R/V Mirai Cruise Report
MR09-03

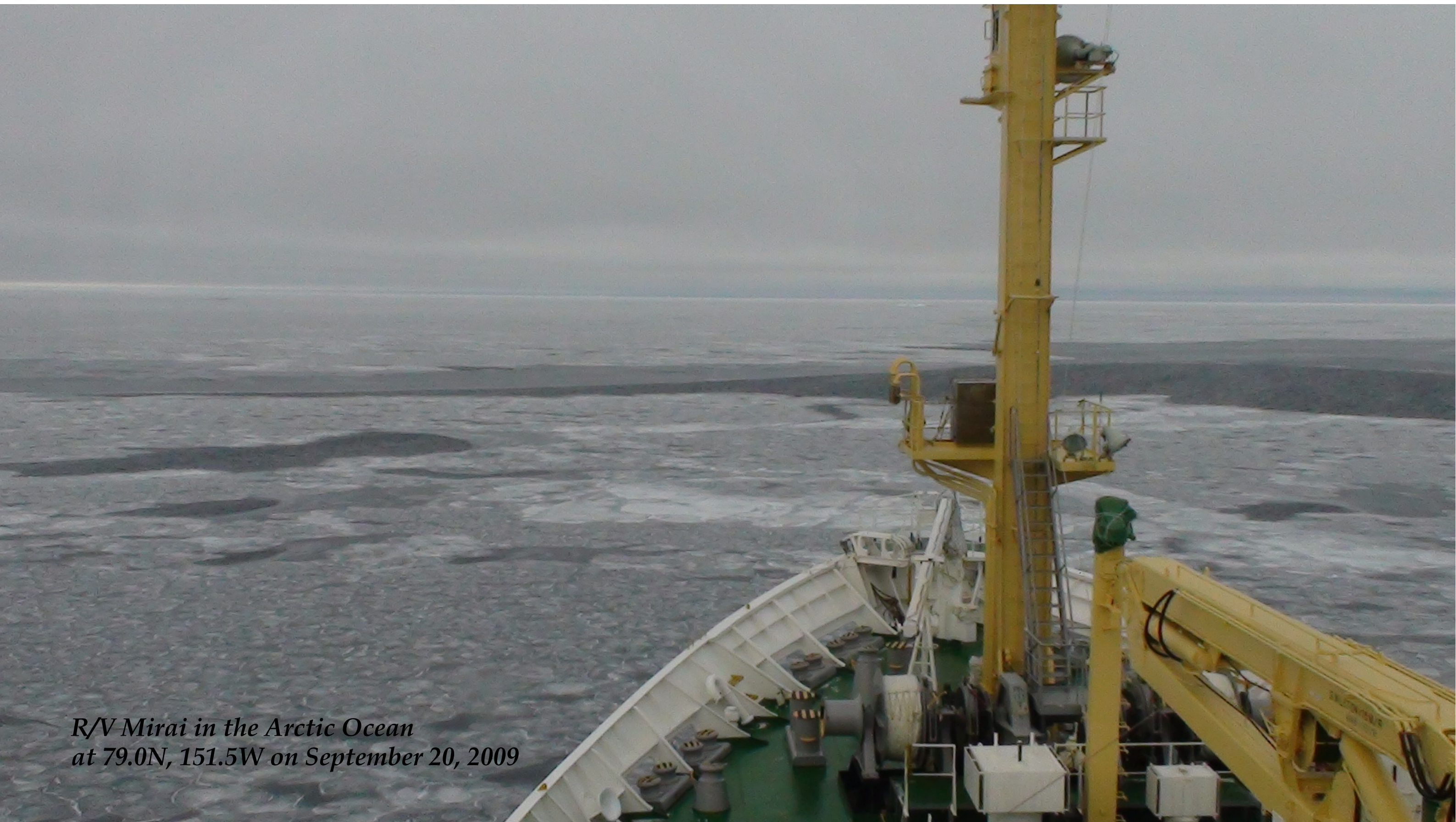
Arctic Ocean, Bering Sea, and North Pacific Ocean

28th August to 25th October, 2009

Japan Agency for

Marine-Earth Science and Technology

(JAMSTEC)



R/V Mirai in the Arctic Ocean
at 79.0N, 151.5W on September 20, 2009

Contents

1. Cruise Narrative

Takashi KIKUCHI (JAMSTEC)
Shigeto NISHINO (JAMSTEC)

1.1. Brief summary of MR09-03

Changes of the Arctic environment are well known as one of the most remarkable evidences of global climate change, attracting public attentions as well as scientists'. Especially, during the International Polar Year (IPY) period (March 2007 to March 2009), sea ice extent of the Arctic Ocean recorded its minimum in the satellite record in September 2007. Under the international framework of the integrated Arctic Ocean Observing System (iAOOS), many cruises for the Arctic Ocean were conducted by research vessels, ice-breakers, and other ships during IPY period and we were able to obtain unique and important observational data which could cover most of the Arctic Ocean. Based on success of international coordination and collaborations for the Arctic Ocean observation during IPY period, we should continue the efforts to have a sustainable observation network as the international collaboration so as to understand on-going changes of the Arctic Ocean climate and its role for global change.

Following the IPY observations in the Arctic Ocean, Japan Agency for Marine-Earth Science and Technology (JAMSTEC) was going to have the R/V Mirai multi-disciplinary cruise for the Arctic Ocean (MR09-03) in September - October 2009. This cruise planned to cover the Pacific side of the Arctic Ocean and focused on;

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 changes of the Arctic Ocean,
c. To collect and distribute data for understanding the effects/impacts of the Arctic Ocean climate changes onto global climate.

In addition to the main research theme as described above, twelve scientific themes which were proposed to this cruise were accepted for obtaining the data in the Arctic Ocean, Bering Sea and North Pacific Ocean.

MR09-03 was totally 59-days cruise, including 39-days for the Arctic Ocean. Especially, during the second leg of MR09-03, R/V Mirai was able to cover ice-free area of the Pacific side of the Arctic Ocean. On September 20, we arrived at 79.0°N, 151.5°W, which is the most northern location of all of the R/V Mirai cruises. Although sea ice sometimes prevented us to conduct our plan of the observation, lots of unique and important data could be obtained during the cruise.

1.2. Basic information

Name of Vessel	R/V Mirai L x B x D 128.58m x 19.0m x 13.2m, Gross Tonnage 8,672 tons Call Sign JNSR
Cruise Code	MR09-03
Title of the Cruise	Multi-disciplinary observation cruise for the Arctic Ocean
Undertaking Institute	Japan Agency for Marine-Earth Science and Technology (JAMSTEC) 2-15 Natsushima-cho, Yokosuka 237-0061, Japan
Chief Scientists	Leg1: Shigeto Nishino Leg2: Takashi Kikuchi Leg3: Shigeto Nishino Arctic Ocean Climate System Research, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (RIGC/JAMSTEC)

Representatives of the Science Parties and Titles of the Proposals

Toshi Nagata (The University of Tokyo); “Studies on the distribution and dynamics of microbial communities in the Arctic Ocean” (Leg2)

Sei-Ichi Saitoh (Hokkaido University); “Elucidation of the role of sea-ice cover change on the primary productivity in the northern Chukchi Sea” (Leg2)

Ken’ichi Ohkushi (Kobe University); “Paleoceanographic study of climate interaction between global warming and deep water circulation in the Arctic Ocean” (Leg2)

Masao Uchida (National Institute for Environmental Studies); “Origin and transport of dissolve and particulate organic carbon from shelf to basin in the Actic Ocean” (Leg2)

Ippei Nagao (Nagoya University); “Flux measurements of marine biogenic gas (dimethylsulfide) by eddy correlation method" (Leg1)

Nobuo Sugimoto (National Institute for Environmental Studies); "Lidar observations of optical characteristics and vertical distribution of aerosols and clouds" (Leg1-Leg3)

Kunio Yoneyama (Research Institute for Global Change); "Archive of surface meteorological data" (Leg1-Leg3)

Yoko Yokouchi (National Institute for Environmental Studies); "A study on the distribution of biogenic volatile organic compounds (BVOCs) over the Arctic Ocean" (Leg1-Leg3)

Masao Nakanishi (Chiba University); "Tectonic evolution of the Pacific Plate" (Leg1-Leg3)

Takeshi Matsumoto (University of the Ryukyus); "Standardizing the marine geophysics data and its application to the ocean floor geodynamics studies" (Leg1-Leg3)

Osamu Tsukamoto (Okayama University); "On-board continuous air-sea eddy flux measurement" (Leg1-Leg3)

Naoyuki Kurita (Research Institute for Global Change); "Water sampling for making isotope distribution map over the Ocean" (Leg1-Leg3)

Cruise Periods and Ports of Call

Leg1: Aug. 28, 2009 – Sep. 6, 2009
(Sekinehama – Hachinohe - Dutch Harbor)

Leg2: Sep. 7, 2009 – Oct. 15, 2009
(Dutch Harbor – Dutch Harbor)

Leg3: Oct. 16, 2009 – Oct. 25, 2009
(Dutch Harbor – Hachinohe – Sekinehama)

Research Areas — Arctic Ocean, Bering Sea, and North Pacific Ocean

Overview of MR09-03 activities

CTD/LADCP,	101 casts
CTD/Water Samplings,	66 casts
XCTD,	102 casts
Radiosonde,	136 points
Mooring Deployment,	1 point

Surface Drifting Buoy deployments,	5 points
Turbulence Ocean Microstructures,	30 casts
Particle Meter (LISST-100),	11 casts
Spectroradiometer (PRR),	16 casts
Absorption and Attenuation Meter (ac-s),	15 casts
Plankton Nets,	6 casts
Piston Cores,	5 casts (at 3 points)
Pilot Cores,	5 casts (at 3 points)
Water Vapor $\delta^{18}O$,	112 points
Rainfall $\delta^{18}O$,	23 points
Sea Surface Water $\delta^{18}O$,	52 points
Biogenic Volatile Organic Compounds (BVOC),	57 points

ADCP Continuous Observation

Sea Surface Water Monitoring System

Meteorological Observation System

Doppler Rador

Dual Polarization Lidar

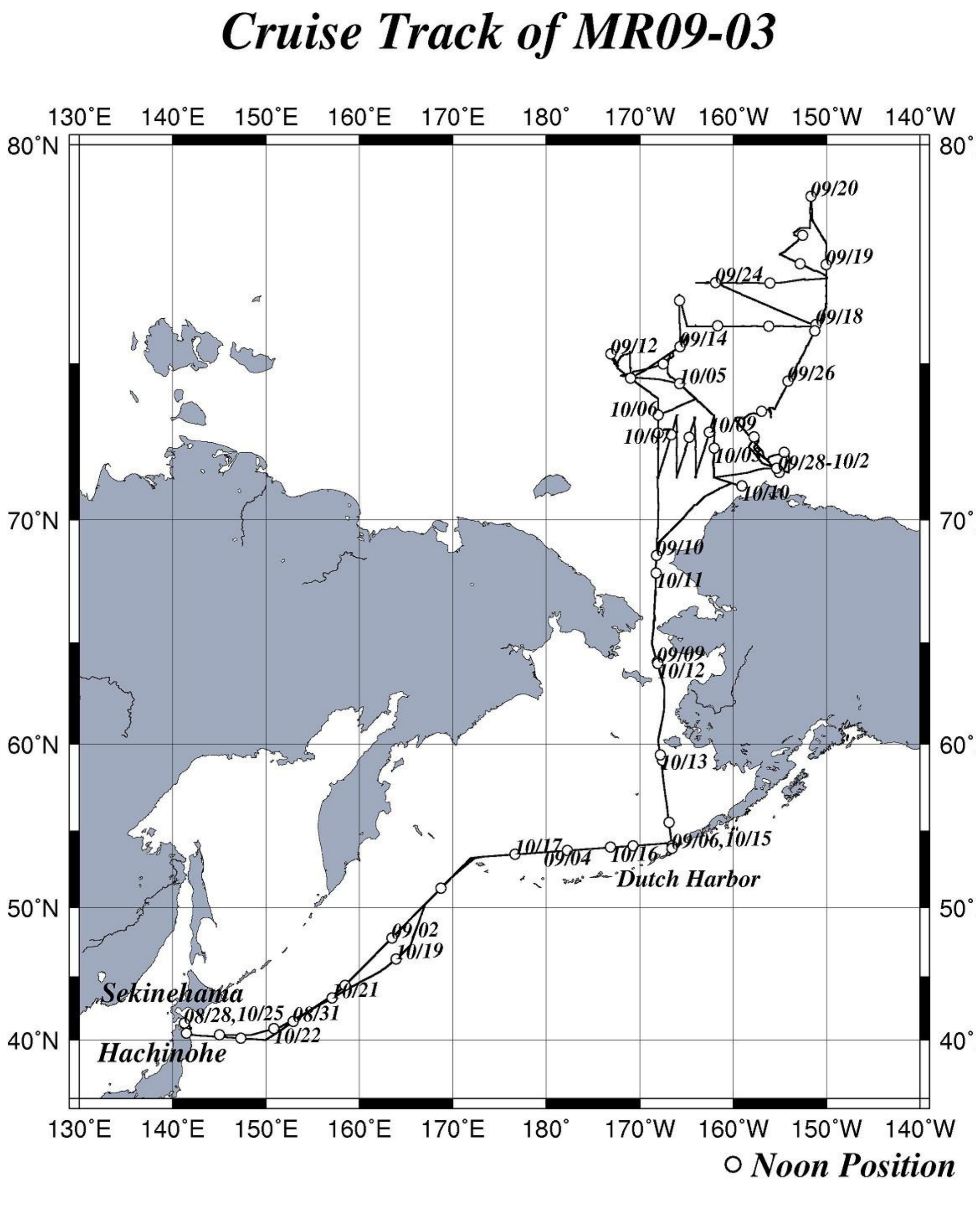
Eddy Flux Measurement System

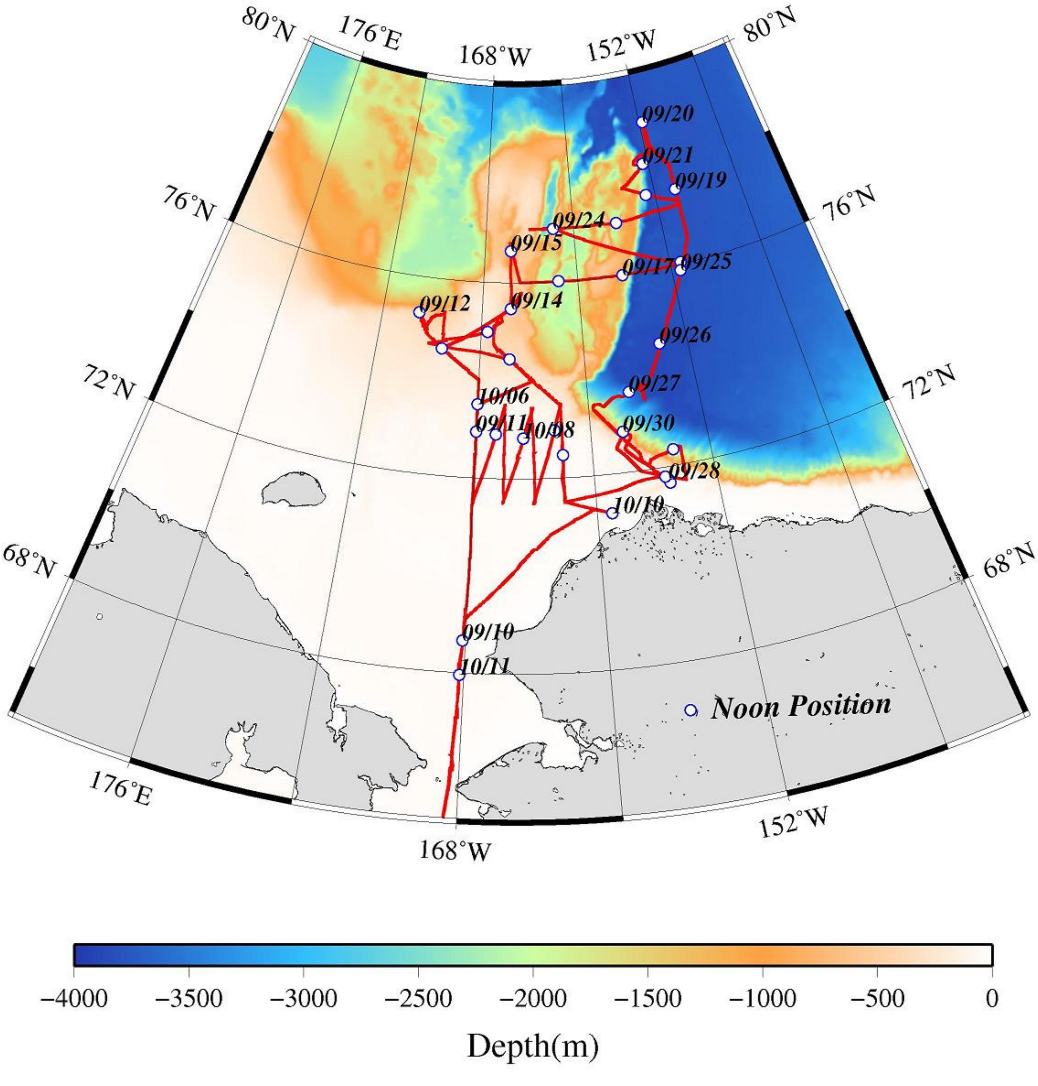
DMS Continuous Measurement（Leg1）

Seabeam

Geophysical Continuous Observation (Magnetometer, Gravity meter)

1.3. Cruise track




80°N
176°E
168°W
152°W
80°N
76°N
76°N
72°N
72°N
68°N
68°N
176°E
168°W
152°W
09/20
09/21
09/19
09/24
09/15
09/17
09/25
09/12
09/14
09/26
09/27
10/06
09/30
09/11
10/08
09/28
10/10
09/10
10/11
Noon Position
−4000
−3500
−3000
−2500
−2000
−1500
−1000
−500
0
Depth(m)

1.4. List of Participants

List of Participants for leg 1

NO	NAME	ORGANIZATION	POSITION
1	Shigeto Nishino	JAMSTEC-RIGC	Research Scientist
2	Toru Hirawake	Hokkaido University	Associate Professor
3	Keitaro Matsumoto	Hokkaido University	Graduate Student
4	Ippei Nagao	Nagoya University	Assistant Professor
5	Shohei Akiyama	University of Tsukuba	University Student
6	Shinsuke Toyoda	Marine Works Japan Ltd.	Technical Staff
7	Fuyuki Shibata	Marine Works Japan Ltd.	Technical Staff
8	Miyo Ikeda	Marine Works Japan Ltd.	Technical Staff
9	Shinya Okumura	Global Ocean Development Inc.	Technical Staff

List of Participants for leg 2

NO	NAME	ORGANIZATION	POSITION
1	Takashi Kikuchi	JAMSTEC-RIGC	Team Leader
2	Jun Inoue	JAMSTEC-RIGC	Senior Scientist
3	Shigeto Nishino	JAMSTEC-RIGC	Research Scientist
4	Yusuke Kawaguchi	JAMSTEC-RIGC	Postdoctoral Scientist
5	Masashi Ito	JAMSTEC-RIGC/Mie University	Student
6	Sergey Pisarev	Shirshov Institute of Oceanology	Leading Scientist
7	Michiyo Kawai	Institute of Ocean Sciences	Postdoctoral Scientist
8	Toru Hirawake	Hokkaido University	Associate Professor
9	Keitaro Matsumoto	Hokkaido University	Graduate Student
10	Katsuhito Shimmyo	Hokkaido University	University Student
11	Hideki Fukuda	The University of Tokyo	Assistant Professor
12	Mario Uchimiya	The University of Tokyo	Graduate Student
13	Minoru Ijichi	The University of Tokyo	Graduate Student
14	Ayako Okamoto	The University of Tokyo	Graduate Student
15	Shohei Akiyama	University of Tsukuba	University Student
16	Kenichi Okushi	Kobe University	Associate Professor
17	Susumu Konno	Yamagata University	Postdoctoral Scientist
18	Shinsuke Toyoda	Marine Works Japan Ltd.	Technical Staff
19	Fuyuki Shibata	Marine Works Japan Ltd.	Technical Staff

20	Miyo Ikeda	Marine Works Japan Ltd.	Technical Staff
21	Masayuki Fujisaki	Marine Works Japan Ltd.	Technical Staff
22	Fujio Kobayashi	Marine Works Japan Ltd.	Technical Staff
23	Kenichi Katayama	Marine Works Japan Ltd.	Technical Staff
24	Tomohide Noguchi	Marine Works Japan Ltd.	Technical Staff
25	Kenichiro Sato	Marine Works Japan Ltd.	Technical Staff
26	Minoru Kamata	Marine Works Japan Ltd.	Technical Staff
27	Masanori Enoki	Marine Works Japan Ltd.	Technical Staff
28	Yoshiko Ishikawa	Marine Works Japan Ltd.	Technical Staff
29	Junji Matsushita	Marine Works Japan Ltd.	Technical Staff
30	Tomonori Watai	Marine Works Japan Ltd.	Technical Staff
31	Misato Kuwahara	Marine Works Japan Ltd.	Technical Staff
32	Ai Ueda	Marine Works Japan Ltd.	Technical Staff
33	Hironori Sato	Marine Works Japan Ltd.	Technical Staff
34	Kazuhiro Yoshida	Marine Works Japan Ltd.	Technical Staff
35	Yasushi Hashimoto	Marine Works Japan Ltd.	Technical Staff
36	Sayaka Kawamura	Marine Works Japan Ltd.	Technical Staff
37	Kohei Miura	Marine Works Japan Ltd.	Technical Staff
38	Satoshi Okumura	Global Ocean Development Inc.	Technical Staff
39	Soichiro Sueyoshi	Global Ocean Development Inc.	Technical Staff
40	Norio Nagahama	Global Ocean Development Inc.	Technical Staff
41	Ryo Kimura	Global Ocean Development Inc.	Technical Staff

List of Participants for leg 3

NO	NAME	ORGANIZATION	POSITION
1	Shigeto Nishino	JAMSTEC-RIGC	Research Scientist
2	Shohei Akiyama	University of Tsukuba	University Student
3	Fujio Kobayashi	Marine Works Japan Ltd.	Technical Staff
4	Tomonori Watai	Marine Works Japan Ltd.	Technical Staff
5	Misato Kuwahara	Marine Works Japan Ltd.	Technical Staff
6	Norio Nagahama	Global Ocean Development Inc.	Technical Staff

2. Meteorological Observation
2.1. GPS Radiosonde

(1) Personnel

Jun Inoue (JAMSTEC): Principal Investigator
Masashi Ito (JAMSTEC/Mie University)
Souichiro Sueyoshi (Global Ocean Development Inc., GODI)
Satoshi Okumura (GODI)
Norio Nagahama (GODI)
Ryo Kimura (GODI)

(2) Objectives

Upper atmospheric data by radiosondes is vital for weather predictions and atmospheric reanalysis to provide more accurate atmospheric structure. However, meteorological data over the Arctic Ocean is very few due to lack of regular meteorological stations. In this study, 6-hourly radiosonde observations were conducted over the Arctic Ocean during a month to understand the thermodynamic structure of boundary layers modified by synoptic scale disturbances and sea/ice surface conditions. The obtained data will be used for studies of clouds, validation of reanalysis data, and data assimilation.

(3) Parameters

Temperature (degC)
Relative humidity (%)
Wind direction (deg)
Wind speed (m/s)
Air pressure (hPa)

(4) Instruments and methods

Radiosonde observations were carried out from 10 September to 11 October 2009, by using GPS radiosonde (RS92-SGPD). We used DigiCORA III (MW21), GPS antenna (GA20), UHF antenna (RB21) and balloon launcher (ASAP) made by Vaisala. Prior to launch, humidity, air temperature, and pressure sensors were calibrated by using the calibrator system (GC25 and PTB220, Vaisala). Measured parameters are temperature (degC), relative humidity (%), wind direction (deg), wind speed (m/s), air pressure (hPa). 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.

(5) Data archives

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

(6) Remark

We couldn't archive RS125 raw data, because of stopping process in DigiCORA software.

(7) Preliminary results

GPS radio sondes were launched from 06UTC 10 September to 06UTC 11 October 2009 (Table 2.1-1). We basically launched them 4 times a day (00, 06, 12, and 18UTC). In addition to this, 3-houly observations were set up over the Chukch Sea on 3, 7, 8, 9, and 10 October. Figure 2.1-1 shows the map of radiosonde stations with sea ice concentration on 10 October 2009.

Time-height section of observed air temperature, time series of sea and air surface temperatures, and GPS positions of launching are shown in Figure 2.1-2. During the former period, data over marginal ice zone was obtained. On 21 September, we reached at the northernmost positions at 79^{o}N. In this period, the surface air temperature was the coldest during the cruise (minimum was -10.1^{o}C). The boundary layer below 1 km was almost saturated in the most of days due to stratus clouds. From late September to the beginning of October, NE/NW-ly cold advection was dominated in the whole troposphere by a persistent high pressure system located in the Eurasian coast. During the intensive observational periods, strong westerly winds prevailed over the Chukch Sea, and boundary layers were well developed over the southern part of SST frontal zone. On 10 October, a polar low passed over the ship, resulting in the rapid change in the wind direction.

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	Amount	Type
RS001	2009091006	65.952	−168.481	1000.0	5.8	96	342	13.6	7.502	35.1	22935	10	St
RS002	2009091012	67.071	−168.347	1001.7	4.2	95	327	9.7	6.279	46.2	21165	10	unknown
RS003	2009091018	68.106	−168.315	1001.5	3.9	95	348	8.6	5.209	46.7	21086	9	St
RS004	2009091100	69.283	−168.128	1000.4	3.8	91	315	6.8	6.614	50.8	20555	9	St
RS005	2009091106	70.286	−168.012	999.3	2.6	97	324	7.7	5.140	48.7	20801	10	St
RS006	2009091112	71.426	−168.039	998.4	3.0	93	335	6.3	5.003	54.2	20100	10	unknown
RS007	2009091118	72.418	−168.028	998.0	−0.5	98	325	8.5	2.794	131.6	14258	9	St
RS008	2009091200	73.249	−168.020	998.3	−1.2	94	317	6.6	1.636	47.4	20952	8	St
RS009	2009091206	74.125	−168.657	998.5	−2.2	98	292	6.8	1.243	48.3	20810	9	St
RS010	2009091212	74.677	−171.499	999.3	−2.2	98	264	3.1	−0.101	64.9	18872	10	unknown
RS011	2009091218	75.181	−172.909	999.1	−2.5	100	35	2.1	−1.123	40.6	21904	10	St
RS012	2009091300	74.986	−172.535	1000.3	−2.1	97	341	5.7	−1.179	64.2	18958	10	St
RS013	2009091306	75.337	−171.021	1001.6	−2.6	99	308	3.8	−1.121	50.1	20572	9	St
RS014	2009091312	75.338	−171.027	1003.3	−1.9	100	264	6.3	−1.154	49.7	20617	10	unknown
RS015	2009091318	74.941	−171.014	1005.6	−1.4	100	279	4.5	0.099	60.6	19338	9	St
RS016	2009091400	74.600	−170.943	1007.0	−1.2	96	252	1.9	0.541	74.5	18016	10	St
RS017	2009091406	74.803	−169.503	1007.4	−1.4	88	211	6.2	0.887	48.8	20752	7	St
RS018	2009091412	75.264	−166.812	1007.9	−1.1	89	216	11.3	1.243	66	18809	10	unknown
RS019	2009091418	75.477	−165.689	1008.6	−1.1	93	202	9.9	1.110	41.4	21864	8	St
RS020	2009091500	75.470	−165.674	1009.0	0.8	90	181	6.9	1.187	39.1	22191	9	St
RS021	2009091506	76.052	−165.696	1009.2	0.2	99	187	7.6	0.124	60.2	19407	10	St
RS022	2009091512	76.642	−165.550	1009.5	−0.3	100	163	6.7	−0.811	108.8	15546	10	unknown
RS023	2009091518	76.640	−165.684	1009.0	−0.2	100	160	9.3	−0.786	64.3	18968	10	St
RS024	2009091600	76.642	−165.646	1009.7	−0.2	100	167	7.1	−0.788	39.1	22205	10	St
RS025	2009091606	76.001	−163.999	1010.1	0.4	100	162	6.8	1.127	60.1	19445	10	St
RS026	2009091612	76.002	−163.144	1010.5	0.1	100	183	4.9	0.135	46.7	21085	10	St
RS027	2009091618	76.006	−161.652	1010.9	−0.8	100	200	4.6	0.348	43.2	21576	10	St
RS028	2009091700	76.019	−161.604	1011.4	0.1	100	244	1.3	0.370	46.7	21095	10	St
RS029	2009091706	75.998	−159.682	1011.9	−0.1	100	314	1.8	0.150	43.9	21481	10	St
RS030	2009091712	76.001	−157.999	1012.8	−0.2	100	56	1.1	0.235	44.1	21450	10	St
RS031	2009091718	76.003	−156.420	1012.9	−0.5	100	46	2.5	0.108	53.9	20152	10	St
RS032	2009091800	76.000	−155.421	1013.2	−1.3	100	78	2.9	0.480	54.9	20028	10	St
RS033	2009091806	76.008	−155.012	1012.8	−1.4	97	63	7.4	0.416	55.8	19915	10	St

RS034	2009091812	76.013	−153.453	1013.2	−0.6	95	50	7.7	0.348	45.9	21164	10	unknown
RS035	2009091818	76.017	−151.027	1014.4	−1.6	95	64	8.4	−0.080	43.7	21468	9	St, Sc
RS036	2009091900	76.134	−150.717	1016.4	−3.2	90	49	9.7	−0.351	53.3	20178	10	St
RS037	2009091906	76.544	−150.068	1018.0	−4.0	90	59	9.0	−0.540	43.0	21554	10	St
RS038	2009091912	77.014	−150.044	1019.4	−4.3	87	54	8.2	−0.460	53.9	20063	10	unknown
RS039	2009091918	77.509	−150.000	1019.9	−4.9	94	11	7.8	−0.771	49.0	20653	10	St
RS040	2009092000	77.769	−150.031	1020.6	−7.1	95	11	5.7	−1.118	41.6	21710	9	St
RS041	2009092006	78.157	−150.487	1021.0	−9.0	96	5	4.8	−1.244	45.1	21172	10	St
RS042	2009092012	78.498	−151.481	1021.6	−7.5	98	339	7.3	−1.389	51.8	20272	10	unknown
RS043	2009092018	78.835	−151.568	1022.8	−8.3	98	355	8.7	−1.427	94.6	16322	10	St
RS044	2009092100	78.968	−151.684	1024.2	−6.6	96	353	7.3	−1.093	48.4	20694	10	St
RS045	2009092106	78.495	−151.702	1024.5	−6.3	95	11	9.9	−1.354	48.2	20718	10	St
RS046	2009092112	78.336	−152.488	1025.2	−6.4	90	0	10.0	−1.354	71.7	18130	10	St
RS047	2009092118	78.163	−153.240	1025.8	−5.9	95	0	9.5	−1.383	66.3	18632	10	St
RS048	2009092200	78.084	−152.884	1026.6	−5.3	90	357	7.7	−1.357	39.1	22084	10	St
RS049	2009092206	77.914	−153.853	1026.1	−5.5	93	353	6.7	−1.414	48.7	20638	10	St
RS050	2009092212	77.727	−154.705	1025.5	−5.6	95	323	5.9	−1.306	55.0	19857	10	unknown
RS051	2009092218	77.560	−153.168	1022.0	−6.0	10	285	7.5	−1.388	50.0	20454	10	St,Sc,Ac
RS052	2009092300	77.383	−151.416	1017.9	−3.2	90	245	12.0	−0.909	97.7	15099	9	St
RS053	2009092306	77.210	−149.933	1012.9	−3.0	94	254	10.2	−0.963	47.8	20741	10	St
RS054	2009092312	77.153	−152.150	1010.4	−2.3	96	267	8.6	−0.929	39.3	21995	10	unknown
RS055	2009092318	77.083	−155.894	1009.1	−2.3	98	301	4.2	−1.162	46.8	20867	10	St
RS056	2009092400	77.080	−158.791	1009.3	−2.3	98	0	4.8	−1.241	45.8	21005	10	St,Ns
RS057	2009092406	77.079	−161.054	1010.1	−2.1	100	6	6.2	−0.947	46.4	20902	10	St
RS058	2009092412	77.086	−163.137	1010.9	−2.1	97	14	5.6	−1.043	58.6	19376	10	unknown
RS059	2009092418	77.095	−162.724	1012.0	−2.4	97	11	5.8	−1.022	46.2	20899	10	St
RS060	2009092500	76.840	−159.366	1012.5	−2.4	95	14	5.3	−0.940	66.0	18618	10	St
RS061	2009092506	76.401	−155.009	1011.7	−2.2	93	5	5.9	−0.299	53.4	19985	10	St
RS062	2009092512	76.300	−154.036	1011.2	−2.1	91	24	4.8	−0.366	52.5	20088	10	unknown
RS063	2009092518	76.080	−151.697	1010.0	−2.9	93	22	4.9	−0.684	45.7	20970	10	St
RS064	2009092600	75.499	−152.008	1009.0	−2.6	93	336	6.7	−0.388	50.3	20359	10	St
RS065	2009092606	75.124	−152.795	1008.8	−2.2	96	352	7.7	−0.597	54.3	19846	10	St
RS066	2009092612	74.734	−153.520	1010.6	−3.0	91	27	8.5	−0.012	40.5	21746	10	unknown
RS067	2009092618	74.505	−154.085	1012.7	−3.9	82	11	5.6	−0.075	56.9	19535	8	St,Sc,As
RS068	2009092700	74.134	−154.717	1015.0	−3.5	87	334	0.5	0.119	49.0	20518	9	St
RS069	2009092706	73.689	−155.519	1016.3	−2.4	89	276	5.2	−0.871	56.5	19581	9	St

RS070	2009092712	73.722	−155.737	1018.1	−2.3	91	307	1.9	−1.049	41.4	21594	10	unknown
RS071	2009092718	73.449	−155.911	1019.3	−2.7	95	11	2.9	−0.974	47.2	20708	9	St,Sc
RS072	2009092800	73.413	−158.773	1021.4	−1.4	95	327	4.4	−0.220	65.8	18640	10	St,Sc
RS073	2009092806	72.705	−157.806	1022.0	−1.0	91	178	2.2	2.155	52.3	20071	10	St,Sc
RS074	2009092812	71.991	−156.004	1022.2	−1.0	78	178	3.0	2.186	138.4	13786	10	unknown
RS075	2009092818	71.674	−155.001	1021.3	−1.2	96	192	4.1	2.379	47.8	20651	10	St,Sc
RS076	2009092900	71.805	−155.331	1019.8	0.0	78	292	4.2	3.031	73.2	17898	10	St
RS077	2009092906	71.914	−154.000	1018.0	−1.0	93	72	0.5	1.828	62.8	18879	9	St
RS078	2009092912	72.185	−154.004	1016.6	−1.5	94	68	1.6	0.313	115.4	14928	10	unknown
RS079	2009092918	72.345	−154.425	1015.1	−1.8	98	93	5.9	−0.285	60.7	19060	10	St
RS080	2009093000	72.256	−155.401	1014.1	−1.3	83	133	4.7	0.417	65.5	18575	10	St,Sc
RS081	2009093006	72.444	−157.656	1013.5	−2.0	95	102	2.9	1.679	45.6	20888	10	St,Sc
RS082	2009093012	72.867	−157.630	1014.0	−3.4	92	112	6.7	1.917	55.3	19633	10	unknown
RS083	2009093018	72.906	−157.663	1014.6	−5.3	89	105	6.8	1.878	40.6	21594	10	St
RS084	2009100100	72.702	−157.932	1015.1	−4.1	88	72	2.0	1.574	53.4	19883	10	St
RS085	2009100106	72.208	−157.414	1015.9	−5.0	87	93	4.8	1.887	51.4	20108	10	unknown
RS086	2009100112	71.729	−155.194	1016.6	−4.2	83	73	6.0	3.477	52.9	19931	10	unknown
RS087	2009100118	71.668	−154.989	1018.8	−4.5	83	70	2.9	3.087	42.5	21351	10	St
RS088	2009100200	71.691	−154.937	1021.5	−3.9	77	100	2.0	3.317	76.1	17616	10	St
RS089	2009100206	71.734	−155.138	1024.5	−5.0	83	83	3.0	3.133	73.4	17867	10	unknown
RS090	2009100212	71.744	−155.137	1026.6	−4.2	79	94	4.5	2.941	117.8	14799	10	unknown
RS091	2009100218	71.804	−155.347	1028.1	−4.0	85	137	6.1	2.578	123.3	14543	10	St
RS092	2009100300	71.804	−155.372	1028.4	−3.4	78	119	7.7	2.848	52.1	19939	10	St
RS093	2009100306	71.787	−156.986	1027.1	−2.0	79	107	8.3	3.080	61.9	19026	10	unknown
RS094	2009100312	71.574	−160.544	1023.8	−2.0	81	98	12.8	1.995	80.4	17336	10	unknown
RS095	2009100315	71.506	−161.904	1022.7	−1.6	80	108	11.8	2.201	48.2	20615	10	unknown
RS096	2009100318	71.954	−162.068	1023.4	−2.0	86	77	11.5	1.871	45.4	21013	10	Sc,St
RS097	2009100321	72.489	−161.999	1024.8	−4.0	89	75	10.8	2.293	51.8	20167	10	St
RS098	2009100400	72.996	−161.952	1025.9	−4.4	90	77	10.7	1.176	47.1	20765	10	St
RS099	2009100403	73.505	−162.016	1026.9	−4.4	99	88	12.2	1.274	50.4	20328	10	St
RS100	2009100406	73.870	−163.460	1027.8	−4.4	93	70	11.5	1.242	53.8	19900	10	St
RS101	2009100412	74.602	−166.443	1029.5	−4.3	82	66	7.7	−0.125	59.8	19226	9	St,Sc
RS102	2009100418	75.275	−166.408	1029.2	−4.4	84	50	5.3	0.607	63.7	18806	10	St
RS103	2009100500	74.792	−170.391	1028.2	−4.7	82	18	3.1	0.173	50.7	20260	7	St,Sc,As
RS104	2009100506	74.618	−170.537	1026.8	−4.8	84	353	4.3	0.289	69.6	18245	10	St
RS105	2009100512	74.541	−167.484	1026.0	−5.3	81	106	1.3	0.071	51.9	20104	10	St

RS106	2009100518	74.435	−165.751	1025.4	−4.7	83	185	0.5	0.409	47.1	20704	10	St
RS107	2009100600	74.438	−165.733	1025.5	−4.1	80	213	4.1	0.510	53.9	19851	10	St
RS108	2009100606	73.991	−163.943	1027.3	−3.9	85	239	3.5	0.859	45.2	20942	10	St, Sc
RS109	2009100612	73.994	−163.972	1029.0	−2.5	79	263	6.8	0.792	49.6	20387	10	unknown
RS110	2009100618	73.686	−166.393	1030.9	−2.4	89	246	8.1	0.264	51.1	20216	10	St
RS111	2009100700	73.506	−168.008	1032.7	−1.3	96	233	9.3	0.326	57.5	19495	10	St
RS112	2009100703	73.052	−168.005	1032.9	−1.8	92	251	7.8	2.161	59.3	19292	10	St
RS113	2009100706	72.546	−167.973	1033.3	−2.0	80	201	0.6	2.065	48.9	20544	10	St
RS114	2009100709	72.039	−168.009	1033.0	−2.2	80	131	3.0	2.563	60.7	19186	10	St
RS115	2009100712	71.541	−168.031	1031.5	−0.5	74	94	8.7	2.922	59.0	19374	10	unknown
RS116	2009100718	72.499	−167.002	1031.8	−0.9	74	95	8.7	2.817	42.8	21400	10	St
RS117	2009100800	73.490	−166.024	1033.8	−2.9	84	108	8.7	0.084	50.9	20318	10	St
RS118	2009100803	73.033	−165.976	1032.3	−2.2	86	114	10.9	1.889	48.4	20640	10	
RS119	2009100806	72.538	−166.005	1030.7	−1.3	84	94	13.2	2.896	50.2	20434	9	St
RS120	2009100809	72.021	−165.999	1027.4	−0.2	79	98	15.5	2.593	52.4	20171	10	unknown
RS121	2009100812	71.546	−165.993	1024.2	−0.3	90	91	16.4	2.714	72.6	18123	10	unknown
RS122	2009100818	72.374	−165.098	1024.9	−0.4	81	84	11.6	2.756	54.9	19883	8	Sc,St
RS123	2009100900	73.395	−164.053	1024.6	−3.4	85	110	15.2	0.235	52.4	20172	10	St,Sc
RS124	2009100903	73.057	−164.031	1021.2	−1.7	88	100	13.8	1.573	48.2	20710	10	St
RS125*	2009100906	72.552	−163.971	1017.0	0.3	86	97	15.7	2.752	−	−	10	unknown
RS126	2009100909	72.033	−163.954	1014.6	0.5	85	91	14.7	2.069	50.2	20453	10	unknown
RS127	2009100912	71.519	−163.944	1012.3	0.4	89	102	10.8	2.941	39.7	21938	10	St
RS128	2009100918	72.460	−163.014	1011.9	0.8	95	119	14.0	2.143	48.7	20645	10	Ns
RS129	2009101000	73.505	−162.000	1011.0	0.1	98	114	12.8	0.610	55.6	19830	10	Ns
RS130	2009101003	73.051	−161.984	1009.7	0.3	99	204	8.6	0.744	57.9	19573	10	St
RS131	2009101006	72.529	−162.017	1011.5	0.7	96	231	9.3	1.906	27.4	23964	10	unknown
RS132	2009101009	72.021	−162.031	1013.1	1.1	95	278	3.8	1.806	54.8	19939	10	unknown
RS133	2009101012	71.527	−162.005	1013.6	1.0	100	2	5.7	2.095	104.4	15892	10	unknown
RS134	2009101018	71.216	−159.100	1011.8	1.3	100	33	8.1	1.584	42.7	21495	6	St,As
RS135	2009101100	71.150	−161.228	1011.1	0.7	100	52	14.7	2.009	36.5	22461	10	St
RS136	2009101106	70.303	−164.760	1005.9	1.5	90	84	14.3	2.013	33.4	22996	10	unknown

* Maximum height information of RS125 had not been recorded.

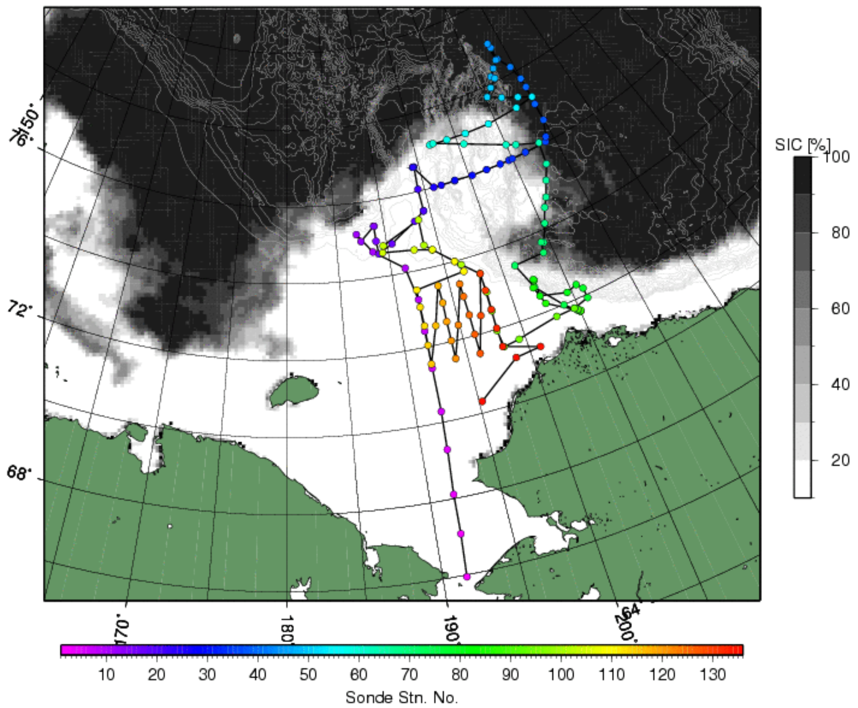


Figure 2.1-1. Radiosonde station map and sea-ice concentration on 10 October 2009. The sea-ice data was provided by JAXA.

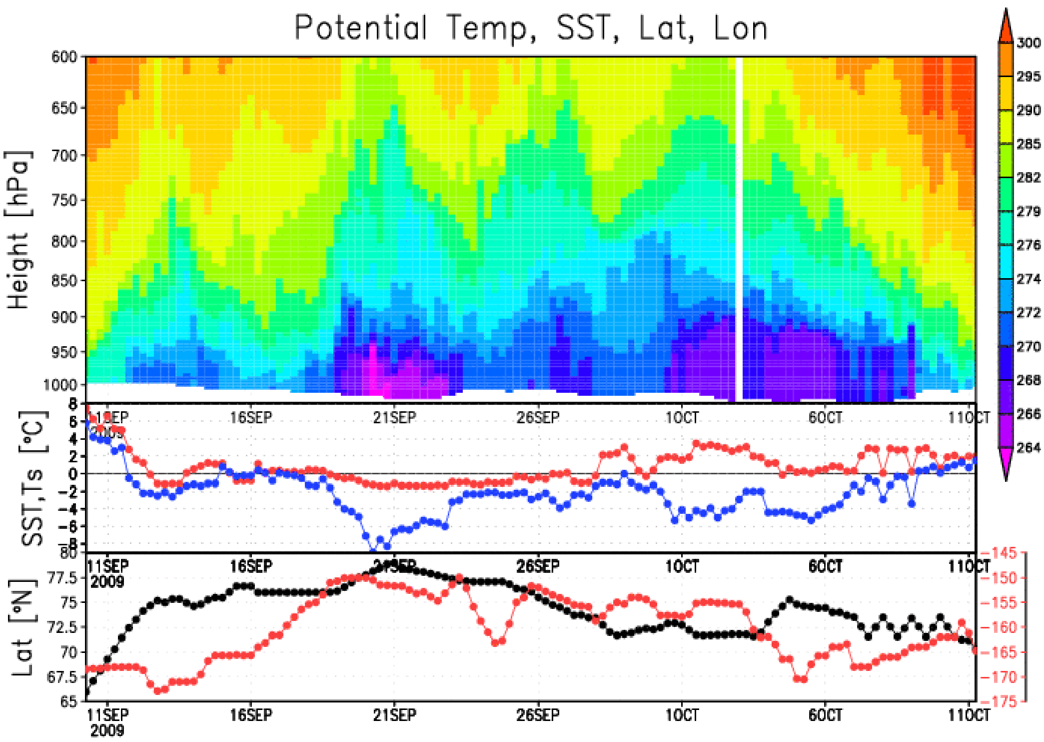


Figure 2.1-2. Time-height section of potential temperature, and time series of sea (red) / air (blue) surface temperatures and GPS positions.

2.2. Doppler Radar

(1) Personnel

Jun Inoue (JAMSTEC)   Principal Investigator
Ito Masashi (JAMSTEC/Mie University)
Souichiro Sueyoshi (GODI)
Satoshi Okumura   (GODI)
Norio Nagahama   (GODI)
Ryo Kimura (GODI)

(2) Objectives

Low level clouds over the Arctic Ocean which usually dominate during summer have a key role for sea/ice surface heat budget. However, a bottom boundary condition has been dramatically changed in last 10 years due to the rapid sea-ice retreat. To understand the recent Arctic cloud structure, three dimensional radar echo structure and wind fields of rain/snow clouds was obtained by C-band Doppler radar observation.

(3) Parameters

Radar reflectivity factor (dBZ)
Doppler velocity (m/s)
Velocity width (m/s)

(4) Instruments and methods

The specifications of R/V MIRAI shipboard Doppler radar (RC-52B, Mitsubishi Electric Co. Ltd., Japan) are as follows.

Frequency:	5290MHz (C-band)
Beam Width:	better than 1.5 degrees
Transmit Power:	250kW (Peak Power)
Signal Processor:	RVP-7 (Vaisala Inc. Sigmet Product Line, U.S.A)
Inertial Navigation Unit:	PHINS (Ixsea SAS, France)
Application Software:	IRIS/Open Ver.8.05.10
	(Vaisala Inc. Sigmet Product Line, U.S.A)

Measured parameters are Radar reflectivity factor (dBZ), Doppler velocity (m/s), and velocity width (m/s). We checked transmitted frequency, mean output power and pulse repetition frequency (PRF) every two days. The transmit pulse width and the receiver performance were checked before and after the observation. The observation was performed throughout in the Arctic Ocean. During the observation, the volume scan consisting of 21 PPIs was conducted every 10 minutes. Meanwhile, a surveillance PPI scan was performed every 30 minutes. In the interval of the volume scan cycles, RHI (Range Height Indicator) scans were operated to obtain detailed vertical cross sections with Doppler-mode. The parameters for above scans are listed in Table 2.2-1.

(5) Data archives

The raw data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC.

(6) Preliminary results

Stratus clouds continuously appeared below 2 km height with maximum echo reflectivity less than 15dBZ. Sometimes the echo top exceeded 4 km with two or three layers. Due to cold advection from sea-ice area induced by a persistent high pressure system, small convective clouds also frequently formed banded structure (Figure 2.2-1). In the offshore region of Barrow, Alaska, well developed convective cells induced by southeasterly winds were also observed.

On 10 October, a polar low passed over Mirai. Based on AVHRR infrared satellite images, its horizontal scale was 800km. The radar range covered most of the area. Echo top of the outer cloud bands which brought frozen rain exceeded 6 km (Figure 2.2-2). After passing the core region with few echo, wind direction shifted from southeasterly to southwesterly.

Table 2.2-1 Selected parameters of C-band Doppler radar

	Surveillance PPI	Volume scan	RHI
Pulse width	2.0 [μs]	0.5 [μs]	
Scan speed	18 [deg/sec]		Automatic
PRF	260 [Hz]	900/720 [Hz]	
Sweep integration	32 samples	50 samples	32samples
Ray spacing	about 1.0 [deg]		about 0.2 [deg]
Bin spacing	250 [m]		
Elevations	0.5	0.5, 1.0, 1.5, 2.1, 2.8, 3.5, 4.3, 5.1, 5.9, 6.8, 7.6, 8.5, 9.4, 10.4, 11.5, 12.7, 14.0, 15.5, 16.8, 18.8, 21.3	0.0 to 60.0
Azimuths	Full Circle		Optional
Range	300 [km]	160 [km]	
Software Filters	No filter	Dual-PRF velocity unfolding	

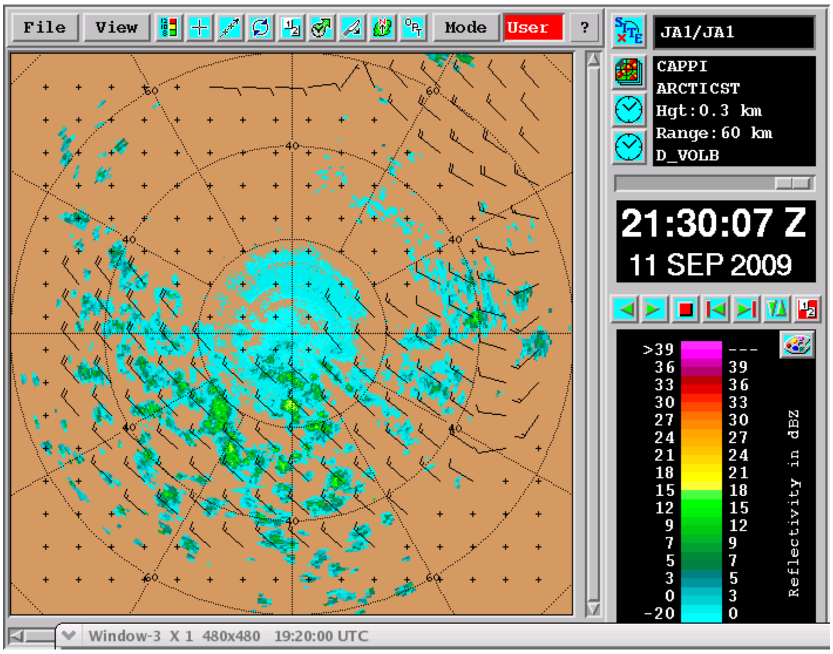


Figure 2.2-1. An example of snow bands during cold advection period (11 September 2009).

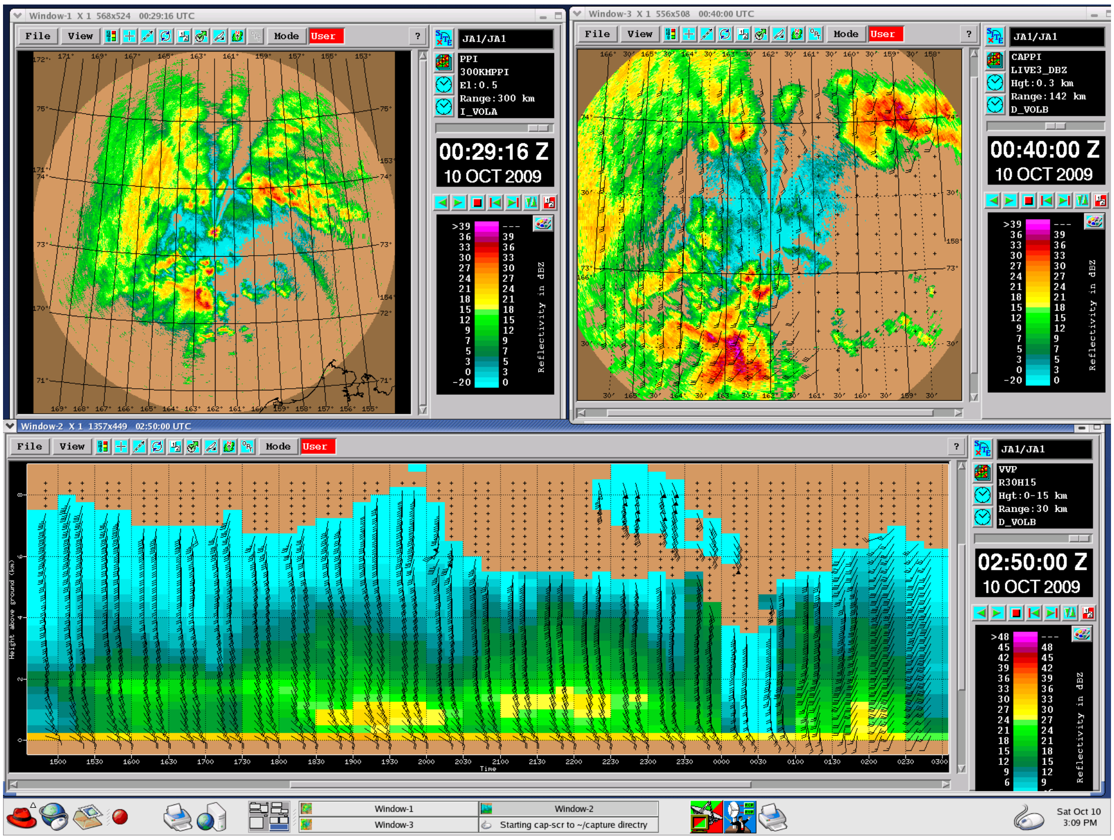


Figure 2.2-2. A snapshot of a polar low observed on 10 October 2009.

2.3. Surface Meteorological Observation

(1) Personnel

Kunio Yoneyama	(JAMSTEC): Principal Investigator (not on-board)
Shinya Okumura	(GODI)
Souichiro Sueyoshi	(GODI)
Satoshi Okumura	(GODI)
Norio Nagahama	(GODI)
Ryo Kimura	(GODI)
Ryo Ohyama	(MIRAI Crew)

(2) Objectives

Surface meteorological parameters are observed as a basic dataset of the meteorology. These parameters bring us the information about the temporal variation of the meteorological condition surrounding the ship.

(3) Instruments and methods

Surface meteorological parameters were observed throughout the MR09-03 cruise. During this cruise, we used three systems for the observation.

i. MIRAI Surface Meteorological observation (SMet) system
ii. Shipboard Oceanographic and Atmospheric Radiation (SOAR) system

i. MIRAI Surface Meteorological observation (SMet) system

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

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

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

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

SCS recorded PRP data every 6 seconds, while Zeno/Met data every 10 seconds. Instruments and their locations are listed in Table.2.3-3 and measured parameters are listed in Table.2.3-4.

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

i. Young Rain gauge (SMet and SOAR)

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

ii. Barometer (SMet and SOAR)
Comparison with the portable barometer value, PTB220CASE, VAISALA.
iii. Thermometer (air temperature and relative humidity) (SMet and SOAR)
Comparison with the portable thermometer value, HMP41/45, VAISALA.

(4) Preliminary results

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

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

(5) Data archives

These meteorological data will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC just after the cruise.

