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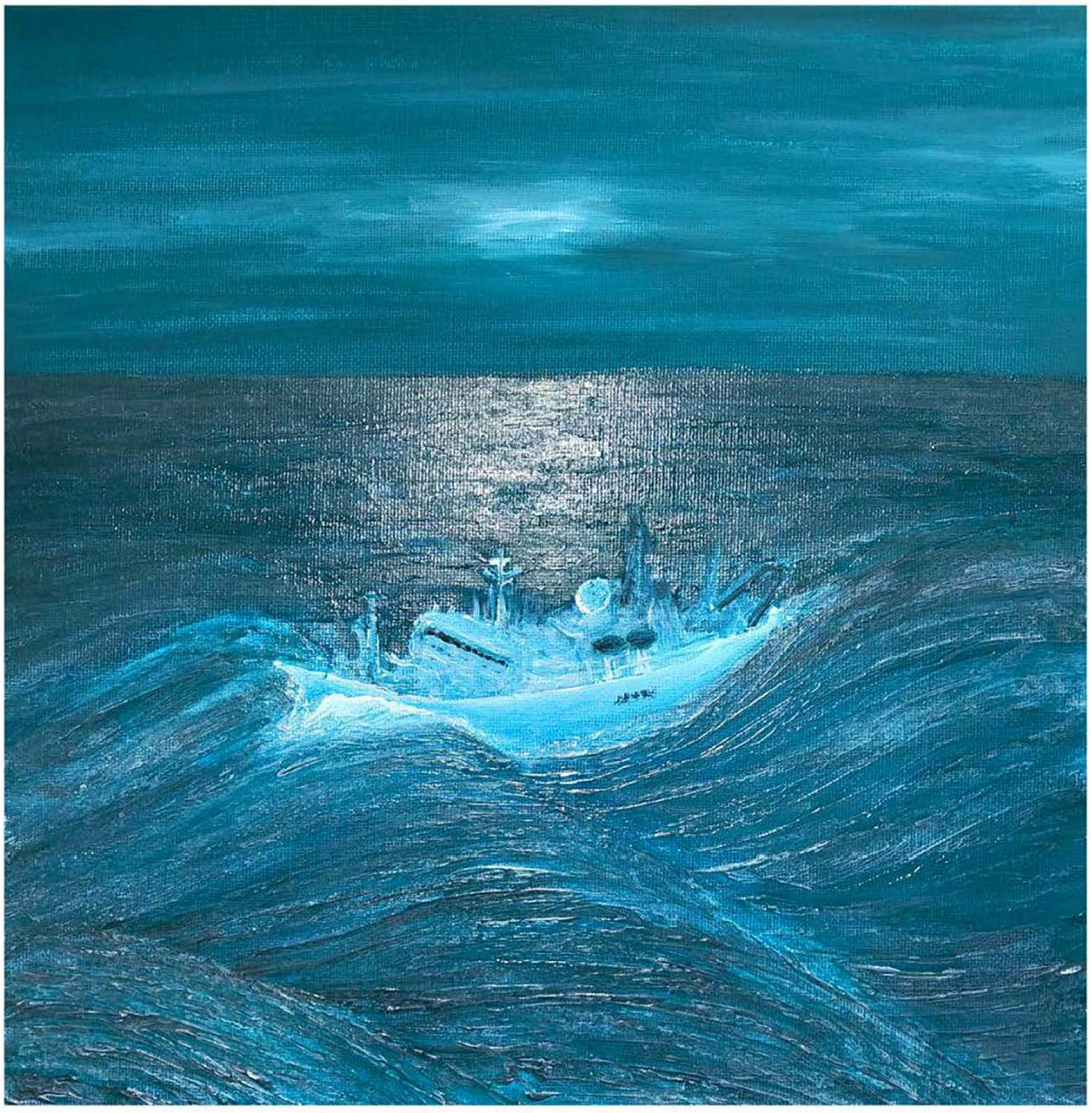
Preliminary Cruise Report

MR24-07 Leg1

1 Oct. - 28 Oct. 2024



Dec. 2024

JAMSTEC

Note

This report may not necessarily be corrected even if there are any inaccuracies. It is subject to revision without notice. Additionally, some data in this report may be raw or unprocessed. If you plan to use or refer to the data in this report, it is recommended to consult the Chief Scientist for the latest status. Users of the information in this report are requested to submit a publication report to JAMSTEC.

Acknowledgments

We would like to express our gratitude to the captain and crew of the R/V MIRAI for their support during the cruise.

Chief Scientist (Leg1)
Katsunori Kimoto (JAMSTEC)

Cover illustration by:
Rina GOTO (Tokyo University of the Art)

Contents of MR24-07 Leg1 Preliminary Cruise Report

1. Outline of MR24-07 Leg1

1.1 Objective

Katsunori Kimoto (JAMSTEC) PI

The MR24-07 Leg1 voyage took place from October 2 to October 29, 2024, for a total of 27 days. This voyage departed from Dutch Harbor in the United States and arrived at Shimizu Port in Japan.

The primary objectives of this cruise included the recovery and reinstallation of the Hybrid mooring system, as well as CTD and water sampling observations, and plankton net observations to investigate the response of the lower trophic level ecosystem to changes in the ocean environments. Among with this, the automatic atmospheric composition observations at sea surface, aerosol measurements, ocean turbulence monitoring, continuous chemical sensor measurements and receiver tests for improving the quality of satellite-based maritime communication. Furthermore, the operation of Virtual Mooring (VM) drones for experiments conducted in rough-sea conditions. In addition, this cruise also resulted in the creation of a collaborative work of art and science.

A notable point is that a new mooring system (K2-OA) designed specifically for studying global warming and ocean acidification (OA) had successfully installed at station K2, the subarctic circulation realm. The mooring system is set to remain in place for approximately 10 months to collect data on OA and its biological impacts in the mixed layer during each season. The K2-OA mooring system will be retrieved in the summer of FY2025.

Because of the continuous approaching of the Aleutian low-pressure system at the observation stations in the North Pacific, the cruise time had compressed. Therefore, we had skip observations at Stations 1, 9, and 10. However, we were able to successfully complete many observations.

We would like to express our sincere gratitude to the captain, all the crew members of the R/V Mirai, the researchers, and all the people on shore who helped us conduct this cruise.

Fig. 1.1-1. Group photo of the crew members who participated in the MR24-07 Leg1 cruise.

1.2 Cruise information

Cruise ID: MR24-07 Leg1

Name of Vessel: R/V/ Mirai

Title of Cruise: Interdisciplinary study of atmosphere-ocean-ecosystem variability in the western North Pacific

Ship Captain: Akihisa Tsuji (Nippon Marine Enterprises, Ltd. (NME))

Chief Scientist: Katsunori Kimoto (Research Institute for Global Change, JAMSTEC)

Chief Technical Staff: Kazuhiro Yoshida (Marine Works Japan, Ltd.)
Ryo Oyama (Nippon Marine Enterprises, Ltd.)

Cruise period: 2 – 28, October 2024 (27 days)

Port of call: Departure; Dutch Harbor (USA), Arrival; Shimizu (JPN)

Research Area: Bering Sea, western North Pacific (subarctic)

1.3 List of research proposal

This cruise has been carried out based on the proposals below.

1. “Interdisciplinary study of atmosphere-ocean-ecosystem variability in the western North Pacific” Representative: Katsunori Kimoto (JAMSTEC)

2. “Operation test of a Virtual Mooring (VM) drone” Representative: Kensuke Watari (JAMSTEC)

3. “Collaboration between Art and Science: Approach to the Field of Micropaleontology through Art” Representative: Rina Goto (Tokyo University of the Arts)

1.4 List of science party

Name	Affiliation	Occupation
Katsunori Kimoto	JAMSTEC	Chief Scientist
Maki Noguchi	JAMSTEC	2nd chief Scientist
Chiho Sukigara	JAMSTEC	Scientist
Keisuke Shimizu	JAMSTEC	Scientist
Hiroshi Uchida	JAMSTEC	Scientist
Hiroyuki Fujiwara	JAMSTEC	Scientist
Masahide Wakita	JAMSTEC	Scientist
Yoshiyuki Nakano	JAMSTEC	Scientist
Kensuke Watari	JAMSTEC	Scientist
Yoshihisa Mino	Nagoya University	Scientist
Kiminori Shitashima	Tokyo University of Marine Science and Technology	Scientist
Takuya Sagawa	Kanazawa University	Scientist
Yusei Miyamoto	Chiba University	Scientist
Rina Goto	Tokyo University of the Arts	Artist
Kazuhiro Yoshida	MWJ	Chief Marine Technician
Aung Tun Htet	MWJ	Marine Technician
Ayane Yoda	MWJ	Marine Technician
Yasuhiro Arii	MWJ	Marine Technician
Nagisa Fujiki	MWJ	Marine Technician
Misato Kuwahara	MWJ	Marine Technician
Tomoko Miyoshi	MWJ	Marine Technician
Tomoki Nakamura	MWJ	Marine Technician
Kengo Fujita	MWJ	Marine Technician
Masaki Furuhata	MWJ	Marine Technician
Kango Fukuyama	MWJ	Marine Technician
Takuya Izutsu	MWJ	Marine Technician
Rei Ito	MWJ	Marine Technician
Ryo Oyama	NME	Marine Technician
Seika Takai	NME	Marine Technician

1.5 Cruise Track and log

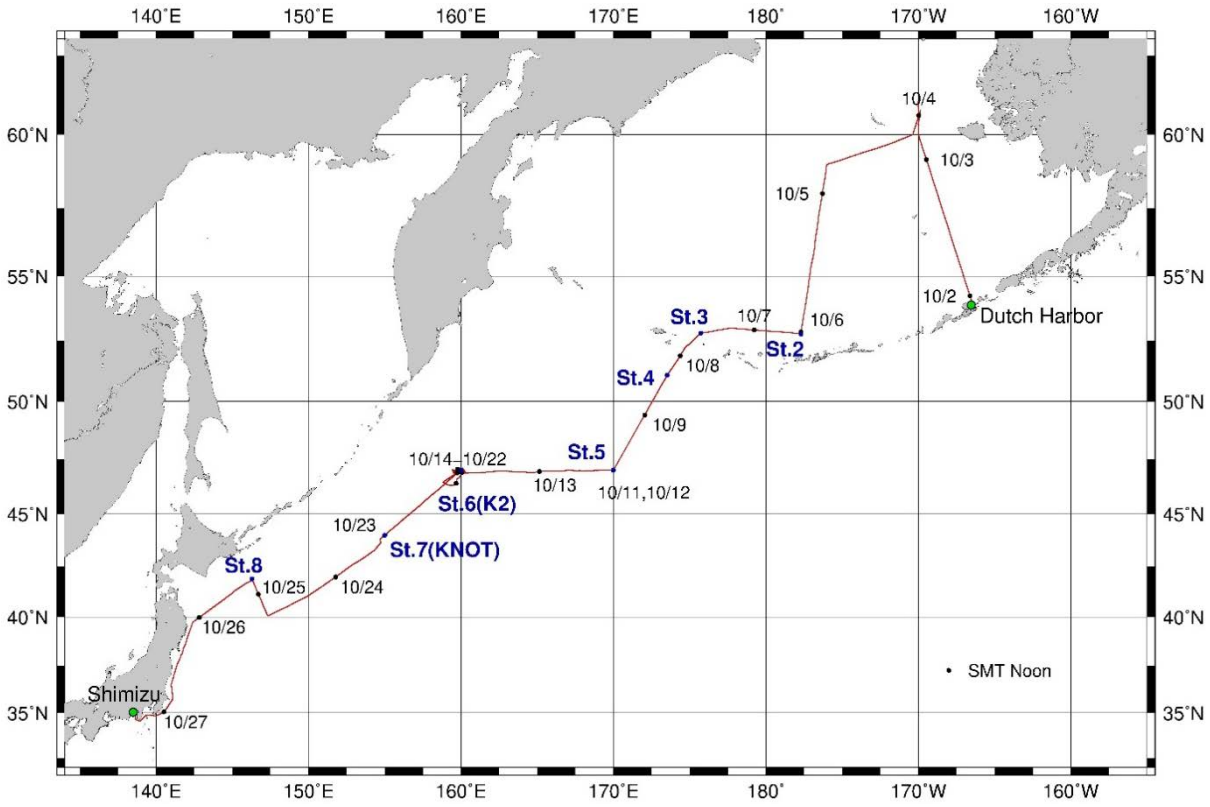


Figure 1.4-1 Cruise track of MR24-07Leg1

Table 1.4-1 Cruise Log of MR24-07Leg1

U.T.C.		S.M.T.		Position		Event logs
Date	Time	Date	Time	Lat.	Lon.	
10/2	18:00	10/2	10:00	53-54.00236N	166-31.72749W	Departure from Dutch Harbor
10/3	00:00		16:00	55-02.62530N	167-03.11234W	Start sea water pump and SSV pump
10/4	05:00	10/3	21:00	61-03.22112N	170-00.17797W	Calibration for magnetometer #1
	06:00		22:00	61-00.95699N	170-01.19794W	Time adjustment -1 hour (SMT=UTC-9h)
10/6	07:00	10/5	22:00	55-54.94835N	176-50.55857W	Time adjustment -1 hour (SMT=UTC-10h)
	22:45	10/6	12:45	52-46.92879N	177-42.17510W	Arrival at St.2
10/7	00:35		14:35	52-47.03946N	177-42.22387W	VMPS #1
	08:40		22:40	52-47.03691N	177-42.16903W	CTD cast #1 (3651m)
	12:00	10/7	02:00	52-47.02399N	177-42.15218W	NORPAC net #1
	13:09		03:09	52-47.00857N	177-42.31882W	Departure from St.2
10/8	08:00		22:00	52-48.10833N	175-45.37898E	Time adjustment -1 hour (SMT=UTC-11h)
	08:06		21:06	52-47.96574N	175-43.93458E	Arrival at St.3
	08:17		21:17	52-47.93402N	175-43.76986E	CTD cast #2 (3905m)
	11:36	10/8	00:36	52-47.90844N	175-43.82609E	VMPS #2
	16:14		05:14	52-47.88768N	175-43.85984E	NORPAC net #2
	17:06		06:06	52-47.86016N	175-43.75500E	Departure from St.3
10/9	03:30		16:30	51-05.99551N	173-32.14971E	Arrival at St.4
	03:36		16:36	51-05.71104N	173-31.71215E	CTD cast #3 (5886m)
	08:14		21:14	51-05.81156N	173-31.62902E	VMPS #3
	12:26	10/9	01:26	51-05.74853N	173-31.63311E	NORPAC net #3
	13:30		02:30	51-05.78124N	173-32.53978E	Departure from St.4
10/10	09:00		22:00	47-39.98736N	170-33.12973E	Time adjustment -1 hour (SMT=UTC-12h)
	11:00	10/10	00:00	47-19.10518N	170-15.64487E	Date adjustment +1 day (SMT=UTC+12h)
	12:51	10/11	00:51	47-00.12718N	170-00.19036E	Arrival at St.5
	13:00		01:00	47-00.07286N	170-00.15978E	CTD cast #4 (4959m)
	16:53		04:53	47-00.11583N	170-00.03271E	Argo float deployment #1
	17:06		05:06	47-00.18023N	169-59.99753E	VMPS #4
	20:46		08:46	47-00.21501N	169-59.99549E	NORPAC net #4
10/11	01:01		13:01	47-00.14864N	170-00.04689E	CTD cast #5 (2000m)
10/12	06:30	10/12	18:30	46-59.18278N	170-02.50043E	Departure from St.5
10/13	10:00	10/13	22:00	46-57.35867N	163-01.64797E	Time adjustment -1 hour (SMT=UTC+11h)

