and phosphate of CRMs. Therefore, we obtained the correction expression (linear function) by the relationships between certified and measured value. In the result, we corrected the concentrations of nitrate and phosphate of CRM and seawater sample using this correction expression, eq (6). As shown in Figures 4.2-12 and Figures 4.2-15, the concentration of nitrate and phosphate of CRM lot. BW measured every run became close to the certified value. The coefficients of the correction expression were shows in Table 4.2-10 and Table 4.2-11.

$$Cp = a * Vp + b \qquad \text{--- (6)}$$

where Cp is the corrected concentration of nitrate or phosphate, a and b are coefficients of correction expression, Vp is the measured value of nitrate or phosphate of CRM and seawater sample.

As shown eq(7), the uncertainty of nitrate or phosphate was combined the uncertainty of measurement depend on concentrations of nitrate or phosphate and coefficients of correction expression.

$$U = (Um^2 + Ui^2 + (Us * Cp)^2)^{(1/2)} \qquad \text{--- (7)}$$

where Um is the uncertainty of measurement depended on concentrations of nitrate or phosphate, Ui is the uncertainty of coefficient of intercept, Us is the uncertainty of coefficient of slope.

Table 4.2-10 Summary of the coefficients of nitrate correction expression.

Station	Cast	Slope a	Intercept b	Uncertainty of slope	Uncertainty of intercept
001	1	0.9905635	0.009229	0.003141257	0.050286314
002	1				
037	1	0.9916651	-0.007635	0.003352171	0.053646379
038	1				
039	1				

Table 4.2-11 Summary of the coefficients of phosphate correction expression.

Station	Cast	Slope a	Intercept b	Uncertainty of slope	Uncertainty of intercept
003	1	0.9897029	-0.002309	0.002248888	0.002407518

004	1				
018	1	0.9899578	-0.002277	0.001992675	0.002132632
019	1				
020	1				
021	1	0.9891677	-0.00161	0.002347508	0.002513146
022	1				
023	1	0.9911822	-0.002567	0.002410085	0.002576728
024	1				
025	1				
026	1				
055	1	0.9861924	0.0038587	0.003716254	0.003974243
056	1				

(9.3) Room temperature variation during this cruise

Room temperature of nutrients measurement laboratory varied from 18.5 to 26.5 degree Celsius during the period from 30th August 2016 to 23rd September 2016 as shown in Figure 4.2-22. We faced relatively unstable measurement condition during this cruise. We suspected the extra heat source (two heating bath) might affect air conditional of the laboratory.

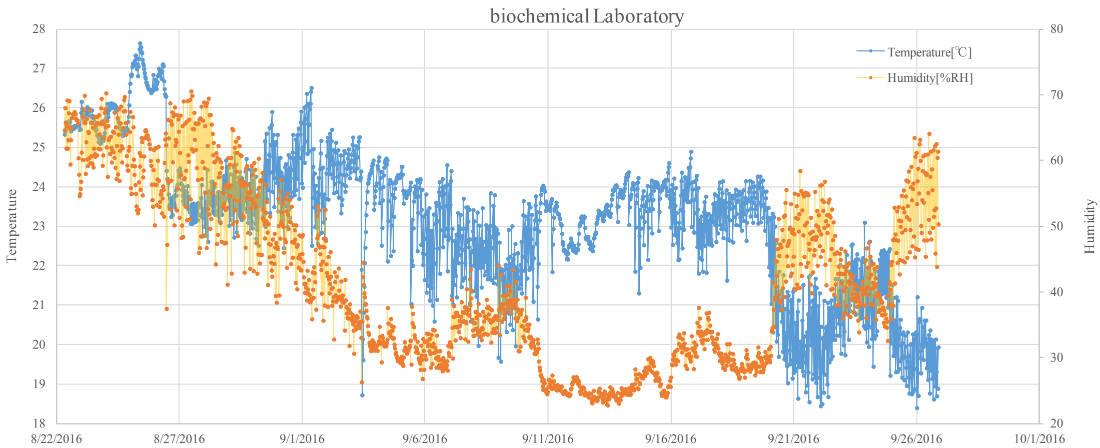


Figure 4.2-22 Room temperature and humidity variation of the biochemical laboratory in MR16-06. Blue line is temperature, orange line is humidity.

(9.4) Possible contamination of phosphate and ammonia

We put the flag 3 to 6 of 2120 samples for phosphate and ammonia because phosphate and ammonia concentrations of these 6 samples were unreasonable high. The molar ratios of excess concentration of phosphate and ammonia were around from 2 to 3. We suspected that a small particle containing phosphate and ammonia fell into samples from air conditioner.

(10) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(11) References

Aminot, A. and Kerouel, R. 1991. Autoclaved seawater as a reference material for the determination of nitrate and phosphate in seawater. Anal. Chim. Acta, 248: 277-283.

Aminot, A. and Kirkwood, D.S. 1995. Report on the results of the fifth ICES intercomparison exercise for nutrients in sea water, ICES coop. Res. Rep. Ser., 213.

Aminot, A. and Kerouel, R. 1995. Reference material for nutrients in seawater: stability of nitrate, nitrite, ammonia and phosphate in autoclaved samples. Mar. Chem., 49: 221-232.

Aoyama M., and Joyce T.M. 1996, WHP property comparisons from crossing lines in North Pacific. In Abstracts, 1996 WOCE Pacific Workshop, Newport Beach, California.

Aoyama, M., 2006: 2003 Intercomparison Exercise for Reference Material for Nutrients in Seawater in a Seawater Matrix, Technical Reports of the Meteorological Research Institute No.50, 91pp, Tsukuba, Japan.

Aoyama, M., Susan B., Minhan, D., Hideshi, D., Louis, I. G., Kasai, H., Roger, K., Nurit, K., Doug, M., Murata, A., Nagai, N., Ogawa, H., Ota, H., Saito, H., Saito, K., Shimizu, T., Takano, H., Tsuda, A., Yokouchi, K., and Agnes, Y. 2007. Recent Comparability of Oceanographic Nutrients Data: Results of a 2003 Intercomparison Exercise Using Reference Materials. Analytical Sciences, 23: 1151-1154.

Aoyama M., J. Barwell-Clarke, S. Becker, M. Blum, Braga E. S., S. C. Coverly,E. Czobik, I. Dahllof, M. H. Dai, G. O. Donnell, C. Engelke, G. C. Gong, Gi-Hoon Hong, D. J. Hydes, M. M. Jin, H. Kasai, R. Kerouel, Y. Kiyomono, M. Knockaert, N. Kress, K. A. Krogslund, M. Kumagai, S. Leterme, Yarong Li, S. Masuda, T. Miyao, T. Moutin, A. Murata, N. Nagai, G.Nausch, M. K. Ngirchechol, A. Nybakk, H. Ogawa, J. van Ooijen, H. Ota, J. M. Pan, C. Payne, O. Pierre-Duplessix, M. Pujo-Pay, T. Raabe, K. Saito, K. Sato, C. Schmidt, M. Schuett, T. M. Shammon, J. Sun, T. Tanhua, L. White, E.M.S. Woodward, P. Worsfold, P. Yeats, T. Yoshimura, A.Youenou, J. Z. Zhang, 2008: 2006 Intercomparison Exercise for Reference Material for Nutrients in Seawater in a Seawater Matrix, Technical Reports of the Meteorological Research Institute No. 58, 104pp.

Aoyama M, Mara Abad, Carol Anstey, Muhamed Ashraf P, Adil Bakir, Susan Becker, Steven Bell, Elisa Berdalet, Marguerite Blum, Rebecca Briggs, Florian Caradec, Thierry Cariou, Matt Church, Laurent Coppola, Mike Crump, Susan Curless, Minhan Dai, Anne Daniel, Clare Davis, Elisabete de Santis Braga, Miriam E. Solis, Lindsey Ekern, David Faber, Tamara Fraser, Kjell Gundersen, Sólvá Jacobsen, Marc Knockaert, Taketoshi Komada, Martina Kralj, Rita Kramer, Nurit Kress, Silvie Lainela, Jesús Ledesma, Xinxin Li, Jae-Hyun Lim, Martina Lohmann, Christian Lønborg, Kai-Uwe Ludwichowski, Claire Mahaffey, Frank Malien, Francesca Margiotta, Trevor McCormack, Iban Murillo, Hema Naik, Günther Nausch, Sólveig Rósa Ólafsdóttir, Jan van Ooijen, Rodolfo Paranhos, Chris Payne, Olivier Pierre-Duplessix, Gary Prove, Emilie Rabiller, Patrick Raimbault, Laura Reed, Christine Rees, TaeKeun Rho, Raymond Roman, E. Malcolm S. Woodward, Jun Sun, Beata Szymczycha, Sukeyoshi Takatani, Alison Taylor, Peter Thamer, Sinhué Torres-Valdés, Katherine Trahanovsky, Howard Waldron, Pamela Walsham, Lifang Wang, Tao Wang, Linda White, Takeshi Yoshimura, Jia-Zhong Zhang. 2016. IOCCP-JAMSTEC 2015 Inter-laboratory Calibration Exercise of a Certified Reference Material for Nutrients in Seawater. IOCCP Report Number 1/2016. ISBN 978-4-901833-24-0.

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

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

Joyce, T. and Corry, C. 1994. Requirements for WOCE hydrographic programmed data reporting. WHPO Publication, 90-1, Revision 2, WOCE Report No. 67/91.

Kawano, T., Uchida, H. and Doi, T. WHP P01, P14 REVISIT DATA BOOK, (Ryoin Co., Ltd., Yokohama, 2009).

Kirkwood, D.S. 1992. Stability of solutions of nutrient salts during storage. Mar. Chem., 38 : 151-164.

Kirkwood, D.S. Aminot, A. and Perttila, M. 1991. Report on the results of the ICES fourth intercomparison exercise for nutrients in sea water. ICES coop. Res. Rep. Ser., 174.

Mordy, C.W., Aoyama, M., Gordon, L.I., Johnson, G.C., Key, R.M., Ross, A.A., Jennings, J.C. and Wilson. J. 2000. Deep water comparison studies of the Pacific WOCE nutrient data set. Eos Trans-American Geophysical Union. 80 (supplement), OS43.

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

Uchida, H. & Fukasawa, M. WHP P6, A10, I3/I4 REVISIT DATA BOOK Blue Earth Global Expedition 2003 1, 2, (Aiwa Printing Co., Ltd., Tokyo, 2005).

4.3. Dissolved Inorganic Carbon
4.3.1. Bottled-water analysis

(1) Personnel

Shigeto Nishino	JAMSTEC: Principal Investigator
Atsushi Ono	MWJ: Operation Leader
Nagisa Fujiki	MWJ

(2) Objective

The Arctic Ocean has a characteristic that Dissolved Inorganic Carbon (DIC) concentrations are low because of the influence of inflow of the large amount of river water, dilution by sea-ice melt water and high biological productivity. Recently, the undersaturation of the calcium carbonate and a change of pCO_2 have been observed in the Arctic Ocean. It is considered that the change of seawater pH and a decrease in the saturation state of calcium carbonate affect a growth of the species that form shells of calcium carbonate. Therefore, quantitative understanding of the cause of these changes is necessary for better assessments and future predictions. The percentage saturation of seawater with respect to calcium carbonate can be computed from DIC and Total Alkalinity (TA; ref. Section 4.4). Accordingly, we measured DIC on-board during the MR16-06 cruise.

(3) Parameters

Dissolved Inorganic Carbon (DIC)

(4) Instruments and Methods

I. Seawater sampling

Seawater samples were collected by 12 L Niskin bottles and a bucket at 85 stations (total 1,341 samples). Seawater was transported into a 300 mL glass bottle (SCHOTT DURAN) which was previously soaked in 5% non-phosphoric acid detergent (pH13) solution at least 3 hours, and rinsed with fresh water for 5 times and Milli-Q deionized water for 3 times. A sampling tube was connected to the Niskin bottle when the sampling was conducted. The glass bottles were filled from the bottom, without rinsing, and were overflowed for 20 seconds. They were sealed using polyethylene inner lids (29 mm in diameter) with care not to leave any bubbles in the bottle. After collecting the samples on the deck, the sampling bottles were moved to the laboratory. Prior to the analysis, 3 mL of the samples (1% of the bottle volume) was removed from the glass bottles to make a headspace, and 100 μL of over saturated solution of mercury chloride was added within 1 hour after sampling. The samples were sealed with polyethylene inner lids (31.9 mm in diameter) and stored in a refrigerator at approximately 5 °C until the analysis.

II. Seawater analysis

Measurements of DIC were made with total CO_2 measuring system (System D; Nippon ANS, Inc.). The system comprises of seawater dispensing system, a CO_2 extraction system and a coulometer (Model 3000, Nippon ANS, Inc.).

The seawater dispensing system has an auto-sampler (6 ports), which takes seawater from a glass bottle to a pipette of nominal 15 mL volume by PC control. The pipette was kept at 20 ± 0.05 ˚C by a water jacket, in which water is circulated from a thermostatic water bath (RTE10, Thermo) set at 20 ˚C.

The CO_2 dissolved in a seawater sample is extracted in a stripping chamber of the CO_2 extraction system by phosphoric acid (10% v/v). The stripping chamber is made approximately 25 cm long and has a fine frit at the bottom. A constant volume of acid is added to the stripping chamber from its bottom by pressurizing an acid bottle with nitrogen gas (99.9999%). A seawater sample kept in a constant volume pipette is introduced to the stripping chamber by the same method. Nitrogen gas is bubbled through a fine frit at the bottom of the stripping chamber to make the reaction well. The stripped CO_2 is carried by the nitrogen gas (flow rate of 140 mL min^{-1}) to the coulometer through a dehydrating module consists of two electronic dehumidifiers (kept at 2 ˚C) and a chemical desiccant ($Mg(ClO_4)_2$).

Measurements of system blank (phosphoric acid blank), 1.5% CO_2 standard gas in a nitrogen base and seawater samples (6 samples) were programmed to repeat. The variation of our own-made JAMSTEC DIC reference material was used to correct the signal drift results from chemical alternation of coulometer solution.

(5) Observation log

The sampling stations for DIC were shown in Figure 4.3-1-1.

(5) Preliminary results

During the cruise, 1,341 samples were analyzed for DIC. A few replicate samples were taken at most of the stations and difference between each pair of analyses was plotted on a range control chart (Figure 4.3-1-2). The average of the differences was provisionally 1.44 μmol kg^{-1}, with its standard deviation of 1.33 μmol kg^{-1} (n = 189), which indicate the analysis was accurate enough according to the Guide to the best practices for ocean CO_2 measurements (Dickson et al., 2007).

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group (DMG) of JAMSTEC, and will be opened to the public via "Data Research for Whole Cruise Information in JAMSTEC" in JAMSTEC web site.

(7) References

Dickson, A. G., Sabine, C. L.., Christian J. R. (2007) Guide to the best practices for

ocean CO_2 measurements; PICES Special Publication 3, 199pp

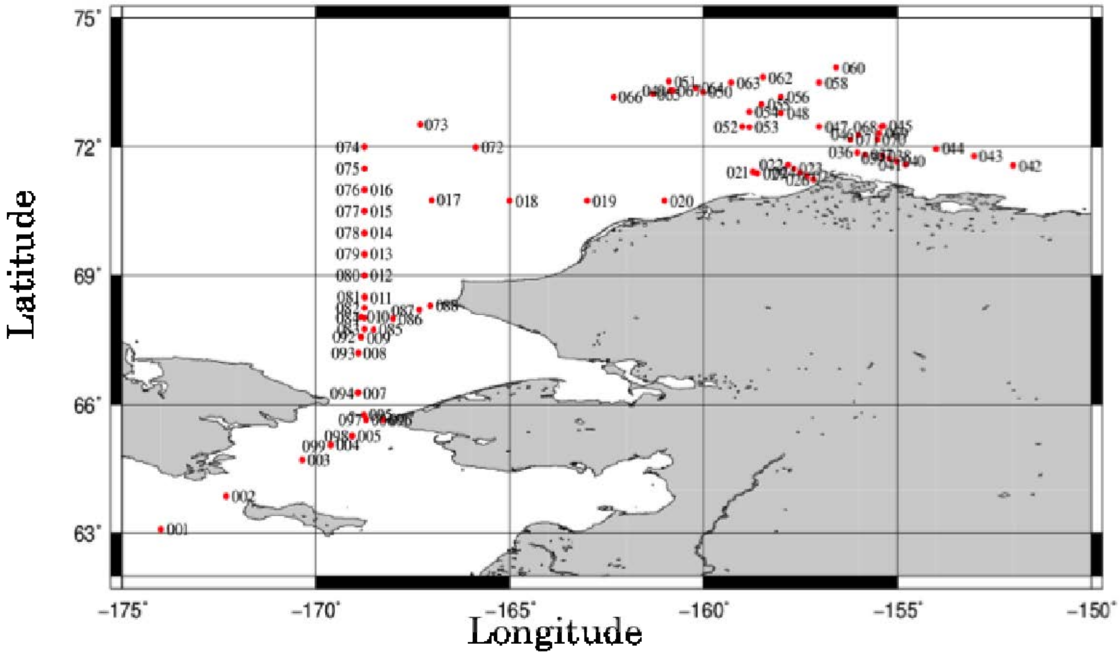


Figure 4.3-1-1: DIC sampling stations in the Arctic Ocean in 2016.

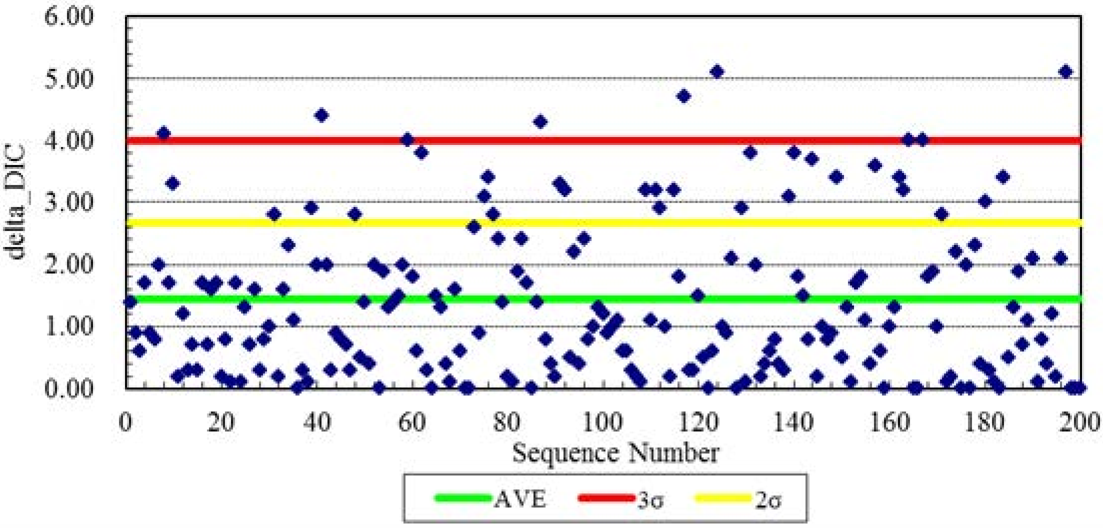


Figure 4.3-1-2: Range control chart of the absolute differences of replicate measurements carried out in the analysis of DIC during the MR16-06. UCL and UWL represent the upper control limit (Average × 3σ) and upper warning limit (Average × 2σ), respectively.

4.3.2. Underway DIC

(1) Personnel

Shigeto Nishino JAMSTEC: Principal Investigator
Tomonori Watai MWJ: Operation Leader
Minoru Kamata MWJ
Atsushi Ono MWJ

(2) Objective

CO_2 concentration in the atmosphere is increasing at a rate of nearly 2 μmol mol^{-1} yr^{-1} owing to human activities such as burning of fossil fuels, deforestation, and cement production. The ocean plays an important role in buffering the increase of atmospheric CO_2, therefore the urgent tasks are to clarify the mechanism of the oceanic CO_2 absorption and to estimate of CO_2 absorption capacity of the ocean. Oceanic biosphere, especially primary production, has an important role in oceanic CO_2 cycle through photosynthesis and respiration. However, the diverseness and variability of the biological system make it difficult to reveal their mechanism and quantitative understanding of the CO_2 cycle. When CO_2 dissolves in water, chemical reaction takes place and CO_2 alters its appearance into several species. Concentrations of the individual species of the CO_2 system in solution cannot be measured directly, but calculated from two of four parameters: total alkalinity, total dissolved inorganic carbon, pH and pCO_2 (Dickson et al., 2007). Furthermore, in recent years, sea ice in the Arctic Ocean melts in a vast area in summer relative to decades ago. Accordingly, the recent Arctic summer open ocean is considered to play an important role for global carbon cycle. We here report onboard measurements of underway total dissolved inorganic carbon during MR16-06 cruise.

(3) Parameters

Dissolved Inorganic Carbon (DIC)

(4) Instruments and Methods

Surface seawater was continuously collected from 24th Aug 2016 to 3rd Oct 2016 during this cruise. Surface seawater was taken from an intake placed at the approximately 4.5 m below the sea surface by a pump, and was filled in a 300 mL glass bottle (SCHOTT DURAN) from the bottom, without rinsing, and overflowed for more than 2 times the amount. Before the analysis, the samples were put in the water bath kept about 20 °C for one hour.

Measurements of DIC were made with total CO_2 measuring system (Nihon ANS, Inc.).

The system comprise of seawater dispensing unit, a CO_2 extraction unit, and a coulometer (Model 3000A, Nihon ANS, Inc.)

The seawater dispensing unit has an auto-sampler (6 ports), which dispenses the seawater from a glass bottle to a pipette of nominal 15 mL volume. The pipette was kept at 20 ± 0.05 ˚C by a water jacket, in which water circulated through a thermostatic water bath (BH201, Yamato).

The CO_2 dissolved in a seawater sample is extracted in a stripping chamber of the CO_2 extraction unit by adding phosphoric acid (10% v/v). The stripping chamber is made approx. 25 cm long and has a fine frit at the bottom. First, the certain amount of acid is taken to the constant volume tube from an acid bottle and transferred to the stripping chamber from its bottom by nitrogen gas (99.9999%). Second, a seawater sample kept in a pipette is introduced to the stripping chamber by the same method as that for an acid. The seawater and phosphoric acid are stirred by the nitrogen bubbles through a fine frit at the bottom of the stripping chamber. The stripped CO_2 is carried to the coulometer through two electric dehumidifiers (kept at 3 ˚C) and a chemical desiccant ($Mg(ClO_4)_2$) by the nitrogen gas (flow rates of 140 mL min^{-1}).

Measurements of 1.5% CO_2 standard gas in a nitrogen base, system blank (phosphoric acid blank), and seawater samples (6 samples) were programmed to repeat. Both CO_2 standard gas and blank signals were used to correct the signal drift results from chemical alternation of coulometer solutions. The coulometer solutions were renewed every about 2 days, and a certified reference material (CRM: batch 156) was measured each time to correct systematic difference between measurements.

(5) Observation log

Cruise track during underway Total Dissolved Inorganic Carbon observation is shown in Figure 4.3.2-1.

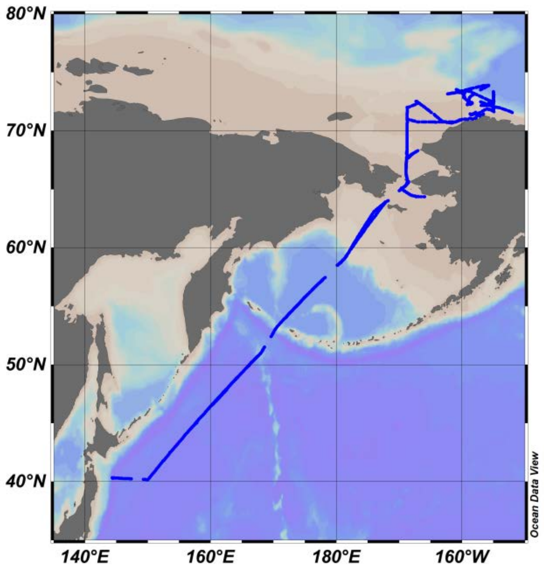


Figure 4.3.2-1 Observation map

(6) Results

The 21 sets of measurement were combined and time-series variation of sea surface DIC concentrations are plotted in the Figure 4.3.2-2. The standard deviation of the absolute differences of CRM was 2.2 μmol kg^{-1} (n=21).

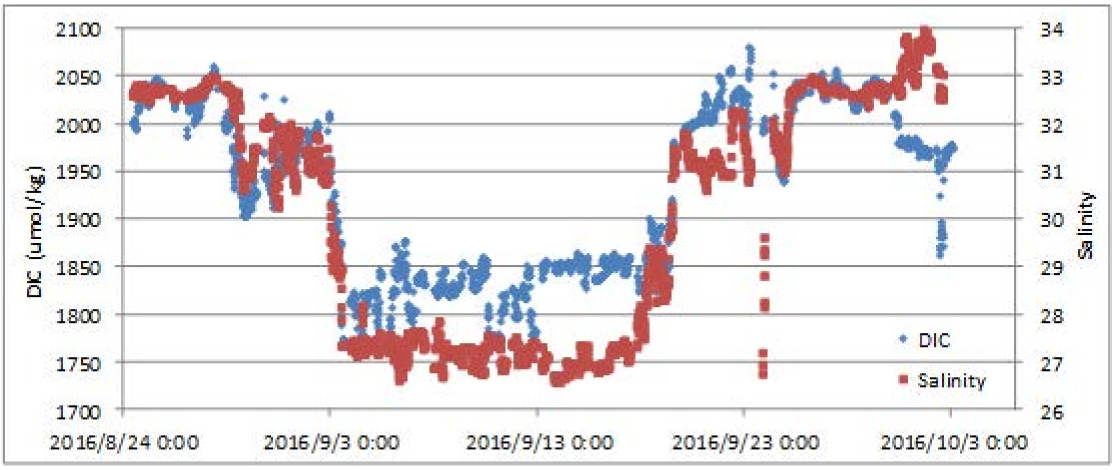


Figure 4.3.2-2 Temporal variations of underway DIC. Blue and red dots represent surface DIC and salinity, respectively.

(7) Date archives

These data obtained in this cruise will be submitted to the Data Management Group (DMG) of JAMSTEC, and will be opened to the public via “Data Research for Whole Cruise Information in JAMSTEC” in JAMSTEC web site.

(8) References

Dickson, A. G., Sabine, C. L. & Christian, J. R. (2007), Guide to best practices for ocean CO_2 measurements; PICES Special Publication 3, 199pp.

4.4. Total Alkalinity

(1) Personnel

Shigeto Nishino (JAMSTEC): Principal Investigator
Tomonori Watai (MWJ): Operation Leader
Emi Deguchi (MWJ)

(2) Objective

As described in the Section 4.3. (DIC), total Alkalinity (TA) is an essential parameter in carbonate system in the ocean. We have measured TA during the MR16-06 cruise to estimate pH, calcium carbonate saturation state and pCO_2. Furthermore, TA is a useful tracer for river water in the Arctic Ocean: TA is high in river runoff (especially in North American rivers) and low in sea ice meltwater. River water carries freshwater, carbon, nutrients, contaminants etc., and the changes in distribution of river water in the Arctic Ocean may affect regional and global climate, through biological productivity. Distribution of river water in the Chukchi Sea/Canada Basin region during the MR16-06 cruise will be estimated from TA and the results will be compared with those observed in previous years.