(6) Remarks

i. SST (Sea Surface Temperature) data was available in the following periods.
07:00UTC 29 Aug. 2009 – 05:55UTC 6 Sep. 2009
22:00UTC 7 Sep. 2009 – 13:55UTC 15 Oct 2009
03:30UTC 16 Oct. 2009 – 05:55UTC 23 Oct 2009

ii. In the following period, FRSR data acquisition was suspended to prevent damage to the shadow-band from freezing.
15:15UTC 13 Sep. 2009 – 04:57UTC 09 Oct 2009

iii. In the following period, SMet data logging was suspended due to PC trouble.
01:31UTC 16 Oct. 2009 – 02:41UTC 16 Oct 2009

iv. In the following periods, SOJ data was not updated due to the Radio Navigation System trouble.
13:10:47UTC 28 Aug. 2009 – 14:11:06UTC 28 Aug. 2009
04:20:47UTC 5 Sep. 2009 – 04:25:28UTC 5 Oct 2009

Table.2.3-1 Instruments and installations of MIRAI Surface Meteorological observation system

Sensors	Type	Manufacturer	Location (altitude from surface)
Anemometer	KE-500	Koshin Denki, Japan	foremast (24 m)
Tair/RH	HMP45A	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	compass deck (21 m)
			starboard side and port side
Thermometer: SST	RFN1-0	Koshin Denki, Japan	4th deck (-1m, inlet -5m)
Barometer	Model-370	Setra System, USA	captain deck (13 m)
			weather observation room
Rain gauge	50202	R. M. Young, USA	compass deck (19 m)
Optical rain gauge	ORG-815DR	Osi, USA	compass deck (19 m)
Radiometer (short wave)	MS-801	Eiko Seiki, Japan	radar mast (28 m)
Radiometer (long wave)	MS-200	Eiko Seiki, Japan	radar mast (28 m)
Wave height meter	MW-2	Tsurumi-seiki, Japan	bow (10 m)

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

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 Ship's speed	knot	Mirai log, DS-30 Furuno
4 Ship's heading	degree	Mirai gyro, TG-6000, Tokimec
5 Relative wind speed	m/s	6sec./10min. averaged
6 Relative wind direction	degree	6sec./10min. averaged
7 True wind speed	m/s	6sec./10min. averaged
8 True wind direction	degree	6sec./10min. averaged
9 Barometric pressure	hPa	adjusted to sea surface level 6sec. averaged
10 Air temperature (starboard side)	degC	6sec. averaged
11 Air temperature (port side)	degC	6sec. averaged
12 Dewpoint temperature (starboard side)	degC	6sec. averaged
13 Dewpoint temperature (port side)	degC	6sec. averaged
14 Relative humidity (starboard side)	%	6sec. averaged
15 Relative humidity (port side)	%	6sec. averaged
16 Sea surface temperature	degC	6sec. averaged
17 Rain rate (optical rain gauge)	mm/hr	hourly accumulation
18 Rain rate (capacitive rain gauge)	mm/hr	hourly accumulation
19 Down welling shortwave radiation	W/m2	6sec. averaged
20 Down welling infra-red radiation	W/m2	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 (Zeno/Met)	Type	Manufacturer	Location (altitude from surface)
Anemometer	05106	R.M. Young, USA	foremast (25 m)
Tair/RH	HMP45A	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	foremast (23 m)
Barometer	61202V	R.M. Young, USA	
with 61002 Gill pressure port		R.M. Young, USA	foremast (23 m)
Rain gauge	50202	R.M. Young, USA	foremast (24 m)
Optical rain gauge	ORG-815DA	Osi, USA	foremast (24 m)

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)

Table.2.3-4 Parameters of SOAR system

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 SOG	knot	
4 COG	degree	
5 Relative wind speed	m/s	
6 Relative wind direction	degree	
7 Barometric pressure	hPa	
8 Air temperature	degC	
9 Relative humidity	%	
10 Rain rate (optical rain gauge)	mm/hr	
11 Precipitation (capacitive rain gauge)	mm	reset at 50 mm
12 Down welling shortwave radiation	W/m2	
13 Down welling infra-red radiation	W/m2	
14 Defuse irradiance	W/m2	

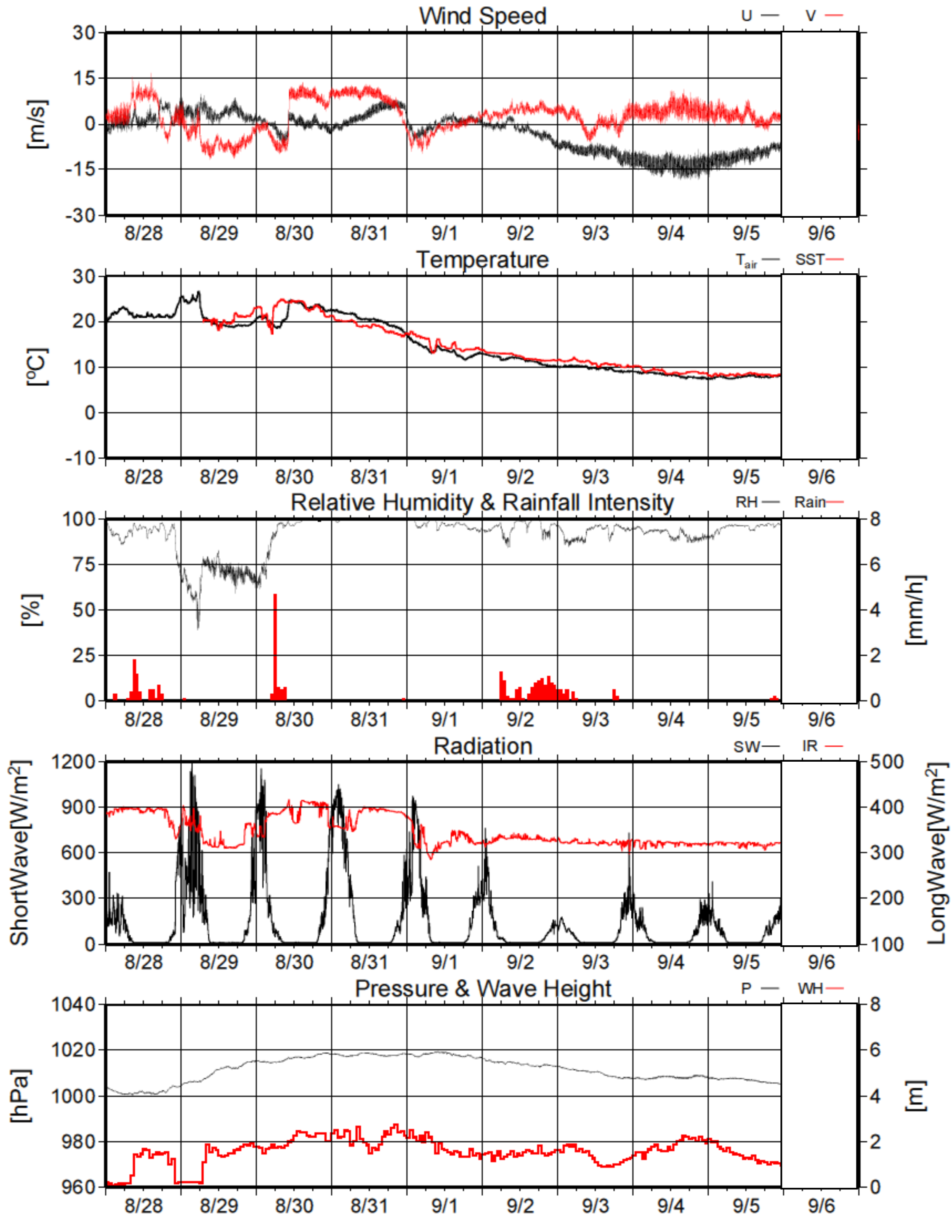


Figure 2.3-1 Time series of surface meteorological parameters during the MR09-03 cruise

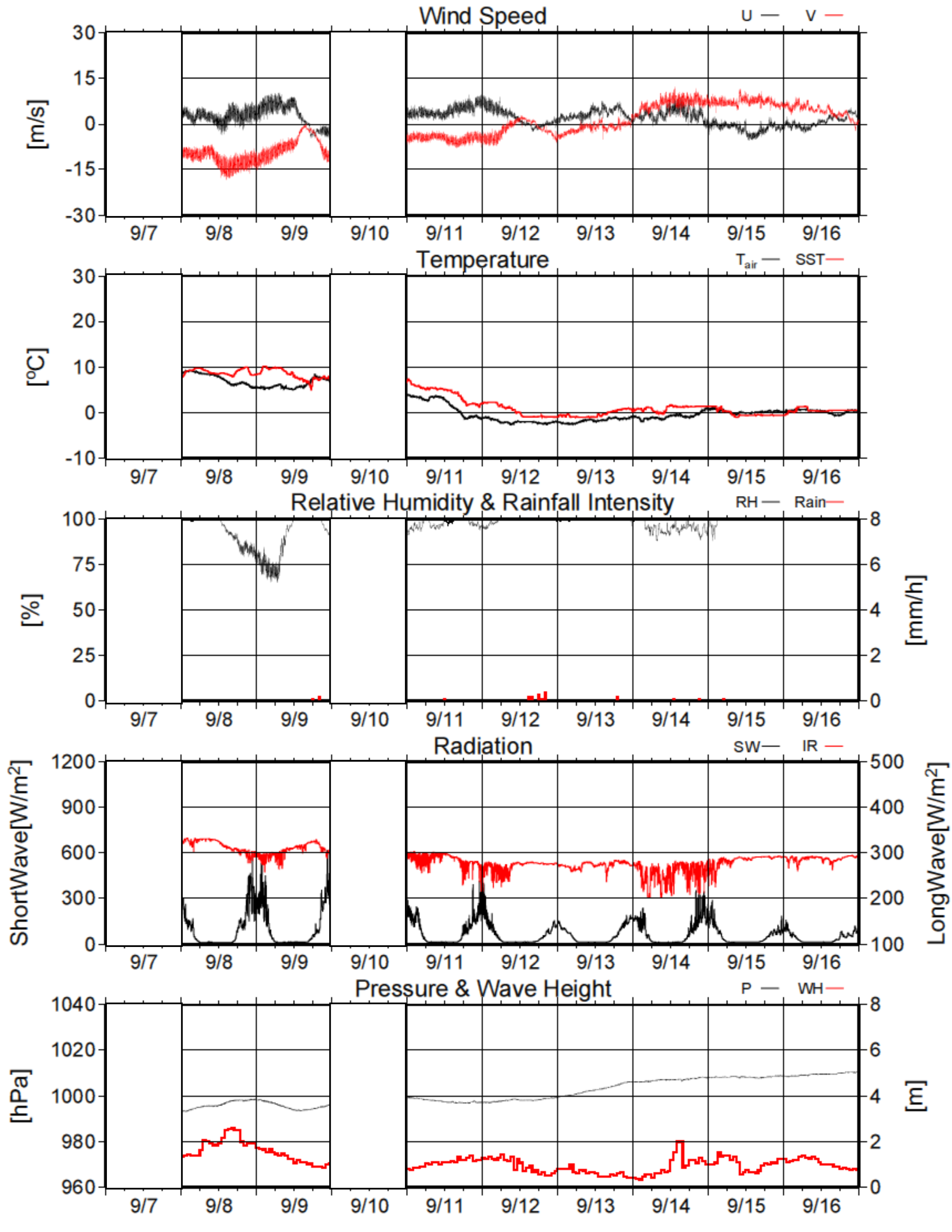


Figure 2.3-1 (Continued)

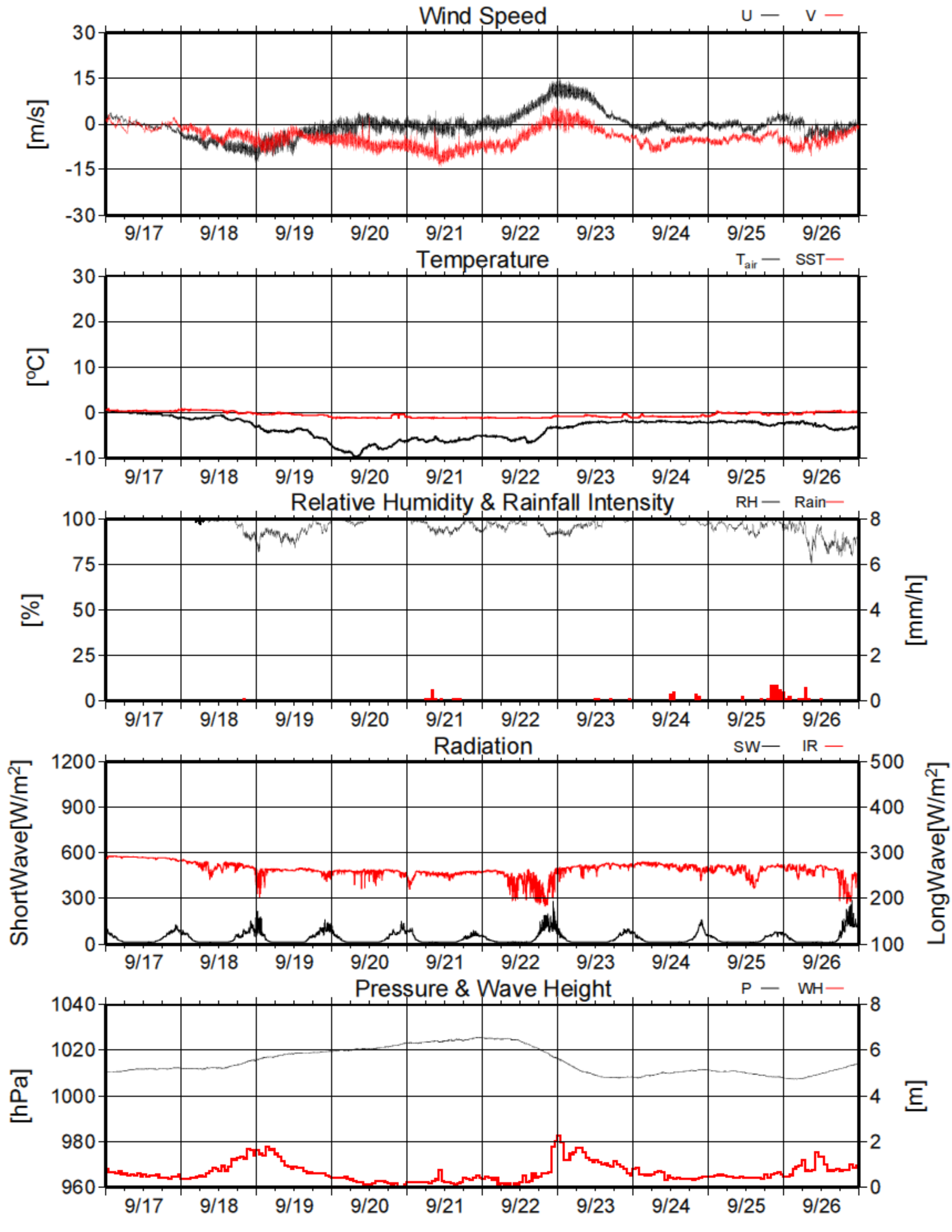


Figure 2.3-1 (Continued)

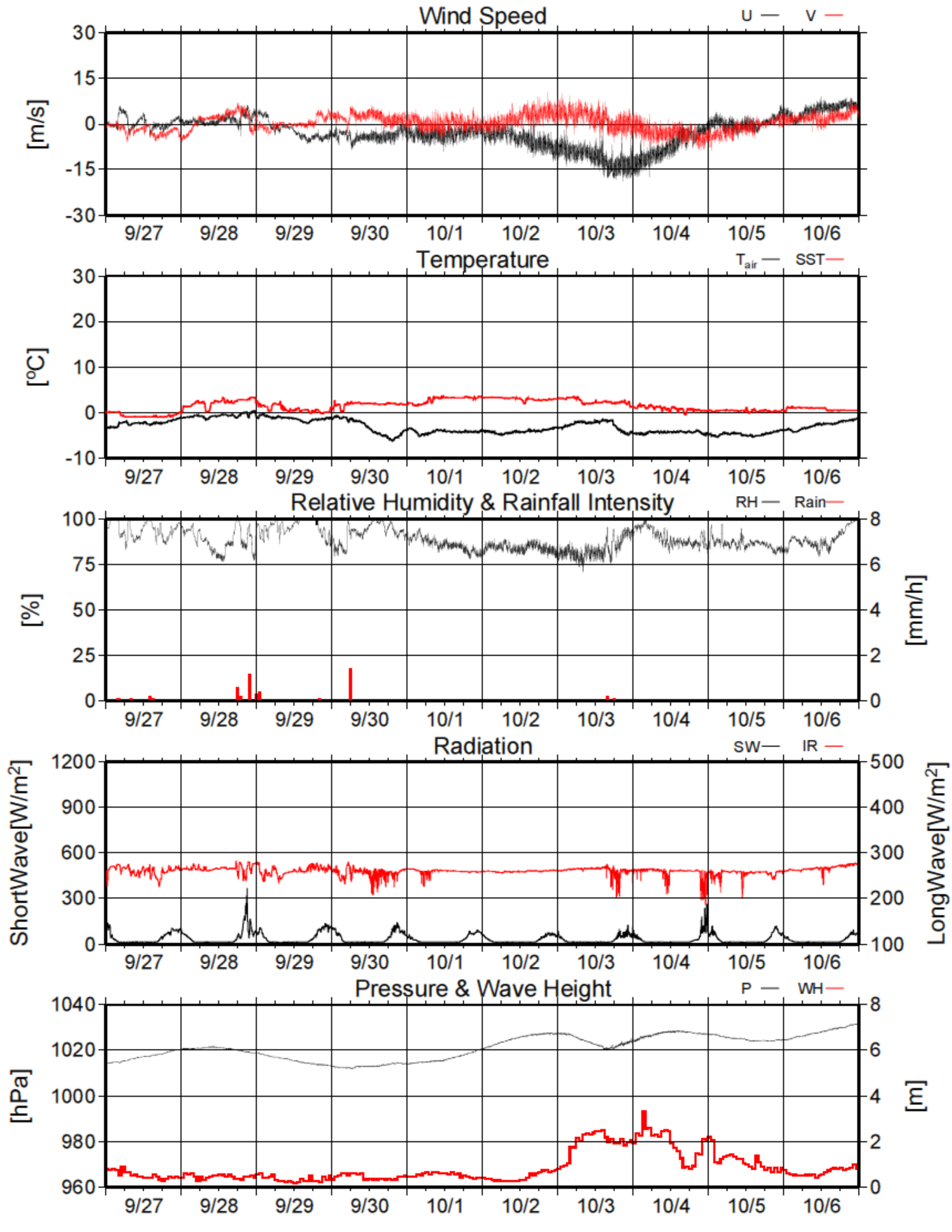


Figure 2.3-1 (Continued)

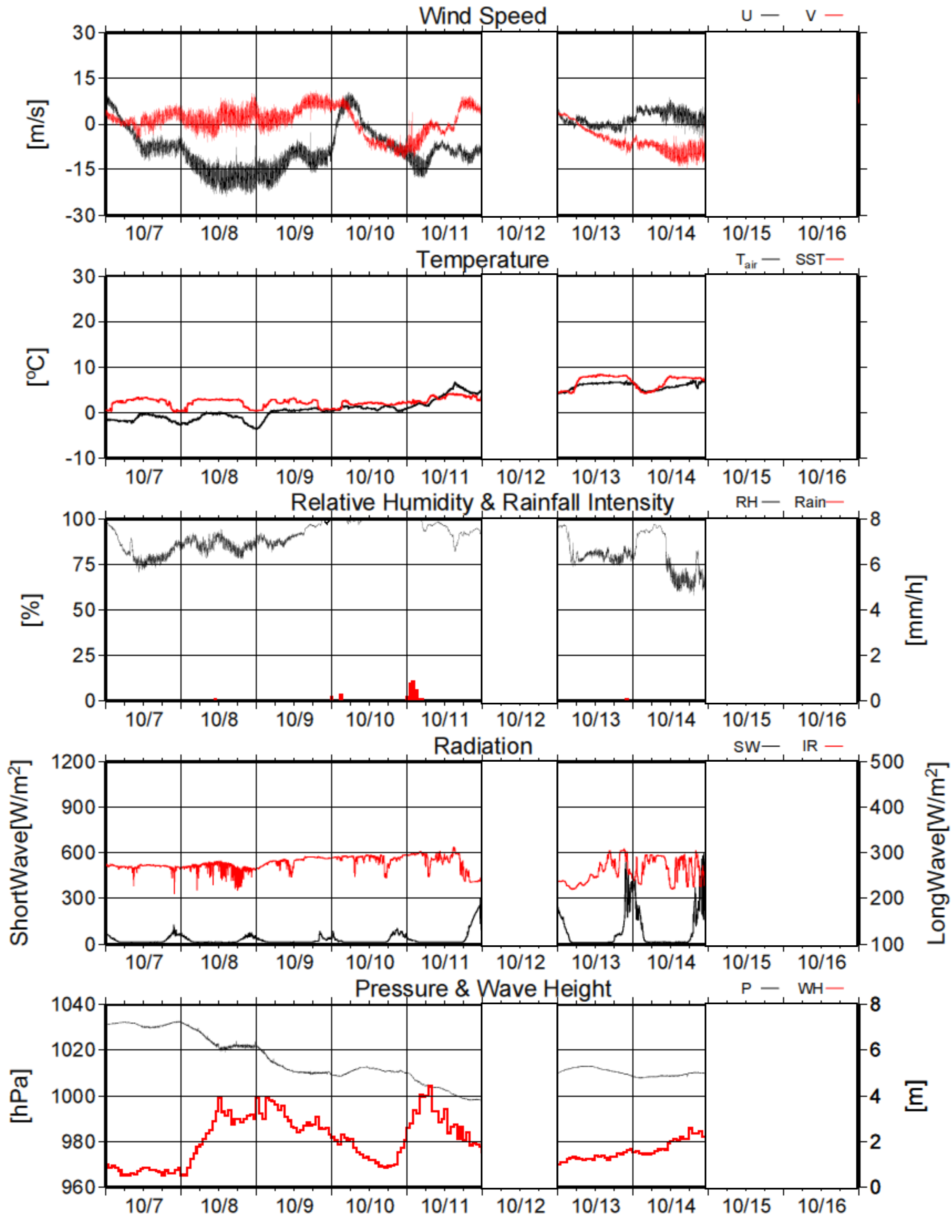


Figure 2.3-1 (Continued)

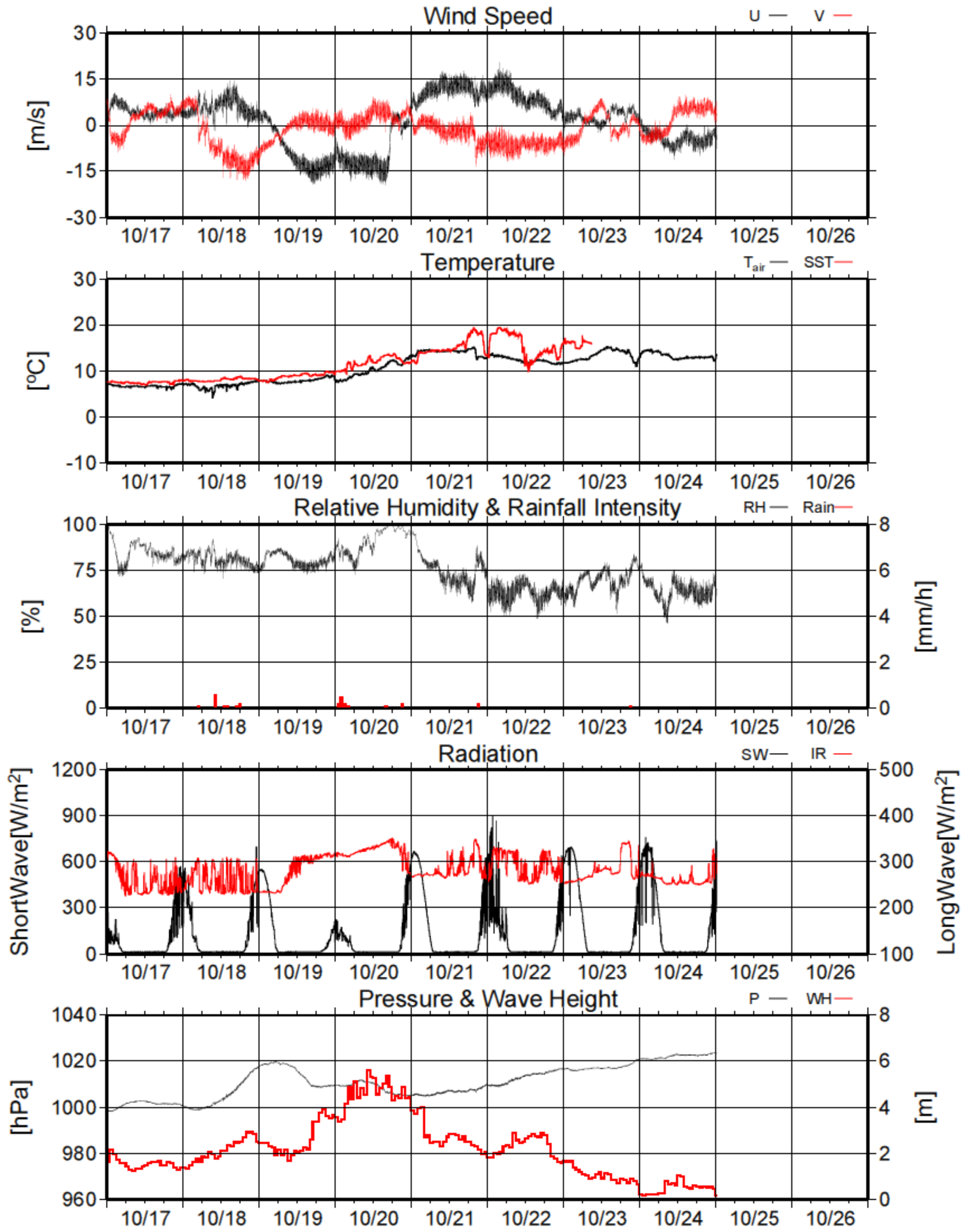


Figure 2.3-1 (Continued)

2.4. Ceilometer

(1) Personnel

Kunio Yoneyama	(JAMSTEC): Principal Investigator (not on-board)
Shinya Okumura	(GODI)
Souichiro Sueyoshi	(GODI)
Satoshi Okumura	(GODI)
Norio Nagahama	(GODI)
Ryo Kimura	(GODI)
Ryo Ohyama	(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 30 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 (CT-25K, VAISALA, Finland) throughout the MR09-03 cruise.

Major parameters for the measurement configuration are as follows;

Laser source:	Indium Gallium Arsenide (InGaAs) Diode
Transmitting wavelength:	905±5 mm at 25 degC
Transmitting average power:	8.9 mW
Repetition rate:	5.57 kHz
Detector:	Silicon avalanche photodiode (APD)
	Responsibility at 905 nm: 65 A/W
Measurement range:	0 ~ 7.5 km
Resolution:	50 ft in full range
Sampling rate:	60 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 30 m (100 ft).

(5) Preliminary results

Figure 2.4-1 shows the time series of the lowest, second and third cloud base height during the cruise.

(6) Data archives

The raw data obtained during this cruise will be submitted to the Data Integration and Analysis Group (DIAG) in JAMSTEC.

(7) Remarks

1. Window cleaning;

00:12UTC 29 Aug. 2009

17:43UTC 26 Sep. 2009

22:00UTC 15 Oct. 2009

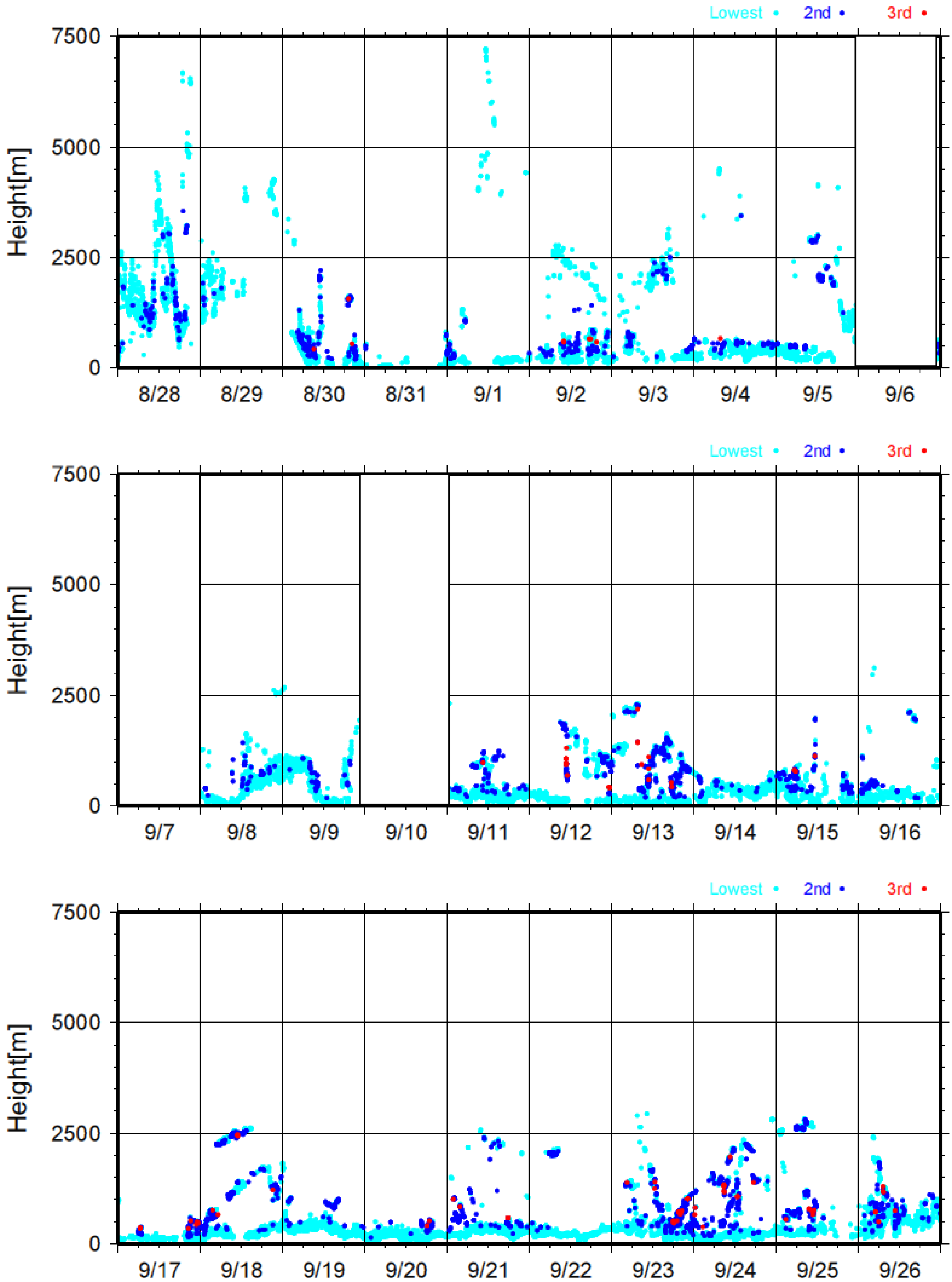


Figure 2.4-1 Lowest, 2nd and 3rd cloud base height during the MR09-03 cruise

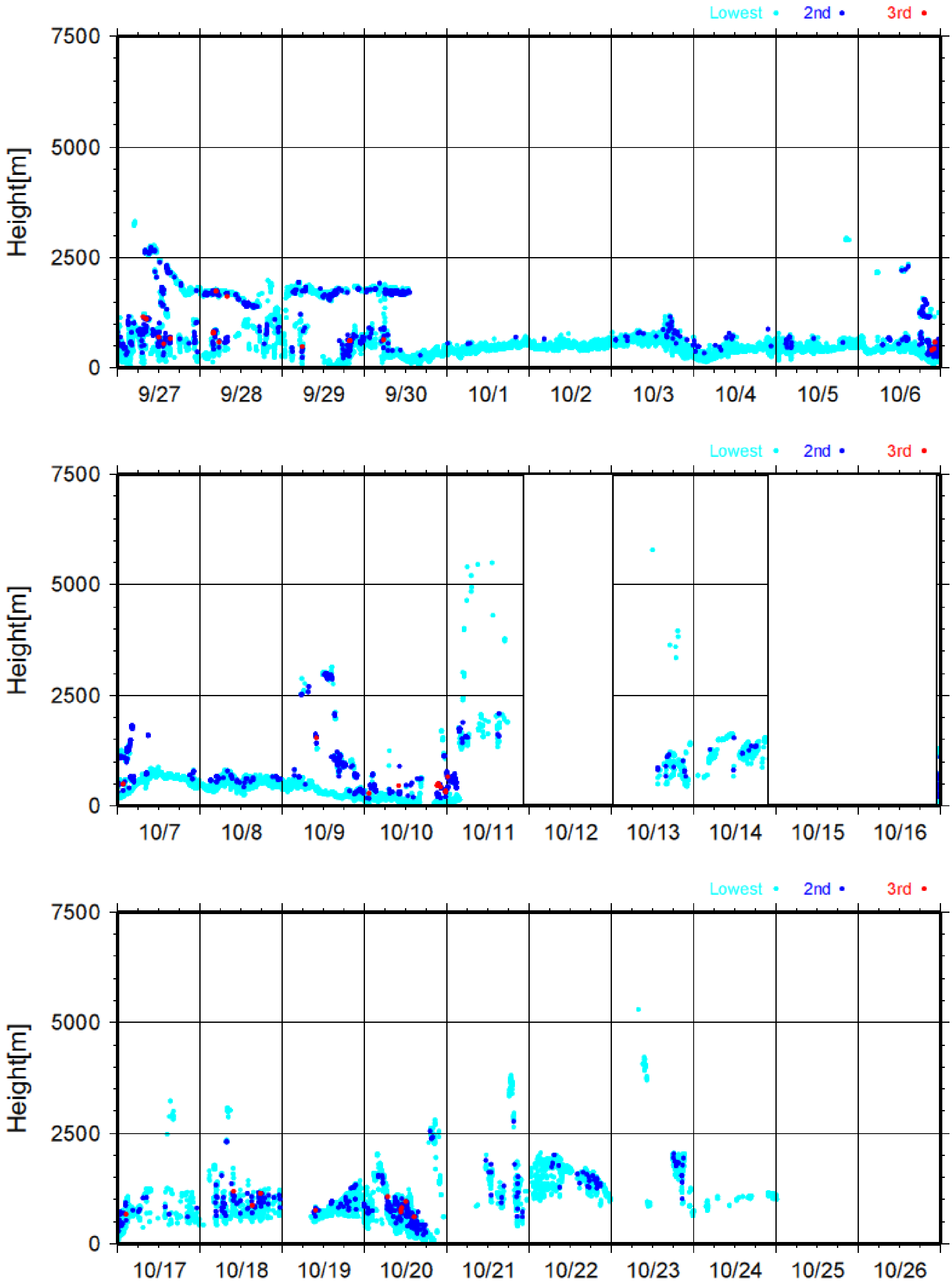


Figure 2.4-1 (Continued)

2.5. Measurements of DMS in surface seawater and atmosphere
- over the northern North Pacific during MR09-03 (Leg 1) -

(1) Personnel

Ippei Nagao (Nagoya University)

(2) Backgrounds and Objectives

An accurate estimation of the sea-air DMS flux is required to improve an estimation of the impact of DMS on the aerosol formation in the marine air. Thus far, the bulk method which is a traditional one but includes a large uncertainty has been used, because no devices of trace gases such as DMS have been presented for the eddy correlation (EC) method, which is more accurate than the bulk method. Utilizing a chemiluminescence induced by reaction of DMS with fluorine, I have attempted to develop the fast measurement system of DMS for the EC method. In this cruise, these two methods are applied to the DMS flux measurement on board R/V Mirai (MR0903 Leg 1) over the northern North Pacific. Then the results of two methods will be analyzed to improve the DMS flux calculation.

(3) Instruments and methods

i. Measurement system by GC/FPD for the bulk method

Atmospheric DMS concentration

Sample air was introduced through 5 m long Teflon-tube (OD: 6mm, and ID: 4 mm) from the compass deck to the Environmental Research Laboratory of R/V Mirai with the flow rate at 30~36 L/min by sampling pump (Iwaki Co. Ltd.). This sample air was separated in the manifold to be introduced to the DMS analysis system with the flow rate at 150 ml min^{-1}. The sample air was then concentrated on the concentration tube packed with Tenax-GR (60/80 mesh, GL Science Co. Ltd.) at -75 ℃ by liquid CO_2 after removing water vapor by perma pure dryer (MD-070-48F, GL Science Co. Ltd.). Then the concentration tube was abruptly heated to +190 ℃ within 1.5 min and DMS trapped on Tenax-GR was introduced to Gas Chromatography equipped with a flame photometric detector (GC-14B, Shimadzu Co. Ltd.) by the carrier gas (ultra high purified (UHP) nitrogen (N_2) gas). Analysis column of this system was β-β' oxydipropionitrile glass column (ZO-1, Shimadzu Co. Ltd.). Temperature in the column oven was set to be 60 ℃. Calibration of this system was performed with DMS standard gas (5.16 ppmv, N_2 base, Nagoya-Kosan Co. Ltd.). The detection limit (DL) was estimated to be 30 pptv in 4.5 liter of STP. The precision was ±10%.

Seawater DMS concentration

100mL of seawater samples were taken to the brown glass bottles in the sea surface water monitoring laboratory of R/V Mirai. After overflow of seawater, the sample bottle was immediately sealed with butyl gum cap with care to exclude air bubbles. Then the analysis of DMS was performed on board within an hour by a purge and trap. A 25 ml of seawater sample was introduced into a degasification vessel by syringe through GF/F filter. Then sample water was sparged for 10 min by the UHP N_2 gas. The flow rate was about 120 ml min^{-1}. The extracted gas was then concentrated on the concentration tube (60/80 mesh Tenax-GR, GL Science Co. Ltd.). Then the determination of DMS was carried out by the same procedures as those for air samples. Reproducibility of this system was about ± 12%, and the detection limit was about 0.1 nM in 25 ml water sample.

ii. Measurement system by fluorine induced chemiluminescence for the EC method

High speed sensor for DMS concentration based on its fast chemiluminescence reaction with molecular fluorine (F_2) was developed following the document by Hills et al [1998] to measure the atmospheric DMS concentration within a 0.1 second for the eddy correlation method. Intense chemiluminescence occurred upon reaction of F_2 with a sulfur-containing compound, as follows;

CH_3SCH_3 (DMS) + F_2 ➔ many steps ➔ $HCF^{\dagger}$and HF* (R1)

$HCF^{\dagger}$ ➔ HCF + *hv* (λ =500~700 nm) (R2)

HF* ➔ HF + *hv* (λ =660~750 nm) (R3)

Emission in the wavelength range 500~750 nm was monitored with a photomultiplier tube (H7421 and R2228P, Hamamatsu Photonics, Co. Ltd.). Under suitable conditions, residence time of the sample air in the reaction cell was very short (much less than 0.1 sec). Assuming that reaction (R1) was a pseudo 1^{st} order reaction, reaction (R1) was expected to almost complete within the residence time of sample air in the cell. Product gases were evacuated from the reaction cell and then scrubbed of F_2 and HF via a chemical trap, which converts excess F_2 to CF_4 on activated carbon. This system was installed on the top pf the foremast of R/V Mirai. Sample air was introduced from the top of the foremast through a Teflon-tube (10mm OD. and c.a. 3m of length), and the sample air after analysis was exhausted outside. Signals of this reaction were recorded in personal computer. For calibration, the output of this reaction with DMS standard gas (1.0 ppmv) was also measured.

Estimation of Flux

The DMS fluxes by the bulk method and the EC method can be calculated as follows:

$$F_{bulk} = K_W (C_W - C_A / H_{DMS}) \quad \text{(Eq.1)}$$

$$F_{EC} = \frac{1}{T}\int_0^T w' C_A' dt \quad \text{(Eq.2)}$$

where Kw is the exchange coefficient of DMS at the sea surface. C_W and C_A are the DMS concentrations in the surface seawater and the atmosphere, respectively. H_{DMS} is the Henry constant of DMS. T is the time for integration (generally about 30min). w' and C_A' are the fluctuations of the vertical wind speed and the DMS concentration in the atmosphere from their average values, respectively. For the bulk method, C_W and C_A were measured by the GC/FPD system, and for the EC method, C_A variations within 0.1 sec were measured by the chemiluminescence system. The vertical component of wind speed as well as inclination and acceleration of ship movement measured by the CO_2 flux measurement system by Okayama University will be used for the DMS flux calculation.

(4) Preliminary results

Figure 2.5-1(a) shows the temporal variations in the DMS concentrations measured by this GC/FPD system. Figure 2.5-1(b) shows the latitudinal distribution of the seawater DMS concentration. High atmospheric DMS concentration was observed on Aug. 31 and Sep. 1 (Figure 2.5-1(a)), while the seawater DMS concentrations was high on Sep. 1 when R/V Miral passed between 46 N and 48 N (Figure 2.5-1(b)). Figure 2.5-2 shows an example of the results of chemiluminescence induced by F_2 on Aug. 31 0945UTC. Significant signals were obtained when the air sample was introduced to this device as compared to that when zero air (UHP N_2 gas) was introduced. This signal can be attributed to the reaction of DMS with F_2.

(5) Data archives

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

(a) (b)

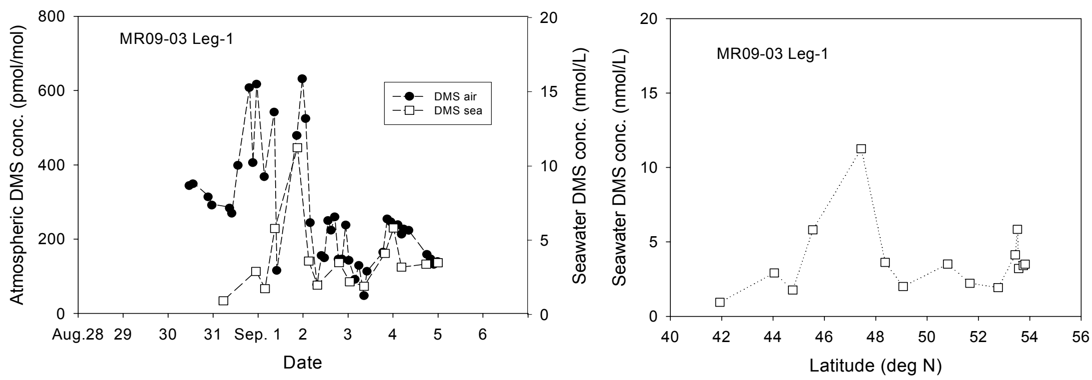


Figure 2.5-1(a). Temporal variations in the DMS concentrations measured with by the GC/FPD system. (b) Latitudinal distribution of the seawater DMS concentration measured by the GC/FPD system.

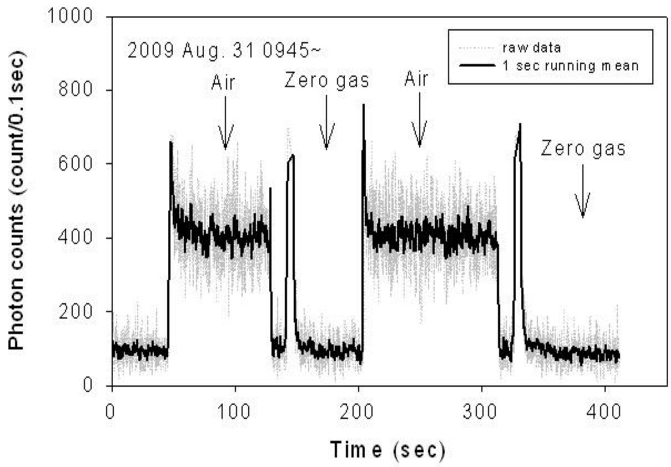


Figure 2.5-2. Photon signal of chemiluminescence of sample air and zero gas with F_2. Data shown in this graph was obtained for 415 sec from 0945UTC on Aug. 31.

3. Physical Oceanographic Observation

3.1. CTD/LADCP casts and water sampling

(1) Personnel

Takashi Kikuchi	(JAMSTEC): Principal investigator
Sergey Pisarev	(P. P. Shirshov Institute of Oceanology)
Shigeto Nishino	(JAMSTEC)
Yusuke Kawaguchi	(JAMSTEC)
Shinsuke Toyoda	(Marine Works Japan Co. Ltd., MWJ): Operation leader
Kenichi Katayama	(MWJ)
Masayuki Fujisaki	(MWJ)
Tomohide Noguchi	(MWJ)

(2) Objectives

Investigation of oceanic structure and water sampling.

(3) Parameters

Temperature (Primary and Secondary)
Conductivity (Primary and Secondary)
Pressure
Dissolved Oxygen (Primary and Secondary)
Fluorescence
Photosynthetically Active Radiation

(4) Instruments and Methods

CTD/Carousel Water Sampling System, which is a 36-position Carousel water sampler (CWS) with Sea-Bird Electronics, Inc. CTD (SBE9plus), was used during this cruise. 12-litter Niskin Bottles, which were washed by alkaline detergent and 1 N HCl, were used for sampling seawater. The sensors attached on the CTD were temperature (Primary and Secondary), conductivity (Primary and Secondary), pressure, dissolved oxygen (Primary and Secondary), deep ocean standards thermometer, altimeter, fluorescence, and PAR sensor. 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.7.19) 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.

101 casts of CTD measurements were conducted (table 3.1-1).

Data processing procedures and used utilities of SBE Data Processing-Win32 (ver.7.18d) 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 temperature (SBE3) sensor.

S/N 031525: -5.92243e-009 (degC/dbar)

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

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 data are systematically delayed with respect to depth mainly because of the long time constant of the dissolved oxygen sensor and of an additional delay from the transit time of water in the pumped pluming line. This delay was compensated by 5 seconds advancing dissolved oxygen sensor output (dissolved oxygen voltage) relative to the temperature data.

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 all variables.

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 fluorescence 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 of 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 2 times for temperature, conductivity and dissolved oxygen voltage (SBE43).

DERIVE: Compute dissolved oxygen (SBE43).

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

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

Stn.000 - 005: MR0903A.con

Stn.006 - 091: MR0903B.con

Specifications of the sensors are listed below.

CTD: SBE911plus CTD system

Under water unit:

SBE9plus (S/N 09P79492-0575, Sea-Bird Electronics, Inc.)

Pressure sensor: Digiquartz pressure sensor (S/N 79492)

Calibrated Date: 23 Jul. 2009

Temperature sensors:

Primary: SBE03-04/F (S/N 031525, Sea-Bird Electronics, Inc.)

Calibrated Date: 07 Jul. 2009

Secondary: SBE03-04/F (S/N 031359, Sea-Bird Electronics, Inc.)

Calibrated Date: 07 Jul. 2009

Conductivity sensors:

Primary: SBE04-04/O (S/N 041203, Sea-Bird Electronics, Inc.)

Calibrated Date: 08 Jul. 2009

Secondary: SBE04-04/O (S/N 041206, Sea-Bird Electronics, Inc.)

Calibrated Date: 08 Jul. 2009

Dissolved Oxygen sensors:

Primary: SBE43 (S/N 430394, Sea-Bird Electronics, Inc.)

Calibrated Date: 24 Jul. 2009

Secondary: SBE43 (S/N 430949, Sea-Bird Electronics, Inc.)

Calibrated Date: 21 Nov. 2009

Deep Ocean Standards Thermometer:

SBE35 (S/N 0022, Sea-Bird Electronics, Inc.)

Calibrated Date: 04 Mar. 2009

Altimeter:

Stn.000 - 005: Benthos PSA-916T (S/N 1157, Teledyne Benthos, Inc.)

Stn.006 - 091: Benthos PSA-916T (S/N 1100, Teledyne Benthos, Inc.)

Fluorescence: Chlorophyll Fluorometer (S/N 3054, Seapoint Sensors, Inc.)

Photosynthetically Active Radiation: PAR sensor (S/N 0049, Satlantic Inc.)

Carousel water sampler:

SBE32 (S/N 3227443-0391, Sea-Bird Electronics, Inc.)

Deck unit: SBE11plus (S/N 11P7030-0272, Sea-Bird Electronics, Inc.)

(5) Preliminary Results

During this cruise, 101 casts of CTD observation were carried out. Date, time and locations of the CTD casts are listed in Table 3.1-1.In some casts, an altimeter did not have a response. So we used a bottom contact sensor.

In the down cast 7 - 11 dbar of Stn.003, noise was observed in primary temperature, primary conductivity and dissolved oxygen raw data.

In the down cast 371, 372 dbar of Stn.075 cast1, noise was observed in primary conductivity raw data.

Vertical profiles (down cast) of primary temperature, primary salinity, primary dissolved oxygen and fluoresce with pressure are shown in Appendix III.

(6) Data archives

All raw and processed data will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

Table 3.1-1 CTD cast table

Stnnbr	Castno	Date(UTC)	Time(UTC)		BottomPosition		Depth	Wire Out	HT Above Bottom	Max Depth	Max Pressure	CTD Filename	Remark
		(mmddyy)	Start	End	Latitude	Longitude							
000	1	083009	22:24	23:06	41-09.19N	152-15.96E	5305.0	1020.1	-	1000.1	1011.7	000M01	nutrients RM sampling: 1000m
001	-	-	-	-	-	-	-	-	-	-	-	-	
002	1	091109	03:16	03:31	70-00.00N	168-00.14W	51.0	41.7	-	45.1	45.5	002M01	
003	1	091109	14:28	14:41	71-59.96N	168-00.14W	56.0	34.8	-	38.7	39.8	003M01	
004	1	091109	20:47	21:09	72-59.49N	167-58.48W	68.0	54.7	-	57.2	57.9	004M01	
005	1	091209	03:28	03:56	74-00.05N	168-00.41W	202.0	182.6	-	186.5	188.6	005M01	
006	1	091209	09:44	10:15	74-35.82N	171-00.09W	224.0	213.8	5.9	212.0	215.0	006M01	altimeter change (S/N 1157→S/N 1100)
007	1	091209	14:49	15:28	75-00.01N	172-24.16W	370.0	359.1	9.1	358.0	362.1	007M01	
008	1	091209	18:04	18:41	75-14.98N	172-58.05W	445.0	430.9	10.1	429.5	433.8	008M01	
009	1	091309	07:48	08:23	75-20.34N	171-01.78W	687.0	671.1	11.6	666.8	674.7	009M01	
009	2	091309	10:37	11:25	75-20.31N	171-01.67W	681.0	674.9	8.1	668.9	677.2	009M02	
010	1	091309	21:33	22:04	74-35.96N	170-54.38W	225.0	210.7	10.2	211.2	213.5	010M01	
011	1	091409	05:05	05:37	74-48.17N	169-30.11W	217.0	196.9	9.3	198.3	200.5	011M01	
012	1	091409	08:02	08:26	75-02.06N	168-09.46W	167.0	153.3	-	154.3	155.9	012M01	
013	1	091409	10:49	11:23	75-15.91N	166-49.20W	271.0	261.5	8.6	259.2	261.9	013M01	
014	1	091409	18:35	19:23	75-28.18N	165-39.14W	559.0	545.9	9.5	546.2	552.1	014M01	
015	1	091509	20:56	22:05	76-38.40N	165-40.61W	1173.0	1160.6	10.2	1151.1	1167.1	015M01	
016	1	091609	05:16	06:12	76-00.09N	163-59.57W	805.0	792.9	9.6	788.0	798.0	016M01	
017	1	091609	09:04	10:44	76-00.28N	163-27.56W	2049.0	2043.9	9.7	2015.2	2046.3	017M01	
018	1	091609	12:40	13:48	76-00.24N	162-57.93W	2065.0	2073.1	9.4	2048.5	2080.3	018M01	
019	1	091609	16:43	18:06	76-00.35N	161-39.08W	2127.0	2126.9	9.4	2105.1	2138.1	019M01	

019	2	091609	21:06	22:40	76-01.09N	161-36.81W	2126.0	2130.4	9.4	2105.2	2138.4	019M02	
020	1	091709	01:52	03:02	75-59.93N	160-19.75W	2104.0	2098.9	9.4	2081.3	2113.9	020M01	
021	1	091709	04:16	05:37	75-59.95N	159-40.43W	1559.0	1566.8	9.6	1551.4	1573.6	021M01	
022	1	091709	08:44	09:40	76-00.28N	159-00.13W	801.0	797.5	9.4	791.0	800.8	022M01	
023	1	091709	11:24	11:43	76-00.16N	157-59.79W	511.0	502.0	9.9	498.4	504.2	023M01	
024	1	091709	13:51	14:26	76-00.02N	156-59.85W	933.0	926.1	9.1	919.8	931.6	024M01	
025	1	091709	18:00	19:05	76-00.34N	156-24.11W	1049.0	1043.4	9.1	1036.5	1050.1	025M01	
026	1	091709	21:41	22:29	76-00.48N	155-50.17W	1394.0	1411.8	10.0	1396.2	1416.7	026M01	
027	1	091709	23:19	00:55	76-00.28N	155-25.54W	3006.0	3040.3	9.3	3006.5	3060.3	027M01	
028	1	091809	02:51	05:23	76-00.29N	155-00.32W	3849.0	3864.7	8.8	3827.3	3903.3	028M01	
029	1	091809	09:02	11:02	76-00.43N	153-29.89W	3850.0	3897.9	9.7	3824.2	3900.0	029M01	
030	1	091809	15:18	17:44	76-00.64N	151-01.34W	3840.0	3888.4	10.0	3812.9	3888.7	030M01	
030	2	091809	19:53	22:09	76-02.74N	151-06.76W	3840.0	3874.8	9.9	3816.9	3892.8	030M02	
031	1	091909	02:23	04:55	76-30.18N	150-01.56W	3837.0	3880.9	10.4	3809.1	3884.5	031M01	
032	1	091909	08:49	11:20	77-00.38N	150-01.03W	3835.0	3865.3	9.5	3810.7	3886.2	032M01	
033	1	091909	17:02	19:31	77-30.70N	150-00.15W	3835.0	3846.2	9.7	3811.1	3887.0	033M01	
034	1	092009	00:47	03:19	78-00.03N	150-00.23W	3833.0	3865.3	8.9	3810.6	3886.3	034M01	
035	1	092009	19:42	22:18	78-59.32N	151-38.53W	3830.0	3894.2	9.5	3801.5	3877.2	035M01	
036	1	092109	04:30	06:49	78-29.55N	151-42.83W	3834.0	3895.0	9.7	3802.9	3878.6	036M01	
037	1	092109	15:48	16:07	78-13.47N	153-28.58W	2100.0	484.9	-	483.5	489.1	037M01	
038	1	092109	18:31	20:34	78-10.02N	152-31.67W	3817.0	3849.9	9.3	3806.3	3881.8	038M01	
039	1	092109	21:27	23:38	78-05.08N	152-51.84W	2686.0	2655.9	9.6	2622.1	2666.8	039M01	
040	1	092209	02:33	03:39	77-59.96N	153-22.64W	2023.0	2037.1	9.6	2018.2	2049.7	040M01	
041	1	092209	04:40	05:29	77-54.89N	153-51.11W	1447.0	1449.6	8.7	1434.5	1455.2	041M01	
042	1	092209	06:57	08:09	77-49.87N	154-19.07W	1297.0	1286.5	10.9	1278.0	1294.9	042M01	
043	1	092209	13:45	14:46	77-37.91N	153-49.97W	993.0	990.8	9.2	983.8	996.1	043M01	

044	1	092209	16:25	17:35	77-33.62N	153-10.17W	2150.0	2142.1	9.9	2124.0	2157.9	044M01	
045	1	092209	19:24	21:22	77-31.63N	152-49.19W	2966.0	2906.3	-	2859.8	2910.0	045M01	
046	1	092309	01:06	03:23	77-14.30N	149-59.03W	3833.0	3921.4	10.1	3806.9	3882.4	046M01	
046	2	092309	05:23	07:58	77-12.28N	149-55.56W	3835.0	3889.3	9.7	3813.0	3889.0	046M02	
047	1	092309	18:09	19:49	77-04.85N	156-00.03W	2199.0	2209.6	9.1	2186.4	2220.9	047M01	
048	1	092309	23:39	01:06	77-04.72N	159-01.07W	1768.0	1771.8	9.5	1750.3	1776.2	048M01	
049	1	092409	03:38	05:05	77-04.89N	161-01.42W	1737.0	1760.1	10.5	1734.7	1760.1	049M01	
050	1	092409	09:10	09:50	77-05.07N	164-00.44W	421.0	403.8	9.7	401.9	406.4	050M01	
051	1	092409	12:07	13:36	77-05.08N	162-36.41W	2629.0	2649.3	9.4	2608.0	2652.5	051M01	
051	2	092409	16:45	18:38	77-05.74N	162-43.71W	2631.0	2624.9	9.8	2602.1	2646.2	051M02	
052	1	092509	04:52	05:43	76-24.02N	155-00.72W	1512.0	1524.9	9.7	1511.1	1532.4	052M01	
053	1	092509	06:48	08:47	76-20.92N	154-31.31W	3851.0	3867.9	9.2	3821.8	3897.5	053M01	
054	1	092509	09:46	11:45	76-17.92N	154-01.33W	3847.0	3885.8	10.0	3821.5	3897.0	054M01	
055	1	092509	13:23	15:21	76-11.76N	152-59.41W	3845.0	3869.1	9.6	3819.7	3895.6	055M01	
056	1	092509	22:56	01:27	75-29.83N	152-01.42W	3845.0	3878.1	9.7	3825.5	3901.7	056M01	
057	1	092609	06:33	09:09	74-59.96N	153-03.13W	3852.0	3911.8	8.2	3832.3	3908.5	057M01	
058	1	092609	13:54	16:09	74-30.15N	154-02.53W	3848.0	3880.1	9.8	3833.5	3909.2	058M01	
058	2	092609	17:58	20:33	74-30.42N	154-05.90W	3861.0	3867.3	9.7	3829.7	3905.5	058M02	
059	1	092709	00:34	03:05	73-59.70N	154-59.84W	3866.0	3883.6	9.0	3831.9	3907.7	059M01	
060	1	092709	05:03	07:34	73-41.18N	155-31.49W	3860.0	3878.8	8.9	3836.2	3912.0	060M01	
061	1	092809	16:00	16:07	71-40.75N	154-59.52W	113.0	96.3	-	99.5	100.4	061M01	
061	2	092809	16:18	16:24	71-40.73N	154-58.94W	110.0	98.3	-	100.2	101.1	061M02	
062	1	092809	18:35	18:47	71-43.97N	155-10.07W	291.0	278.6	10.2	277.5	280.5	062M01	
062	2	092809	20:13	20:53	71-43.99N	155-08.11W	269.0	258.7	10.9	257.9	260.7	062M02	
063	1	092809	22:27	22:35	71-48.41N	155-20.13W	169.0	154.0	9.3	155.0	156.7	063M01	
064	1	092909	02:01	02:15	71-39.86N	154-00.01W	50.0	36.4	-	38.7	39.1	064M01	

065	1	092909	03:16	03:21	71-44.88N	154-00.17W	66.0	52.4	-	54.3	54.9	065M01	
066	1	092909	04:06	04:29	71-49.90N	154-00.11W	167.0	151.8	10.0	153.7	155.4	066M01	
067	1	092909	06:14	07:05	71-55.79N	153-59.42W	603.0	591.0	9.5	589.6	596.8	067M01	
068	1	092909	09:01	09:49	72-03.91N	154-00.55W	1334.0	1322.6	9.5	1303.7	1321.4	068M01	
069	1	092909	10:54	12:25	72-11.11N	154-00.23W	1980.0	1982.9	9.4	1964.0	1993.8	069M01	
070	1	092909	14:41	15:55	72-20.50N	154-00.12W	2387.0	2416.2	9.8	2369.8	2408.2	070M01	
071	1	092909	18:22	19:47	72-19.82N	154-28.51W	1733.0	1724.6	9.8	1706.3	1731.1	071M01	
072	1	092909	21:26	22:26	72-16.65N	154-59.27W	1825.0	1797.7	9.6	1780.2	1806.5	072M01	
073	1	092909	23:35	00:16	72-15.15N	155-30.60W	1151.0	1160.1	7.0	1147.5	1162.4	073M01	
074	1	093009	01:24	01:36	72-11.93N	156-00.47W	287.0	265.1	9.4	263.6	266.7	074M01	
075	1	093009	10:10	11:25	72-51.83N	157-37.91W	1765.0	1764.3	7.8	1742.2	1767.6	075M01	
075	2	093009	18:15	19:36	72-52.46N	157-39.14W	1691.0	1618.3	10.7	1594.0	1616.9	075M02	
076	1	093009	21:33	22:12	72-46.37N	157-47.85W	1041.0	1037.1	8.8	1027.1	1040.3	076M01	
077	1	093009	22:58	23:37	72-42.11N	157-55.85W	331.0	315.5	8.7	314.7	318.1	077M01	
078	1	100109	01:04	01:29	72-36.11N	158-08.17W	190.0	177.9	8.9	177.5	179.3	078M01	
079	1	100109	02:55	03:14	72-30.15N	158-19.78W	74.0	64.6	-	67.3	68.0	079M01	
080	1	100509	02:23	02:57	74-39.85N	172-02.14W	291.0	278.6	9.6	277.6	279.9	080M01	
081	1	100509	06:08	06:36	74-36.01N	170-00.56W	207.0	195.6	8.7	194.3	196.9	081M01	
082	1	100509	09:43	10:14	74-33.93N	168-00.13W	271.0	261.0	8.4	261.5	264.7	082M01	
083	1	100509	20:10	20:50	74-26.30N	165-43.47W	369.0	351.5	10.2	351.2	355.0	083M01	
084	1	100609	12:06	12:34	73-59.85N	164-00.00W	262.0	240.5	11.1	241.6	244.4	084M01	
085	1	100609	16:04	16:23	73-44.83N	165-59.58W	122.0	106.6	10.3	109.1	110.4	085M01	
086	1	100609	20:23	20:47	73-29.79N	167-59.43W	116.0	100.4	10.6	103.1	104.1	086M01	
087	1	100709	17:36	17:48	72-30.00N	166-59.79W	55.0	38.8	-	42.8	43.3	087M01	
088	1	100809	11:52	11:59	71-30.01N	166-02.46W	47.0	24.7	-	31.7	31.8	088M01	
089	1	100909	23:00	23:27	73-30.25N	161-59.93W	200.0	184.3	8.5	188.3	190.0	089M01	

090	1	101009	11:39	11:50	71-30.03N	162-00.02W	45.9	30.9	-	35.1	35.3	090M01	
091	1	101009	19:19	19:48	71-12.04N	158-59.96W	104.0	95.2	-	99.3	100.3	091M01	

3.2. Salinity measurement of sampled water

(1) Personnel

Takashi Kikuchi (JAMSTEC): Principal Investigator
Shigeto Nishino (JAMSTEC)
Fujio Kobayashi (MWJ)

(2) Objectives

To provide a calibration for the measurement of salinity of bottle water collected on the CTD casts and EPCS.