U.T.C.		S.M.T.		Position		Event logs
Date	Time	Date	Time	Lat.	Lon.	
10/13	20:33	10/14	07:33	46-51.99974N	160-00.01880E	Arrival at St.6, MBES Survey line in
	22:29		09:29	47-00.00305N	159-48.65334E	XCTD #1
10/14	06:42		17:42	46-59.99532N	159-44.94899E	MBES Survey line out
10/15	02:20	10/15	13:20	46-49.49974N	159-48.03128E	Deployed K2-OA Mooring Buoy
	05:50		16:50	46-53.5758N	159-40.2137E	K2-OA Mooring Buoy fixed position
	11:00		22:00	46-53.43011N	159-49.30842E	Time adjustment -1 hour (SMT=UTC+10h)
	22:05	10/16	08:05	46-59.99862N	159-59.95702E	Recovered K2-HB Mooring System
10/16	21:04	10/17	07:04	46-59.99862N	159-59.95702E	CTD #6
10/17	00:57		10:57	46-59.92076N	159-59.77842E	Argo float deployment #2
	01:13		11:13	46-59.97623N	160-00.26200E	Calibration for magnetometer #2
	03:00		13:00	46-59.99974N	159-59.99154E	VMPS #5
	06:46		16:46	47-00.05029N	159-59.96334E	NORPAC #5
	16:06	10/18	02:06	47-00.00203N	159-59.93073E	CTD #7
	20:12		06:12	47-00.01080N	159-59.99994E	Deployed VM drone
	21:02		07:02	47-00.01455N	160-00.08462E	CTD #8
10/18	03:53		13:53	46-49.46871N	160-02.99270E	Recovered VM drone
	04:11		14:11	46-49.17671N	160-03.39311E	NORPAC #6
	07:58		17:58	46-59.99097N	159-59.98985E	NORPAC #7
	19:02	10/19	05:02	46-59.98662N	160-00.04559E	VMPS #6
	20:35		06:35	46-59.76862N	160-00.04968E	NORPAC #8
10/19	00:01		10:01	47-00.05977N	160-00.12084E	CTD #9
	03:05		13:05	47-00.04286N	160-00.00545E	CTD #10
10/21	04:19	10/21	14:19	47-00.02418N	160-00.03318E	CTD #11
	05:39		15:39	46-59.99431N	160-00.00557E	CTD #12
	22:15	10/22	08:15	47-03.60738N	160-06.30282E	Deployed K2-HB Mooring Buoy
10/22	02:34		12:34	47-00.15934N	159-57.70517E	K2-HB Mooring Buoy fixed position
	02:45		12:45	47-00.15460N	159-57.66404E	Departure from St.6
10/23	00:30	10/23	10:30	44-00.07747N	154-59.94559E	Arrival at St.7
	00:32		10:32	44-00.07033N	154-59.96093E	CTD #13
	04:39		14:39	44-00.11098N	155-00.13781E	VMPS #7
	05:53		15:53	44-00.52128N	155-00.37147E	NORPAC #9
	07:34		17:34	43-59.96786N	154-59.99375E	CTD #14
	09:30		19:30	43-59.97320N	154-59.99066E	Departure from St.7

U.T.C.		S.M.T.		Position		Event logs
Date	Time	Date	Time	Lat.	Lon.	
10/25	00:00	10/25	10:00	40-46.04530N	146-56.41933E	Stop doppler rader observation
	06:18		16:18	41-54.25294N	146-17.86179E	Arrival at St.8
	06:22		16:22	41-54.32920N	146-17.80574E	CTD #15
	10:49		20:49	41-52.01319N	146-19.28925E	NORPAC #10
	12:00		22:00	41-49.63644N	146-19.44261E	Departure from St.8
	12:00		22:00	41-49.63644N	146-19.44261E	Time adjustment -1 hour (SMT=UTC+9h)
10/26	00:30	10/26	09:30	40-15.83577N	143-20.99525E	Calibration for magnetometer #3
10/27	04:07	10/27	13:07	34-56.54414N	140-17.21250E	Stop sea water pump and SSV pump
	23:50	10/28	08:50	35-01.92891N	138-30.29455E	Arrival at Shimizu

2. Observations
2.1 General observations
2.1.1 Meteorological observations

Katsunori KIMOTO (JAMSTEC) - PI
Ryo OYAMA (NME)
Seika TAKAI (NME)
Masanori MURAKAMI (MIRAI crew)

(1) Objectives

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

(2) Instruments and Methods

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

i) MIRAI Surface Meteorological observation (SMet) system

Instruments of SMet system are listed in Table2.1.1-1 and measured parameters are listed in Table2.1.1-2. Data were collected and processed by KOAC-7800 weather data processor made by Koshin-Denki, Japan. The data set consists of 6 seconds averaged data.

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

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

a) Analog meteorological data sampling with CR1000 logger manufactured by Campbell Inc., Canada - wind, pressure, and rainfall (by a capacitive rain gauge (CRG)) measurement.
b) Digital meteorological data sampling from individual sensors - air temperature, relative humidity and rainfall (by optical rain gauge (ORG)) measurement.
c) Radiation data sampling with CR1000X logger manufactured by Campbell Inc., Radiometers designed by Hukseflux Thermal Sensors B.V. Netherlands. – short and long wave downward radiation measurement.
d) Photosynthetically Available Radiation (PAR) and Ultraviolet Irradiance (UV) sensor manufactured by Biospherical Instruments Inc., USA. – PAR and UV measurement.
e) Scientific Computer System (SCS) developed by NOAA (National Oceanic and Atmospheric Administration, USA) - centralized data acquisition and logging of all data sets.SCS recorded radiation, air temperature, relative humidity, CR1000, ORG and PAR data. SCS composed Event data (JamMet) from these data and ship's navigation data every 6 seconds. Instruments and their locations are listed in Table 2.1.1.1-3 and measured parameters are listed in Table 2.1.1.1-4.

iii) Quality control

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

a) 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.
b) Barometer (SMet and SOAR)
   Comparison with the portable barometer value, PTB330, VAISALA
c) Thermometer (air temperature and relative humidity) (SMet and SOAR)
   Comparison with the portable thermometer value, HMP75, VAISALA

(3) Preliminary results

Fig.2.1.1-1 show the time series of the following parameters;

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

(4) Data archives

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

(5) Remarks (Times in UTC)

i) The following period, Sea surface temperature of SMet data were available.
   00:00UTC 03 Oct. 2024 - 04:07UTC 27 Oct. 2024

ii) The following time, air temperature and relative humidity (port side) data were invalid.
   18:00UTC 02 Oct. 20241 (The start of this cruise) - 05:00UTC 16 Oct. 2024

iii) The following time, increasing of SMet optical rain gauge data were invalid due to window cleaning.
   01:19UTC 16 Oct. 2024

iv) The following period, increasing of SMet capacitive rain gauge data were invalid due to transmitting for MF/HF or VHF radio.
   02:57UTC 18 Oct. 2024

Table 2.1.1-1. Instruments and installation locations of Smet system

Sensors	Type	Manufacturer	Location (altitude from surface)
Anemometer	KS-5900	Koshin Denki, Japan	Foremast (25 m)
Tair/RH	HMP155	Vaisala, Finland	Compass deck (21 m)
with aspirated radiation shield	43408 Gill	R.M. Young, USA	starboard side and port side
Thermometer: SST	RFN2-0	Koshin Denki, Japan	4th deck (-1m, inlet -5m)
Barometer	Model-370	Setra System, USA	Captain deck (13 m) weather observation room
Capacitive rain gauge	50202	R. M. Young, USA	Compass deck (19 m)
Optical rain gauge	ORG-815DS	Osi, USA	Compass deck (19 m)
Radiometer (short wave)	MS-802	Eko Seiki, Japan	Radar mast (28 m)
Radiometer (long wave)	MS-202	Eko Seiki, Japan	Radar mast (28 m)
Wave height meter	WM-2	Tsurumi-seiki, Japan	Bow (10 m) Stern (8 m)

Table 2.1.1-2. Parameters of Smet system

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 Ship's speed	knot	MIRAI log
4 Ship's heading	degree	MIRAI gyro
5 Relative wind speed	m/s	6sec./10min. averaged
6 Relative wind direction	degree	6sec./10min. averaged
7 True wind speed	m/s	6sec./10min. averaged
8 True wind direction	degree	6sec./10min. averaged
9 Barometric pressure	hPa	adjusted to sea surface level 6sec. averaged
10 Air temperature (starboard)	degC	6sec. averaged
11 Air temperature (port)	degC	6sec. averaged
12 Dewpoint temperature (starboard)	degC	6sec. averaged
13 Dewpoint temperature (port)	degC	6sec. averaged
14 Relative humidity (starboard)	%	6sec. averaged
15 Relative humidity (port)	%	6sec. averaged
16 Sea surface temperature	degC	6sec. averaged
17 Precipitation intensity (optical rain gauge)	mm/hr	hourly accumulation
18 Precipitation (capacitive rain gauge)	mm/hr	hourly accumulation

19 Down welling shortwave radiation	W/m^2	6sec. averaged
20 Down welling infra-red radiation	W/m^2	6sec. averaged
21 Significant wave height (bow)	m	hourly
22 Significant wave height (stern)	m	hourly
23 Significant wave period (bow)	second	hourly
24 Significant wave period (stern)	second	hourly

Table 2.1.1-3. Instruments and installation locations of SOAR system

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

Sensors (Radiation)	Type	Manufacturer	Location *
Radiometer (short wave)	SR20	Hukseflux Thermal Sensors B.V., Netherlands	foremast (25 m)
Radiometer (long wave)	IR20	Hukseflux Thermal Sensors B.V., Netherlands	foremast (25 m)

Sensor (PAR&UV)	Type	Manufacturer	Location *
PAR&UV sensor	PUV-510	Biospherical Instruments Inc., USA	Navigation deck (18m)

*Location : Altitude from surface

Table 2.1.1-4. Parameters of SOAR system (JamMet)

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 SOG	knot	
4 COG	degree	
5 Relative wind speed	m/s	
6 Relative wind direction	degree	
7 Barometric pressure	hPa	
8 Air temperature	degC	
9 Relative humidity	%	
10 Precipitation intensity (optical rain gauge)	mm/hr	
11 Precipitation (capacitive rain gauge)	mm/hr	reset at 50 mm
12 Down welling shortwave radiation	W/m^2	
13 Down welling infrared radiation	W/m^2	
14 PAR	$microE/cm^2/sec$	
15 UV 305 nm	$microW/cm^2/nm$	
16 UV 320 nm	$microW/cm^2/nm$	
17 UV 340 nm	$microW/cm^2/nm$	
18 UV 389 nm	$microW/cm^2/nm$	

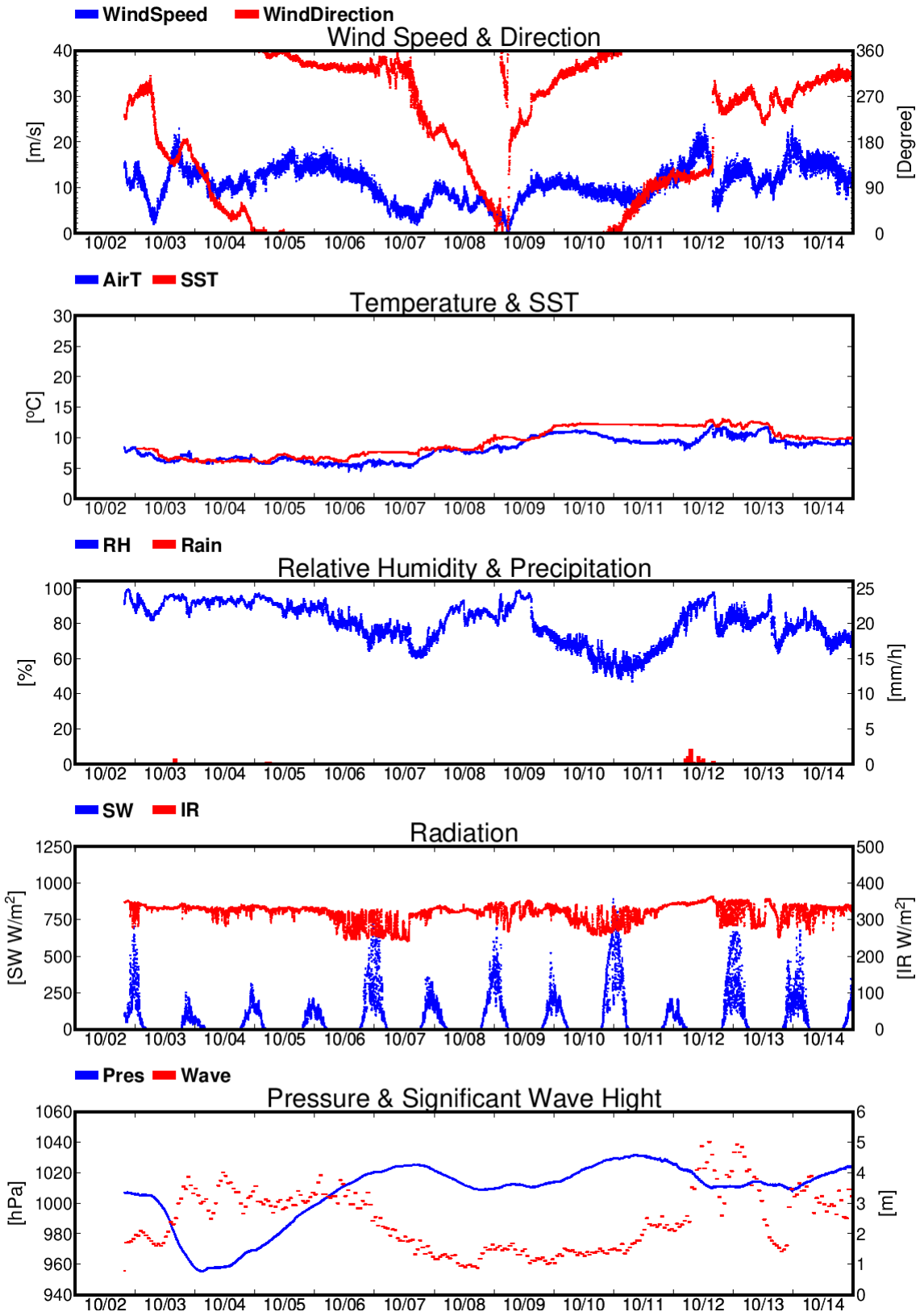


Fig. 2.1.1-1 Time series of surface meteorological parameters during MR24-07Leg1.