(3) Parameters

Total Alkalinity, TA

(4) Instruments and Methods

(4)-1 Seawater sampling

Seawater samples were collected at 85 stations / 86 casts in 12 L Niskin bottles mounted on the CTD-carousel system. A sampling silicone rubber with PFA tip was connected to the Niskin bottle when the sampling was carried out. The 125 ml borosilicate glass bottles (SHOTT DURAN) were filled from the bottom smoothly, without rinsing, and were overflowed for 2 times bottle volume (10 seconds) with care not to leave any bubbles in the bottle. These bottles were pre-washed by soaking in 5 % non-phosphoric acid detergent (pH = 13) for more than 3 hours and then rinsed 5 times with tap water and 3 times with Milli-Q deionized water. After collecting the samples on the deck, the bottles were carried into the lab and stored in the refrigerator, and the samples were put in the water bath kept about 25° C for one hour before the measurement.

(4)-2 Seawater analysis

Measurement of TA was made using a spectrophotometric system (Nippon ANS, Inc.) using a scheme of Yao and Byrne (1998). The sampled seawater in the glass bottle is transferred to a sample cell via dispensing unit, and its temperature is kept at 25° C in a thermostatic compartment. The TA is calculated by measuring two sets of absorbance at three wavelengths (730, 616 and 444 nm) applied by the spectrometer (TM-UV/VIS C10082CAH, HAMAMATSU). One is the absorbance of seawater sample before injecting an acid with indicator solution (bromocresol green) and another is the one after the injection. For mixing the acid with indicator solution and the seawater sufficiently, they are circulated through the line by a peristaltic pump 9 minutes before the measurement.

The TA is calculated based on the following equation:

$$pH_T = 4.2699 + 0.002578 \times (35 - S) + \log((R(25) - 0.00131) / (2.3148 - 0.1299 \times R(25))) - \log(1 - 0.001005 \times S), \quad (1)$$

$$A_T = (N_A \times V_A - 10^{pH_T} \times DensSW(T, S) \times (V_S + V_A)) \times (DensSW(T, S) \times V_S)^{-1}, \quad (2)$$

where R(25) represents the difference of absorbance at 616 and 444 nm between before and after the injection. The absorbance of wavelength at 730 nm is used to subtract the variation of absorbance caused by the system. DensSW (T, S) is the density of seawater at temperature (T) and salinity (S), N_A the concentration of the added acid, V_A and V_S the volume of added acid and seawater, respectively.

To keep the high analysis precision, some treatments were carried out during the cruise. The acid with indicator solution stored in 1 L DURAN bottle is kept in room temperature, and about 10 mL of it is discarded at first before the batch of measurement. Furthermore, we injected the acid so that pH_T of a sample might become the range of 3.6 to 4.6 values. For mixing the seawater and the acid with indicator solution sufficiently, TYGON tube used on the peristaltic pump was periodically renewed. Absorbance measurements were done 3 times during each analysis, and each three values are averaged and used for above listed calculation for before and after the injection, respectively.

(5) Station list or Observation log

Seawater samples were collected at 85 stations / 86 casts (Figure 4.4-1).

Figure 4.4-1 Map of sampling station.

(6) Preliminary results

The repeatability of this system was provisionally 2.04 μmol kg^{-1} (n = 26) which was estimated from standard deviation of measured CRM value during this cruise. At each station, samples were taken in replicate for waters of the following table 4.4-1. The difference between each pair of analyses was plotted on a range control chart (Figure 4.4-2). The average of the difference was provisionally 2.00 μmol kg^{-1} (n = 188 pair) with its standard deviation of 1.70 μmol kg^{-1}, which indicates that the analysis was accurate enough according to Guide to best practices for ocean CO_2 measurements (Dickson et al., 2007).

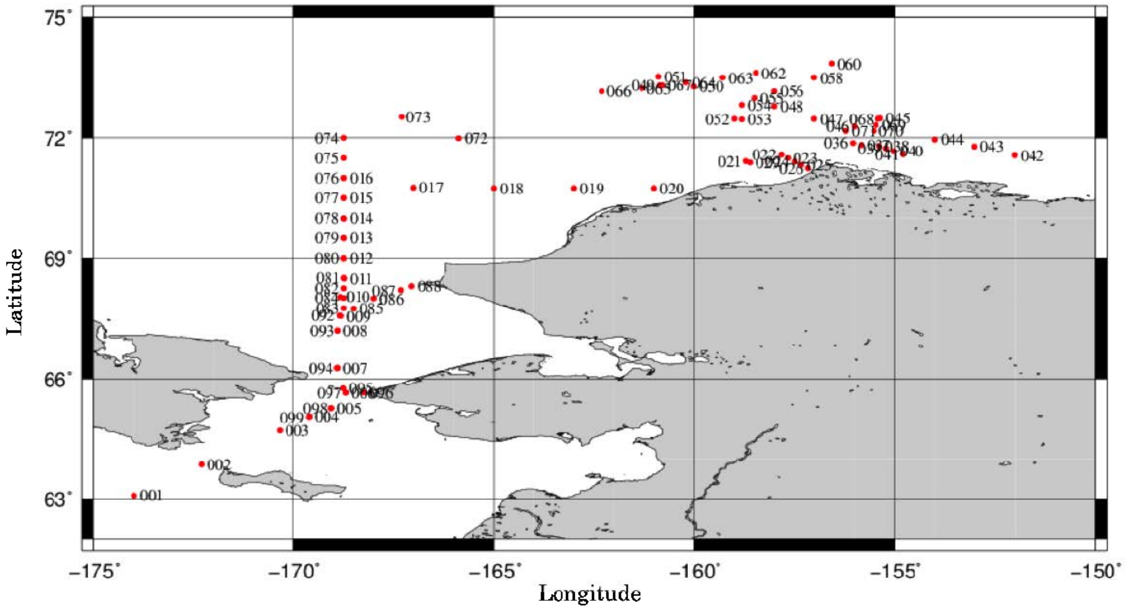


Table 4.4-1 The layer taken in replicate for waters.

Bottom depth	Replicate layer
< 100 m	10 m, Bottom
100 - 400 m	50 m, 100 m, Bottom
> 400 m	100 m, 400 m, Bottom

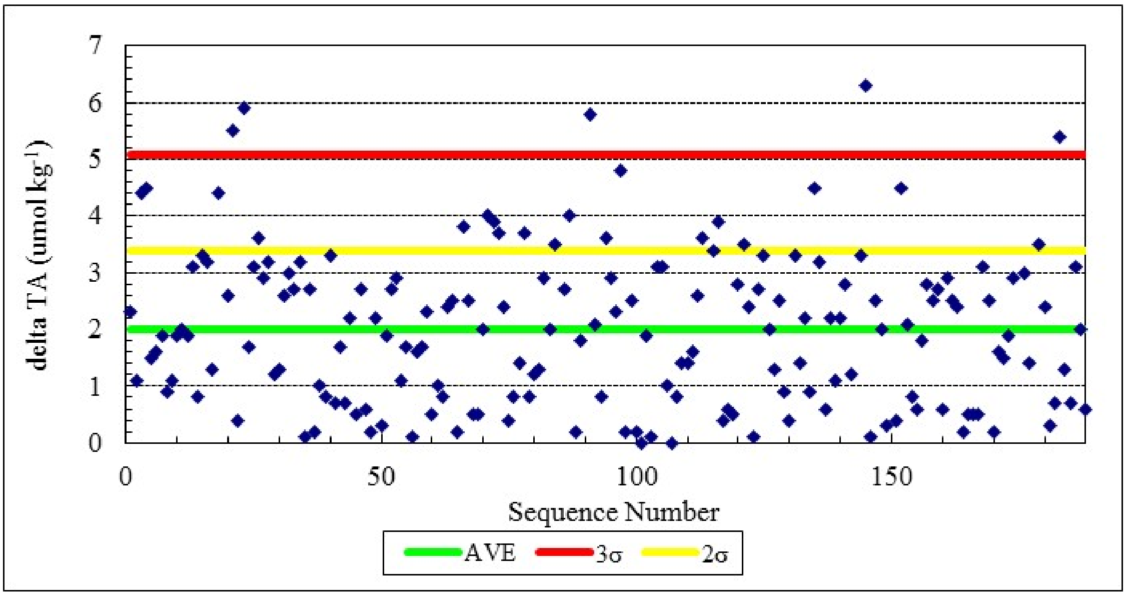


Figure 4.4-2 Range control chart of the absolute differences of replicate measurements of TA carried out during this cruise.

(7) Data Archives

These data obtained in this cruise will be submitted to the Data Management

Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(8) References

Yao, W. and Byrne, R. H. (1998), Simplified seawater alkalinity analysis: Use of linear array spectrometers. *Deep-Sea Research Part I, Vol. 45,* 1383-1392.

Dickson, A. G., Sabine, C. L. & Christian, J. R. (2007), Guide to best practices for ocean CO2 measurements; PICES Special Publication 3, 199

4.5. Underway surface water monitoring

(1) Personnel

Shigeto Nishino (JAMSTEC): Principal Investigator

Masahiro Orui (MWJ) : Operation leader

Hiroshi Hoshino (MWJ)

Haruka Tamada (MWJ)

(2) Objective

Our purpose is to obtain temperature, salinity, dissolved oxygen, and fluorescence data continuously in near-sea surface water.

(3) Parameters

Temperature (surface water)

Salinity (surface water)

Dissolved oxygen (surface water)

Fluorescence (surface water)

Turbidity (surface water)

(4) Instruments and Methods

The Continuous Sea Surface Water Monitoring System (Marine Works Japan Co. Ltd.) has four sensors and automatically measures temperature, salinity, dissolved oxygen and fluorescence in near-sea surface water every one minute. This system is located in the "*sea surface monitoring laboratory*" and connected to shipboard LAN-system. Measured data, time, and location of the ship were stored in a data management PC. The near-surface water was continuously pumped up to the laboratory from about 4.5 m water depth and flowed into the system through a vinyl-chloride pipe. The flow rate of the surface seawater was adjusted to 10 dm^3 min^{-1}.

a. Instruments

Software

Seamoni-kun Ver.1.50

Sensors

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

Temperature and Conductivity sensor

Model:	SBE-45, SEA-BIRD ELECTRONICS, INC.
Serial number:	4552788-0264
Measurement range:	Temperature -5 to +35 ^{o}C
	Conductivity 0 to 7 S m^{-1}
Initial accuracy:	Temperature 0.002 ^{o}C
	Conductivity 0.0003 S m^{-1}
Typical stability (per month):	Temperature 0.0002 ^{o}C
	Conductivity 0.0003 S m^{-1}
Resolution:	Temperatures 0.0001 ^{o}C
	Conductivity 0.00001 S m^{-1}

Bottom of ship thermometer

Model:	SBE 38, SEA-BIRD ELECTRONICS, INC.
Serial number:	3852788-0457
Measurement range:	-5 to +35 ^{o}C
Initial accuracy:	±0.001 ^{o}C
Typical stability (per 6 month):	0.001 ^{o}C
Resolution:	0.00025 ^{o}C

Dissolved oxygen sensor

Model:	OPTODE 3835, AANDERAA Instruments.
Serial number:	1915
Measuring range:	0 - 500 μmol dm^{-3}
Resolution:	< 1 μmol dm^{-3}
Accuracy:	< 8 μmol dm^{-3} or 5 % whichever is greater
Settling time:	< 25 s

Dissolved oxygen sensor

Model:	RINKO II, JFE ADVANTECH CO. LTD.
Serial number:	13
Measuring range:	0 - 540 μmol dm^{-3}
Resolution:	< 0.1 μmol dm^{-3}
	or 0.1 % of reading whichever is greater
Accuracy:	< 1 μmol dm^{-3}

or 5 % of reading whichever is greater

Fluorescence & Turbidity sensor

Model: C3, TURNER DESIGNS

Serial number: 2300384

(5) Observation log

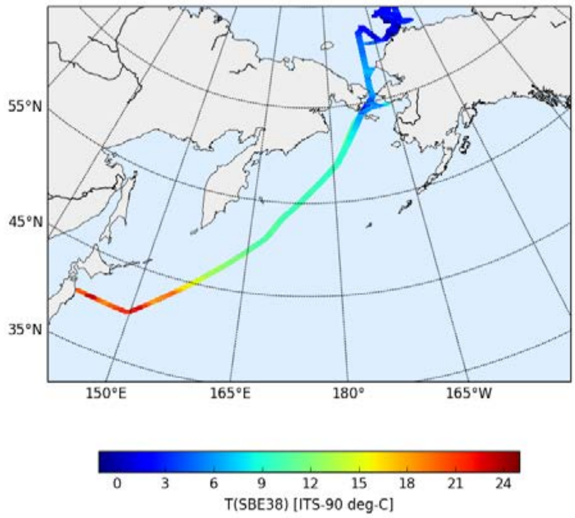
Periods of measurement, maintenance, and problems during MR16-06 are listed in Table 4.5-1.

Table 4.5-1: Events list of the Sea surface water monitoring during MR16-06

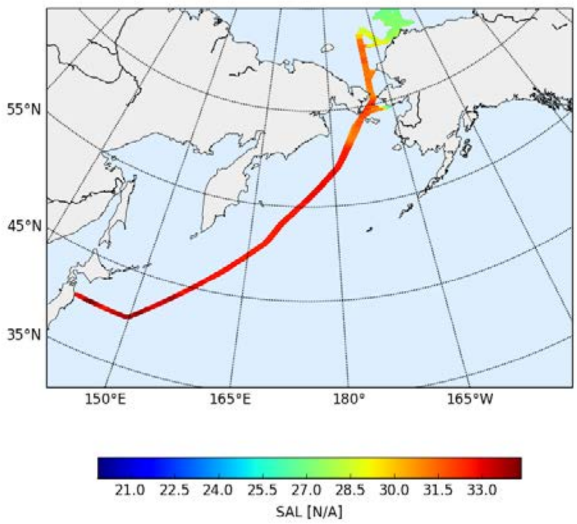
System Date [UTC]	System Time [UTC]	Events	Remarks
2016/08/22	03:08	All the measurements started and data was available.	Start
2016/08/29	06:01	All the measurements stopped.	Filter Cleaning
2016/08/29	07:31	All the measurements started.	Logging restart
2016/09/03	23:31	All the measurements stopped.	Filter Cleaning
2016/09/04	00:40	All the measurements started.	Logging restart
2016/09/11	02:50	All the measurements stopped.	Filter Cleaning
2016/09/11	03:41	All the measurements started.	Logging restart
2016/09/12	05:46	All the measurements stopped.	Maintenance
2016/09/12	07:49	All the measurements started.	Logging restart
2016/09/18	18:37	All the measurements stopped.	Filter Cleaning
2016/09/18	19:27	All the measurements started.	Logging restart
2016/09/23	08:09	All the measurements stopped.	Maintenance
2016/09/23	21:24	All the measurements started.	Logging restart
2016/09/23	21:53	All the measurements stopped.	C3 Maintenance
2016/09/23	22:37	All the measurements started.	Logging restart

We took the surface water samples once a day to compare sensor data with bottle data of salinity, dissolved oxygen, chlorophyll *a*. The results are shown in Figure 4.5 -2. All the salinity samples were analyzed by the Guideline 8400B "AUTOSAL" (see 3.5), and dissolve oxygen samples were analyzed by Winkler method (see 4.1), chlorophyll *a* were analyzed by 10-AU (see 4.7).

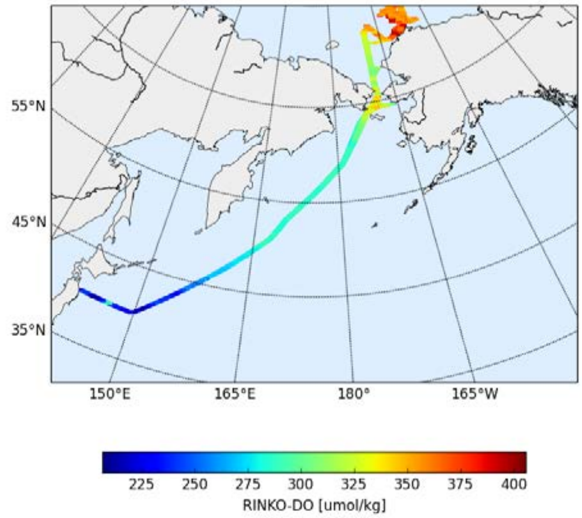
(a)


55°N
45°N
35°N
150°E
165°E
180°
165°W
0 3 6 9 12 15 18 21 24
T(SBE38) [ITS-90 deg-C]

(b)


55°N
45°N
35°N
150°E
165°E
180°
165°W
21.0 22.5 24.0 25.5 27.0 28.5 30.0 31.5 33.0
SAL [N/A]

(c)



(d)

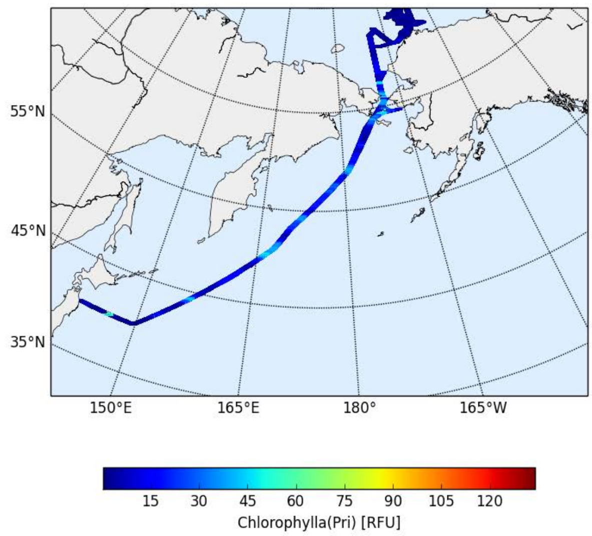


Figure 4.5-1: Spatial and temporal distribution of (a) temperature, (b) salinity, (c) dissolved oxygen, and (d) fluorescence in MR16-06 cruise.

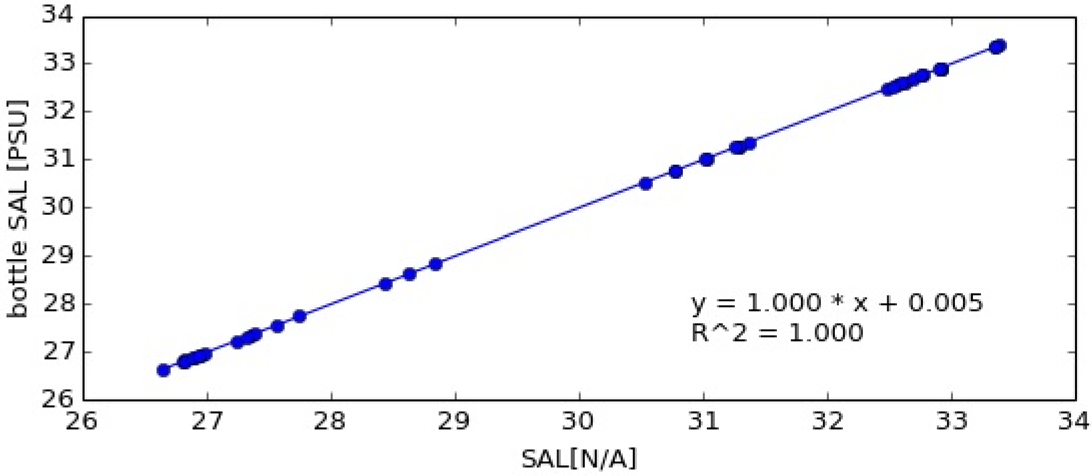
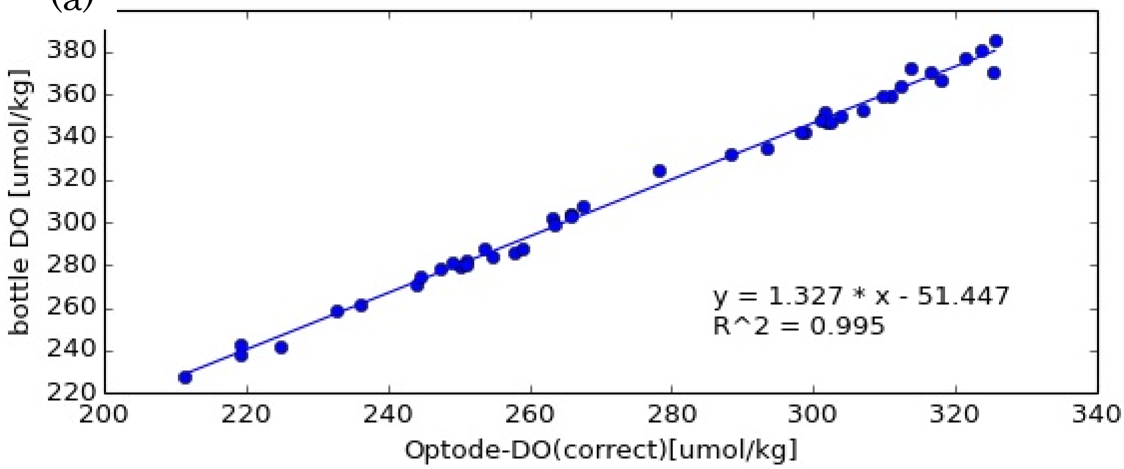


Figure 4.5-2-1: Correlation of salinity between sensor data and bottle data.

(a)



(b)

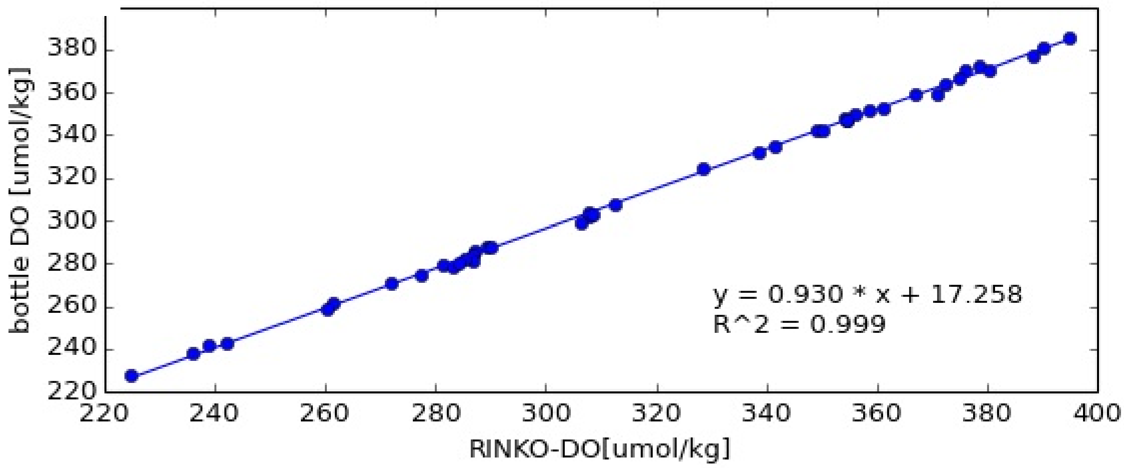


Figure 4.5-2-2: Correlation of dissolved oxygen between sensor data and bottle data. (a: OPTODE, b: RINKO)

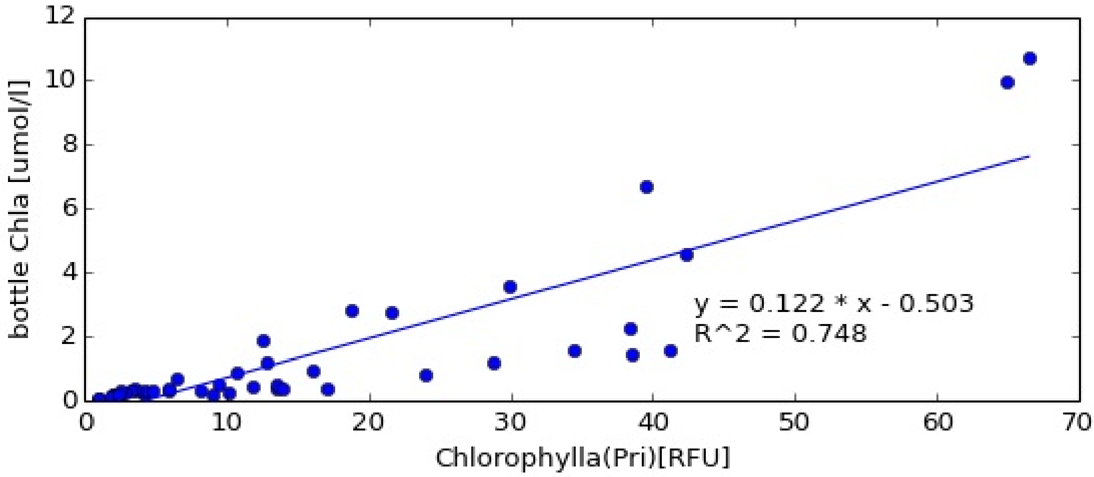


Figure 4.5-2-3: Correlation of fluorescence between sensor data and bottle data.

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

4.6. Continuous measurement of pCO_2

(1) Personnel

Shigeto Nishino (JAMSTEC): Principal Investigator
Tomonori Watai (MWJ): Operation Leader
Emi Deguchi (MWJ)
Nagisa Fujiki (MWJ)

(2) Objectives

The oceans have strong interactions with the atmosphere and are the major sinks for the increasing CO_2. Although it is believed that the Arctic Ocean is playing an important role for the variations of greenhouse gases in the atmosphere, their spatial and temporal variations in the Arctic Ocean is not well known. Furthermore, sea ice in the Arctic Ocean has been decreasing in summer, leading to change the air-sea interaction and biological activity due to increasing the area of open sea, and possibly leading to affect the global carbon cycle.

(3) Parameters

Partial pressure of CO_2 (pCO_2) in the atmosphere and in near-surface seawater.

(4) Instruments and methods

Oceanic and atmospheric CO_2 concentrations were measured during the cruise using an automated system equipped with a non-dispersive infrared gas analyzer (NDIR; LI-7000, Li-Cor). Measurements were done every about one and a half hour, and 4 standard gasses, atmospheric air, and the CO_2 equilibrated air with sea surface water were analyzed subsequently in this hour. The concentrations of the CO_2 standard gases were about 230, 290, 370 and 430 ppmv, and their accurate concentrations will be determined after the cruise. Atmospheric air taken from the bow of the ship (approx.13 m above the sea level) was introduced into the NDIR by passing through an electrical cooling unit, a mass flow controller which controls the air flow rate of 0.5 L min^{-1}, a membrane dryer (MD-110-72P, perma pure llc.) and chemical desiccant ($Mg(ClO_4)_2$). The CO_2 equilibrated air was the air with its CO_2 concentration was equivalent to the sea surface water. Seawater was taken from an intake placed at the approximately 4.5 m below the sea surface and introduced into the equilibrator at the flow rate of 4 - 5 L min^{-1} by a pump. The equilibrated air was circulated in a closed loop by a pump at flow rate of 0.6 - 0.8 L min^{-1} through two cooling units, a membrane dryer, the chemical desiccant, and the NDIR.