(3) Parameter

Salinity (of bottle water)

(4) Instruments and methods

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)

a. Salinity sample collection

Seawater samples were collected with 12 liter Niskin-X bottles, bucket, and EPCS. The salinity sample bottle of the 250ml brown glass bottle 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 EPCS and for shallower than 100dbar 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 12 hours in the laboratory before the salinity measurement.

The kind and number of samples taken are shown as follows ;

Table 3.2-1 Kind and number of samples

Kind of Samples	Number of Samples
Samples for CTD and bucket	835
Samples for EPCS	56
Total	891

b. Instruments and method

The salinity analysis was carried out on R/V MIRAI during the cruise of MR09-03 using the salinometer (Model 8400B “AUTOSAL” ; Guildline Instruments Ltd.: S/N 62827 and S/N 62556) with an additional peristaltic-type intake pump (Ocean Scientific International, Ltd.). S/N 62827 was used to measure samples for shallower than 100dbar and EPCS. S/N 62556 was done for equal and deeper than 100dbar.

Two pair of precision digital thermometers (Model 9540 ; Guildline Instruments Ltd.) were used. The thermometer monitored the ambient temperature and the other monitored a 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 24 deg C. The ambient temperature varied from approximately 21 deg C to 24 deg C, while the bath temperature was very stable and varied within +/- 0.002 deg C 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 a 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 or the salinity of these two fillings being smaller than the criteria* we decided, 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 the criteria, an eighth filling of the cell was done. In the case of the difference between the double conductivity ratio or the salinity of these two fillings being smaller than the criteria, the average value of the double conductivity ratio was used to calculate the bottle salinity. The cell was cleaned with soap after the measurement of the day.

*criteria:

for equal and deeper than 100dbar	: 0.00002 in double conductivity ratio
for shallower than 100dbar and EPCS	: 0.00002 in double conductivity ratio

(5) Results

a. Standard seawater (SSW)

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

<For standardization>

Batch	:	P150
conductivity ratio	:	0.99978
salinity	:	34.991
preparation date	:	22nd May 2008

<For check of the linearity for the salinometer (Linearity Pack)>

Batch	:	38H10
conductivity ratio	:	1.07562
salinity	:	37.997
preparation date	:	1st Oct 2008
Batch	:	30L14
conductivity ratio	:	0.87154
salinity	:	30.003
preparation date	:	29th Sep 2008
Batch	:	10L11
conductivity ratio	:	0.32060
salinity	:	9.998
preparation date	:	23rd July 2008

Standardization control of the salinometer S/N 62827 was set to 440 (12 Sep.). The value of STANDBY was 5377 +/- 0003 and that of ZERO was 0.0+0001 or 0.0+0002. SSW (P150) was used as the standard for salinity. 15 bottles of SSW were measured (6 bad bottles were excluded).SSW (Linearity Pack) was used to check the linearity of the salinometer within the measurement range. The difference between the certificated value and the measurement value was 0.000 to 0.002, the salinometer showed the linearity sufficiently.

Standardization control of the salinometer S/N 62556 was set to 636 (14 Sep.) and all measurements were done at this setting. The value of STANDBY was 5480 +/- 0003 and that of ZERO was 0.0-0001 +/- 0001. SSW (P150) was used as the standard for salinity. 43 bottles of SSW were measured (2 bad bottles were excluded).

Figure 3.2-1 shows the history of the double conductivity ratio of the Standard Seawater batch P150 measured by S/N 62556 before correction. The average of the double conductivity ratio was 1.99954 and the standard deviation was 0.00002, which is equivalent to 0.0004 in salinity.

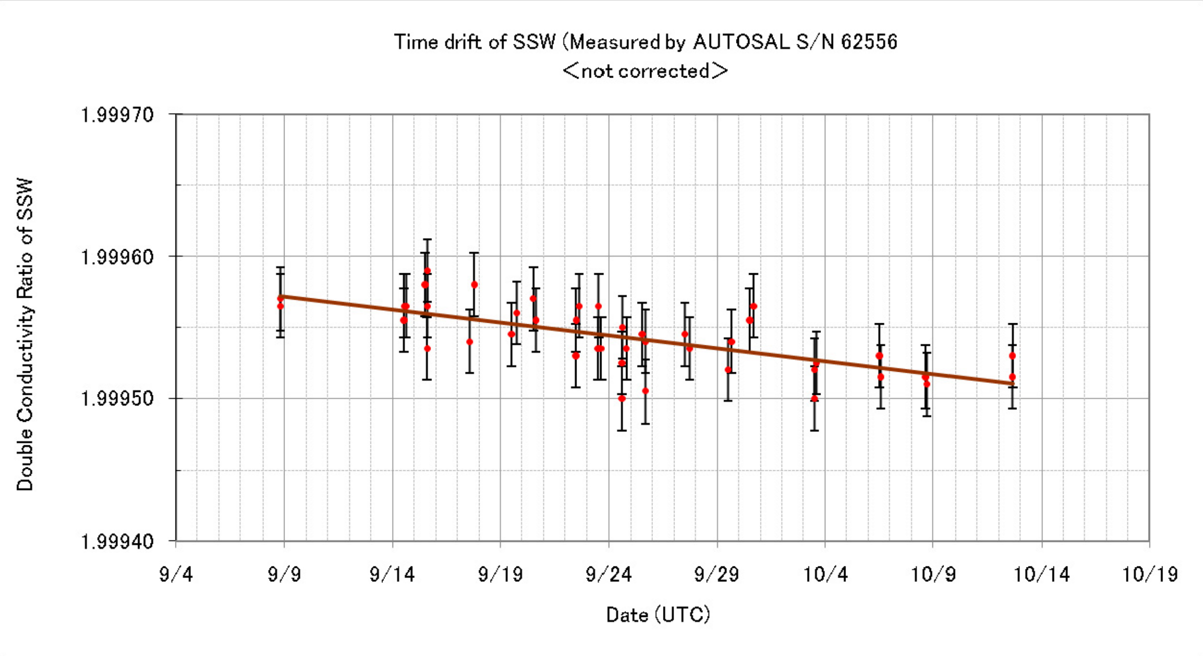


Figure 3.2-1. History of double conductivity ratio for the Standard Seawater batch P150 (S/N 62556: before correction)

Figure 3.2-2 shows the history of the double conductivity ratio of the Standard Seawater batch P150 measured by S/N 62556 after correction. The average of the double conductivity ratio after correction was 1.99956 and the standard deviation was 0.00002, which is equivalent to 0.0003 in salinity.

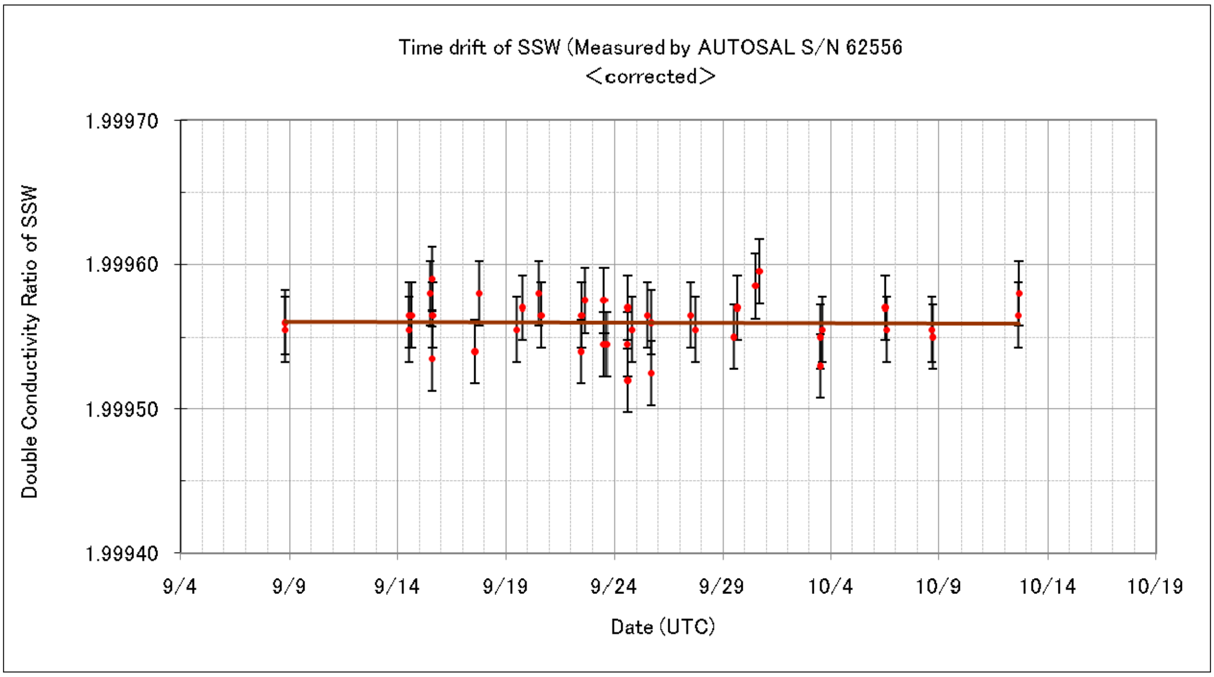


Figure 3.2-2. History of double conductivity ratio for the Standard Seawater batch P150 (S/N 62556: after correction)

Figure 3.2-3 shows the history of the double conductivity ratio of the Standard Seawater batch P150 measured by S/N 62827. The average of the double conductivity ratio was 1.99953 and the standard deviation was 0.00004, which is equivalent to 0.0007 in salinity.

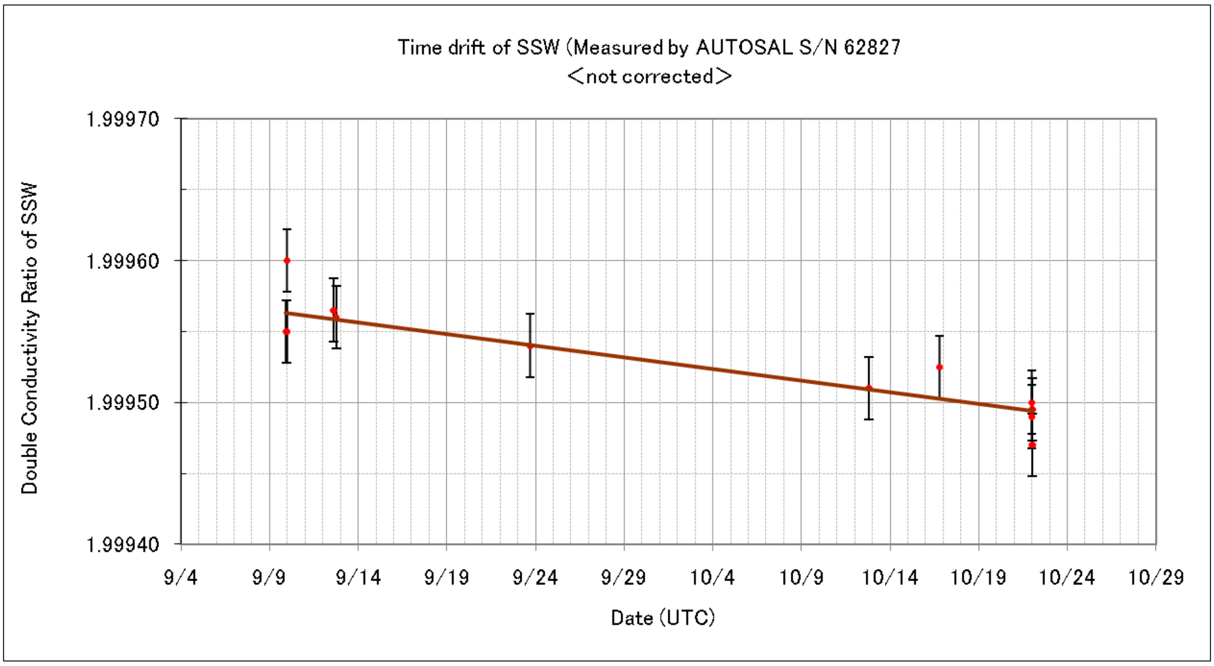


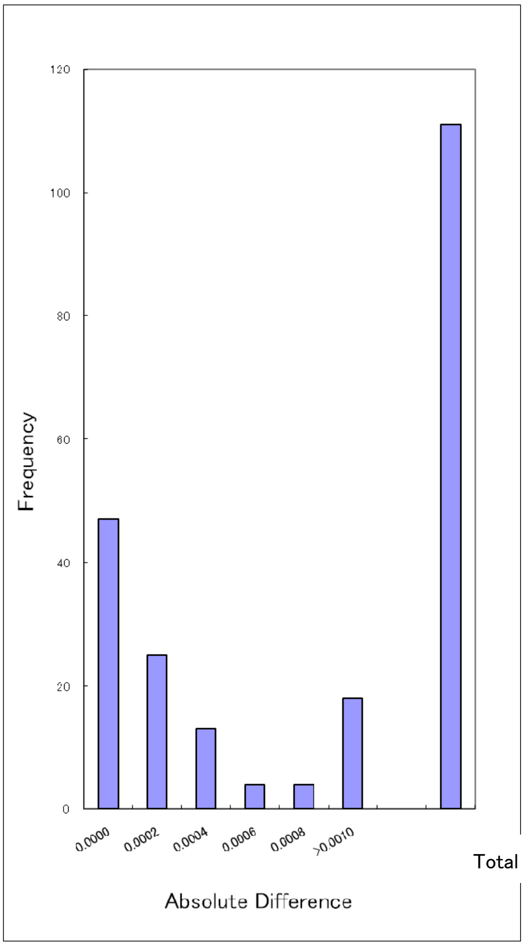
Figure 3.2-3. History of double conductivity ratio for the Standard Seawater batch P150 (S/N 62827: not corrected)

b. Sub-standard seawater

Sub-standard seawater was made from deep-sea water 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 about every 6 samples in order to check for the possible sudden drifts of the salinometer.

c. Replicate samples

We estimated the precision of this method using 111 pairs of replicate samples taken from the same Niskin bottle. The average and the standard deviation of absolute difference among 111 pairs of all replicate samples were 0.0017 and 0.0058 in salinity, respectively. 81 pairs of samples for deeper than 500dbar were 0.0004 and 0.0004 in salinity, respectively.



d. Data correction for samples

For equal and deeper than 100dbar, the data were corrected according to the result of the correction for SSW measured by S/N 62556. For shallower than 100dbar and EPCS, the data were not corrected.

(6) Data archives

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

(7) References

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

3.3. XCTD observation

(1) Personnel

Takashi Kikuchi	(JAMSTEC): Principal Investigator
Souichiro Sueyoshi	(GODI)
Satoshi Okumura	(GODI)
Norio Nagahama	(GODI)
Ryo Kimura	(GODI)
Ryo Ohyama	(MIRAI Crew)

(2) Objectives

XCTD observations were performed between CTD stations and were substituted for CTD.

(3) Parameters

According to the manufacturer's nominal specifications, the range and accuracy of parameters measured by the XCTD (eXpendable Conductivity, Temperature & Depth profiler) are as follows;

XCTD-1	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)

XCTD-2	Parameter	Range	Accuracy
	Conductivity	10 ~ 60 [mS/cm]	+/- 0.03 [mS/cm]
	Temperature	-2 ~ 35 [deg-C]	+/- 0.02 [deg-C]
	Depth	0 ~ 1850 [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 salinity measured by XCTD-1 and XCTD-2. The signal was converted by digital converter MK-130 and was recorded by MK-130 software (Ver.3.07). Above system was manufactured by Tsurumi-Seiki Co.. We cast 102 probes by automatic and hand launcher.

(5) Observation log

Table3.3-1 XCTD observation log

	Station No.	Date [YYYY/MM/DD]	Time [hh:mm]	Latitude	Longitude	Depth [m]	SST [deg-C]	SSS [PSU]	Probe S/N
1	X01	2009/09/12	16:32	75-07.46N	172-43.51W	408	-1.074	26.562	08069536
2	X02	2009/09/15	03:10	75-38.89N	165-40.05W	545	0.386	26.890	08069546
3	X03	2009/09/15	03:58	75-49.61N	165-37.83W	503	1.131	27.059	08069544
4	X04	2009/09/15	04:49	75-59.85N	165-40.77W	436	0.097	26.814	08069536
5	X05	2009/09/15	05:48	76-09.98N	165-43.21W	602	-0.055	26.763	08069620
6	X06	2009/09/15	06:36	76-19.83N	165-43.24W	980	-0.040	26.805	08069545
7	X07	2009/09/15	07:27	76-29.82N	165-43.11W	1144	-0.423	26.604	08069622
8	X08	2009/09/16	04:07	75-59.95N	164-45.35W	426	0.151	26.823	08069541
9	X09	2009/09/16	14:42	76-00.04N	164-21.20W	2127	0.302	26.764	08069621
10	X10	2009/09/17	00:41	76-00.03N	161-01.09W	2089	0.501	26.735	08069542
11	X11	2009/09/18	07:39	76-00.02N	154-15.52W	3850	0.438	25.378	09022814
12	X12	2009/09/18	12:28	75-59.93N	152-40.27W	3844	0.322	25.834	09012812
13	X13	2009/09/18	13:49	75-59.98N	151-50.28W	3843	-0.086	25.708	09012813
14	X14	2009/09/18	22:58	76-07.43N	150-45.33W	3836	-0.291	25.468	09022822
15	X15	2009/09/19	00:13	76-14.89N	150-30.00W	3837	-0.533	25.273	09022819
16	X16	2009/09/19	01:13	76-22.42N	150-15.28W	3839	-0.463	25.677	09022820
17	X17	2009/09/19	05:57	76-37.40N	150-00.29W	3837	-0.364	26.002	09022818
18	X18	2009/09/19	06:54	76-44.98N	149-59.77W	3834	-0.219	25.980	09022815
19	X19	2009/09/19	07:49	76-52.48N	149-59.99W	3838	-0.337	26.090	09022823
20	X20	2009/09/19	12:09	77-07.50N	150-00.14W	3838	-0.608	25.854	09022821
21	X21	2009/09/19	12:59	77-15.00N	149-59.81W	3858	-0.573	25.936	09022817
22	X22	2009/09/19	13:49	77-22.41N	150-00.05W	3836	-0.664	25.914	09022816
23	X23	2009/09/19	21:59	77-37.49N	150-00.78W	3836	-0.768	25.950	09022845
24	X24	2009/09/19	22:51	77-44.92N	150-01.86W	3835	-1.014	25.992	09022847
25	X25	2009/09/19	23:43	77-52.45N	149-59.25W	3833	-1.120	26.044	09022846
26	X26	2009/09/20	04:50	78-07.49N	150-22.66W	3835	-1.245	26.115	09022843
27	X27	2009/09/20	05:55	78-14.99N	150-44.95W	3834	-1.329	26.189	09022844
28	X28	2009/09/20	06:54	78-22.45N	151-07.30W	3837	-1.268	26.241	09022844
29	X29	2009/09/20	07:51	78-29.97N	151-29.89W	3836	-1.317	26.479	09022840
30	X30	2009/09/20	14:37	78-37.48N	151-30.13W	3833	-1.376	26.442	09022841
31	X31	2009/09/20	16:10	78-44.95N	151-32.36W	3836	-1.412	26.410	09022839
32	X32	2009/09/20	17:33	78-52.43N	151-34.47W	3827	-1.427	26.474	09022836
33	X33	2009/09/21	11:00	78-20.00N	151-21.67W	3841	-1.396	26.310	08069546
34	X34	2009/09/21	12:00	78-19.08N	152-52.75W	3412	-1.396	26.274	08069539
35	X35	2009/09/22	01:00	78-02.68N	153-04.37W	2361	-1.296	26.673	08069537
36	X36	2009/09/22	04:04	77-57.60N	153-34.19W	1584	-1.284	26.705	08069540
37	X37	2009/09/22	12:28	77-41.05N	154-20.06W	1792	-1.232	26.573	09064410
38	X38	2009/09/22	15:26	77-36.14N	153-30.75W	1550	-1.398	26.729	09064413
39	X39	2009/09/22	21:50	77-29.88N	152-31.19W	3840	-1.358	26.520	09064411
40	X40	2009/09/22	22:25	77-27.18N	152-01.12W	3839	-1.037	26.241	09064414
41	X41	2009/09/22	23:02	77-23.67N	151-31.17W	3839	-0.952	26.194	09064404
42	X42	2009/09/22	23:39	77-21.82N	151-00.99W	3836	-0.985	26.083	09064407
43	X43	2009/09/23	11:01	77-09.41N	151-59.23W	3842	-1.014	26.384	09064415
44	X44	2009/09/23	12:36	77-08.96N	152-59.34W	3839	-0.992	26.419	09064412
45	X45	2009/09/23	13:20	77-07.78N	153-29.34W	3209	-1.077	26.378	09064408
46	X46	2009/09/23	14:28	77-06.37N	154-14.14W	1261	-1.080	26.362	09064406
47	X47	2009/09/23	15:37	77-05.08N	154-.59.23W	936	-1.112	26.350	09064405
48	X48	2009/09/23	21:05	77-04.50N	156-58.83W	501	-0.522	26.386	09064438
49	X49	2009/09/23	22:14	77-05.08N	157-59.01W	1169	-0.753	26.462	09064409
50	X50	2009/09/24	02:17	77-05.00N	159-58.78W	2002	-1.049	26.454	09064437
51	X51	2009/09/24	11:15	77-05.14N	163-04.89W	1719	-1.040	26.552	09064439
52	X52	2009/09/24	19:52	77-05.02N	162-01.25W	733	-0.970	26.505	09064436
53	X53	2009/09/24	20:25	77-04.77N	161-31.13W	515	-1.030	26.463	09064428
54	X54	2009/09/24	21:08	76-59.94N	161-00.93W	2024	-1.004	26.470	09064429
55	X55	2009/09/24	22:23	76-53.99N	160-01.09W	2091	-0.680	26.568	09064435
56	X56	2009/09/24	23:38	76-47.60N	159-01.01W	2118	-0.983	26.440	09064433
57	X57	2009/09/25	00:52	76-42.10N	158-01.12W	1031	-0.904	26.459	09064431
58	X58	2009/09/25	02:15	76-35.41N	156-53.94W	1353	-0.416	26.170	09064434
59	X59	2009/09/25	03:23	76-30.13N	156-01.09W	825	-0.113	25.888	09064432
60	X60	2009/09/25	12:34	76-15.01N	153-30.28W	3849	-0.241	25.502	09064440

Table3.3-1 Continued

	Station No.	Date [YYYY/MM/DD]	Time [hh:mm]	Latitude	Longitude	Depth [m]	SST [deg-C]	SSS [PSU]	Probe S/N
61	X61	2009/09/25	16:08	76-09.02N	152-31.01W	3844	-0.209	25.444	09064441
62	X62	2009/09/25	16:47	76-06.10N	152-01.02W	3845	-0.224	25.675	09064442
63	X63	2009/09/25	17:39	76-03.12N	151-28.55W	3842	-0.566	25.612	09064430
64	X64	2009/09/25	18:05	76-00.06N	151-30.25W	3843	-0.446	25.611	09022826
65	X65	2009/09/25	18:58	76-00.02N	151-00.35W	3843	-0.878	25.407	09022837
66	X66	2009/09/25	20:00	75-52.57N	151-14.81W	3845	-0.394	25.508	09022838
67	X67	2009/09/25	20:56	75-45.08N	151-29.81W	3843	-0.405	25.033	09022829
68	X68	2009/09/25	21:53	75-37.57N	151-44.82W	3844	-0.538	24.913	09022838
69	X69	2009/09/26	03:18	75-22.59N	152-14.97W	3848	-0.427	24.316	09022825
70	X70	2009/09/26	04:12	75-15.03N	152-30.00W	3852	-0.539	24.413	09022831
71	X71	2009/09/26	05:11	75-07.51N	152-47.48W	3853	-0.602	24.205	09022827
72	X72	2009/09/26	10:02	74-52.53N	153-15.40W	3855	-0.083	23.395	09022824
73	X73	2009/09/26	10:56	74-45.04N	153-29.14W	3850	-0.017	23.611	09022828
74	X74	2009/09/26	11:53	74-37.48N	153-45.22W	3851	-0.044	24.031	09022835
75	X75	2009/09/26	21:22	74-22.64N	154-14.29W	3858	-0.186	23.420	09022830
76	X76	2009/09/26	22:16	74-15.10N	154-28.39W	3859	0.119	24.585	09022834
77	X77	2009/09/26	23:12	74-07.61N	154-43.95W	3861	0.071	22.876	09022833
78	X78	2009/09/27	03:50	73-52.73N	155-12.12W	3863	-0.131	23.055	09064446
79	X79	2009/09/27	04:32	73-45.12N	155-25.07W	3867	-0.238	23.422	09064445
80	X80	2009/09/27	16:53	73-30.72N	155-57.02W	3795	-1.145	23.282	09064448
81	X81	2009/09/27	20:50	73-32.46N	157-30.00W	3168	-0.860	23.617	09064450
82	X82	2009/09/28	00:56	73-20.16N	159-38.58W	1506	1.195	27.488	09064451
83	X83	2009/09/28	02:05	73-10.17N	159-08.88W	1302	1.103	27.527	09064444
84	X84	2009/09/28	03:13	73-00.12N	158-38.98W	1387	1.287	27.549	09064443
85	X85	2009/09/28	04:19	72-50.11N	158-10.95W	541	1.871	27.922	09064447
86	X86	2009/09/28	05:29	72-39.99N	157-42.25W	321	2.151	28.637	09064550
87	X87	2009/09/28	06:42	72-30.17N	157-13.74W	331	1.972	28.568	09064553
88	X88	2009/09/28	07:52	72-29.02N	156-46.73W	269	0.041	27.167	09064449
89	X89	2009/09/28	09:36	72-10.02N	156-36.75W	209	1.895	28.438	09064552
90	X90	2009/09/28	11:30	72-00.00N	156-03.31W	89	2.331	28.873	09064549
91	X91	2009/10/07	08:28	72-00.08N	168-00.62W	43	2.562	31.602	09064551
92	X92	2009/10/08	02:23	73-00.22N	165-58.29W	55	1.776	31.036	09064548
93	X93-1	2009/10/08	23:41	73-26.50N	164-04.26W	80	-	-	09064557
94	X93-2	2009/10/08	23:45	73-26.34N	164-06.84W	80	0.280	29.190	09064559
95	X94	2009/10/09	02:36	73-00.20N	164-04.95W	79	1.104	30.873	09064556
96	X95	2009/10/09	05:34	72-30.34N	164-00.72W	43	2.756	31.821	09064558
97	X96	2009/10/09	08:30	71-59.63N	163-58.38W	38	2.067	30.473	09064555
98	X97	2009/10/09	11:21	71-30.05N	164-00.55W	37	2.932	31.401	09064554
99	X98	2009/10/09	17:25	72-30.15N	164-59.14W	35	2.142	31.394	09064545
100	X99	2009/10/10	02:34	72-59.82N	162-02.91W	105	0.701	29.906	09064542
101	X100	2009/10/10	05:20	72-30.11N	162-01.10W	35	1.991	31.357	09064547
102	X101	2009/10/10	08:25	71-59.66N	162-04.16W	23	1.812	29.939	09064546

Acronyms in Table XCTD observation log are as follows;

Depth: Water Depth [m]

SST: Sea Surface Temperature [deg-C] measured by Continuous Sea Surface Monitoring System

SSS: Sea Surface Salinity [PSU] measured by Continuous Sea Surface Monitoring System

(6) Data archives

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

3.4. Shipboard ADCP

(1) Personnel

Takashi Kikuchi	(JAMSTEC): Principal Investigator
Souichiro Sueyoshi	(GODI)
Satoshi Okumura	(GODI)
Norio Nagahama	(GODI)
Ryo Kimura	(GODI)
Ryo Ohyama	(MIRAI Crew)

(2) Objectives

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

(3) Instruments and methods

Upper ocean current measurements were made in MR09-03 Leg2&3 cruise, using the hull-mounted Acoustic Doppler Current Profiler (ADCP) system. For most of its operation in the Arctic Ocean, bottom-tracking mode, interleaved bottom-ping with water-ping, was made to get the calibration data for evaluating transducer misalignment angle. The system consists of following components;

1) R/V MIRAI has installed the Ocean Surveyor for vessel-mount (acoustic frequency 75 kHz; Teledyne RD Instruments). 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 (Tokimec, Japan), continuously providing heading to the ADCP system directory. Additionally, we have Inertial Navigation System (INS) which provide high-precision heading, attitude information, pitch and roll, are stored in ".N2R" data files with a time stamp.
3) DGPS system (Trimble SPS751 & StarFixXP) providing position fixes.
4) We used VmDas version 1.4.2 (TRD Instruments) for data acquisition.
5) To synchronize time stamp of ping with GPS time, the clock of the logging computer is adjusted to GPS time every 1 minute
6) We have placed ethylene glycol into the fresh water to prevent freezing in the sea chest.
7) The sound speed at the transducer does affect the vertical bin mapping and vertical velocity measurement, is calculated from temperature, salinity (constant value; 35.0 psu) and depth (6.5 m; transducer depth) by equation in Medwin (1975).

Data was configured for 4-m intervals starting 19-m below the surface in MR09-03Leg2 cruise, and 8-m intervals starting 23-m below the surface in MR09-03Leg3 cruise. Every ping was recorded as raw ensemble data (.ENR). Also, 60 seconds and 300 seconds averaged data were recorded as short term average (.STA) and long term average (.LTA) data, respectively. Major parameters for the measurement (Direct Command) are shown in Table 3.4-1.

(4) Preliminary results

Figure 3.4-1 shows vertical cross section plot of water current in the mooring area of Barrow Canyon.

(5) Data archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via "R/V MIRAI Data Web Page" in JAMSTEC home page.

(6) Remarks

1. Following period, we did not collect data in the territorial waters of United States of America.
   13:55UTC 15 Oct. 2009 to 04:57UTC 16 Oct. 2009
2. In this cruise, the data quality was not in good condition, because some problem might be occurred on transducer system. Paying attention for using ADCP data is highly recommended, including checking correlation and echo amplitude data.

Table 3.4-1 Major parameters

Bottom-Track Commands	
BP = 001	Pings per Ensemble (almost less than 1000m depth)
Environmental Sensor Commands	
EA = +04500	Heading Alignment (1/100 deg)
EB = +00000	Heading Bias (1/100 deg)
ED = 00065	Transducer Depth (0 - 65535 dm)
EF = +001	Pitch/Roll Divisor/Multiplier (pos/neg) [1/99 - 99]
EH = 00000	Heading (1/100 deg)
ES = 35	Salinity (0-40 pp thousand)
EX = 00000	Coord Transform (Xform:Type; Tilts; 3Bm; Map)
EZ = 10200010	Sensor Source (C; D; H; P; R; S; T; U)
	C (1): Sound velocity calculates using ED, ES, ET (temp.)
	D (0): Manual ED
	H (2): External synchro
	P (0), R (0): Manual EP, ER (0 degree)
	S (0): Manual ES
	T (1): Internal transducer sensor
	U (0): Manual EU
Timing Commands	
TE = 00:00:02.00	Time per Ensemble (hrs:min:sec.sec/100)
TP = 00:02.00	Time per Ping (min:sec.sec/100)
Water-Track Commands	
WA = 255	False Target Threshold (Max) (0-255 count)
WB = 1	Mode 1 Bandwidth Control (0=Wid, 1=Med, 2=Nar)
WC = 120	Low Correlation Threshold (0-255)
WD = 111 100 000	Data Out (V; C; A; PG; St; Vsum; Vsum^2;#G;P0)
WE = 1000	Error Velocity Threshold (0-5000 mm/s)
WF = 0800	Blank After Transmit (cm)
WG = 001	Percent Good Minimum (0-100%)
WI = 0	Clip Data Past Bottom (0 = OFF, 1 = ON)
WJ = 1	Rcvr Gain Select (0 = Low, 1 = High)
WM = 1	Profiling Mode (1-8)
WN = 100	Number of depth cells (1-128)
WP = 00001	Pings per Ensemble (0-16384)
WS = 0400	Depth Cell Size (cm) : MR09-03Leg2 Cruise

=0800 Depth Cell Size (cm) : MR09-03Leg3 Cruise

WT = 000 Transmit Length (cm) [0 = Bin Length]

WV = 0390 Mode 1 Ambiguity Velocity (cm/s radial)

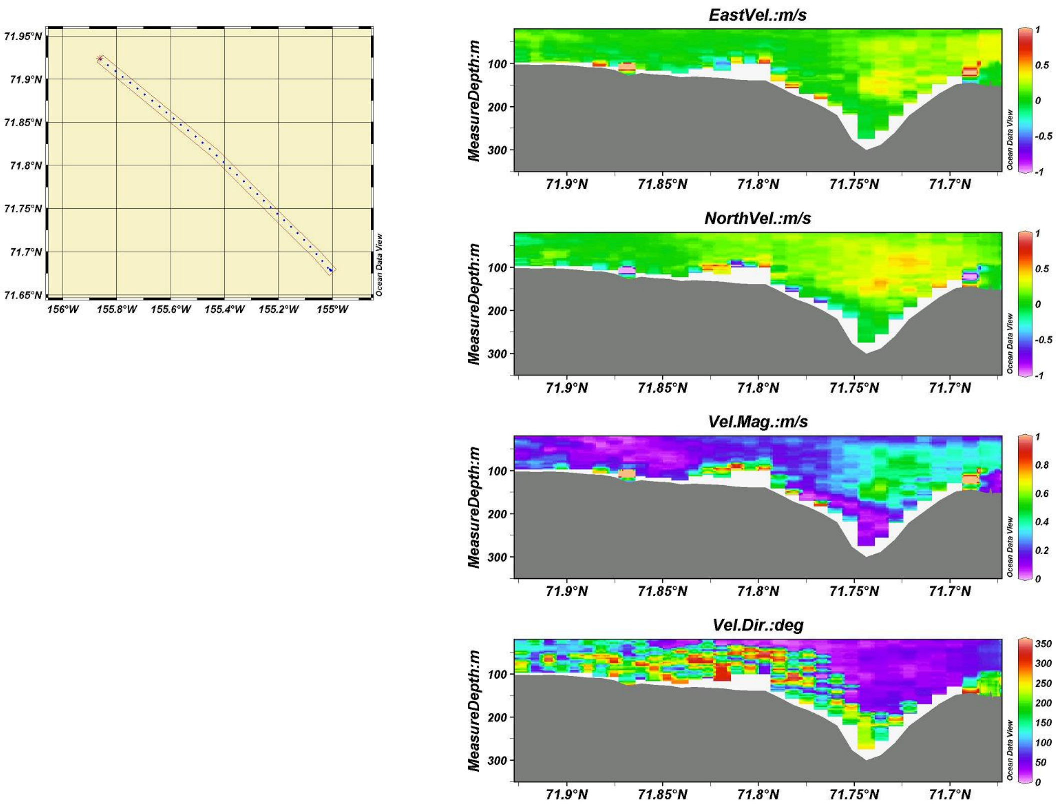


Figure 3.4-1 Cross section of water current in the Barrow Canyon

3.5. Mooring deployment

(1) Personnel

Takashi Kikuchi	(JAMSTEC): Principal Investigator
Shigeto Nishino	(JAMSTEC)
Motoyo Itoh	(JAMSTEC)
Tomohide Noguchi	(MWJ): Operation leader
Masayuki Fujisaki	(MWJ): Technical staff
Fujio Kobayashi	(MWJ): Technical staff
Kenichi Katayama	(MWJ): Technical staff

(2) Objectives

The purpose of mooring measurements is to monitor the variations of waters from the Pacific and East Siberian Sea. Components of this mooring are depicted in Figure 3.5-1.

(3) Parameters

・Ocean current velocities
・Echo intensity, bottom tracking range and velocities for sea ice measurements
・Pressure, Temperature and Conductivity
・Dissolved oxygen

(4) Instruments

1) Ice profiling sonar
Model IPS 4 (ALS Environmental Sciences)

2) Current meters
Workhorse ADCP 300 kHz (Teledyne RD Instruments, Inc.)

3) CTD
SBE16 (Sea Bird Electronics Inc.)
SBE37-SM (Sea Bird Electronics Inc.)

4) Oxygen sensor
Compact – Optode (JFF ALEC Co., Ltd.)

5) Acoustic Releaser

Model-L (Nichiyu giken kogyo co., LTD)
8242XS (ORE offshore)

(5) List of deployed mooring

Deployment mooring

Mooring ID	Deployment date (UTC)	Latitude	Longitude
ESS-09	2009/9/13	74-36.1725 N	170-59.8053 W

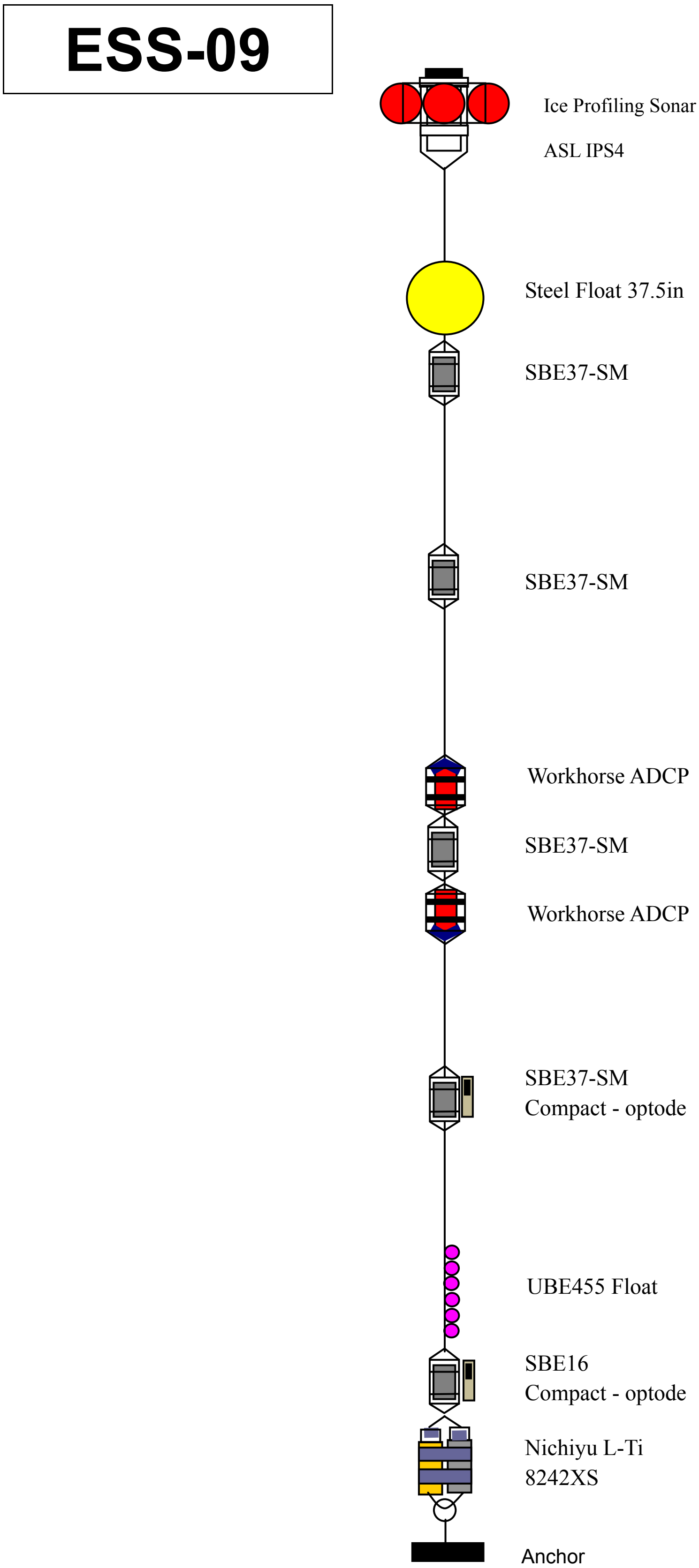


Figure 3.5-1. Diagram of deployed mooring

4. Chemical and Biological Observation

4.1. Dissolved Oxygen of Sampled Water

(1) Personnel

Shigeto Nishino	(JAMSTEC): Principal Investigator
Misato Kuwahara	(MWJ): Operation Leader
Minoru Kamata	(MWJ)
Hironori Sato	(MWJ)

(2) Objectives

Dissolved oxygen is important parameter to identify water masses of intermediate and deep water in the Arctic Ocean. We measured dissolved oxygen in seawater by Winkler titration.

(3) Parameter

Dissolved oxygen

(4) Instruments and methods

a. 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)

b. Instruments:

Burette for sodium thiosulfate;

APB-510 manufactured by Kyoto Electronic Co. Ltd. / 10 cm^3 of titration vessel

Burette for potassium iodate;

APB-510 manufactured by Kyoto Electronic Co. Ltd. / 10 cm^3 of titration vessel

Detector and Software;

Automatic photometric titrator (DOT-01) manufactured by Kimoto Electronic Co. Ltd.

c. Sampling

Following procedure is based on the WHP Operations and Methods (Dickson, 1996). Seawater samples were collected with Niskin bottle attached to the CTD-system. Seawater for oxygen measurement was transferred from Niskin sampler bottle 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 0.5 cm^3 each were added immediately into the sample flask and the stopper was inserted carefully into the flask. The sample flask was then shaken vigorously to mix the contents and to disperse the precipitate finely throughout. After the precipitate has settled at least halfway down the flask, the flask was shaken again 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. A magnetic stirrer bar and 1 cm^3 sulfuric acid solution were added into the sample flask and stirring began. Samples were titrated by sodium thiosulfate solution whose 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 sample, and titrated volume of sodium thiosulfate solution without the blank.

e. Standardization and determination of the blank

Concentration of sodium thiosulfate titrant (ca. 0.025 mol/dm^3) was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130^{o}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 calibrated dispenser. Then 90 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were added into the flask in order. Amount of sodium thiosulfate titrated gave the morality of sodium thiosulfate titrant.

The blank from the presence of redox species apart from oxygen in the reagents was determined as follows. Firstly, 1 cm3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 100 cm3 of deionized water, 1 cm3 of sulfuric acid solution, and 0.5 cm3 of pickling reagent solution II and I were added into the flask in order. Secondary, 2 cm3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 100 cm3 of deionized water, 1 cm3 of sulfuric acid solution, and 0.5 cm3 of pickling reagent solution II and I were added into the flask in order. The blank was determined by difference between the first and second titrated volumes of the sodium thiosulfate.

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 this cruise.

Date	KIO_3	$Na_2S_2O_3$	DOT-01(No.1)		DOT-01(No.2)	
			E.P.	Blank	E.P.	Blank
2009/9/8	20081204-17-01	20080704-14-1	3.964	0.000	3.965	0.001
2009/9/9	CSK	20080704-14-1	3.960	0.000	3.961	0.001
2009/9/9	20081204-17-02	20080704-14-1	-	-	3.966	0.003
2009/9/12	20081204-17-03	20080704-14-1	-	-	3.962	0.000
2009/9/13	20081204-17-04	20080704-14-1	3.963	-0.001	3.964	0.001
2009/9/13	20081204-17-04	20080704-14-2	3.963	-0.002	3.965	0.000
2009/9/15	20081204-17-05	20080704-14-2	3.961	-	3.962	-
2009/9/16	20081204-17-07	20080704-14-2	3.961	-0.002	3.962	0.000
2009/9/16	20081204-17-06	20080704-14-2	3.960	0.000	3.963	0.001
2009/9/16	20081204-17-06	20080704-15-1	3.961	-0.002	3.964	0.001
2009/9/18	20081204-17-08	20080704-15-1	3.959	-0.001	3.961	0.001
2009/9/18	20081204-17-08	20080704-15-2	3.960	-0.003	3.962	0.000
2009/9/21	20081204-17-09	20080704-15-2	3.961	-0.002	3.962	-0.002
2009/9/21	20081204-17-09	20080704-16-1	3.965	-0.002	3.965	0.001
2009/9/24	20081204-17-10	20080704-16-1	3.964	-0.001	3.964	0.000
2009/9/24	20081204-17-10	20080704-16-2	3.963	-0.001	3.965	0.000
2009/9/25	20081204-17-11	20080704-16-2	3.962	-0.001	3.964	0.000
2009/9/25	20081204-18-01	20080704-16-2	3.962	-0.002	3.963	0.001
2009/9/26	20081204-18-02	20080704-16-2	3.960	-0.002	3.960	0.002
2009/9/27	20081204-18-02	20080704-17-1	3.963	-0.002	3.965	0.000
2009/9/30	20081204-18-03	20080704-17-1	3.962	-0.002	3.963	0.000
2009/9/30	20081204-18-03	20080704-17-2	3.962	-0.002	3.964	0.000
2009/10/5	20081204-18-04	20080704-17-2	3.961	-0.001	3.964	0.003
2009/10/7	20081204-18-05	20080704-17-2	3.960	-0.002	3.960	0.000
2009/10/7	20081204-18-05	20080704-18-1	3.961	-0.002	3.962	0.002
2009/10/12	20081204-16-06	20080704-18-1	3.957	-0.001	3.962	0.001
2009/10/12	CSK	20080704-18-1	3.959	-0.001	3.961	0.001

f. Repeatability of sample measurement

During this cruise we measured oxygen concentration in 1453 seawater samples at 65 stations. Replicate samples were taken at every CTD casts. Results of replicate samples were shown in Table 4.1-2 and this diagram shown in Figure 4.1-1. The standard deviation was calculated by a procedure in Guide to best practices for ocean CO2 measurements Chapter4 SOP23 Ver.3.0 (2007).

Table 4.1-2. Results of the replicate sample measurements.

Layer	Number of replicate sample pairs	Oxygen concentration (μmol/kg) Standard Deviation.
1000m>=	141	0.23
>1000m	46	0.12
All	187	0.21

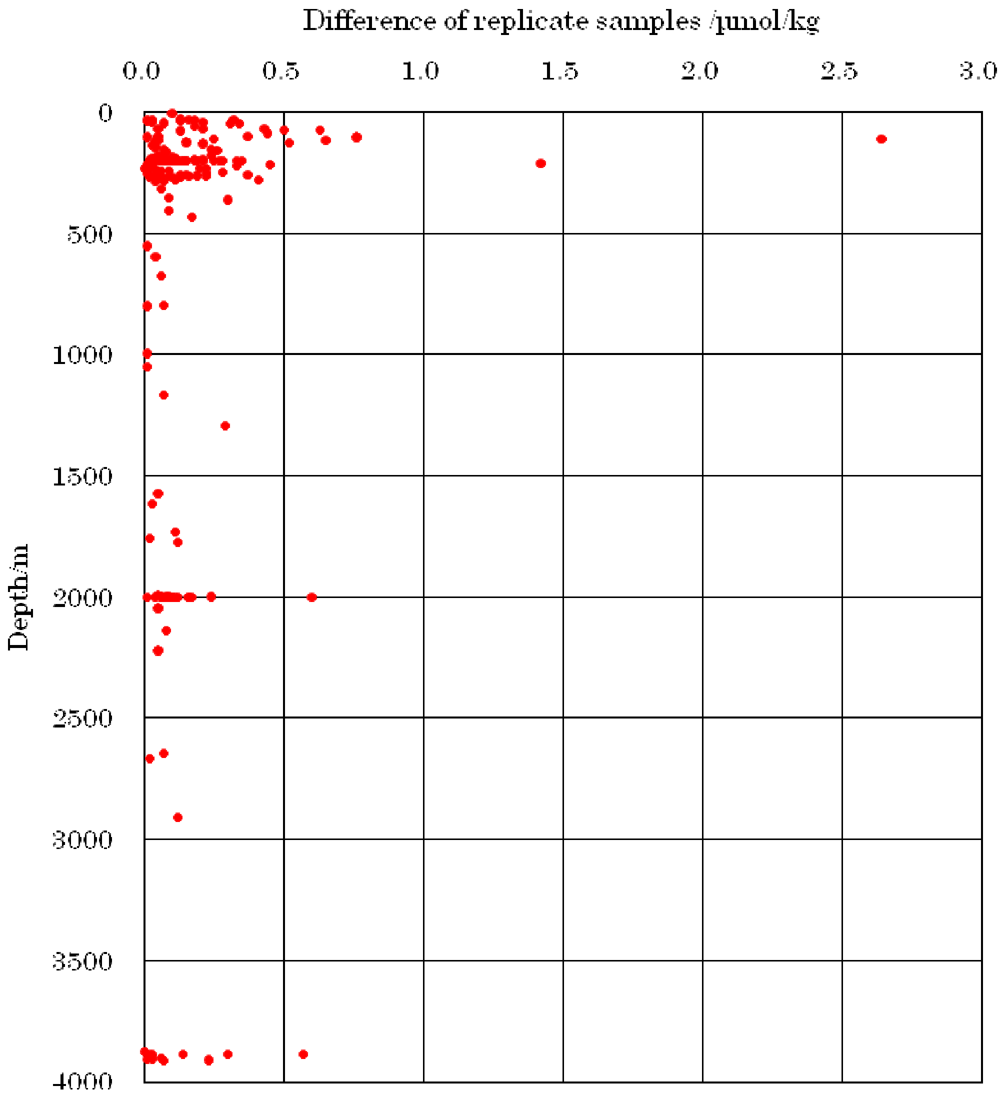


Figure 4.1-1.　Differences of replicate samples against sampling depth.

(5) Data archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

(6) 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

Shigeto Nishino	(JAMSTEC): Principal Investigator
Kenichiro Sato	(MWJ): Operation Leader
Junji Matsushita	(MWJ)
Ai Ueda	(MWJ
Kohei Miura	(MWJ)

(2) Objectives

The vertical and horizontal distributions of nutrients are one of most important factors on the primary production. On the other hand, nutrients data are used to study of climate changes as chemical tracers of sweater mass movement. During this cruise, nutrients measurements will give us the important information on the mechanism of the primary production and/or seawater circulation.

(3) Parameters

Nitrate, Nitrite, Silicate (although silicic acid is correct, we use silicate because a term of silicate is widely used in oceanographic community), Phosphate and Ammonia. See below for further details.

(4) Instruments and methods

Nutrient analysis was performed on two QuAAtro systems produced by SEAL. Silicon heater panels at 40 deg C for stable chemical reaction heated each console on QuAAtro. Ammonia reaction line equipped a heating bath at 45 deg C. Cells of detector using on this method was 1 cm flow cell. The laboratory temperature was maintained between 23 to 29 deg C.

a. Measured parameters

Nitrate + nitrite and nitrite are analyzed 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 seawater 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. N1-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. Wavelength using nitrate and nitrite analysis is 550 nm, which is absorbance of azo dye.

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 or “molybdenum blue” using L-ascorbic acid as the reductant. Wavelength using phosphate analysis is 880 nm, which is absorbance of phosphomolybdous acid.

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 silicic acid in the seawater sample and added molybdic acid; then the silicomolybdic acid is reduced to silicomolybdous acid, or “molybdenum blue” using L-ascorbic acid as the reductant. Wavelength using silicate analysis is 630 nm, which is absorbance of silicomolybdous acid.

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.

b. Standard

For nitrate standard, we used potassium nitrate 99.995 SupraPUR®, CAS No. 7757-91-1, provided by Merck.

For phosphate standard, we used potassium dihydrogen phosphate anhydrous 99.995 SupraPUR®, CAS No. 7778-77-0, provided by Merck.

For nitrite standard, we used sodium nitrite, CAS No. 7632-00-0, provided by Wako chemical Co. Assay of nitrite salt was determined according to JIS K8019 and purity was 98.77%.

For silicate standard, we used silicon standard solution SiO_2 in NaOH 0.5 mol/l CertiPUR®, CAS No. 1310-73-2, provided by Merck of which lot number is HC814662. The silicate concentration was certified by NIST-SRM 3150 with the uncertainty of 0.5%.

For ammonia standard, we used ammonium sulfate, CAS No. 7783-20-2, provided by Wako chemical Co.

c. Low nutrients sea water (LNSW)

Surface water having low nutrients concentration was taken and filtered using 0.45 μm pore size membrane filter. This water is stored in 20-liter cubitainer with paper box. The concentrations of nutrients of LNSW were measured carefully in July 2008.

d. Sampling procedures

Samples were drawn into virgin 10 ml polyacrylate vials that were rinsed three times before sampling without sample drawing tubes.

e. Analysis procedures

Working standards for calibration were prepared at on board before every analysis. The calibration curves for each run were obtained using four levels, and fitted by second order approximation. The standard of highest concentration was measured every 6 to 13 samples for correction of sensitivity and evaluation of precision. We also used reference material for nutrients in seawater, RMNS (KANSO Co., Ltd., lots BA, AY, AX and AR), for every runs to secure comparability on nutrient analysis throughout this cruise. We made duplicate measurement at all layer samples.

(5) Results

Analytical precisions in this cruise were less than 0.09% (36.7 μM) for nitrate, 0.15% (0.8 μM) for nitrite, 0.10% (85.4 μM) for silicate, 0.11% (3.6 μM) for phosphate and 0.30% (8.0 μM) for ammonia, respectively. Results of RMNS are shown in Table 4.2-1.

(6) Data archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

(7) References

Grasshoff, K. (1970), Technicon paper, 691-57.

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

Murphy, J. and Riley, J.P. (1962), Analytical chim. Acta 27, 31-36.

Table 4.2-1. Summary of RMNS concentration during this cruise.

unit: μ mol/kg

RMNS Lot.		Nitrate	Nitrite	Silicate	Phosphate	Ammonia
BA	average	0.09	0.02	1.59	0.059	0.96
	S.D.	0.02	0.00	0.07	0.006	0.03
	n	48	48	48	48	48
AY	average	5.69	0.62	29.44	0.517	0.80
	S.D.	0.03	0.00	0.09	0.006	0.03
	n	48	48	48	48	48
AX	average	21.58	0.35	58.12	1.618	0.67
	S.D.	0.05	0.00	0.11	0.007	0.03
	n	95	95	95	95	48
AR	average	-	-	-	-	4.97
	S.D.	-	-	-	-	0.05
	n	-	-	-	-	90

4.3. Underway surface water monitoring

(1) Personnel

Shigeto Nishino	(JAMSTEC): Principal Investigator
Misato Kuwahara	(MWJ): Operation leader
Minoru Kamata	(MWJ): Technical Staff
Hironori Sato	(MWJ): Technical Staff

(2) Objectives

Measurements of temperature, salinity, dissolved oxygen and fluorescence of the sea surface water in the Arctic Sea.

(3) Parameters

Temperature (surface water)
Salinity (surface water)
Dissolved oxygen (surface water)
Fluorescence (surface water)

(4) Instruments and methods

The *Continuous Sea Surface Water Monitoring System* (Nippon Kaiyo Co. Ltd.) that equips five sensors of 1) salinity, 2) temperatures (two sensors), 3) dissolved oxygen and 4) fluorescence can continuously measure their values in near-sea surface water. Salinity is calculated by conductivity on the basis of PSS78. Specifications of these sensors are listed below.

This system is settled in the "*sea surface monitoring laboratory*" on R/V MIRAI, and near-surface water was continuously pumped up to the system through a vinyl-chloride pipe. The flow rate for the system is manually controlled by several valves with its value of 12 L min^{-1} except for the fluorometer (about 0.5 L min^{-1}). Each flow rate is monitored with respective flow meter. The system is connected to shipboard LAN-system, and measured data is stored in a hard disk of PC every 1-minute together with time (UTC) and position of the ship.

a) Temperature and Conductivity sensor

Model:	SBE-21, SEA-BIRD ELECTRONICS, INC.
Serial number:	2126391-3126
Measurement range:	Temperature -5 to +35℃, Conductivity 0 to 7 S m^{-1}

Resolution: Temperatures 0.001℃, Conductivity 0.0001 S m^{-1}

Stability: Temperature 0.01℃ 6 $months^{-1}$, Conductivity 0.001 S m^{-1} $month^{-1}$

b) Bottom of ship thermometer

Model: SBE 3S, SEA-BIRD ELECTRONICS, INC.

Serial number: 032607

Measurement range: -5 to +35℃

Resolution: ±0.001℃

Stability: 0.002℃ $year^{-1}$

c) Dissolved oxygen sensor

Model: 2127A, Hach Ultara Analytics Japan, INC.

Serial number: 61230

Measurement range: 0 to 14 ppm

Accuracy: ±1% in ±5℃ of correction temperature

Stability: 5% $month^{-1}$

d) Fluorometer

Model: 10-AU-005, TURNER DESIGNS

Serial number: 5562 FRXX

Detection limit: 5 ppt or less for chlorophyll a

Stability: 0.5% $month^{-1}$ of full scale

e) Flow meter

Model: EMARG2W, Aichi Watch Electronics LTD.

Serial number: 8672

Measurement range: 0 to 30 L min^{-1}

Accuracy: <= ±1%

Stability: <= ±1% day^{-1}

The monitoring period (UTC) during this cruise are listed below.

LEG1 Start: 2009/8/29 7:49 Stop: 2009/09/06 13:55

LEG2 Start: 2009/9/7 23:02 Stop: 2009/10/15 13:54

LEG3 Start: 2009/10/16 13:59 Stop: 2009/10/23 5:53

(5) Preliminary Result

Preliminary data of temperature, salinity, dissolved oxygen, fluorescence at the sea surface are shown in Figures 4.3-1, 4.3-2 and 4.3-3.We took the surface water samples once a day to compare sensor data with bottle data of salinity and dissolved oxygen. The results are shown in Figures 4.3-4 and 4.3-5. All the salinity samples were analyzed by the Guildline 8400B “AUTOSAL”, and dissolve oxygen samples were analyzed by Winkler method.