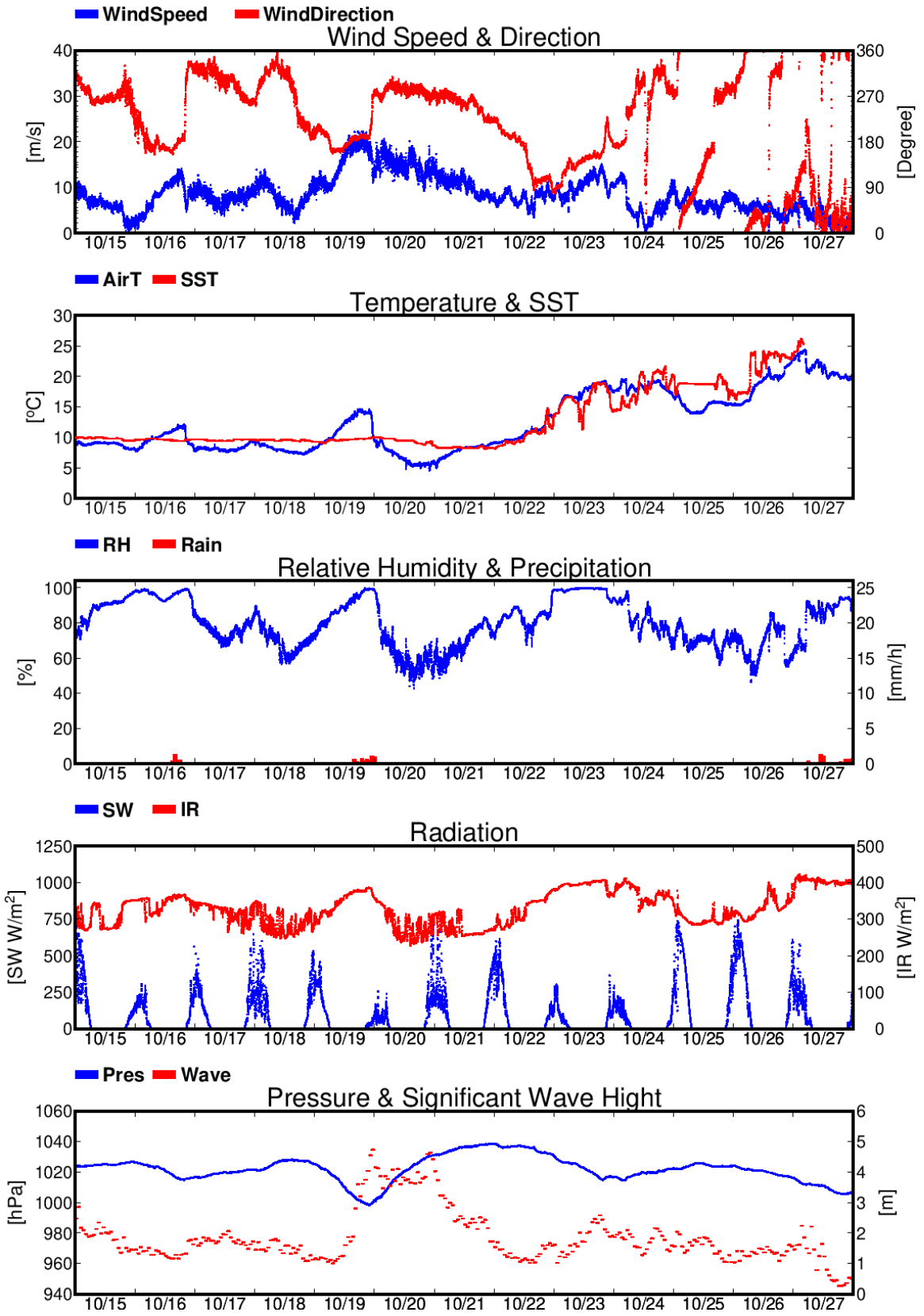


Fig. 2.1.1-1 (Continued)

2.1.2 Ceilometer

Katsunori KIMOTO (JAMSTEC) - PI
Ryo OYAMA (NME)
Seika TAKAI (NME)
Masanori MURAKAMI (MIRAI crew)

(1) 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.

(2) Instruments and methods

Cloud base height and backscatter profile were observed by ceilometer (CL51, VAISALA, Finland). On the archive dataset, the profile was recorded with the resolution of 10 m.

i). Parameters

a). Cloud base height [m].
b). Backscatter profile, sensitivity and range normalized at 10 m resolution.
c). Estimated cloud amount [oktas] and height [m]; Sky Condition Algorithm.

ii). The measurement configurations are shown in Table 2.1.2-1.

Table 2.1.2-1 The measurement configurations

Property	Description	
Laser source	Indium Gallium Arsenide (InGaAs) Diode	
Transmitting center wavelength	910±10 nm at 25 degC	
Transmitting average power	19.5 mW	
Repetition rate	6.5 kHz	
Detector	Silicon avalanche photodiode (APD)	
Responsibility at 905 nm	65 A/W	
Cloud detection range	0 ~ 13 km	
Measurement range	0 ~ 15 km	
Resolution	10 m in full range	
Sampling rate	36 sec.	
Sky Condition	Cloudiness in octas (0 ~ 9)	
	0	Sky Clear
	1	Few
	3	Scattered
	5-7	Broken
	8	Overcast
	9	Vertical Visibility

(3) Preliminary results

Figure 2.1.2-1 show the time-series of the lowest, second and third cloud base height during the cruise.

(4) Data archives

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

< https://www.godac.jamstec.go.jp/darwin/en >

(5) Remarks (Times in UTC)

Window cleaning

20:50UTC 08 Oct. 2024

01:03UTC 16 Oct. 2024

23:09UTC 21 Oct. 2024

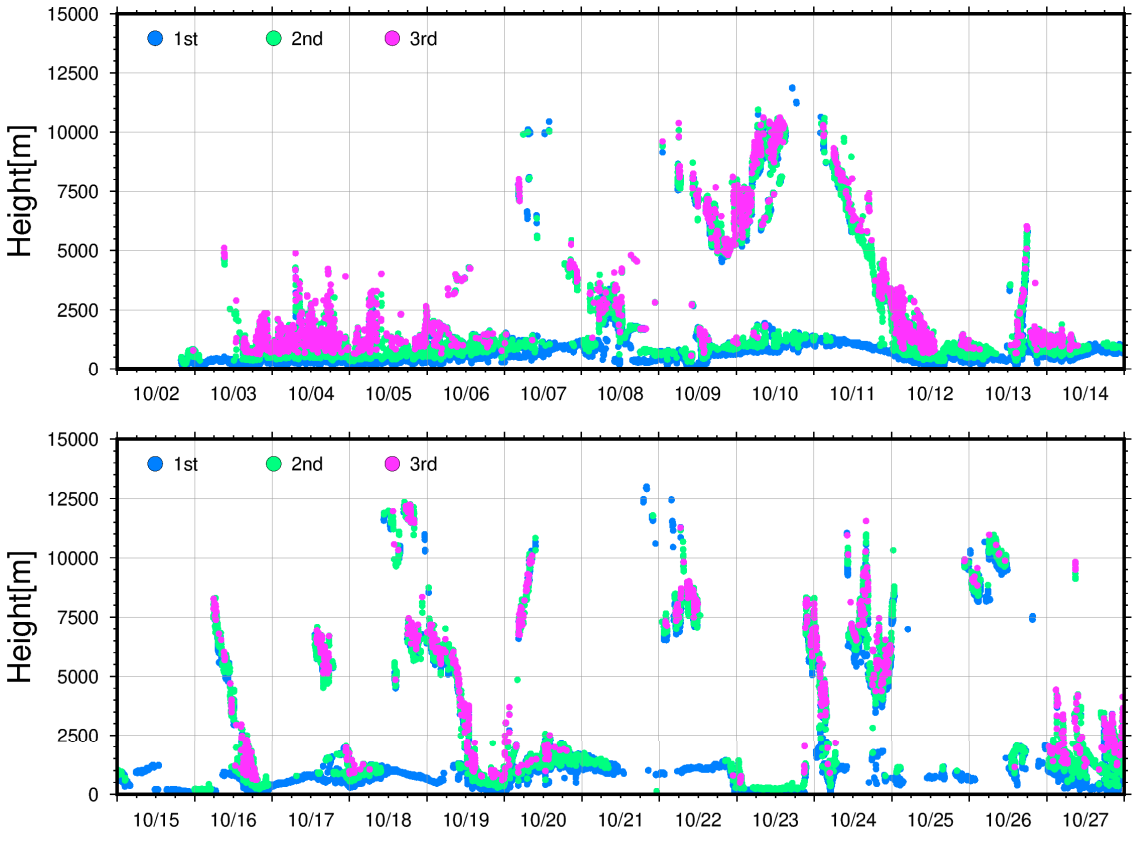


Figure 2.1.2-1 Time series of cloud base height during MR24-07Leg1

2.1.3 Atmospheric composition observation over the ocean

Fumikazu Taketani (JAMSTEC) PI - not on board
Yugo Kanaya (JAMSTEC)- not on board
Takuma Miyakawa (JAMSTEC) - not on board
Hisahiro Takashima (JAMSTEC/Fukuoka Univ.) - not on board
Zhu Chunmao (JAMSTEC) - not on board

Operation for online instruments was supported by Nippon Marine Enterprises, Ltd

(1) Objectives

• To investigate roles of gas and aerosols in the marine atmosphere in relation to climate change
• To investigate processes of biogeochemical cycles between the atmosphere and the ocean.
• To investigate gas and aerosol transports from anthropogenic activities
• To investigate physical and chemical particle states of aerosols

(2) Parameters

• Fluorescent particles
• Individual particle features of ambient particles
• Surface ozone(O_3), and carbon monoxide(CO) mixing ratios
• Aerosol extinction coefficient (AEC) and trace gases

(3) Instruments and methods

(3-1) Online observations:

(3-1-1) Fluorescent property

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

(3-1-2) CO and O_3

Ambient air was continuously sampled on the compass deck and drawn through ~20m long Teflon tubes connected to a nondispersive infrared (NDIR) CO analyzer (Model 48i-TLE, Thermo Fisher Scientific) and a UV photometric ozone analyzer (model 205, 2B Technologies), located in the environmental research room. The data will be used for characterizing air mass origins.

(3-1-3) Aerosol extinction coefficient (AEC) and trace gases

Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS), a passive remote sensing technique measuring spectra of scattered visible and ultraviolet (UV) solar radiation, was used for atmospheric aerosol and gas profile measurements. MAXDOAS were installed at the deck above stabilizer of ship. Our MAX-DOAS instrument consists of two main parts: an outdoor telescope unit and an indoor spectrometer (Acton SP-2358 with Princeton Instruments PIXIS-400B), connected to each other by a 14-m bundle optical fiber cable. The line of sight was in the directions of the portside of the vessel and the scanned elevation angles were 1.5, 3, 5, 10, 20, 30, 90 degrees in the 30-min cycle. The roll motion of the ship was measured to autonomously compensate additional motion of the prism, employed for scanning the elevation angle. For the selected spectra recorded with elevation angles with good accuracy, DOAS spectral fitting was performed to quantify the slant column density (SCD) of NO_2 (and other gases) and O_4 (O_2-O_2, collision complex of oxygen) for each elevation angle. Then, the O_4 SCDs were converted to the aerosol optical depth (AOD) and the vertical profile of aerosol extinction coefficient (AEC) using an optimal estimation inversion method with a radiative transfer model. Using derived aerosol information, retrievals of the tropospheric vertical column/profile of NO_2, IO, and other gases were made.

(5) Data archives

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

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

(6) Acknowledgments

We thank the crew of the R/V Mirai, staff of Nippon Marine Enterprises, Ltd., and Dr. Amane FUJIWARA, Dr. Yuri FUKAI, and Dr. Motoyo ITO for their support with observations throughout the cruise.

2.1.4 C-band weather radar

Masaki KATSUMATA	(JAMSTEC)	Principal Investigator (not on board)
Ryo OYAMA	(NME)	Operation Leader
Seika TAKAI	(NME)	

(1) Objective

Weather radar observations in this cruise aim to investigate the structure and evolution of precipitating systems over the tropical ocean.

(2) Radar specifications

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

Frequency:	5370 MHz (C-band)
Polarimetry:	Horizontal and vertical (simultaneously transmitted and received)
Transmitter:	Solid-state transmitter
Pulse Configuration:	Using pulse-compression
Output Power:	6 kW (H) + 6 kW (V)
Antenna Diameter:	4 meter
Beam Width:	1.0 degrees
Inertial Navigation Unit:	PHINS (IXBLUE SAS France)

(3) Available radar variables

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

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

(4) Operational methodology

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

For maintenance, internal signals of the radar are checked and calibrated at the beginning and the end of the cruise. Meanwhile, the peak output power and the radar's pulse width are checked daily. During the cruise, the radar is operated in modes shown in Table 2.1.4-1. A dual PRF mode is used for volume scans. For RHI and surveillance PPI scans, a single PRF mode is used.

(5) Data

The C-band weather radar observations were conducted continuously during the cruise, except nearby the main islands of Japan.

The observation periods were

from: 20:30UTC on 02 Oct. 2024

to: 00:00UTC on 25 Oct. 2024.

Note that the data acquisition was suspended due to maintenance

from: 00:00UTC on 06 Oct. 2024

to: 00:11UTC on 06 Oct. 2024.

An example of the obtained snapshots is shown in Fig. 2.1.4-1, when a frontal system passed over the vessel. On the reflectivity field (in the upper panel), we can see a band of the precipitating area elongated from northeast to southwest, with the width of approximately 100 km. Inside the band, narrow line parallel to the band orientation can be found from the east (approx. 25 km from the vessel) to the south (approx. 40 km from the vessel). The line collocated to the sharp discontinuity of the Doppler velocity field (in the lower panel). These indicate the exact location of the front between west-southwesterly wind in the southeast of the front and westerly wind in the west of the front.

Further detailed analyses of the obtained data, as well as the quality controls, will be performed after the cruise.

(6) Data archive

The obtained data will be submitted to the Data Management Group of JAMSTEC.