(5) Preliminary results

Cruise track during pCO_2 observation is shown in Figure 4.6-1, and the temporal variations of both oceanic and atmospheric CO_2 concentration (xCO_2) are shown in Figure 4.6-2.

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(7) References

Dickson, A. G., Sabine, C. L. & Christian, J. R. (2007), Guide to best practices for ocean CO_2 measurements; PICES Special Publication 3, 199pp.

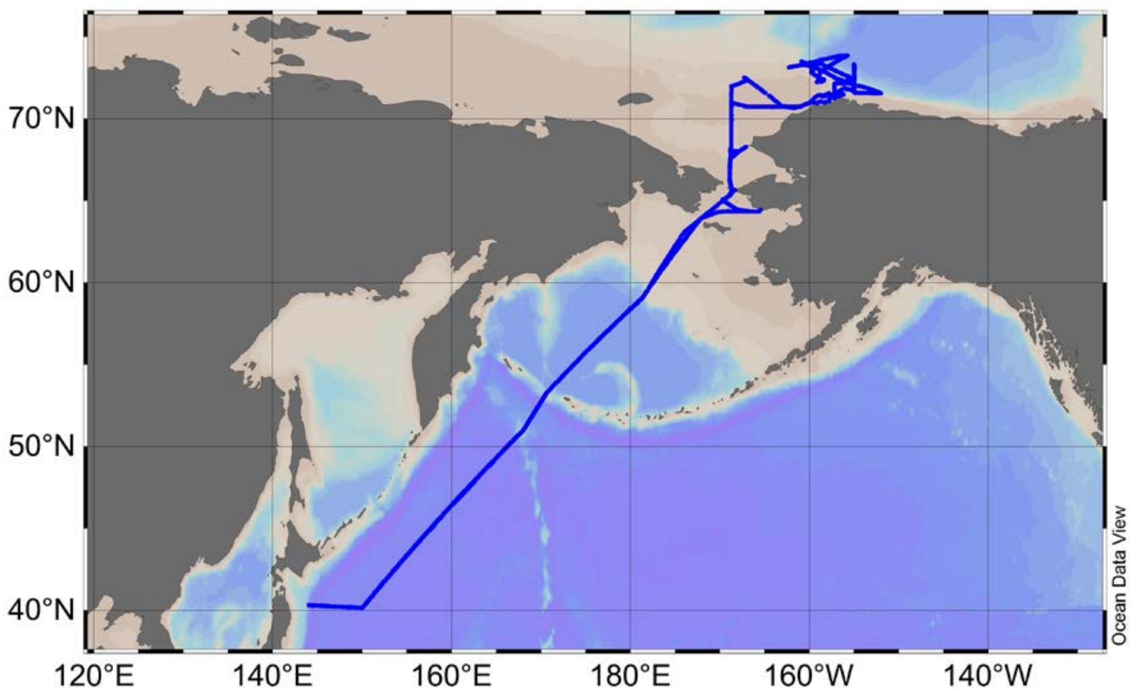


Figure 4.6-1 Observation map

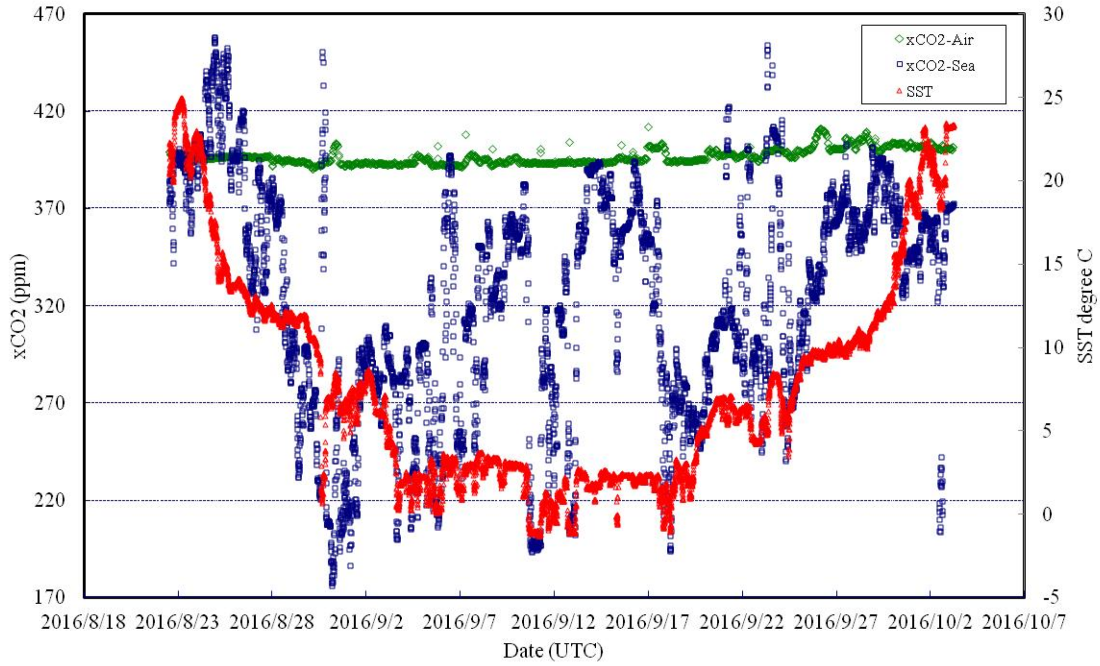


Figure 4.6-2 Temporal variations of oceanic and atmospheric CO_2 concentration (xCO_2). Blue dots represent oceanic xCO_2 variation and green atmospheric xCO_2. SST variation (red) is also shown.

4.7. Chlorophyll *a*

(1) Personnel

Shigeto Nishino (JAMSTEC): Principal Investigator
Amane Fujiwara (JAMSTEC)
Masahiro Orui (MWJ) : Operation leader
Hironori Sato (MWJ)
Rio Kobayashi (MWJ)

(2) Objective

Phytoplankton distributes in various species and sizes in the ocean were examined. Phytoplankton species are roughly characterized by the cell size. The objective of this study is to investigate the vertical and horizontal distributions of phytoplankton biomass and size in the Arctic Ocean, in terms of phytoplankton pigment, chlorophyll *a*, by using the size-fractionated filtration method.

(3) Parameters

Total chlorophyll *a*
Size-fractionated chlorophyll *a*

(4) Instruments and methods

We collected samples for total chlorophyll *a* (chl-*a*) from 7 to 20 depths and size-fractionated chl-*a* from 2 to 12 depths between the surface and 200 m depth including a chl-*a* maxmum layer. The chl-*a* maximum layer was determined by a fluorometer (Seapoint Sensors, Inc.) attached to the CTD system.

Water samples for total chl-*a* were vacuum-filtrated (<0.02MPa) through 25mm-diameter Whatman GF/F filter. Water samples for size-fractionated chl-*a* were passed through 20 µm pore-size Nylone filter (47 mm in diameter), 10µm and 2µm pore-size nuclepore filters (47 mm in diameter), and Whatman GF/F filter (25 mm in diameter) under gentle vacuum (<0.02MPa). Phytoplankton pigments retained on the filters were immediately extracted in a polypropylene tube with 7 ml of N,N-dimethylformamide. The tubes were stored at –20°C under the dark condition to extract chl-*a* at least for 24 hours.

Fluorescences of each sample were measured by Turner Design fluorometer (10-AU-005), which was calibrated against a pure chl-*a* (Sigma chemical Co.). We applied fluorometric determination for the samples of chl-*a* “Non-acidification method”

(Welschmeyer, 1994). Analytical conditions of this method were listed in Table 4.7-1.

(5) Station list

Samples for total and size-fractionated chl-*a* were collected at 86 (see Figure 4.7-1) and 57 casts (see Figure 4.7-2), respectively. The numbers of samples for total and size-fractionated chl-*a* were 1098 and 1520, respectively.

(6) Preliminary results

At each station, water samples were taken in replicate for water of 5 m and chl-*a* maximum layer. Results of replicate samples were shown in Fig 4.7-2.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN) in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(8) Reference

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

Table 4.7-1. Analytical conditions of non-acidification method for chlorophyll *a* with Turner Design fluorometer (10-AU-005).

Excitation filter (nm)	: 436
Emission filter (nm)	: 680
Lamp	: Blue F4T5,B2/BP

Table 4.7-2. Results of the replicate sample measurements.

	All samples	Samples over 1.0 µmol/L	Samples under 1.0 µmol/L
Number of replicate sample pairs	170	72	98
Standard deviation (µmol/L)	0.129	0.197	0.015
Relative error (%)	3.9	5.0	3.1

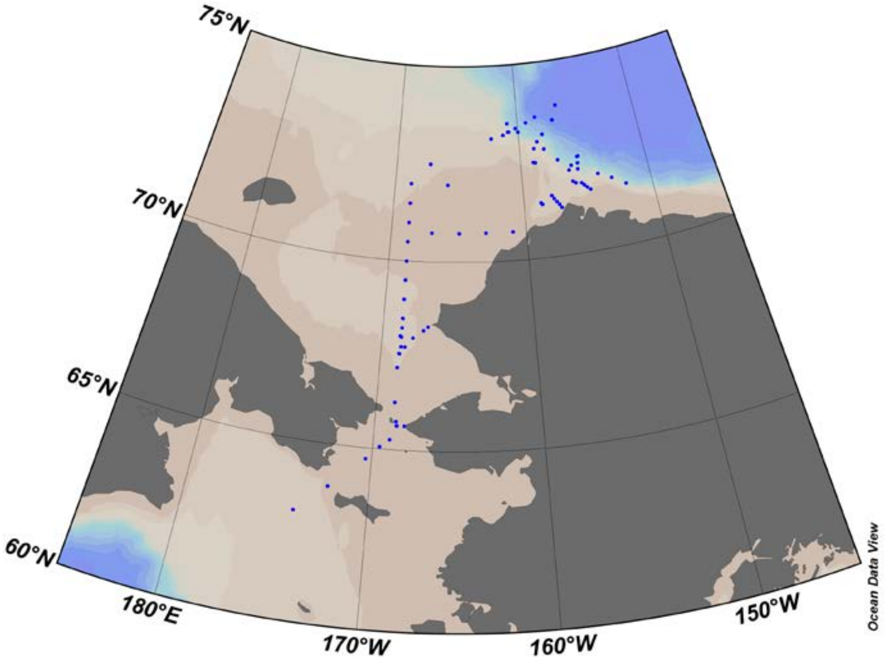


Figure 4.7-1. Sampling positions of total chlorophyll *a*.

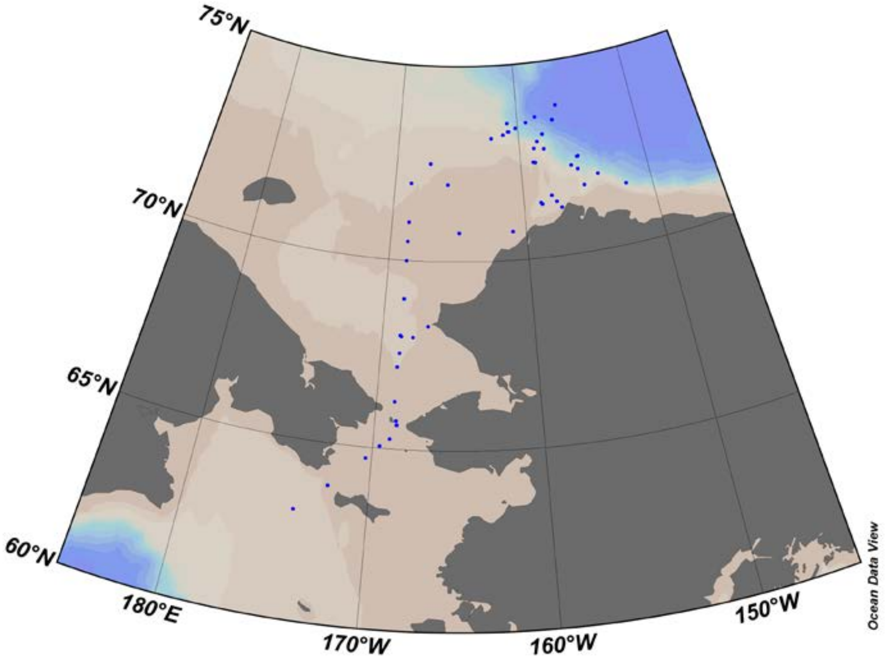


Figure 4.7-2. Sampling positions of size-fractionated chlorophyll *a*.

4.8. Phytoplankton pigments
4.8.1. HPLC

(1) Personnel

Amane Fujiwara	JAMSTEC
Hisatomo Waga	Hokkaido University

(2) Objectives

Samples of phytoplankton pigment concentration were collected to investigate vertical and horizontal distribution of phytoplankton community structure.

(3) Parameters

Phytoplankton pigments

(4) Instruments and methods

Seawater samples for phytoplankton pigments were collected from the sea surface and several depths shallower than 70 m using a bucket or Niskin-X bottles on a CTD/Carousel Multi Sampler (Sea-Bird Electronics Inc.). 1–4 L of water sample were filtered on a glass fiber filter (GF/F, 47 mm) and stored in a super freezer (-80°C). Pigment concentrations will be analyzed on land with using high performance liquid chromatography (HPLC) (Agilent Technologies 1300 series) after the cruise.

(5) Station list or Observation log

Table 4.8-1: List of station/cast for HPLC samples

stationID	castID	date [UTC]	Lon	Lat	HPLC	Multi-Exciter
1	1	08/30/2016	63.094	186.015	x	x
4	1	08/30/2016	65.060	190.394	x	x
7	1	08/31/2016	66.269	191.086	x	x
10	1	09/01/2016	68.035	191.169	x	x
16	1	09/02/2016	70.996	191.256	x	x
21	1	09/04/2016	71.428	201.284	x	x
29	1	09/05/2016	71.385	201.393	x	x
42	1	09/07/2016	71.567	207.997	x	x
45	1	09/08/2016	72.491	204.648	x	
52	1	09/10/2016	72.476	200.998	x	x
53	1	09/11/2016	72.466	201.187	x	x
58	1	09/13/2016	73.500	202.992	x	x
63	1	09/14/2016	73.507	200.709	x	
67	1	09/15/2016	73.305	199.198	x	x
68	1	09/16/2016	72.476	204.579	x	
72	1	09/18/2016	71.991	194.121	x	x
77	1	09/19/2016	70.499	191.256	x	x
84	1	09/20/2016	68.008	191.249	x	x
93	1	09/21/2016	67.197	191.112	x	x
94	1	09/21/2016	66.271	191.108	x	x
99	1	09/22/2016	65.052	190.382	x	x

4.8.2. Multi-spectral excitation/emission fluorescence measurement

(1) Personnel

Amane Fujiwara	JAMSTEC
Jonaotaro Onodera	JAMSTEC
Atsushi Yamaguchi	Hokkaido University
Yoshiyuki Abe	Hokkaido University

(2) Objectives

Vertical and horizontal measurements of multi-spectral excitation/emission fluorescence were conducted to derive phytoplankton pigment composition.

(3) Parameters

Multi-spectral excitation/emission fluorescence

(4) Instruments and methods

Vertical and horizontal distribution of multi-spectral excitation/emission fluorescence was measured using *Multi-Exciter* instrument (JFE-Advantech Inc.). *Multi-Exciter* detects fluorescence signals from 630 to 1000 nm which excited at 9 bands (375, 400, 420, 435, 470, 505, 525, 570, and 590 nm). A *Multi-Exciter* was attached to the CTD profiling system where HPLC samples were collected (see Table 4.8-1). Another *Multi-Exciter* continuously measured the spectral fluorescence of surface water for every 15 minute.

(5) Station list or Observation log

Table 4.8-1: List of station/cast for *Multi-Exciter* measurement

(6) Preliminary result

Surface distribution of excited fluorescence at 470 nm is shown in Figure 4.8-1, which is widely used as a proxy of chlorophyll-a concentration.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

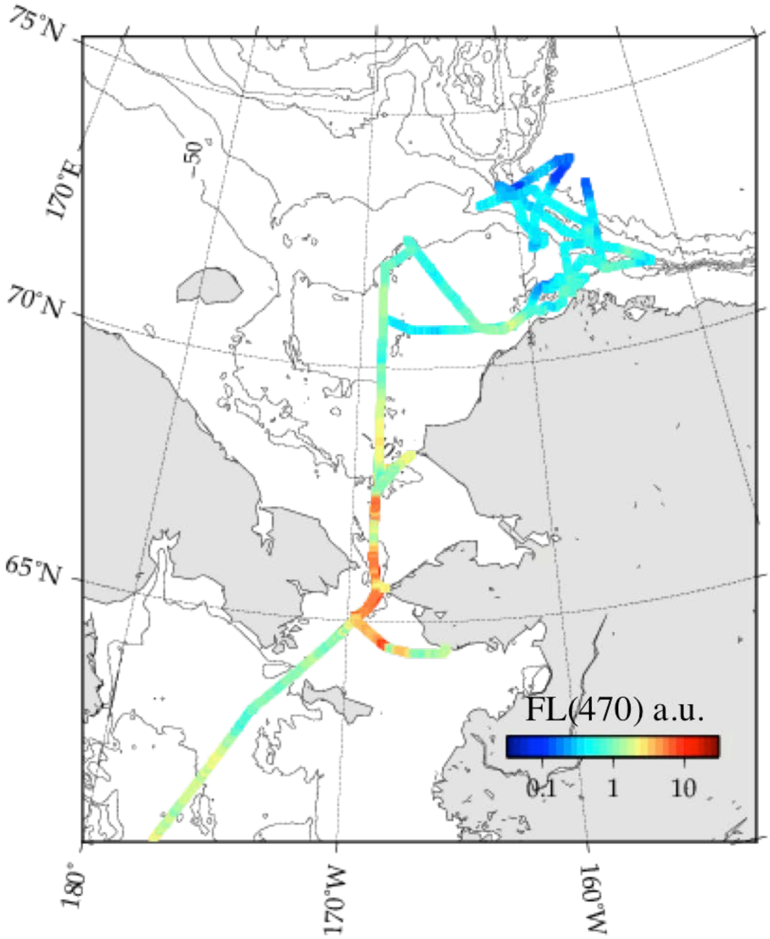


Figure 4.8-1. Surface distribution of fluorescence signal excited at 470 nm.

4.9. Bio-optical Observations

(1) Personnel

Toru Hirawake (Hokkaido University; non-bording): PI

Amane Fujiwara (JAMSTEC)

Hisatomo Waga (Hokkaido University)

(2) Objectives

Objective of these observations is to develop and evaluate an ocean color algorithm to estimate algal size using optical properties of seawater. Results from these investigations will be applied to satellite remote sensing and used to clarify the responses of phytoplankton to the recent climate change in the western Arctic Ocean.

(3) Parameters

A) Underwater spectral irradiance and radiance (C-OPS)
B) In-situ backscattering coefficients (HydroScat-6)
C) Incident photosynthetic available radiation (PAR)
D) Light absorption coefficients of particles and colored dissolved organic materials (CDOM)

(4) Instruments and methods

A) C-OPS

Underwater spectral downwelling irradiance $E_d(\lambda, z)$ (µW cm^{-2} nm^{-1}) and upwelling radiance $L_u(\lambda, z)$ (µW cm^{-2} nm^{-1} str^{-1}) at 19 wavelengths over 320-875 nm were measured with a spectroradiometer, C-OPS (Biospherical Instrument Inc.). The C-OPS was deployed in free-fall mode up to 30-60 m deep distancing from the stern of ship to avoid her shadow. Incident downwelling irradiance to sea surface $E_d(\lambda, 0+)$ (µW cm^{-2} nm^{-1}) was also monitored by reference sensor with same specification as the underwater sensor. Before each deployment of the instrument, 10 minutes averaged dark values were recorded. In addition, underwater photosynthetic available radiation (PAR), $E_q(z)$, was also calculated by converting the $E_d(\lambda, z)$ to quantum unit, $E_q(\lambda, z)$ (µmol photons m^{-2} s^{-1}), and integrating the $E_q(\lambda, z)$ from 395 to 710 nm.

B) HydroScat-6

In-situ volume scattering function at 140o angle of 6 wavelengths (420, 442, 488, 510, 550 and 676 nm) to determine backscattering coefficient of light $b_{bp}(\lambda)$ and fluorescence at 2 wavelengths (510 and 676 nm) were measured with a backscattering sensor – fluorometer HydroScat-6 (HOBI Labs). It is deployed up to 100 m deep.

C) Incident photosynthetic available radiation (PAR)

Incident PAR, E_q (0+), was monitored with a LI-190R air quantum sensor. Mean value for five minutes was recorded to a LI-1500 data logger (LICOR Inc.) during the cruise.

D) Light absorption coefficients of particles and colored dissolved organic materials (CDOM)

Seawater samples for absorption coefficients measurement were collected from the sea surface and subsurface chlorophyll maximum using Niskin-X bottles on a CTD/Carousel Multi Sampler (Sea-Bird Electronics Inc.).

For measurements of spectral absorption coefficient of particles, particles in 1-4 liter(s) of water sample were concentrated on a glass fiber filter (Whatman GF/F, 25 mm). Optical density (*OD*) of particles on the filter pad was measured with a spectrophotometer, UV-2400 (Shimadzu) equipped an end-on type detector, and absorption coefficient of particles ($a_p(\lambda, z)$) was determined from the *OD* according to the Quantitative Filter Technique (QFT) (Mitchell, 1990). The filter was then soaked in methanol to extract and remove the pigments (Kishino et al., 1985) and absorption coefficient of detritus ($a_d(\lambda, z)$) was quantified again. Absorption coefficient of phytoplankton, $a_{ph}(\lambda, z)$, was determined subscribing $a_d(\lambda, z)$ from $a_p(\lambda, z)$.

For measurements of spectral absorption coefficient of CDOM ($a_{CDOM}(\lambda, z)$), 250 ml of water sample was filtrated through a 0.2 µm Nuclepore filter (Whatman, 47 mm). *OD* of the filtrated water against pure water (Milli-Q) was measured with 10 cm cylindrical quartz cell and spectrophotometer, UV-2400 (Shimadzu), and calculated $a_{CDOM}(\lambda, z)$.

(5) Station list and Observation log

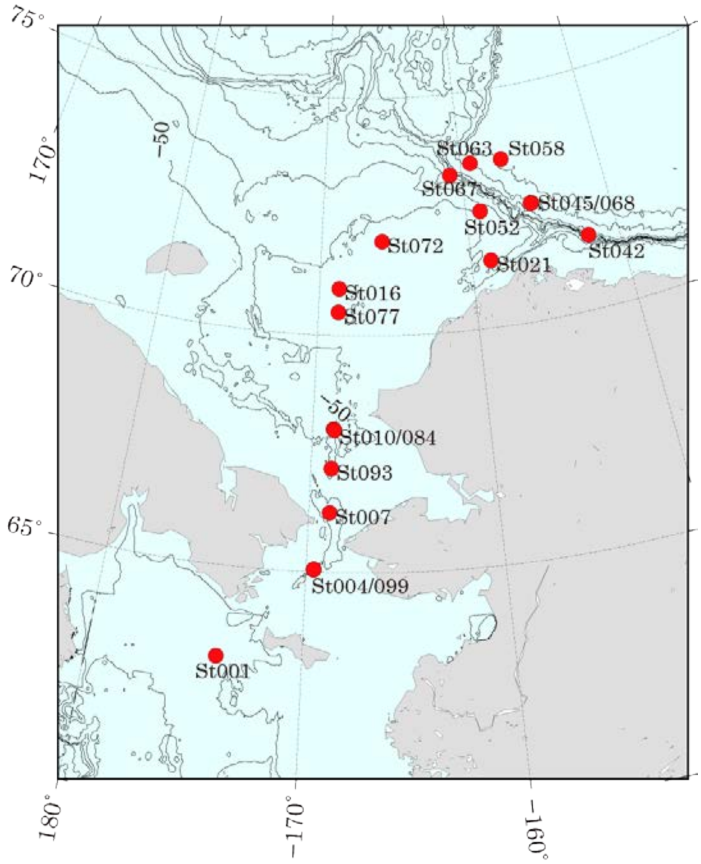


Figure 4.9-1: Sampling positions of bio-optical observations.

Table 4.9: List of sampling site, date and information of cast conditions

Station No.	Lat [N]	Long [E]	Date	C-OPS started	Weather	Cloud Cover
001	63.090	186.008	8/30	1:48	o	10
004	65.057	190.400	8/30	21:21	b	0
007	66.269	191.104	8/31	19:09	o	10
010	68.034	191.179	9/1	19:03	bc	6
016	70.996	191.269	9/2	18:59	bc	6
021	71.427	201.284	9/4	0:08	o, f	10
042	71.563	207.960	9/7	22:49	o	10
045	72.478	204.634	9/8	19:05	o	10
052	72.477	201.004	9/10	21:29	bc	8
058	73.499	203.005	9/13	17:37	o	10
063	73.508	200.720	9/14	19:19	o	10
067	73.305	199.142	9/15	21:07	s	10
068	72.478	204.581	9/16	21:06	s	10
072	71.989	194.106	9/18	23:01	bc	8

077	70.497	191.259	9/19	20:55	b	0
084	68.002	191.252	1/20	18:32	bc	4
093	67.197	191.123	9/21	18:07	bc	8
099	65.056	190.397	9/22	18:07	bc	8

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

4.10. Primary production

(1) Personnel

Shigeto Nishino (JAMSTEC): Principal Investigator

Amane Fujiwara (JAMSTEC)

Keitaro Matsumoto (MWJ): Operation Leader

Hiroshi Hoshino (MWJ)

(2) Objectives

Primary production was measured to estimate underwater photosynthesis by phytoplankton in the Arctic Ocean.

(3) Parameters

Primary production

(4) Instruments and methods

a. Instruments

Stable isotope analyzer

ANCA-SL by Europa Scientific Ltd.; now SerCon Ltd.

Software

ANCA Ver.3.6

b. Methods

Primary production was measured at 14 stations (Sta. 004, 007, 010, 016, 029, 042, 052, 058, 067, 068, 072, 084, 093 and 099) by simulated in situ incubation method (See Figure 4.14-1 and Table 4.14-1). We sampled seawater using shading and acid-treatment bottles and tubes connected to the Niskin bottles, which are derived from 7 optical depths, 100%, 43%, 14%, 6%, 3%, 0.9% and 0.2% of surface irradiance.