(6) Date archives

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

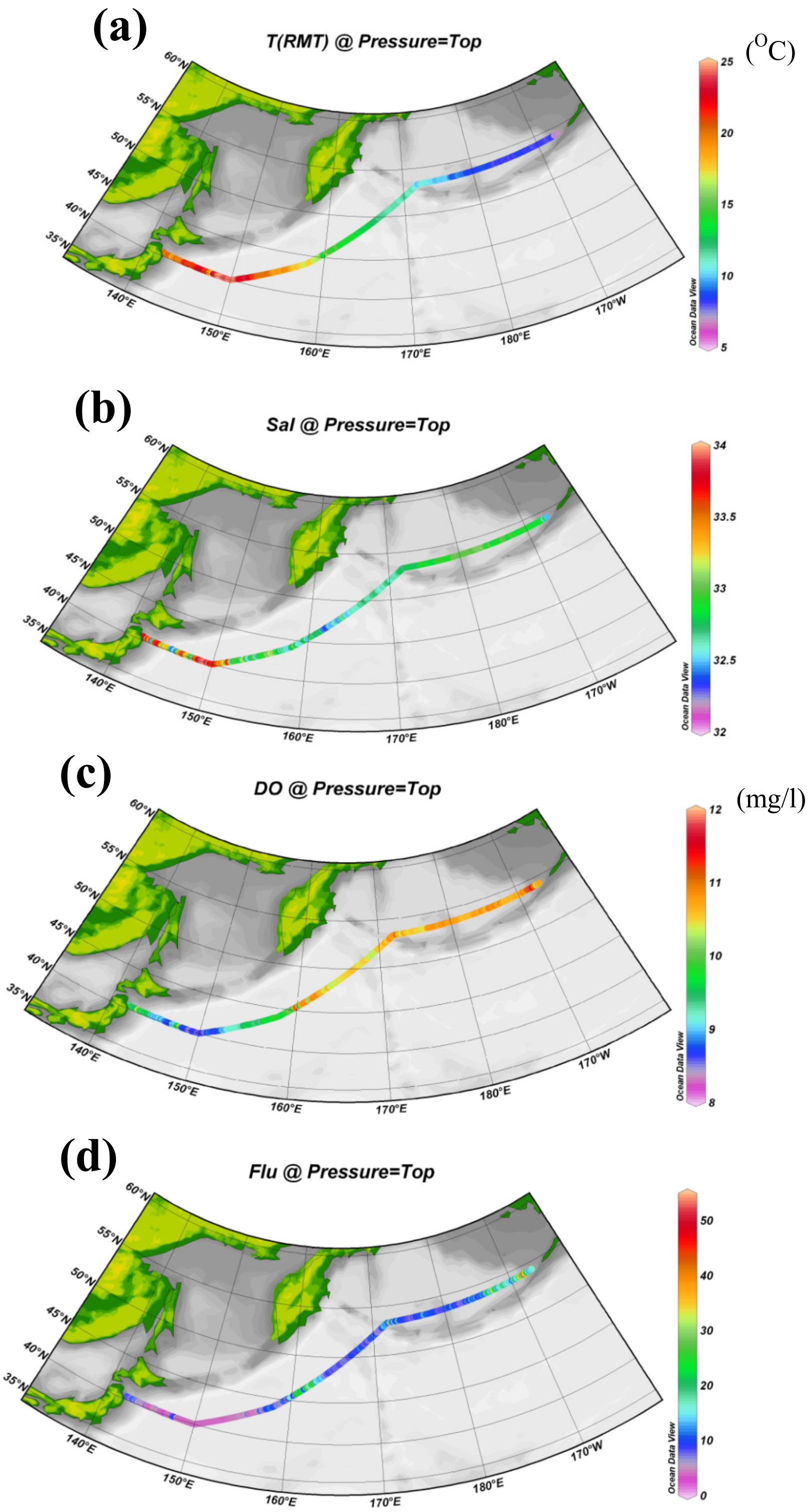


Figure 4.3-1. Spatial and temporal distributions of (a) temperature, (b) salinity, (c) dissolved oxygen and (d) fluorescence in MR09-03 LEG1 cruise. Fluorescence is relative value.

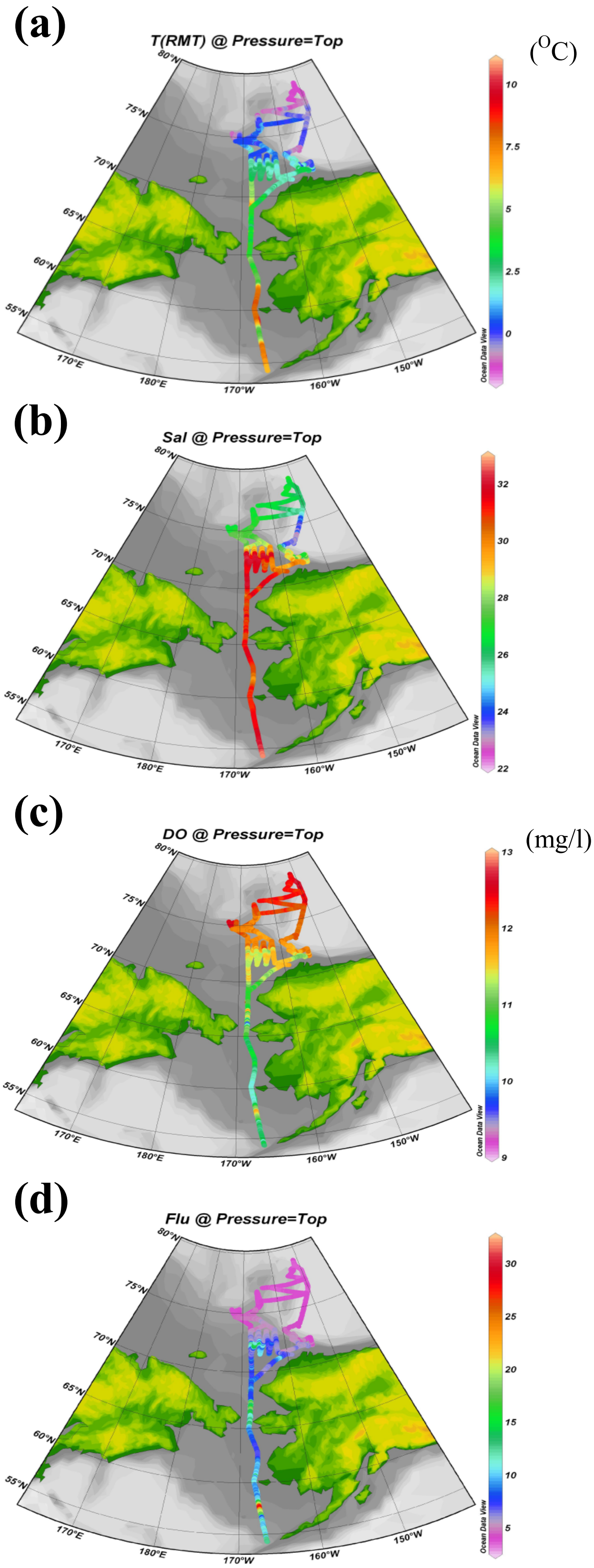


Figure 4.3-2. Spatial and temporal distributions of (a) temperature, (b) salinity, (c) dissolved oxygen and (d) fluorescence in MR09-03 LEG2 cruise. Fluorescence is relative value.

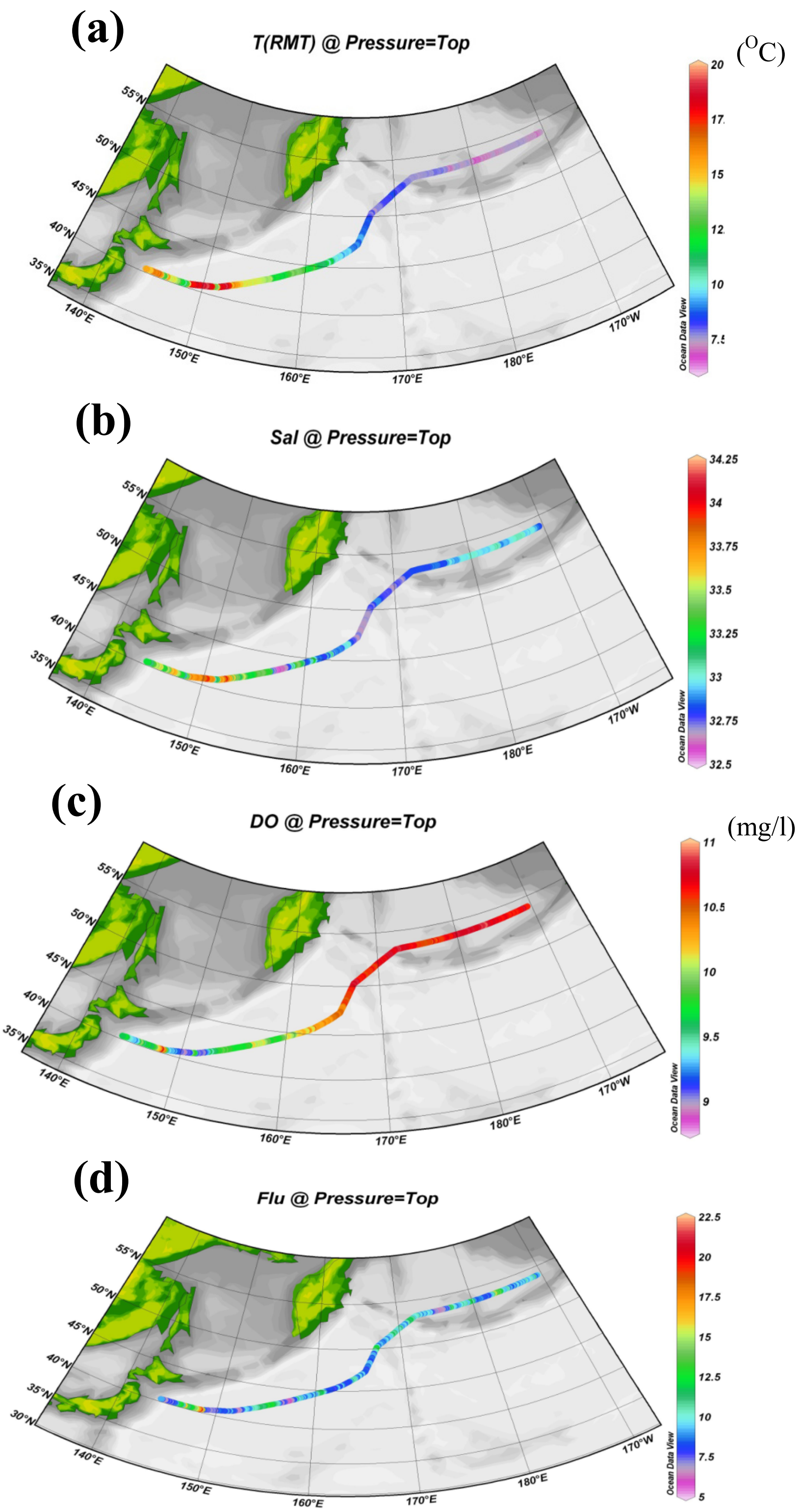


Figure 4.3-3. Spatial and temporal distributions of (a) temperature, (b) salinity, (c) dissolved oxygen and (d) fluorescence in MR09-03 LEG3 cruise. Fluorescence is relative value.

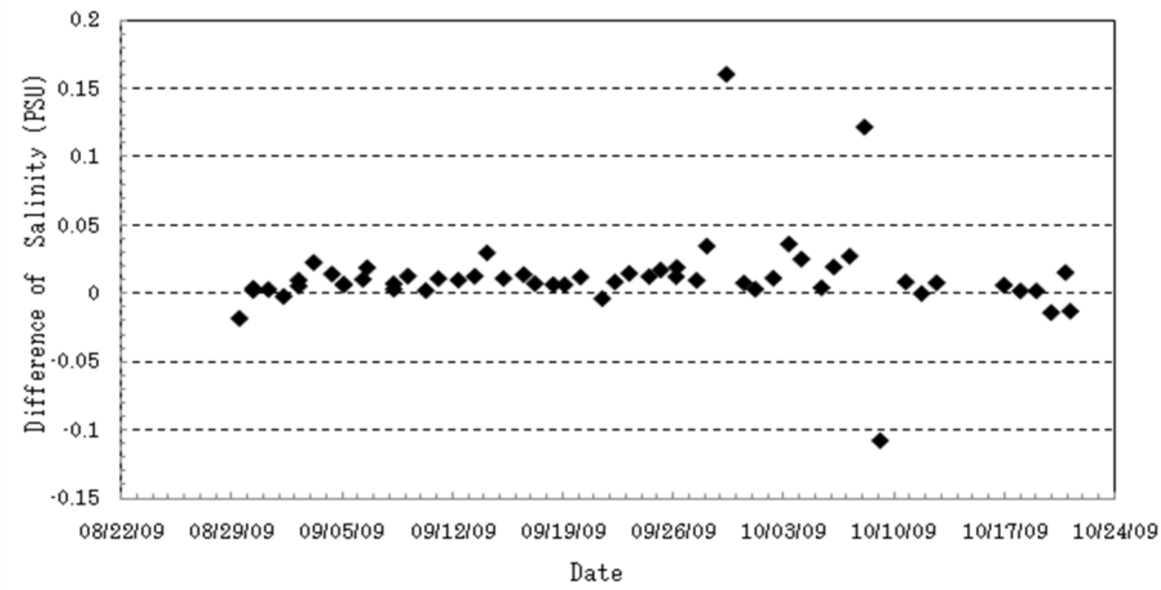


Figure 4.3-4. Difference of salinity between sensor data and bottle data. The mean difference is 0.0160 PSU.

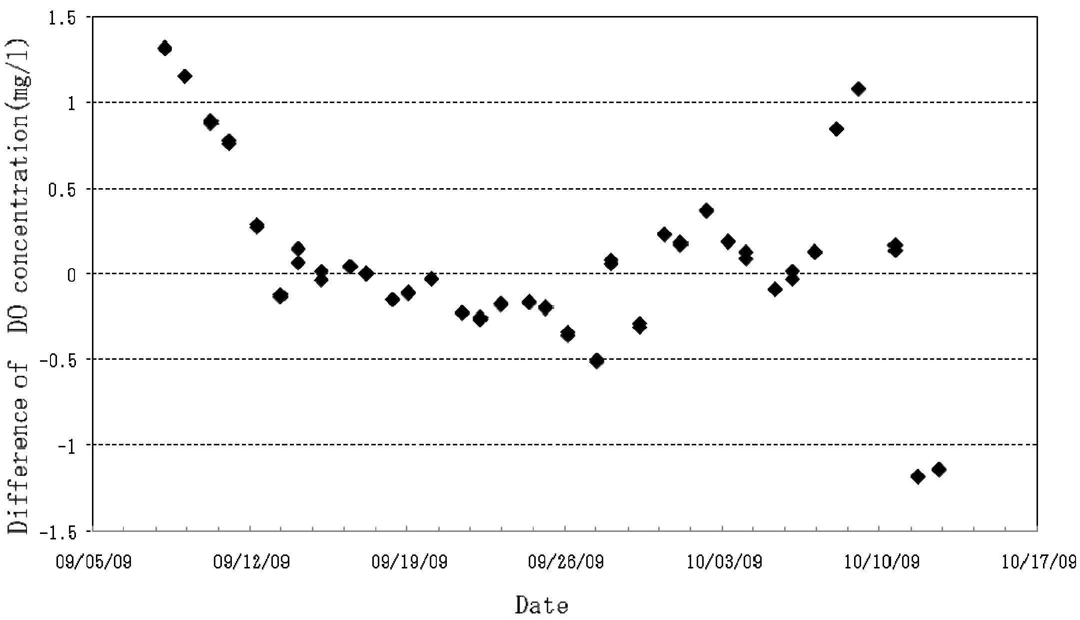


Figure 4.3-5. Difference of dissolved oxygen between sensor data and bottle data. The mean difference is -0.01mg/l.

4.4. pCO_2

(1) Personnel

Shigeto Nishino	(JAMSTEC): Principal Investigator
Fuyuki Shibata	(MWJ): Operation Leader
Yoshiko Ishikawa	(MWJ)
Tomonori Watai	(MWJ)

(2) Objectives

Magnitude of the anticipated global warming depends on the levels of CO_2 in the atmosphere, however, the ocean have an important role because one third of the 6 Gt of carbon emitted into the atmosphere by human activities each year is absorbed into the ocean. Hence, the clarification of both mechanism and capacity of oceanic CO_2 uptake are urgent tasks. Furthermore, in recent years, sea ice in the Arctic Ocean melts in vast area in summer relative to decades ago. The CO_2 flux between atmosphere and ocean directly depends on their CO_2 partial pressure (pCO_2) difference, therefore, the recent Arctic summer open ocean is considered to play an important role for global carbon cycle. We here report onboard measurements of pCO_2 during MR09-03 cruise.

(3) Parameters

Atmospheric and oceanic CO_2 partial pressure (pCO_2)

(4) Instruments and method

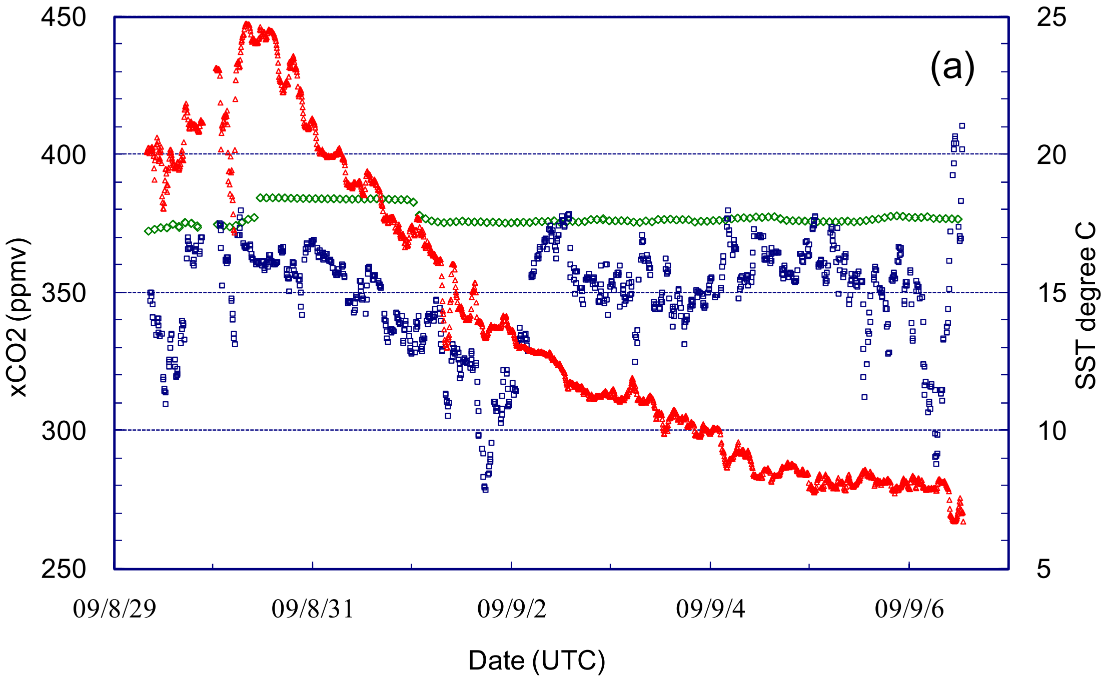
Concentrations of atmospheric and oceanic CO_2 were measured onboard during the cruise using an automated system with a non-dispersive infrared gas analyzer (NDIR; MLT 3T-IR). Four standard gases, atmospheric air and CO_2 equilibrated air with surface seawater were analyzed every one and half hour. The CO_2 in air with their concentrations of 270.22, 330.43, 360.04 and 420.33 ppmv were used for the standard gases.

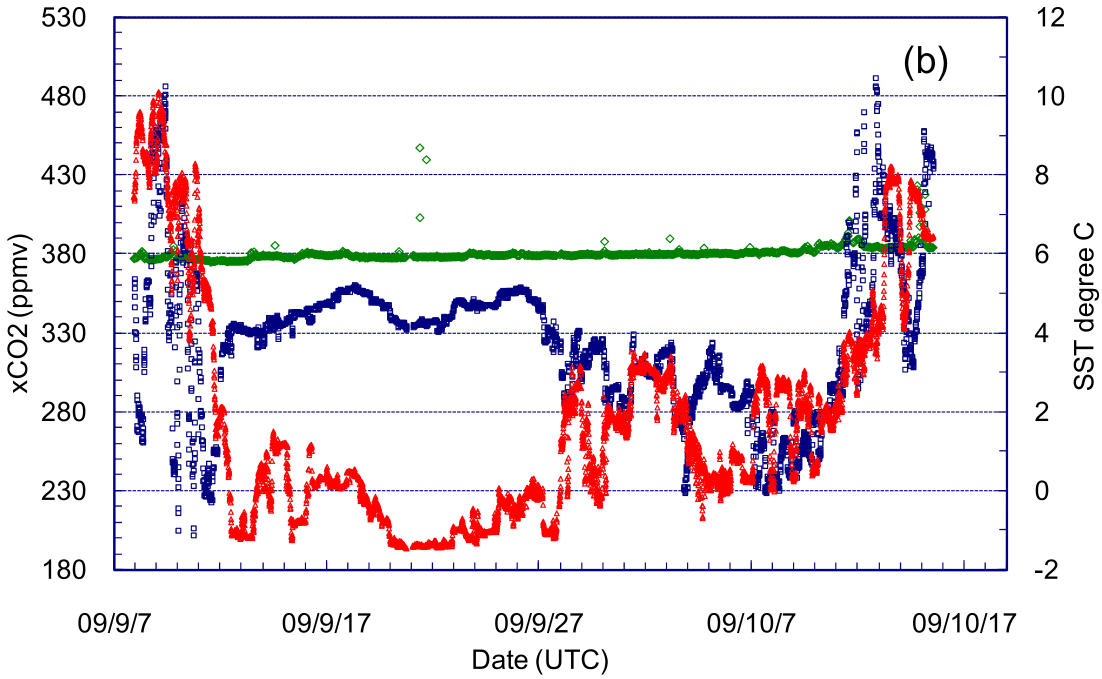
Atmospheric air was introduced from the bow of the ship (approx.30m above the sea level) into the analyzer through 1) a mass flow controller with its flow rate of 0.5 L min^{-1}, 2) a electric cooling unit, 3) a perma-pure dryer (GL Sciences Inc.) and 4) a chemical desiccant ($Mg(ClO_4)_2$).

Oceanic CO_2 concentration was measured by analyzing the CO_2 equilibrated air with surface seawater. Seawater pumped up from approx. 4.5 m below the sea surface was continuously showered into an equilibrator at a rate of 5 L min^{-1} and the CO_2 concentration in the equilibrator was equal to that of surface seawater within 6 minutes. The CO_2 equilibrated air was then introduced into the analyzer by another pump with its flow rate of 0.7 - 0.8 L min^{-1} through 1) two electronic cooling units, 2) the perma-pure dryer and 3) the chemical desiccant.

(5) Results

Temporal variations of atmospheric and oceanic CO_2 concentration (xCO2) are shown in Figure 4.4-1.





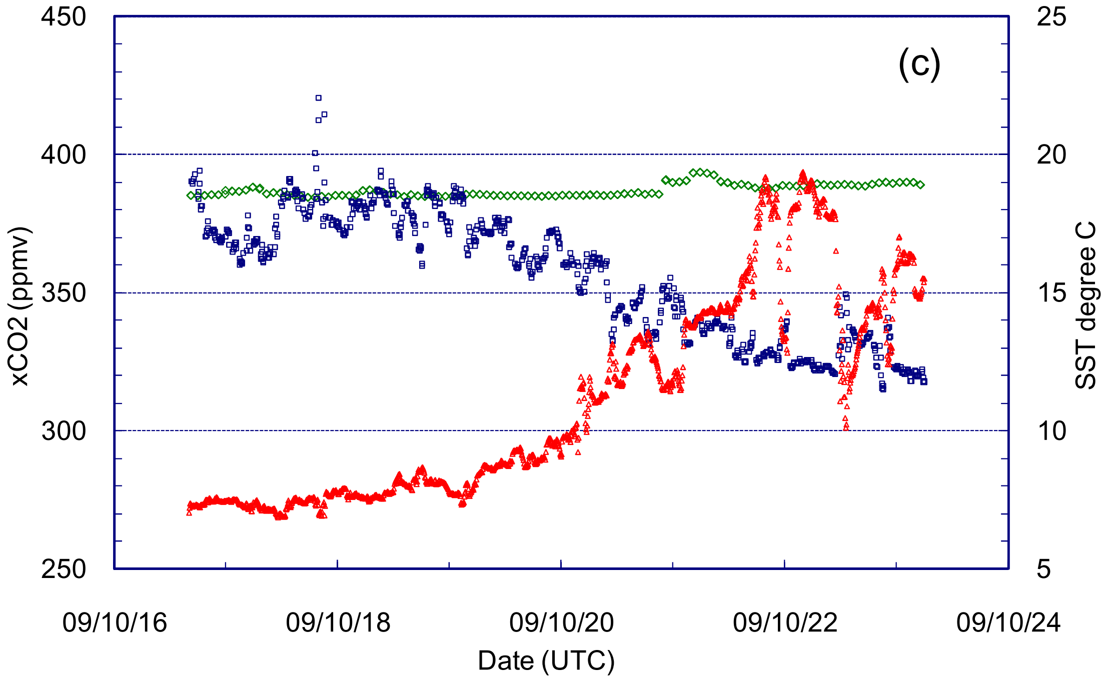


Figure 4.4-1. Temporal variations of atmospheric and oceanic CO_2 concentration (xCO2) for Leg 1 (a), Leg 2 (b) and Leg 3 (c). Green dots represent atmosphere xCO2 variation and blue oceanic xCO2. SST variation (red) is also shown.

(6) Date archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis

Group (DIAG) of JAMSTEC, and will be opened to the public via “R/V Mirai Data Web Page” in JAMSTEC home page.

4.5. Dissolved Inorganic Carbon

(1) Personnel

Michiyo Yamamoto-Kawai	(Institute of Ocean Sciences/ Department of Fisheries and Oceans Canada, IOS/DFO): Principal Investigator
Shigeto Nishino	(JAMSTEC)
Yoshiko Ishikawa	(MWJ)
Tomonori Watai	(MWJ)

(2) Objectives

The Arctic Ocean has the feature that Dissolved Inorganic Carbon (DIC) concentration is low, under the influence of inflow of a large amount of river water and dilution by sea ice melt water, and high biological productivity. Recently, surface undersaturation of calcium carbonate was observed caused by sea ice dilution, and we are anxious about its influences on growth of biota which forms shells of calcium carbonate. The percentage saturation of seawater in respect to calcium carbonate can be computed from DIC and Total Alkalinity (TA; ref. Section 4.6). We here report on-board measurements of DIC performed during the MR09-03 cruise.

(3) Parameter

Dissolved Inorganic Carbon, DIC

(4) Instruments and methods

a. Seawater sampling

Seawater samples were collected by 12L Niskin bottles and by a bucket at 60 stations. Seawater was then transferred into a 300ml glass bottle (SCHOTT DURAN) that 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 carried out. The glass bottles were filled from the bottom, without rinsing, and were overflowed for 20 seconds. They were sealed using the 29mm polyethylene inner lids with care not to leave any bubbles in the bottle. After collecting the samples on the deck, the glass bottles were moved to the lab to be measured. Prior to the analysis, 3ml of the sample (1% of the bottle volume) was removed from the glass bottle in order to make a headspace. The samples were then poisoned with 100μl of over saturated solution of mercury chloride within one hour after the sampling. After poisoning, the samples were sealed using the 31.9mm polyethylene inner lids and stored in a refrigerator at approximately 5degC until being analyzed.

b. Seawater analysis

Measurements of DIC were made with total CO_2 measuring system (systems A; Nippon ANS, Inc.). The system comprise of seawater dispensing system, a CO_2 extraction system and a coulometer (Model 5012, UIC Inc.)

The seawater dispensing system has an auto-sampler (6 ports), which takes seawater from a glass bottle to a pipette of nominal 21ml volume by PC control. The pipette was kept at 20 ± 0.05 degC by a water jacket, in which water is circulated from a thermostatic water bath (LP-3110, ADVANTEC) set at 20 degC.

DIC dissolved in a seawater sample is extracted in a stripping chamber of the CO_2 extraction system by adding phosphoric acid (10% v/v). The stripping chamber is made approx. 20 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 then 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 rates of 140ml min^{-1}) to the coulometer through a dehydrating module consists of two electric dehumidifiers (kept at 0.5 degC) and a chemical desiccant ($Mg(ClO_4)_2$).

The measurement sequence such as 1.5% CO_2 gas in a nitrogen base, system blank (phosphoric acid blank), and seawater samples (6 samples) was programmed to repeat. The measurement of 1.5% CO_2 gas was made to monitor response of coulometer solutions (from UIC, Inc.).

(5) Preliminary results

During the cruise, 858 samples were analyzed for DIC. A few replicate samples were taken at most of stations and the difference between each pair of analyses was plotted on a range control chart (see Figure 4.5-1). The average of the differences was 0.5 μmol/kg (n=93). The standard deviation was 0.5 μmol/kg, which indicates that the analysis was accurate enough according to the Guide to 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 Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via “R/V Mirai Data Web Page” in JAMSTEC home page.

(7) Reference

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

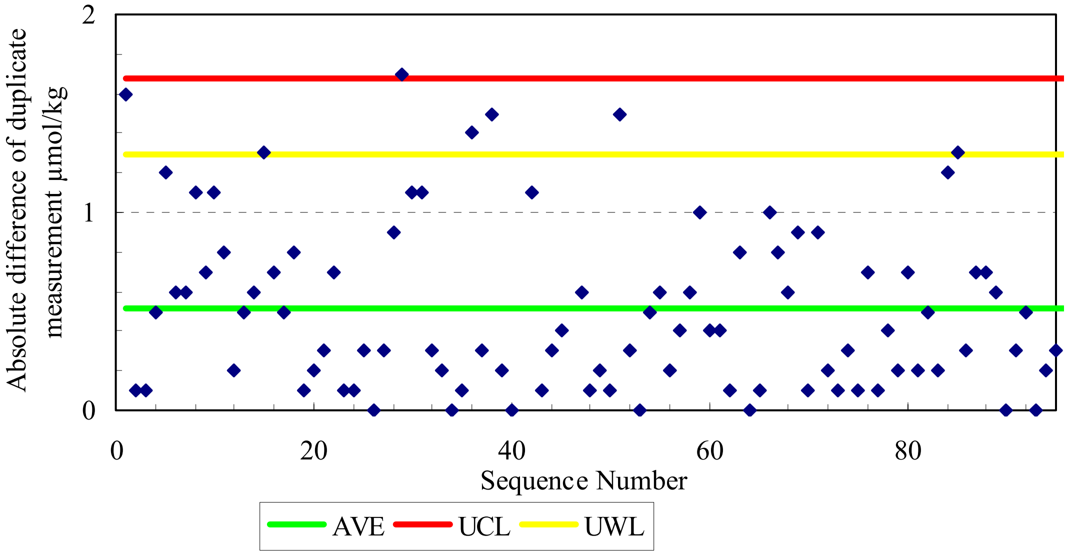


Figure 4.5-1. Range control chart of the absolute differences of replicate measurements carried out in the analysis of DIC during the MR09-03 cruise. UCL and UWL represents the upper control limit (UCL=AVE*3.267) and upper warning limit (UWL=AVE*2.512), respectively.

4.6. Total Alkalinity

(1) Personnel

Michiyo Yamamoto-Kawai	(IOS/DFO): Principal Investigator
Shigeto Nishino	(JAMSTEC)
Tomonori Watai	(MWJ)

(2) Objectives

The Arctic Ocean receives a large amount of river water from the surrounding continents. Since river water carries not only freshwater but also carbon, nutrients, contaminants etc., changes in distribution and residence time of river water in the Arctic Ocean may affect regional and global climate, productivity and human health. In order to trace river water in the Arctic Ocean, we have analyzed total alkalinity (TA) of seawater, with which river runoff (TA ~1000 μmol kg^{-1}) can be distinguished from sea ice meltwater (TA ~260 μmol kg^{-1}). Moreover, by using TA with oxygen isotope ratio (ref. section 4.6), the source of river water can be further distinguished between North American rivers (TA ~1600 μmol kg^{-1}) and Eurasian rivers (TA ~800 μmol kg^{-1}). We here report on-board measurements of total alkalinity performed during the MR09-03 cruise.

(3) Parameter

Total Alkalinity, TA

(4) Instruments and methods

a. Seawater sampling

Seawater samples were collected at 60 stations in 12 L Niskin bottles mounted on the CTD-rosette 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 put in the water bath kept about 25° C for one hour before the measurement.

b. Seawater analysis

Measurement of alkalinity 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 in the spectrophotometer (Carry 50 Scan, Varian) via dispensing unit. The length and volume of the cell are 8 cm and 13 ml, respectively, and its temperature is kept at 25° C in a thermostated compartment. The TA is calculated by measuring two sets of absorbance at three wavelengths (750, 616 and 444 nm). 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 5 and half minutes before the measurement.

The TA is calculated based on the following equation:

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

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

where R(25) represents the difference of absorbance at 616 and 444 nm between before and after the injection. The absorbance of wavelength at 750 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 a bath with its temperature of 25° C, and about 10 ml of it is discarded at first before the batch of measurement. 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 10 times during each analysis, and the stable last five and three values are averaged and used for above listed calculation for before and after the injection, respectively.

(5) Preliminary results

At each station, samples were taken in duplicate for waters at 50 m and at a layer close to the sea bottom (ranging from 30 to 3500 m depending on the bottom depth). The difference between each pair of analyses was plotted on a range control chart (Figure 4.6-1). The average of the difference was 0.66 µmol kg^{-1} (n = 107 pair) with its standard deviation of 0.39 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).

(6) Data Archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

(7) 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.

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

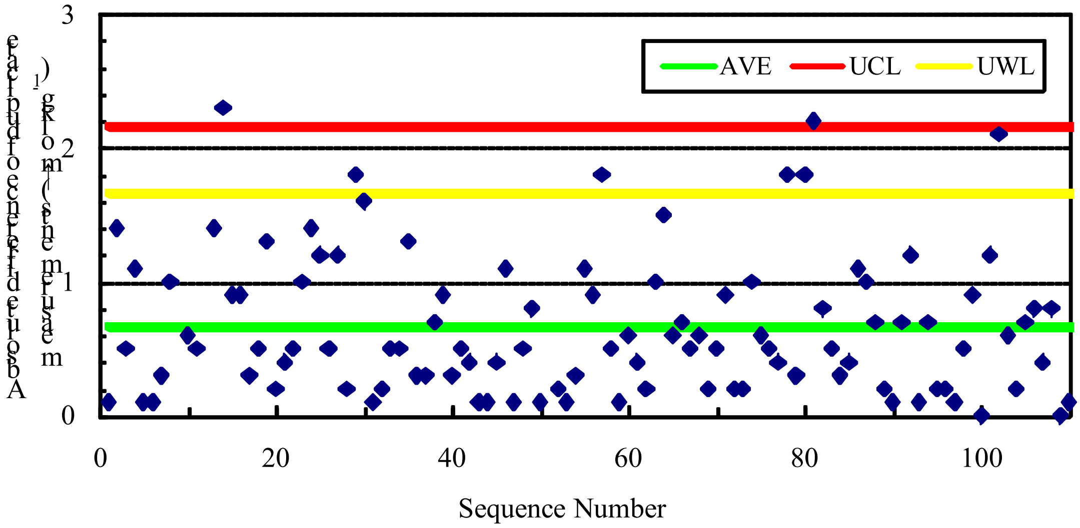


Figure 4.6-1. Range control chart of the absolute differences of duplicate measurements of TA carried out during this cruise.

4.7. Oxygen isotope ratio (δ18O)

(1) Personnel

Michiyo Yamamoto-Kawai (IOS/DFO): Principal Investigator (PI)

Shigeto Nishino (JAMSTEC): Co-PI

(2) Objectives

Oxygen isotope ratio (δ18O) of seawater is a tracer to distinguish the source of freshwater between sea ice meltwater and meteoric water (river runoff and precipitation). We have collected seawater samples for δ18O analysis during the cruise. Results will be compared with previous observations observed during cruises of R/V Mirai in 2002 and 2008 in order to detect on-going changes in freshwater distributions in the Arctic Ocean under the recent conditions of warming and attendant increase in sea ice melt. Furthermore, a combination of δ18O with total alkalinity (ref. Section 4.6) may provide additional information about the distribution of North American river runoff because, although American and Eurasian rivers have identical oxygen isotope ratios, the total alkalinity of American river water is higher than Eurasian river water.

(3) Parameter

Oxygen isotope ratio (δ18O)

(4) Instruments and methods

Seawater samples were collected in 12L Niskin bottles mounted on the CTD-rosette system and then transferred into 20 ml glass vials for $\delta^{18}O$ analysis. The sampling list is summarized in Table 4.7-1. Samples are stored in refrigerator (~5˚C) and will be analyzed at JAMSTEC. Results will be reported as a permil deviation of oxygen isotope ratio of the sample from that of international standard seawater (VSMOW):

$$\delta^{18}O = \{(H_2{}^{18}O/H_2{}^{16}O)_{sample} - (H_2{}^{18}O/H_2{}^{16}O)_{VSMOW}\}/(H_2{}^{18}O/H_2{}^{16}O)_{VSMOW} \times 1000\ [‰].$$

(5) Data archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

Table 4.7-1 Sampling list for $\delta^{18}O$

Sample #	Sta	Niskin #	Sample #	Sta	Niskin #	Sample #	Sta	Niskin #
1	-	-	51	6	27	101	9	25
2	-	-	52	6	26	102	9	24
3	-	-	53	6	26	103	9	23
4	-	-	54	6	25	104	9	22
5	-	-	55	6	24	105	9	15
6	-	-	56	6	15	106	9	1
7	2	36	57	6	1	107	10	36
8	2	35	58	7	0	108	10	35
9	2	34	59	7	36	109	10	34
10	2	33	60	7	35	110	10	33
11	2	15	61	7	34	111	10	32
12	2	1	62	7	33	112	10	32
13	2	0	63	7	32	113	10	31
14	3	36	64	7	31	114	10	30
15	3	35	65	7	30	115	10	29
16	3	34	66	7	29	116	10	29
17	3	33	67	7	28	117	10	28
18	3	15	68	7	27	118	10	27
19	3	1	69	7	26	119	10	26
20	3	1	70	7	25	120	10	15
21	3	0	71	7	24	121	10	1
22	4	36	72	7	15	122	11	0
23	4	35	73	8	0	123	11	36
24	4	34	74	8	36	124	11	35
25	4	33	75	8	35	125	11	34
26	4	32	76	8	35	126	11	33
27	4	1	77	8	34	127	11	32
28	4	0	78	8	33	128	11	32
29	5	36	79	8	32	129	11	31
30	5	35	80	8	31	130	11	30
31	5	34	81	8	30	131	11	29
32	5	33	82	8	29	132	11	28
33	5	32	83	8	28	133	11	27
34	5	31	84	8	27	134	11	1
35	5	30	85	8	26	135	12	0
36	5	29	86	8	25	136	12	36
37	5	28	87	8	24	137	12	35
38	5	27	88	8	15	138	12	34
39	5	1	89	9	0	139	12	33
40	5	0	90	9	36	140	12	32
41	6	0	91	9	35	141	12	31
42	6	36	92	9	34	142	12	30
43	6	35	93	9	33	143	12	29
44	6	34	94	9	32	144	12	28
45	6	33	95	9	31	145	12	1
46	6	32	96	9	30	146	13	0
47	6	31	97	9	29	147	13	36
48	6	30	98	9	28	148	13	35
49	6	29	99	9	27	149	13	34
50	6	28	100	9	26	150	13	33

Table 4.7-1 Sampling list for $\delta^{18}O$

Sample #	Sta	Niskin #	Sample #	Sta	Niskin #	Sample #	Sta	Niskin #
151	13	32	201	16	33	251	21	34
152	13	31	202	16	32	252	21	33
153	13	30	203	16	31	253	21	32
154	13	29	204	16	30	254	21	31
155	13	28	205	16	29	255	21	30
156	13	27	206	16	28	256	21	29
157	13	26	207	16	27	257	21	28
158	13	25	208	16	26	258	21	28
159	13	1	209	16	25	259	21	27
160	14	0	210	16	24	260	21	26
161	14	36	211	17	0	261	21	25
162	14	35	212	17	36	262	21	24
163	14	34	213	17	35	263	22	0
164	14	33	214	17	34	264	22	36
165	14	32	215	17	34	265	22	35
166	14	31	216	17	33	266	22	34
167	14	30	217	17	32	267	22	33
168	14	29	218	17	31	268	22	32
169	14	28	219	17	30	269	22	31
170	14	27	220	17	29	270	22	30
171	14	26	221	17	28	271	22	29
172	14	25	222	17	27	272	22	28
173	14	24	223	17	26	273	22	27
174	14	24	224	17	25	274	22	26
175	14	23	225	17	24	275	22	25
176	14	22	226	19	0	276	22	24
177	15	0	227	19	36	277	25	0
178	15	36	228	19	35	278	25	36
179	15	35	229	19	34	279	25	35
180	15	34	230	19	33	280	25	35
181	15	33	231	19	32	281	25	34
182	15	32	232	19	31	282	25	33
183	15	31	233	19	30	283	25	32
184	15	30	234	19	29	284	25	31
185	15	29	235	19	29	285	25	30
186	15	28	236	19	28	286	25	29
187	15	27	237	19	27	287	25	28
188	15	26	238	19	26	288	25	27
189	15	25	239	19	25	289	25	26
190	15	24	240	19	24	290	25	25
191	15	23	241	19	23	291	25	24
192	15	22	242	19	22	292	28	0
193	15	21	243	19	21	293	28	36
194	15	20	244	19	20	294	28	35
195	15	1	245	19	19	295	28	34
196	15	1	246	19	18	296	28	33
197	16	0	247	19	1	297	28	32
198	16	36	248	21	0	298	28	31
199	16	35	249	21	36	299	28	30
200	16	34	250	21	35	300	28	29

Table 4.7-1 Sampling list for $\delta^{18}O$

Sample #	Sta	Niskin #	Sample #	Sta	Niskin #	Sample #	Sta	Niskin #
301	28	28	351	35	31	401	45	25
302	28	27	352	35	30	402	45	25
303	28	26	353	35	29	403	45	24
304	28	25	354	35	28	404	47	0
305	28	24	355	35	27	405	47	36
306	30	0	356	35	27	406	47	35
307	30	36	357	35	26	407	47	34
308	30	35	358	35	25	408	47	33
309	30	34	359	35	24	409	47	32
310	30	34	360	39	0	410	47	31
311	30	33	361	39	36	411	47	30
312	30	32	362	39	35	412	47	29
313	30	31	363	39	35	413	47	28
314	30	30	364	39	34	414	47	27
315	30	29	365	39	33	415	47	26
316	30	28	366	39	32	416	47	25
317	30	27	367	39	31	417	47	24
318	30	26	368	39	30	418	48	0
319	30	25	369	39	29	419	48	36
320	30	24	370	39	28	420	48	35
321	30	23	371	39	27	421	48	34
322	30	22	372	39	26	422	48	33
323	30	21	373	39	25	423	48	33
324	30	20	374	39	24	424	48	32
325	30	19	375	42	0	425	48	31
326	30	18	376	42	36	426	48	30
327	30	17	377	42	35	427	48	29
328	30	16	378	42	34	428	48	28
329	30	1	379	42	33	429	48	27
330	33	0	380	42	32	430	48	26
331	33	36	381	42	31	431	48	25
332	33	35	382	42	30	432	48	24
333	33	34	383	42	29	433	49	0
334	33	33	384	42	28	434	50	0
335	33	32	385	42	27	435	50	36
336	33	31	386	42	26	436	50	35
337	33	30	387	42	25	437	50	34
338	33	29	388	42	24	438	50	33
339	33	28	389	45	0	439	50	33
340	33	27	390	45	36	440	50	32
341	33	27	391	45	35	441	50	31
342	33	26	392	45	34	442	50	30
343	33	25	393	45	33	443	50	29
344	33	24	394	45	32	444	50	28
345	35	0	395	45	31	445	50	28
346	35	36	396	45	30	446	50	27
347	35	35	397	45	29	447	50	26
348	35	34	398	45	28	448	50	25
349	35	33	399	45	27	449	50	24
350	35	32	400	45	26	450	51	0

Table 4.7-1 Sampling list for $\delta^{18}O$

Sample #	Sta	Niskin #	Sample #	Sta	Niskin #	Sample #	Sta	Niskin #
451	51	36	501	60	0	551	67	36
452	51	35	502	60	36	552	67	35
453	51	34	503	60	35	553	67	35
454	51	33	504	60	34	554	67	34
455	51	32	505	60	33	555	67	33
456	51	31	506	60	32	556	67	32
457	51	30	507	60	31	557	67	31
458	51	29	508	60	31	558	67	30
459	51	28	509	60	30	559	67	29
460	51	28	510	60	29	560	67	28
461	51	27	511	60	28	561	67	27
462	51	26	512	60	27	562	67	26
463	51	25	513	60	26	563	67	25
464	51	24	514	60	25	564	67	24
465	51	24	515	60	24	565	69	0
466	51	23	516	60	15	566	69	36
467	51	22	517	62	0	567	69	35
468	51	21	518	62	36	568	69	35
469	51	20	519	62	35	569	69	34
470	51	19	520	62	34	570	69	33
471	51	18	521	62	33	571	69	32
472	51	17	522	62	33	572	69	31
473	51	1	523	62	32	573	69	30
474	56	0	524	62	31	574	69	29
475	57	0	525	62	30	575	69	28
476	58	0	526	62	29	576	69	27
477	58	36	527	62	28	577	69	26
478	58	35	528	62	27	578	69	25
479	58	34	529	62	26	579	69	25
480	58	33	530	62	25	580	69	24
481	58	32	531	62	1	581	71	0
482	58	31	532	64	0	582	71	36
483	58	30	533	64	36	583	71	35
484	58	29	534	64	36	584	71	34
485	58	28	535	64	35	585	71	33
486	58	27	536	64	34	586	71	32
487	58	27	537	64	33	587	71	31
488	58	26	538	64	1	588	71	30
489	58	25	539	66	0	589	71	29
490	58	24	540	66	36	590	71	28
491	58	23	541	66	35	591	71	27
492	58	22	542	66	34	592	71	26
493	58	21	543	66	33	593	71	25
494	58	20	544	66	32	594	71	24
495	58	19	545	66	31	595	75	0
496	58	18	546	66	30	596	75	36
497	58	17	547	66	29	597	75	35
498	58	16	548	66	28	598	75	34
499	58	1	549	66	1	599	75	33
500	59	0	550	67	0	600	75	33

Table 4.7-1 Sampling list for $\delta^{18}O$

Sample #	Sta	Niskin #	Sample #	Sta	Niskin #	Sample #	Sta	Niskin #
601	75	32	651	80	36	701	83	29
602	75	31	652	80	36	702	83	28
603	75	30	653	80	35	703	83	27
604	75	29	654	80	34	704	83	26
605	75	28	655	80	33	705	83	25
606	75	27	656	80	32	706	83	24
607	75	26	657	80	31	707	83	1
608	75	25	658	80	30	708	84	0
609	75	24	659	80	29	709	84	0
610	75	23	660	80	28	710	84	36
611	75	22	661	80	27	711	84	35
612	75	21	662	80	26	712	84	34
613	75	20	663	80	25	713	84	33
614	75	19	664	81	0	714	84	32
615	75	1	665	81	36	715	84	31
616	77	0	666	81	35	716	84	30
617	77	36	667	81	35	717	84	29
618	77	35	668	81	34	718	84	28
619	77	34	669	81	33	719	84	27
620	77	33	670	81	32	720	84	26
621	77	32	671	81	31	721	84	1
622	77	31	672	81	30	722	85	0
623	77	30	673	81	29	723	85	36
624	77	29	674	81	28	724	85	35
625	77	28	675	81	27	725	85	34
626	77	27	676	81	1	726	85	33
627	77	26	677	82	0	727	85	33
628	77	25	678	82	36	728	85	32
629	77	24	679	82	35	729	85	31
630	78	0	680	82	34	730	85	30
631	78	36	681	82	33	731	85	1
632	78	35	682	82	32	732	86	0
633	78	34	683	82	31	733	86	36
634	78	33	684	82	30	734	86	35
635	78	32	685	82	29	735	86	34
636	78	31	686	82	28	736	86	33
637	78	30	687	82	27	737	86	32
638	78	29	688	82	26	738	86	32
639	78	28	689	82	25	739	86	31
640	78	27	690	82	1	740	86	30
641	78	1	691	83	0	741	86	1
642	79	0	692	83	36	742	87	0
643	79	36	693	83	36	743	87	36
644	79	35	694	83	35	744	87	36
645	79	34	695	83	34	745	87	35
646	79	33	696	83	33	746	87	34
647	79	32	697	83	32	747	87	33
648	79	1	698	83	31	748	87	1
649	79	1	699	83	30	749	88	0
650	80	0	700	83	30	750	88	35

Table 4.7-1 Sampling list for $\delta^{18}O$

Sample #	Sta	Niskin #	Sample #	Sta	Niskin #	Sample #	Sta	Niskin #
751	88	34						
752	88	1						
753	89	0						
754	89	36						
755	89	36						
756	89	35						
757	89	34						
758	89	33						
759	89	32						
760	89	31						
761	89	30						
762	89	29						
763	89	28						
764	89	27						
765	89	1						
766	90	0						
767	90	36						
768	90	36						
769	90	35						
770	90	34						
771	90	1						
772	91	0						
773	91	36						
774	91	35						
775	91	34						
776	91	33						
777	91	32						
778	91	31						
779	91	1						

4.8. Chlorophyll *a* measurements of total and size-fractionated phytoplankton

(1) Personnel

Shigeto Nishino (JAMSTEC) : Principal Investigator
Toru Hirawake (Hokkaido University) : Principal Investigator
Masanori Enoki (MWJ) : Operation Leader
Keitaro Matsumoto (Hokkaido University) : Operator
Katsuhito Simmyo (Hokkaido University) : Operator

(2) Objectives

Phytoplankton distributes in various species and size in the ocean. Phytoplankton species are roughly characterized by the cell size. The object of this study is to investigate the vertical and horizontal distributions of phytoplankton by using the size-fractionated filtration method in the Arctic Ocean.

(3) Parameters

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

(4) Instruments and methods

We collected samples for total chlorophyll *a* (chl-*a*) from 9 depths between the surface and 200 m during routine casts. In some routine casts, we also collected samples for size-fractionated chl-*a* from 4 depth including a chl-*a* maximum depth, which was determined by a fluorometer (Seapoint Sensors, Inc.) attached to the CTD system. Furthermore, we collected samples for total chl-*a* and size-fractionated chl-*a* from 12 depths within the euphotic layer and the layer below down to 200 m during the casts where the primary productivity measurements were conducted. The euphotic layer was determined by a downward irradiance sensor for the experiments of primary productivity, and the sampling depths were determined as light intensities of 50, 25, 10, 5, 2.5, 1 and 0.5% to the surface incident irradiance.

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 sequentially vacuum-filtrated (<0.02MPa) through the three types of 47mm-diameter nuclepore filters (pore size of 10.0μm, 5.0μm and 2.0μm) and the 25mm-diameter Whatman GF/F filter. 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* for 24 hours or more.

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 4.8-1.

(5) Results

Samples for total and size-fractionated chl-*a* were collected at 41 and 22 stations, respectively (See Figure 4.8-1). The numbers of samples for total and size-fractionated chl-*a* were 582 and 776, respectively. The analytical precision of total chl-*a* is 4.8% (n = 154).

The distributions of total and size-fractionated chl-*a* along a north-south section in the Canada Basin are shown in Figure 4.8-2.

(6) Data archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC, and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

(7) Reference

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

Table 4.8-1. Analytical conditions of non-acidification method for chlorophyll *a* with Turner Design fluorometer (10-AU-005).

	Non-acidification method
Excitation filter (nm)	436
Emission filter (nm)	680
Lamp	Blue F4T5,B2/BP

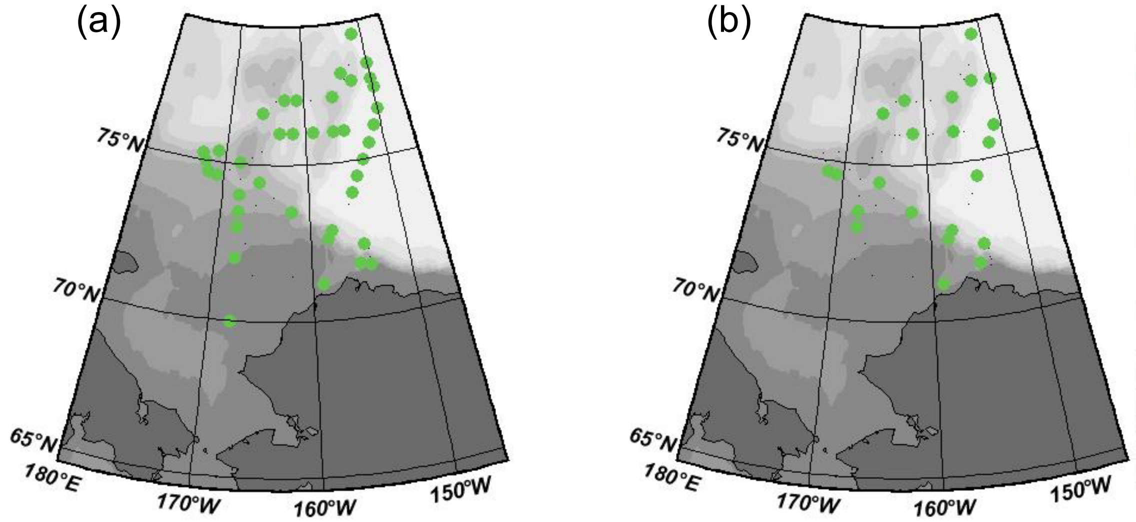


Figure 4.8-1. Maps of stations for (a) total and (b) size-fractionated chlorophyll *a* measurements.

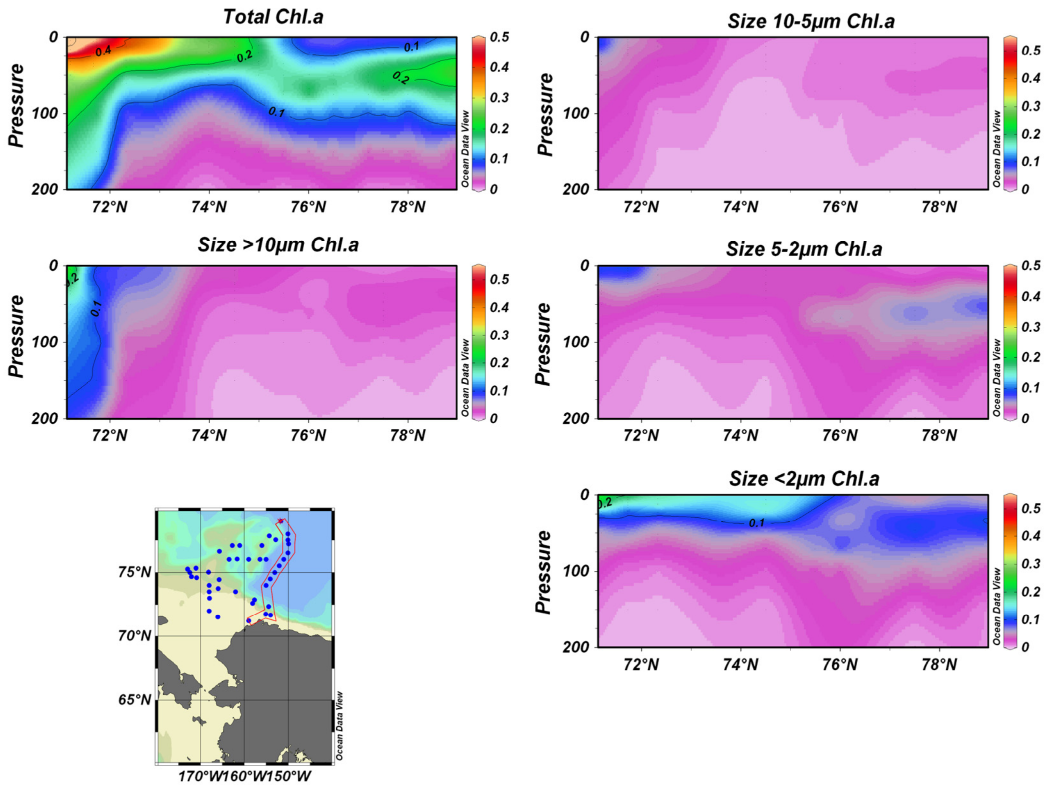


Figure 4.8-2. Distributions of total and size-fractionated chlorophyll *a* (μg/L) along a north-south section in the Canada Basin.

4.9. New production and regenerated production

(1) Personnel

Shigeto Nishino (JAMSTEC): Principal Investigator
Fuyuki Shibata (MWJ): Operation Leader
Miyo Ikeda (MWJ)

(2) Objectives

New and regenerated productions were measured to examine biological activities in terms of nutrient and chlorophyll *a* distributions and light conditions, especially focused on how the primary production is sustained by nitrate supplied from deeper layers or ammonium regenerated from organisms.

(3) Parameters

New production and regenerated production

(4) Instruments and methods

a. Instruments

Stable isotope analyzer
ANCA-NT SYSTEM by Europa Scientific Ltd.

b. Methods

New and regenerated production was measured at stations 004, 010, 015, 025, 033, 035, 058, 062, 075, and 083 (See Figure 4.9-1) by simulated in situ incubation method. We sampled seawater by using light-blocking and acid-treatment bottles and tubes connected to the Niskin bottles, which are derived from 5 optical depths, 100%, 25%, 10%, 1% and 0.5% light intensities relative to the surface irradiance.

After sampling, at a dark room, seawater was dispersed into 1L Nalgene polycarbonate bottles for incubation. Nalgene bottles were used after acid treatment. These seawater samples were inoculated with labeled carbon ($NaH^{13}CO_3$), nitrate ($K^{15}NO_3$), and ammonium ($^{5}NH_4Cl$) substances. 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 concentrations of labeled nitrate ($K^{15}NO_3$) and ammonium ($^{5}NH_4Cl$) were 0.05 or 0.1 μM that depended on the concentration of total inorganic nitrogen in the ambient water. Bottles were placed into incubators with neutral density filters corresponding to nominal light levels at the depths where the seawater was sampled. Incubations by using dark bottles and light-blocking incubators were also conducted at each light level.

All samples were incubated in a bath on the deck for 3 hours. At the end of the incubation period, samples were filtered through glass fiber filters (Whattman GF/F 25mm, pre-combusted under 450 degC while 6 hours). GF/F filters were kept to freeze -20 degC till measurements. After that, filters were dried on the oven of 45 degC for at least 20 hours and treated with hydrochloric acid to remove the inorganic carbon.

(5) Results

Primary production, new production, and regenerated production are calculated as the carbon, nitrate, and ammonium uptake rates, respectively. Figure 4.9-2 shows the vertical profiles of primary production, new production, and regenerated production from the Chukchi Sea shelf slope to the Canada Basin. Figure 4.9-3 also shows the vertical profiles of primary production, new production, and regenerated production along the Chukchi Sea shelf slope.