	Surveillance PPI Scan	Volume Scan						RHI Scan
Repeated Cycle (min.)	30	6						6
Times in One Cycle	1	1						3
PRF(s) (Hz)	400	dual PRF (ray alternative)						1250
		667	833	938	1250	1333	2000	
Azimuth (deg)	Full Circle							Option
Bin Spacing (m)	150							
Max. Range (km)	300	150		100		60		100
Elevation Angle(s) (deg.)	0.5	0.5		1.0, 1.8, 2.6, 3.4, 4.2, 5.1, 6.2, 7.6, 9.7, 12.2, 15.2		18.7, 23.0, 27.9, 33.5, 40.0		0.0~ 60.0

Table 2.1.4-1 Scan modes of C-band weather radar

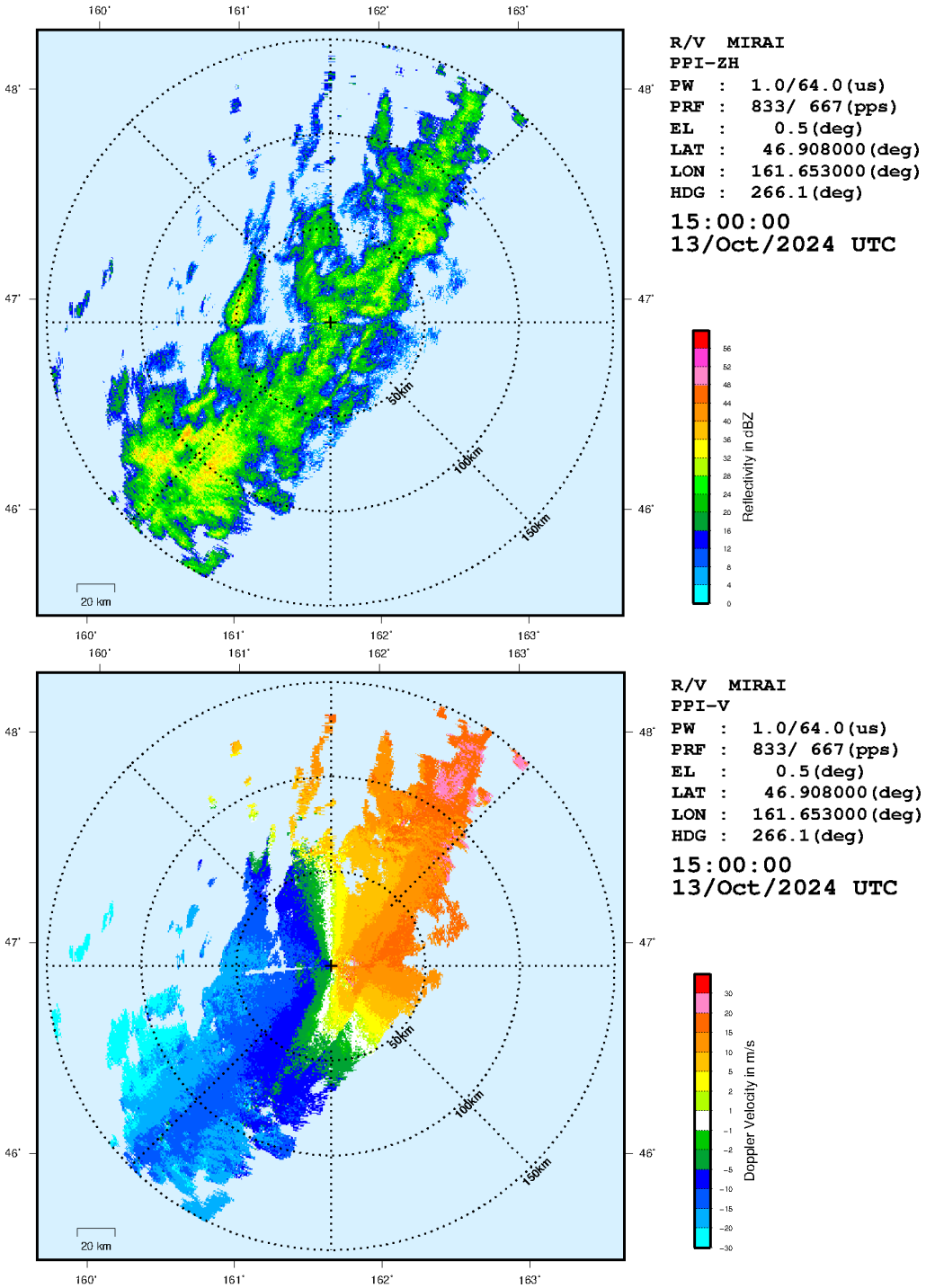


Fig. 2.1.4-1: Example of the obtained data by the PPI scans at (around) 1500UTC on Oct. 13, 2024. The upper and lower panel is for the radar reflectivity and for the Doppler velocity, respectively, at the elevation of 0.5º within a 150-km range distance.

2.1.5 Microwave Radiometer

Masaki KATSUMATA (JAMSTEC)
Akira KUWANO-YOSHIDA (Kyoto Univ.) (not on board)
Masahiro MINOWA (Furuno Electric Co., Ltd.) (not on board)

(1) Objective

To retrieve the total column integrated water vapor, and the vertical profiles of water vapor and temperature, in the atmosphere

(2) Method

Two microwave radiometers (hereafter MWR; manufactured by Furuno Electric Co., Ltd.) are used. The MWRs received natural microwave within the angle of 20 deg. from zenith. One of the MWRs for the water vapor observes at the frequencies around 22 GHz, to retrieve the column integrated water vapor (or precipitable water), and the vertical profile of the water vapor. The other MWR measures at the frequencies around 55 GHz to retrieve vertical profile of the air temperature. The observation was made approximately every 20 seconds except when periodic auto-calibration was on-going (once in several minutes). The rain sensor is equipped to identify the period of rainfall.

In addition to the MWRs, the whole sky camera was installed beside the MWR. This is to monitor cloud cover, which also affects the microwave signals. The camera obtained the whole-sky image every 2 minutes.

All instruments were installed at the top of the roof of aft wheelhouse, as in Fig. 2.1.5-1. The data were continuously obtained all through the cruise period.

(3) Results

The data have been obtained all through the cruise. The further analyses for the water vapor (column-integrated amount and vertical profile), the air temperature (vertical profile), etc., will be carried out after the cruise.

(4) Data archive

The data will be submitted to the JAMSTEC Data Management Group (DMG).

(6) Acknowledgment

The observation was supported by the JSPS KAKENHI Grant 23H00519.

Fig. 2.1.5-1: Outlook of the instruments installed at the roof of the aft wheelhouse; the microwave radiometer for the air temperature (right), microwave radiometer for the water vapor (middle), and the whole-sky camera (left).

2.1.6 Mie / Raman Lidar

Masaki KATSUMATA (JAMSTEC)
Kyoko TANIGUCHI (JAMSTEC)
Ryo OYAMA (NME)
Seika TAKAI (NME)
Masanori MURAKAMI (Mirai Crew)

(1) Objective

The objective of this observation is to capture the vertical distribution of clouds, aerosols, and water vapor in high spatio-temporal resolution.

(2) Method

The Mirai Lidar system transmits a 10-Hz pulse laser in three wavelengths: 1064nm, 532nm, 355nm. For cloud and aerosol observation, the system detects Mie scattering at these wavelengths. The separate detections of polarization components at 532 nm and 355 nm obtain additional characteristics of the targets. The system also detects Raman water vapor signals at 660 nm and 408nm, Raman nitrogen signals at 607 nm and 387nm at nighttime. Based on the signal ratio of Raman water vapor to Raman nitrogen, the system offers water vapor mixing ratio profiles.

The obtained parameters are as follows:

355nm Mie scattering signal
532nm Mie scattering signal
1064nm Mie scattering signal
387nm Raman nitrogen scattering signal (nighttime only)
408nm Raman water vapor scattering signal (nighttime only)
607nm Raman nitrogen scattering signal (nighttime only)
660nm Raman water vapor scattering signal (nighttime only)

(3) Results

The Lidar was operated from 2 Ocbober 2024 to 27 October 2024.
All datasets will be analyzed and examined after the cruise.

(4) Data archive

The data will be submitted to the JAMSTEC Data Management Group (DMG).

2.1.7 Aerosol optical properties measured by Shipborne Sky radiometer

Kazuma Aoki (University of Toyama) not onboard
Sky radiometer operation was supported by Nippon Marine Enterprises, Ltd.

(1) Objectives
Objective of this observation is to study distribution and optical characteristics of marine aerosols by using a ship-borne sky radiometer (POM-01 MK-III: PREDE Co. Ltd., Japan). Furthermore, collections of the data for calibration and validation to the remote sensing data were performed simultaneously.

(2) Instruments and methods
i) Sky radiometer measurement
The sky radiometer measures the direct solar irradiance and the solar aureole radiance distribution with seven interference filters (0.315, 0.4, 0.5, 0.675, 0.87, 0.94, and 1.02 μm). Analysis of these data was performed by SKYRAD.pack version 4.2 developed by Nakajima et al. 1996 and 2020.

ii) Parameters
- Aerosol optical thickness at five wavelengths (400, 500, 675, 870 and 1020 nm)
- Ångström exponent
- Single scattering albedo at five wavelengths
- Size distribution of volume (0.01 μm – 20 μm)
- # GPS provides the position with longitude and latitude and heading direction of the vessel, and azimuth and elevation angle of the sun. Horizon sensor provides rolling and pitching angles.

(3) Data archive
Aerosol optical data are to be archived at University of Toyama (K.Aoki, SKYNET/SKY: http://skyrad.sci.u-toyama.ac.jp/sobs/) after the quality check and will be submitted to JAMSTEC.

(4) References
Nakajima,T., G.Tonna, R.Rao, P.Boi, Y.Kaufman and B.Holben (1996) Use of sky brightness measurements from ground for remote sensing of particulate polydispersions, Appl. Opt., 35, 2672–2686, https://doi.org/10.1364/AO.35.002672.
Aoki. K., T.Takemura, K.Kawamoto, and T.Hayasaka (2013), Aerosol climatology over Japan site measured by ground-based sky radiometer, AIP Conf. Proc. 1531, 284-287 (2013); doi: 10.1063/1.4804762.
Nakajima,T., Campanelli,M., Che,H., Estellés,V., Irie,H., Kim,S.-W., Kim,J., Liu,D., Nishizawa,T., Pandithurai,G., Soni,V.K., Thana,B., Tugjsurn,N.-U., Aoki,K., Hashimoto,M., Higurashi,A., Kazadzis,S., Khatri,P., Kouremeti,N., Kudo,R., Marenco,F., Momoi,M., Ningombam,S. S., Ryder,C.L., and Uchiyama,A.(2020) An overview and issues of the sky

radiometer technology and SKYNET, Atmos. Meas. Tech., 13, 4195–4218, 2020, https://doi.org/10.5194/amt-13-4195-2020.

2.1.8 Evaluation of performance of the DFMC SBAS from QZSS

Toru Takahashi (ENR, MPATI)
Mitsunori Kitamura (ENRI, MPAT)

(1) Objectives

The aviation and maritime activities in the Arctic are growing with the recession of the Arctic sea ice. A model study suggested that the Global Navigation Satellite System (GNSS), which operates with the augmentation system such as the Satellite-based augmentation systems (SBAS) and Advanced Receiver Autonomous Integrity Monitoring (ARAIM), is effective for the navigation of aviation and maritime in the Arctic because of poor infrastructures (Reid et al., 2016). However, the current L1 SBAS broadcasts augmentation messages from geostationary (GEO) satellites, which are not available practically in the polar region at a latitude of 72 degrees or higher.

The Dual Frequency Multi Constellation Satellite Based Augmentation System (DFMC SBAS) has been standardization by the International Civil Aviation Organization (ICAO). Broadcasting augmentation messages from the Inclined Geosynchronous Orbit (IGSO) satellite is considered to be included in the future updates. The Electronic Navigation Research Institute (ENRI) developed the DFMC SBAS prototype based on the draft standards (Kitamura et al., 2018), and test messages are broadcasted from the Japanese Quasi-Zenith Satellite System (QZSS).

In the polar region, an auroral activity often generates the irregularity ionospheric plasma density and the ionospheric electric filed is intensified simultaneously. The carrier phase of the GNSS signal is fluctuated by the auroral activity. Since the fluctuation sometimes causes the loss of lock on GNSS signals, the impact the auroral activity on the GNSS carrier phase should be investigated.

The main objective of this study is to evaluate the performance DFMC SBAS broadcasted from Japanese QZSS in the Arctic and mid-high latitude regions. To test the DFMC SBAS in the Arctic, we installed the GNSS antenna, GNSS receivers, DFMC SBAS receivers, and Inertial Measurement Unit (IMU) to oceanographic research vessel MIRAI.

(2) Parameters

Signals from GNSS satellites and Dual Frequency and Multi-Constellation (DFMC) Satellite Based Augmentation System (SBAS) messages transmitted from the Quasi-Zenith Satellite System (QZSS) are recorded by GNSS receivers. Performance (accuracy and integrity) of the DFMC SBAS from QZSS is evaluated in the on-board environment at mid to high latitudes.

(3) Instruments and methods

i. GNSS Receiver

A NovAtel OEM6 receiver recorded signals from GPS, Galileo, GLONASS, BeiDou, and QZSS at the frequency of L1, L2, and L5 bands. The receiver recorded the observation message, including the pseudorange and carrier phase, with a sampling rate of 10 Hz. The navigation message, including the satellite obit information were also recorded.

A u-blox F9P also observed the GPS, Galileo, GLONASS, BeiDou, and QZSS signals and provided the antenna position by the NMEA format. A u-blox D9C recorded the MADOCA message broadcasted from QZSS satellite to derive the precise antenna position by a post processing.

ii. DFMC SBAS Message receivers

To obtain DFMC SBAS messages, a Furuno prototype DFMC SBAS receiver and CORE Chronosphere receivers were installed. The DFMC SBAS messages were generated by Electronic Navigation Research Institute (ENRI) and broadcasted from QZS02 and OZS04 satellites with a frequency of 1 Hz.

iii. Scintillation receiver

The GNSS signals are sometimes fluctuated by a combination of the ionospheric irregularity and electric field. The fluctuation is called scintillation and becomes a cause of the loss-of-lock GNSS signal. Since we need to receive the carrier phase with high and precise sampling to observe the scintillation, the Septentrio PolaRx5S, which records the GNSS signals with a sampling rate of 100 Hz.

iv. GNSS Antenna

The GNSS Antenna used was a Trimble GA830 capable of receiving L1, L2, and L5 bands. The antenna was designed for maritime and cold weather specification.

v. Inertial Measurement Unit (IMU)

It is challenging to differentiate GNSS signal fluctuations caused by ionospheric irregularities from those caused by vessel motion. The IMU recorded velocity and acceleration at the antenna's position, which are planned to be used to compensate for the vessel's motion.