After sampling, the seawater was dispensed into four 1L Nalgene polycarbonate bottles for incubation in a dark room (duplicate for the light level controlled incubation, and in a single for the dark incubation and isotope ratio of ^{13}C of ambient seawater). Sea water sample for the ambient carbon isotope ratio was filtered immediately through the GF/F filter. The Nalgene bottles were used after acid treatment. These seawater samples were inoculated with labeled carbon substrate ($NaH^{13}CO_3$) for the measurements of primary production. The concentration of labeled carbon ($NaH^{13}CO_3$) was 200 µM that was ca. 10 % enrichment to the total inorganic carbon in the ambient water. The bottles were placed into incubators with neutral density filters corresponding to light levels at the seawater sampling depths. Incubations using dark bottles were also conducted at each light level.

Samples for the measurements of primary production were incubated in a bath on the deck for 24 hours. At the end of the incubation period, samples were filtered through glass fiber filters (Whatman GF/F 25mm, pre-combusted under 450 degC over 4 hours). The filters were kept to freeze at -20 degC until measurements. Before the measurements, the filters were oven-dried at 45 degC for at least 20 hours and treated with hydrochloric acid to remove the inorganic carbon. The measurements were performed on board using a stable isotope analyzer (ANCA-SL, Europa Scientific Ltd.; now SerCon Ltd.).

(5) Station list

Table 4.14-1 shows a station list for the measurement of primary production, date, and positions.

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

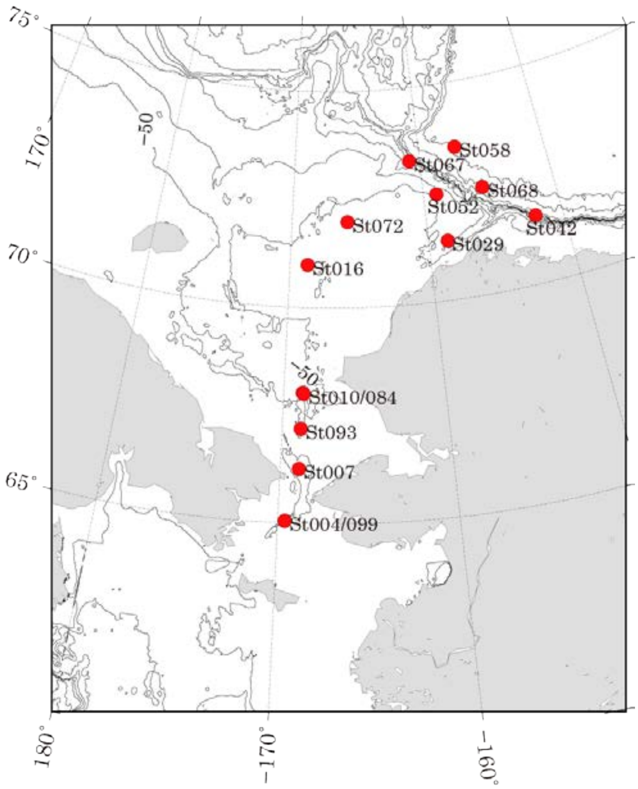


Figure 4.10-1. Map of stations for the measurements of primary production.

Table 4.10. List of stations, date, and positions.

Station	Cast	Date(UTC)	Latitude	Longitude
004	01	08/30	65-03.58N	169-36.36W
007	01	08/31	66-16.16N	168-54.83W
010	01	09/01	68-02.09N	168-49.89W
016	01	09/02	70-59.77N	168-44.62W
029	01	09/05	71-02.31N	158-36.45W
042	01	09/07	71-34.01N	152-00.19W
052	01	09/10	72-28.57N	159-00.10W
058	02	09/13	73-30.46N	157-02.97W
067	01	09/15	73-18.31N	160-48.13W
068	01	09/16	72-28.57N	155-25.25W
072	01	09/18	71-59.43N	165-52.77W
084	01	09/20	68-00.46N	168-45.08W
093	01	09/21	67-11.81N	168-53.26W
099	01	09/22	65-03.14N	169-37.10W

4.11. New production

(1) Personnel

Takuhei Shiozaki (JAMSTEC) -PI

Koji Sugie (JAMSTEC)

(2) Objectives

The ocean contains the largest active reservoir of carbon on Earth and determines atmospheric carbon dioxide. Understanding the efficiency and the factors limiting the carbon export from the sunlit surface waters to the ocean interior is consequently essential for tracing anthropogenic carbon dioxide which causes global warming and ocean acidification. The efficiency of microbe-mediated carbon sequestration, the biological carbon pump, is commonly evaluated by comparing so-called new production with primary production. Marine primary production is generally limited by nitrogen availability, and scales with the input of new nitrogen to the photic zone. New production is defined as production based on nitrogenous nutrient newly introduced from outside of the productive layer, and is balanced with sinking particle flux in a steady-state system. To elucidate spatial variation of new production in the Arctic Ocean, we conducted following experiments during this cruise.

(3) Parameters

Nitrogen fixation rate

Nitrate assimilation rate

Ammonium assimilation rate

Ammonia oxidation rate

Ammonia regeneration rate

Primary production

Chlorophyll *a*

Nutrients

Microbial community (DNA and RNA)

(4) Instruments and methods

Water samples for incubation experiments, nutrients, chlorophyll *a*, and DNA analysis were collected in an acid-cleaned bucket and Niskin-X bottles from those layers having surface light intensities of 100, 10, 1, and 0.1%. Further, samples for ammonia oxidation and DNA were collected from additional depths (100 m, 200 m, 1000 m, and bottom depth minus 10 m). The depth profiles of light intensity were obtained using C-OPS (Biospherical Instruments) before the sampling.

Nitrogen fixation, nitrate assimilation, ammonium assimilation, ammonia oxidation, and ammonia regeneration rates were evaluated using ^{15}N tracer. Nitrogen fixation rate was determined by the gas dissolution method (Mohr et al., 2010, PLoS one). Primary production was determined using ^{13}C tracer. After addition of the tracers, the incubation bottles were placed into on-deck incubators cooled by flowing surface seawater. Light levels were adjusted using neutral-density screens. Samples of 1 or 2 L collected for estimating the initial ^{15}N and ^{13}C enrichment of particulate organic matter were filtered immediately at the beginning of the incubation. The incubations for nitrogen fixation, nitrate assimilation, and ammonia assimilation were terminated by gentle vacuum filtration of the seawater samples through a precombusted GF/F filter. Those for ammonia oxidation and ammonia regeneration were terminated by filtration using 0.2 μm pore-size filters, and filtrate was collected. The filters and filtrate except for ammonia regeneration were kept frozen (-20 °C) for on-shore analysis. The filtrate for ammonia regeneration was incubated in room temperature for 5 days after added MgO and H_2SO_4-soaked filter pack (ammonium diffusion method), and then, the filter pack was stored in glass bottle with silica gel.

Samples for nutrients analysis were collected in 10 mL acrylic tubes and were immediately determined on board using a QuAAtro system (see a report of S. Nishino and colleagues in this issue). Samples for chlorophyll *a* of 290 ml were filtered onto 25-mm Whatman GF/F filters, and the chlorophyll *a* concentrations were measured fluorometrically using a Turner Design 10-AU fluorometer after extraction with N', N'-dimethylformamide on board. Samples for DNA and RNA analyses were filtered onto Sterivex-GP pressure filter units with a 0.22 μm pore size (Millipore). RNA samples were filtered within 30 min of the water sampling and then added to RNA*later* Stabilization Solution (Life Technologies). The Sterivex filter units were frozen at -80°C until onshore analyses.

(5) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC when ready.

4.12. Phytoplankton incubation

(1) Personnel

Koji Sugie (JAMSTEC): Principal Investigator (PI)
Amane Fujiwara (JAMSTEC)
Jonaotaro Onodera (JAMSTEC)
Takuhei Shiozaki (JAMSTEC)

(2) Objective

On-deck incubation experiment was conducted to assess the synergistic impacts of ocean acidification, global warming and seawater freshing on phytoplankton community structure and biogeochemical cycling of bio-elements.

(3) Parameters

Chlorophyll-*a*, nutrients (NO_3, NO_2, NH_4, PO_4, $Si(OH)_4$), particulate organic carbon, particulate nitrogen, particulate phosphorus, particulate biogenic silica, dissolved organic carbon, dissolved organic nitrogen, dissolved organic phosphorus, diatoms (microscopy), pico- and nano-sized phytoplankton, heterotrophic bacteria, phytoplankton pigments, temperature, photosynthetic active radiation, dissolved inorganic carbon, total alkalinity

(4) Instruments and methods

Teflon® coated, Niskin-X sampling bottle attached to a CTD-CMS to collect seawater samples from a depth of 5 (1^{st} experiment) and 15 m (2^{nd} experiment) for incubation. Seawater for the incubations were collected at 66.3°N, 168.9°W and 73.3°N, 160.8°W for 1^{st} and 2^{nd} experiment, respectively. Eight treatments were prepared as follows:

1^{st} experiment

LT:	Unamended controls
LT+CO_2-1:	Added CO_2 ca. 40 μmol L^{-1} relative to the controls
LT+CO_2-2:	Added CO_2 ca. 75 μmol L^{-1} relative to the controls
LT+Glc.	Added glucose at 25 μmol L^{-1} in final concentrations.
HT:	+4.5°C relative to LT
HT+CO_2-1:	+4.5°C relative to LT+CO_2-1
HT+CO_2-2:	+4.5°C relative to LT+CO_2-2
HT+Glc.	+4.5°C relative to LT+Glc.

2^{nd} experiment

LT:	Unamended controls
LT800:	High CO_2 condition was achieved by adding CO_2 saturated filtered seawaters to the controls to make the seawater pCO_2 ca. 800 μatm.

LTLS:	Salinity decreased −1.5 relative to the controls by the addition of pure water.
LTLS800:	Salinity decreased −1.5 and pCO_2 increased ca. 800 µatm relative to the controls.
HT:	+4.5°C relative to the controls
HT800:	+4.5°C relative to the LT800
HTLS:	+4.5°C relative to the LTLS
HTLS800:	+4.5°C relative to the LTLS800

Seawater for the experiment was sieved by 200 µm acid-cleaned Teflon-mesh to eliminate mesozooplankton and poured into 24 of 12-L acid-washed polyethylene bag. In the 1st experiment, carbonate chemistry was manipulated by adding CO_2 saturated (at 1 atm) seawater or 0.1N NaOH (suprapur, Merck). In the 2nd experiment, Fe, nutrients, pure water, filtered seawater and/or CO_2 saturated filtered seawater were added and homogenized before the collection of seawater samples. Bags were prepared in triplicate per treatment. Temperature of the incubation tanks were set at 7 and 2.3 (LT group) and 11 and 6.3°C (HT group) for the 1st and 2nd experiment, respectively. Incubations were lasted for 8 and 9 days the 1st and 2nd experiment, respectively. Chlorophyll-*a* and nutrients were once in two days, and other parameters were collected periodically during the exponential growth phase of phytoplankton.

(5) Observation log
September 1 (UTC), 2016 at 66.3°N, 168.9°W for the 1st experiment.
September 15 (UTC), 2016 at 73.3°N, 160.8°W for the 2nd experiment.

(6) Preliminary results
Time course of photosynthetic active radiation (PAR) and temperature and chlorophyll-*a* concentrations during the 1st and 2nd incubations are shown in Figs. 4.12.1, 4.12.2 and 4.12.3, respectively.

(7) Data archives
All data obtained during MR16-06 cruise will be submitted to Data Management Group (DMG) of JAMSTEC after the sample analysis and validation. The data will be opened to the public via "Data Research System for Whole Cruise Information (DARWIN)" in JAMSTEC web site.

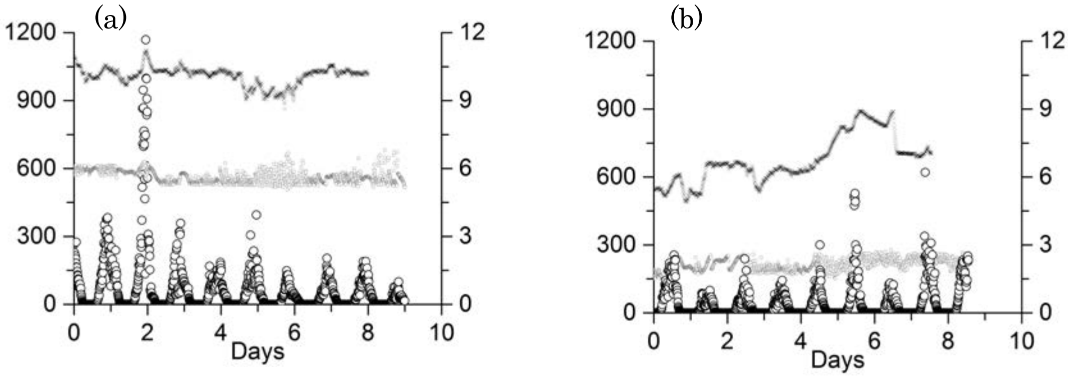


Figure 4.12-1. Temporal change in photosynthetic active radiation (PAR, black open circle) and temperature (gray open circle and black cross represent for low- and high-temperature tank, respectively) during the incubation.

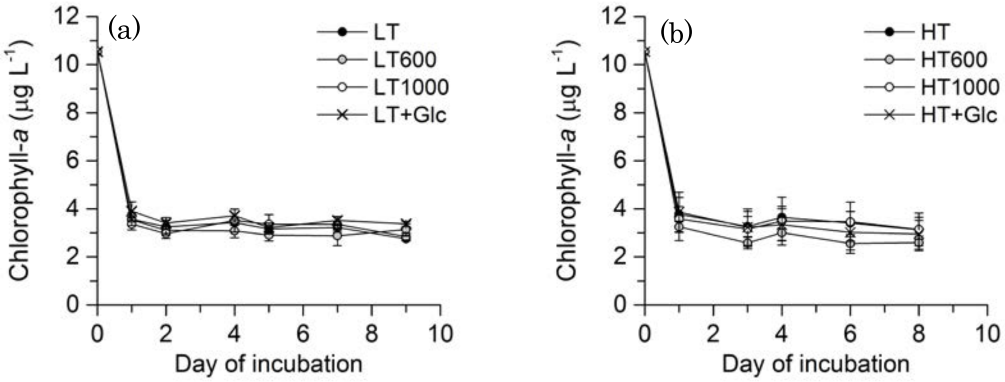


Figure 4.12-2. Temporal change in chlorophyll-*a* concentration during the 1st incubation. (a) Low- (b) high-temperature tank.

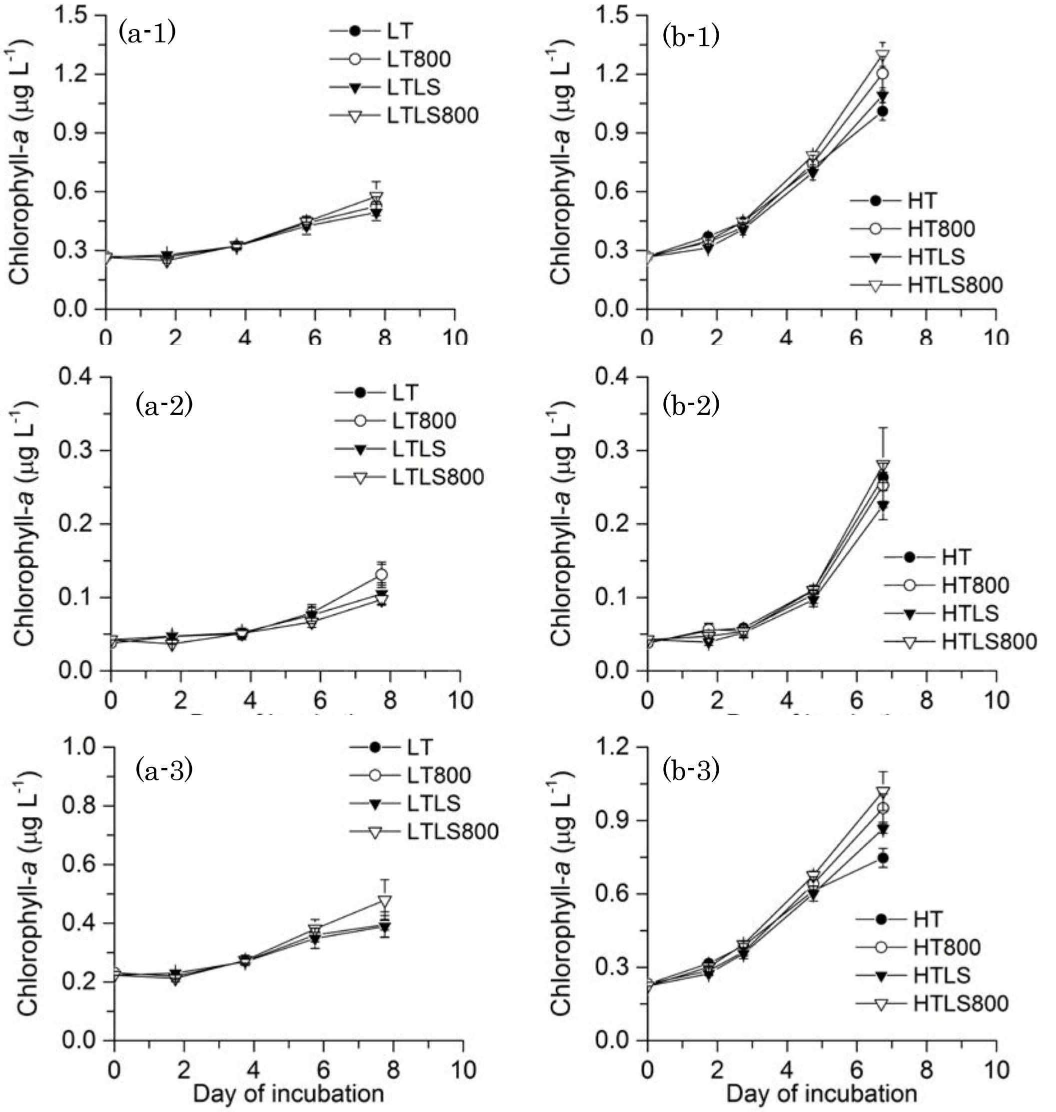


Figure 4.12-3. Temporal change in chlorophyll-*a* concentration during the 2nd incubation. (a) Low- (b) high-temperature tanks. (-1), (-2) and (-3) represent total, >10 μm, and 0.7–10 μm size fractionated chlorophyll-*a*.

4.13. Zooplankton nets

(1) Personnel

Toru Hirawake (Hokkaido University): Principal Investigator
Atsushi Yamaguchi (Hokkaido University)
Naomi Harada (JAMSTEC)
Katsunori Kimoto (JAMSTEC)
Yoshiyuki Abe (Hokkaido University)
Kohei Matsuno (Australia Antarctic Division)

(2) Objective

The goals of this study are following:

1) Estimate the amount of the transported Pacific copepods into the Arctic Ocean.
2) Evaluate physical conditions (gut pigment and lipid accumulation) of the Pacific and Arctic copepods and appendicularians in the Arctic Ocean.
3) Clarify the grazing impact of the arctic copepods and appendicularians in the Arctic Ocean ecosystem.

(3) Sampling

Zooplankton samples were collected by vertical haul of quadruple NORPAC nets at 67 stations in the western Arctic Ocean. Quadruple NORPAC net (mesh sizes: 335, 150 and two 62 μm [one is for fixed sample and the other has large size cod-end to collected fresh samples for incubation], mouth diameter: 45 cm) was towed between surface and 150 m depth or bottom -6 m (stations where the bottom shallower than 150 m) at all stations (Figure 4.13-1 and Table 4.13-1). Zooplankton samples collected by the NORPAC net with 335 and 150 μm mesh were immediately fixed with 5% buffered formalin for zooplankton structure analysis. Samples collected with 62 μm mesh at 54 stations were fixed with 99.5% ethanol for analysis on Foraminifera and Radiolaria (investigator: Katsunori Kimoto [JAMSTEC]). The remaining 62 μm mesh samples at 13 stations were immediately fixed with 5% buffered formalin for zooplankton structure analysis later. The volume of water filtered through the net was estimated from the reading of a flow-meter mounted in the mouth ring.

Bucket net with large size cod-end (mesh: 62 μm, mouth diameter: 45 cm) was towed between surface and 150 m depth or bottom -6 m at 62 stations (Figure 4.13-1 and Table 4.13-2), fresh samples were used for evaluation of the copepod physiological activity (i.e. wet mass, dry mass, ash-free dry mass and gut pigment).

Closing PCP net (mesh size: 63 μm, mouth diameter: 45 cm) was towed at 4 stations from 5 layers (0–50, 50–100, 100–250, 250–300 and 300–500 m). The volume of water filtered through the net was estimated from the reading of a flow-meter mounted in the mouth ring. Zooplankton samples collected by closing PCP net were split with Motoda box splitter. One aliquot was immediately fixed with 5% buffered formalin for zooplankton structure analysis (Figure 4.13-1 and Table 4.13-3). The remaining aliquot was demineralized and fixed with 99.5% ethanol for analysis on foraminiferans and pteropods (investigator: Katsunori Kimoto [JAMSTEC]).

(4) On-board treatment

[Individual wet weight, dry weight, ash-free dry mass and gut pigment]

Fresh zooplankton samples collected with Bucket net were immediately added with 10% soda water (CO_2 water) used for gut pigment analysis. We sorted with late copepodid stages of the Pacific copepods (*Neocalanus cristatus, N. plumchrus, N. flemingeri, Eucalanus bungii, Metridia pacifica*), the Arctic copepods (*Calanus glacialis, C. hyperboreus, M. longa*) and appendicularians (*Oikopleura vanhoeffeni* and *O. labradoriensis*). Some specimens were rinsed with distilled water, transferred into pre-weighted aluminum pan and stored in -30°C. At land laboratory, these samples will be weighed for wet weight, dry weight, ash-free dry mass with a precision of 0.01 g using an electronic balance. Other specimens transferred into a cuvette tube immersed with 6 ml dimethylformamide, stored and extracted for >24 hours. After extract the pigment, these samples were measured fluorescence with a Turner model 10-005-R Filter Fluorometer.

(5) Station list

Table 14.3-1: Data on plankton samples collected by vertical hauls with quadruple NORPAC net. GG54: 335 μm mesh.

Table 14.3-2: Data on plankton samples collected by vertical hauls with closing net (mesh size 63 μm).

Table 14.3-1. Data on plankton samples collected by vertical hauls with quadruple NORPAC net.

Station no.	Position Lat. Deg.	Lat. Min.		Lon. Deg.	Lon. Min.		S.M.T. Date	Hour	Depth estimated to be lowered (m)	Mesh size of net (μm)	Flowmeter No.	Reading	Estimated volume of water filtered (m^3)	Remark
St. 001	63	5.54	N	173	59.21	W	29 Aug.	16:13	70	335	2446	678	12.29	
										150	3690	798	14.34	
										62	3691	655	12.05	1)
										62	–	–	–	2)
St. 002	63	51.68	N	172	17.8	W	29 Aug.	23:26	47	335	2446	390	7.07	
										150	3690	300	5.39	
										62	3691	141	2.59	
										62	–	–	–	2)
St. 003	64	42.64	N	170	20.99	W	30 Aug.	7:11	41	335	2446	620	11.24	
										150	3690	620	11.14	
										62	3691	495	9.11	
										62	–		–	2)
St. 004	65	3.93	N	169	38.22	W	30 Aug.	14:02	45	335	2446	360	6.52	
										150	3690	222	3.99	
										62	3691	150	2.76	1)
										62	–		–	2)
St. 005	65	16.38	N	169	3.54	W	30 Aug.	17:26	45	335	2446	422	7.65	
										150	3690	380	6.83	
										62	3691	160	2.94	
										62	–		–	2)
St. 006	65	39.1	N	168	42.34	W	30 Aug.	21:28	43	335	2446	403	7.30	
										150	3690	331	5.95	
										62	3691	115	2.12	
										62	–		–	2)
St. 007	66	16.38	N	168	55.19	W	31 Aug.	9:22	49	335	2446	410	7.43	
										150	3690	390	7.01	
										62	3691	165	3.04	
										62	–		–	2)
St. 008	67	11.95	N	168	54.23	W	31 Aug.	20:12	42	335	2446	432	7.83	
										150	3690	435	7.82	
										62	3691	218	4.01	1)
										62	–		–	2)
St. 009	67	34.13	N	168	49.58	W	31 Aug.	23:42	44	335	2446	397	7.20	
										150	3690	485	8.72	
										62	3691	210	3.86	
										62	–		–	2)
St. 010	68	1.98	N	168	50.78	W	1 Sep.	10:14	52	335	2446	540	9.79	
										150	3690	483	8.68	
										62	3691	240	4.41	1)
										62	–		–	2)
St. 012	68	59.96	N	168	45	W	1 Sep.	18:20	46	335	2446	478	8.66	
										150	3690	468	8.41	
										62	3691	185	3.40	1)
										62	–		–	2)
St. 014	70	0	N	168	45	W	2 Sep.	1:38	34	335	2446	360	6.52	
										150	3690	359	6.45	
										62	3691	205	3.77	1)
										62	–		–	2)
St. 016	71	0	N	168	45	W	2 Sep.	9:00	38	335	2446	310	5.62	
										150	3690	298	5.36	
										62	3691	103	1.89	1)
										62	–		–	2)
St. 018	70	45	N	165	0	W	2 Sep.	16:58	35	335	2446	295	5.35	
										150	3690	260	4.67	
										62	3691	55	1.01	1)
										62	–		–	2)
St. 020	70	45	N	161	0	W	3 Sep.	0:59	37	335	2446	308	5.58	
										150	3690	298	5.36	
										62	3691	75	1.38	1)
										62	–		–	2)

S.M.T. was UTC-11h.