(6) Data archives

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

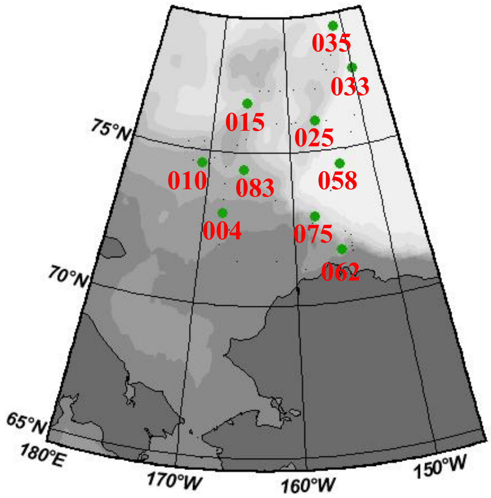


Figure 4.9-1. Map of stations with station numbers for new and regenerated production measurements.

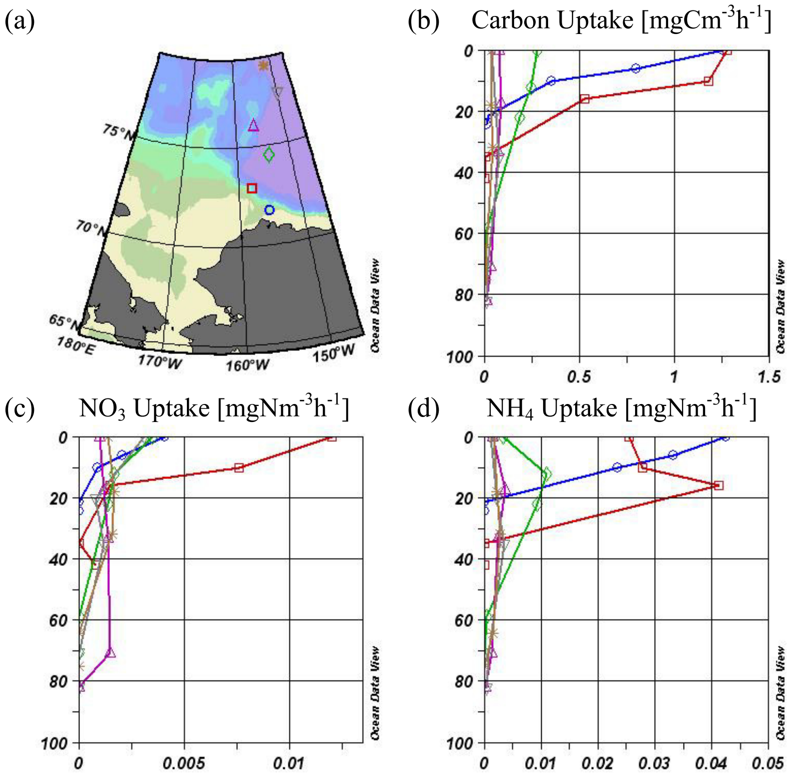


Figure 4.9-2. (a) Locations of stations used for the illustrations of vertical profiles of (b) carbon uptake rate (primary production), (c) nitrate uptake rate (new production), and (d) ammonium uptake rate (regenerated production) from the Chukchi Sea shelf slope to the Canada Basin.

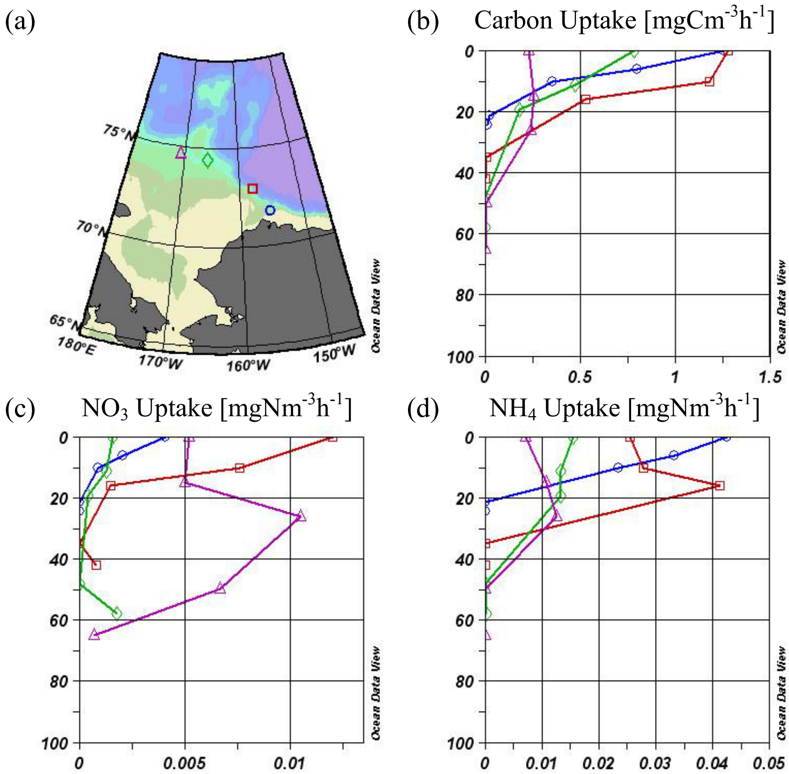


Figure 4.9-3. (a) Locations of stations used for the illustrations of vertical profiles of (b) carbon uptake rate (primary production), (c) nitrate uptake rate (new production), and (d) ammonium uptake rate (regenerated production) along the Chukchi Sea shelf slope.

4.10. Primary productivity and bio-optical properties

(1) Personnel

Sei-ichi Saitoh	(Hokkaido University): Principal Investigator (non-boarding)
Toru Hirawake	(Hokkaido University)
Keitaro Matsumoto	(Hokkaido University)
Katsuhito Simmyo	(Hokkaido University)

(2) Objectives

Objectives of these measurements are (1) to investigate contribution of phytoplankton biomass within subsurface chlorophyll maximum to primary productivity of water column and, (2) to develop an algorithm to discriminate phytoplankton size using optical properties of seawater. Results from these investigations will be applied to satellite remote sensing and used to clarify responses of phytoplankton to the abrupt sea ice change in the Arctic Ocean.

(3) Parameters

A) Underwater spectral irradiance and radiance (PRR-800/810)
B) *In-situ* light absorption, beam attenuation and backscattering coefficients (*ac*-s and VSF3)
C) Incident photosynthetic available radiation (PAR)
D) Daily net primary productivity of phytoplankton (NPP)
E) Light absorption coefficients of particles and colored dissolved organic materials (CDOM)
F) Phytoplankton pigments (HPLC)
G) Bulk and size fractionated chlorophyll *a* concentration (see Section 4.8)

(4) Instruments and methods

Bio-optical measurements and incubation for primary productivity were carried out at 15 stations (Figure 4.10-1 and Table 4.10-1). Most of the bio-optical casts started from 2-3 hours before noon.

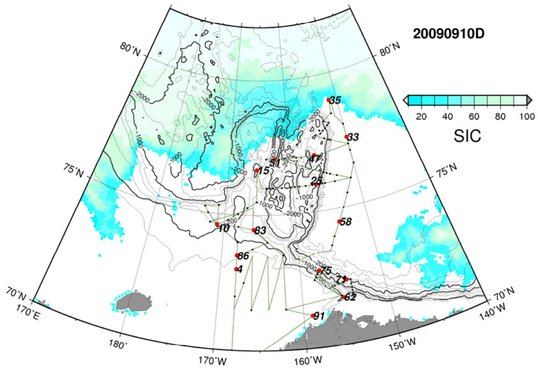


Figure 4.10-1. Map of sampling stations. Sea ice concentration (SIC) of the AMSR-E product on September 10, 2009 was provided by JAXA.

A) PRR-800/810

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 17 wavelengths over 380-765 nm were measured with a spectroradiometer, PRR-800 (Biospherical Instrument Inc.). The PRR-800 was deployed in free-fall mode up to 80-120 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 monitored by reference spectroradiometer, PRR-810 (Biospherical Instrument Inc.) with same specification as the underwater sensor. After each deployment of the instrument, dark values were recorded for about one minute. 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 412 to 710 nm.

Table 4.10-1. Log of PRR-800 and *ac*-s casts

Date(GMT)	Time(GMT)	latitude(N)		longitude(W)		PRR file name	max_depth (m)	remarks	ac-s file name	max_depth (m)
2009/09/11	20:24	72	59.4	167	58.61	2009_09_11_2024.mdb	40		run008	50
2009/09/13	21:03	74	36.01	170	54.39	2009_09_13_2103.mdb	120	Missed reference data	run009	200
2009/09/15	20:36	76	38.41	165	40.12	2009_09_15_2036.mdb	130		run010	200
2009/09/17	17:37	76	0.45	156	24.5	2009_09_17_1737.mdb	150		run011	200
2009/09/19	16:39	77	30.76	150	0.73	2009_09_19_1639.mdb	100	Cast for PP	run012	200
2009/09/19	20:10	77	30.76	150	0.73	2009_09_19_2010.mdb	150	Cast for optics		
2009/09/20	19:04	78	59.8	151	37.27	2009_09_20_1904.mdb	150		run013	200
2009/09/23	17:53	77	4.69	155	59.82	2009_09_23_1753.mdb	150		run014	200
2009/09/24	16:28	77	5.71	162	43.13	2009_09_24_1628.mdb	100	Cast for PP	run015	200
2009/09/24	16:48	77	5.71	162	43.13	File not found	150	Cast for optics		
2009/09/26	17:34	74	30.43	154	5.21	2009_09_26_1734.mdb	170		run016	200
2009/09/28	19:29	71	44.05	155	7.77	2009_09_28_1929.mdb	150		run017	200
2009/09/29	18:02	72	19.65	154	28.62	2009_09_29_1802.mdb	130		run018	200
2009/09/30	17:57	72	52.26	157	39.31	2009_09_30_1757.mdb	130		run019	200
2009/10/05	19:43	74	26.43	165	43.16	2009_10_05_1943.mdb	120		Failed	Failed
2009/10/06	19:58	73	29.7736	167	59.3889	2009_10_06_1958.mdb	80		run028	100
2009/10/10	18:47	71	12.16	158	59.74	2009_10_10_1847.mdb	85		run029	80

B) *ac*-s and VSF3

In-situ spectral light absorption (a) and beam attenuation coefficients (c) were measured with two spectral absorption and attenuation meters, *ac*-s (WET Labs Inc.). One of them (S/N ASC035) measured total (particles and CDOM) absorption and attenuation coefficients ($a_{tot}(\lambda, z)$ and $c_{tot}(\lambda, z)$) and another one (S/N ACS036) measured absorption coefficient of CDOM ($a_{CDOM}(\lambda, z)$) by removing particulate matter using 0.2 μm pre-filter (Pall Gelman Part No. 12122) on sample inlet of flow tubes. Volume scattering function at three scattering angle of three wavelengths to determine backscattering coefficient of light was measured with a volume scattering function meter, VSF3 (WET Labs Inc.). They were deployed up to 200 m deep with a SBE-19 SEACAT Profiler CTD (Sea-Bird Electronics, Inc., S/N 2575). All data was recorded on a data logger DH4 (WET Labs Inc.). Field calibration using Milli-Q water was carried out twice during the cruise.

C) Incident photosynthetically available radiation (PAR)

Incident PAR, E_q (0+), was monitored with a LI-190SB air quantum sensor. Mean value for one minute was recorded to a LI-1400 data logger (LI. COR Inc.) during the cruise.

D) Daily net primary productivity of phytoplankton (NPP)

Seawater samples for primary productivity measurement were collected from the sea surface and depths corresponding to 25%, 10%, 5%, 2.5% and 1% of incident PAR using Niskin-X bottles on a CTD/Rosset Multi Sampler (Sea-Bird Electronics Inc.).

Net primary productivity of phytoplankton was determined using the stable ^{13}C isotope method (Hama *et al.*, 1983). For incubation, samples were transferred into 1000 ml or 500 ml clear polycarbonate bottles. After adding $NaH^{13}CO_3$ (ISOTEC Inc.) with approximately 10% of the total carbonate, the samples were regulated their exposed light intensity to corresponding layers with black nylon meshes and incubated under natural light for 24 hours in a water bath. Temperature in the water bath was maintained with running water from the sea surface. Two samples for each depth were incubated and no dark bottle controls were measured. Another 1000 ml or 500 ml of natural seawater samples (not added $NaH^{13}CO_3$ and not incubated) were immediately filtrated onto glass fiber filters (Whatman GF/F, 25 mm diameter) precombusted at 450 °C for four hours to measure natural abundance of ^{13}C.

After the incubation, the water samples were filtered onto the glass fiber filters and stored in liquid N_2. The isotope ratio of ^{12}C and ^{13}C and POC will be determined by a stable isotope GCMS in a laboratory after the cruise. Daily net primary productivity will be calculated from the ratio and DIC data using the equation of Hama *et al.* (1983).

Sampling depth, and start/finished time of the incubation at each station are shown in Table 4.10-2.

Table 4.10-2. Sampling depth and incubated time for primary productivity measurement.

Station No.	Sampling depth						Incubation		Notice
	100%	25%	10.0%	5%	2.5%	1%	Start Time (GMT)	Stop Time (GMT)	
sta 004	0	13	23	30	36	42	2009/09/11 23:27	2009/09/12 23:25	
sta 010	0	15	26	34	42	50	2009/09/13 23:52	2009/09/14 23:47	
sta 015	0	19	34	43	53	66	2009/09/15 23:55	2009/09/16 23:55	
sta 025	0	17	33	46	57	71	2009/09/17 21:08	2009/09/18 21:08	
sta 033	0	20	35	47	58	71	2009/09/19 21:54	2009/09/20 21:54	ezed a little while incubat
sta 035	0	18	32	42	51	64	2009/09/20 20:35	2009/09/21 20:35	Northernmost point!
sta 047	0	21	36	46	55	67	2009/09/23 21:33	2009/09/24 21:33	
sta 051	0	22	36	46	55	68	2009/09/24 20:50	2009/09/25 20:50	
sta 058	0	12	21	32	43	59	2009/09/26 22:41	2009/09/27 22:41	
sta 062	0	6	10	13	16	21	2009/09/28 22:55	2009/09/29 22:55	
sta 071	0	12	23	31	40	52	2009/09/29 21:25	2009/09/30 21:30	
sta 075	0	10	16	21	26	35	2009/09/30 21:28	2009/10/01 21:30	
sta 083	0	11	19	28	37	48	2009/10/05 22:46	2009/10/06 22:46	
sta 086	0	12	22	30	39	52	2009/10/06 22:12	2009/10/07 22:12	
sta 091	0	9	16	21	26	32	2009/10/10 21:25	2009/10/11 21:25	finale

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

Seawater samples for absorption coefficients measurement were collected from the sea surface and depths corresponding to 25%, 10%, 5%, 2.5% and 1% of incident PAR using Niskin-X bottles on a CTD/Rosset 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, MPS-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 calculated as a difference between values before and after the pigments extraction. To optimize the QFT, pathlength amplitude factor (β) was determined. Approximately 50-100 liters of pumped up water was concentrated to 20 ml using 5 μm nylon mesh. After optical density of the suspended sample (OD_s) was measured, the sample was filtrated on a GF/F filter and its optical density (OD_f) was measured.

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 filtrate water against pure water (Milli-Q) was measured with 10 cm cylindrical quartz cell and spectrophotometer, MPS-2400 (Shimadzu), and calculated $a_{CDOM}(\lambda, z)$.

F) Phytoplankton pigments (HPLC)

Seawater samples for phytoplankton pigments were collected from the sea surface and depths corresponding to 25%, 10%, 5%, 2.5% and 1% of incident PAR using Niskin-X bottles on a CTD/Rosset Multi Sampler (Sea-Bird Eloctronics Inc.).

Phytoplankton in 2 liters of water sample were concentrated on a glass fiber filter (Whatman GF/F, 25 mm) and stored in liquid N_2. Pigments concentration will be determined with a high performance liquid chromatography (HPLC) according to a method of Zapata *et al*. (2000) in a laboratory after the cruise.

G) Bulk and size fractionated chlorophyll *a* concentration

Bulk and size fractionated chlorophyll *a* concentration was measured fluorometrically. The details were described in Section 4.8

(5) Results

The data of PRR-800/810, *ac*-s and VSF3 will be analyzed after the cruise, because they will need many corrections against low temperature and on their dark values. Effects of small bubbles found in *ac*-s data at near sea surface also should be considered. Primary productivity and pigments of phytoplankton will also be analyzed after the cruise. So we show a part of the results on relationship between absorption coefficients of phytoplankton and size fractionated chlorophyll *a*, and CDOM absorption at the sea surface.

Absorption coefficient and phytoplankton size

While a peak around 667 nm (red) generally shows absorption by only chlorophyll *a*, another peak around 443 nm (blue) shows sum of absorptions by chlorophyll *a* and accessory pigments (Figure 4.10-2). Contents of accessory pigments were different between phytoplankton groups. Therefore, difference of peak height in blue region relative to red one is expected to show discrimination of phytoplankton groups and size accompanied by the group. As shown in Figure 4.10-3, the absorption ratio, $a_{ph}(443)/a_{ph}(667)$, increased with decrease of large size fraction in chlorophyll *a* concentration. Although the studied season of this cruise is 1-2 month later than MR08-04 and T/V Oshoro-Maru cruises and small size fraction (<2 μm) was dominated in most of studied, The relationship in Figure 4.10-3 was almost same as the previous cruises.

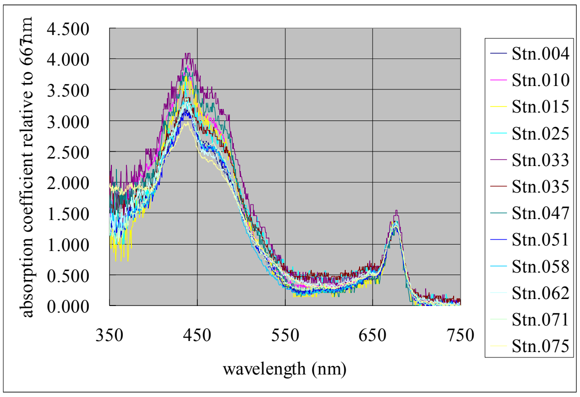


Figure 4.10-2. Spectra of light absorption coefficient of phytoplankton normalized at 667 nm.

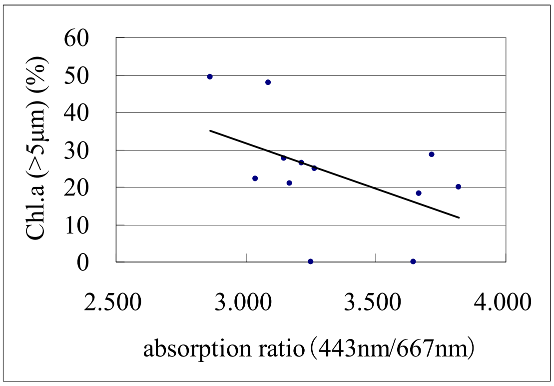


Figure 4.10-3. Relation between ratio of large size (>5 µm fraction) and absorption ratio $a_{ph}(443)/a_{ph}(667)$.

CDOM absorption

CDOM absorbs UV to blue light and high CDOM absorption inhibits correct estimation of chlorophyll *a* concentration from ocean color satellite. High level of CDOM due to huge amount of river discharge in the Arctic Ocean has been reported. CDOM absorption in this cruise was also higher level (Figure 4.10-4) and the highest value at 400 nm was found off Barrow where salinity was less than 24 psu (Figure 4.10-5). The contribution of CDOM to total absorption was 50-80% in this station and overestimation of chlorophyll *a* estimation are concerned.

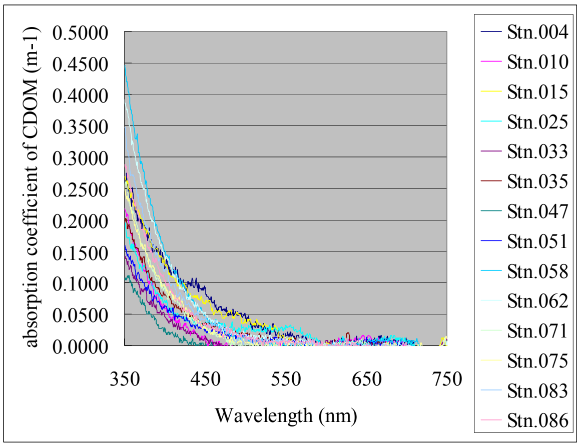


Figure 4.10-4. Spectrums of light absorption coefficient of CDOM.

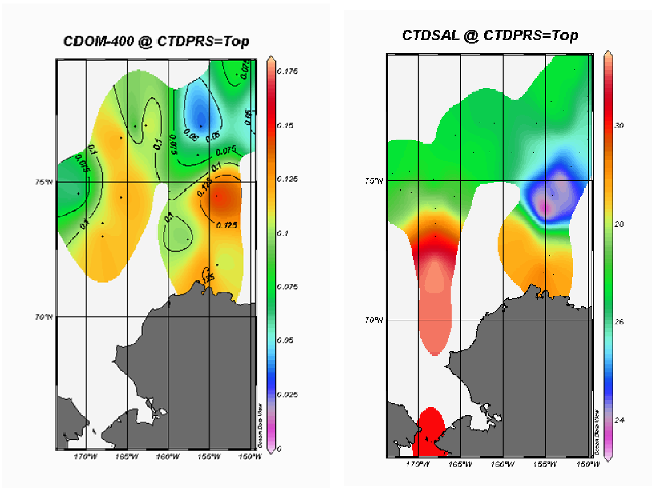


Figure 4.10-5. Distribution of light absorption of CDOM at 400 nm (left panel) and salinity (right panel).

(6) Date archives

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

4.11. Phytoplankton

(1) Personnel

Susumu Konno (Yamagata University): Principal Investigator

Ken'ichi Ohkushi (Kobe University)

(2) Objectives

The main aims of this project are to:

1) study the phytoplankton communities in the surface waters along continuous transects so as to understand the biogeographic distributions of individual species and the effects of oceanographic features like straits, sea-ice, algal blooms, and oceanic frontal systems,

2) study the vertical distribution of phytoplankton communities in order to understand the ecologic preferences and seasonal cycles of individual species,

3) study in detail the taxonomy of various phytoplankton groups and to compile photographic catalogues (identification guides) for publication and laboratory use.

(3) Methods

Surface water samples were obtained using the shipboard seawater supply for research use on a regular basis, 0-6 times a day when the ship was steaming (i.e. not on station). About 2 l of seawater were collected in plastic bottles with the following information recorded at the same time as sampling: the date and time (GMT), coordinates, and those parameters (such as temperature, salinity, and chlorophyll) being continuously recorded by instruments connected to the seawater supply. In total, 34 samples were collected using this method during Leg 2 of MR09-03 (see Table 4.11-1).

Vertical samples were obtained from shallow and deep hydrocasts at 61 stations, with about 2-8 depths sampled during each cast. About 1-2 l of seawater were collected in plastic bottles after the CTD rig had returned to the ship. A bucket sample was also taken to represent 0 m. In total 486 samples were collected using this method during Leg 2 of MR09-03 (see Table 4.11-2).

Most of the water samples collected using these methods were then filtered through 47 mm (0.45 μm porosity) HA-type Millipore polycarbonate filters using an Eyela A3-S aspirator and 3 filter holder manifold system. The filters were 1) air dried and then sealed in plastic petrislides, or 2) sealed in plastic petrislides and then frozen. Later, the filters will be washed briefly in distilled water and air dried again. A 3 x 3 mm portion of each filter will be cut out and mounted onto an aluminum SEM stub, coated with Pt/Pd in an Eiko IB-3 ion sputter coater, and observed in a Hitachi S-2250N

SEM.

(4) Data archives

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

Table 4.11-1. Surface water samples from the shipboard seawater supply for research use.

Date	Time	Station	Latitude			Longitude			Water filtered	Filter No.	Temp(℃)	Salinity	FUL	DO
9/7/09	23:49	sw001	54	54.6521	N	166	43.1288	W	2.0	sw001	7.751	32.528	14.696	11.301
9/8/09	3:40	sw002	55	45.8350	N	166	54.3573	W	2.0	sw002	9.231	32.083	15.779	11.109
9/8/09	7:38	sw003	56	36.5836	N	167	5.5075	W	2.0	sw003	9.345	31.632	10.541	11.011
9/8/09	15:53	sw004	58	15.5904	N	167	30.4811	W	2.0	sw004	8.165	31.379	9.357	11.210
9/8/09	19:37	sw005	59	1.3888	N	167	31.9366	W	2.0	sw005	9.662	31.532	9.113	10.446
9/9/09	0:28	sw006	59	58.6975	N	167	56.7702	W	2.0	sw006	8.486	30.955	10.358	10.716
9/9/09	3:43	sw007	60	36.0608	N	167	51.4458	W	2.0	sw007	9.650	30.920	17.544	10.648
9/9/09	7:47	sw008	61	26.1588	N	167	29.6609	W	2.0	sw008	9.734	31.011	7.328	10.447
9/9/09	16:12	sw009	63	15.3290	N	167	54.5863	W	2.0	sw009	6.511	30.949	4.848	10.992
9/9/09	20:23	sw010	64	11.1171	N	168	10.5203	W	2.0	sw010	7.412	30.732	8.349	10.908
9/9/09	23:38	sw011	64	53.6774	N	168	38.7548	W	2.0	sw011	7.203	30.429	10.785	10.849
9/10/09	7:36	sw012	66	21.2555	N	168	25.7165	W	2.0	sw012	7.619	29.199	9.240	10.767
9/10/09	19:09	sw013	68	29.7680	N	168	11.4440	W	2.0	sw013	6.479	30.783	11.826	11.146
9/10/09	20:59	sw014	68	50.8365	N	168	9.5122	W	2.0	sw014	8.161	28.795	10.493	10.571
9/10/09	23:33	sw015	69	19.6515	N	168	3.9460	W	2.0	sw015	6.771	30.368	8.331	10.904
9/11/09	8:00	sw016	70	49.8189	N	168	0.0144	W	2.0	sw016	5.474	31.772	6.117	11.342
9/20/09	16:01	sw017	78	44.4124	N	151	32.2250	W	2.0	sw017	-1.248	26.457	3.660	12.571
9/21/09	19:39	sw018	78	10.0415	N	152	31.9732	W	2.0	sw018	-1.370	26.629	3.619	12.360
9/25/09	1:54	sw019	76	37.0529	N	157	10.5172	W	2.0	sw019	-0.483	26.324	3.573	12.211
9/25/09	6:33	sw020	76	21.1348	N	154	32.8907	W	2.0	sw020	0.011	25.651	3.667	12.145
9/26/09	3:51	sw021	75	18.3719	N	152	22.8802	W	2.0	sw021	-0.172	24.014	3.771	12.056
9/28/09	1:47	sw022	73	12.7295	N	159	16.0706	W	2.0	sw022	1.301	27.391	4.608	11.820
9/28/09	8:57	sw023	72	13.7120	N	156	43.6473	W	2.0	sw023	0.383	27.241	4.338	11.912
10/11/09	1:47	sw024	70	50.0878	N	163	1.9402	W	2.0	sw024	2.330	31.386	8.525	11.255
10/11/09	7:58	sw025	69	53.7636	N	165	50.3258	W	2.0	sw025	3.817	30.300	5.556	10.979
10/11/09	23:32	sw026	67	19.2839	N	168	17.5816	W	2.0	sw026	3.053	31.290	16.202	11.763
10/12/09	4:02	sw027	66	32.2594	N	168	22.9219	W	2.0	sw027	3.980	31.013	12.766	10.279
10/12/09	16:38	sw028	64	36.5257	N	168	26.9418	W	2.0	sw028	5.198	21.450	8.607	10.439
10/12/09	23:11	sw029	63	27.8843	N	167	42.2111	W	2.0	sw029	4.303	31.367	7.122	10.637
10/13/09	3:31	sw030	62	39.7647	N	167	20.1937	W	2.0	sw030	4.700	30.682	6.773	10.580
10/13/09	8:06	sw031	61	44.3189	N	167	23.2498	W	2.0	sw031	7.854	29.677	9.779	10.290
10/13/09	17:00	sw032	59	58.9923	N	167	57.3606	W	2.0	sw032	8.040	30.971	10.779	10.181
10/13/09	20:25	sw033	59	19.4570	N	167	46.7349	W	2.0	sw033	8.026	30.992	8.694	10.140
10/14/09	2:13	sw034	58	13.4551	N	167	28.8438	W	2.0	sw034	4.976	31.380	12.787	10.755
10/14/09	7:59	sw035	57	10.7659	N	167	14.8559	W	2.0	sw035	5.238	31.355	19.809	11.190
10/14/09	16:30	sw036	55	56.6853	N	166	56.7494	W	2.0	sw036	7.751	31.951	10.478	10.376
10/14/09	22:48	sw037	55	8.6595	N	166	45.4881	W	2.0	sw037	7.180	32.332	10.718	10.507

Table 4.11-2. Vertical water samples from CTD hydrocasts.

Date	Station	Latitude	Longitude	Bucket	10m(35)	20m(34)	35m(33)	50m(32)	75m(31)	100m(30)	150m(28)	200m(26)	EX	
2009/09/11	2	70	-169.998	2	2	2	2							
2009/09/11	3	71.999	-169.998	2	2	2	2							
2009/09/11	4	72.992	-168.025	2	2	2	2	2						
2009/09/12	5	74.001	-169.993	2	2	2	2	2	2	2	1.5			
2009/09/12	6	74.597	-172.999	2	2	2	2	2	2	2	2	2		
2009/09/12	7	75	-173.597	2	2	2	2	2	2	2	2	2		
2009/09/12	8	75.25	-173.033	2	2	2	2	2	2	2	2	2		
2009/09/13	9M02	75.339	-172.972	2	2	2	1.5	1.5	2	1.5	2			
2009/09/14	12	75.034	-169.842	2	2	2	2	2	2	2	2			
2009/09/14	13	75.265	-167.18	2	2	2	2	2	2	2	2	2		
2009/09/14	14	75.47	-166.348	2	2	2	2	2	2	2	2	2		
2009/09/15	15	76.64	-166.323	2	2	2	2	2	2	2	2	2		
2009/09/16	16	76.002	-164.007	2	2	2	2	2	2	2	2	2		
2009/09/16	19	76.018	-162.387	2	2	2	2	2	2	2	2	2		
2009/09/17	21	75.999	-160.326	2	2	2	2	2	2	2	2	2		
2009/09/17	22	76.005	-160.998	2	1	2	2	1.5	2		2		100m(16) 2	200m(17) 2
2009/09/17	25	76.006	-157.598	2	2	2	2	2	2	2	1.5	2		
2009/09/18	28	76.005	-156.995	2	2	2	2	2	2	2	2	2		
2009/09/18	30M02	76.011	-152.978	2	2	2	2	2	2	2	2	2		
2009/09/19	31	76.503	-151.974	2	2	2	2	2	2	2	2	2		
2009/09/19	32	77.006	-151.983	2	2	2	2	2	2	2	2	2		
2009/09/19	33	77.512	-151.998	2	2	2	2	2	2	2	2	0.85		
2009/09/20	34	78.001	-151.996	2	2	2	2	2	2	2	2	2		
2009/09/20	35	78.989	-152.358	2	2	2	2	1.5	2		2		235m(15) 2	
2009/09/21	39	78.085	-153.136	2	2	2	2	2	2	2	2	2		
2009/09/22	42	77.831	-155.682	2	2	2	2	2	2	2	2	2		
2009/09/22	45	77.527	-153.18	2	2	2	2	2	2	2	2	2		
2009/09/23	46M02	77.205	-150.074	2	2	2	2	2	2	2	2	2		
2009/09/23	47	77.081	-156	2	2	2	2	2	2	2	2	2		
2009/09/24	48	77.079	-160.982	2	2	2	2	2	2	2	2	2		
2009/09/24	49	77.082	-162.976	2	2	2	2	2	2	2	2	2		
2009/09/24	50	77.085	-165.993	2	2	2	2	2	2	2	2	2		
2009/09/24	51M02	77.096	-163.272	2	2	2	2	2	2		2			
2009/09/25	56	75.497	-153.976	2	2	2	2	2	2	2	2	2		
2009/09/26	57	74.999	-154.948	2	2	2	2	2	2	2	2	2		
2009/09/26	58M02	74.507	-155.902	2	2	2	2	2	2	2	1.5			
2009/09/27	59	73.995	-155.003	2	2	2	2	2	2	2	2	2		
2009/09/27	60	73.686	-156.475	2	2	2	2	2	2	2	2	2		
2009/09/28	62M02	71.733	-156.865	2	2	2	2	2	2	2	2	2		
2009/09/29	64	71.664	-154	2	2	2	2							
2009/09/29	66	71.832	-155.998	2	2	2	2	2	2	2	2			
2009/09/29	67	71.93	-154.01	2	2	2	2	2	2	2	2	2		
2009/09/29	69	72.185	-155.996	2	2	2	2	2	2	2	2	2		
2009/09/29	71	72.33	-155.525	2		2	2	2	2	2	2	2		
2009/09/30	75M02	72.874	-158.348	2	1.5	2	2	2	2	1.5	1.5	1		
2009/09/30	77	72.702	-158.069	2	2	2	2	2	2	2	2	2		
2009/10/01	78	72.602	-159.864	2	2	2	2	2	2	1.5	2			
2009/10/01	79	72.503	-159.67	2	2	2	2	2						
2009/10/05	80	74.664	-173.964	2		2	2	2	2	2	2	2	10m(20) 2	
2009/10/05	81	74.6	-171.991	2	2	2	2	2	2	2	2			
2009/10/05	82	74.566	-169.998	2	2	2	2	2	2	2	2	2		
2009/10/05	83	74.438	-166.276	2	2	2	2	2	2	1	2	2		
2009/10/06	84	73.998	-164	2	2	2	2	2	2	2	2	2		
2009/10/06	85	73.747	-166.007	2	2	2	2	2	2	2				
2009/10/06	86	73.497	-168.01	2	2	2	2	2	2	2				
2009/10/07	87	72.5	-167.004	2	2	2	2							
2009/10/08	88	71.5	-167.959	2	2	2							31m(1) 2	
2009/10/09	89	73.504	-162.001	2	2	2	2	1	2	2	2			
2009/10/10	90	71.501	-162	2	2	2								
2009/10/10	91	71.201	-159.001	2	2	2	2	2	2					

4.12. Zooplankton

(1) Personnel

Ken'ichi Ohkushi	(Kobe University): Principal Investigator
Susumu Konno	(Yamagata University)
Michiyo Yamamoto-Kawai	(IOS/DFO)

On-shore scientists:

Takuya Itaki	(AIST)
Katsunori Kimoto	(JAMSTEC)

(2) Objectives

In this study, we collected planktic foraminifers, radiolarian and diatom samples used the multi-depth plankton net (NORPAC closing net) from the water column in the Arctic Ocean, and try to make general view of their habitat and ecology. 45 cm ring net (mesh: 63 µm, mouth diameter: 45 cm) was towed between surface and ~1000 m depth at 7 stations.

(3) Equipments and sampling strategy

The closing net was used for multiple-depth plankton sampling in this study. The closing net is a kind of vertical-towing plankton sampler and it can close the mouth at the any depth by the messenger actions. Flow meter was also used in this study. Details of sampling stations and data for collection were listed in Table 4.12-1. Fundamental strategy for sampling by closing net is as follows:

1) Closing net was lowered from starboard side of R/V Mirai by vinyl-coated wire to avoid the oil contamination. The lowering speed of wire was at 1.0 m /sec.
2) After closing net reached at the bottom of target water depth, it was pulled up from bottom to top water depth where we targeted. At this moment, pulling up speed of wire was at 0.5 m /sec.
3) Messenger (0.7 kg weight) was through out to close the net mouth at the given water depth.
4) After the releaser activated, closing net was pulled up to the deck at 1.0 m wire speed.
5) Samples were collected on the deck.

(4) Shipboard treatments

Plankton tow experiments were performed at seven stations in Leg 2. For zooplankton assemblages, they were fixed by 99.5% ethanol immediately in the laboratory. After that, they were kept in the refrigerator.

(5) Analytical items

All plankton samples were shared for following analysis.

1) Faunal analysis of planktic foraminifers, radioralians, pterapod, and diatoms

2) Stable isotope and trace metal analyses of planktic foraminiferal shells

(6) Data archives

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

Table 4.12-1. Plankton tow sample list

Station	Target depth (m)	Date	Latitude (¼)	(')	Longitude (¼)	(')	Start Time(LT)	Wire angle (¼)	Wire out (m)	Messenger Throw (Wire angle)	(Wire out)	(Time)	Net closed (Wire out)	End Time
9	0-50	12-Sep	75	20	171	1	0:42	1	50.7			0:46		
	50-100						0:53	1	100.5	3	60.3	0:59	51	1:01
	100-150		75	20	171	1	1:10	0	150.6	0	117	1:17	100.8	1:19
	150-300						1:26	7	302.3	3	177.2	1:40	154	1:44
	300-500		75	20	171	1	1:52	15	518.4	4	370	2:11	317.4	2:18
15	0-100	15-Sep	76	38	165	39	14:42	2	100					14:49
	100-200						14:58	5	200.5	5	118.2	15:08	100	15:11
	200-300						15:20	15	309.4	7	244.6	15:32	207.9	15:38
	300-500						15:48	9	507.7	6	359.7	16:08	311.4	16:15
19	0-100	16-Sep	76	0	161	39	10:24	4	100.6					10:31
	100-200						10:37	5	201	5	117.9	10:47	101.1	10:50
	200-300		76	1	161	39	10:59	5	301.5	3	234.9	11:10	201.4	11:15
	300-500		76	1	161	38	11:24	7	503.5	5	352.9	11:42	302.9	11:49
	500-1000						11:58	12	1022.8	8	584.4	12:38	501.4	12:50
36	0-100	20-Sep	78	28	151	43	23:22	7	101.7					23:28
	100-200						23:40	6	201.1	6	118.6	23:49	101	23:51
	200-400		78	28	151	44	23:59	10	406.5	6	234.8	0:19	200	0:24
51	0-100	24-Sep	77	5	162	38	5:52	9	101.2					6:00
	100-200						6:07	4	200.4	0	117	6:16	101.1	6:19
	200-300		77	5	162	40	6:43	13	308.1	15	234	6:37	203.8	6:43
	0-100						6:48	6	100.4					6:55
75	0-100	30-Sep	72	52	157	38	3:41	5	101.7					3:41
	100-200						3:53	11	204.2	1	118.2	4:03	100.4	4:06
	200-300		72	53	157	39	4:12	6	302.1	5	235.2	4:22	201.6	4:27
	300-500		72	53	157	39	4:33	8	505.3	12	352.8	4:51	301.1	4:59
80	0-50	4-Oct	74	40	171	60	17:11	3	50.4					17:15
	50-150						17:21	8	151.3	6	59.7	17:29	49.1	17:31
	150-291		74	40	172	1	17:38	13	291	5	176.4	17:50	141.3	17:55
	0-50		74	40	172	1	18:05	2	50.5					18:10

5. Geological observation

5.1. Sediment core sampling

(1) Personnel

Kenichi Ohkushi	(Kobe University): Principal Investigator
Susumu Konno	(Yamagata University)
Kazuhiro Yoshida	(MWJ)
Yasushi Hashimoto	(MWJ)
Sayaka Kawamura	(MWJ)
Satoshi Okumura	(GODI)
Soichiro Sueyoshi	(GODI)
Ryo Kimura	(GODI)
Norio Nagahama	(GODI)

(2) Objectives

The main aims of this project are to:

1) study time-series changes in temperature, salinity, water circulation, biological productivity, and sea-ice distribution in the Arctic Ocean during the Quaternary

2) study the relationship between global warming and Arctic Ocean during the last interglacial episode and Holocene.

The geological, paleontological, geochemical analyses achieved by this project include:

a) microfossils, tephra, Ice-rafted debris (IRD), mineral compositions, and size fraction

b) stable isotopes and radio-isotopes, such as Nd isotopes and 14C ages of foraminifera

c) paleomagnetism

d) optically stimulated luminescence dating

e) paleo-proxies such as marine phytoplankton biomarkers and TEX86

f) total organic carbon and nitrogen content, biomarkers compositions, and compound-specific stable isotopic and radiocarbon analysis of sedimentary organic materials

g) molecular-level terrestrial organic matter including plant debris and black carbon

h) trace elements such as Cd, Co, Cu, Fe, Ni, Zn, V, Zr, Hf, Nb, Ta, Mo, W, U, and Mn

i) amino acid racemization dating of foraminifera

(3) Parameters

Site survey

Site survey was conduced using SEABEAM 2100 system with a 4 kHz sub-bottom profiler (SBP) equipped on R/V Mirai. Seabeam maps for stations 14, 15, 83 were constructed for determination of coring points. Seabeam maps and sub-bottom profiles at coring sites are shown in Figures 5.1-1~6.

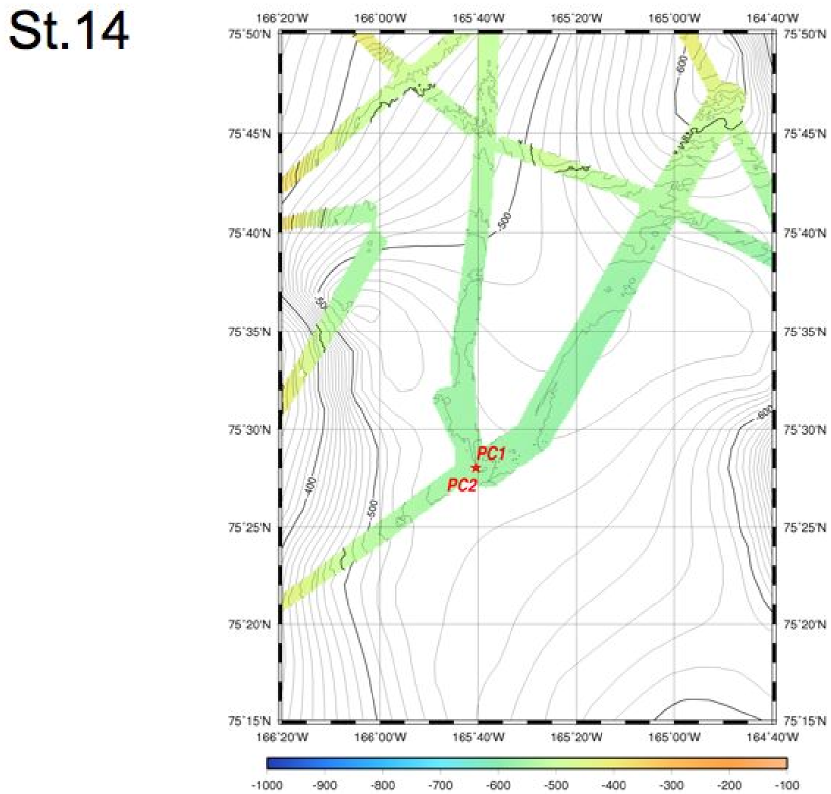


Figure 5.1-1. Bathymetrical map of MR09-03 PC01 and PC02 (PL01 and PL02).

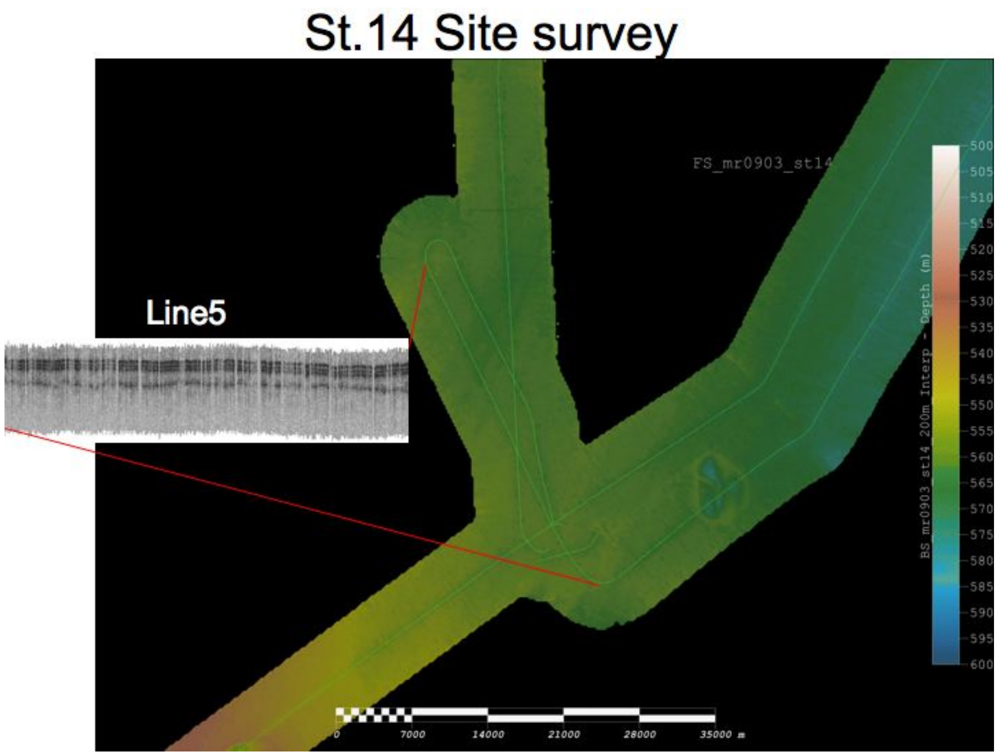


Figure 5.1-2. Bathymetric map of piston core site (PC01 and PC02).

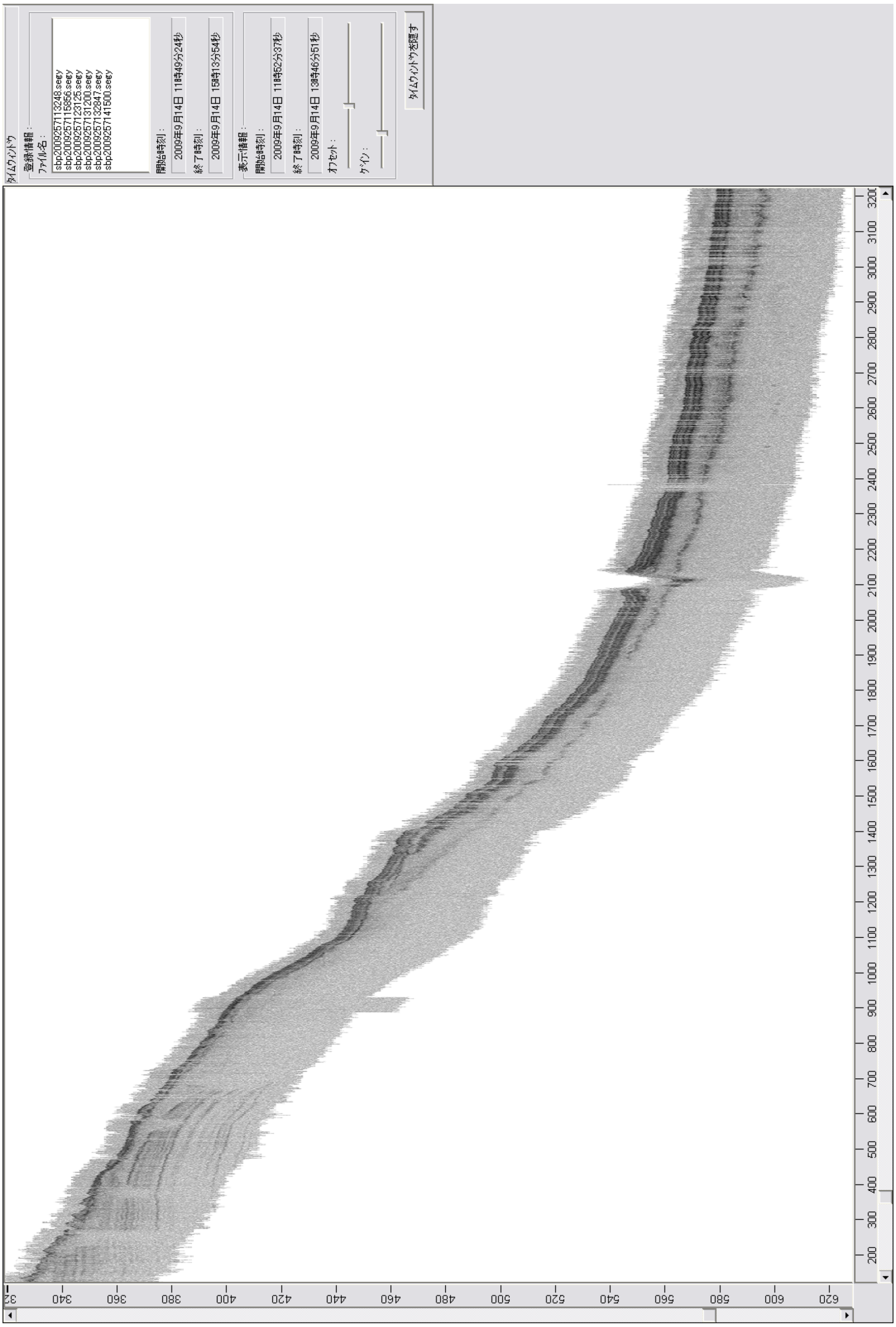


Figure 5.1-3. Sub-bottom profile of core site (MR09-03 PC01 and PC02).

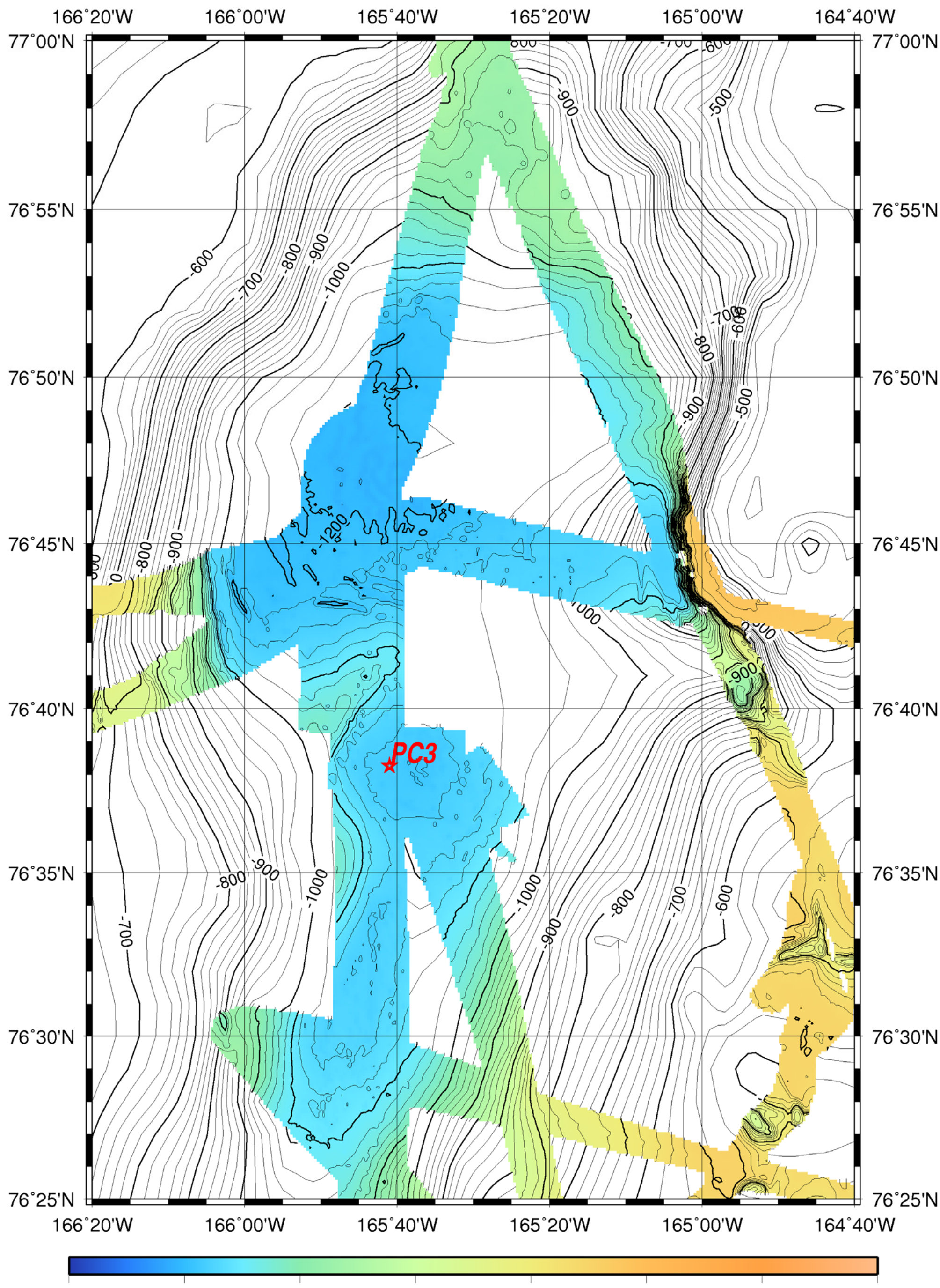


Figure 5.1-4. Bathymetric map of piston core site (MR09-03 PC03 and PL03).

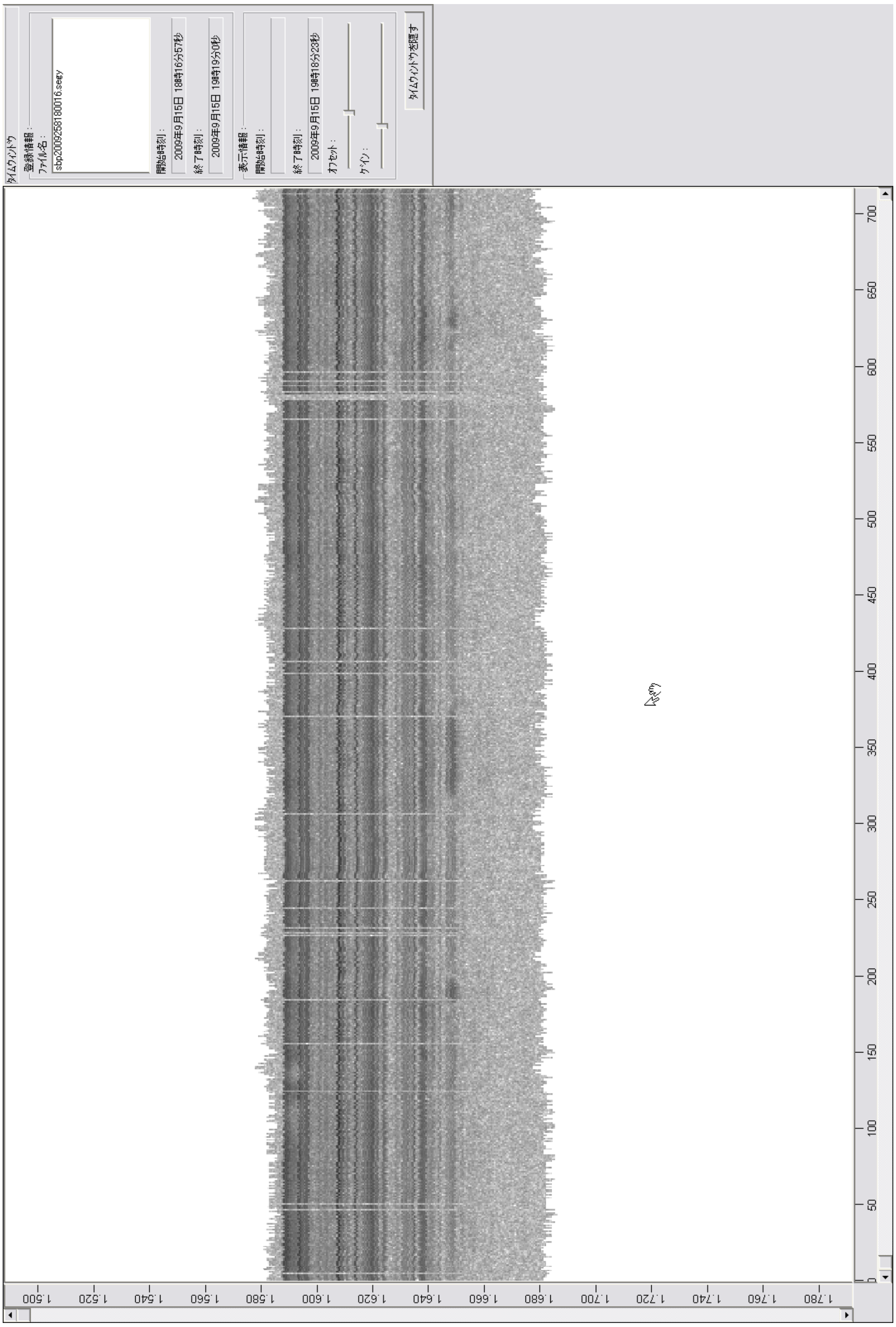


Figure 5.1-5. Sub-bottom profile of core site (MR09-03 PC03 and PL03).

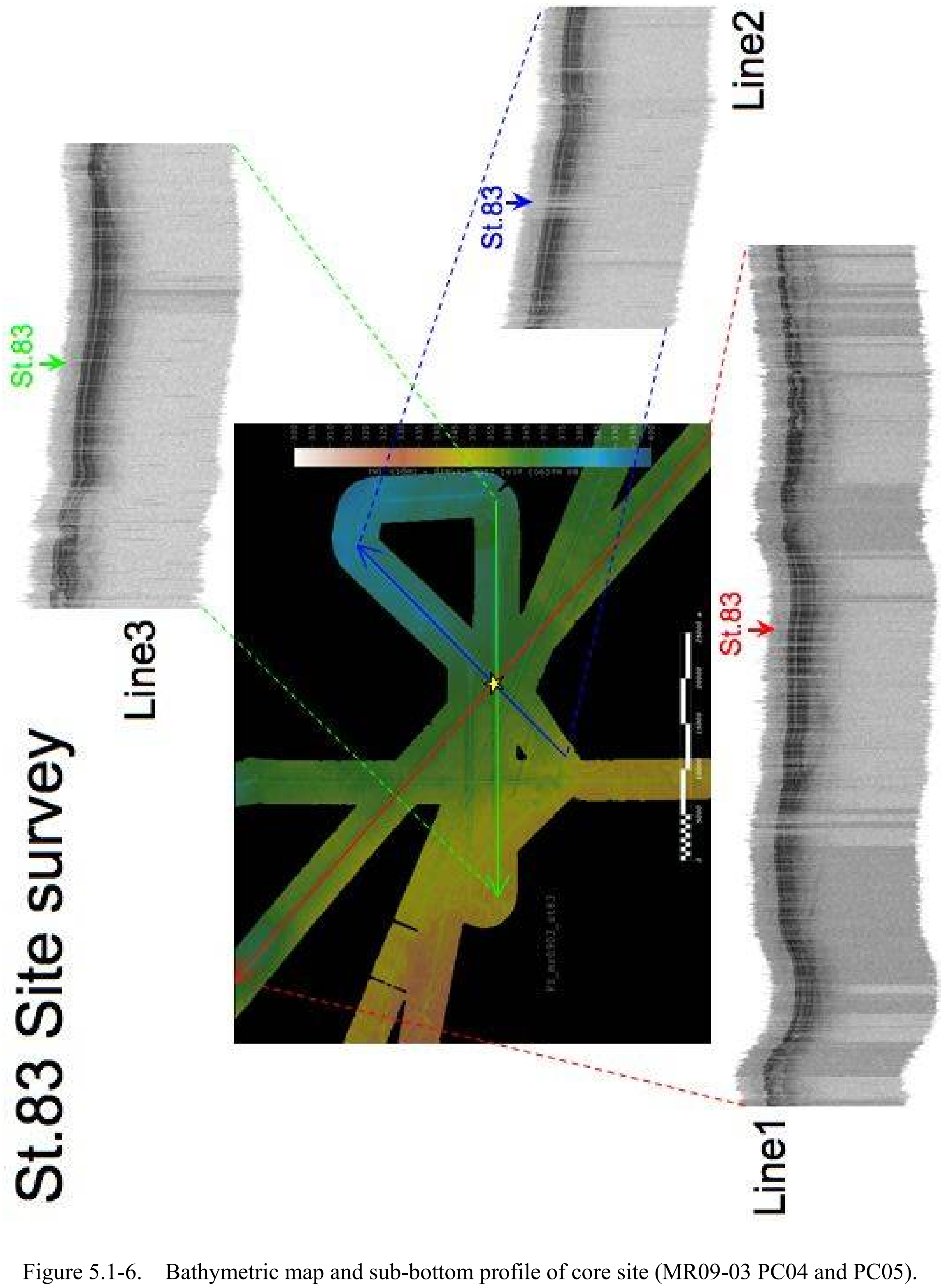


Figure 5.1-6. Bathymetric map and sub-bottom profile of core site (MR09-03 PC04 and PC05).