(4) Station list or Observation log

This observation continuously conducted from 21 August 2024 to 16 November 2024.

(5) Preliminary Results

We successfully received ranging signals from GPS, Galileo, GLONASS, BeiDou, and QZSS using NovAtel receivers, as well as the DFMC SBAS messages transmitted from QZSS-02, QZSS-04, and QZSS-1R during the cruise. Unfortunately, the Septentrio PolaRx5S stopped the recording the ranging signals on October 7 at 11 UT, and the IMU stopped functioning immediately after leaving shore.

(6) Data archives

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

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

References

Kitamura, M., Aso, T., & Sakai, T. (2018) Wide Area Augmentation Performance of DFMC SBAS Using Global Monitoring Stations, The 16th IAIN World Congress 2018.

Reid, T., Walter, T., Blanch, J., & Enge, P. (2016) GNSS Integrity in The Arctic. NAVIGATION, 63: 469– 492. doi: 10.1002/navi.169.

2.2 Geophysical surveys
2.2.1 Sea surface gravity

Katsunori KIMOTO (JAMSTEC) - PI
Ryo OYAMA (NME)
Seika TAKAI (NME)
Masanori MURAKAMI (MIRAI crew)

(1) Objectives

The local gravity is an important parameter in geophysics and geodesy. We collected gravity data at the sea surface.

(2) Instruments and methods

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 gravity at Shimizu as the reference points. Parameters of gravity meter are as follows:

Relative Gravity [CU: Counter Unit]
[mGal] = (coef1: 0.9946) * [CU]

(3) Preliminary results

Absolute gravity table is shown in Table 2.2.1-1

Table 2.2.1-1 Absolute gravity table of this cruise

No.	Date UTC Gravity m/d [mGal]	Port	Absolute Gravity [mGal]	Sea Level [cm]	Ship Draft [cm]	Gravity at Sensor *1 [mGal]	S-116
#1	8/25 03:20 12647.52	Sekinehama	980371.89	280	647	980373.01	
#2	10/28 23:45 12001.24	Shimizu	979728.98	232	615	979729.88	

*1: Gravity at Sensor = Absolute Gravity + Sea Level*0.3086/100 + (Draft-530)/100*0.2222

(4) Data archive

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

2.2.2 Sea surface three component magnetic field

Katsunori KIMOTO (JAMSTEC) - PI
Ryo OYAMA (NME)
Seika TAKAI (NME)
Masanori MURAKAMI (MIRAI crew)

(1) Objectives

Measurement of magnetic force on the sea is required for the geophysical investigations of marine magnetic anomaly caused by magnetization in upper crustal structure. We measured geomagnetic field using a three-component magnetometer during this cruise.

(2) Instruments and methods

A shipboard three-component magnetometer system (Tierra Tecnica SFG2018) 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, PHINS). Ship's position and speed data are taken from LAN every second.

(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:

$$\boldsymbol{Hob = A * R * P * Y * F + Hp} \qquad \text{(a)}$$

where, ***R***, ***P*** and ***Y*** are the matrices of rotation due to roll, pitch and heading of a ship, respectively. ***A*** is a 3 x 3 matrix which represents magnetic susceptibility of the ship, and ***Hp*** is a magnetic field vector produced by a permanent magnetic moment of the ship's body. Rearrangement of Eq. (a) makes

$$\boldsymbol{B * Hob + Hbp = R * P * Y * F} \qquad \text{(b)}$$

where $\boldsymbol{B = A^{-1}}$, and ***Hbp = -B * Hp***. The magnetic field, ***F***, can be obtained by measuring ***R***, ***P***, ***Y*** and ***Hob***, if ***B*** and ***Hbp*** are known. Twelve constants in ***B*** and ***Hbp*** can be determined by measuring variation of Hob with ***R***, ***P*** and ***Y*** at a place where the geomagnetic field, ***F***, is known.

(4) Preliminary result

The results will be published after primary processing.

(5) Data archive

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

(6) Remarks (Times in UTC)

1. The following periods, we made a “figure-eight” turn (a pair of clockwise and anti-clockwise rotation) for calibration of the ship’s magnetic effect.

05:00 04 Oct. 2024 - 05:19 04 Oct. 2024 (61-03N, 170-00W)
01:13 17 Oct. 2024 - 01:37 17 Oct. 2024 (47-00N, 160-00E)
00:30 26 Oct. 2024 - 00:52 26 Oct. 2024 (40-16N, 143-21E)

2.2.3 Swath bathymetry

Katsunori KIMOTO (JAMSTEC) - PI
Ryo OYAMA (NME)
Seika TAKAI (NME)
Masanori MURAKAMI (MIRAI crew)

(1) Objectives

R/V MIRAI is equipped with the Multi Beam Echo Sounding system (MBES; SEABEAM 3012 (L3 Communications ELAC Nautik, Germany)). The objective of MBES is collecting continuous bathymetric data along ship's track to make a contribution to geological and geophysical investigations and global data sets.

(2) Instruments and methods

The "SEABEAM 3012" on R/V MIRAI was used for bathymetry mapping during this cruise. To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data to get the sea surface (6.62m) sound velocity, and the deeper depth sound velocity profiles were calculated by temperature and salinity profiles from CTD, and Argo float data by the equation in Del Grosso (1974) during the cruise. The system configuration and performance are shown in Table 2.2.3-1.

Table 2.2.3-1 SEABEAM 3012 System configuration and performance

Frequency:	12 kHz
Transmit beam width:	2.0 degree
Transmit power:	4 kW
Transmit pulse length:	2 to 20 msec.
Receive beam width:	1.6 degree
Depth range:	50 to 11,000 m
Number of beams:	301 beams (Spacing mode: Equi-angle)
Beam spacing:	1.5 % of water depth (Spacing mode: Equi-distance)
Swath width:	60 to 150 degrees
Depth accuracy:	< 1 % of water depth (average across the swath)

(3) Preliminary result

The results will be published after primary processing.

(4) Data archive

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

2.3 Physical oceanography
2.3.1 CTD

Hiroshi UCHIDA	**(JAMSTEC)**	**(Principal Investigator)**
Masahide WAKITA	**(JAMSTEC)**	
Tun HTET AUNG	**(MWJ)**	**(Operation Leader)**
Aine YODA	**(MWJ)**	
Rei ITO	**(MWJ)**	

(1) Objective

The $CTDO_2$/water sampling measurements were conducted to obtain vertical profiles of seawater properties by sensors and water sampling.

(2) Parameters

Measured parameters are pressure, temperature, conductivity, dissolved oxygen, beam transmission, fluorescence, turbidity, photosynthetically active radiation (PAR), fluorescent dissolved organic matter (FDOM), refractive index, height above bottom (100 m range)

(3) Instruments

Winch and cable

Traction winch system (3.0 ton) (Dynacon, Inc., Bryan, Texas, USA)

Armored cable (φ = 9.53 mm) (Rochester Wire & Cable, LLC, Culpeper, Virginia, USA)

Compact underwater slip ring swivel (Hanayuu Co., Ltd., Shizuoka, Japan) (Uchida et al. 2018)

Frame

592 kg stainless steel frame for 36-position 12-L water sample bottles

Aluminum rectangular fin (54 × 90 cm) to resist frame's rotation

Water sampler and sampling bottle

36-position carousel water sampler, SBE 32 (Sea-Bird Scientific, Washington, USA)

Serial no. 3254451-0826

12-L sample bottle, model OTE 110 (OceanTest Equipment, Inc., Fort Lauderdale, Florida, USA) (No TEFLON coating with Viton O-rings)

Deck unit

SBE11plus (Sea-Bird Scientific, Washington, USA)

Serial no. 11P39850-0705

Underwater unit

Pressure sensor, SBE 9plus (Sea-Bird Scientific, Washington, USA)

Serial no. 09P27443-0677 (79511) (calibration date: June 10, 2022)

Temperature sensor

Deep ocean standard thermometer, SBE 35, (Sea-Bird Scientific, Washington, USA)

Serial no. 22 (calibration date: January 26, 2024)

Primary, SBE 3F (Sea-Bird Scientific, Washington, USA)

Serial no. 03P2730 (calibration date: January 18, 2024)

Secondary, SBE 3Plus (Sea-Bird Scientific, Washington, USA)

Serial no. 031525 (calibration date: June 14, 2024)

Conductivity sensor

Primary, SBE 4C (Sea-Bird Scientific, Washington, USA)

Serial no. 042854 (calibration date: November 14, 2023)

Secondary, SBE 4C (Sea-Bird Scientific, Washington, USA)

Serial no. 041206 (calibration date: June 06, 2024)

Dissolved oxygen sensor

Primary, RINKO III (JFE Advantech Co., Ltd., Hyogo, Japan)

Serial no. 0278, Sensing foil no. 163010BA
(in situ calibrated on MR24-04 cruise)

Secondary, SBE 43 (Sea-Bird Scientific, Washington, USA)

Serial no. 432471 (calibration date: September 02, 2023)

Transmissometer

C-Star, (WET Labs, Inc., Philomath, Oregon, USA)

Serial no. 1727DR (in situ calibrated on MR24-07Leg1 cruise)

Chlorophyll fluorometer

Seapoint Chlorophyll Fluorometer (Seapoint Sensors Inc., New Hampshire, USA)

Serial no. 3701, Gain: 10X (0-15 ug/L)

FDOM sensor

Seapoint Ultraviolet Fluorometer (Seapoint Sensors Inc., New Hampshire, USA)

Serial no. 6246, Gain: 30X (0-50 QSU)

Turbidity meter

Seapoint Turbidity Meter (Seapoint Sensors Inc., New Hampshire, USA)

Serial no. 14954, Gain setting: 100X (0-25 FTU)

PAR sensor

PAR-Log ICSW (Sea-Bird Scientific, Washington, USA)

Serial no. 2180 (calibration date: September 14, 2021)

Altimeter

PSA-916T (Teledyne Benthos, Inc.)

Serial no. 1100

Pump

SBE 5T (Sea-Bird Scientific, Washington, USA)

Primary serial no. 055816

Secondary serial no. 054598

Bottom contact switch (Sea-Bird Scientific, Washington, USA)

Other sensors connected to a data logger

Data logger

Two 16 bit A/D channels and four serial (RS-232) channels, JAMSTEC

Analog channel

Dissolved oxygen sensor, RINKO III, ARO-CAV (JFE Advantech Co., Ltd., Hyogo, Japan)

Serial no. 0252

Pressure sensor, UNIK 5000 (Druck, Baker Hughes)

Serial channel

Fluorometer/turbidity meter, ACLD70 (JFE Advantech Co., Ltd., Hyogo, Japan)

Serial no. 0001

Dissolved oxygen sensor, AROD-FT (JFE Advantech Co., Ltd., Hyogo, Japan)

Serial no. 0099

PAR sensor, MPE-PAR (Biospherical Instruments Inc., San Diego, CA, USA)

Serial no. 2982

Other stand-alone sensors

Refractive index density sensor (JAMSTEC, Uchida et al., 2019)

Lowered ADCPs (upward and downward looking), WHM300 (Teledyne RD Instruments)

Temperature microstructure sensor, MR6000 (Rockland Scientific International Inc.)

Gamma-ray sensor (Tokyo University of Marine Science and Technology)

pH/pCO_2 sensors (Tokyo University of Marine Science and Technology)

Software

Data acquisition software, SEASAVE-Win32, version 7.26.7.121

Data processing software, SBEDataProcessing-Win32, version 7.26.7.129

and some original modules

(4) Data Collection and processing

(4.1) Data collection

The CTD system was powered on at least 20 minutes in advance of the data acquisition to stabilize the pressure sensor. The data was acquired at least two minutes before and after the CTD cast to collect atmospheric pressure data on the ship's deck.

The CTD package was lowered into the water from the starboard side and held 10 m beneath the surface to activate the pump. After the pump was activated, the package was lifted to the surface and lowered at a rate of 1.0 m/s to 200 m then the package was stopped to operate the heave compensator of the crane. The package was lowered again at a rate of 1.0 m/s to the bottom, except for the deeper casts, where it was lowered at 1.2 m/s after it passed the depths where vertical gradient of water properties was large. For the up cast, the package was lifted at a rate of 1.2 m/s except for bottle firing stops.

As a rule, the bottle was fired after waiting from the stop for more than 30 seconds and the package was stayed at least 5 seconds for measurement of the SBE 35 at each bottle firing stops. For depths where vertical gradient of water properties was expected to be large (from surface thermocline), the bottle was fired after waiting from the stop fir 60 seconds to changing the water between inside and outside of the bottle. At 200 m from the surface, the package was stopped to stop the heave compensator of the crane.

(4.2) Data Processing

The following are the data processing software (SBEDataProcessing-Win32) and original software data processing module sequence and specifications used in reduction of CTD data in this cruise (the process in order).

DATCNV converted the raw data to engineering unit data. DATCNV also extracts bottle information where scans were marked with the bottle confirm bit during acquisition. The scan duration to be included in bottle file was set to 4.4 seconds, and the offset was set to 0.0 seconds. The hysteresis correction for the SBE 43 data (voltage) was applied for both profile and bottle information data.

TCORP (original module, version 1.1) corrected the pressure sensitivity of the primary temperature (SBE3) sensor for both profile and bottle information data.

RINKOCOR (original module, 1.0) corrected the time-dependent, pressure-induced effect (hysteresis) of the RINKOIII profile data.

RINKOCORROS (original module) corrected the time-dependent, pressure-induced effect (hysteresis) of the RINKOIII bottle information data by using the hysteresis-corrected profile data.

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

ALIGNCTD converted the time-sequence of sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9plus CTD with the ducted temperature and conductivity sensors and a 3000-rpm pump, the typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit was set to advance the primary and the secondary conductivity for 1.73 scans (1.75/24 = 0.073 seconds). Oxygen data are also systematically delayed with respect to depth mainly because of the long-time constant of the oxygen sensor and of an additional delay from the transit time of water in the pumped plumbing line. This delay was compensated by 6 seconds advancing the SBE 43 oxygen sensor output (voltage) relative to the temperature data. Delay of the RINKO III data was also compensated by 1 second advancing sensor output (voltage) relative to the temperature data. Delay of the transmissometer data was also compensated by 2 seconds advancing sensor output (voltage) relative to the temperature data.

WILDEDIT marked extreme outliers in the data files. The first pass of WILDEDIT obtained the accurate estimate of the true standard deviation of the data. The data were read in blocks of 1000 scans. Data greater than 10 standard deviations were flagged. The second pass computed a standard deviation over the same 1000 scans excluding the flagged values. Values greater than 20 standard deviations were marked bad. This process was applied to pressure, depth, temperature, conductivity, and SBE 43 output.