1) sample for JAMSTEC Kimoto

2) sample for experiments

Table 14.3-1. (Continued)

Station no.	Position Lat. Deg.	Lat. Min.		Lon. Deg	Lon. Min.		S.M.T. Date	Hour	Depth estimated to be lowered (m)	Mesh size of net (μm)	Flowmeter No.	Reading	Estimated volume of water filtered (m^3)	Remark
St. 021	71	25.46	N	158	43.58	W	3 Sep.	14:14	52	335	2446	333	6.04	
										150	3690	282	5.07	
										62	3691	145	2.67	1)
										62	–		–	2)
St. 022	71	34.74	N	157	49.62	W	3 Sep.	18:04	58	335	2446	403	7.30	
										150	3690	373	6.70	
										62	3691	182	3.35	1)
										62	–		–	2)
St. 023	71	29.73	N	157	39.67	W	3 Sep.	19:29	77	335	2446	525	9.52	
										150	3690	510	9.17	
										62	3691	260	4.78	
										62	–		–	2)
St. 024	71	24.82	N	157	29.51	W	3 Sep.	22:38	117	335	2446	1039	18.83	
										150	3690	991	17.81	
										62	3691	380	6.99	1)
										62	–		–	2)
St. 025	71	19.8	N	157	19.57	W	4 Sep.	0:08	83	335	2446	691	12.52	
										150	3690	662	11.90	
										62	3691	362	6.66	
										62	–		–	2)
St. 026	71	14.68	N	157	9.76	W	4 Sep.	3:04	39	335	2446	360	6.52	
										150	3690	345	6.20	
										62	3691	148	2.72	1)
										62	–		–	2)
St. 036	71	52.5	N	156	2.26	W	6 Sep.	19:52	73	335	2446	643	11.65	
										150	3690	629	11.30	
										62	3691	301	5.54	1)
										62	–		–	2)
St. 039	71	44.18	N	155	12.52	W	7 Sep.	3:44	150	335	2446	1572	28.49	
										150	3690	1558	28.00	
										62	3691	848	15.60	1)
										62	–		–	2)
St. 041	71	35.81	N	154	47.59	W	7 Sep.	7:04	34	335	2446	349	6.33	
										150	3690	369	6.63	
										62	3691	179	3.29	1)
										62	–		–	2)
St. 042	71	34.2	N	152	0.19	W	7 Sep.	13:50	150	335	2446	1260	22.84	
										150	3690	1233	22.16	
										62	3691	642	11.81	1)
										62	–		–	2)
St. 043	71	47.63	N	153	1.2	W	7 Sep.	17:56	150	335	2446	1485	26.91	
										150	3690	1443	25.93	
										62	3691	661	12.16	
										62	–		–	2)
St. 044	71	57.52	N	153	59.72	W	7 Sep.	22:59	150	335	2446	1178	21.35	
										150	3690	1146	20.59	
										62	3691	498	9.16	1)
										62	–		–	2)
St. 045	72	29.54	N	155	19.21	W	8 Sep.	11:07	150	335	2446	1210	21.93	
										150	3690	1133	20.36	
										62	3691	433	7.97	1)
										62	–		–	2)
St. 046	72	16.56	N	156	0.37	W	8 Sep.	20:20	150	335	2446	1143	20.72	
										150	3690	1110	19.95	
										62	3691	471	8.66	1)
										62	–		–	2)
St. 047	72	28.29	N	157	0	W	8 Sep.	22:35	150	335	2446	1523	27.60	
										150	3690	1388	24.94	
										62	3691	670	12.32	
										62	–		–	2)

S.M.T. was UTC-11h.
1) sample for JAMSTEC Kimoto
2) sample for experiments

Table 14.3-1. (Continued)

Station no.	Position Lat. Deg.	Lat. Min.		Lon. Deg	Lon. Min.		S.M.T. Date	Hour	Depth estimated to be lowered (m)	Mesh size of net (μm)	Flowmeter No.	Reading	Estimated volume of water filtered (m^3)	Remark
St. 048	72	47.23	N	158	0.59	W	9 Sep.	4:07	150	335	2446	1160	21.02	
										150	3690	1108	19.91	
										62	3691	382	7.03	1)
										62	–		–	2)
St. 049	73	18.7	N	160	48.12	W	9 Sep.	13:17	150	335	2446	1205	21.84	
										150	3690	1108	19.91	
										62	3691	242	4.45	1)
										62	–		–	2)
St. 050	73	17.43	N	160	2	W	9 Sep.	19:32	150	335	2446	1143	20.72	
										150	3690	1011	18.17	
										62	3691	315	5.79	
										62	–		–	2)
St. 051	73	31.38	N	160	53.6	W	9 Sep.	21:35	150	335	2446	1210	21.93	
										150	3690	1175	21.12	
										62	3691	430	7.91	
										62	–		–	2)
St. 052	72	28.36	N	159	0.15	W	10 Sep.	11:42	46	335	2446	382	6.92	
										150	3690	355	6.38	
										62	3691	125	2.30	1)
										62	–		–	2)
St. 053	72	28	N	158	49.67	W	11 Sep.	10:02	47	335	2446	380	6.89	
										150	3690	349	6.27	
										62	3691	98	1.80	1)
										62	–		–	2)
St. 054	72	49.84	N	158	48.66	W	12 Sep.	18:46	150	335	2446	1242	22.51	
										150	3690	1145	20.58	
										62	3691	323	5.94	1)
										62	–		–	2)
St. 055	72	59.93	N	158	29.62	W	12 Sep.	20:10	150	335	2446	1265	22.93	
										150	3690	1258	22.61	
										62	3691	465	8.55	1)
										62	–		–	2)
St. 056	73	9.95	N	158	0.68	W	13 Sep.	1:50	150	335	2446	1170	21.21	
										150	3690	1112	19.98	
										62	3691	349	6.42	1)
										62	–		–	2)
St. 058	73	30.13	N	157	2.22	W	13 Sep.	9:45	150	335	2446	1120	20.30	
										150	3690	1108	19.91	
										62	3691	368	6.77	1)
										62	–		–	2)
St. 060	73	51.44	N	156	35.68	W	13 Sep.	20:33	150	335	2446	1262	22.87	
										150	3690	1282	23.04	
										62	3691	548	10.08	1)
										62	–		–	2)
St. 062	73	37.7	N	158	27.74	W	14 Sep.	6:17	150	335	2446	1130	20.48	
										150	3690	1148	20.63	
										62	3691	272	5.00	1)
										62	–		–	2)
St. 063	73	30.33	N	159	18.14	W	14 Sep.	11:01	150	335	2446	1135	20.57	
										150	3690	1072	19.26	
										62	3691	273	5.02	1)
										62	–		–	2)
St. 064	73	23.3	N	160	10.52	W	14 Sep.	12:57	150	335	2446	1205	21.84	
										150	3690	1097	19.71	
										62	3691	310	5.70	1)
										62	–		–	2)
St. 065	73	13.86	N	161	19.4	W	14 Sep.	17:48	150	335	2446	1230	22.29	
										150	3690	1121	20.15	
										62	3691	286	5.26	1)
										62	–		–	2)
St. 066	73	9.47	N	162	18.5	W	14 Sep.	19:56	150	335	2446	1250	22.66	
										150	3690	1205	21.66	
										62	3691	222	4.08	1)
										62	–		–	2)

S.M.T. was UTC-11h.
1) sample for JAMSTEC Kimoto
2) sample for experiments

Table 14.3-1. (Continued)

Station no.	Position Lat. Deg.	Lat. Min.		Lon. Deg	Lon. Min.		S.M.T. Date	Hour	Depth estimated to be lowered (m)	Mesh size of net (μm)	Flowmeter No.	Reading	Estimated volume of water filtered (m^3)	Remark
St. 067	73	18.2	N	160	48.34	W	15 Sep.	12:04	150	335	2446	1418	25.70	
(NHC16t)										150	3690	1248	22.43	
										62	3691	439	8.08	1)
										62	–		–	2)
St. 068	72	28.22	N	155	23.49	W	16 Sep.	16:35	150	335	2446	1221	22.13	
(NBC16t)										150	3690	1190	21.39	
										62	3691	433	7.97	1)
										62	–		–	2)
St. 072	71	59.3	N	165	52.65	W	18 Sep.	13:13	39	335	2446	399	7.23	
										150	3690	382	6.86	
										62	3691	199	3.66	1)
										62	–		–	2)
St. 073	72	31.13	N	167	18.6	W	18 Sep.	18:45	44	335	2446	410	7.43	
										150	3690	342	6.15	
										62	3691	231	4.25	1)
										62	–		–	2)
St. 074	72	0	N	168	45	W	18 Sep.	23:27	44	335	2446	383	6.94	
										150	3690	389	6.99	
										62	3691	138	2.54	1)
										62	–		–	2)
St. 076	71	0	N	168	45	W	19 Sep.	6:54	38	335	2446	373	6.76	
										150	3690	388	6.97	
										62	3691	151	2.78	1)
										62	–		–	2)
St. 078	70	0	N	168	45	W	19 Sep.	13:41	35	335	2446	320	5.80	
										150	3690	323	5.80	
										62	3691	105	1.93	1)
										62	–		–	2)
St. 080	69	0	N	168	45	W	19 Sep.	21:03	47	335	2446	431	7.81	
										150	3690	405	7.28	
										62	3691	147	2.70	1)
										62	–		–	2)
St. 084	68	0	N	168	45	W	20 Sep.	8:40	53	335	2446	495	8.97	
										150	3690	503	9.04	
										62	3691	212	3.90	1)
										62	–		–	2)
St. 085	67	45	N	168	30	W	20 Sep.	10:27	44	335	2446	415	7.52	
										150	3690	381	6.85	
										62	3691	124	2.28	
										62	–		–	2)
St. 086	68	0.1	N	168	0	W	20 Sep.	13:36	48	335	2446	500	9.06	
										150	3690	438	7.87	
										62	3691	110	2.02	1)
										62	–		–	2)
St. 087	68	12.4	N	167	20.37	W	20 Sep.	15:26	42	335	2446	483	8.75	
										150	3690	449	8.07	
										62	3691	252	4.64	
										62	–		–	2)
St. 088	68	18.12	N	167	3.25	W	20 Sep.	17:49	33	335	2446	332	6.02	
										150	3690	336	6.04	
										62	3691	185	3.40	1)
										62	–		–	2)
St. 092	67	34.4	N	168	50.65	W	21 Sep.	1:30	44	335	2446	502	9.10	
										150	3690	491	8.82	
										62	3691	228	4.19	
										62	–		–	2)
St. 093	67	11.84	N	168	53.86	W	21 Sep.	6:10	43	335	2446	330	5.98	
										150	3690	271	4.87	
										62	3691	145	2.67	1)
										62	–		–	2)
St. 094	66	16.26	N	168	53.55	W	21 Sep.	13:33	50	335	2446	323	5.85	
										150	3690	292	5.25	
										62	3691	122	2.24	1)
										62	–		–	2)

S.M.T. was UTC-11h.
1) sample for JAMSTEC Kimoto
2) sample for experiments

Table 14.3-1. (Continued)

Station no.	Position Lat. Deg.	Lat. Min.		Lon. Deg	Lon. Min.		S.M.T. Date	Hour	Depth estimated to be lowered (m)	Mesh size of net (μm)	Flowmeter No.	Reading	Estimated volume of water filtered (m³)	Remark
St. 095	65	45.82	N	168	45.5	W	21 Sep.	18:21	46	335	2446	375	6.80	
										150	3690	260	4.67	
										62	3691		0.00	
										62	-		-	2)
St. 096	65	39.15	N	168	15		21 Sep.	20:05	37	335	2446	348	6.31	
										150	3690	332	5.97	
										62	3691	152	2.80	1)
										62	-		-	2)
St. 097	65	39	N	168	41.82	W	21 Sep.	21:59	44	335	2446	393	7.12	
										150	3690	394	7.08	
										62	3691	161	2.96	1)
										62	-		-	2)
St. 098	65	15.9	N	169	3.7	W	22 Sep.	1:30	47	335	2446	360	6.52	
										150	3690	232	4.17	
										62	3691	143	2.63	1)
										62	-		-	2)
St. 099	65	3.8	N	169	37.98	W	22 Sep.	8:21	45	335	2446	305	5.53	
										150	3690	198	3.56	
										62	3691	61	1.12	1)
										62	-		-	2)

S.M.T. was UTC-11h.
1) sample for JAMSTEC Kimoto
2) sample for experiments

Table 14.3-2. Data on plankton collected by vertical hauls with closing net.

Station no.	Position Lat. Deg.	Lat. Min.		Lon. Deg	Lon. Min.		S.M.T. Date	Hour	Depth of closed (m)		Depth estimated to be lowered (m)	Mesh size of net (μm)	Flowmeter No.	Reading	Estimated volume of water filtered (m³)	Remark
St. 042	71	33.68	N	152	0	W	7 Sep.	14:11	301	–	470	63	2888	184	3.09	1)
								14:41	252	–	300	63	2888	240	4.03	1)
								15:01	101	–	250	63	2888	618	10.37	1)
								15:21	50	–	100	63	2888	312	5.24	1)
								15:33	0	–	50	63	2888	280	4.70	1)
St.045	72	29.85	N	155	18.55	W	8 Sep.	11:22	302	–	500	63	2888	158	2.65	1)
								11:50	249	–	300	63	2888	332	5.57	1)
								12:13	100	–	250	63	2888	551	9.25	1)
								12:34	55	–	100	63	2888	396	6.65	1)
								12:46	0	–	50	63	2888	162	2.72	1)
St.049	73	18.37	N	160	50.65	W	9 Sep.	13:35	301	–	400	63	2888	245	4.11	1)
								14:00	250	–	300	63	2888	63	1.06	1)
								14:19	100	–	250	63	2888	220	3.69	1)
								14:38	50	–	100	63	2888	165	2.77	1)
								14:48	0	–	50	63	2888	51	0.86	1)
St.060	73	51.32	N	156	36.46	W	13 Sep.	20:50	303	–	500	63	2888	1040	17.46	1)
								21:20	253	–	300	63	2888	826	13.86	1)
								21:39	100	–	250	63	2888	61	1.02	1)
								21:57	50	–	100	63	2888	117	1.96	1)
								22:08	0	–	50	63	2888	300	5.04	1)

S.M.T. was UTC-11h.
1) shared 1/2 sample with JAMSTEC Kimoto

(6) Preliminary results

As a preliminary results, we present following items.

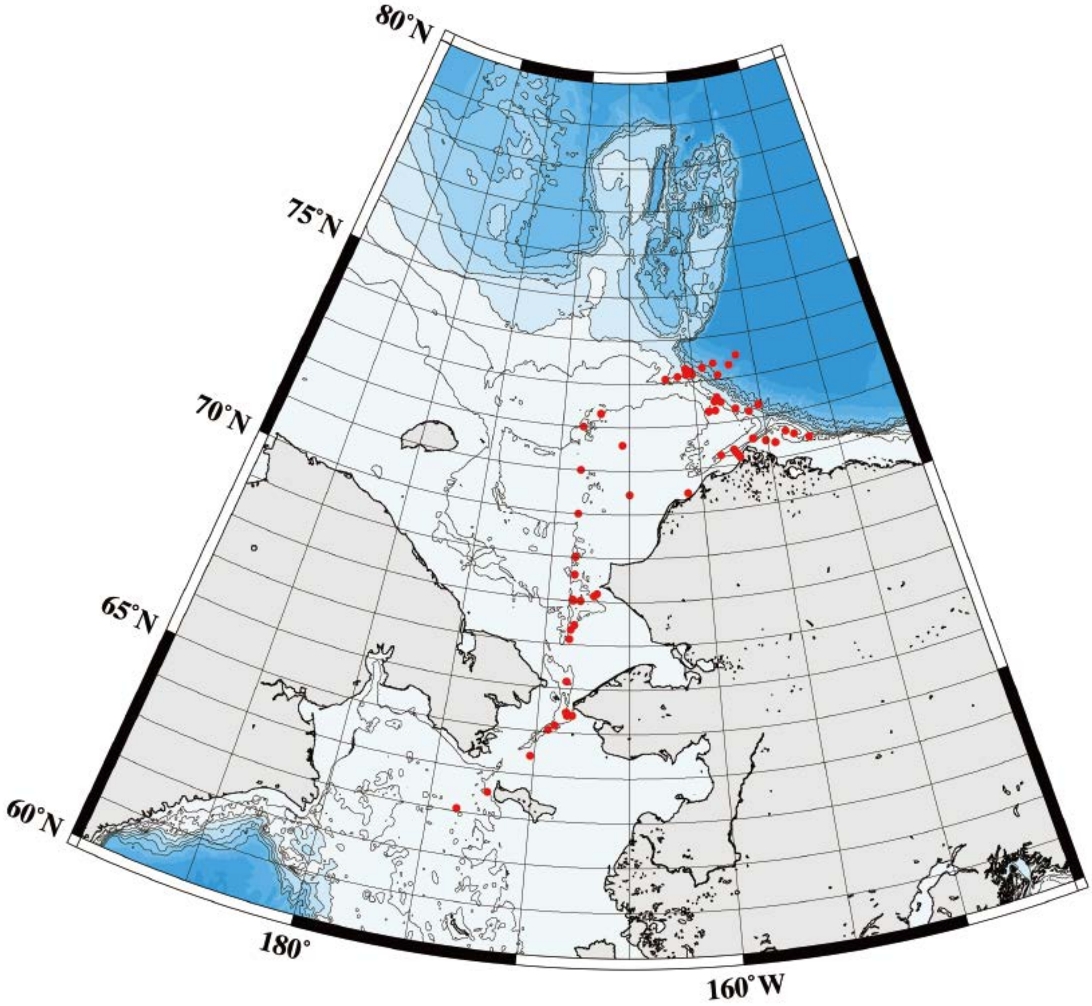


Figure 4.13-1: Location of the plankton net sampling stations

4.14. Zooplankton incubations
4.14.1. Gut evacuation rate and fecal pellet production experiments

(1) Personnel:
Toru Hirawake (Hokkaido Univ., -PI)
Makoto Sampei (Hokkaido Univ.)

(2) Objectives

The Arctic Challenge Study (ArCS) has been launched in end-half of last financial year. A part of theme 6 in the ArCS project (Marine ecosystem group) address to understand and predict how will marine ecosystem be altered by on-going environmental changes (e.g., sea ice reduction and warm water inflow) and by human activities (e.g. fisheries, mining and traffics). As a part of the ArCS subproject, GAMAGUCHI NET vertical tow were conducted in waters near the Bering Strait. Based on those collected samples, grazing rate by major copepod species and fecal pellet production rate will be estimated to quantify POC consumption rate and fecal pellet loss rate in the water column.

(3) Parameters
Biomass, Gut evacuation rate, fecal pellet production rate

(4) Instruments and methods

GAMAGUCHI NET (200 μm mesh size and 2 m long) was hauled vertically from 5 m above the bottom to the surface at sampling sites (see Station list). Zooplankton specimens were got frozen at -80°C or fixed with 5% (v/v) formalin solution for later analyses (taxonomic observation, pigment measurement) in the laboratory.

(5) Station list

Table 4-14-1-1 List of sampling and analyses

Stn No.	Latitude			Longitude			Depth	Date Collected (UTC)			Taxonomic observation	Gut pigments	Fecal pellets
	Deg.	Min.	N/S	Deg.	Min.	E/W	[m]	YYYY	MM	DD			
Stn. 001	63	5.54	N	173	59.21	W	0-70	2016	8	30	○	○	
Stn. 002	63	51.68	N	172	17.8	W	0-50	2016	8	30	○	○	
Stn. 003	64	42.64	N	170	20.99	W	0-41	2016	8	30	○	○	
Stn. 004	65	3.93	N	169	38.22	W	0-45	2016	8	31	○	○	○
Stn. 005	65	16.38	N	169	3.54	W	0-48	2016	8	31	○	○	
Stn. 006	65	39.1	N	168	42.34	W	0-43	2016	8	31	○	○	
Stn. 007	66	16.38	N	168	55.19	W	0-50	2016	8	31	○		
Stn. 008	67	11.95	N	168	54.23	W	0-35	2016	9	1		○	○
Stn. 009	67	34.13	N	168	49.58	W	0-45	2016	9	1	○	○	
Stn. 010	68	1.98	N	168	50.78	W	0-53	2016	9	1	○	○	
Stn. 094	66	16.26	N	168	53.55	W	0-45	2016	9	21		○	
Stn. 095	65	45.82	N	168	45.5	W	0-44	2016	9	21		○	
Stn. 096	65	39.15	N	168	15	W	0-51	2016	9	22	○	○	○
Stn. 097	65	39	N	168	41.82	W	0-45	2016	9	22		○	
Stn. 098	65	15.9	N	169	3.7	W	0-48	2016	9	22		○	
Stn. 099	65	3.8	N	169	37.98	W	0-46	2016	9	22	○		○

(6) Preliminary results

NOT AVAILABLE

4.14.2. Appendicularians incubation

(1) Personnel

Toru Hirawake (Hokkaido University): Principal Investigator
Atsushi Yamaguchi (Hokkaido University)
Yoshiyuki Abe (Hokkaido University)
Kohei Matsuno (Australia Arctic Division)

(2) Objective

The goals of this study are following:

1. Evaluate gut evacuation rate of the Arctic appendicularians in the Arctic Ocean.

4) Bring the fresh appendicularians back to land laboratory.

(3) Sampling and treatment

Fresh appendicularians samples were collected by Bucket net with large size cod-end (mesh: 62 µm, mouth diameter: 45 cm) in the western Arctic Ocean. Bucket net was towed between surface and 150 m depth or bottom -6 m (stations where the bottom shallower than 150 m) at st. 18, 53 and 72. Fresh appendicularians specimens (*Oikopleura vanhoeffeni* and *O. labradoriensis*) were immediately sorted and poured into a bucket filled filtered 10-L seawater. Appendicularians rearing was conducted at 2°C in the temperature-controlled room.

(4) Station list

Incubation specimens were collected at st. 18, 53 and 72. Sampling station detail is describe a Table 14.3-1

(5) Preliminary results

As a preliminary result, we present following items.

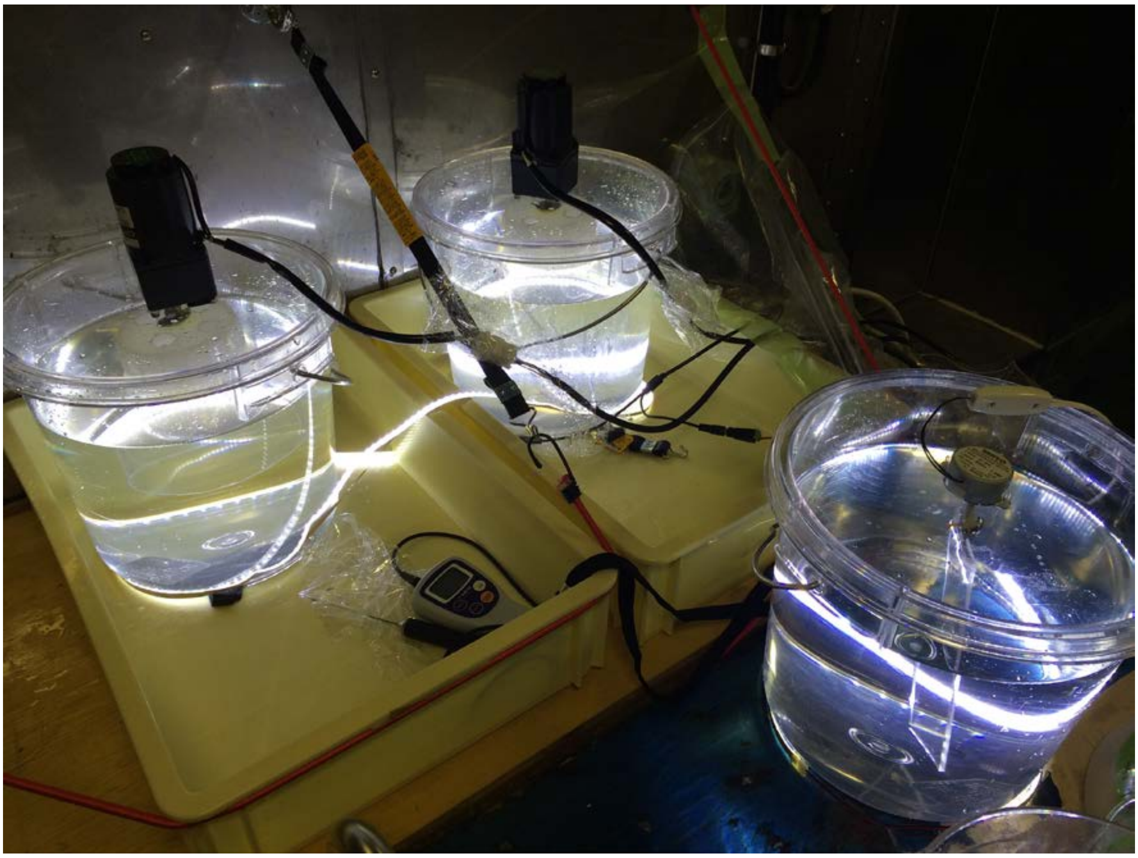


Figure 4.14.2-1: The picture of appendicularian incubation in the temperature-controlled room.

4.15. Water sampling for microscopic observation

(1) Personnel

Jonaotaro Onodera (PI, JAMSTEC), Koji Sugie (JAMSTEC),

(2) Objectives

In general, shell-bearing planktons partially take an important role in lower trophic ecosystem and biogeochemical cycles. Water samples were taken to observe relationship between plankton distribution and hydrography.

(3) Parameters

Numerical abundance of diatom frustules, and shells or skeletons of other nano- and micro- phytoplankton groups (e.g., silicoflagellate, Parmales, coccolithophore).

(4) Instruments and methods

Water samples from sea surface and subsurface chlorophyll maximum (SCM) are applied. Sea surface water was taken by bucket. The SCM water was taken by CTD/Carousel Water Sampling System. Obtained water samples were filtered on membrane filter with grid (45mm diameter, 0.45μm pore size). Filtering water volume was adjusted from 0.3 to 2.0 L because of different particle concentration among samples. The sample filter was desalted by milli-Q water, and then it was dried in oven (45°C). The dried filter in petri dish is packed in zip-lock bag, and it is brought to lab on shore. After the cruise, plankton remains on the filter will be observed and counted under scanning electron microscope and light microscope.

(5) Results

Total of 99 samples were taken from 50 CTD stations (Table 4.15-1).