Piston corer system (PC)

Piston corer system consists of 1.25t-weight, 5m-long duralumin barrel with polycarbonate liner tube and a pilot core sampler. The inner diameter (I.D.) of polycarbonate liner tube is 74mm. The total weight of the system is approximately 1.5t. The length of the core barrel was 10m and 15m that was decided by site survey data. We used black type polycarbonate liner tube for measurement of photoluminescence (PC02, 05). We used a small multiple corer ("Ashura") for a pilot core sampler.

In this cruise, we used three types of piston, Normal type, Short type, Outer type. Normal type and short type piston is composing of stainless steel body and two O-rings (size: P63). Short type piston is shorter than Normal type one, few centimeters. Normal type was used three times (PC01, 02 and 03), Short type was used one time (PC05). Outer type piston was put four O-rings (size: P67), it is used one time (PC04).

(4) Instruments and methods

Winch operation

When we started lowering PC, a speed of wire out was set to be 0.2 m/s., and then gradually increased to the maximum of 1.0 m/s. The corers were stopped at a depth about 100 m above the seafloor for 2-3 minutes to reduce some pendulum motion of the system. After the corers were stabilized, the wire was stored out at a speed of 0.3 m/s., and we carefully watched a tension meter. When the corers touched the bottom, wire tension abruptly decreases by the loss of the corer weight. Immediately after confirmation that the corers hit the bottom, wire out was stopped and winding of the wire was started at a speed of 0.3m/s., until the tension gauge indicates that the corers were lifted off the bottom. After leaving the bottom, winch wire was wound in at the maximum speed.

MSCL measurements

A GEOTEK multi-sensor core logger (MSCL) has three sensors, which is gamma-ray attenuation (GRA), P-wave velocity (PWV), and magnetic susceptibility (MS). There were measured on whole-core section before splitting using the onboard MSCL. These data measurement was carried on every 1 or 2cm.

GRA was measured a gamma-ray source and detector. These mounted across the core on a sensor stand that aligns them with the center of the core. A narrow beam of gamma-ray is emitted by Caesium-137 (^{137}Cs) with energies principally at 0.662MeV. Also, the photon of gamma-ray is collimated through 5mm diameter in rotating shutter at the front of the housing of ^{137}Ce. The photon passes through the core and is detected on the other side. The detector comprises a scintillator (a 2" diameter and 2" thick NaI crystal).

GRA calibration assumes a two-phase system model for sediments, where the two phases are the minerals and the interstitial water. Aluminum has an attenuation coefficient similar to common minerals and is used as the mineral phase standard. Pure water is used as the interstitial-water phase standard. The actual standard consists of a telescoping aluminum rob (five elements of varying thickness) mounted in a piece of core liner and filled with distilled water. GRA was measured with 10 seconds counting.

MS was measured using Bartington loop sensor that has an internal diameter of 100mm installed in MSCL. An oscillator circuit in the sensor produces a low intensity (approx. 80 A/m RMS) non-saturating, alternating magnetic field (0.565kHz). MS was measured with 1 second.

PWV was measured two oil filled Acoustic Rolling Contact (ARC) transducers, which are mounted on the center sensor stand with gamma system. These transducers measure the velocity of P-Wave through the core and the P-Wave pulse frequency.

CCR measurements

After splitting each section of piston and pilot cores into working and archive halves, Archive halves was measured the Core Color Reflectance (CCR), that was the value calculated the spectral reflectance from 400 to 700nm in wavelengths by using the Konica Minolta CM-700d. This device is a compact and hand-held instrument, and can measure spectral reflectance of sediment surface with a scope of 8mm diameter. To ensure accuracy, the CM-700d was used with a double-beam feedback system, monitoring the illumination on the specimen at the time of measurement and automatically compensating for any changes in the intensity or spectral distribution of the light. The CM-700d has a switch that allows the specular component to be include (SCI) or excluded (SCE). We chose setting the switch to SCE. The SCE setting is the recommended mode of operation for sediments in which the light reflected at a certain angle (angle of specular reflection) is trapped and absorbed at the light trap position on the integration sphere.

Calibrations are zero calibration and white calibration before the measurement of core samples. Zero calibration is carried out into the air. White calibration is carried out using the white calibration piece (CM-700d standard accessories) without crystal clear polyethylene wrap. The color of the split sediment (Archive half core) was measured on every 2cm through crystal clear polyethylene wrap.

There are different systems to quantify the color reference for soil and sediment measurements, the most common is the L*a*b* system, also referred to as the CIE (Commision International d'Eclairage) LAB system. It can be visualized as a cylindrical coordinate system in which the axis of the cylinder is the lightness variable L*, ranging from 0% to 100%, and the radii are the chromaticity variables a* and b*. Variable a* is the green (negative) to red (positive) axis, and variable b* is the blue (negative) to yellow (positive) axis. Spectral data can be used to estimate the abundance of certain components of sediments.

Core Photographs

After measuring CCR of the Archive halves, sectional photographs of archive were taken using a single-lens reflex digital camera (Body: Nikon D1x / Lens: Nikon AF-S Nikkor 18-105mm). When using the digital camera, shutter speed was 1/10 ~ 1/20 sec, F-number was 5.0 ~ 8.0, sensitivity was ISO 125. File format of raw data is Exif-JPEG. Details for settings were included on property of each file. After choosing different exposure photographs, white correction was carried out using by the editing software (Adobe Photoshop Elements 2.0).

Soft X-ray photographs

Soft X-ray photographs were taken to observe sedimentary structures of cores.
Sediment samples were put into the original plastic cases (200x30x7mm) from cores. Each case has a TEPURA seal showing cruise code, core number, section number, case number, and section depth (cm). Each case was rimmed by PARAFILM to seal the sediment.

Soft X-ray photographs were taken to using the device SOFTEX PRO-TEST 150 on board. The condition of X-ray was decided from results of test photographs by each core section. The condition was ranged 50kVp, 2mA, and 200 seconds. All photographs were developed into the negative films by the device FIP-1400 on board.

The negative films were scanned by Epson Offirio ES-10000G to digital image files. The file quality was 300dpi. And the file format was TIFF. Afterward the images were carried out histogram coordination.

(5) Results

Piston Coring

Results of the PC are summarized in table 5-1-1.

Table 5-1-1. Coring summary

Core ID	Date (UTC)	Latitude (°)	Longitude (°)	Depth (m)	Core length (cm)	remarks
PC01	2009/9/14	75-28.0692N	165-40.4005W	558	587.4	Pipe 10m.
PC02	2009/9/15	75-28.0780N	165-40.3790W	558	553.3	Pipe 10m. Black type inner tube
PC03	2009/9/15	76-38.3060N	165-41.0572W	1,174	931.7	Pipe 15m.
PC04	2009/10/5	74-26.2740N	165-44.3328W	370	927.8 *Excluding flow-in	Pipe 15m. Outer type PC
PC05	2009/10/5	74-26.2777N	165-44.1244W	368	791.6	Pipe 10m. Black type inner tube

MSCL and CCR

All results are processed to eliminate data gaps between sections and then plotted in Figures 5.1-7~10.

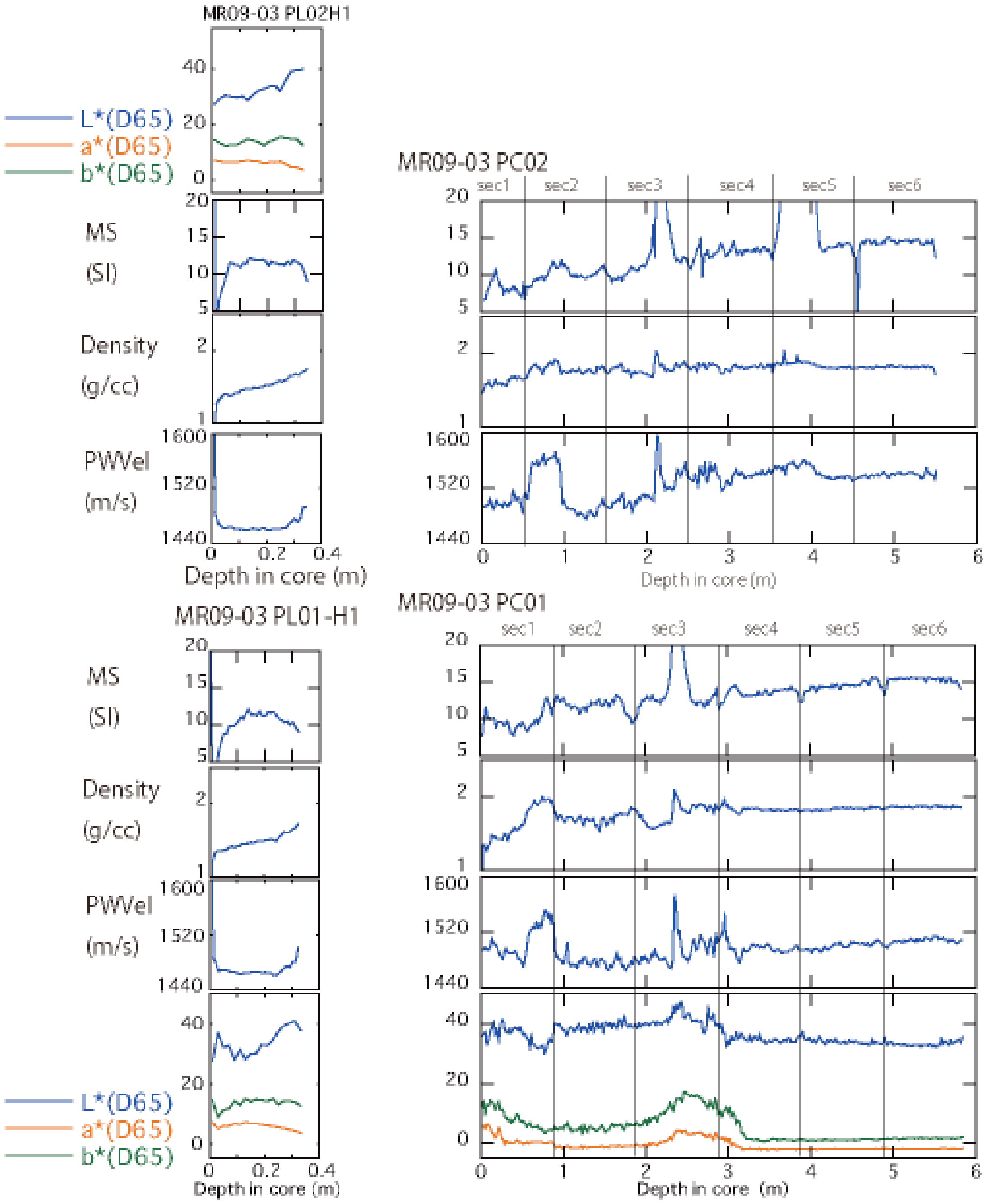


Figure 5.1-7. MSCL and Color reflectance results of A-half piston core cores and pilot cores. MS: magnetic susceptibility, PWVel: P-wave velocity.

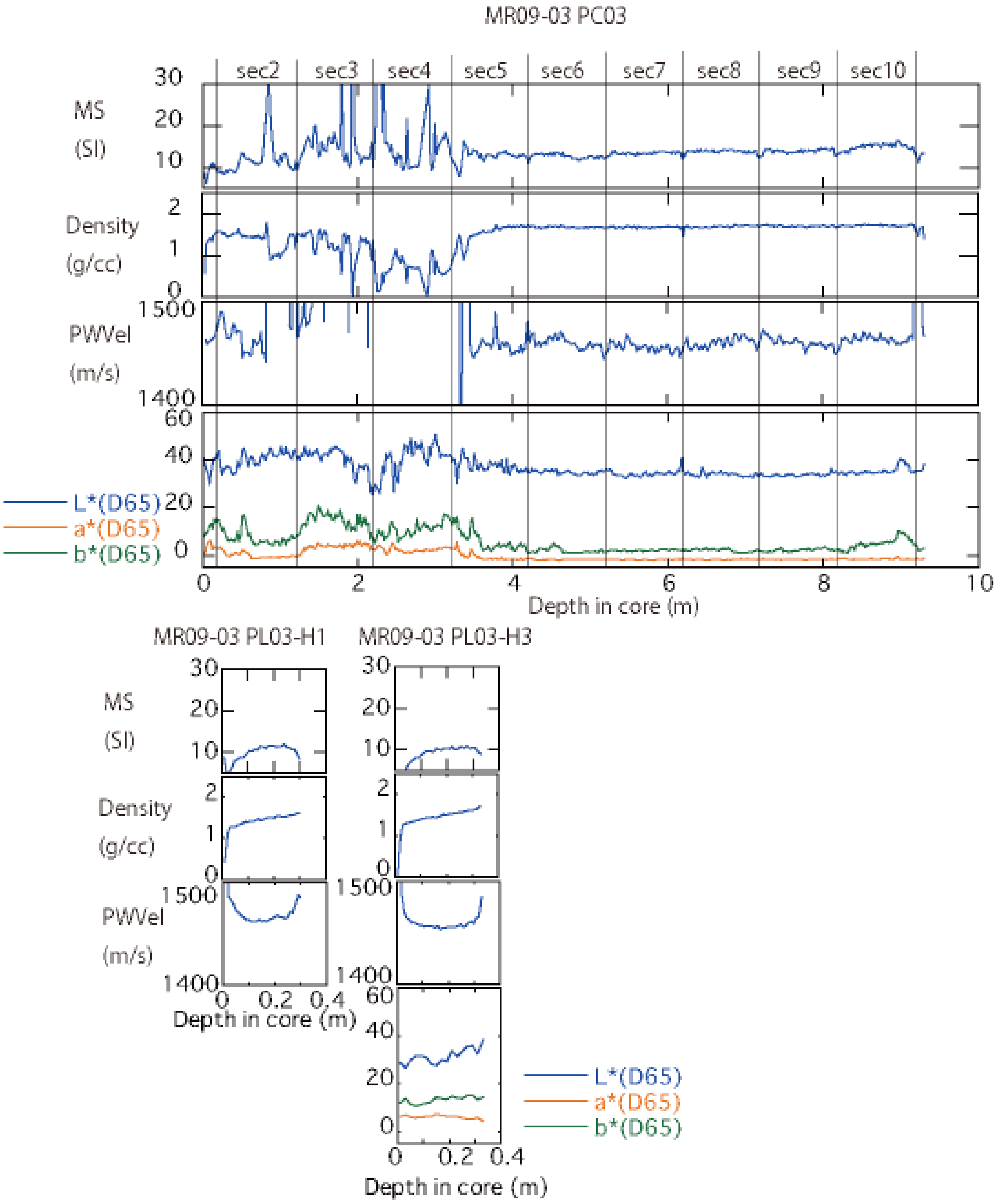


Figure 5.1-8. MSCL and Color reflectance results of A-half piston core cores and pilot cores. MS: magnetic susceptibility, PWVel: P-wave velocity.

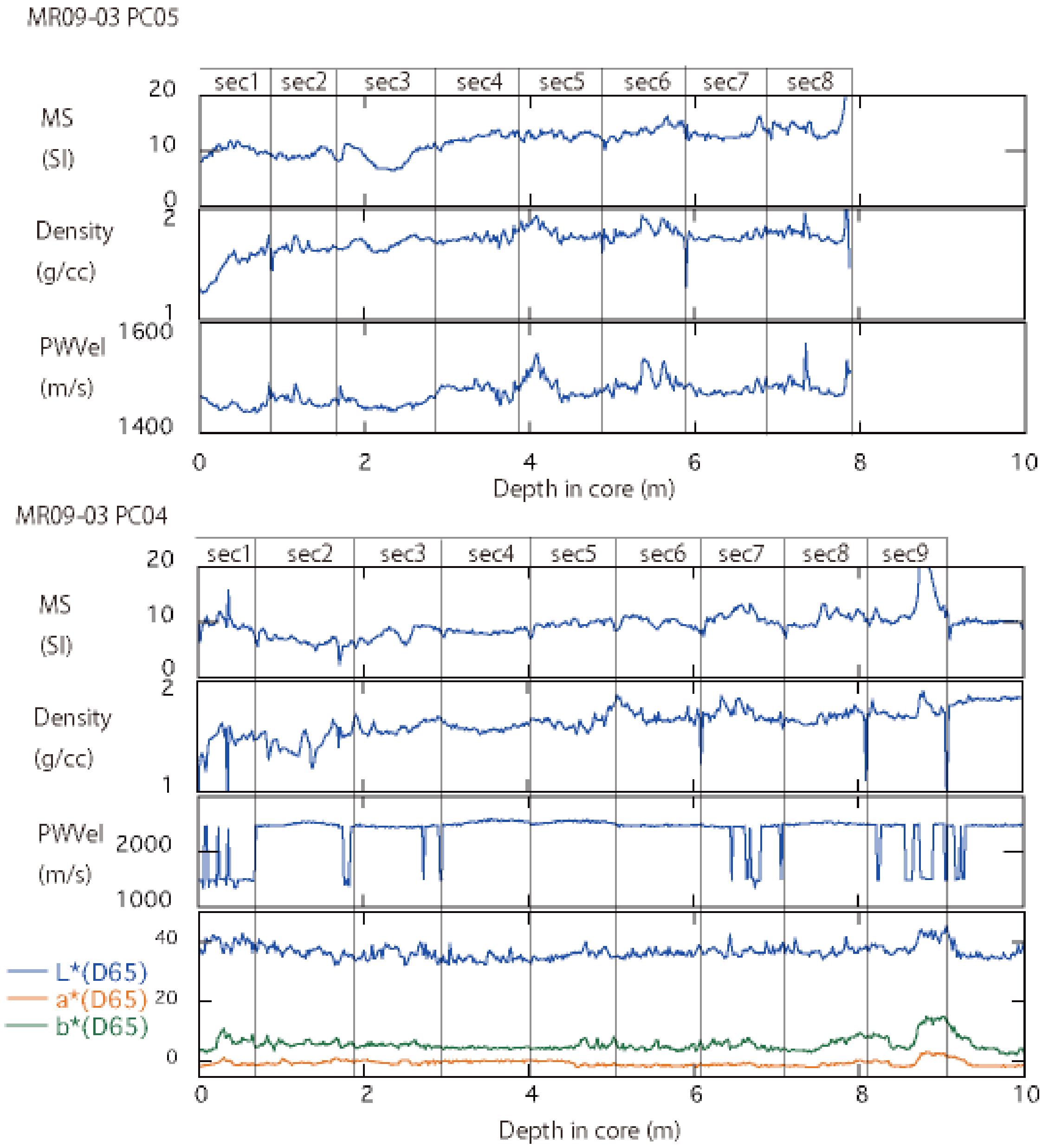


Figure 5.1-9. MSCL and Color reflectance results of A-half piston core cores. MS: magnetic susceptibility, PWVel: P-wave velocity.

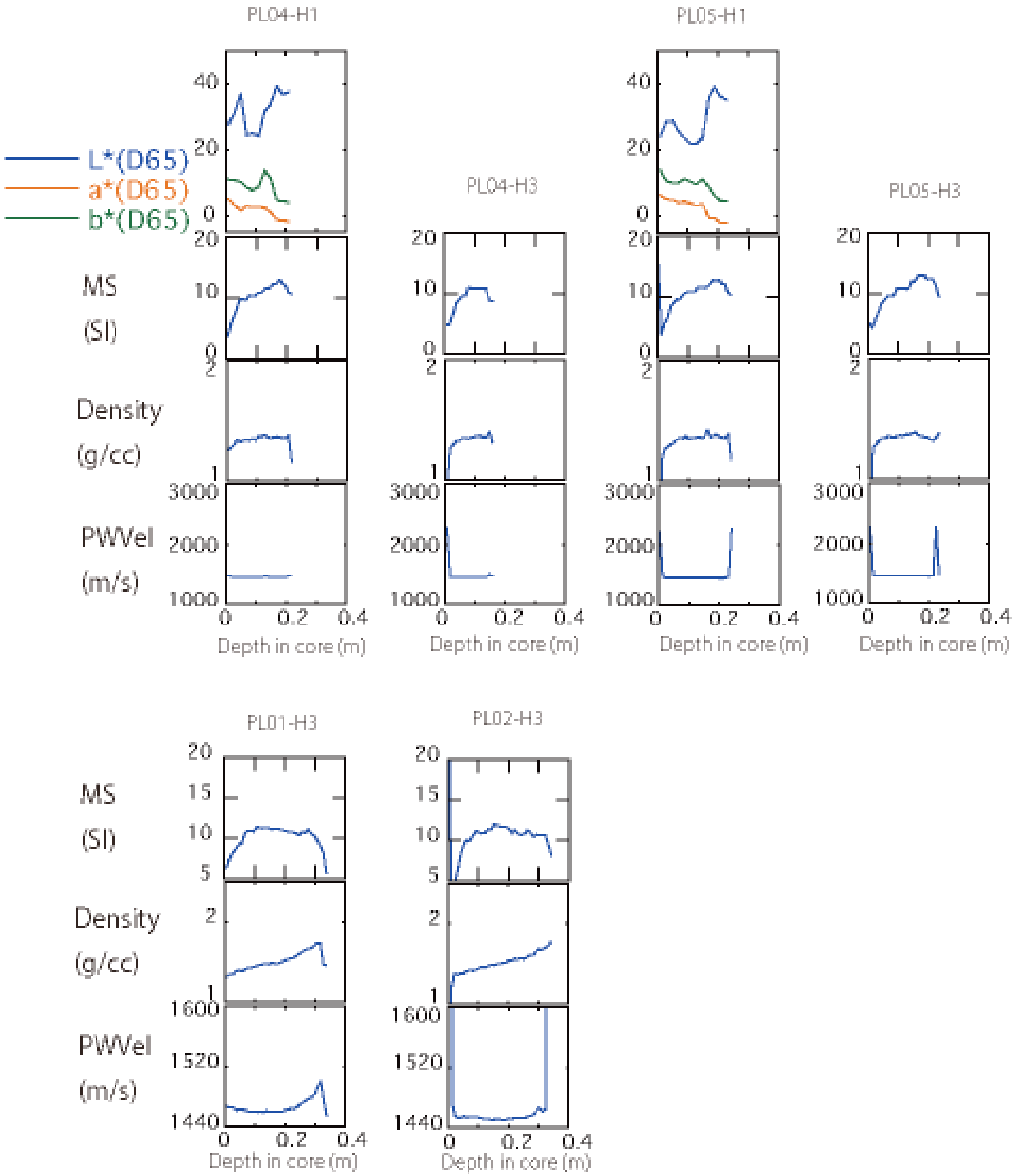


Figure 5.1-10. MSCL and Color reflectance results of A-half pilot cores. MS: magnetic susceptibility, PWVel: P-wave velocity.

Core Photographs

Photographs of each core are shown in Figures 5.1-11~15.

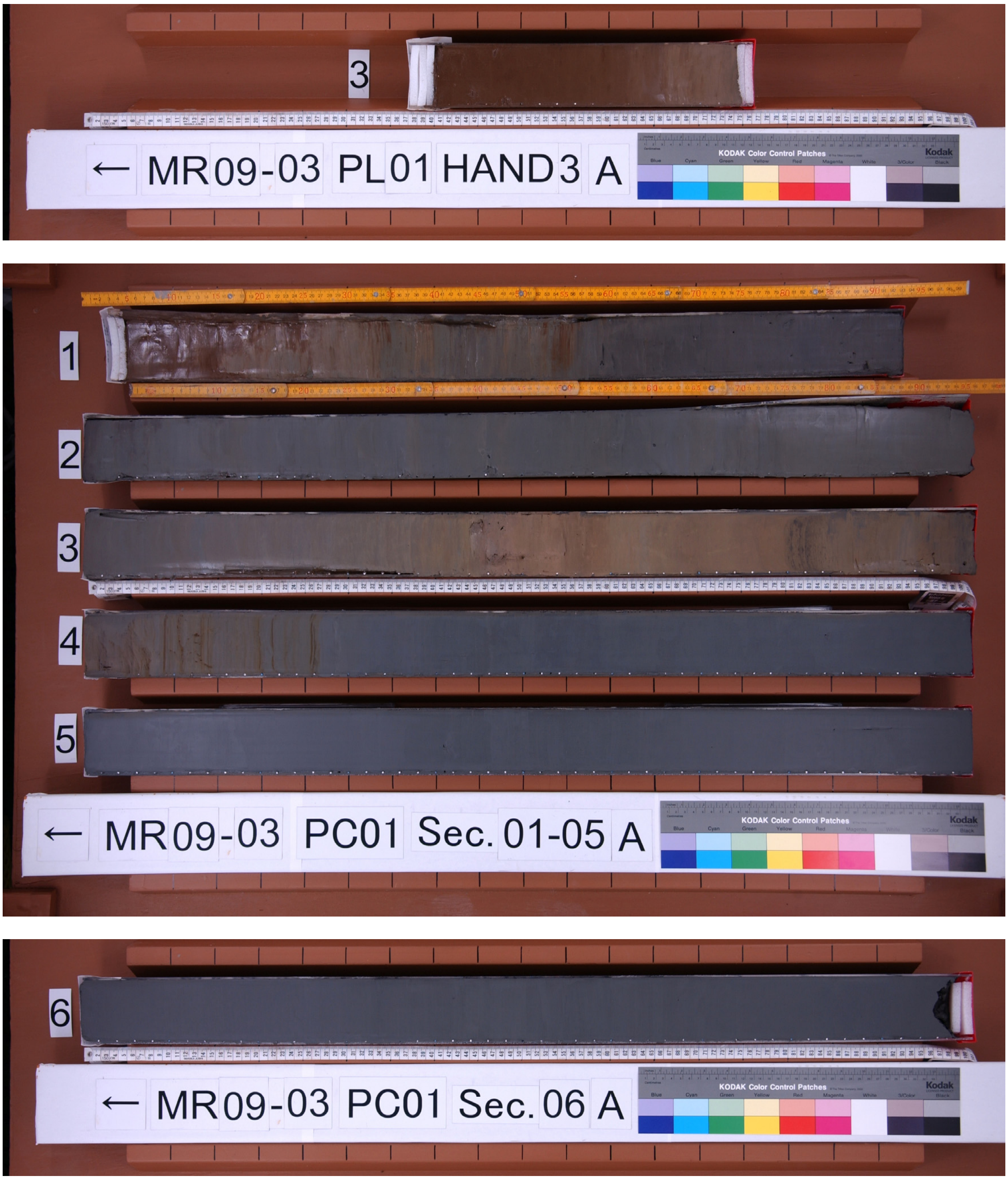


Figure 5.1-11. Photographs of A-half core PC01 and PL01. (F6.3, 1/20 sec)

Figure 5.1-12. Photographs of A-half core PL02. (F6.0, 1/15 sec)

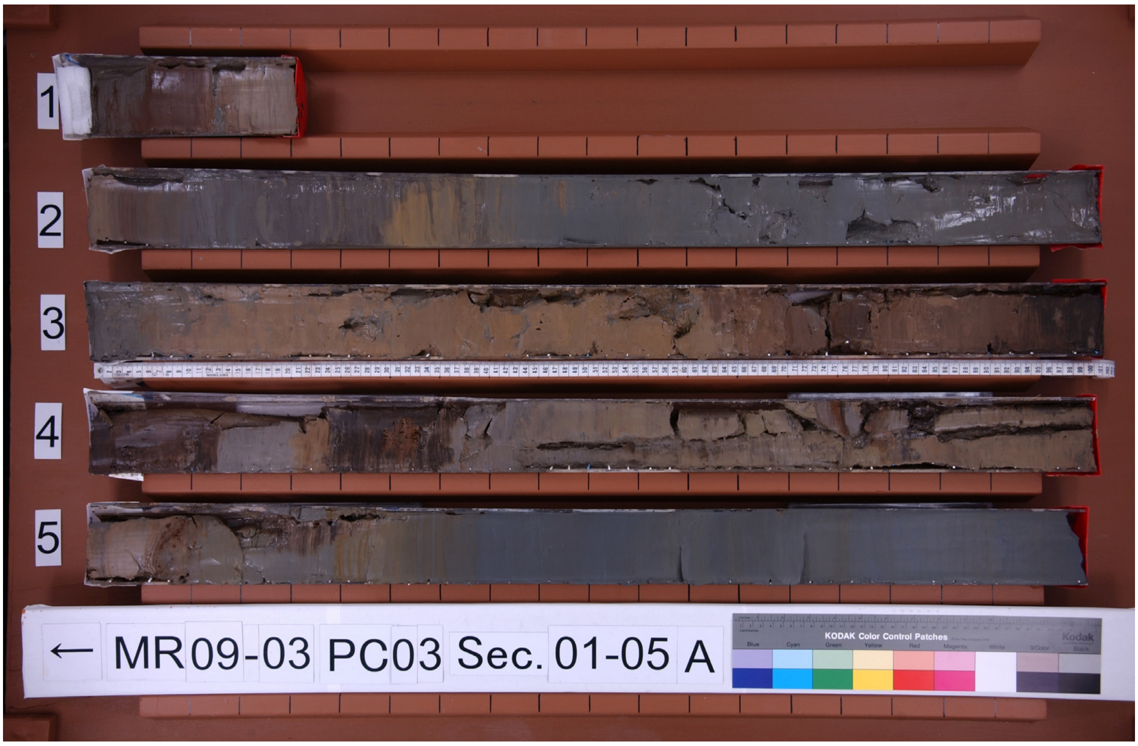


Figure 5.1-13. Photographs of A-half core PC03 and PL03. (F7.1~7.6, 1/15~1/13 sec)

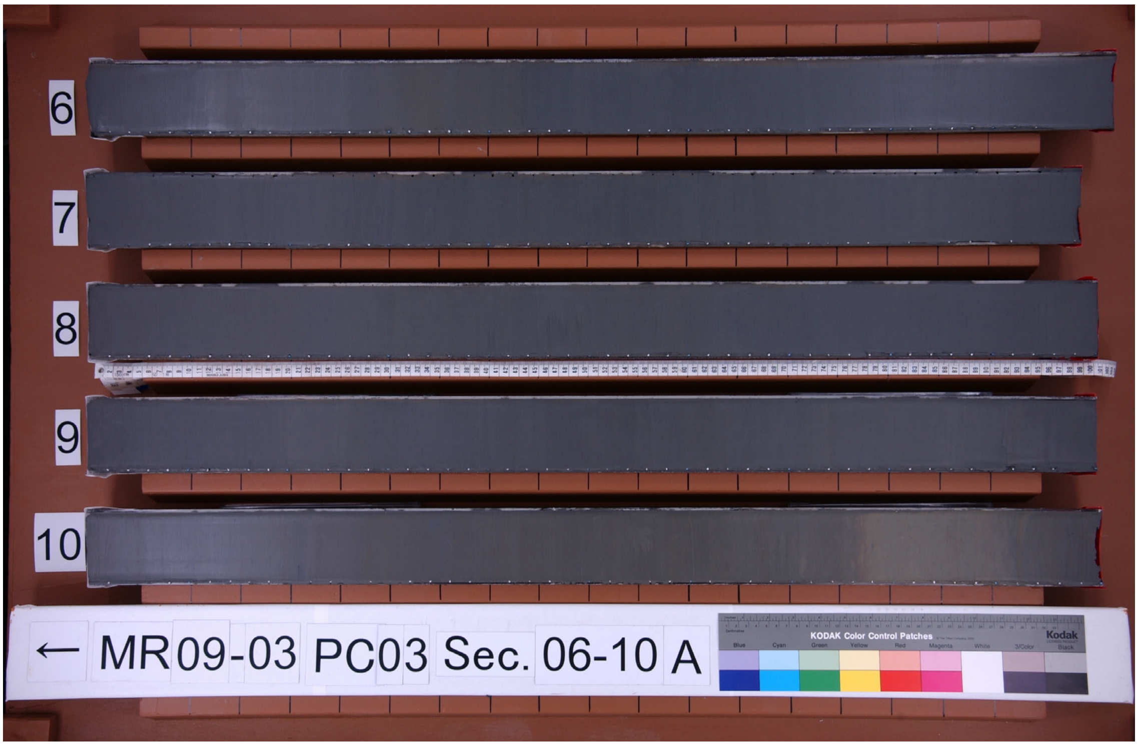


Figure 5.1-13. (Continued).

Figure 5.1-14. Photographs of A-half core PC04 and PL04. (F6.7~7.6, 1/20~1/13 sec)

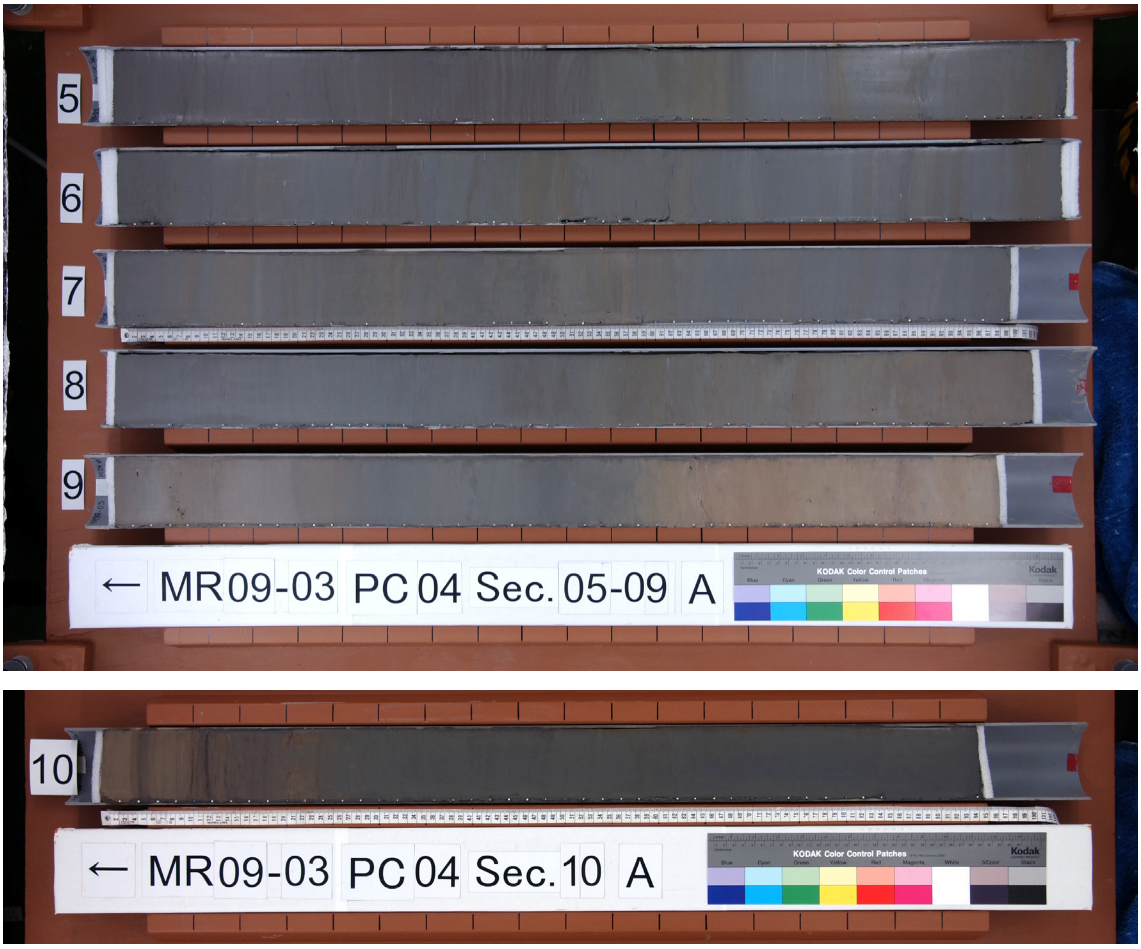


Figure 5.1-14. (Continued).

Figure 5.1-15. Photographs of A-half core PL05. (F6.3, 1/20 sec)

Soft X-ray photographs

In this cruise, the total 138 sediment sample cases were collected from cores, and the total 33 negative films were taken soft X-ray photograph and developed. These results will be stored at Kobe University. Soft X-ray photographs of each core are shown in Figures 5.1-16~17.

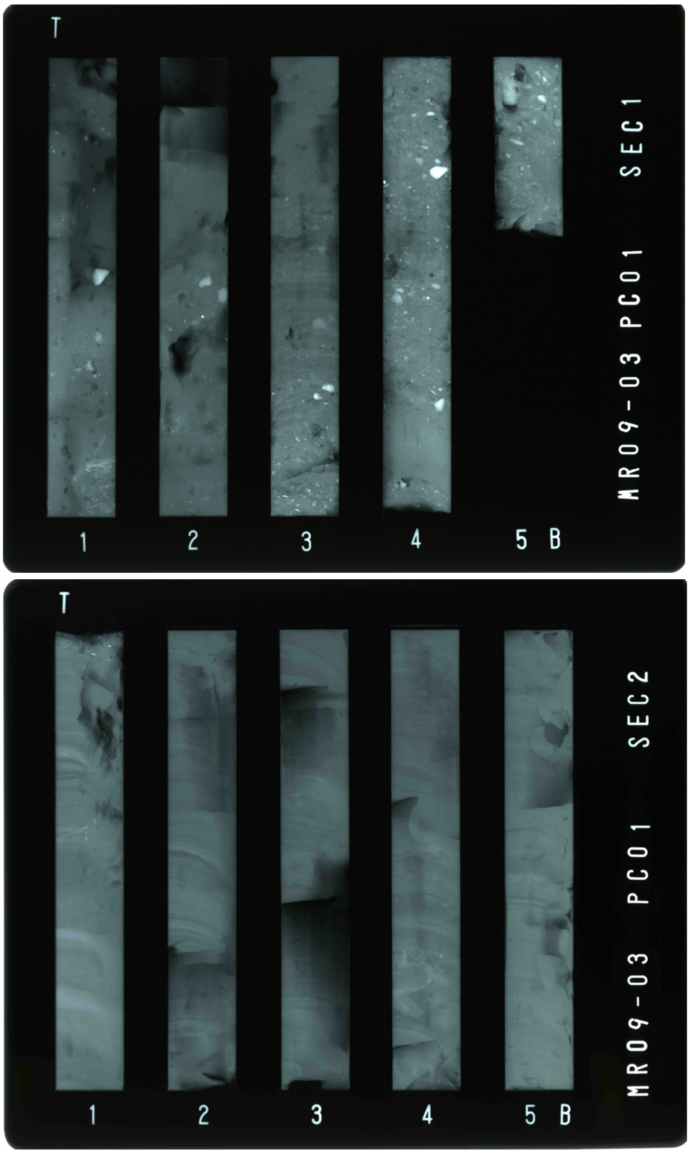


Figure 5.1-16.   Soft X-ray photographs of W-half core PC01 (Sec.1~6).

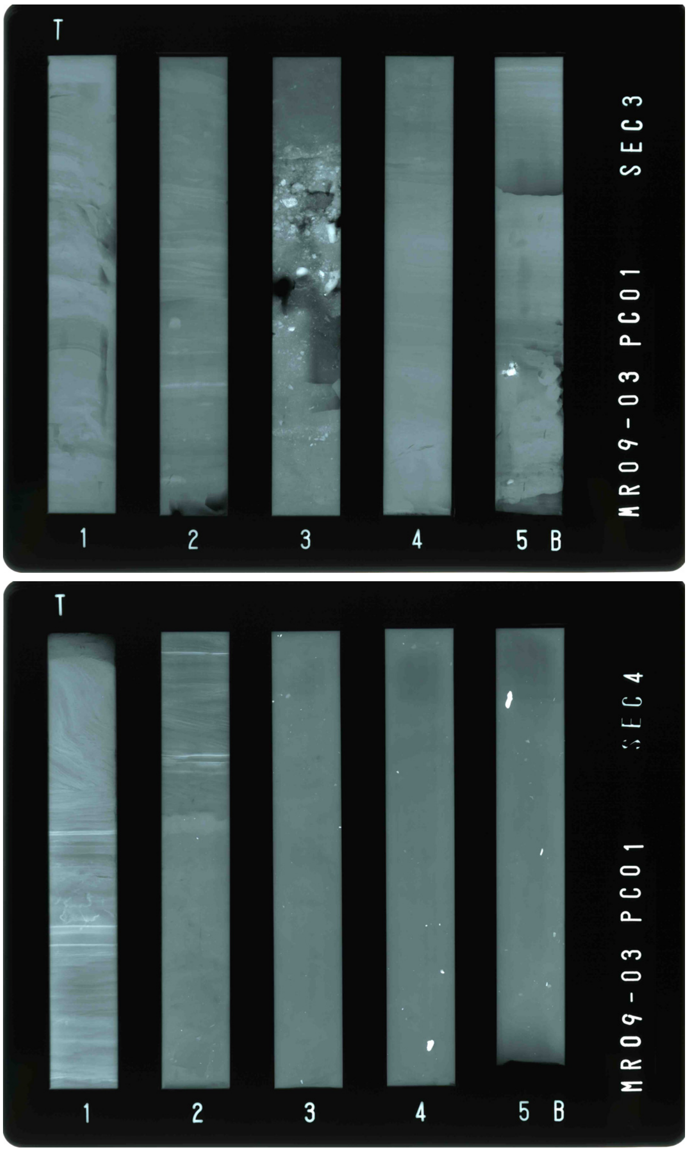
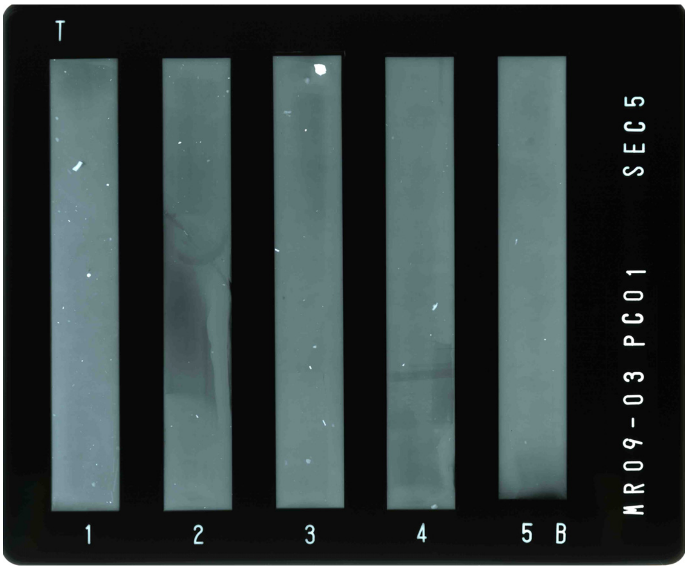


Figure 5.1-16. (Continued).



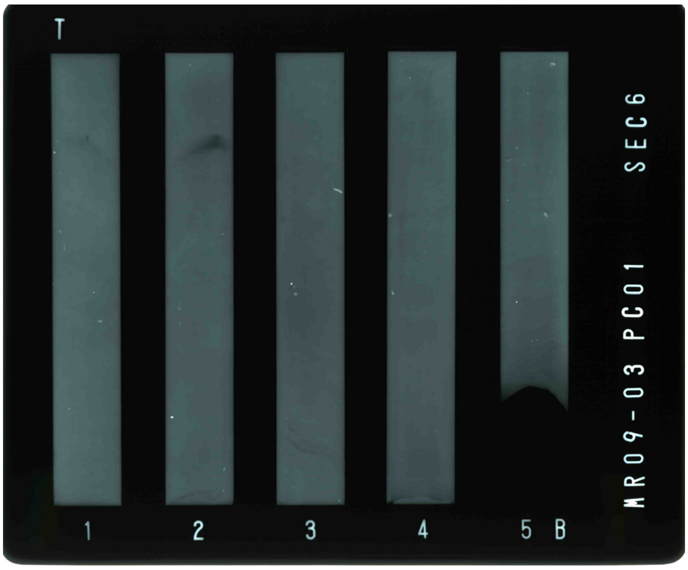


Figure 5.1-16. (Continued).

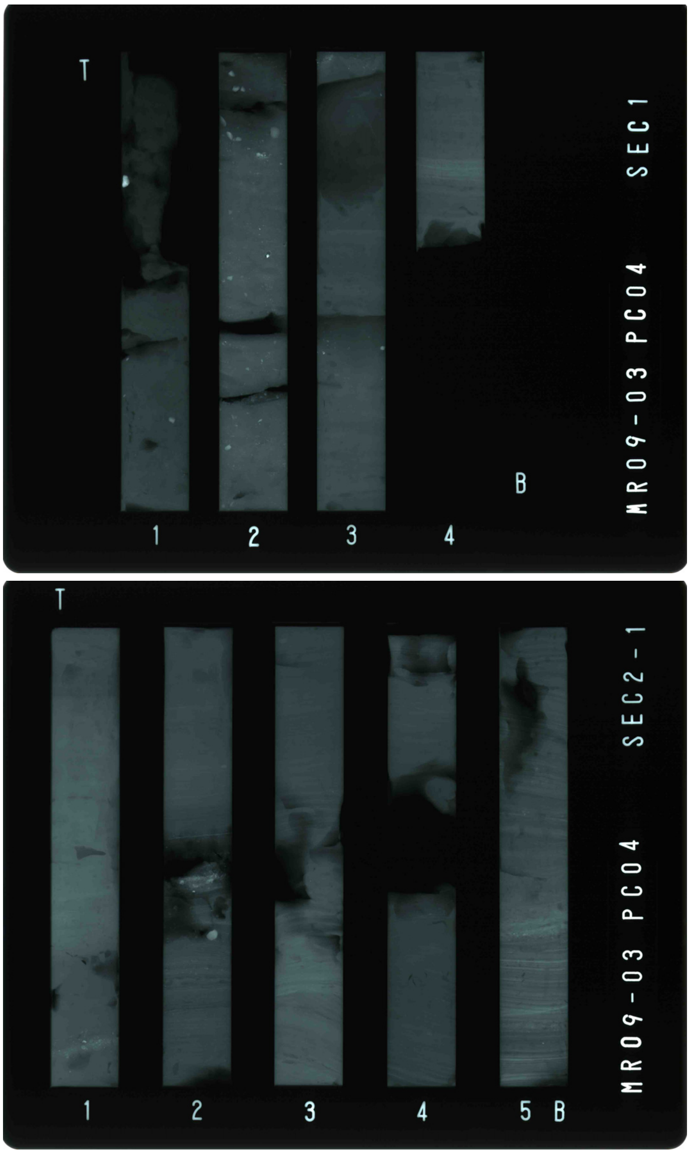


Figure 5.1-17. Soft X-ray photographs of W-half core PC04 (Sec.1~10).

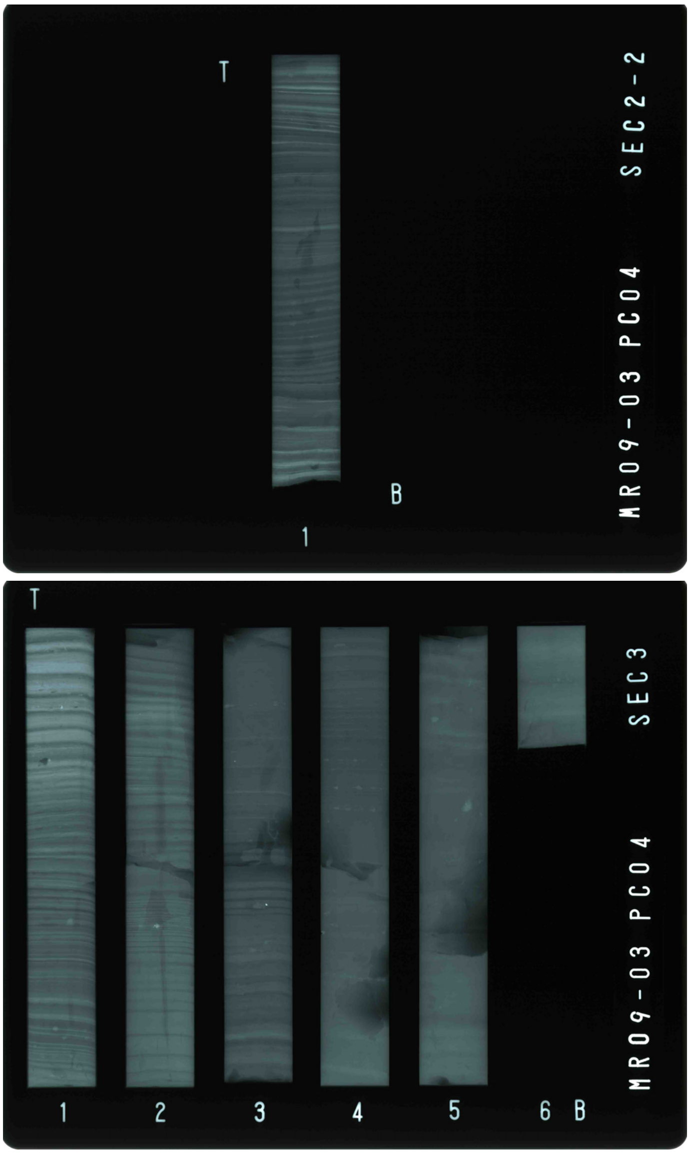


Figure 5.1-17. (Continued).

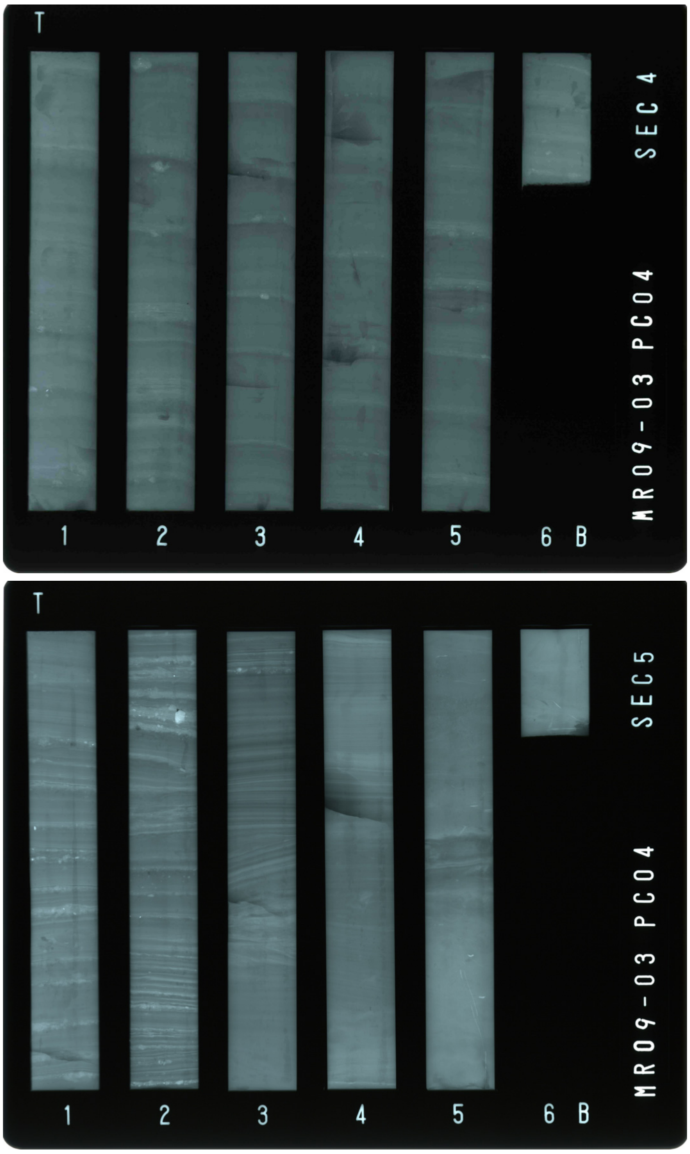


Figure 5.1-17.   (Continued).

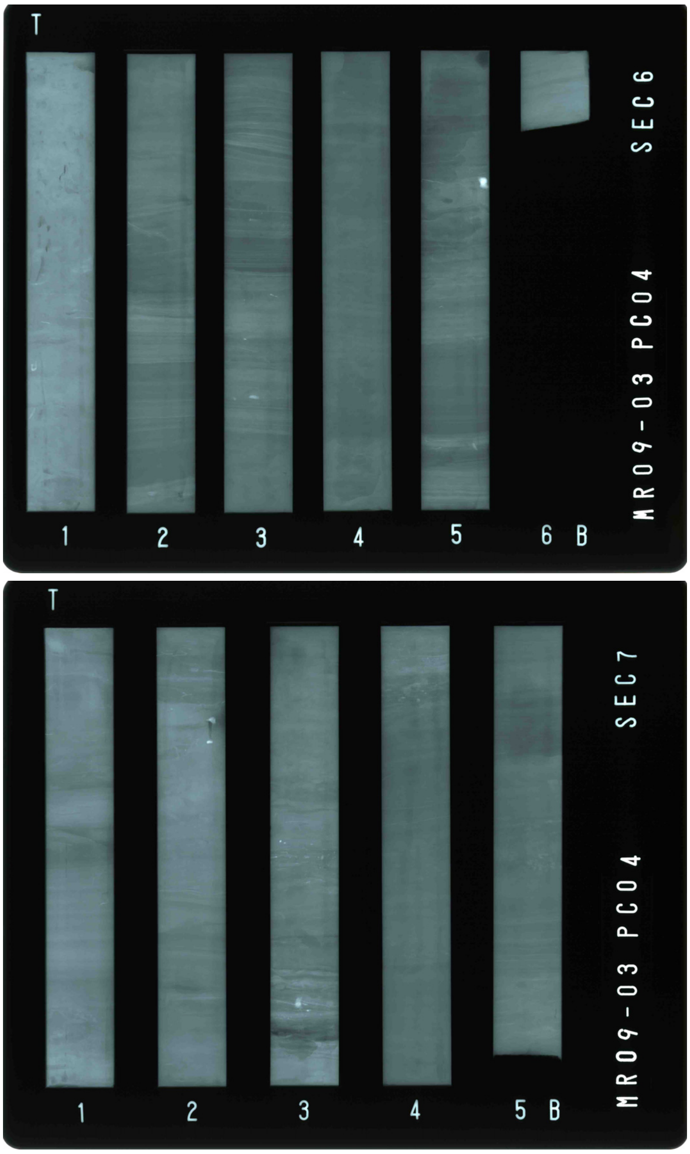


Figure 5.1-17. (Continued).

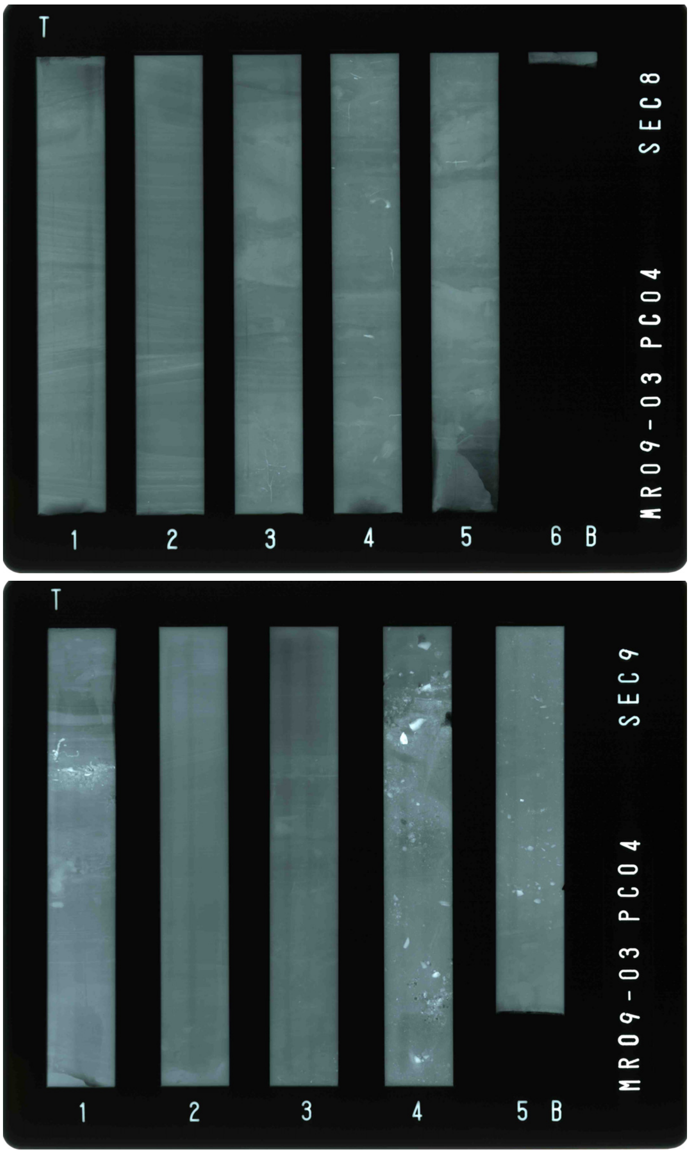


Figure 5.1-17. (Continued).

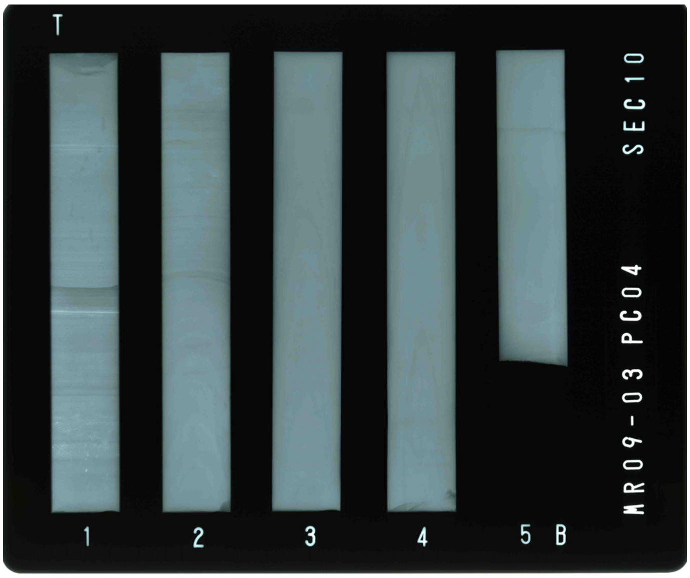


Figure 5.1-17. (Continued).

(6) Observation log

Observation logs are shown in table 5.1-2-1~5.1-2-5.

Table 5.1-2-1. Observation log of PC01.