CELLTM used a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. Typical values for SBE 9plus with TC duct and 3000 rpm pump which were 0.03 for thermal anomaly amplitude alpha and 7.0 for the time constant 1/beta were used.

FILTER performed a low-pass filter on pressure and depth 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 performed as a median filter to remove spikes in transmissometer data, fluorometer data, turbidity meter data, and ultraviolet fluorometer data. A median value was determined by 49 scans of the window.

SECTIONU (original module, version 1.1) selected a time span of data based on scan number in order to reduce a file size. The minimum number was set to be the starting time when the CTD package was beneath the sea-surface after activation of the pump. The maximum number was set to be the end time when the depth of the package was 1 dbar below the surface. The minimum and maximum numbers were automatically calculated in the module.

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

DESPIKE (original module, version 1.0) removed spikes of the data. A median and mean absolute deviation was calculated in 1-dbar pressure bins for both down and up cast, excluding the flagged values. Values greater than 4 mean absolute deviations from the median were marked bad for each bin. This process was performed twice for temperature, conductivity and RINKOIII output.

DERIVE was used to compute dissolved oxygen (SBE43), salinity, potential temperature, and sigma-theta.

BINAVG averaged the data into 1-decibar pressure bins and 1-sec time bins. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center values plus and minus half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data recorded exist every dbar.

BOTTOMCUT (original module, version 0.1) deleted the deepest pressure bin when the averaged scan number of the deepest bin was smaller than the average scan number of the bin just above.

SPLIT was used to split data into down cast and up cast.

(4.3) Data collection problems

At the first cast of this cruise (station 002), CTD real-time data acquisition was lost at about 733 dbar of the down cast, and was lost again at about 820 dbar of the down cast of the second try after replacing the RS-232C cable connecting between the deck unit and PC. The third try (CTD cast 002M001) was carried out without any problem by disconnecting a power supply cable, which was connected to auxiliary port of SBE 9plus for the data logger.

At CTD cast 003M001, the data logger was attached to the CTD system by suppling power from an external battery for the refractive index density sensor by using a Y-cable. However, the fuse on the external battery blew during the down cast, and the data logging stopped for the refractive index density sensor and the data logger after that. Therefore, after the cast, the fuse was replaced and the data logger was removed from the CTD system.

At CTD cast 006M003, the data logger was attached to the CTD system by suppling power from the external battery and by connecting only the pressure sensor (UNIK5000) and the fluorometer/turbidity meter (ACLD70). However, the fuse on the external battery blew again during the down cast, and the data logging stopped for the refractive index density sensor and the data logger after that. Therefore, after the cast, the fuse was replaced and the pressure sensor and its cable were removed from the data logger and the other serial sensors (AROD-FT and MPE-PAR) were connected to the data logger.

At CTD cast 006M006 (a test cast), the data logger was attached to the CTD system by suppling power from SBE 9plus and the cable for the pressure sensor (UNIK5000) was connected to the data logger without the pressure senor. CTD real-time data acquisition was lost again at about 1140 dbar of the down cast, and the cast was aborted. The cables that were causing the problem were replaced and the CTD casts with the data logger and additional sensors were carried out without any problem after that.

At CTD cast 006M008, there was no data for the refractive index density sensor due to unknown problem.

Detailed information about the irregularities in data (noise, spike or shift, etc.) is recorded in remarks sheet included in data submission. The definitions of these irregularities are as follows:

Noise: not singly but continuously detected outliers.

Spike: one-off outlier which is detected after data processing and is oceanographically impossible.

Shift: continuous data trend which is deviated from accurate ones.

(5) Station list

The CTD casts conducted in this cruise were listed in Table 2.3.1-1.

Table 2.3.1-1. CTD cast table.

MR24-07 Leg1 CTD cast table

Stnnbr	Castno	Date(UTC)	Time(UTC)		BottomPosition		Depth	Wire	HT Above	Max	Max	CTD	Remark
		(mmddyy)	Start	End	Latitude	Longitude	(m)	Out (m)	Bottom (m)	Depth	Pressure	Filename	
002	001	100724	08:46	11:47	52-46.98N	177-42.22W	3667.0	3659.9	9.9	3651.2	3716.0	002M001	
003	001	100824	08:23	11:18	52-47.90N	175-43.83E	3923.0	3915.1	9.4	3905.3	3977.0	003M001	
004	001	100924	03:41	07:54	51-05.81N	173-31.70E	5906.0	5901.7	8.9	5890.4	6025.0	004M001	
005	001	101024	13:06	16:43	47-00.18N	169-59.98E	4986.0	4971.2	9.4	4959.3	5060.0	005M001	
005	002	101124	01:06	02:45	47-00.17N	170-00.00E	4968.0	1975.7	-	1974.9	2001.0	005M002	
006	001	101624	21:09	00:48	46-59.98N	159-59.97E	5188.0	5181.2	8.6	5171.5	5279.0	006M001	
006	002	101724	16:12	17:09	47-00.00N	159-59.88E	5186.0	292.9	-	297.3	300.0	006M002	
006	003	101724	21:07	00:18	47-00.00N	160-00.02E	5191.0	5177.9	9.6	5167.6	5275.0	006M003	
006	004	101924	00:06	00:33	46-59.94N	159-59.99E	5188.0	293.3	-	297.3	300.0	006M004	
006	005	101924	03:10	03:59	47-00.00N	160-00.00E	5188.0	1186.3	-	1187.6	1201.0	006M005	
006	007	102124	04:24	05:11	47-00.00N	159-59.99E	5185.0	1481.8	-	1483.2	1501.0	006M007	
006	008	102124	05:44	06:26	47-00.01N	160-00.01E	5186.0	290.9	-	297.3	300.0	006M008	
007	001	102324	00:37	04:24	44-00.10N	155-00.04E	5319.0	5297.1	9.2	5291.0	5401.0	007M001	
007	002	102324	07:39	09:26	43-59.98N	155-00.02E	5320.0	2003.5	-	2000.1	2026.0	007M002	
008	001	102524	06:29	10:38	41-53.31N	146-18.60E	6837.0	6048.7	-	5998.6	6132.0	008M001	

(6) References

Uchida H., Y. Kayukawa, and Y. Maeda (2019): Ultra high-resolution seawater density sensor based on a refractive index measurement using the spectroscopic interference method. Sci. Rep., 9:15482, doi:10.1038/s41598-019-52020-z.

Uchida, H., Y. Maeda, and S. Kawamata (2018): Compact underwater slip ring swivel: Minimizing effect of CTD package rotation on data quality, Sea Technology, 11, 30–32.

(7) Data archive

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

2.3.2 Salinity

Hiroshi UCHIDA (JAMSTEC)

(1) Objective

Bottle salinities were measured to calibrate the CTD and thermo-salinograph salinity data and to collect backet sampling salinity data. Salinity samples collected by the Remote Automatic Sampler (RAS) were also measured.

(2) Instruments and method

Salinity measurement was conducted basically based on the method by Kawano (2010) with modification of the time drift correction method (Uchida et al., 2020). Materials used in this cruise are as follows:

Standard Seawater: IAPSO Standard Seawater, Ocean Scientific International Ltd., Hampshire, UK
Batch P166
Salinometer: Autosal model 8400B; Guildline Instruments, Ltd., Ontario, Canada
Serial no. 62556
A peristaltic-type sample intake pump: Ocean Scientific International Ltd.
Thermometers: PRT model 1502A, Fluke Co., Everett, Washington, USA
Serial no. B81550 (for monitoring the bath temperature)
Serial no. B78466 (for monitoring the room temperature)
Stabilized power supply: model PCR1000LE, Kikusui Electronics Co., Japan
Serial no. XH004198
Data acquisition software: Vs8400B, Virtual Systems Co., Japan
Version 1.05T, Rev.02
Sample bottles:
250 mL brown borosilicate glass bottles with translucent screw caps (PTFE packing)
Used 200 mL borosilicate glass bottles for IAPSO SSW (for MR24-06C samples)
Secondary Standard Seawater: Multiparametric Standard Seawater, KANSO TECHNOS Co., Ltd.
Lot PRE20, PRE21

The bath temperature of the salinometer was set to 24 °C. The salinometer was standardized previously by using the IAPSO Standard Seawater (SSW). The standardization dial was set to 601 for serial no. 62556 and never changed during the cruise. The mean with standard deviation of the STANDBY, ZERO value, the bath temperature, and the ambient temperature was listed in Table 2.3.2-1.

The double conductivity ratios measured by the salinometer were used to calculate Practical Salinity using the algorithm for Practical Salinity Scale 1978 (IOC et al., 2010). A constant temperature of 24 °C was used in the calculation instead of using the measured bath temperature.

Table 2.3.2-1. Mean with standard deviation of the STANDBY, ZERO, bath temperature and room temperature.

Variable	Salinometer sn. 62556
STANDBY	5127 ± 0.8
ZERO	−0.00001 ± 0.00001
Bath temperature	24.017 ± 0.0007 °C
Room temperature	22.5 ± 0.7 °C

(3) Results

Ultra-pure water (Milli-Q water, Millipore, Billerica, Masachusetts, USA) and the IAPSO SSW were measured at the beginning and the end of the measurements for each day. Time-series of the measured Practical Salinity are shown in Fig. 2.3.2-1. Correction factors of the salinometer were estimated from the mean Practical Salinity value of the SSW measurements and the certified Practical Salinity value for each day (Uchida et al., 2020). The measured Practical Salinities for the water samples were corrected by using the correction factors. The standard deviation of the IAPSO SSW measurements was 0.0001 in Practical Salinity.

A total of 48 pairs of replicate samples was collected and the SD of the replicate samples was 0.00021 in Practical Salinity.

A total of 3 bottles of Multiparametric Standard Seawater (MSSW) lot PRE20 was measured and the mean ± SD was 34.2774 ± 0.0002 in Practical Salinity. Also, one bottle of MSSW lot PRE21 was measured (34.3156 in Practical Salinity).

(4) References

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

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

Uchida, H., T. Kawano, T. Nakano, M. Wakita, T. Tanaka and S. Tanihara (2020): An updated batch-to-batch correction for IAPSO standard seawater. J. Atmos. Oceanic Technol., 37, 1507-1520, doi:10.1175/JTECH-D-19-0184.1.

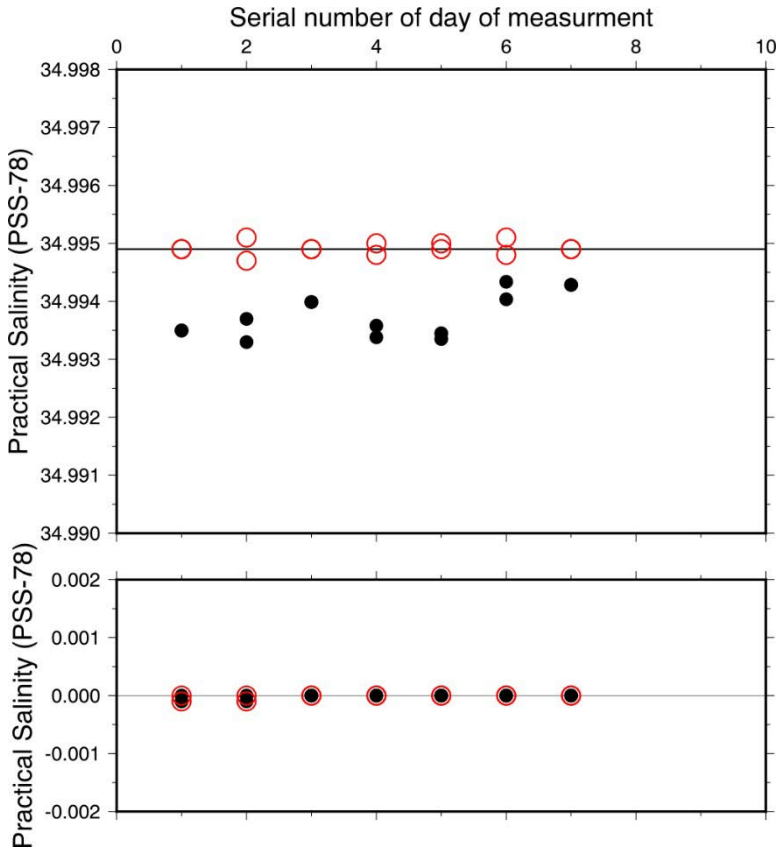


Figure 2.3.2-1. Time-series of the measured Practical Salinities for the ultra-pure water (lower panel) and the IAPSO SSW (upper panel) (black circles). The time-drift corrected Practical Salinities for the IAPSO SSW were also shown (red circles).

(5) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.3.3 Seawater density

Hiroshi UCHIDA (JAMSTEC RIGC)

(1) Objective

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

(2) Instruments and method

Seawater density for water samples was measured with a vibrating-tube density meter (DMA 5000M [serial no. 80570578], Anton-Paar GmbH, Graz, Austria) with a sample changer (Xsample 122 [serial no. 8548492], Anton-Paar GmbH). The sample changer was used to load samples automatically from up to forty-eight 12-mL glass vials.

The water samples collected in 250 mL brown borosilicate glass bottles with translucent screw caps (PTFE packing) for practical salinity measurement were measured by taking the water sample into a 12-mL glass vial for each bottle just before practical salinity measurement. The glass vial was sealed with Parafilm M (Pechiney Plastic Packaging, Inc., Menasha, Wisconsin, USA) immediately after filling. Densities of the samples were measured at 20 °C by the density meter.

The density meter was initially calibrated by measuring air and pure water according to the instrument manual. However, measured density for IAPSO Standard Seawater deviates from density of TEOS-10 calculated from practical salinity and composition of seawater, probably due to non-linearity of the density meter (Uchida et al., 2011). The non-linearity can be corrected by measuring a reference sample simultaneously as:

$$\rho_{corr} = \rho - (\rho_{ref} - \rho_{ref\_true}) + c\,(\rho - \rho_{ref\_true}),$$

where ρ_{corr} is the corrected density of the sample, ρ is measured density of the sample, ρ_{ref} is measured density of the reference, ρ_{ref_true} is true density of the reference, and c is non-linearity correction factor. However, the correction factor may slightly shift with each cruise or slightly drift in time during each measurement day.

Therefore, in this cruise, the non-linearity of the density meter was corrected for time drift uniformly from IAPSO Standard Seawater measurements for each measurement day, regardless of the presence or absence of time drift. Ultra-pure water (Milli-Q water, Millipore, Billerica, Massachusetts, USA) produced on the R/V Mirai was used as reference. Density of the ultra-pura water was estimated to be 998.2041 kg m^{-3} at 20 ºC, and measured at the beginning and the end of each measurement day. IAPSO Standard Seawater batch P166 was used to determine the non-linearity correction factor. Density of batch IAPSO Standard Seawater batch P166 was estimated to be 1024.7640 kg/m^3 from practical salinity and composition changes of Standard Seawater using TEOS-10 (see Uchida et al., 2024), and measured at the beginning and the end of each measurement day. In addition, IAPSO Standard Seawater was also measured every about 20 samples along the way of measurement.