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via “Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)” in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

Table 4.15-1: The filter sample list for microscopy

Filter #	2016/MM/DD hh:mm (UTC)	Station	Latitude	Longitude	Sampled Depth (m)	Filtered Water Volume (mL)	Remarks
1	08/30 03:05	1	63°05.664'N	173°59.088'W	0	1000	

2	08/30 03:05	1	63°05.664'N	173°59.088'W	38	1000	SCM
3	08/30 21:36	4	65°03.582'N	169°36.354'W	0	1000	St.NB16t
4	08/30 21:36	4	65°03.582'N	169°36.354'W	30	1000	SCM, St.NB16t
5	08/31 07:45	6	65°38.952'N	168°42.096'W	0	500	
6	08/31 07:45	6	65°38.952'N	168°42.096'W	8	500	SCM
7	08/31 19:25	7	66°16.164'N	168°54.834'W	0	500	St.BS16t
8	08/31 19:25	7	66°16.164'N	168°54.834'W	7	500	SCM, St.BS16t
9	09/01 06:35	8	67°11.946'N	168°54.096'W	0	500	
10	09/01 06:35	8	67°11.946'N	168°54.096'W	15	500	SCM
11	09/01 19:25	10	68°02.094'N	168°49.890'W	0	750	St.SCH
12	09/01 19:25	10	68°02.094'N	168°49.890'W	35	750	SCM, St.SCH
13	09/02 04:35	12	68°59.970'N	168°44.508'W	0	750	
14	09/02 04:35	12	68°59.970'N	168°44.508'W	23	750	SCM
15	09/02 12:00	14	69°59.970'N	168°44.580'W	0	1000	
16	09/02 12:00	14	69°59.970'N	168°44.580'W	30	1000	SCM
17	09/02 21:16	16	70°59.766'N	168°44.616'W	0	1000	
18	09/02 21:16	16	70°59.766'N	168°44.616'W	33	500	SCM
19	09/03 03:22	18	70°45.006'N	164°59.940'W	0	1000	
20	09/03 03:22	18	70°45.006'N	164°59.940'W	24	1000	SCM
21	09/03 12:23	20	70°44.970'N	161°00.096'W	0	1000	
22	09/03 12:23	20	70°44.970'N	161°00.096'W	26	1000	SCM
23	09/04 00:24	21	71°25.656'N	158°42.978'W	0	900	
24	09/04 00:24	21	71°25.656'N	158°42.978'W	30	500	SCM
25	09/04 04:20	22	71°34.752'N	157°49.638'W	0	1000	
26	09/04 04:20	22	71°34.752'N	157°49.638'W	37	750	SCM
27	09/04 08:54	24	71°24.852'N	157°29.922'W	0	1000	
28	09/04 08:54	24	71°24.852'N	157°29.922'W	28	1000	SCM
29	09/04 13:28	26	71°14.664'N	157°09.720'W	0	1000	
30	09/04 13:28	26	71°14.664'N	157°09.720'W	18	750	SCM
31	09/07 06:07	36	71°52.542'N	156°02.262'W	0	970	
32	09/07 06:07	36	71°52.542'N	156°02.262'W	40	1000	SCM
33	09/07 10:42	38	71°47.958'N	155°23.148'W	0	1000	
34	09/07 13:32	39	71°44.136'N	155°12.666'W	0	1000	St.BCC
35	09/07 13:32	39	71°44.136'N	155°12.666'W	22	1000	SCM, St.BCC
36	09/07 17:29	41	71°35.832'N	154°47.820'W	0	1000	
37	09/07 17:29	41	71°35.832'N	154°47.820'W	18	1000	SCM
38	09/07 23:18	42	71°34.008'N	152°00.192'W	0	970	
39	09/07 23:18	42	71°34.008'N	152°00.192'W	37	1000	SCM
40	09/08 08:36	44	71°57.510'N	154°00.132'W	0	1000	

41	09/08 08:36	44	71°57.510'N	154°00.132'W	28	1000	SCM
42	09/08 19:36	45	72°29.484'N	155°21.126'W	0	2000	St.NBC
43	09/08 19:36	45	72°29.484'N	155°21.126'W	55	2000	SCM, St.NBC
44	09/09 05:53	46	72°16.788'N	156°00.030'W	0	2000	
45	09/09 05:53	46	72°16.788'N	156°00.030'W	24	2000	SCM
46	09/09 13:30	48	72°47.310'N	158°00.456'W	0	2000	
47	09/09 13:30	48	72°47.310'N	158°00.456'W	28	2000	SCM
48	09/10 02:55	49	73°18.528'N	160°51.798'W	0	1950	St.NHC
49	09/10 02:55	49	73°18.528'N	160°51.798'W	83	1970	SCM, St.NHC
50	09/10 21:50	52	72°28.566'N	159°00.102'W	0	2000	Ice Margin
51	09/10 21:50	52	72°28.566'N	159°00.102'W	22	2000	SCM, Ice Margin
52	09/11 20:26	53	72°27.960'N	158°48.786'W	0	2000	Ice Margin
53	09/11 20:26	53	72°27.960'N	158°48.786'W	18	2000	SCM, Ice Margin
54	09/13 04:41	54	72°49.836'N	158°48.834'W	0	1000	
55	09/13 04:41	54	72°49.836'N	158°48.834'W	38	1000	SCM
56	09/13 07:33	55	72°59.820'N	158°29.910'W	0	1950	
57	09/13 07:33	55	72°59.820'N	158°29.910'W	35	2000	SCM
58	09/13 10:35	56	73°09.978'N	158°00.570'W	0	2000	
59	09/13 10:35	56	73°09.978'N	158°00.570'W	23	2000	SCM
60	09/13 17:57	58	73°29.982'N	157°00.504'W	0	2000	
61	09/13 17:57	58	73°29.982'N	157°00.504'W	57	2000	SCM
62	09/14 04:37	60	73°51.558'N	156°34.836'W	0	2000	
63	09/14 04:37	60	73°51.558'N	156°34.836'W	65	2000	SCM
64	09/14 14:34	62	73°37.314'N	158°28.026'W	0	2000	
65	09/14 14:34	62	73°37.314'N	158°28.026'W	34	2000	SCM
66	09/14 19:38	63	73°30.438'N	159°17.484'W	0	2000	
67	09/14 19:38	63	73°30.438'N	159°17.484'W	40	2000	SCM
68	09/15 00:16	64	73°23.226'N	160°12.240'W	0	2000	
69	09/15 00:16	64	73°23.226'N	160°12.240'W	86	2000	SCM
70	09/15 03:43	65	73°13.854'N	161°18.786'W	0	2000	
71	09/15 03:43	65	73°13.854'N	161°18.786'W	56	2000	SCM
72	09/15 07:15	66	73°09.528'N	162°18.978'W	0	2000	
73	09/15 07:15	66	73°09.528'N	162°18.978'W	53	2000	SCM
74	09/15 21:40	67	73°18.312'N	160°48.132'W	0	2000	
75	09/15 21:40	67	73°18.312'N	160°48.132'W	37	2000	SCM
76	09/17 23:19	72	71°59.430'N	165°52.770'W	0	1000	
77	09/17 23:19	72	71°59.430'N	165°52.770'W	27	1000	SCM
78	09/19 05:03	73	72°31.158'N	167°18.684'W	0	2000	
79	09/19 05:03	73	72°31.158'N	167°18.684'W	33	1000	SCM
80	09/19 17:23	76	70°59.880'N	168°44.940'W	0	1000	

81	09/19 17:23	76	70°59.880'N	168°44.940'W	28	750	SCM
82	09/20 00:54	78	69°59.886'N	168°44.796'W	0	1000	
83	09/20 00:54	78	69°59.886'N	168°44.796'W	32	500	SCM
84	09/20 07:23	80	69°00.042'N	168°44.880'W	0	1000	
85	09/20 07:23	80	69°00.042'N	168°44.880'W	40	500	SCM
86	09/20 18:49	84	68°00.462'N	168°45.084'W	0	1000	
87	09/20 18:49	84	68°00.462'N	168°45.084'W	13	800	SCM
88	09/20 23:59	86	68°00.072'N	167°59.712'W	0	1000	
89	09/20 23:59	86	68°00.072'N	167°59.712'W	41	1000	SCM
90	09/21 04:18	88	68°18.114'N	167°03.264'W	0	800	
91	09/21 04:18	88	68°18.114'N	167°03.264'W	14	750	SCM
92	09/21 18:25	93	67°11.808'N	168°53.262'W	0	500	
93	09/21 18:25	93	67°11.808'N	168°53.262'W	26	500	SCM
94	09/21 23:47	94	66°16.248'N	168°53.544'W	0	500	St.BS16t
95	09/21 23:47	94	66°16.248'N	168°53.544'W	13	500	SCM, St.BS16t
96	09/22 06:28	96	65°39.138'N	168°14.910'W	0	900	
97	09/22 06:28	96	65°39.138'N	168°14.910'W	8	800	SCM
98	09/22 18:25	99	65°03.144'N	169°37.104'W	0	600	St.NB16t
99	09/22 18:25	99	65°03.144'N	169°37.104'W	24	500	SCM, St.NB16t

4.16. Sediment Trap

4.16.1. Canada Basin

(1) Personnel

Naomi Harada (PI, JAMSTEC)*, Jonaotaro Onodera (JAMSTEC), Yuichiro Tanaka (AIST) *, Motoyo Itoh (JAMSTEC)*, Shigeto Nishino (JAMSTEC), Katsunori Kimoto (JAMSTEC)*, Kazumasa Oguri (JAMSTEC)*, Takashi Kikuchi (JAMSTEC)*, Eiji Watanabe (JAMSTEC)*, Kohei Mizobata (TUMSAT)*, Takuhei Shiozaki (JAMSTEC), Koji Sugie (JAMSTEC), Yoshiyuki Abe (Hokkaido Univ.), Takeshi Tamura (NIPR)*, Amane Fujiwara (JAMSTEC), Fumihiro Itoh (JAMSTEC)*, Keisuke Matsumoto (MWJ technical staff leader for mooring operation) , Rei Itoh (MWJ), Keisuke Takeda (MWJ), Okumura Shinya (NME technical staff for bathymetry survey), Yutaro Murakami (NME for bathymetry survey) , Kazuho Yoshida (NME for bathymetry survey)

*: not onboard

(2) Objectives

It has been considered that recent sea-ice decrease in the western Arctic Ocean has significant impact to climate, hydrography, and biogeochemical cycle conditions. The input of Pacific water with large amount of heat, shelf materials, and Pacific species to the southern Canada Basin is important key to understand changing physical oceanographic condition, biogeochemical cycles, and lower trophic marine ecosystems. This sediment trap mooring experiments have three major objectives. The obtained data may be partially studied with data from other interannual mooring stations in the Barrow Canyon (BCC, BCE, BCW), the Bering Strait (BS-16t), and the western Chukchi Borderland (KAMS-1 and -2 operated by KOPRI).

- Monitoring of pH condition in subsurface waters

It is considered that ocean acidification may influence to marine ecosystems. The Arctic Ocean is one of the most important area for sentinel of ocean acidification. The acidification of Arctic Ocean is essentially explained by freshening of salinity at sea surface and increasing pCO2 in subsurface layer. The one of two pH sensor is prepared for the upper most part of mooring with CT sensor (~50 m depth). Another pH sensor is prepared for oxygen minimum layer with dissolved oxygen (DO) sensor. In the deploying mooring, one pCO2 sensor is prepared for the monitoring of oxygen minimum layer, which will be deployed with pH and DO sensors. To qualitatively estimate calcareous shell density, some specimens of calcareous plankton shells (e.g, Pteropods, foraminifer) in sediment trap samples will be applied for micro-X lay computed tomography (MXCT) developed in JAMSTEC.

- Investigation of shelf-basin interaction

Large amount of shelf material transportation to southern area of Northwind Abyssal Plain (NAP) was suggested by the previous sediment trap experiment and model study at Station NAP10t and NAP11t (75°N 162°W). The model experiments for physical oceanographic circulation and lower trophic marine ecosystem suggested that the oceanic eddies developed off the Barrow Canyon and the westward travel of those eddies including shelf materials was contributed to temporal increase of high settling particle flux at Station NAP (Watanabe et al. 2014). In order to monitor the shelf-basin interaction in upper stream of sea-surface flow around Station NAP, annual deployment of bottom-tethered mooring with sediment trap and physical oceanographic sensors were planned at two stations along the pass way of oceanic eddies in southwestern Canada Basin and the eastern Chukchi Borderland.

- Study on diversity of lower trophic communities

Our research group is developing new technique for extracting e-DNA from formalin-fixed samples. By applying this technique in addition to microscopic observation, further understanding is expected on diversity of lower trophic communities in studied region. This technique was successfully tested using NAP10t sediment trap samples. This method will be applied for new sediment trap samples recovered in this cruise.

(3) Parameters

Downward flux and the composition of settling particles, meso-zooplanktons, current, water temperature, salinity, dissolved oxygen, pH, chlorophyll-a, turbidity, underwater camera (recovering moorings), subsurface pCO2 (one deploying mooring),

(4) Instruments and methods

The recovered and deployed equipment are tabulated in the mooring operation log (Tables 4.16.1-1, -2, -3, and -4). Our sediment trap moorings for recovery were locating in the north of Barrow Canyon (NBC) and the northern edge of Hannna Canyon (NHC) (Figures 4.16.1-1, and -2). The deployment of sediment trap moorings were planned at NBC and NAP region. Because of the export control, all mooring equipment for deployment and recovery was embarked and disembarked at Hachinohe, northeastern Japan. The response test of acoustic releasers in deep water was conducted in transit from the Hachinohe to the Bering Strait. The examining releasers for response test were attached to CTD frame, and the frame with releasers was sent to 2000 m depth on 25 August 2016 (UTC).

Sample cups of sediment trap were filled with filtered sea water obtained from 1000m depth in the southern Canada Basin. This sea water contains about 4% formalin, and the pH was neutralized to ~8.1 by sodium tetraborate. Hydrographic sensors except for MMP, pH, and pCO2 sensors were configured by MWJ mooring technicians. After a short safety meeting on deck, mooring operation started. The deck work for mooring operation was conducted by crew and mooring technicians of Marin Works Japan. The assembly check of deployment mooring was performed by Shigeto Nishino. The deploying method was a top buoy first and sinker last. After the deployment, acoustic ranging was conducted from ship to deployed releaser to determine the mooring location. The water depth of deployment position is the SeaBeam depth at determined mooring position. The response of enable command to transponder at upper part of moorings was tested. Because the mooring depth of Nichiyu Model-L releasers at Station NBC-15t was deeper than 2000m, ship's transducer cannot be applied. Portable deck unit and transducer for Nichiyu Model-L releasers was set on the after main deck.

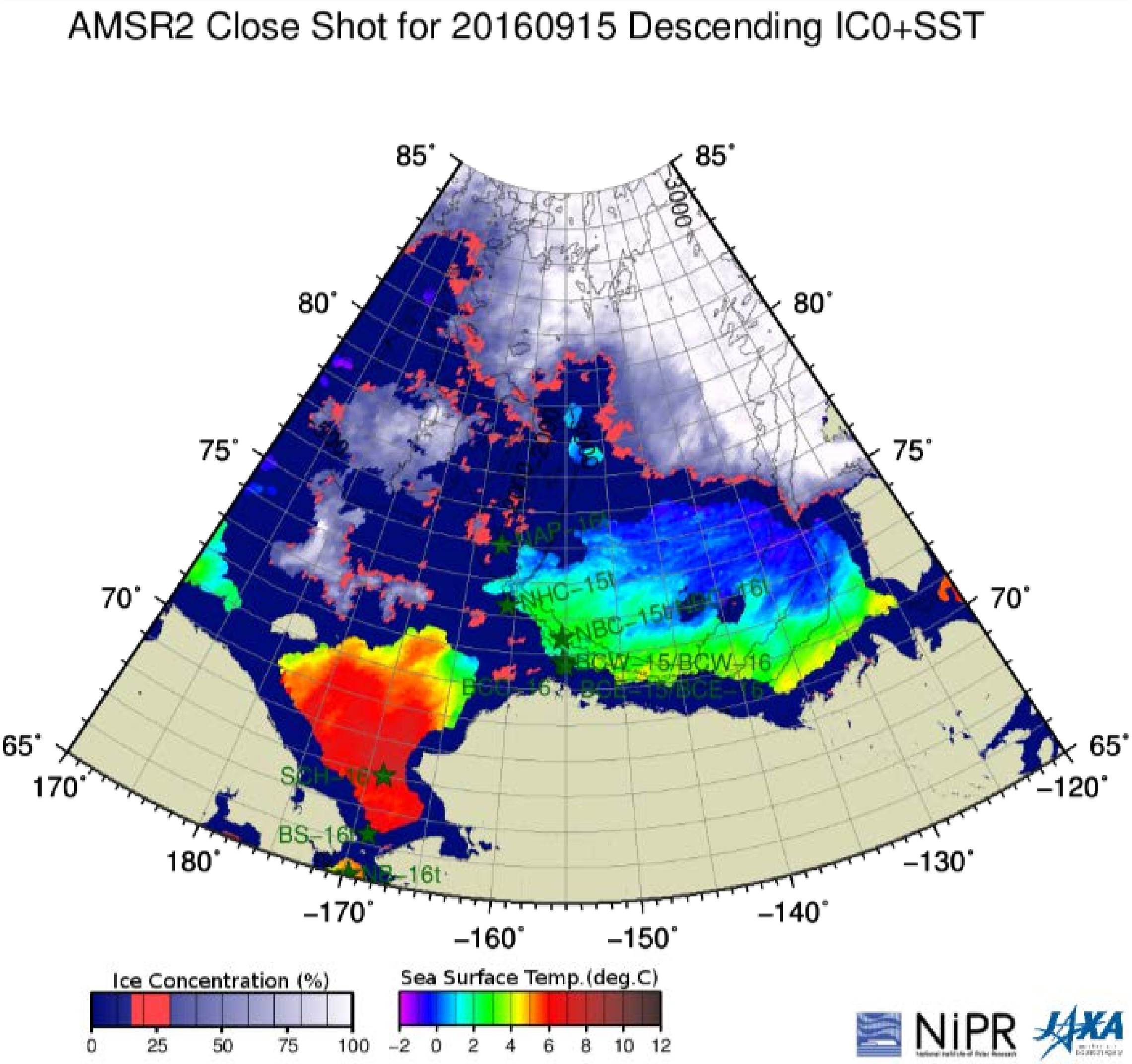


Figure 4.16.1-1: The map with sea ice distribution, sea surface temperature, and mooring stations in this cruise at 15 September 2016. Sediment trap stations in the Canada Basin is NAP, NHC, and NBC.

(5) Mooring operation log and mooring position

Table 4.16.1-1: Log on the recovery of mooring NBC-15t, recorded by A. Fujiwara.

Send time of release (UTC)	9 Sep. 2016 01:14
Send position of release (GPS)	72°28.80'N 155°23.57'W
Depth at release position	2057.0 m

Time of instruments out of water

Frame#	Type	Model	s/no.	time (UTC)
-	Float	Benthos 17"		02:08
	CT	SBE37-IDO	9417	
1	pH	SP-11	346258010	02:08
	Chl.	MFL50W-USB	20	
-	Float	Benthos 17"		02:09
-	Transponder	XT6001-13	60644	02:09
2	CT	SBE37-SM	13677	02:14
	CT	SBE37-SM	13678	
3	pH	SP-11	346259009	02:19
	DO	ARO-USB	131	
4	ADCP	WHS-300	13838	02:22
	CT	A7CT	283	
-	Float	Benthos 17"		02:27
5	CT	SBE37-SM	7668	02:27
6	Trap	SMD26S-6000	98063	02:35
	Camera	(Handmade)	13G1	
-	Float	Benthos 17"		03:02
7	Trap	SMD26S-6000	98057	03:26
-	Float	Benthos 17"		03:51
8	Releaser	Model-L	4441	03:52
	Releaser	Model-L	4447	

End time of recovery (UTC)	9 Sep. 2016 03:55
Position of recovery (GPS)	72°28.3173'N 155°22.9688'W
Depth of recovery position	2003 m

Table 4.16.1-2: Log on the recovery of mooring NHC-15t, recorded by A. Fujiwara.

Send time of release (UTC)	15 Sep. 2015 19:02
Send position of release (GPS)	73°18.0832'N 160°45.4080'W
Depth of release position	443.0 m

Time of instruments out of water

Frame#	Type	Model	s/no.	time (UTC)

-	Transponder	XT6001-13	60645	20:14
-	Float	Benthos 17”		20:14
	CT	A7CT2-USB	274	
1	pH	SP-11	346258008	20:14
	Chl.	MFL50W-USB	19	
-	Float	Benthos 17”		20:21
	CT	SBE37-SM	6934	
2	DO	ARO-USB	130	20:21
	pH	SP-11	346259004	
3	ADCP	WHS-300	13836	20:28
	Float	Benthos 17”		20:29
4	Trap	SMD26S-6000	98042	20:33
	Camera	(Handmade)	13G1	
-	Float	Benthos 17”		20:45
5	Releaser	Model-L	4391	20:45
	Releaser	Model-LGC	LGC0021	

End time of recovery (UTC)	15 Sep. 2016 20:47
Position of recovery	73°17.97’N 160°51.38’W
Depth of recovery position	394.0 m

Table 4.16.1-3: Log on the deployment of mooring NBC-16t, recorded by A. Fujiwara.

Start time of deploy (UTC)	17 Sep. 2015 00:46
Start position of deploy (GPS)	72°28.45’N 155°18.32’W
Depth of start position	1995 m

Time in water of instruments and anchor

Frame#	Type	Model	s/no.	time (UTC)
-	Float	34” Alminum	Float-Al-101	00:50
	Transponder	EdgeTech CAT	36221	
1	CT	A7CT2-USB	0274	00:50
	Chl	MFL50W-USB	19	
-	CTD, ADCP	MMP	ML12870-02	00:50
2	ADCP	WHS-300	24023	01:07
-	Float	Benthos 17”		01:08
3	CT	SBE37	8889	01:08
	DO	ARO-USB	0136	
4	CT	SBE37	8888	01:13
5	Trap	SMD26S-6000	98052	01:20

	CT	A7CT-USB	0373	
-	Float	Benthos 17”		01:56
6	Trap	SMD26S-6000	98083	02:14
-	Float	Benthos 17”		02:45
7	Releaser	Benthos 865A	537	02:45
	Releaser	Model-LGC	0066	
-	Anchor	1000kg in air		02:53

Position of anchor release	72°28.32’N 155°24.88’W
Depth of anchor release position	2002 m
Releaser position	72°28.3208’N 155°24.5086’W
Water depth of mooring position	1995 m (SeaBeam depth)
Estimated top depth	42 m

Table 4.16.1-4: Log on the deployment of mooring NHC-16t, recorded by A. Fujiwara.

Start time of deploy (UTC)	16 Sep. 2015 00:13
Start position of deploy (GPS)	73°18.81’N 160°40.14’W
Depth of start position	580 m

Time in water of instruments and anchor

Frame#	Type	Model	s/no.	time (UTC)
-	Transponder	XT6001-17”	55947	00:15
-	Float	Benthos 17”		00:15
	CT	A7CT2-USB	0310	
1	CT	MFL50W-USB	0041	00:15
	pH	SPS-14	390262005	
-	Float	Benthos 17”		00:15
	CT	SBE37	8860	
	pH	SPS-14	390262006	
2	DO	ARO-USB	0135	00:20
	pCO2	Aanderaa	70	
3	CT	SBE37	8858	00:21
4	ADCP	WHS-300	17021	00:27
-	Float	Benthos 17”		00:32
5	Trap	SMD26S-6000	98058	00:42
	CT	A7CT-USB	0626	
-	Float	Benthos 17”		00:57
7	Releaser	Benthos 865A	1078	00:58
	Releaser	Model-LGC	0067	

-	Anchor	1000kg in air	01:30

Position of anchor release	73°18.14'N 160°47.00'W
Depth of anchor release position	424.4 m
Releaser position	73°18.1658'N 160°46.9514'W
Water depth of mooring position	425 m (SeaBeam depth)
Estimated top depth	47 m

(6) Preliminary results

- NBC15t recovery

The recovery operation of NBC15t was conducted on 9th September, which was one day earlier than the closing date of final particle sampling by sediment trap. Therefore, sediment trap was recovered on deck with much of sea water in the trap cone. The mooring line under deeper sediment trap was partially getting tangled in the recovery operation (Figs. 4.16.1-4a, and -4b). This trouble probably occurred by different surfacing speed of mooring equipment between glass buoy sets in the released mooring. Unclosed sediment trap might be the cause of unexpected slow surfacing speed. Severe biofouling was not observed. Among deployed hydrographic sensors, data of CT(D), ADCP, multi-wave length excitation fluorescence photometer (Multi-Exciter) was successfully obtained whereas DO data was not recorded in the mounted memory. The cause of DO sensor trouble will be investigated after the cruise. The data of pH and underwater camera are retrieved on shore. The depth data suggested that the top of mooring usually located at 53 m depth. The top depth was about 9 m shallower than the planned depth. The sediment trap samples in summer 2016 were not obtained because of particle clogging at the bottom of trap cone (Figs. 4.16.1-4c, and -5).

- NHC15t recovery

Another recovery of sediment trap mooring NHC15t were successfully done on 15 September. Biofouling was slightly observed on turn table of sediment trap. The decrease of zinc anode was severer than that of recovered NBC15t equipment. Among deployed hydrographic sensors, data of CT(D), ADCP, Multi-Exciter, and DO was successfully obtained. The data of pH and underwater camera are retrieved on shore. The depth data suggested that the top of mooring usually located at about 49 m, which was 3 m shallower than the planned depth. The sediment trap samples were successfully obtained throughout the planned sampling schedule (Figure 4.16.1-5).

- NHC16t deployment

At first, the response test of applying releasers at 2000 m depth in North Pacific Ocean was successfully done. The planned station NAP16t had been covered by sea ice throughout the cruise. Instead of NAP16t, NHC site was chosen and mooring design for NAP16t was fixed for the deployment at NHC site in this cruise (Figs. 4.16.1-2b, -6, and

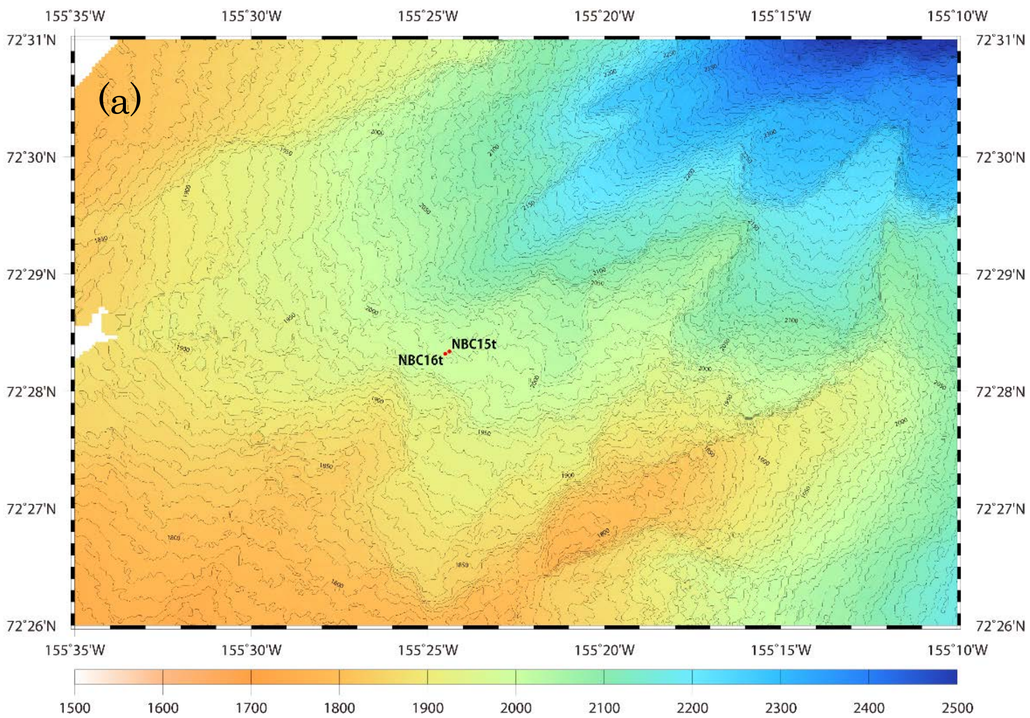
-7). The deployment operation was safely and successfully performed. The response by all transponders (two releasers and one transponder) to call from ship was confirmed. The water depth of deployed position is 425 m as planned. The estimated top depth is 47 m.