Cruise Name:	MR09-03_Leg2	Operator:	Yoshida (MWJ)
Date: (UTC)	2009/9/14		
Core Number:	PC01	Pilot Number:	PL01
Area:	Arctic ocean		
Sampling Site:	sta.014		
Corer type:	Inner type piston corer	Pilot type:	Ashura
Pipe length:	10m	Pilot weight:	100kg
Main wire length:	18.8m	Pilot wire length:	18.9m
Free fall:	5.075m		
Weather:	Cloudy		
Wind direction:	205deg.	Wind speed:	8.7m/s
Current direction:	9.8deg.	Current speed:	0.1knot

Time* (UTC)	Depth (m)	Wire length (m)	Latitude	Longitude	Tension (ton)	Wire speed (m/s)	Wire in/out (↑/↓)
20:55	-	-			-	-	-
21:31	-	-			-	-	-
21:33	559	0	75°28.0422' N	165°40.4161' W	1.0	0.0	-
21:40	560	43			1.2	~1.0	↓
21:45	559	200			1.3	~1.0	↓
21:51	557	450			1.5	0.0	-
21:58	559	450			1.5	~0.3	↓
22:02:38	**558**	**537**	**75°28.0692' N**	**165°40.4005' W**	**Min. 0.1**	**0.3**	↓
			75°28.0351' N	**165°40.4886' W**			
22:03:49	**559**	**520**	**75°28.0690' N**	**165°40.3983' W**	**Max. 3.1**	**0.3**	↑
			75°28.0344' N	**165°40.4881' W**			
22:10	557	200			1.3	~1.0	↑
22:13	559	100			1.3	1.0	↑
22:16	558	42			1.2	~0.6	↑
22:18	558	0	75°27.9758' N	165°40.5604' W	1.1	0.6	-
22:22	-	-			-	-	-
22:48	-	-			-	-	-

*LST: UTC -8h

**Latitude and Longitude was used the transponder's position.

Table 5.1-2-2. Observation log of PC02.

Cruise Name:	MR09-03_Leg2	Operator:	Yoshida (MWJ)
Date: (UTC)	2009/9/15		
Core Number:	PC02	Pilot Number:	PL02
Area:	Arctic ocean		
Sampling Site:	sta.014		
Corer type:	Inner type piston corer	Pilot type:	Ashura
Pipe length:	10m***	Pilot weight:	100kg
Main wire length:	18.8m	Pilot wire length:	18.9m
Free fall:	5.075m		
Weather:	Cloudy		
Wind direction:	177deg.	Wind speed:	7.9m/s
Current direction:	224.2deg.	Current speed:	0.2knot

Time* (UTC)	Depth (m)	Wire length (m)	Latitude	Longitude	Tension (ton)	Wire speed (m/s)	Wire in/out (↑/↓)
0:32	-	-			-	-	-
0:53	-	-			-	-	-
0:55	558	0	75°28.0735' N	165°40.4328' W	1.2	0.0	-
1:00	556	43			1.2	~1.0	↓
1:08	558	204			1.3	~1.0	↓
1:14	559	450			1.6	0.0	-
1:17	560	450			1.6	~0.3	↓
1:22:33	**558**	**536**	**75°28.0780' N**	**165°40.3790' W**	**Min. 0.1**	**0.3**	↓
			75°28.0405' N	**165°40.4467' W**			
1:24:03	**557**	**521**	**75°28.0776' N**	**165°40.3820' W**	**Max. 3.0**	**0.3**	↑
			75°28.0363' N	**165°40.4544' W**			
1:31	557	200			1.4	~1.0	↑
1:34	558	100			1.3	1.0	↑
1:37	557	43			1.2	~0.5	↑
1:39	557	0	75°27.9764' N	165°40.5878' W	1.2	0.5	-
1:43	-	-			-	-	-
2:04	-	-			-	-	-

*LST: UTC -8h

**Latitude and Longitude was used the transponder's position.

***Inner tube is used Black polycarbonate pipe for photoluminescence analysis.

Table 5.1-2-3. Observation log of PC03.

Cruise Name:	MR09-03_Leg2	Operator:	Hashimoto (MWJ)
Date: (UTC)	2009/9/15		
Core Number:	PC03	Pilot Number:	PL03
Area:	Arctic ocean		
Sampling Site:	sta.015		
Corer type:	Inner type piston corer	Pilot type:	Ashura
Pipe length:	15m	Pilot weight:	100kg
Main wire length:	23.8m	Pilot wire length:	23.6m
Free fall:	4.775m		
Weather:	snow		
Wind direction:	162deg.	Wind speed:	7.7m/s
Current direction:	254.4deg.	Current speed:	0.4knot

Time* (UTC)	Depth (m)	Wire length (m)	Latitude	Longitude	Tension (ton)	Wire speed (m/s)	Wire in/out (↑/↓)
17:34	-	-			-	-	-
18:10	-	-			-	-	-
18:12	1175	0	76°38.3088' N	165°41.0060' W	1.2	0.0	-
18:17	1174	43			1.2	~1.0	↓
18:23	1174	200			1.3	~1.0	↓
18:30	1174	500			1.5	1.0	↓
18:38	1175	1000			2.0	0.7	↓
18:41	1172	1070			2.0	0.0	-
18:44	1174	1070			2.2	~0.3	↓
18:49:07	**1174**	**1140**	**76°38.3060' N**	**165°41.0572' W**	**Min. 0.3**	**0.3**	↓
			76°38.2614' N	**165°40.9958' W**			
18:50:44	**1175**	**1080**	**76°38.3048' N**	**165°41.0489' W**	**Max. 3.3**	**0.3**	↑
			76°38.2609' N	**165°40.9807' W**			
18:52	1173	1000			2.2	1.0	↑
19:01	1171	500			1.7	1.0	↑
19:08	1174	200			1.5	~1.0	↑
19:12	1174	100			1.4	1.0	↑
19:15	1172	42			1.4	~0.4	↑
19:17	1173	0	76°38.2181' N	165°41.2624' W	1.3	0.4	↑
19:21	-	-			-	-	-
19:47	-	-			-	-	-

*LST: UTC -8h

**Latitude and Longitude was used the transponder's position.

Table 5.1-2-4. Observation log of PC04.

Cruise Name:	MR09-03_Leg2	Operator:	Hashimoto (MWJ)
Date: (UTC)	2009/10/5		
Core Number:	PC04	Pilot Number:	PL04
Area:	Arctic ocean		
Sampling Site:	sta.083		
Corer type:	Outer type piston corer	Pilot type:	Ashura
Pipe length:	15m	Pilot weight:	100kg
Main wire length:	23.8m	Pilot wire length:	24.6m
Free fall:	5.775m		
Weather:	Cloudy		
Wind direction:	231deg.	Wind speed:	0.9m/s
Current direction:	106.9deg.	Current speed:	0.4knot

Time* (UTC)	Depth (m)	Wire length (m)	Latitude	Longitude	Tension (ton)	Wire speed (m/s)	Wire in/out (↑/↓)
17:58	-	-			-	-	-
18:31	-	-			-	-	-
18:33	371	0	74°26.2599' N	165°44.1718' W	1.1	0.0	-
18:38	368	43			1.1	~1.0	↓
18:44	369	260			1.4	0.0	-
18:47	368	260			1.3	~0.3	↓
18:51:13	**370**	**334**	**74°26.2740' N**	**165°44.3328' W**	**Min. 0.02**	**0.3**	↓
			74°26.2640' N	**165°44.1985' W**			
18:52:36	**368**	**310**	**74°26.2748' N**	**165°44.3353' W**	**Max. 2.8**	**0.3**	↑
			74°26.2635' N	**165°44.1993' W**			
18:57	369	100			1.3	~1.0	↑
19:00	368	43			1.3	~0.5	↑
19:02	368	0	74°26.2446' N	165°43.9635' W	1.3	0.3	-
19:07	-	-			-	-	-
19:28	-	-			-	-	-

*LST: UTC -8h

**Latitude and Longitude was used the transponder's position.

Table 5.1-2-5. Observation log of PC05

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Cruise Name:	MR09-03_Leg2	Operator:	Kawamura (MWJ)
Date: (UTC)	2009/10/5		
Core Number:	PC05	Pilot Number:	PL05
Area:	Arctic ocean		
Sampling Site:	sta.083		
Corer type:	Inner type piston corer	Pilot type:	Ashura
Pipe length:	10m	Pilot weight:	100kg
Main wire length:	18.3m	Pilot wire length:	18.9m
Free fall:	5.075m		
Weather:	Cloudy		
Wind direction:	266deg.	Wind speed:	3.6m/s
Current direction:	141.3deg.	Current speed:	0.4knot

Time* (UTC)	Depth (m)	Wire length (m)	Latitude	Longitude	Tension (ton)	Wire speed (m/s)	Wire in/out (↑/↓)
22:40	-	-			-	-	-
23:00	-	-			-	-	-
23:03	369	0	74°26.2581' N	165°43.8757' W	1.1	0.0	-
23:08	370	43			1.1	~1.0	↓
23:15	368	260			1.3	0.0	-
23:18	370	260			1.2	~0.3	↓
23:23:35	**368**	**340**	**74°26.2777' N**	**165°44.1244' W**	**Min. 0.03**	**0.3**	↓
			74°26.2656' N	**165°43.9912' W**			
23:24:27	**367**	**329**	**74°26.2773' N**	**165°44.1217' W**	**Max. 2.4**	**0.3**	↑
			74°26.2677' N	**165°43.9949' W**			
23:30	369	100			1.2	~0.3	↑
23:34	370	43			1.2	~0.5	↑
23:36	370	0	74°26.3099' N	165°43.5825' W	1.1	0.5	-
23:40	-	-			-	-	-
0:00	-	-			-	-	-

*LST: UTC -8h

**Latitude and Longitude was used the transponder's position.

5.2. Sea bottom topography measurement

(1) Personnel

Takeshi Matsumoto	(University of the Ryukyus): Principal Investigator (Not on-board)
Masao Nakanishi	(Chiba University): Principal Investigator (Not on-board)
Shinya Okumura	(GODI)
Souichiro Sueyoshi	(GODI)
Satoshi Okumura	(GODI)
Norio Nagahama	(GODI)
Ryo Kimura	(GODI)
Ryo Ohyama	(MIRAI Crew)

(2) Introduction

R/V MIRAI equipped a Multi Beam Echo Sounding system (MBES), SEABEAM 2112.004 (SeaBeam Instruments Inc.).

The main objective of MBES survey is collecting continuous bathymetry data along ship's track to make a contribution to geological and geophysical investigations and global datasets. We had carried out bathymetric survey throughout the MR09-03 cruise.

(3) Data acquisition

MBES was used for bathymetry mapping during this cruise. To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data for the surface (6.2m) sound velocity, and below that the sound velocity profile calculated from temperature and salinity data obtain CTD or XCTD based on the equation in Del Grosso (1974).

System configuration and performance of SEABEAM 2112.004

Frequency:	12 kHz
Transmit beam width:	2 degree
Transmit power:	20 kW
Transmit pulse length:	3 to 20 msec.
Depth range:	100 to 11,000 m
Beam spacing:	1 degree athwart ship
Swath width:	150 degree (max)
	120 degree to 4,500 m
	100 degree to 6,000 m
	90 degree to 11,000 m

Depth accuracy: Within < 0.5% of depth or +/-1m,
whichever is greater, over the entire swath.
(Nadir beam has greater accuracy; typically within < 0.2% of depth or +/-1m, whichever is greater)

(4) Data archives

Bathymetry data obtained during this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC.

(5) Remarks

Following periods, the navigation data was not updated due to stopping output process of the Radio Navigation System.

28 Aug. 2009, 13:10:47 to 14:11:06UTC

05 Oct. 2009, 04:20:46 to 04:25:36UTC

5.3. Sea surface gravity measurement

(1) Personnel

Takeshi Matsumoto	(University of the Ryukyus): Principal Investigator (Not on-board)
Masao Nakanishi	(Chiba University): Principal Investigator (Not on-board)
Shinya Okumura	(GODI)
Souichiro Sueyoshi	(GODI)
Satoshi Okumura	(GODI)
Norio Nagahama	(GODI)
Ryo Kimura	(GODI)
Ryo Ohyama	(MIRAI Crew)

(2) Introduction

The distribution of local gravity is an important parameter in geophysics and geodesy. We collected gravity data at the sea surface throughout the MR09-03 cruise from Sekinehama on 29 August 2009 to Sekinehama on 25 October 2009.

(3) Parameters

Relative Gravity [CU: Counter Unit]

[mGal] = (coefl: 0.9946) * [CU]

(4) Data acquisition

We measured relative gravity using LaCoste and Romberg air-sea gravity meter S-116 (Micro-g LaCoste, LLC) during this cruise. To convert the relative gravity to absolute one, we measured gravity using portable gravity meter (Scintrex gravity meter CG-3M), at Sekinehama Port as reference point.

(5) Preliminary results

Absolute gravity table is shown in Tabel 5.3-1

Table 5.3-1 Absolute gravity table

	Date	UTC	Port	Absolute Gravity [mGal]	Sea Level [cm]	Draft [cm]	Gravity at Sensor *[1] [mGal]	L&R*[2] Gravity [mGal]
No.1	Aug/24	02:53	Sekinehama	980,371.92	286	620	980,372.84	12,649.07
No.2	Oct/25	02:34	Sekinehama	980,371.95	256	628	980,372.78	12,642.05

*[1]: Gravity at Sensor= Absolute Gravity + Sea Level*0.3086/100 + (Draft-530)/100*0.0431

*[2]: LaCoste and Romberg air-sea gravity meter S-116

Differential (No.1-No.2): G at sensor=-0.06 mGal ---(a) L&R value=-7.02 mGal ---(b)

L&R drift value (b)-(a): -6.96 mGal / 63.00 days

Daily drift ratio: -0.11 mGal/day

(6) Data archives

Gravity data obtained during this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC.

5.4. Surface three component magnetic field measurements

(1) Personnel

Takeshi Matsumoto	(University of the Ryukyus): Principal Investigator (Not on-board)
Masao Nakanishi	(Chiba University): Principal Investigator (Not on-board)
Shinya Okumura	(GODI)
Souichiro Sueyoshi	(GODI)
Satoshi Okumura	(GODI)
Norio Nagahama	(GODI)
Ryo Kimura	(GODI)
Ryo Ohyama	(MIRAI Crew)

(2) Introduction

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 the MR09-03 cruise from Sekinehama on 29 August 2009 to Sekinehama on 25 October 2009.

(3) Principle of ship-board geomagnetic vector measurement

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:

$$\mathbf{H}\text{ob} = \mathbf{A}\ \mathbf{R}\ \mathbf{P}\ \mathbf{Y}\ \mathbf{F} + \mathbf{H}\text{p} \qquad \text{(a)}$$

where **R**, **P** and **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 **H**p is a magnetic field vector produced by a permanent magnetic moment of the ship's body. Rearrangement of Eq. (a) makes

$$\mathbf{B}\ \mathbf{H}\text{ob} + \mathbf{H}\text{bp} = \mathbf{R}\ \mathbf{P}\ \mathbf{Y}\ \mathbf{F} \qquad \text{(b)}$$

where **B** = A-1, and **H**bp = -B **H**p. The magnetic field, **F**, can be obtained by measuring **R**, **P**, **Y** and **H**ob, if **B** and **H**bp are known. Twelve constants in **B** and **H**bp can be determined by measuring variation of **H**ob with **R**, **P** and **Y** at a place where the geomagnetic field, **F**, is known.

(4) Instruments on R/V MIRAI

A shipboard three-component magnetometer system (Tierra Tecnica SFG1214) 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. Ship's heading, pitch, and roll are measured by the Inertial Navigation System (INS) for controlling attitude of a Doppler radar. Ship's position (GPS) and speed data are taken from LAN every second.

(5) Data archives

These data obtained in this cruise will be submitted to the Data Integration and Analysis Group (DIAG) of JAMSTEC.

(6) Remarks

a) For calibration of the ship's magnetic effect, we made a "figure-eight" turn (a pair of clockwise and anti-clockwise rotation). This calibration was carried out as below.

   22 Sep. 2009, 03:27 to 04:02UTC around at 78-00.5N, 150-01.6W

   06 Oct. 2009, 05:02 to 05:29UTC around at 74-01.9N, 164-07.7W

b) Following periods, the navigation data was not updated due to the Radio Navigation System trouble.

   28 Aug. 2009, 13:10:47 to 14:11:06UTC

   05 Oct. 2009, 04:20:46 to 04:25:36UTC

Appendix I. Sea ice distribution during the cruise

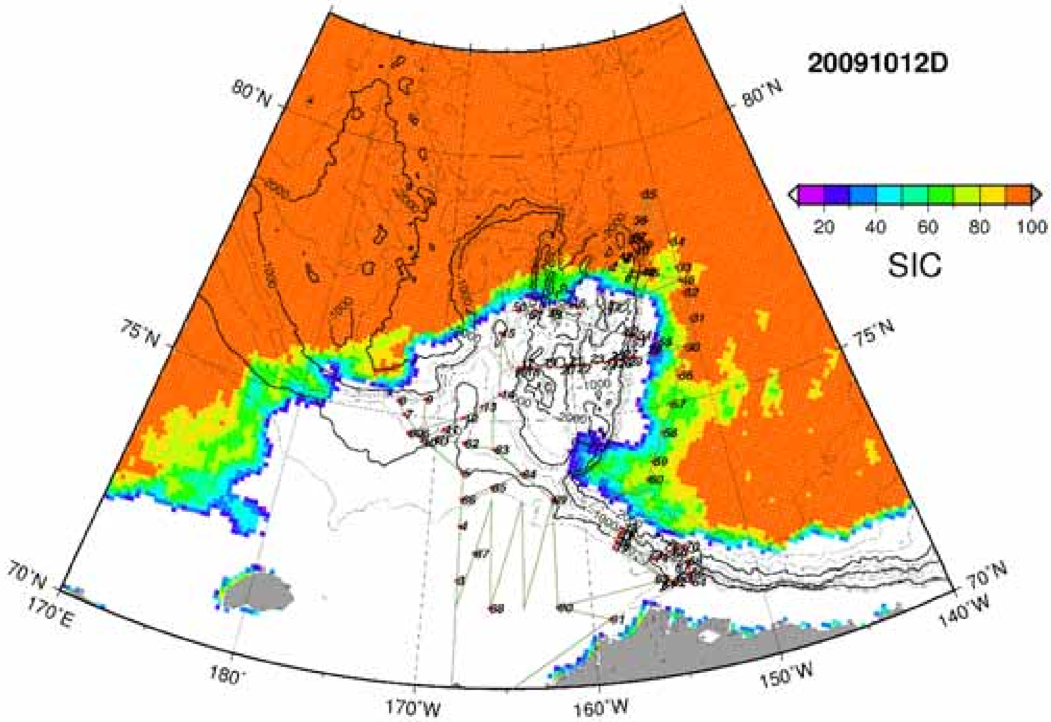


Figure A1-1. Sea-ice concentration on 12 October 2009 and CTD stations with the cruise track.

Appendix II. Bottle Data Inventory

	JAMSTEC									The University of Tokyo							Hokkaido Univ.		Yamagata Univ.	NIES		
Sta	SAL	OXY	NUT	TA	DIC	18O	CHL	f-CHL	CN	BA	VIRUS	BCS	LEU	HNF	POM	DOM	HPLC	PP	BIA	BAC	DI14C	DO14C
000_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
002_1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	1	1	1
003_1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0
004_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
005_1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	1	1	1
006_1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0
007_1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0
008_1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
009_1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	1	0	0
009_2	1	1	1	1	1	1	1	0	0	1	1	0	1	1	1	1	0	0	1	1	1	1
010_1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0
011_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
012_1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0
013_1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0
014_1	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
015_1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0
016_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
017_1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
019_1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0
019_2	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	0	1	0	0	0
021_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
022_1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	1	1	1	1
025_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
028_1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
030_1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0
030_2	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	1	0	0	0
031_1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
032_1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
033_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
034_1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
035_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0

	JAMSTEC									The University of Tokyo							Hokkaido Univ.		Yamagata Univ.	NIES		
Sta	SAL	OXY	NUT	TA	DIC	18O	CHL	f-CHL	CN	BA	VIRUS	BCS	LEU	HNF	POM	DOM	HPLC	PP	BIA	BAC	DI14C	DO14C
036_1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	0
039_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
042_1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
043_1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
045_1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	0	1	0	0	0
046_1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	0
046_2	1	1	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0
047_1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	0	0	0
048_1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
049_1	1	1	1	1	1	0	1	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
050_1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
051_1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	0	0
051_2	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1
056_1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	0	0	0
057_1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
058_1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	1	1
058_2	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	1	1	0	0	0
059_1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
060_1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0
062_2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	0	0
064_1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
066_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
067_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
069_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
071_1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0
075_1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	1	1
075_2	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	1	1	0	0	0
077_1	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
078_1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	0	0	0
079_1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0
080_1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	0	1	1	1	1
081_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

	JAMSTEC									The University of Tokyo							Hokkaido Univ.		Yamagata Univ.	NIES		
Sta	SAL	OXY	NUT	TA	DIC	18O	CHL	f-CHL	CN	BA	VIRUS	BCS	LEU	HNF	POM	DOM	HPLC	PP	BIA	BAC	DI14C	DO14C
082_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
083_1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1
084_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
085_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
086_1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0
087_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
088_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
089_1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
090_1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
091_1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1

0: Not sampled
1: Sampled
Sta: Station and cast
SAL: Salinity
OXY: Oxygen
NUT: Nutrients
TA: Total Alkalinity
DIC: Dissolved inorganic carbon
18O: Oxygen isotope ratio
CHL: Chlorophyll a
f-CHL: Size-fractionated chlorophyll a
CN: Carbon and nitrogen uptake rates
BA: Bacteria
VIRUS: Virus
BCS: Bacteria community structure
LEU: Leucine uptake rate
HNF: Heterotrophic nanoflagellate
POM: Particlate organic matter
DOM: Dissolved organic matter
HPLC: Pigments for HPLC
PP: Primary productivity
BIA: Phytoplankton
BAC: Bacteria
DI14C 14C-Dissolved inorganic carbon
DO14C: 14C-Dissolved organic carbon

Appendix III. Figures of CTD observations

(1) Vertical profiles of CTD

Table A3-1. Regional classification of CTD stations.

MR09-03 CTD Stations		
Stns.	Regions	Figures
000	Northwestern North Pacific	Fig.A3-1-1, Fig.A3-1-2
002-004	Chukchi Sea shelf (Ascending)	Fig.A3-1-3
005-011	Western Chukchi Sea shelf slope	Fig.A3-1-4, Fig.A3-1-5
012-015	Chukchi Rise to Chukchi Gap	Fig.A3-1-6, Fig.A3-1-7
016-029	Northwind Abyssal Plain to Northwind Ridge (76N)	Fig.A3-1-8, Fig.A3-1-9
030-035	Northern Canada Basin	Fig.A3-1-10, Fig.A3-1-11
036-045	Northern Northwind Ridge	Fig.A3-1-12, Fig.A3-1-13
046-051	Norhern Canada Basin to Chukchi Plateau (77N)	Fig.A3-1-14, Fig.A3-1-15
052-055	Eastern slope of Northwind Ridge	Fig.A3-1-16, Fig.A3-1-17
056-060	Southern Canada Basin	Fig.A3-1-18, Fig.A3-1-19
061-074	Barrow Canyon	Fig.A3-1-20, Fig.A3-1-21
075-079	Eastern Chukchi Sea shelf slope	Fig.A3-1-22, Fig.A3-1-23
0800-84, 0 89	Along Chukchi Sea shelf slope	Fig.A3-1-24
085, 086	Northern end of Chukchi Sea shelf	Fig.A3-1-25
087, 088, 090, 091	Chukchi Sea shelf (Descending)	Fig.A3-1-26

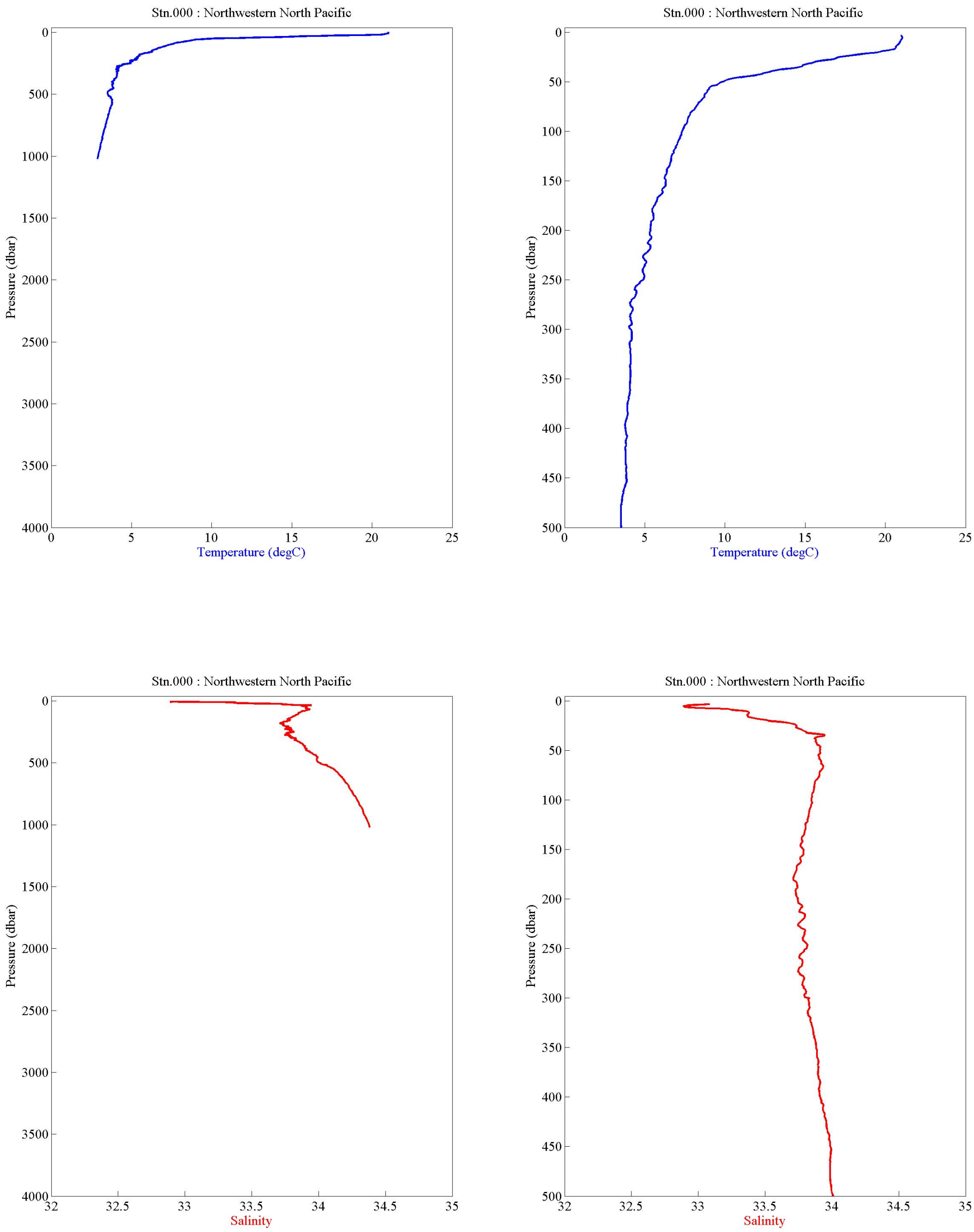


Figure A3-1-1. Temperature and salinity of Stn.000 (4000dbar and 500dbar).

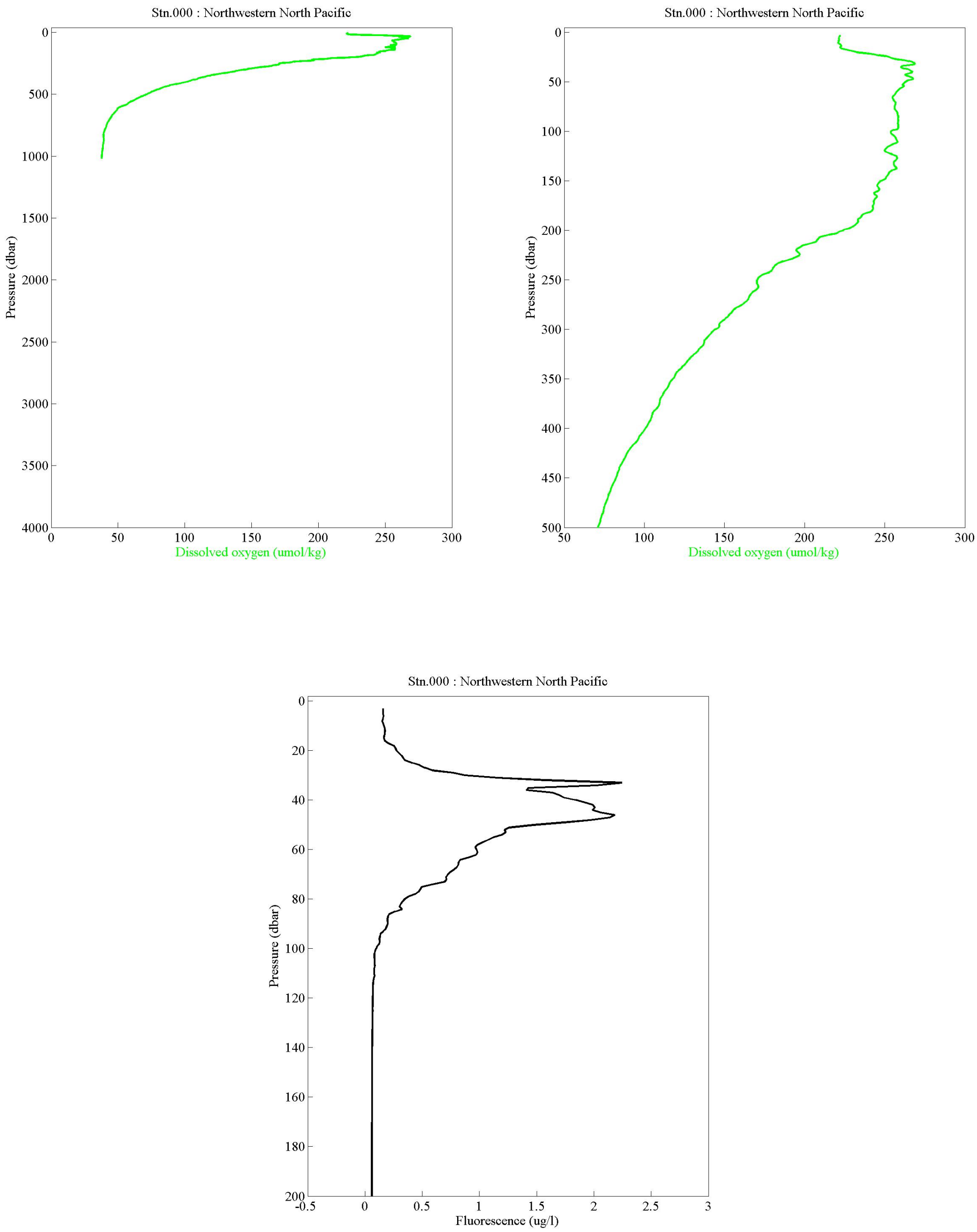


Figure A3-1-2. Dissolved oxygen and fluorescence of Stn.000 (4000dbar, 500dbar and 200dbar).

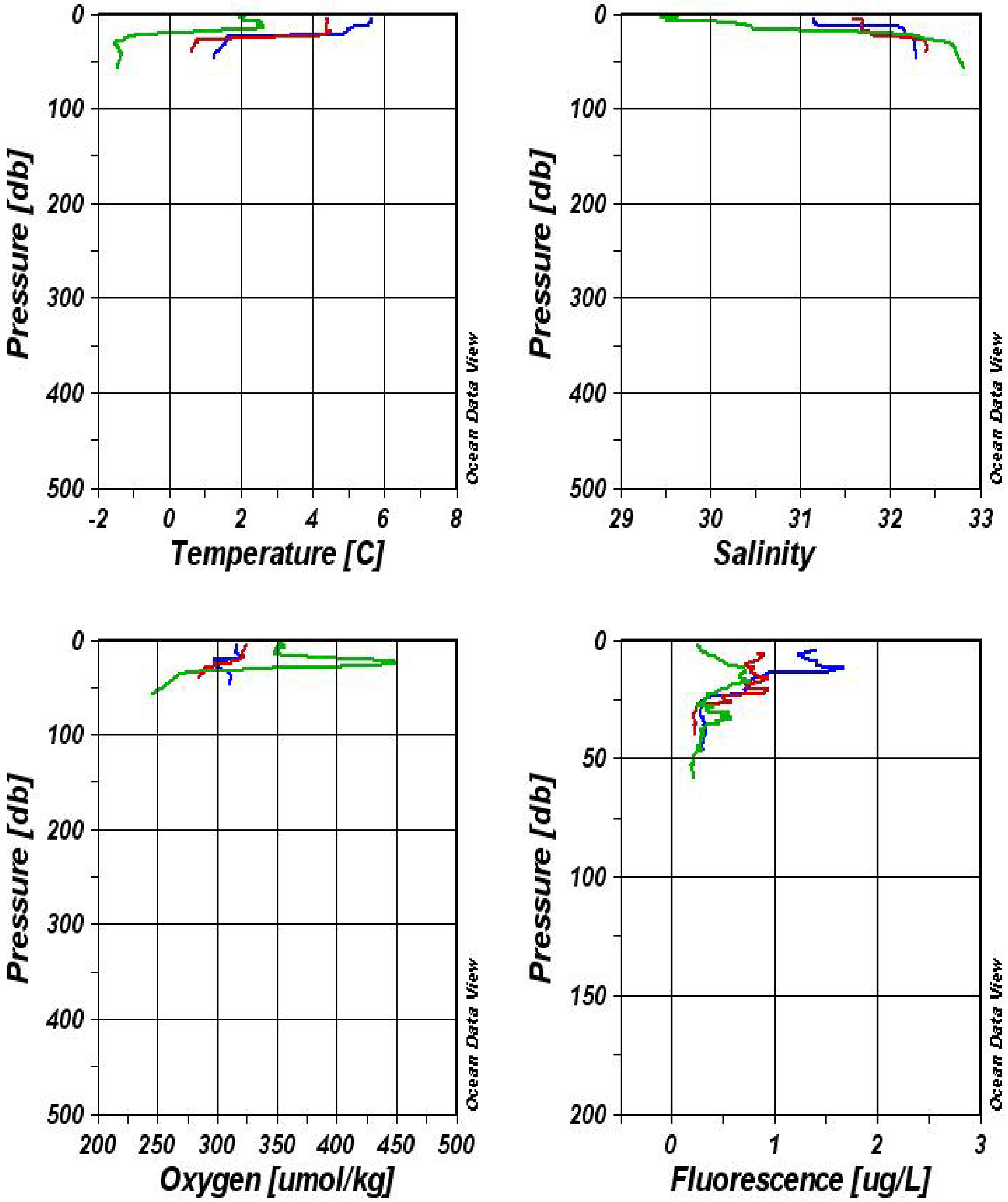


Figure A3-1-3. Temperature, salinity, dissolved oxygen and fluorescence of Stns. 002 (blue), 003 (red), and 004 (green).

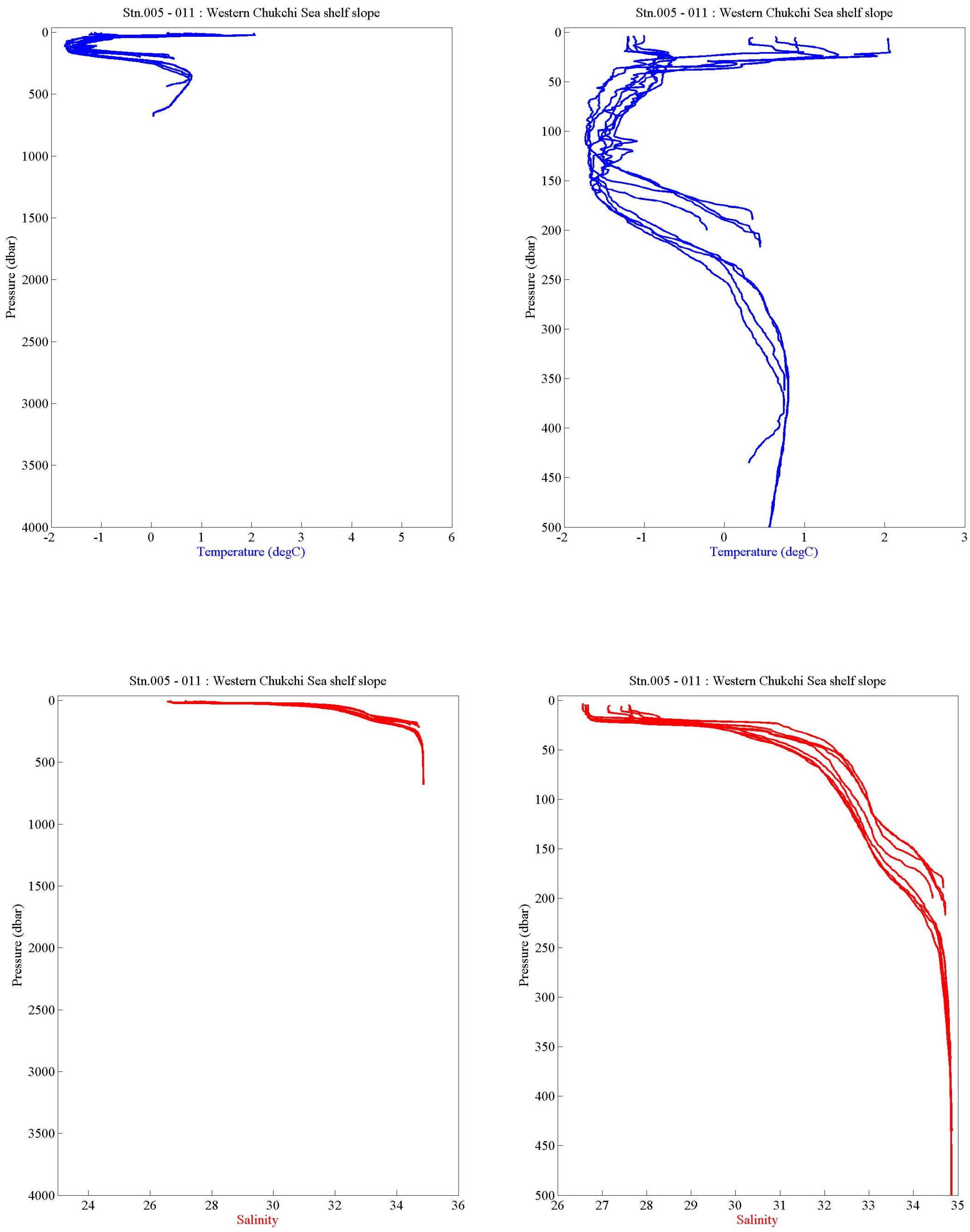
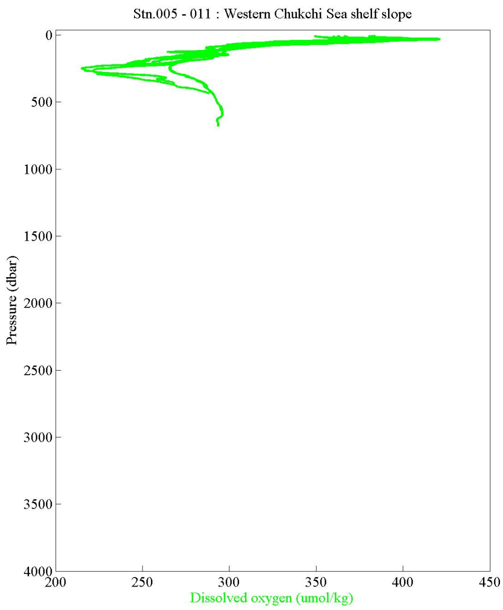
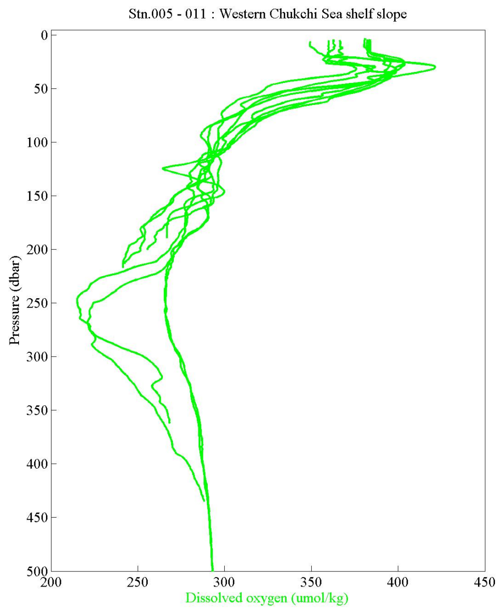


Figure A3-1-4. Temperature and salinity of Stn.005 - 011 (4000dbar and 500dbar).





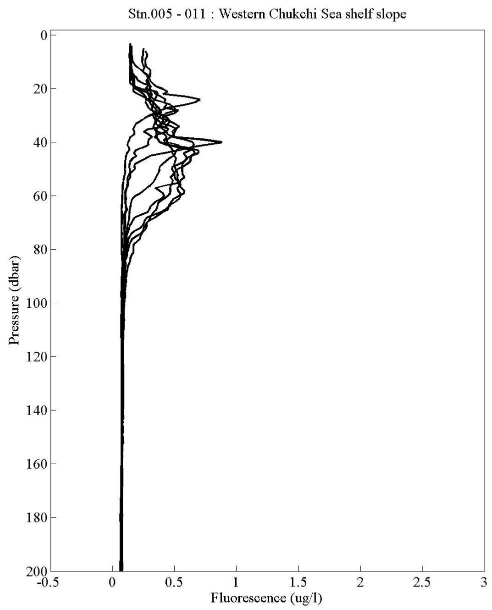


Figure A3-1-5. Dissolved oxygen and fluorescence of Stn.005 - 011 (4000dbar, 500dbar and 200dbar).

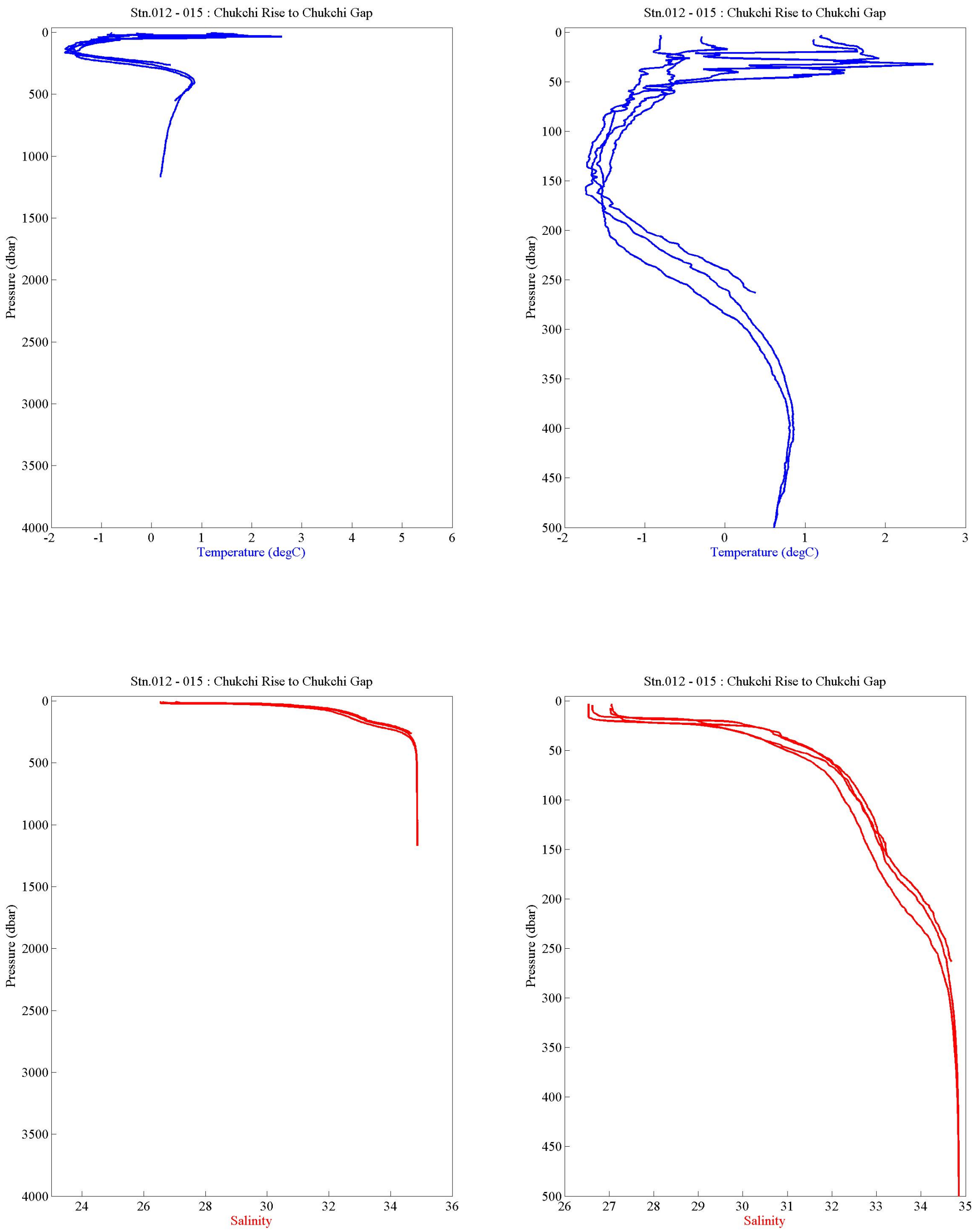


Figure A3-1-6. Temperature and salinity of Stn.012 - 015 (4000dbar and 500dbar).

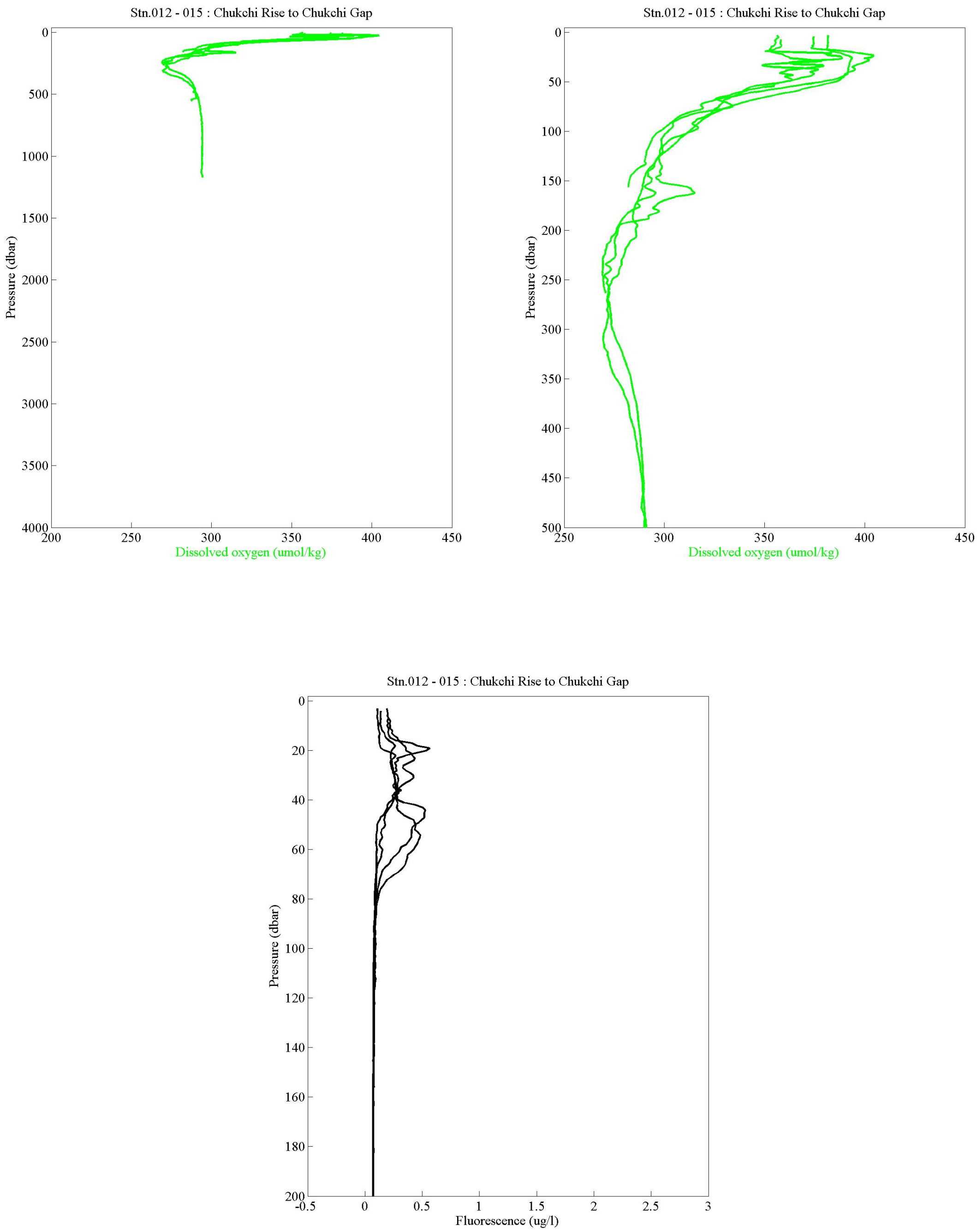


Figure A3-1-7. Dissolved oxygen and fluorescence of Stn.012 - 015 (4000dbar, 500dbar and 200dbar).

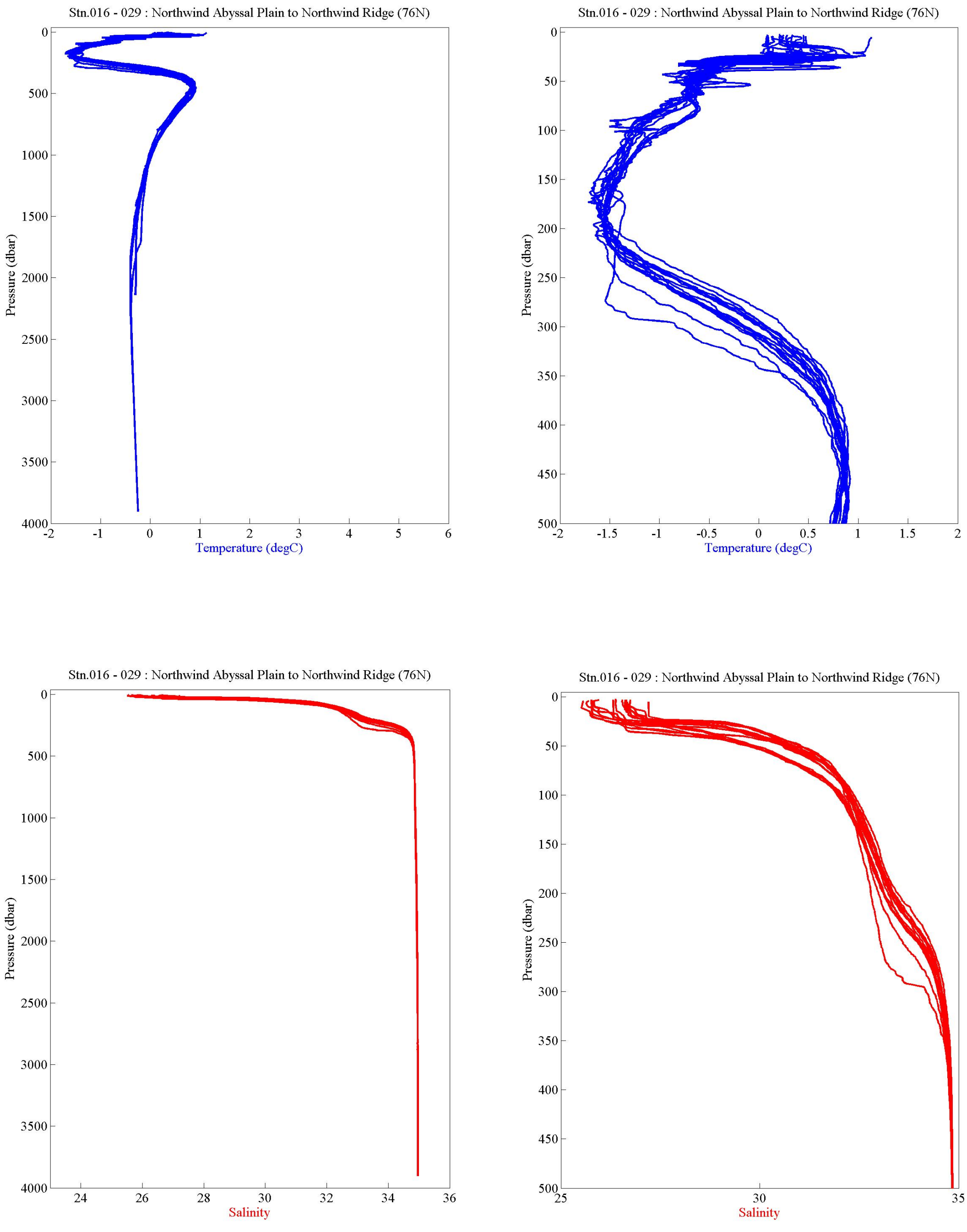
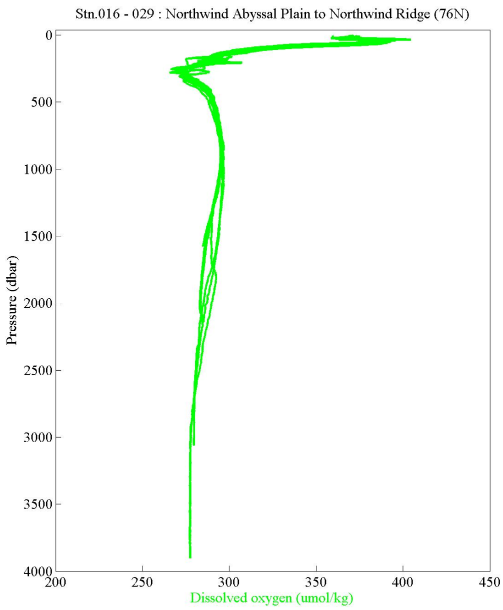
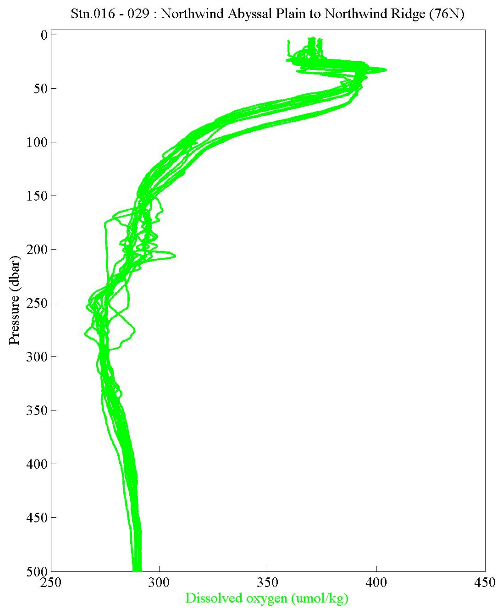


Figure A3-1-8. Temperature and salinity of Stn.016 - 029 (4000dbar and 500dbar).





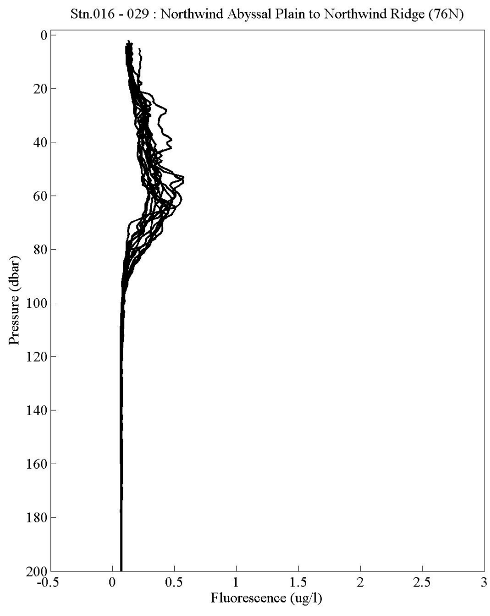


Figure A3-1-9. Dissolved oxygen and fluorescence of Stn.016 - 029 (4000dbar, 500dbar and 200dbar).

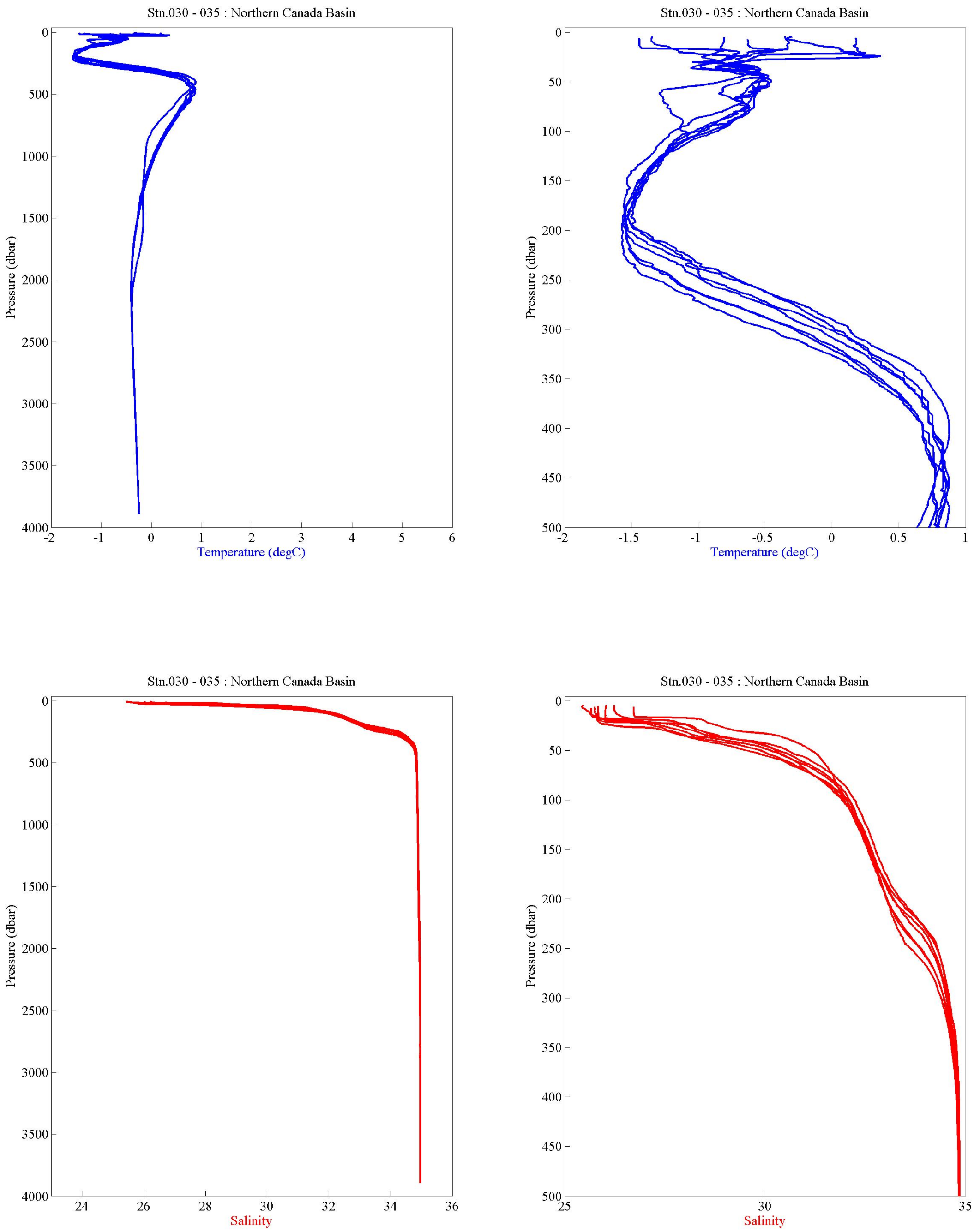
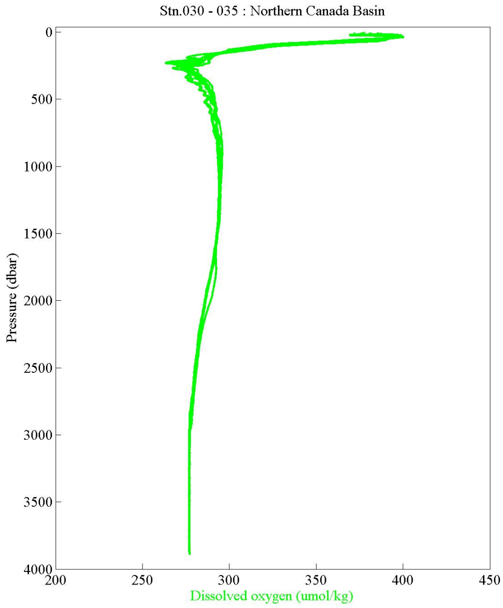
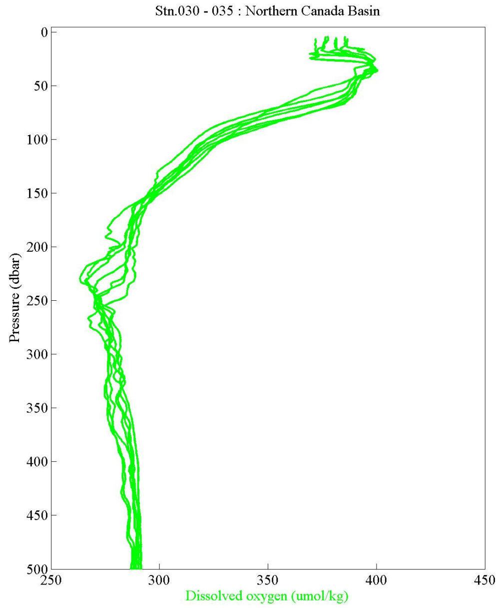


Figure A3-1-10. Temperature and salinity of Stn.030 - 035 (4000dbar and 500dbar).