Average with standard deviation for the 29 measurements of the batch P166 was 1024.7639 ± 0.0007 kg/m^3.

A total of 3 bottles of Multiparametric Standard Seawater (MSSW, KANSO TECHNOS Co., Ltd.) lot PRE20 was also measured and the mean ± SD was 1024.2208 ± 0.0004 kg/m^3. And the density of one bottle of MSSW PRE21 was 1024.2475 kg/m^3.

(3) Results

Density salinity ("DNSSAL") can be back calculated from the measured density and temperature (20 °C) with TEOS-10. A total of 28 pairs of replicate samples was measured and the standard deviation of the replicate samples was 0.0014 g/kg. The measured density salinity anomalies (δS_A) are shown in Fig. 2.3.3-1. The measured δS_A were well agree with the δS_A estimated from Pawlowicz et al. (2011) which exploits the correlation between δS_A and nutrient concentrations and carbonate system parameters based on mathematical investigation using a model relating composition, conductivity and density of arbitrary seawaters.

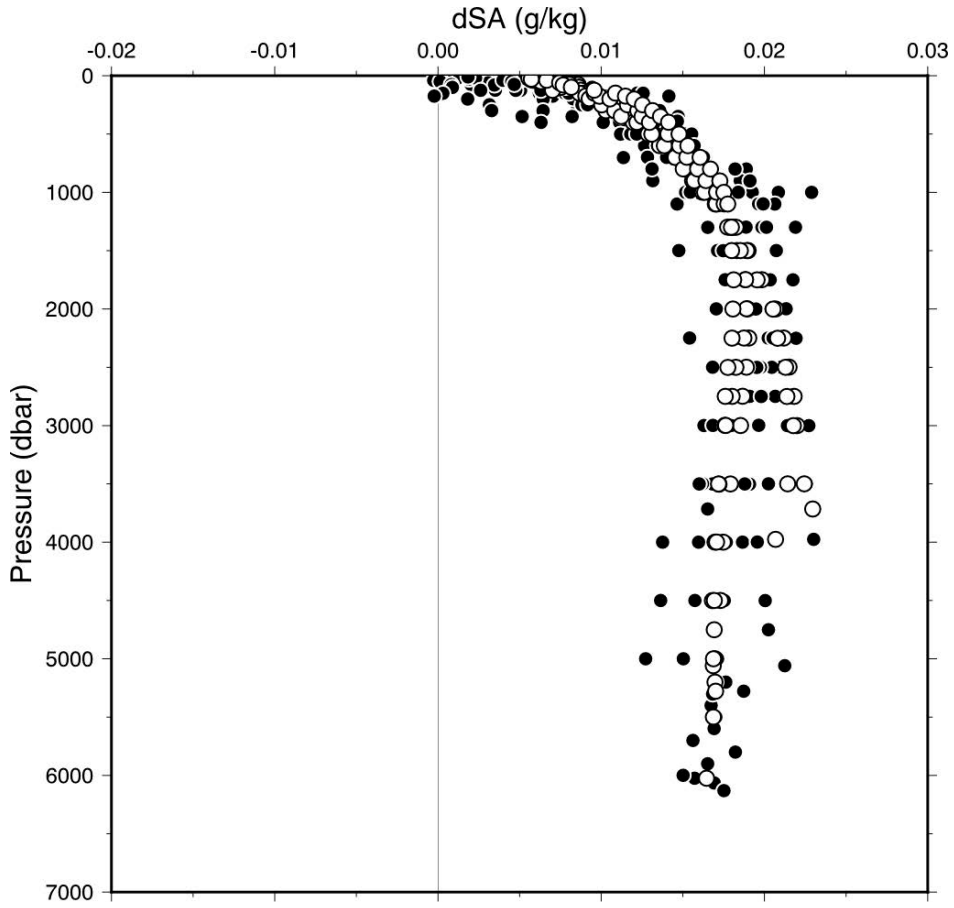


Figure 2.3.3-1. Vertical distribution of density salinity anomaly measured by the density meter (closed circles). Absolute salinity anomaly estimated from nutrients and carbonate system parameters (Pawlowicz et al., 2011) are also shown (open circles), except for stations 007 and 008 because total alkalinity data is not yet available for these stations.

(4) References

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

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

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

Uchida, H., M. Wakita, A. Makabe, A. Murata and A. Petrovic (2024): Changes of the composition of International Association for the Physical and Sciences of the Ocean standard seawater. In: Aoyama M., Murata A., Cheong C., editors. Chemical Reference Materials for Oceanography: History, Production and Certification. Springer Nature, Singapore (in press).

(5) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.3.4 Ocean turbulence

Shinya KOUKETSU (JAMSTEC RIGC) (not onboard)
Hiroshi UCHIDA, (JAMSTEC RIGC)
Tun HTET AUNG (MWJ)
Rei ITO (MWJ)
Aine YODA (MWJ)

(1) Objective

The objective is to measure microstructure in temperature to evaluate ocean mixing.

(2) Instruments and method

Microstructure observations were carried out by MR6000 (Rockland Scientific International Inc.), which were mounted on the CTD rosette and were powered from the CTD (SBE 9plus). We installed two fast response thermistors (FP07) on MR6000 to measure microstructure in temperature. We had to replace probes, as some of the probes failed during the cruise. Low-frequency profiles of temperature and conductivity were recorded in MR6000 with the input from the SBE-3 sensors on the CTD system. We downloaded the raw data from the instruments after each cast. We plan to examine methods for calibration and quality check of the data after the cruise.

(2) Measurements

Microstructure measurements were conducted by using the following thermistors (FP07):

Sensor socket 1: T1973
Sensor socket 2: T2787

(3) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.3.5 Lowered ADCP

Shinya KOUKETSU (JAMSTEC RIGC) (not onboard)
Hiroshi UCHIDA, (JAMSTEC RIGC)
Tun HTET AUNG (MWJ)
Rei ITO (MWJ)
Aine YODA (MWJ)

(1) Overview of the equipment

Two acoustic Doppler current profilers (ADCP) were integrated with the CTD/RMS package. The lowered ADCP (LADCP)s, Workhorse Monitor WHM300 (Teledyne RD Instruments, San Diego, California, USA), which has 4 facing transducers with 20-degree beam angles, rated to 6000 m, make direct current measurements at the depth of the CTD, thus providing a full profile of velocity. The LADCPs were powered during the CTD casts by a 48 volts battery pack. The LADCP unit was set for recording internally prior to each cast. After each cast the internally stored observed data were downloaded to the computer in the onboard laboratory. After the cruise, by combining the measured velocity of the sea water and ocean bottom relative to the instrument, shipboard navigation data, and pressure time series from the CTD, the absolute velocity profiles will be obtained with the software implemented by A.Thunherr. The software is based on the method of Visbeck (2002) and available online at ftp://ftp.ldeo.columbia.edu/pub/LADCP.

The instruments used in this cruise were as follows.

WHM300 (serial no. 24545; downward)
WHM300 (serial no. 20754; upward)

(2) Data collection

In this cruise, data were collected with the following configuration.

Bin size: 8.0 m
Number of bins: 12

(3) Reference

Visbeck, M. (2002): Deep velocity profiling using Lowered Acoustic Doppler Current Profilers: Bottom track and inverse solutions. *J. Atmos. Oceanic Technol.*, **19**, 794-807.

(4) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.3.6 Shipboard ADCP

Katsunori KIMOTO (JAMSTEC) – PI
Masahide WAKITA (JAMSTEC)
Ryo OYAMA (NME)
Seika TAKAI (NME)
Masanori MURAKAMI (MIRAI crew)

(1) Objectives

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

(2) Instruments and methods

Upper ocean current measurements were made during this cruise, using the hull-mounted Acoustic Doppler Current Profiler (ADCP) system. For most of its operation, the instrument was configured for water-tracking mode. Bottom-tracking mode, interleaved bottom-ping with water-ping, was made to get the calibration data for evaluating transducer misalignment angle in the shallow water. Major parameters for the measurement, Direct Command, are shown in Table 2.3.5-1. The system consists of following components;

i) R/V MIRAI has installed the Ocean Surveyor for vessel-mount ADCP (frequency 76.8 kHz; Teledyne RD Instruments, USA). It has a phased-array transducer with single ceramic assembly and creates 4 acoustic beams electronically. We mounted the transducer head rotated to a ship-relative angle of 45 degrees azimuth from the keel.

ii) For heading source, we use ship's gyro compass (Tokyo Keiki, Japan), continuously providing heading to the ADCP system directory. Additionally, we have Inertial Navigation Unit (Phins, Ixblue, France) which provide high-precision heading, attitude information, pitch and roll. They are stored in ".N2R" data files with a time stamp.

iii) Differential GNSS system (StarPack-D, Fugro, Netherlands) providing precise ship's position.

iv) We used VmDas software version 1.50.19 (TRDI) for data acquisition.

v) To synchronize time stamp of ping with Computer time, the clock of the logging computer is adjusted to GPS time server by using NTP (Network Time Protocol).

vi) Fresh water is charged in the sea chest to prevent bio fouling at transducer face.

vii) The sound speed at the transducer does affect the vertical bin mapping and vertical velocity measurement, and that is calculated from temperature, salinity (constant value; 35.0 PSU) and depth (6.5 m; transducer depth) by equation in Medwin (1975).

viii) Data were configured for “8 m” layer intervals starting about 19m below sea surface. Data were recorded every ping as raw ensemble data (.ENR). Additionally, 15 seconds averaged data were recorded as short-term average (.STA). 300 seconds averaged data were long-term average (.LTA), respectively.

Table 2.3.6-1 Major parameters

Bottom-Track Commands	
BP = 001	Pings per Ensemble (almost less than 1,300m depth)
Environmental Sensor Commands	
EA = 04500	Heading Alignment (1/100 deg)
ED = 00065	Transducer Depth (0 - 65535 dm)
EF = +001	Pitch/Roll Divisor/Multiplier (pos/neg) [1/99 - 99]
EH = 00000	Heading (1/100 deg)
ES = 35	Salinity (0-40 pp thousand)
EX = 00000	Coordinate Transform (Xform:Type; Tilts; 3Bm; Map)
EZ = 10200010	Sensor Source (C; D; H; P; R; S; T; U)
	C (1): Sound velocity calculates using ED, ES, ET (temp.)
	D (0): Manual ED
	H (2): External synchro
	P (0), R (0): Manual EP, ER (0 degree)
	S (0): Manual ES
	T (1): Internal transducer sensor
	U (0): Manual EU
EV = 0	Heading Bias(1/100 deg)
Timing Commands	
TE = 00:00:02.00	Time per Ensemble (hrs:min:sec.sec/100)
TP = 00:02.00	Time per Ping (min:sec.sec/100)
Water-Track Commands	
WA = 255	False Target Threshold (Max) (0-255 count)
WC = 120	Low Correlation Threshold (0-255)
WD = 111 100 000	Data Out (V; C; A; PG; St; Vsum; Vsum^2; #G; P0)
WE = 1000	Error Velocity Threshold (0-5000 mm/s)

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

(3) Preliminary results

Horizontal velocity along the ship's track is shown in Fig. 2.3.5-1. In vertical direction, the data are averaged from 34 to 58m

(4) Data archives

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

< https://www.godac.jamstec.go.jp/darwin/en >

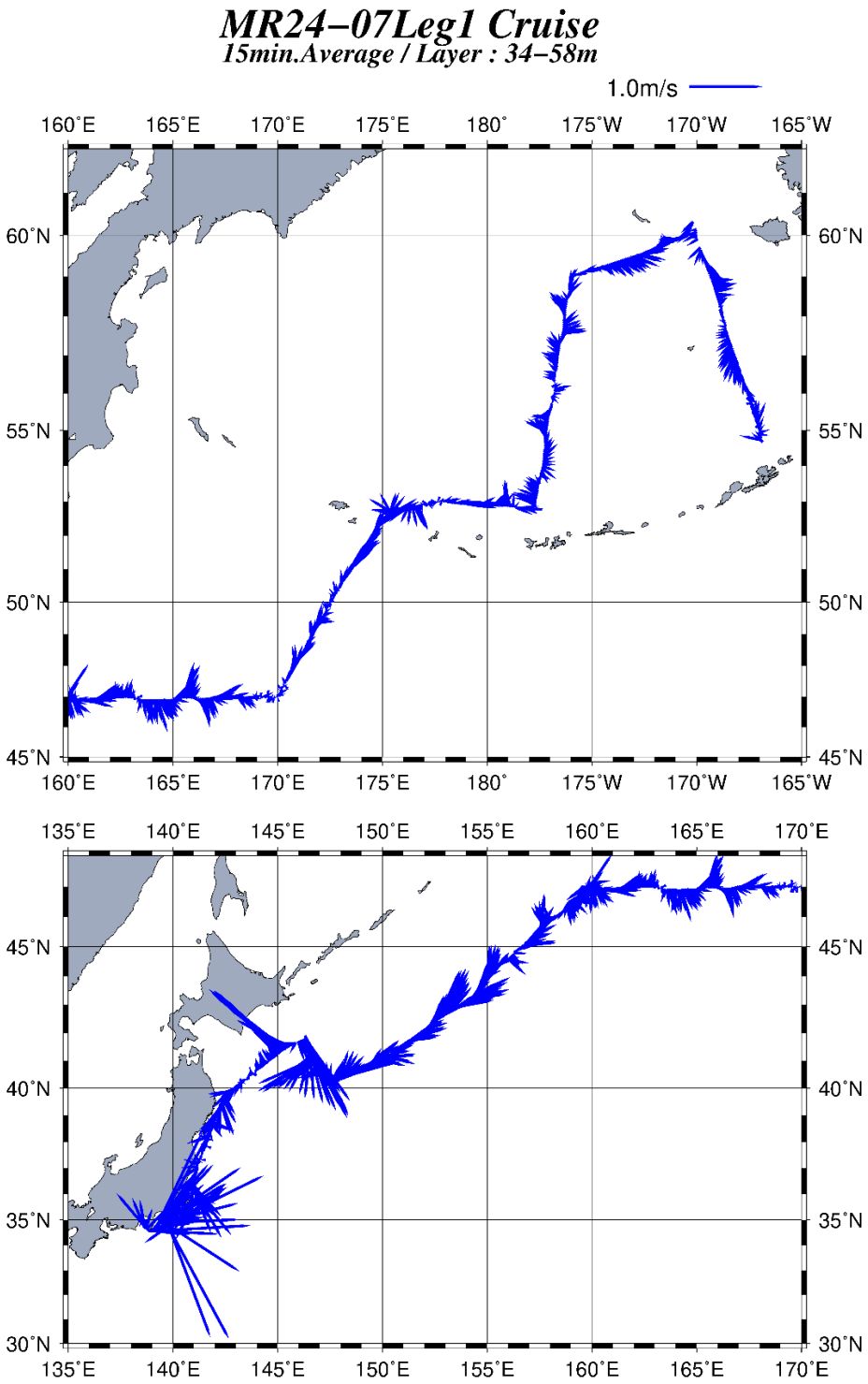


Fig. 2.3.6-1. Horizontal velocity along the ship's track of this cruise.
(15 min. Average / Layer: 34-58m)

2.4 Chemical Oceanography
2.4.1 Surface water properties
2.4.1.1. DIC

Akihiko MURATA (JAMSTEC): PI
Nagisa FUJIKI (MWJ)
Yasuhiro ARII (MWJ)

(1) Objective

To elucidate spatial variations of total dissolved inorganic carbon (DIC) concentration in sea surface water in the North Pacific.