- NBC16t deployment

The deployment of NBC16t was conducted 8 days later from NBC15t recovery because the re-use of recovered sensors from NHC15t was planned (Figs. 4.16.1-6, and -8). The deployment operation was safely and successfully performed. All transponders (two releasers and one transponder at top of mooring) were confirmed to response to call from the ship. According to SeaBeam depth at calculated mooring position, the water depth at Station NBC16t is 1995m, which is 5 m shallower than the planned depth. The estimated top depth is 42 m.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>



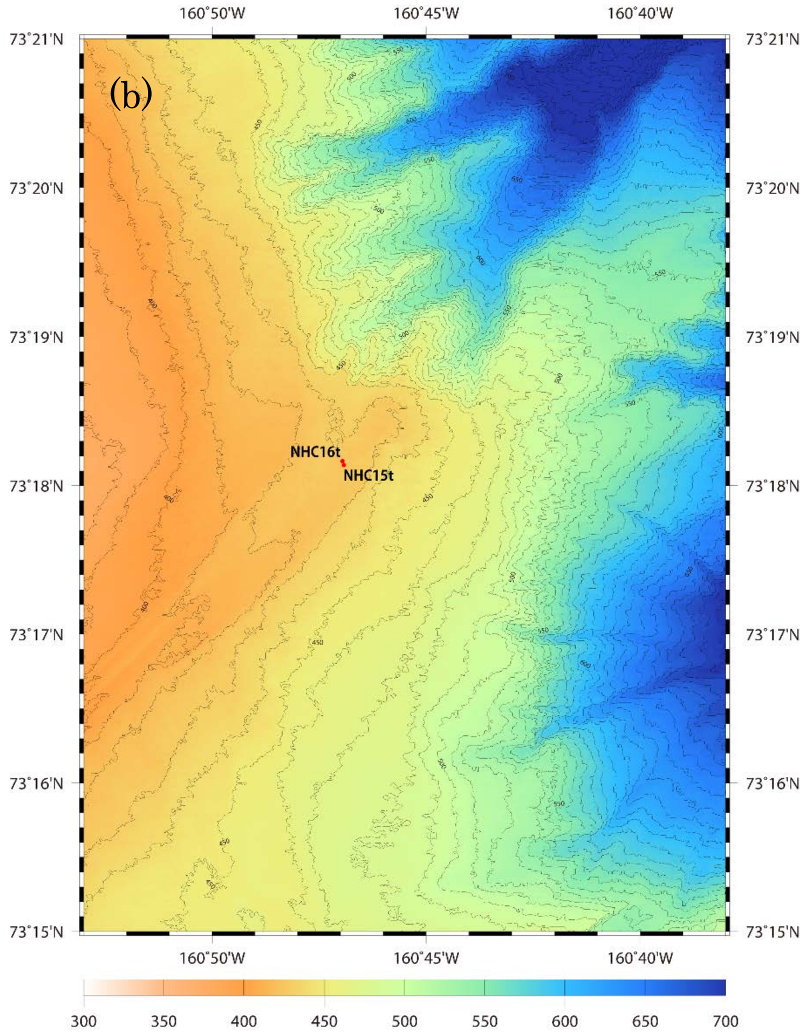


Figure 4.16.1-2: The detail bathymetry map around the mooring positions.
(a) NBC, and
(b) NHC area

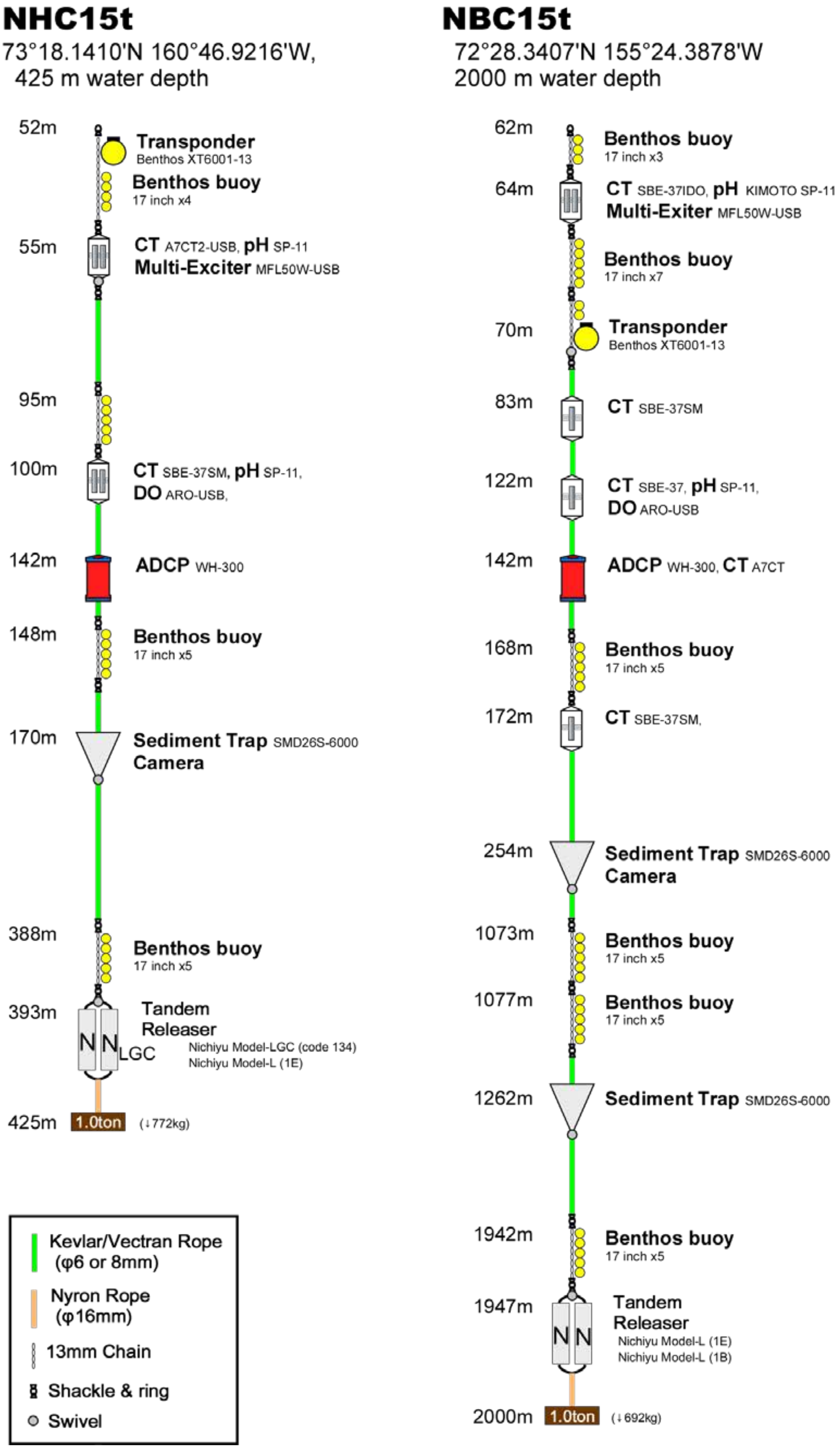


Figure 4.16.1-3: The outlined design of sediment trap mooring for recovery.

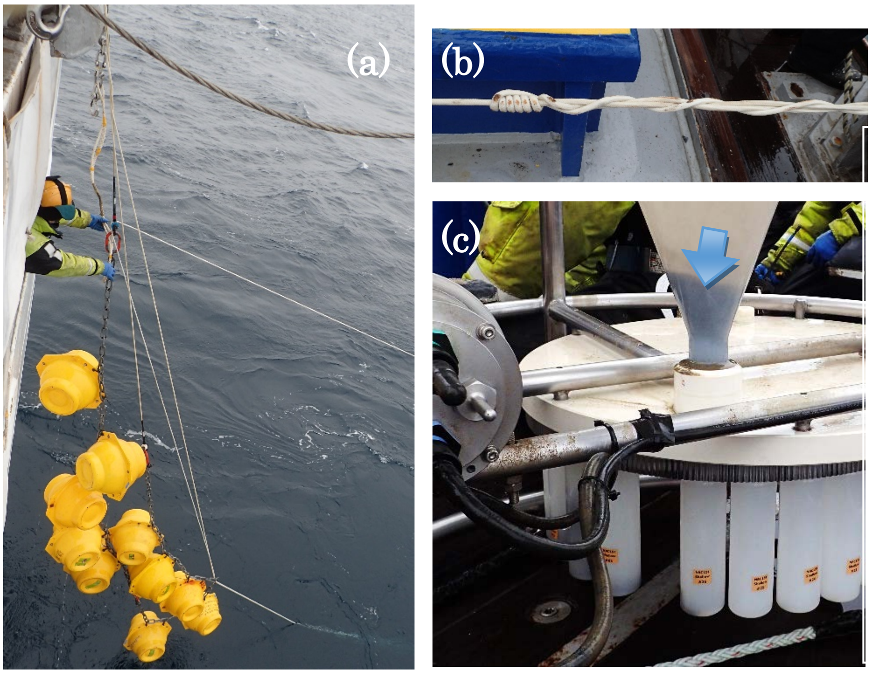


Figure 4.16.1-4: (a), (b) tangled mooring line of NBC15t, and (c) NBC15t shallow trap on deck. The blue arrow shows particle clogging at the bottom of trap cone.

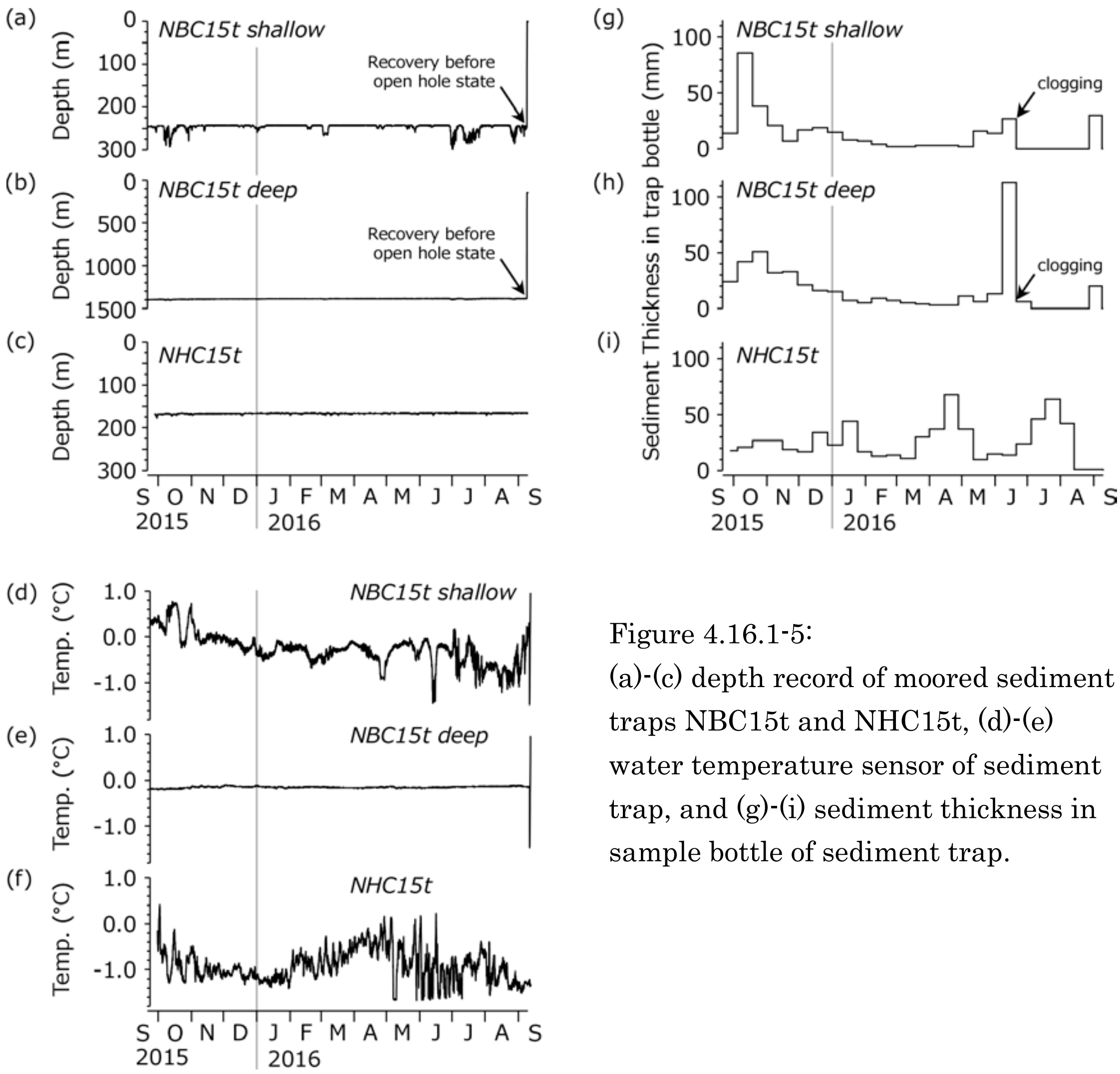


Figure 4.16.1-5:
(a)-(c) depth record of moored sediment traps NBC15t and NHC15t, (d)-(e) water temperature sensor of sediment trap, and (g)-(i) sediment thickness in sample bottle of sediment trap.

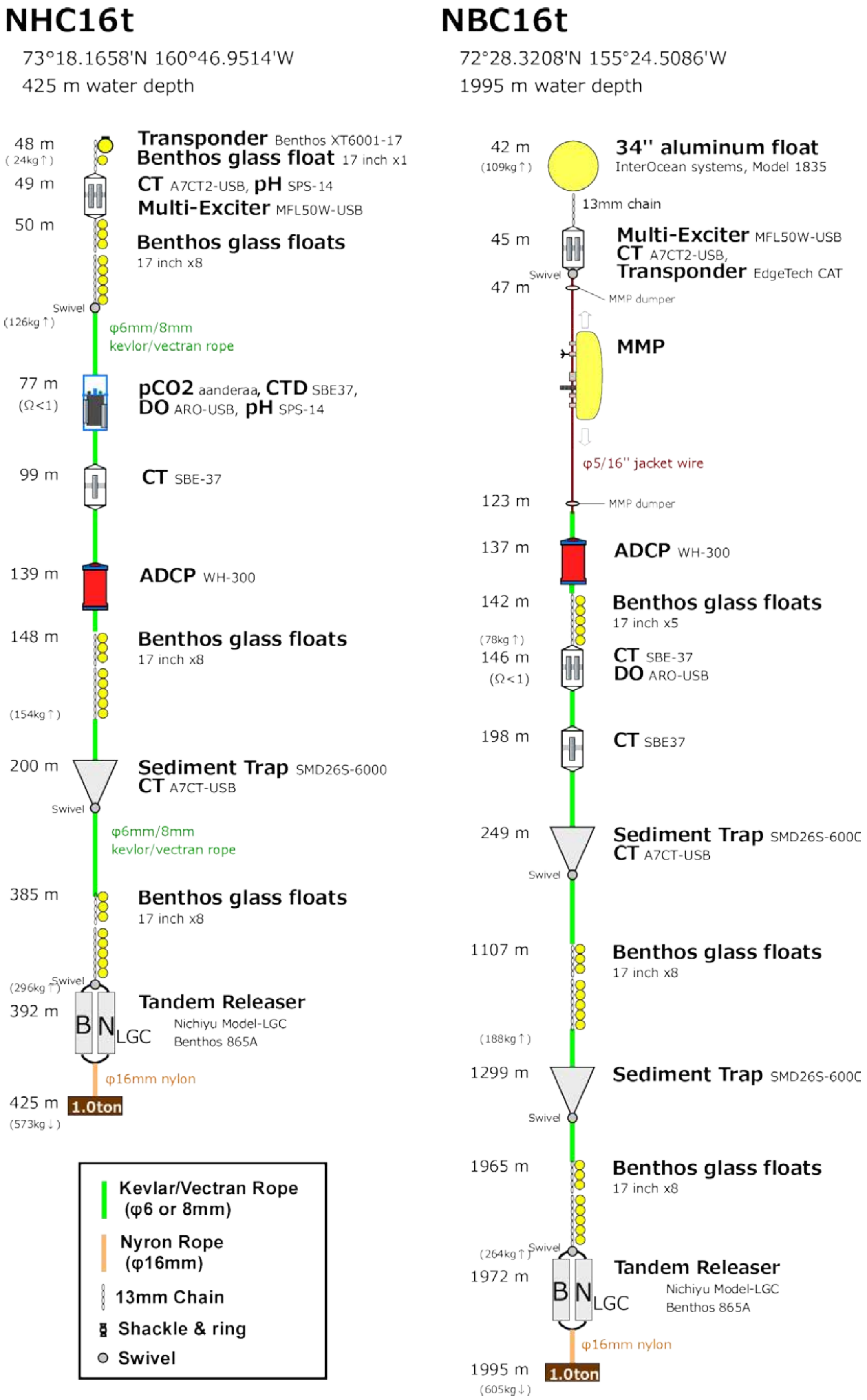


Figure 4.16.1-6. The outlined design of sediment trap mooring for deployment in Canada Basin.

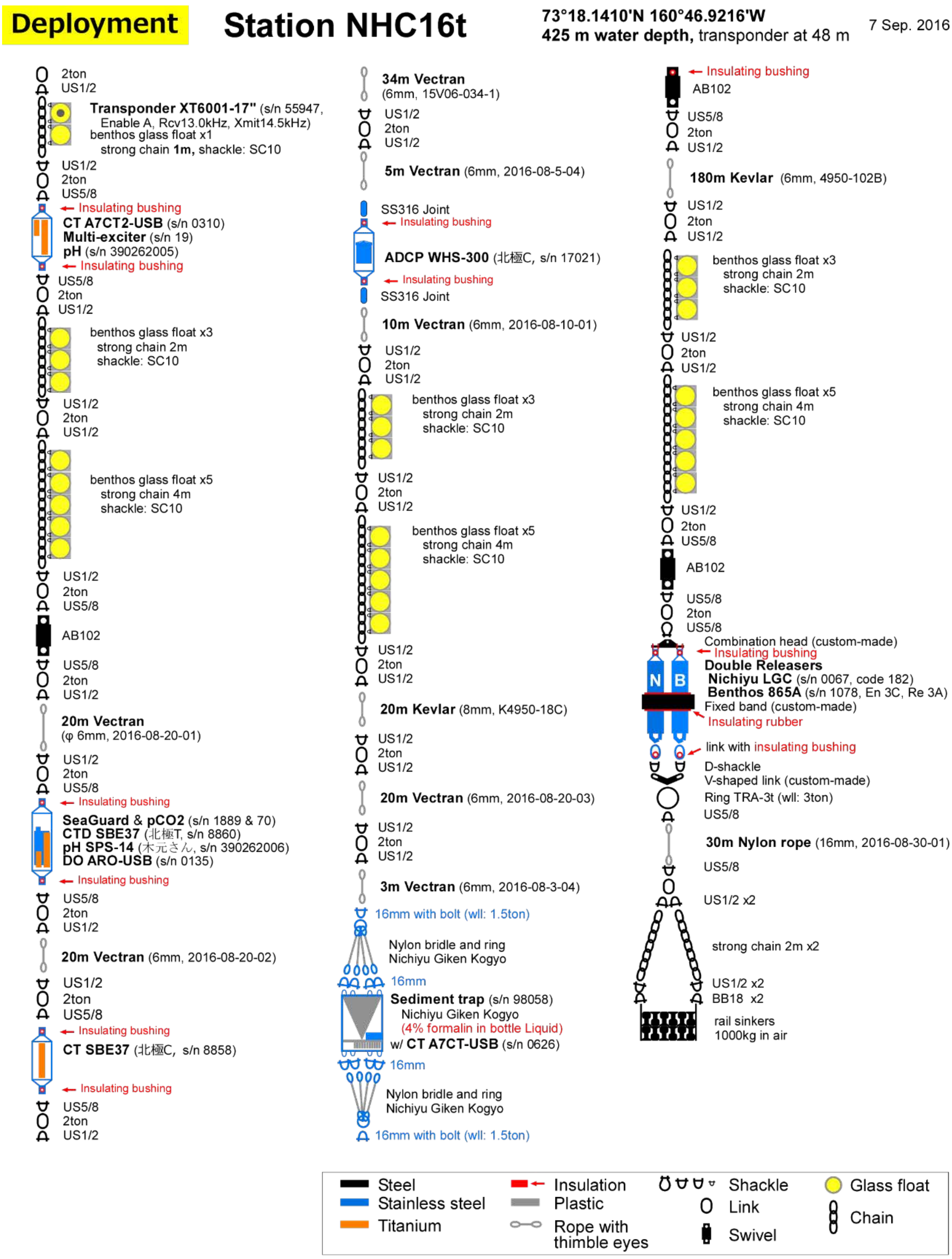


Figure 4.16.1-7. The design of deployed sediment trap mooring NHC16t.

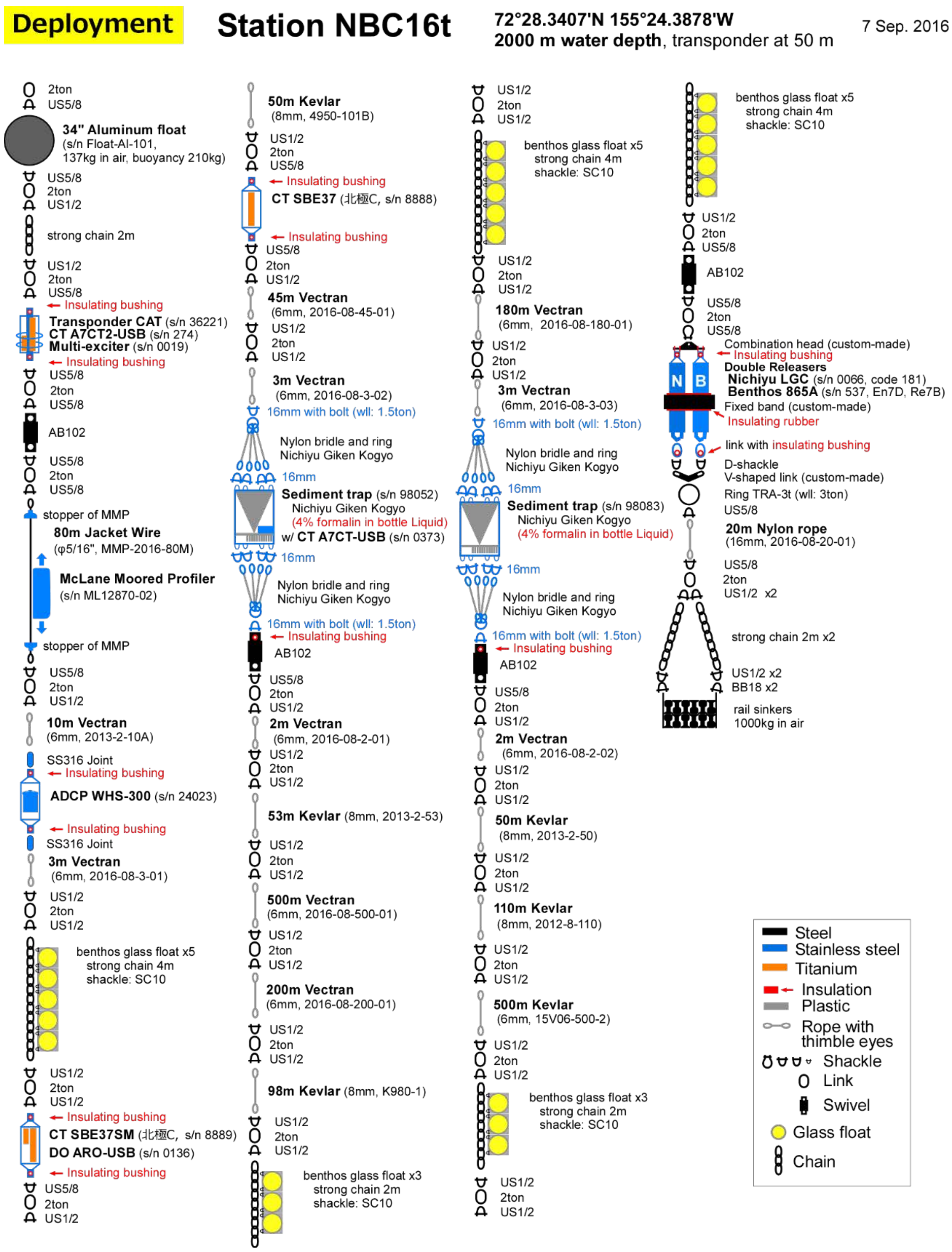


Figure 4.16.1-8. The design of deployed sediment trap mooring NBC16t.

4.16.2. Bering Strait

(1) Personnel:

Toru Hirawake (Hokkaido Univ., -PI)
Makoto Sampei (Hokkaido Univ.)
Shigeto Nishino (JAMSTEC)

(2) Objectives

As a part of an ArCS subproject (marine ecosystem group in the theme 6), two moorings equipped with time-sequential sediment traps and other oceanographic sensors were deployed in waters near the Bering Strait. Those mooring would remain in the water and be retrieved in July 2017. After retrievement, sinking particle samples and time-sequential data sets from the sensors will be analyzed to estimate vertical fluxes of particles in the highly productive Anadyr water and around.

(3) Parameters

Downward flux of particles, current profile, water temperature, chlorophyll-a, turbidity

(4) Instruments and methods

A modified McLane Mark78 sediment trap (Cylindrical shape, 16 cm diameter, trap aspect ratio (AR) =6.4: see Figure 4-16-2-1) was set at 35 or 40 m on each mooring line. Sampling schedule for sediment traps are in Table 4-16-2-1. WH ADCP and a chlorophyll-a/turbidity sensor were set at 48 or 53 m on each mooring line. Detail information on mooring sites and mooring instruments are shown in Table 4-16-2-2. Mooring diagram is shown in Figure 4-16-2-2.

Figure 4.16-2-1. Picture of the sediment trap.

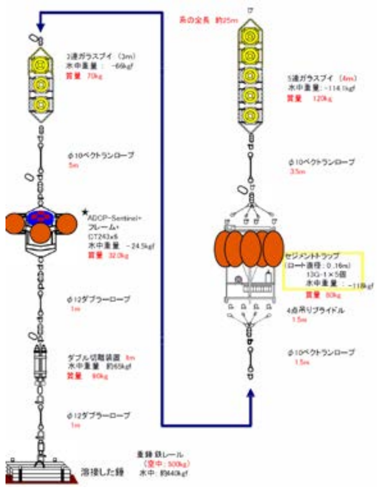


Figure 4-16-2-2. Mooring diagram.