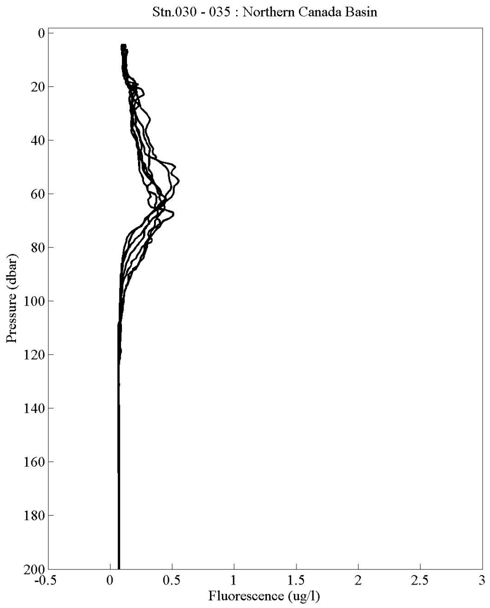


Figure A3-1-11. Dissolved oxygen and fluorescence of Stn.030 - 035 (4000dbar, 500dbar and 200dbar).

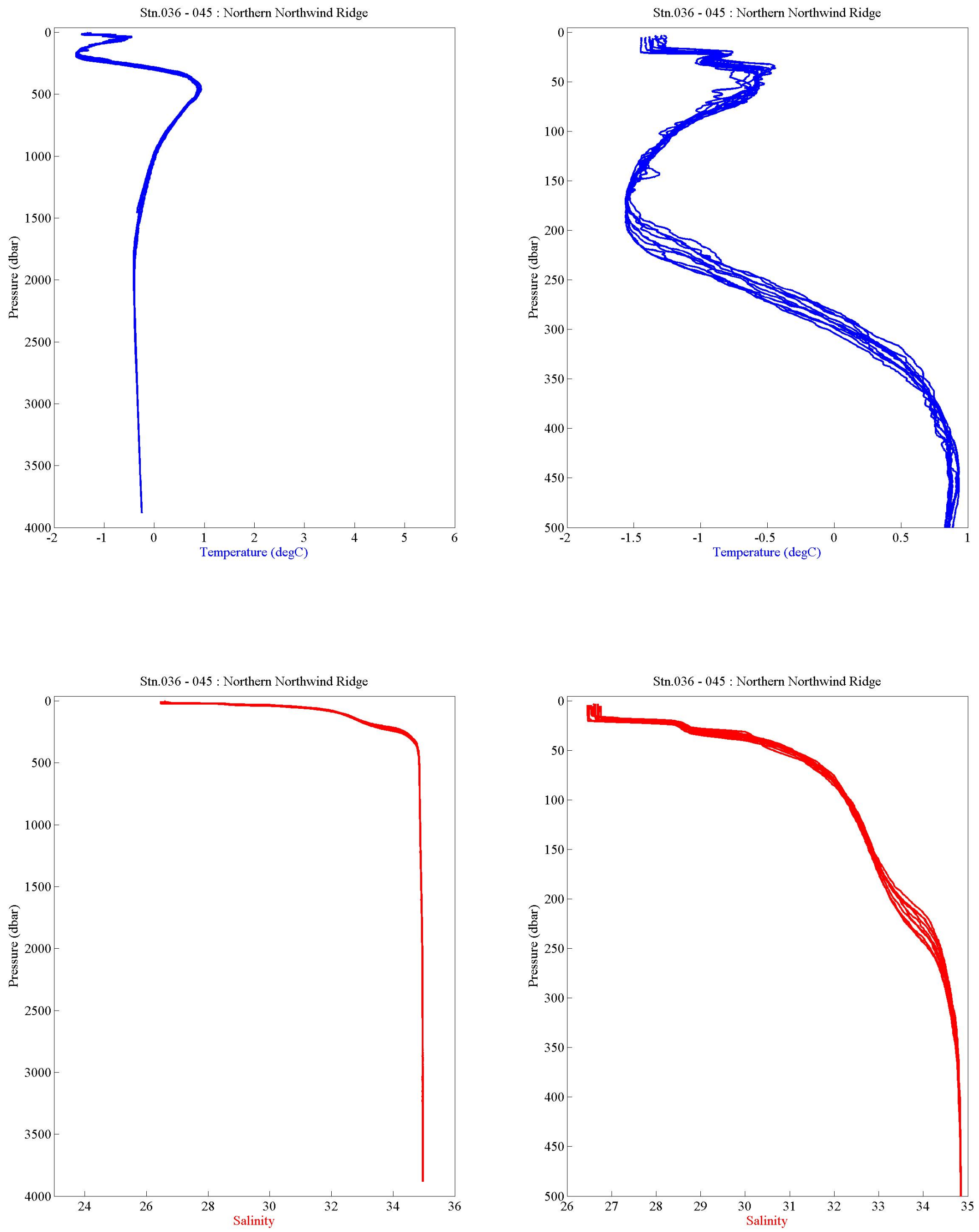


Figure A3-1-12. Temperature and salinity of Stn.036 - 045 (4000dbar and 500dbar).

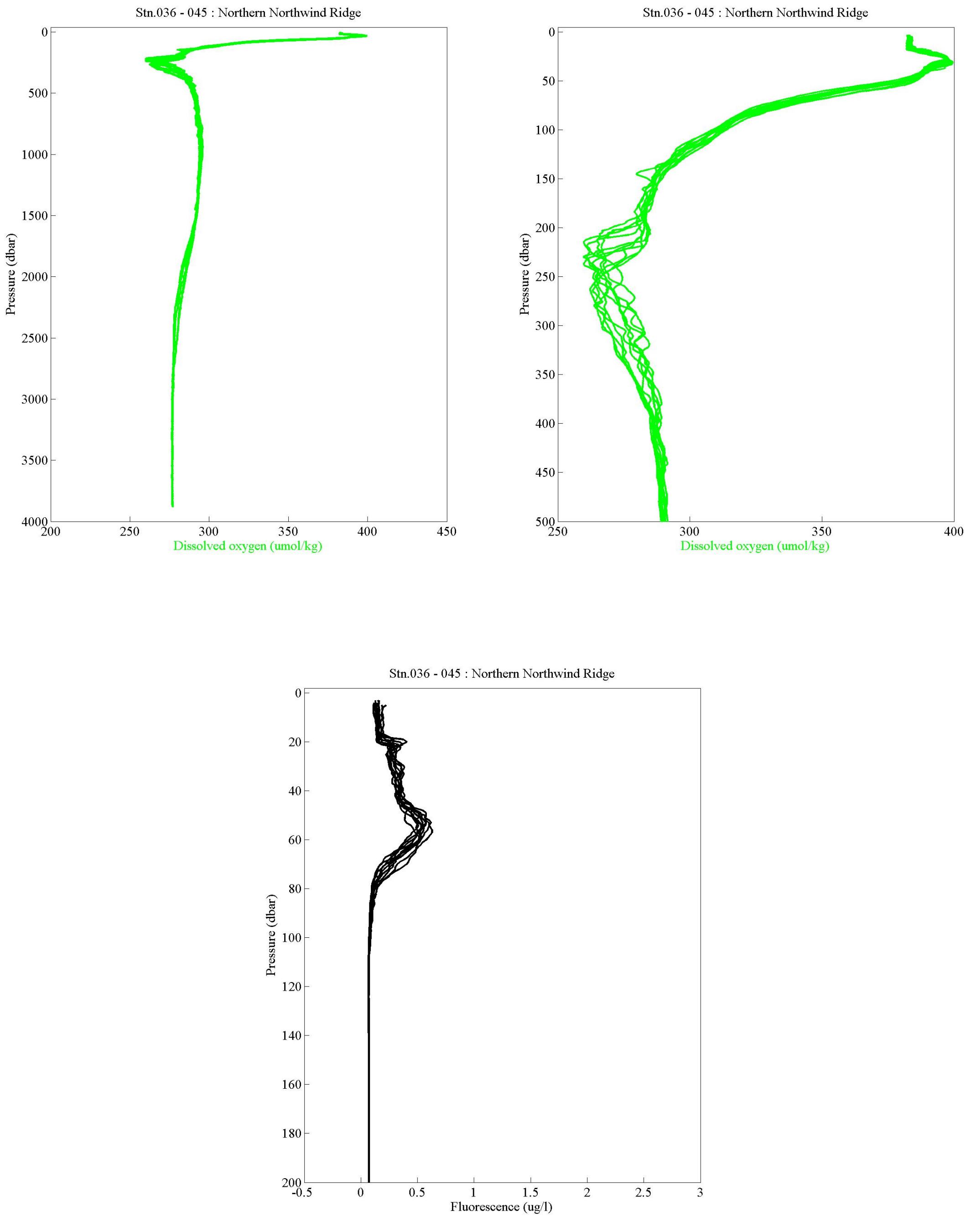


Figure A3-1-13. Dissolved oxygen and fluorescence of Stn.036 - 045 (4000dbar, 500dbar and 200dbar).

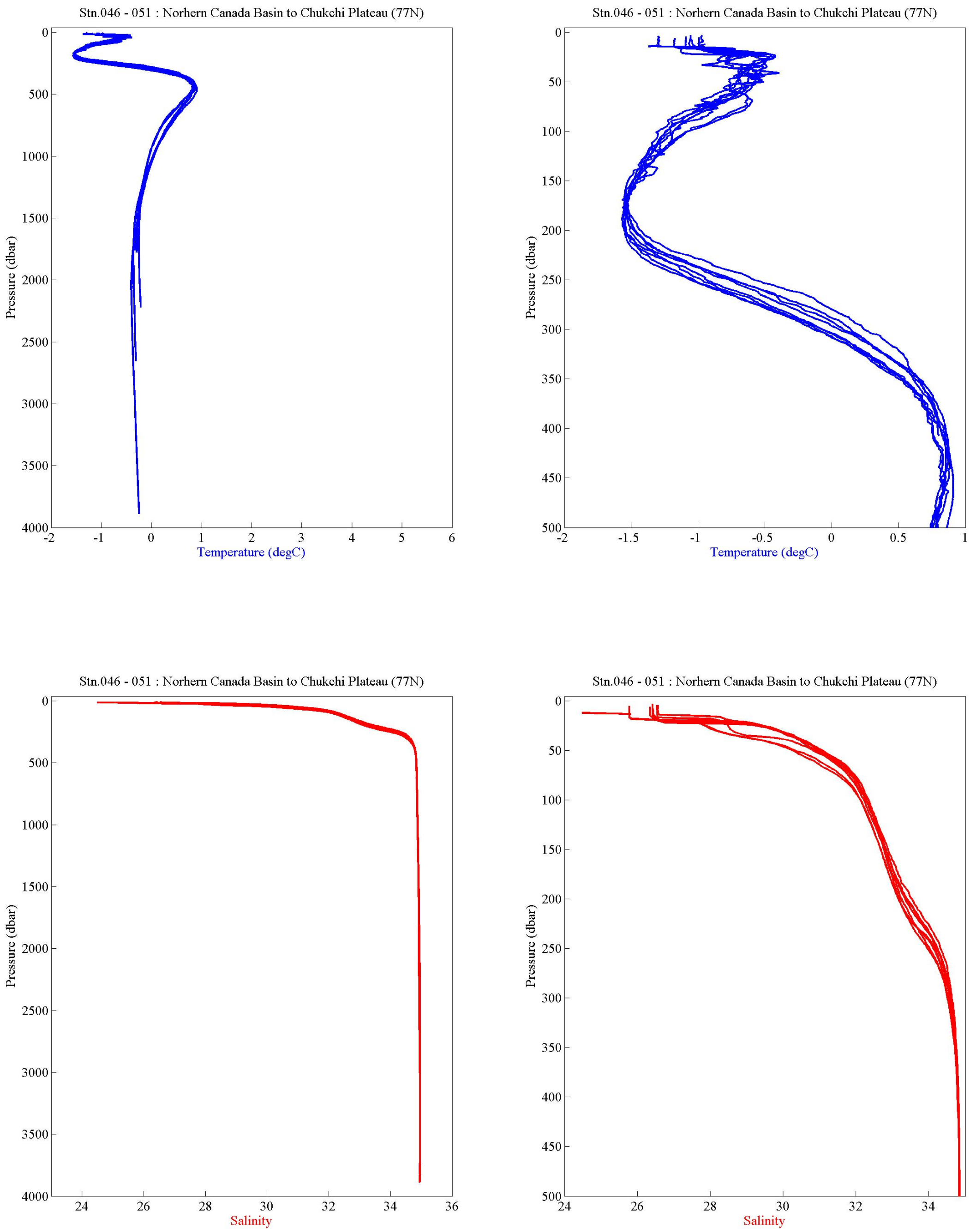
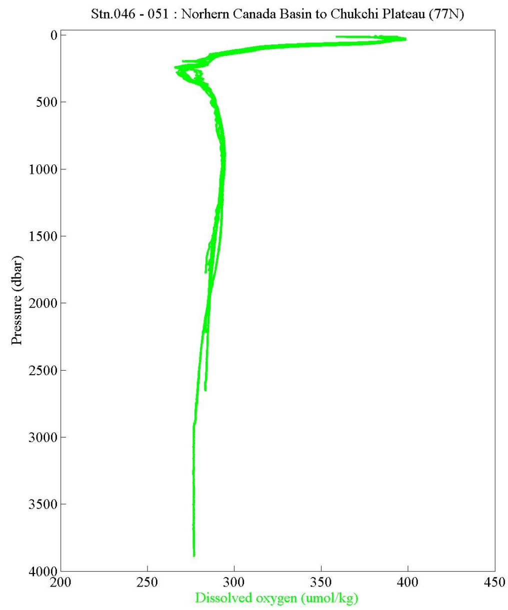
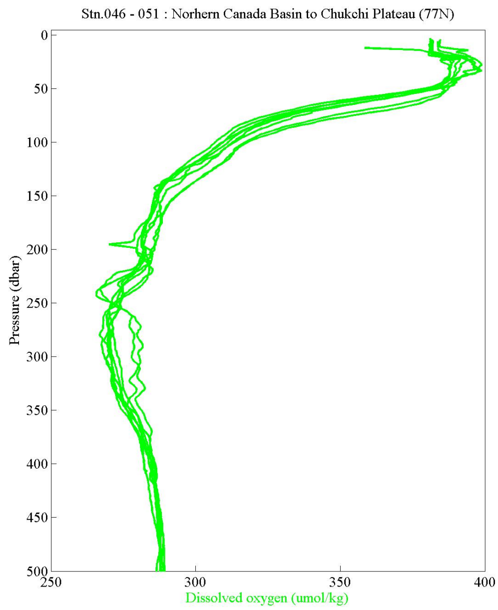


Figure A3-1-14. Temperature and salinity of Stn.046 - 051 (4000dbar and 500dbar).





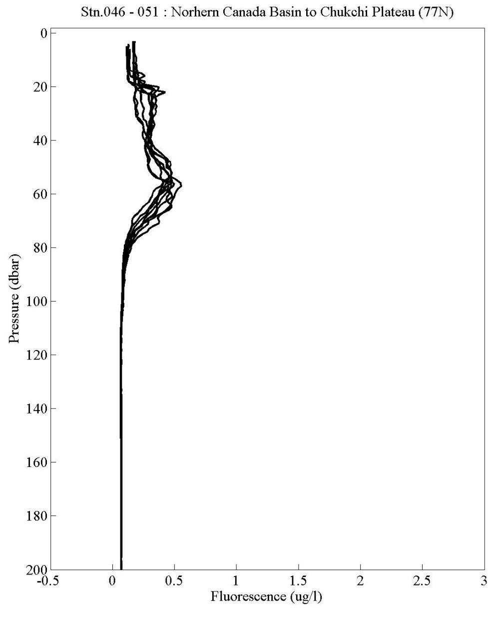


Figure A3-1-15. Dissolved oxygen and fluorescence of Stn.046 - 051 (4000dbar, 500dbar and 200dbar).

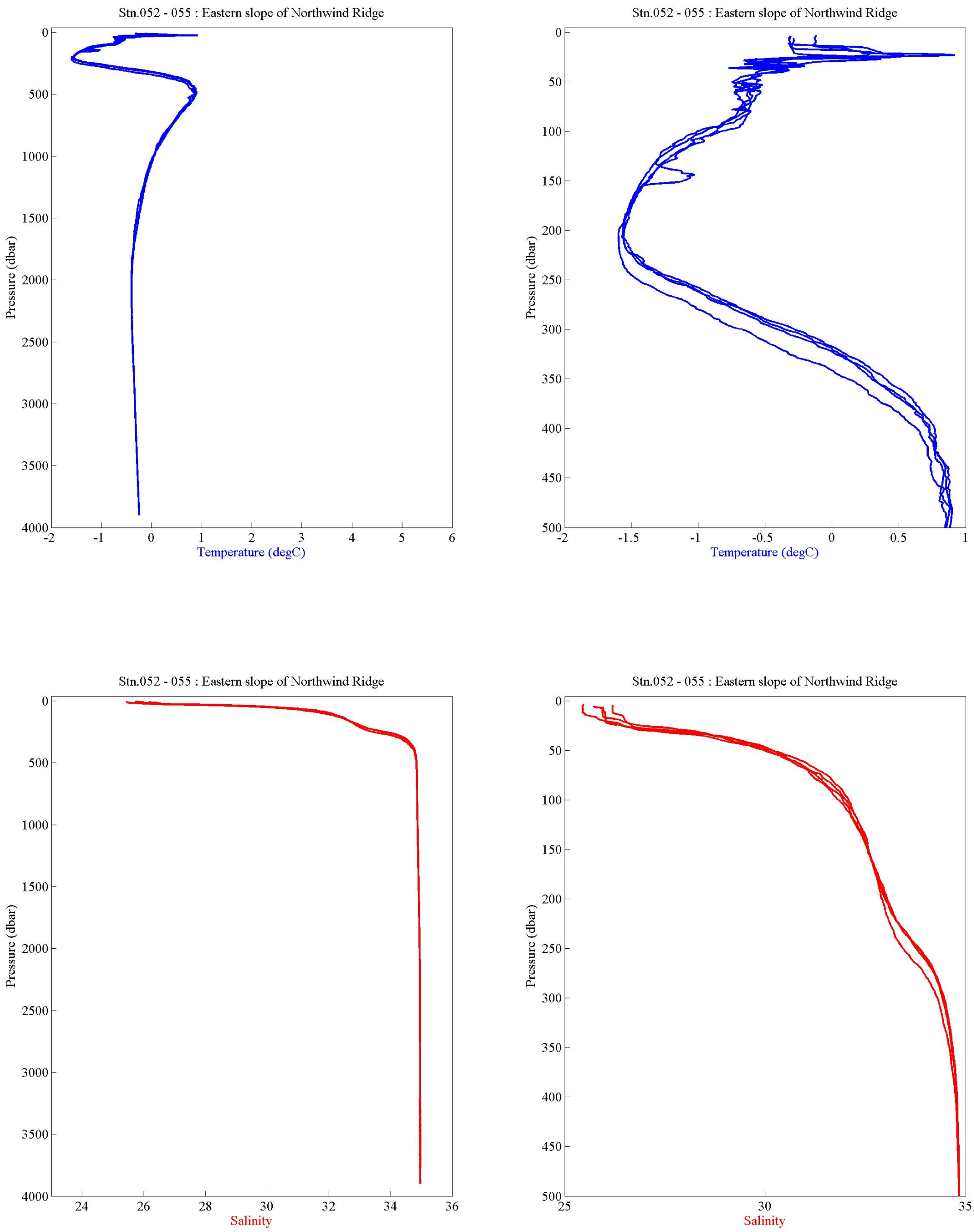
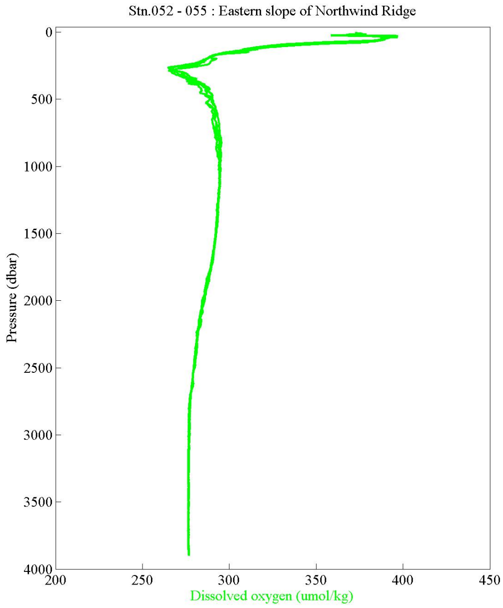
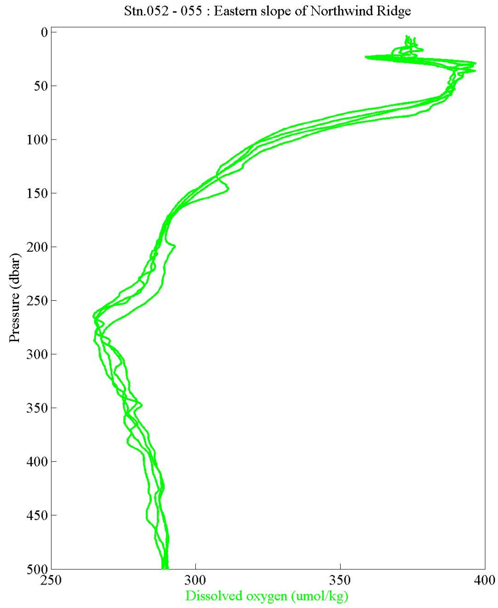


Figure A3-1-16. Temperature and salinity of Stn.052 - 055 (4000dbar and 500dbar).





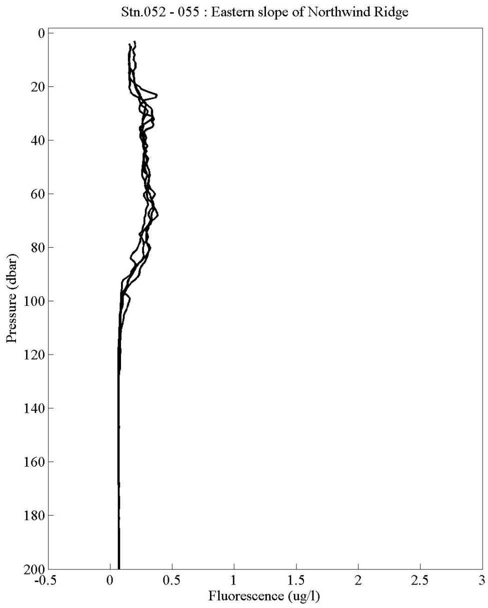


Figure A3-1-17. Dissolved oxygen and fluorescence of Stn.052 - 055 (4000dbar, 500dbar and 200dbar).

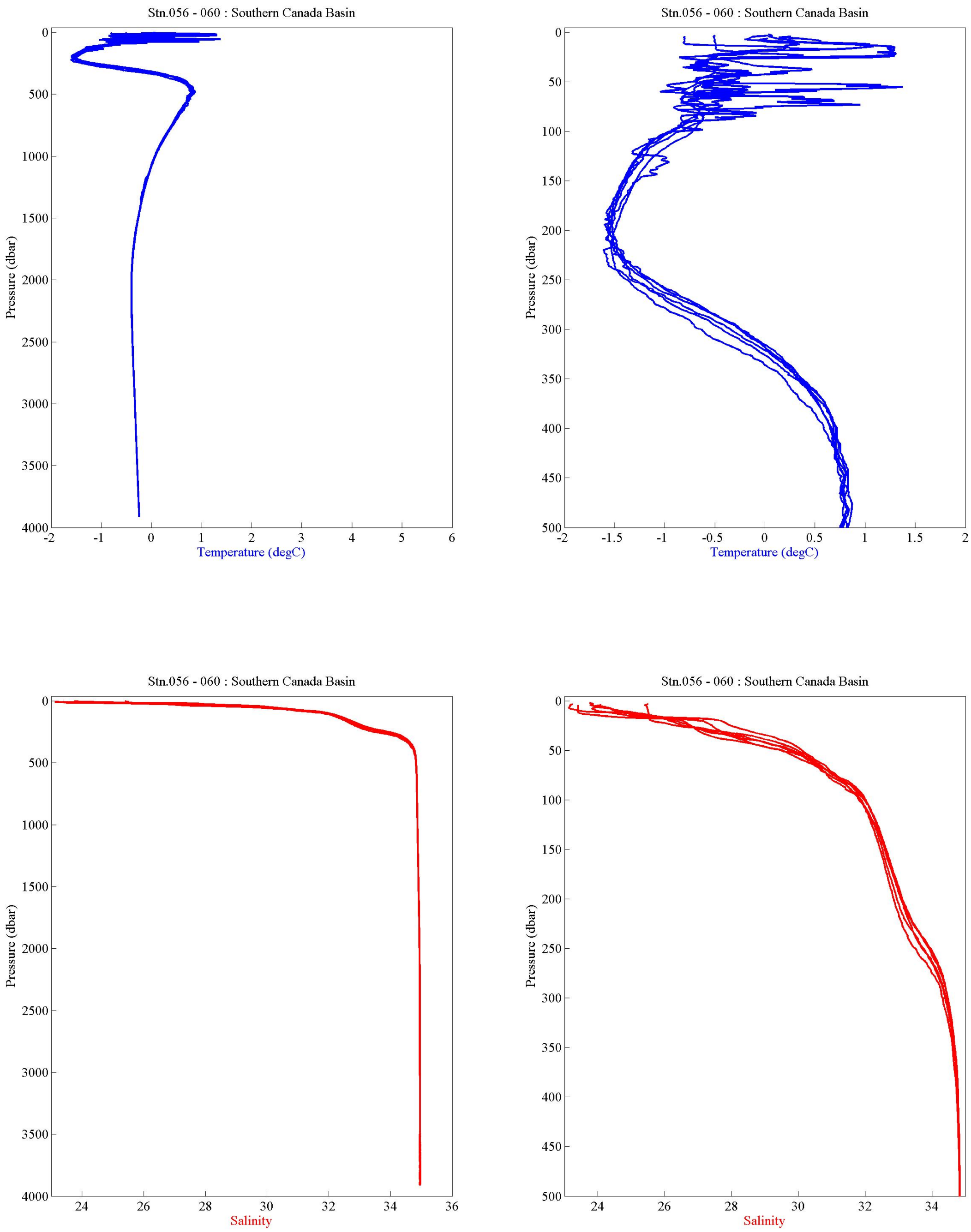
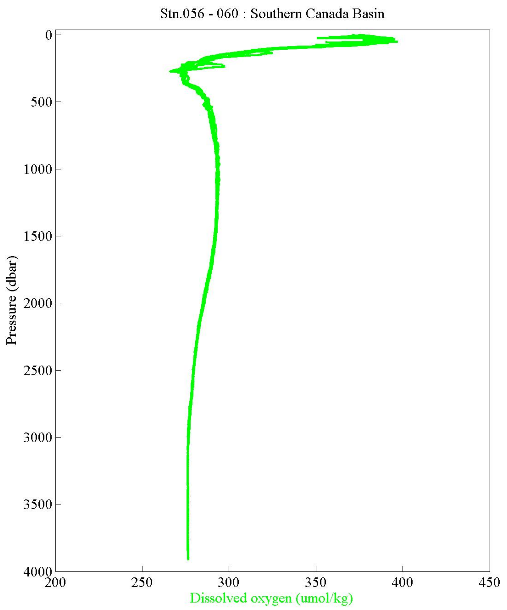
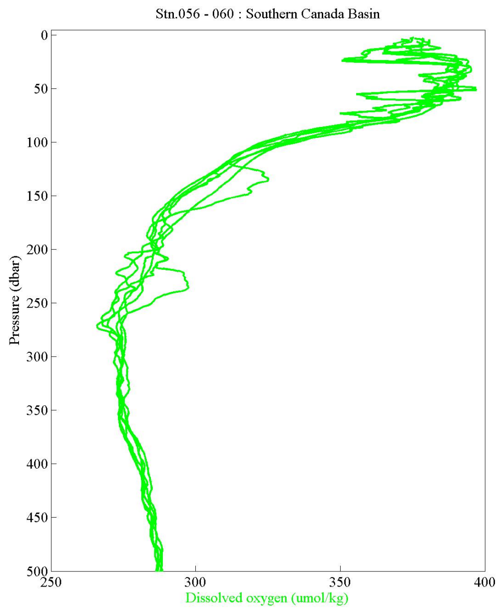


Figure A3-1-18. Temperature and salinity of Stn.056 - 060 (4000dbar and 500dbar).





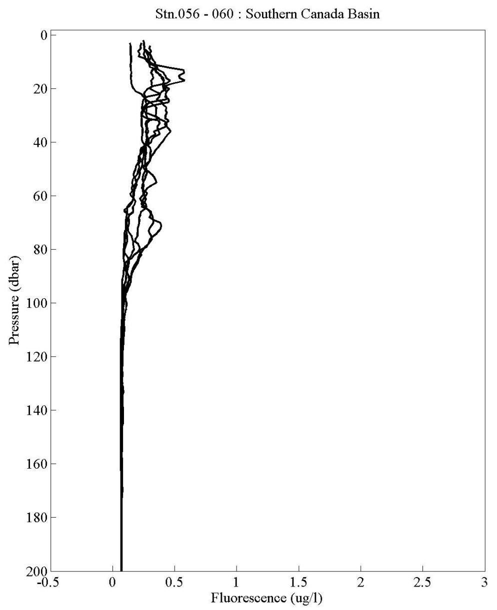


Figure A3-1-19. Dissolved oxygen and fluorescence of Stn.056 - 060 (4000dbar, 500dbar and 200dbar).

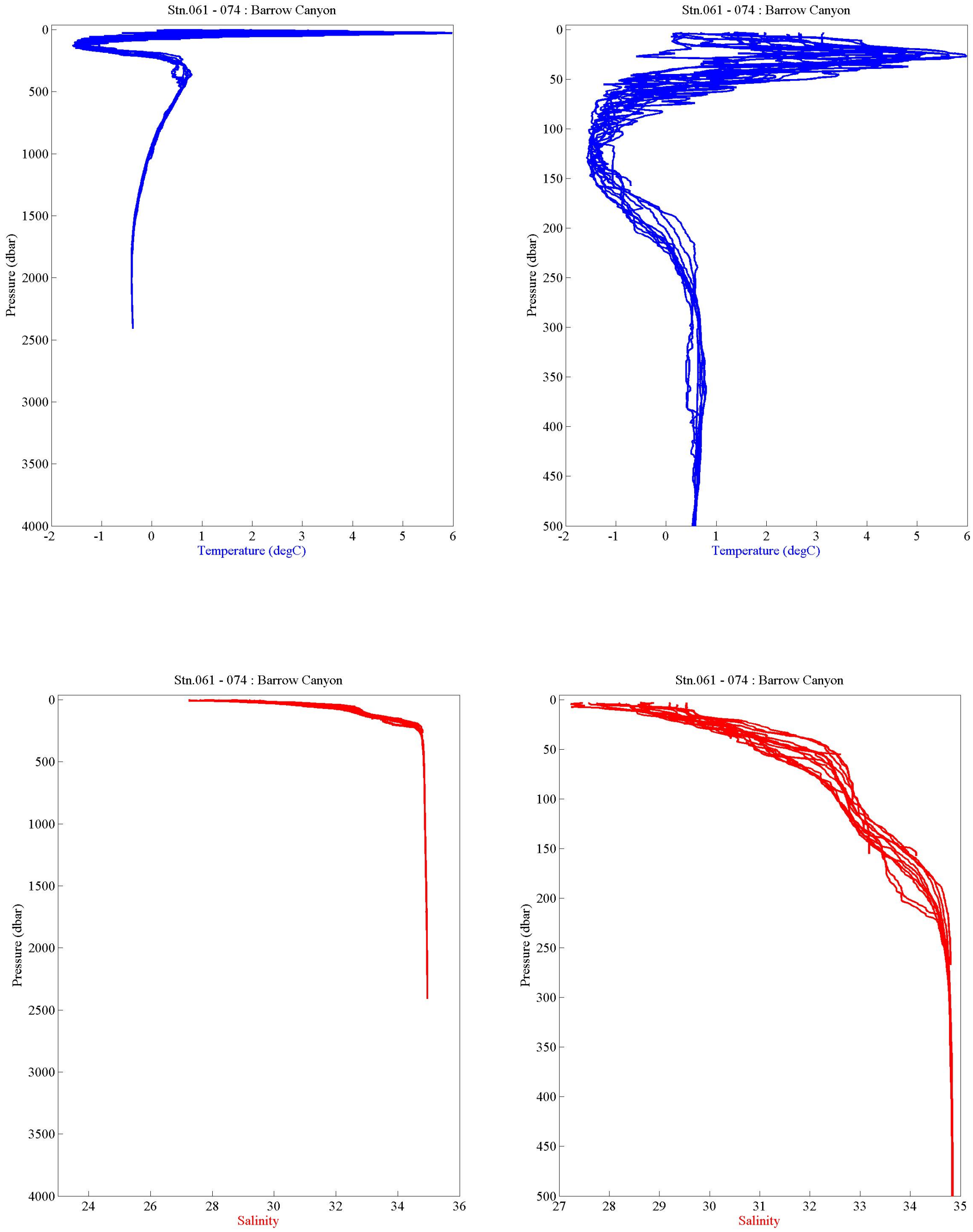


Figure A3-1-20. Temperature and salinity of Stn.061 - 074 (4000dbar and 500dbar).

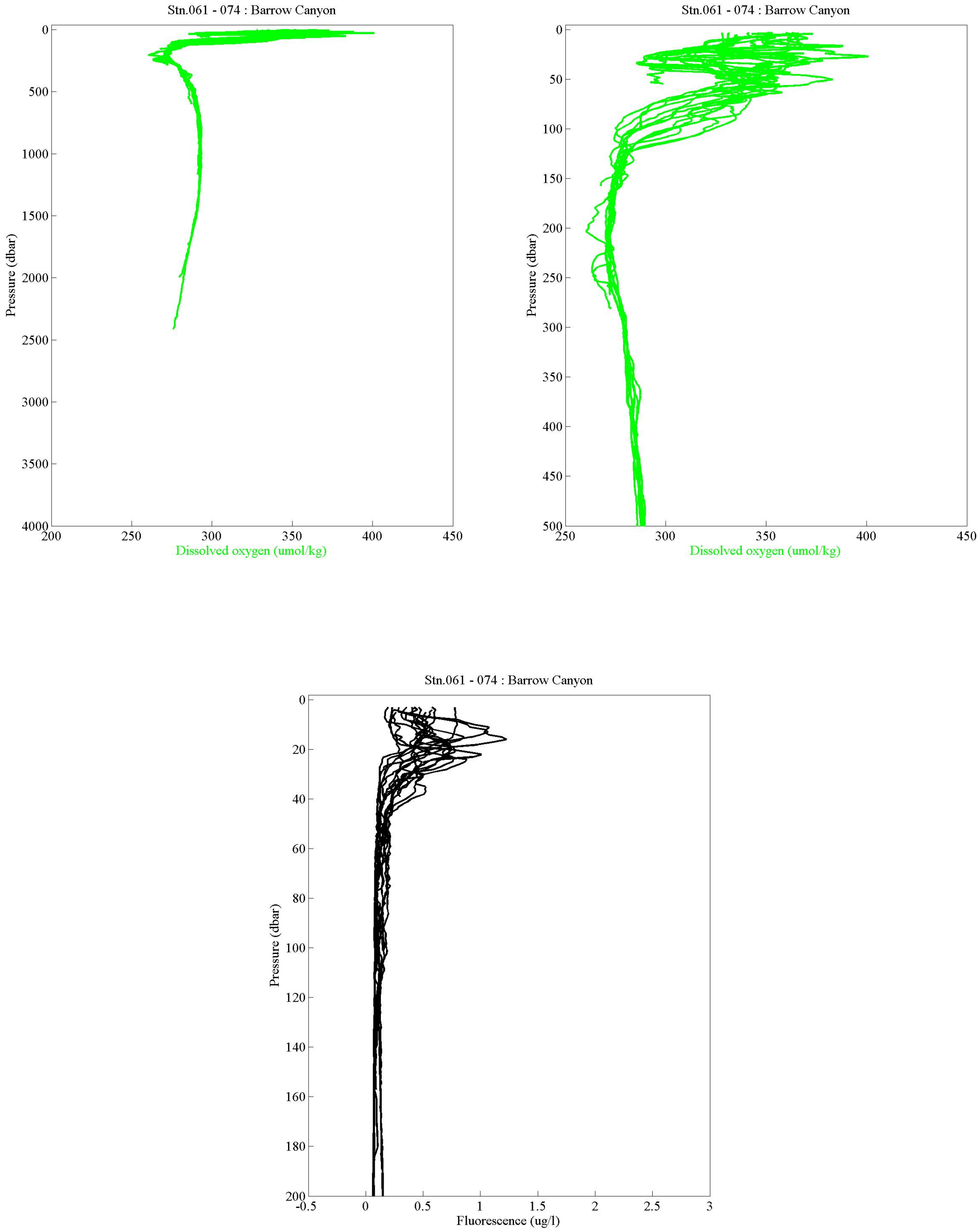


Figure A3-1-21.　Dissolved oxygen and fluorescence of Stn.061 - 074 (4000dbar, 500dbar and 200dbar).

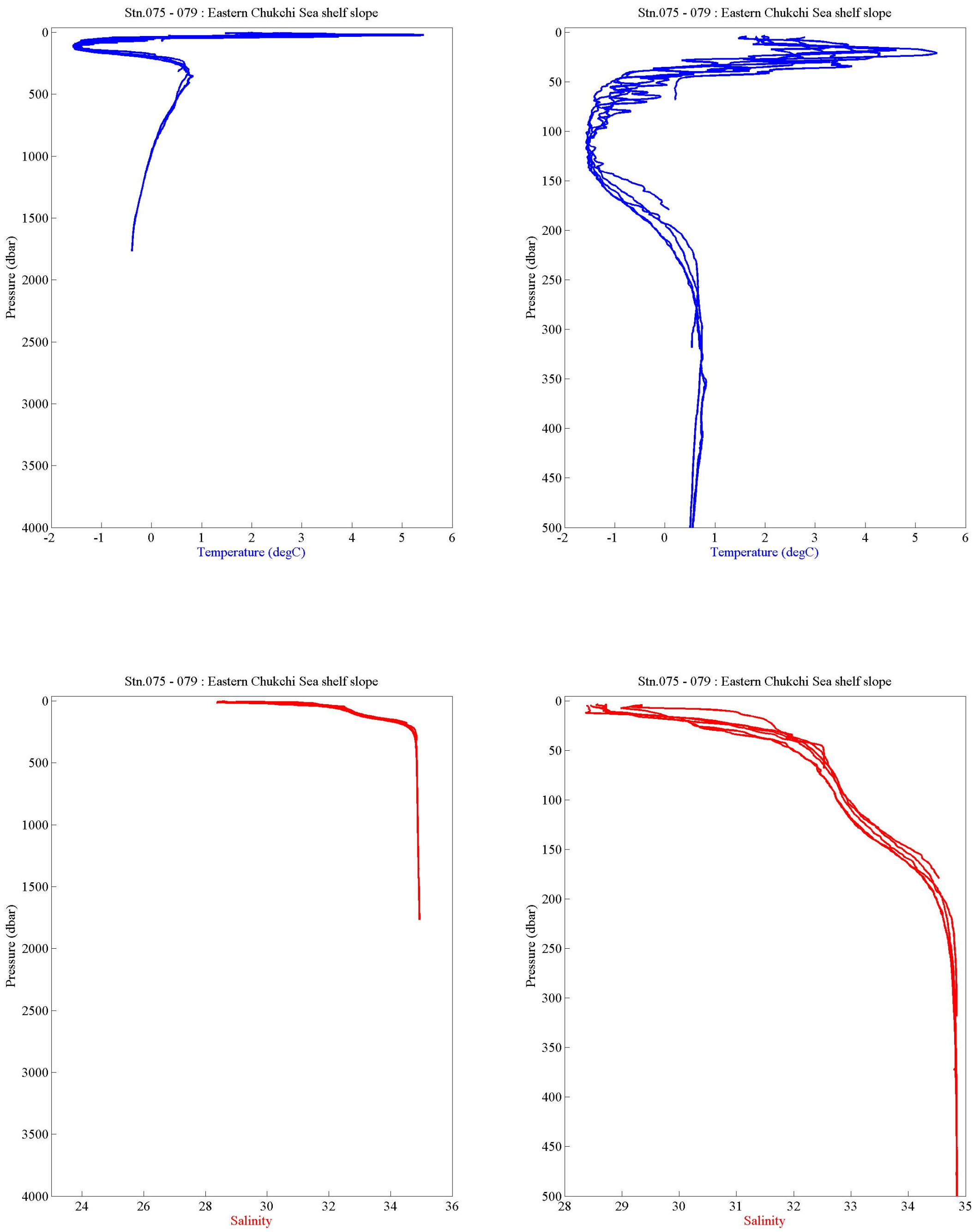


Figure A3-1-22. Temperature and salinity of Stn.075 - 079 (4000dbar and 500dbar).

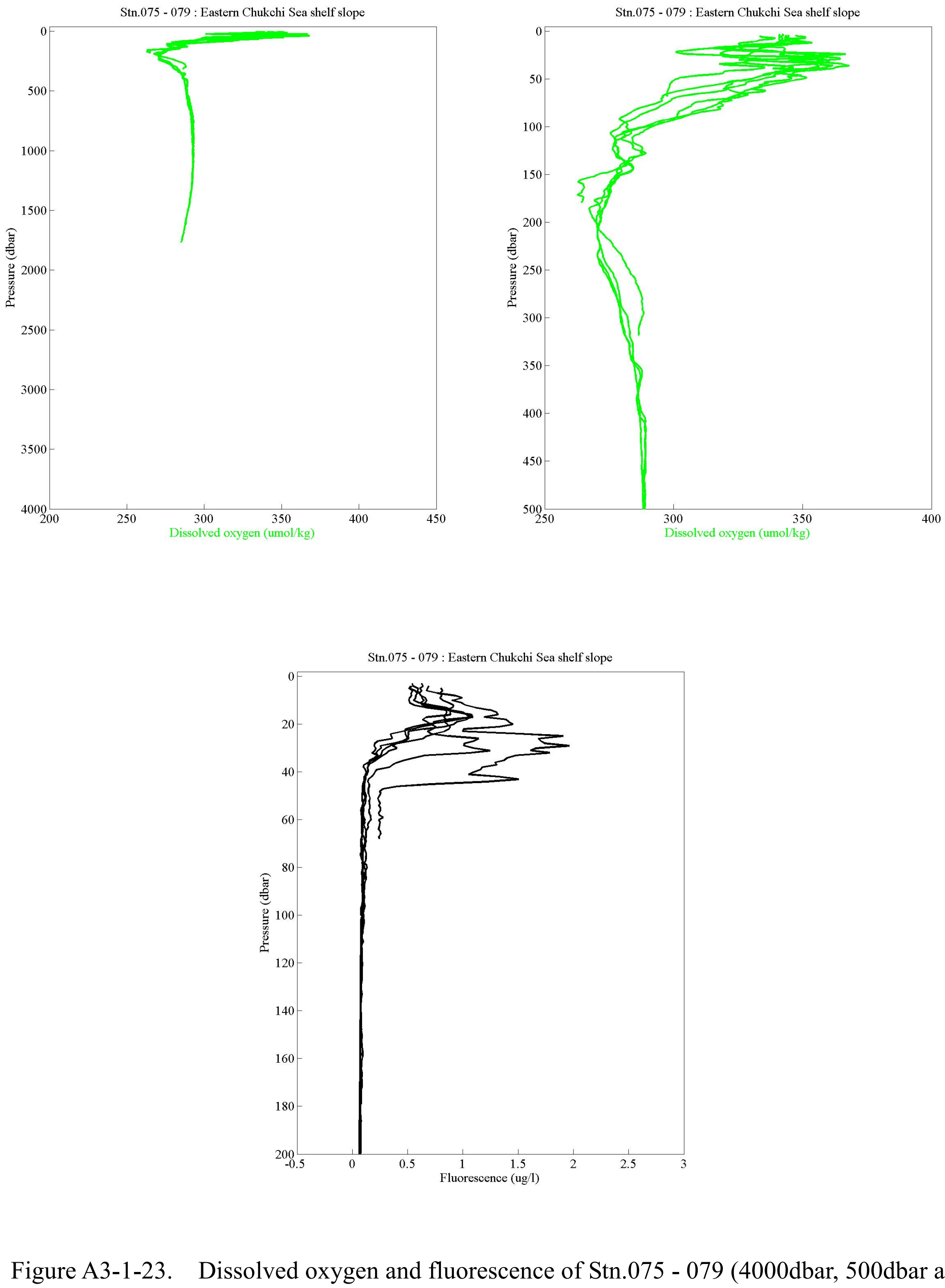


Figure A3-1-23. Dissolved oxygen and fluorescence of Stn.075 - 079 (4000dbar, 500dbar and 200dbar).

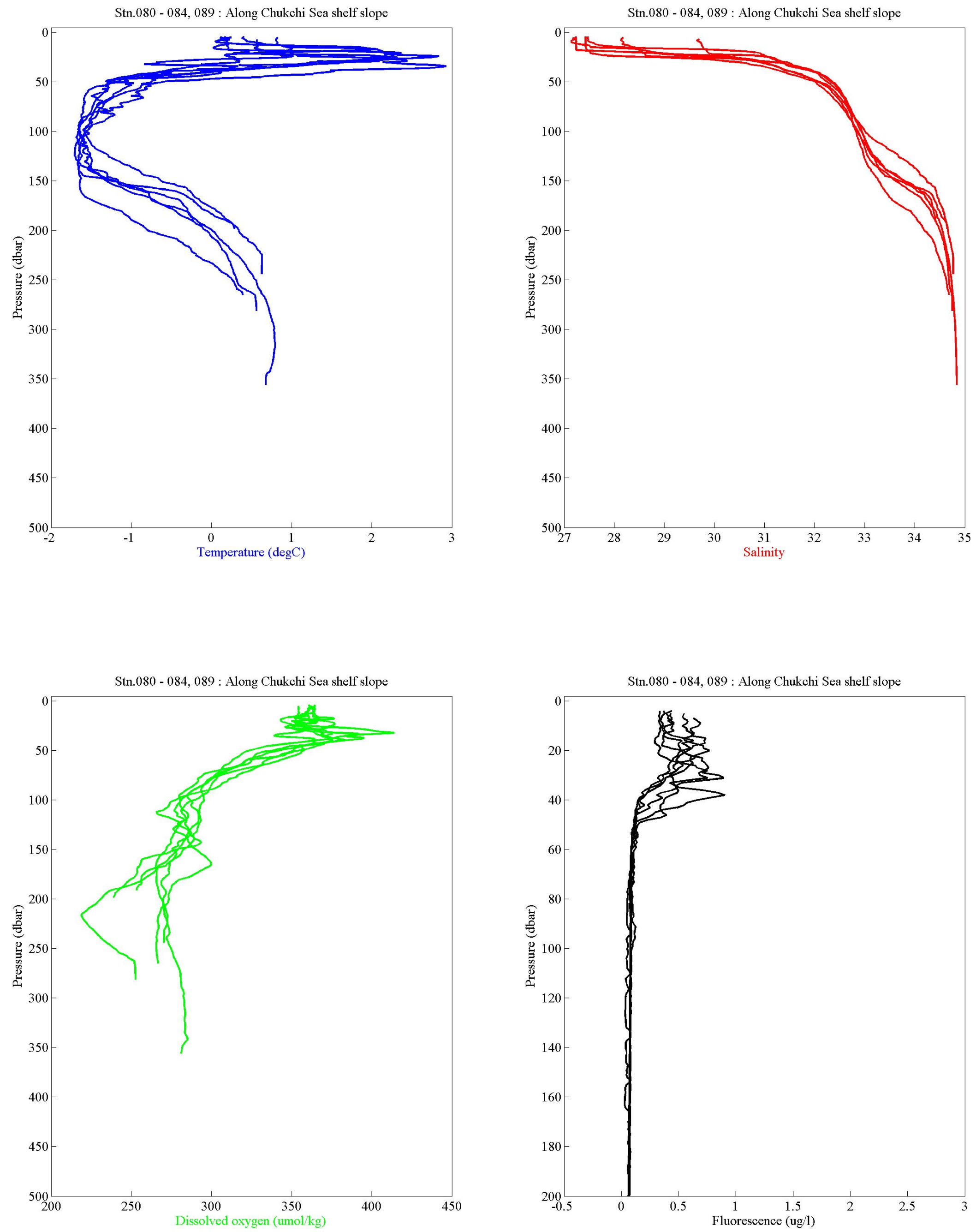


Figure A3-1-24. Temperature, salinity, dissolved oxygen and fluorescence of Stn.080 – 084, 089 (500dbar and 200dbar).

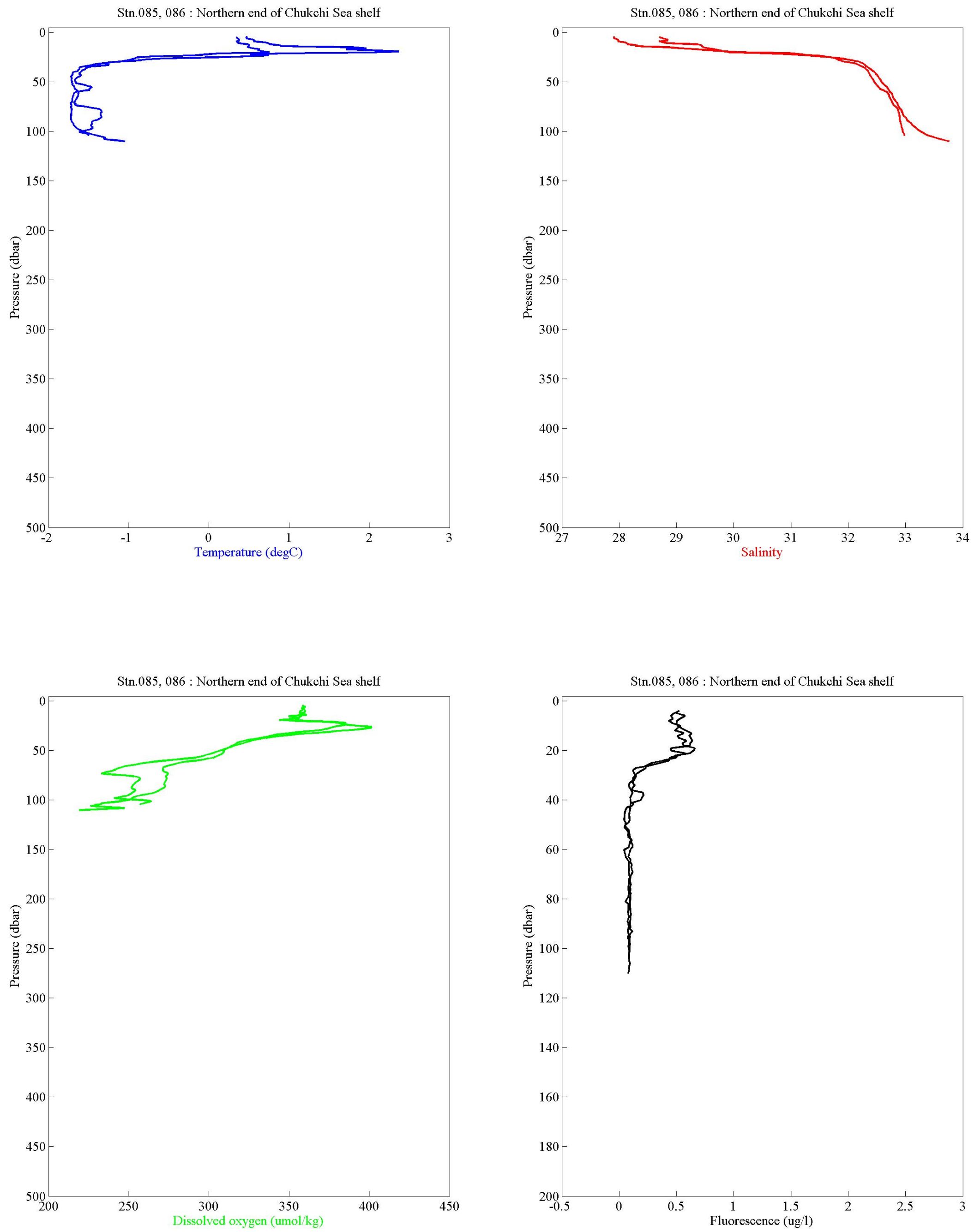


Figure A3-1-25. Temperature, salinity, dissolved oxygen and fluorescence of Stn.085, 086 (500dbar and 200dbar).

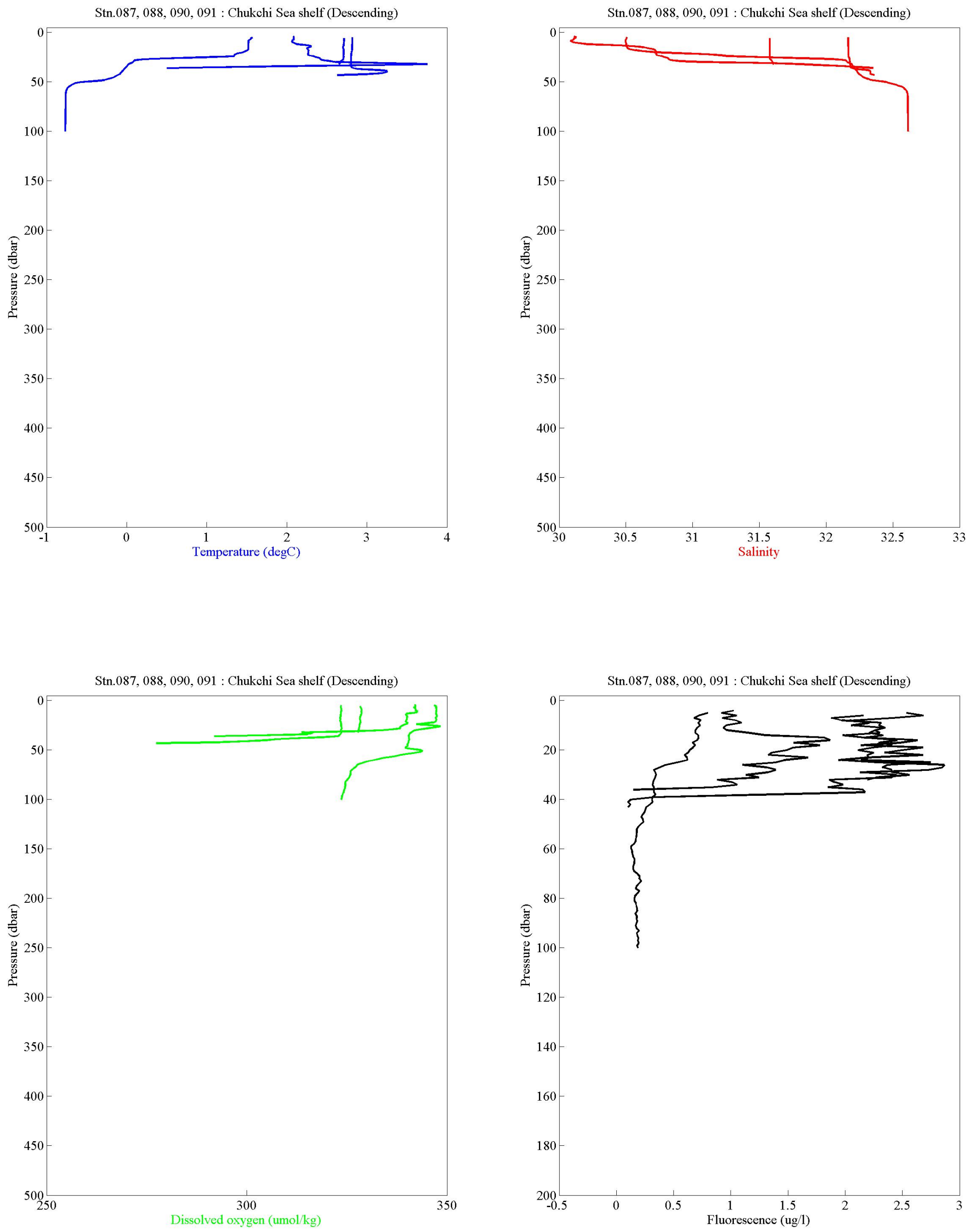


Figure A3-1-26. Temperature, salinity, dissolved oxygen and fluorescence of Stn.087, 088, 090, 091 (500dbar and 200dbar).