Table 4.16-2-1 Time schedule for sediment trap sampling

Sumple cup No.	Open	Close	Collection days
1	1 Sept., 2016	15 Sept., 2016	15
2	16 Sept., 2016	30 Sept., 2016	15
3	1 Oct., 2016	31 Oct., 2016	31
4	1 Nov., 2016	30 Nov., 2016	30
5	1 Dec., 2016	31 Dec., 2016	31
6	1 Jan., 2017	31 Jan., 2017	31
7	1 Feb., 2017	28 Feb., 2017	28
8	1 Mar., 2017	31 Mar., 2017	31
9	1 Apr., 2017	30 Apr., 2017	30
10	1 May, 2017	31 May, 2017	31
11	1 Jun., 2017	15 Jun., 2017	15
12	16 Jun., 2017	30 Jun., 2017	15
13	1 Jul., 2017	6 Jul., 2017	6
Total (days)			309

(5) Station list

Table 4.16-2-2 Detail information of moorings

Station	Latitude			Longitude			Depth of top float (m)	Water depth (m)	Instrument	Instrument depth (m)	Instrument info
NB-16t	65	03.665	N	169	38.331	W	26	51			
									Glass floats	26	Benthos
									Sediment trap	35	MacLane Mark78
									Glass floats	40	Benthos
									ADCP	48	WH sentinel 300 kHz
									chlorophyll/turbidity sensor	48	JFEADVANTEC INFINITY-CLW ACLW2-USB
									Twin releases	50	NICHIYU Model L (code:166, 167)
									Anchor	51	500kg
BS-16t	66	16.046	N	168	54.016	W	31	56			
									Glass floats	31	Benthos
									Sediment trap	40	MacLane Mark78
									Glass floats	45	Benthos
									ADCP	53	WH sentinel 600 kHz
									chlorophyll/turbidity sensor	53	JFEADVANTEC INFINITY-CLW ACLW2-USB
									Twin releases	55	NICHIYU Model L (code:168, 169)
									Anchor	56	500kg

(6) Preliminary results

NOT AVAILABLE

4.17. Sea bottom sediment

(1) Personnel:

Toru Hirawake (Hokkaido Univ., -PI),
Yutaka Watanuki (Hokkaido Univ.)
Makoto Sampei (Hokkaido Univ.)
Bungo Nishizawa (Hokkaido Univ.)
Hisatomo Waga (Hokkaido Univ.)

(2) Objectives

As a part of an ArCS subproject (marine ecosystem group in the theme 6), sea bottom sediments were sampled by Smith and McIntyre grab sampler at 23 cites in Bering Sea and Chukchi Sea (Table 4-17-1). Sediment samples are processed and analyzed to understand particulate organic carbon (POC) contents, chlorophyll contents, persistent organic pollutants (POPs) contents, biomass and species composition of Macro-benthos in the sediment. The data set contributes to quantify "positive impact" (i.e., food supply) and "negative impact" (i.e., bioaccumulation of POPs) to the marine food web.

(3) Parameters

POC contents, chlorophyll contents, POPs contents, Biomass and species composition of Macro-benthos

(4) Instruments and methods

Smith and McIntyre grab sampler (Figure 4-17-1) was deployed to sample sea bottom sediment in the Bering Sea and Chukchi Sea (See table 4-17-1). The sampler was going down by 1 m sec^{-1} to 5 m above the sea bottom. Then, wire speed dropped down to ~0.2 m sec^{-1} until the sampler hit the bottom. The sampler stopped at the bottom for a few seconds and began to be up by ~0.2 m sec^{-1} for several seconds. Then, the sampler picked speed up to 1 m sec^{-1} until the surface.

Duplicated 1 cm^3, triplicated ~2 cm^3 and a ~50 cm^3 of sediment subsamples were taken from the sediment surface (Figure 4-17-2) for chlorophyll analysis, POC analysis and POPs analysis, respectively. Subsamples are kept in 6mL of DMF for chlorophyll analysis, and without any chemicals for others under -20°C temperature until analyses in the laboratory. Half amount of whole sediment samples was sieved with 1 mm mesh and benthos was collected from the mesh. Those benthos is preserved in 10% (v/v) formalin solution under room temperature for later biomass and species composition analyses.

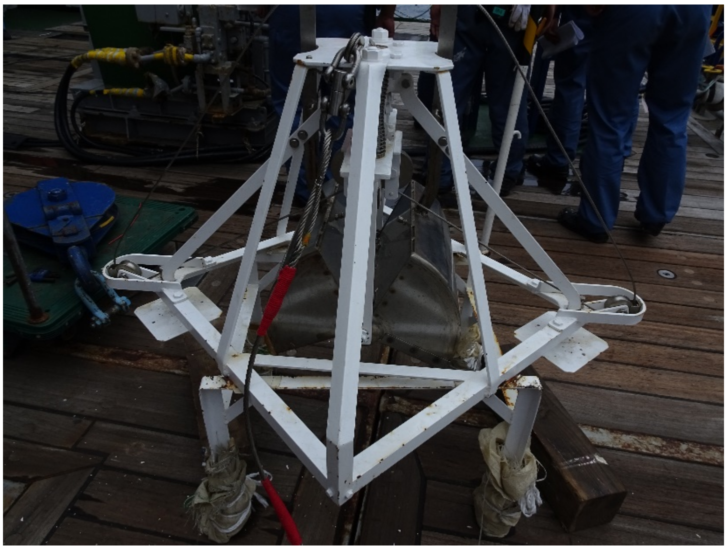


Figure 4-17-1. Picture of the Smith and McIntyre grab sampler.

Figure 4-17-2. Sediment surface.

(5) Station list

Table 4-17-1 Detail information of sampling

Station No.	Latitude			Longitude			Depth	Date Collected			POC contents	Cholophyll contents	POPs contents	Biomass/ species composition
	Deg.	Min.	N/S	Deg.	Min.	E/W	[m]	YYYY	MM	DD				
Stn.1	63	06.10	N	173	58.74	W	75	2016	08	30	○	○	○	○
Stn.2	63	51.72	N	172	17.76	W	54	2016	08	30	○	○	○	○
Stn.3	64	42.73	N	170	21.04	W	47	2016	08	30	○	○	○	○
Stn.4	65	03.99	N	169	38.54	W	51	2016	08	31	○	○	○	○
Stn.5	65	16.66	N	169	03.75	W	53	2016	08	31	○	○	○	○
Stn.6	65	39.18	N	168	42.64	W	49	2016	08	31	○	○	○	○
Stn.7	66	15.89	N	168	53.84	W	55	2016	09	01	○	○	○	○
Stn.8	67	12.15	N	168	54.74	W	48	2016	09	01	○	○	○	○
Stn.9	67	34.33	N	168	49.78	W	50	2016	09	01	○	○	○	○
Stn.10	68	01.99	N	168	50.50	W	58	2016	09	01	○	○	○	○
Stn.19	70	44.89	N	162	59.78	W	44	2016	09	03		○	○	○
Stn.72	71	59.22	N	165	52.55	W	45	2016	09	18		○	○	○
Stn.76	70	59.68	N	168	44.39	W	44	2016	09	19		○	○	○
Stn.77	70	29.48	N	168	44.66	W	39	2016	09	19		○	○	○
Stn.80	69	0.17	N	168	44.64	W	53	2016	09	20		○	○	○
Stn.92	67	34.39	N	168	50.14	W	50	2016	09	21		○	○	○
Stn.93	67	11.84	N	168	53.58	W	49	2016	09	21		○	○	○
Stn.94	66	16.31	N	168	50.50	W	57	2016	09	22	○	○	○	○
Stn.95	65	45.85	N	168	46.03	W	52	2016	09	22	○	○	○	○
Stn.96	65	39.27	N	168	14.99	W	43	2016	09	22	○	○	○	○
Stn.97	65	38.97	N	168	41.92	W	50	2016	09	22	○	○	○	○
Stn.98	65	15.90	N	169	03.06	W	53	2016	09	22	○	○	○	○
Stn.99	65	03.08	N	169	37.75	W	52	2016	09	22	○	○	○	○

(6) Preliminary results

NOT AVAILABLE

4.18. Seabird observations

(1) Personnel

Yutaka Watanuki (Hokkaido University): Principal Investigator (not on-board)

Bungo Nishizawa (Hokkaido University)

(2) Objectives

The marine ecosystems of the Bering Sea and adjacent Chukchi Sea are experiencing rapid changes due to reductions in sea-ice. In the Bering Sea and Chukchi Sea shelf regions, seabirds, as homoeothermic top predators, play a significant role in the trophic energy flow. As mobile predators that can respond quickly to shifts in the distribution of prey (i.e., by switching foraging areas or prey species), changes in their distribution can potentially serve as indicators of fluctuations of trophic relationships. Thus, knowledge of recent changes in the distributions of top predators and their prey should provide useful information about large-scale ecosystem changes in these regions with seasonal sea-ice. Short-tailed shearwaters *Puffinus tenuirostris* visit this region between the summer and fall during non-breeding season, and show highest biomass among seabirds distributed in the region during the periods. The main objective of this study is to understand the links between seasonal distribution of short-tailed shearwaters, their prey (i.e., krill) and marine environments.

(3) Parameters

Seabird distribution, abundance, and behaviors (flying, sitting on water or foraging) at sea.

(4) Instruments and methods

As the ship cruised during the daytime, one observer recorded numbers and behaviors (flying, sitting on water or foraging) of seabirds at every 1-minute detected within a 300 m arc (from the bow to 90° to port or to starboard) of the side of the vessel that afforded the best observation conditions (i.e., least sun glare). The Observer confirmed species identification and counted the number of seabirds using a 8 × binocular (Victory FL 8 x 56, ZEISS, Germany) from the ship's bridge, approximately 16 m eye-height above the sea surface. Ship-following birds were recorded when they first entered the survey range, and were ignored thereafter.

(5) Observation log

Table 4.18-1 Seabird observation effort

Transect_ID	Start/End	UTC_date (yyyymmdd)	UTC (hhmm)	Latitude	Longitude
1	Start	20160826	2042	51-15.49540N	168-17.71930E
	End	20160826	2231	51-33.45700N	168-37.58210E
2	Start	20160827	0237	52-15.21100N	169-26.35760E
	End	20160827	0500	52-39.99450N	169-52.95180E
3	Start	20160827	2005	54-57.14180N	173-31.54510E
	End	20160827	2026	55-00.26920N	173-36.59620E
4	Start	20160827	2032	55-01.09040N	173-38.21590E
	End	20160827	2108	55-05.86820N	173-48.04390E
5	Start	20160828	0025	55-33.70120N	174-37.05250E
	End	20160828	0331	55-59.39680N	175-23.65040E
6	Start	20160828	0547	56-18.92360N	176-01.08260E
	End	20160828	0720	56-32.72170N	176-26.23660E
7	Start	20160828	1908	58-10.37990N	179-30.82070E
	End	20160828	2255	58-41.25190N	179-26.56450W
8	Start	20160829	0036	58-50.19150N	179-07.38780W
	End	20160829	0251	59-10.70310N	178-34.23560W
9	Start	20160829	0448	59-30.87820N	178-08.87360W
	End	20160829	0610	59-44.93350N	177-52.90340W
10	Start	20160829	1906	61-59.17370N	175-20.87690W
	End	20160829	2257	62-39.89840N	174-31.49160W
11	Start	20160829	2345	62-45.56360N	174-25.30170W
	End	20160830	0135	63-05.17740N	174-00.00640W
12	Start	20160830	1934	64-48.83530N	170-06.69860W
	End	20160830	2110	65-03.14720N	169-36.31210W
13	Start	20160831	0249	65-10.44810N	169-20.40590W
	End	20160831	0335	65-15.87070N	169-03.38620W
14	Start	20160831	0539	65-19.84260N	168-53.53920W
	End	20160831	0645	65-31.04980N	168-37.44050W
15	Start	20160901	0141	66-18.81200N	168-53.78620W
	End	20160901	0620	67-10.06100N	168-53.89330W
16	Start	20160901	2335	68-15.36810N	168-44.06950W
	End	20160902	0057	68-29.71250N	168-44.19330W
17	Start	20160902	0155	68-32.47660N	168-44.46840W
	End	20160902	0428	68-59.78940N	168-44.50090W
18	Start	20160902	2103	70-55.86280N	168-16.08480W
	End	20160902	2320	70-45.05590N	167-00.53980W
19	Start	20160903	0000	70-45.22570N	166-57.66340W
	End	20160903	0318	70-44.94710N	165-00.46420W
20	Start	20160903	0431	70-45.05670N	164-47.68030W
	End	20160903	0526	70-44.79760N	164-15.79580W
21	Start	20160903	0536	70-43.94170N	164-11.51360W
	End	20160903	0630	70-45.00570N	163-39.86480W
22	Start	20160904	0233	71-24.90180N	158-21.89810W
	End	20160904	0414	71-34.61530N	157-49.56110W
23	Start	20160904	1900	71-24.48250N	158-26.26890W
	End	20160904	1915	71-25.04210N	158-30.85660W
24	Start	20160905	0428	71-22.45210N	158-24.01620W
	End	20160905	0553	71-31.96230N	157-45.52990W
25	Start	20160906	0129	71-46.27050N	154-59.73040W
	End	20160906	0401	72-14.72590N	155-00.08060W
26	Start	20160906	0427	72-19.81490N	154-59.89390W
	End	20160906	0532	72-31.40430N	154-56.58510W
27	Start	20160907	1905	71-35.84540N	154-19.25340W
	End	20160907	2241	71-33.73620N	152-01.11760W
28	Start	20160908	0318	71-37.93150N	152-16.57550W
	End	20160908	0449	71-47.47760N	153-00.60490W
29	Start	20160909	1852	73-11.57740N	159-30.01330W
	End	20160909	2222	73-17.96470N	160-45.78320W
30	Start	20160910	0318	73-18.57560N	160-46.71920W
	End	20160910	0436	73-17.14400N	160-00.79280W
31	Start	20160913	0102	72-14.72680N	159-09.52620W
	End	20160913	0435	72-49.68320N	158-48.75910W
32	Start	20160913	1623	73-21.57790N	157-26.28680W
	End	20160913	1725	73-29.88360N	156-59.84820W

Table 4.18-1 (Continued)

Transect_ID	Start/End	UTC_date (yyyymmdd)	UTC (hhmm)	Latitude	Longitude
33	Start	20160913	2222	73-31.63440N	157-00.83310W
	End	20160914	0002	73-45.08800N	156-10.48940W
34	Start	20160914	0231	73-45.79020N	156-05.72230W
	End	20160914	0433	73-51.63240N	156-33.46300W
35	Start	20160914	2221	73-29.78500N	159-21.22750W
	End	20160914	2352	73-23.28290N	160-10.46540W
36	Start	20160915	0156	73-23.05060N	160-15.47130W
	End	20160915	0337	73-13.81190N	161-17.72760W
37	Start	20160917	1720	71-30.75360N	156-34.79950W
	End	20160917	1848	71-28.51880N	156-16.91420W
38	Start	20160917	1903	71-27.81630N	156-22.01190W
	End	20160917	2313	71-05.91500N	157-45.34260W
39	Start	20160917	2342	71-04.17450N	157-55.80750W
	End	20160918	0307	70-59.93290N	159-24.54070W
40	Start	20160918	0316	71-00.28600N	159-27.27180W
	End	20160918	0427	70-57.23210N	160-03.09320W
41	Start	20160918	1904	71-29.67680N	164-43.24160W
	End	20160918	2251	71-59.05210N	165-53.88290W
42	Start	20160919	0119	72-05.17440N	166-08.10100W
	End	20160919	0447	72-31.61810N	167-18.63170W
43	Start	20160919	1902	70-50.29110N	168-44.91960W
	End	20160919	2049	70-29.85940N	168-44.28700W
44	Start	20160919	2235	70-23.64800N	168-44.30900W
	End	20160920	0038	69-59.86430N	168-45.13450W
45	Start	20160920	0138	69-57.26860N	168-43.93610W
	End	20160920	0401	69-29.97770N	168-45.14930W
46	Start	20160920	1956	67-59.80670N	168-44.15400W
	End	20160920	2123	67-45.13260N	168-30.47370W
47	Start	20160920	2219	67-45.25730N	168-28.45630W
	End	20160920	2355	68-00.05060N	168-00.22460W
48	Start	20160921	0100	68-01.59140N	167-54.10890W
	End	20160921	0222	68-12.02700N	167-20.74940W
49	Start	20160921	0324	68-12.70960N	167-18.14200W
	End	20160921	0406	68-18.16150N	167-03.49020W
50	Start	20160921	1910	67-11.39320N	168-53.28760W
	End	20160921	2340	66-16.39360N	168-54.00710W
51	Start	20160922	0140	66-15.39480N	168-53.71740W
	End	20160922	0405	65-45.85360N	168-45.82050W
52	Start	20160922	2203	65-02.43790N	169-38.15440W
	End	20160922	2305	64-56.80620N	169-27.53260W
53	Start	20160922	2343	64-54.36400N	169-19.04240W
	End	20160923	0025	64-50.91910N	169-10.15050W
54	Start	20160923	0032	64-50.34910N	169-08.64100W
	End	20160923	0111	64-47.29550N	168-59.66820W
55	Start	20160923	0119	64-46.66100N	168-57.82410W
	End	20160923	0420	64-32.64590N	168-18.30620W
56	Start	20160923	2035	64-25.21860N	165-32.46440W
	End	20160923	2302	64-22.03820N	166-40.11960W
57	Start	20160923	2355	64-22.76510N	167-01.71670W
	End	20160924	0410	64-22.28280N	169-04.13030W
58	Start	20160924	1918	62-31.38160N	174-07.52380W
	End	20160924	2051	62-14.92650N	174-30.01850W
59	Start	20160924	2055	62-14.22960N	174-30.98320W
	End	20160924	2302	61-52.59890N	175-01.25640W
60	Start	20160924	2356	61-45.76750N	175-13.77280W
	End	20160925	0218	61-21.46820N	175-42.03820W
61	Start	20160925	0229	61-19.68040N	175-44.51690W
	End	20160925	0401	61-04.40940N	176-05.64310W
62	Start	20160926	2017	55-25.84120N	174-23.65230E
	End	20160927	0000	54-57.65460N	173-32.55870E
63	Start	20160927	0108	54-49.23910N	173-18.29290E
	End	20160927	0503	54-24.64790N	172-34.79540E

(6) Preliminary results

Figure 4.18-1: Map showing ship tracks where seabird observations were conducted during this cruise.

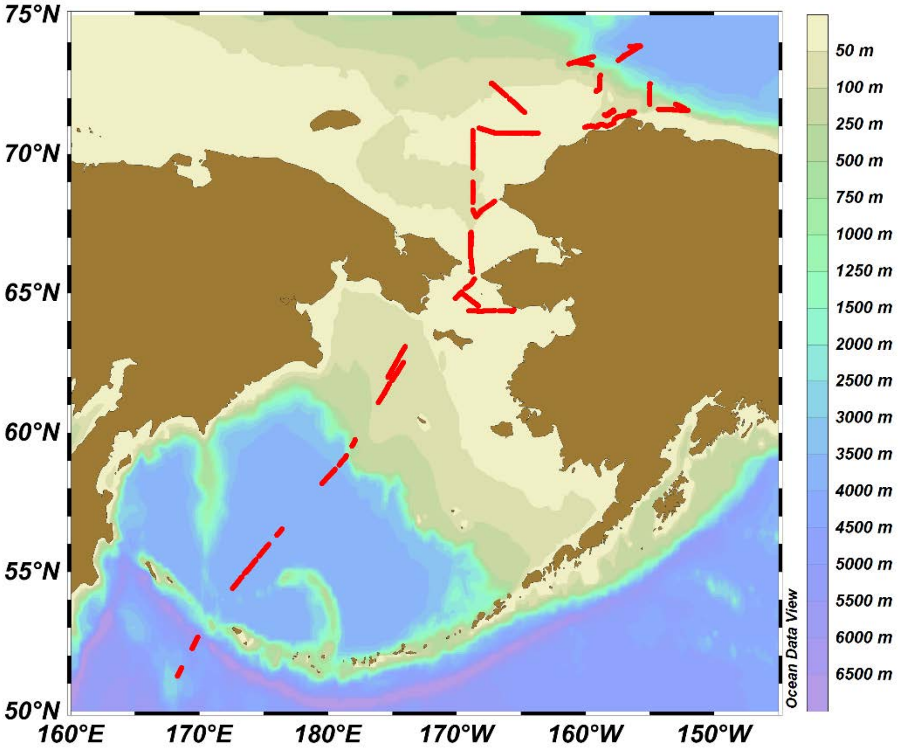


Figure 4.18-1 Ship tracks where seabird observations were conducted.

(7) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

5. Geology

5.1. Sea bottom topography measurement

(1) Personnel

Shigeto Nishino	JAMSTEC	-PI
Shinya Okumura	NME (Nippon Marine Enterprises, Ltd.)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objective

R/V MIRAI is equipped with the Multi Beam Echo Sounding system (MBES; SEABEAM 3012 (L3 Communications ELAC Nautik)). The objective of MBES is collecting continuous bathymetric data along ship's track except shallow depth, to make a contribution to geological and geophysical studies.

(3) Instruments and Methods

The "SEABEAM 3012" on R/V MIRAI was used for bathymetry mapping during this cruise.

To get accurate sound velocity of water column for ray-path correction of acoustic beams, we determined sound velocities at the depth of 6.62m, the bottom of the ship, by a surface sound velocimeter. We made sound velocity profiles based on the observations of CTD, XCTD and Argo float conducted in this cruise by the equation in Del Grosso (1974).

The system configuration and performance are shown in Table 5.1-1.

Table 5.1-1: SEABEAM 3012 System configuration and performance

Frequency:	12 kHz
Transmit beam width:	2.0 degree
Transmit power	4 kW
Transmit pulse length:	2 to 20 msec.
Receive beam width:	1.6 degree
Depth range:	50 to 11,000 m
Number of beams:	301 beams (Spacing mode: Equi-angle)
Beam spacing:	1.5 % of water depth (Spacing mode: Equi-distance)
Swath width:	60 to 150 degrees
Depth accuracy:	< 1 % of water depth (average across the swath)

(4) Preliminary Results

The results will be published after the primary processing.

(5) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

5.2. Sea surface gravity measurement

(1) Personnel

Shigeto Nishino	JAMSTEC	-PI
Shinya Okumura	NME (Nippon Marine Enterprises, Ltd.)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objective

The local gravity is an important parameter in geophysics and geodesy. We collected gravity data during this cruise.

(3) Parameters

Relative Gravity [CU: Counter Unit]

[mGal] = (coefl: 0.9946) * [CU]

(4) Instruments and Methods

We measured relative gravity using LaCoste and Romberg air-sea gravity meter S-116 (Micro-g LaCoste, LLC) during the cruise. To convert the relative gravity to absolute one, we measured gravity, using portable gravity meter (Scintrex gravity meter CG-5), at Sekinehama to Sekinehama port as the reference points.

(5) Preliminary Results

Absolute gravity table is shown in Table 5.2-1

Table 5.2-1: Absolute gravity table of the MR16-06 cruise

No.	Date	UTC	Port	Absolute Gravity [mGal]	Sea Level [cm]	Ship Draft [cm]	Gravity at Sensor * [mGal]	S-116 Gravity [mGal]
#1	8-Aug-16	05:35	Shimizu	979729.110	205	630	979729.96	12019.37
#2	5-Oct-16	06:53	Sekinehama	980371.932	233	643	980372.90	12658.03

*: Gravity at Sensor

= Absolute Gravity + Sea Level*0.3086/100 + (Draft-530)/100*0.2654

(6) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via “Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)” in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

5.3. Surface magnetic field measurement: Three-components magnetometer

(1) Personnel

Shigeto Nishino	JAMSTEC	-PI
Shinya Okumura	NME (Nippon Marine Enterprises, Ltd.)	
Kazuho Yoshida	NME	
Yutaro Murakami	NME	
Masanori Murakami	MIRAI Crew	

(2) Objective

Measurement of magnetic force on the sea is required for the geophysical investigations of marine magnetic anomaly caused by magnetization in upper crustal structure. We measured geomagnetic field using a three-component magnetometer during this cruise.

(3) Instruments and Methods

A shipboard three-component magnetometer system (SFG1214, Tierra Tecnica) is equipped on-board R/V MIRAI. Three-axes flux-gate sensors with ring-cored coils are fixed on the fore mast. Outputs from the sensors are digitized by a 20-bit A/D converter (1 nT/LSB), and sampled at 8 times per second. Yaw (heading), Pitch and Roll are measured by the Inertial Navigation System (INS) for controlling attitude of a Doppler radar. Ship's position (Differential GNSS), speed over ground and gyro data are taken from LAN every second.

The relation between a magnetic-field vector observed on-board, Hob, (in the ship's fixed coordinate system) and the geomagnetic field vector, F, (in the Earth's fixed coordinate system) is expressed as:

$\mathbf{H}ob = \tilde{\mathbf{A}}\ \tilde{\mathbf{R}}\ \tilde{\mathbf{P}}\ \tilde{\mathbf{Y}}\ \mathbf{F} + \mathbf{H}p$ (a)

where $\tilde{\mathbf{R}}$, $\tilde{\mathbf{P}}$ and $\tilde{\mathbf{Y}}$ are the matrices of rotation due to roll, pitch and heading of a ship, respectively. $\tilde{\mathbf{A}}$ is a 3 x 3 matrix which represents magnetic susceptibility of the ship, and $\mathbf{H}p$ is a magnetic field vector produced by a permanent magnetic moment of the ship's body. Rearrangement of Eq. (a) makes

$\tilde{\mathbf{R}}\ \mathbf{H}ob + \mathbf{H}bp = \tilde{\mathbf{R}}\ \tilde{\mathbf{P}}\ \tilde{\mathbf{Y}}\ \mathbf{F}$ (b)

where $\tilde{\mathbf{R}} = \tilde{\mathbf{A}}^{-1}$, and $\mathbf{H}bp = -\tilde{\mathbf{R}}\ \mathbf{H}p$. The magnetic field, $\mathbf{F}$, can be obtained by measuring $\tilde{\mathbf{R}}$, $\tilde{\mathbf{P}}$, $\tilde{\mathbf{Y}}$ and $\mathbf{H}ob$, if $\tilde{\mathbf{R}}$ and $\mathbf{H}bp$ are known. Twelve constants in $\tilde{\mathbf{R}}$ and $\mathbf{H}bp$ can be determined by measuring variation of $\mathbf{H}ob$ with $\tilde{\mathbf{R}}$, $\tilde{\mathbf{P}}$ and $\tilde{\mathbf{Y}}$ at a place where the geomagnetic field, $\mathbf{F}$, is known.

(4) Preliminary Results

The results will be published after the primary processing.

(5) Data archives

These data obtained in this cruise will be submitted to the Data Management Group of JAMSTEC, and will be opened to the public via "Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)" in JAMSTEC web site.
<http://www.godac.jamstec.go.jp/darwin/e>

(6) Remarks

For calibration of the ship's magnetic effect, we made "figure-eight" turns (a pair of clockwise and anti-clockwise rotation) at the following period and positions.

16:50 - 17:10 08 Sep. 2016 around 72-27N, 155-23W

02:41 - 03:03 03 Oct. 2016 around 40-19N, 144-23E

6. Notice on using

This cruise report is a preliminary but final documentation as of the end of the cruise. This report may not be corrected even if changes on contents (e.g. taxonomic classifications) are found after its publication. This report may also be changed without notice. Data on this cruise report may be raw or unprocessed. If you are going to use or refer to the data written on this report, please ask the Chief Scientist for the latest information.

Users of data or results on this cruise report are requested to submit their results to Planning Group, Research Fleet Department, Marine Technology and Engineering Center of JAMSTEC.

E-mail : submit-rv-cruise@jamstec.go.jp