(2) Instruments and Methods

Surface seawater was continuously during the cruise. Surface seawater was taken from an intake placed at the approximately 4.5 m below the sea surface by a pump, and was filled in a 250 mL glass bottle (SCHOTT DURAN) from the bottom, without rinsing, and overflowed for more than 2 times the amount. Before the analysis, the samples were put in the water bath kept about 20°C for one hour. Measurements of DIC were made with total CO_2 measuring system (Nihon ANS Inc.). The system was comprised of seawater dispensing unit, a CO_2 extraction unit, and a coulometer (Model 3000A, Nihon ANS Inc.). The seawater dispensing unit has an auto-sampler (6 ports), which dispenses the seawater from a glass bottle to a pipette of nominal 15 mL volume. The pipette was kept at 20.00 °C ± 0.05 °C by a water jacket, in which water circulated through a thermostatic water bath. The CO_2 dissolved in a seawater sample is extracted in a stripping chamber of the CO_2 extraction unit by adding 10 % phosphoric acid solution. The stripping chamber is made approx. 25 cm long and has a fine frit at the bottom. First, the certain amount of acid is taken to the constant volume tube from an acid bottle and transferred to the stripping chamber from its bottom by nitrogen gas (99.9999 %). Second, a seawater sample kept in a pipette is introduced to the stripping chamber by the same method as that for an acid. The seawater and phosphoric acid are stirred by the nitrogen bubbles through a fine frit at the bottom of the stripping chamber. The stripped CO_2 is carried to the coulometer through two electric dehumidifiers (kept at 2 °C) and a chemical desiccant (Magnesium perchlorate) by the nitrogen gas (flow rate of 140 mL min^{-1}). Measurements of approx.1.5 % CO_2 standard gas in a nitrogen base, system blank (phosphoric acid blank), and seawater samples (6 samples) were programmed to repeat. Both CO_2 standard gas and blank signals were used to correct the signal drift results from chemical alternation of coulometer solutions. The coulometer solutions were renewed every about 2 days, and an in-house reference material (RM, batch QRM Q43) was measured to correct systematic difference between measurements. The reported values are corrected by RM of Scripps Institution of Oceanography (batch #217).

(3) Results

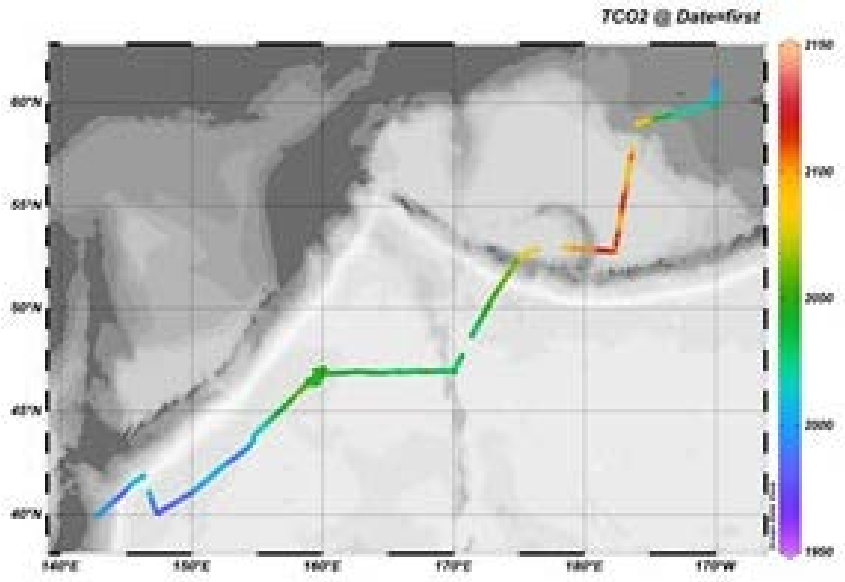


Fig. 2.4.1.1-1 Distributions of surface seawater DIC observed along the cruise track of the leg 1 of MR24-07.

2.4.1.2. pCO_2

Akihiko MURATA (JAMSTEC): PI
Yasuhiro ARII (MWJ)
Nagisa FUJIKI (MWJ)

(1) Objective

Concentrations of CO_2 in the atmosphere are now increasing at a rate of about 2.0 ppmv y^{-1} owing to human activities such as burning of fossil fuels, deforestation, and cement production. It is an urgent task to estimate as accurately as possible the absorption capacity of the oceans against the increased atmospheric CO_2, and to clarify the mechanism of the CO_2 absorption, because the magnitude of the anticipated global warming depends on the levels of CO_2 in the atmosphere, and because the ocean currently absorbs 1/3 of the 6 Gt of carbon emitted into the atmosphere each year by human activities.

In this cruise, we measured pCO_2 (partial pressure of CO_2) in the atmosphere and surface seawater continuously along cruise tracks in the North Pacific in order to quantify how much CO_2 is absorbed in the region. During the operation of the system, atmospheric and surface seawater pCH_4 were also measured.

(2) Apparatus

Atmospheric and surface seawater pCO_2 were measured with a system having the off-axis integrated-cavity output spectroscopy gas analyzer (Off-Axis ICOS; 911-0011, Los Gatos Research). Standard gases were measured every about 12 hours, and atmospheric air taken from the bow of the ship (approx.13 m above the sea level) were measured every about 3 hours. Seawater was taken from an intake placed at the approximately 4.5 m below the sea surface and introduced into the equilibrator at the flow rate of (4 - 5) L min^{-1} by a pump. The equilibrated air was circulated in a closed loop by a pump at flow rate of (0.6 - 0.7) L min^{-1} through two electric cooling units, a starling cooler, and the Off-Axis ICOS.

(3) Results

Concentrations of CO_2 (xCO_2) of marine air and surface seawater are shown in Fig. 3.4.1, together with SST.

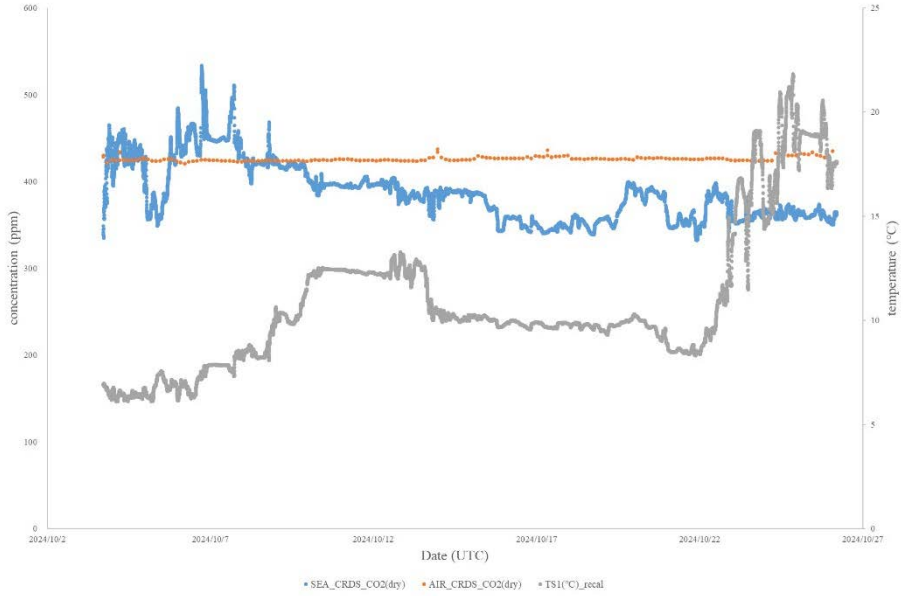


Fig. 2.4.1.2-1 Preliminary results of concentrations of CO_2 (xCO_2) in atmosphere (orange) and surface seawater (blue), and SST (grey) observed along the cruise track of the leg 1 of MR24-07.

2.4.1.3 Density and FDOM

Hiroshi UCHIDA (JAMSTEC RIGC)
Misato KUWAHARA (MWJ)

(1) Objective

The objective of this study is to examine effect of river water on surface seawater by measuring density and fluorescent dissolved organic matter (FDOM).

(2) Instruments and method

Seawater density was measured with a refractive index density sensor (Uchida et al., 2019) by attaching the density sensor to the Continuous Sea Surface Water Monitoring System (downstream of SBE 45). FDOM was also measured with an UV fluorometer (serial no. 6262, gain setting was 30X [0-50 QSU], Seapoint Sensors, Inc.) by attaching the fluorometer to the system (downstream of the density sensor). The raw data from the density sensor and temperature measured inside the spectroscope of the density sensor were recorded with a data logger (JAMSTEC) at a sampling rate of 1 Hz. The analogue output of voltage (0-5 V) from the fluorometer was also recorded with the data logger by using a 16-bit A/D converter at a sampling rate of 1 Hz.

To calibrate the density sensor, the density of seawater samples, which were collected once a day for correction of the conductivity sensor of the Continuous Sea Surface Water Monitoring System, was measured. Details of the density measurements for the seawater samples are described elsewhere in this cruise report.

(3) Reference

Uchida, H., Y. Kayukawa, and Y. Maeda (2019): Ultra high-resolution seawater density sensor based on a refractive index measurement using the spectroscopic interference method. Sci. Rep., 9:15482, doi:10.1038/s41598-019-52020-z.

(4) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.4.2 DO

Masahide Wakita (JAMSTEC): Principal Investigator
Misato Kuwahara (MWJ): Operation Leader
Yasuhiro Arii (MWJ)
Takuya Izutsu (MWJ)

(1) Objective

Determination of dissolved oxygen in seawater by Winkler titration.

(2) Parameters

Dissolved Oxygen

(3) Instruments and Methods

Following procedure is based on winkler method (Dickson, 1996; Culberson, 1991).

a. Instruments

Burette for sodium thiosulfate and potassium iodate;
Automatic piston burette (APB-510 / APB-620) manufactured by Kyoto Electronics Manufacturing Co., Ltd. / 10 cm^3 of titration vessel
Detector;
Automatic photometric titrator (DOT-15X) manufactured by Kimoto Electric Co., Ltd.
Software;
DOT_Terminal Ver. 1.3.1

b. Reagents

Pickling Reagent I:
Manganese (II) 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})

c. Sampling

Seawater samples were collected with 12 Liter water sampling bottles attached to the CTD/Carousel Water Sampling System (CTD system). Seawater for oxygen measurement was transferred from the bottle to a volume calibrated flask (ca. 100 cm^3), and two times volume of the flask was overflowed. Temperature was simultaneously measured by digital thermometer during the overflowing. After transferring the sample, two reagent solutions (Reagent I and II) of 1 cm^3 each were added immediately 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

For over two hours after the re-shaking, the pickled samples were measured on board. Sulfuric acid solution with its volume of 1 cm^3 and a magnetic stirrer bar were put into the sample flask and the sample was stirred. The 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. Dissolved oxygen concentration (μmol kg^{-1}) was calculated by sample temperature during seawater sampling, salinity of the sensor on CTD system, flask volume, and titrated volume of sodium thiosulfate solution without the blank. During this cruise, 2 sets of the titration apparatus were used.

e. Standardization and determination of the blank

Concentration of sodium thiosulfate titrant was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130 ºC, and 1.7835 g of it was dissolved in deionized water and diluted to final weight of 5 kg in a flask. After 10 cm^3 of the standard potassium iodate solution was added to an another flask using a volume-calibrated dispenser, 90 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 1 cm^3 of pickling reagent solution II and I were added in order. Amount of titrated volume of sodium thiosulfate for this diluted standard potassium iodate solution (usually 5 times measurements average) gave the morality of sodium thiosulfate titrant.

The oxygen in the pickling reagents I (1 cm^3) and II (1 cm^3) was assumed to be 7.6 × 10^{-8} mol (Murray et al., 1968). The blank due to other than oxygen was determined as follows. First, 1 and 2 cm^3 of the standard potassium iodate solution were added to each flask using a calibrated dispenser. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, 1 cm^3 of pickling II reagent solution, and same volume of pickling I reagent solution were added into the flask in order. The blank was determined by difference between the first (1 cm^3 of potassium iodate) titrated volume of the sodium thiosulfate and the second (2 cm^3 of potassium iodate) one. The titrations were conducted for 3 times and their average was used as the blank value.

(4) Observation log

a. Standardization and determination of the blank

Table 2.4.2-1 shows results of the standardization and the blank determination during this cruise.

Table 2.4.2-1 Results of the standardization and the blank determinations during cruise

Date (yyyy/mm/dd)	Potassium iodate ID	Sodium thiosulfate ID	DOT-15X (No.10)		Stations
			E.P. (cm^3)	Blank (cm^3)	
2024/10/02	K23E06	T-24B	3.968	0.000	
2024/10/08	K23E05	T-24B	3.970	0.002	002M001 003M001 004M001 005M001
2024/10/11	K23E07	T-24B	3.969	0.001	
2024/10/16	K23E08	T-24B	3.969	0.001	006M001 006M002 006M003
2024/10/20	K23E09	T-24B	3.968	0.000	006M008
2024/10/24	K23E10	T-24B	3.967	0.002	007M001 007M002 008M001
2024/10/26	K23F01	T-24B	3.968	0.000	

b. Repeatability of sample measurement

Replicate samples were taken at every CTD casts. The standard deviation of the replicate measurement (Dickson et al., 2007) was 0.12 μmol kg^{-1} (n=34).

(5) Data archives

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

(6) References

Culberson, C. H. (1991). *Dissolved Oxygen.* WHPO Publication 91-1.

Dickson, A. G. (1996). Determination of dissolved oxygen in sea water by Winkler titration. In *WOCE Operations Manual*, Part 3.1.3 Operations & Methods, WHP Office Report WHPO 91-1.

Dickson, A. G., Sabine, C. L., & Christian, J. R.(Eds.), (2007). *Guide to best practices for ocean CO_2 measurements, PICES Special Publication 3*: North Pacific Marine Science Organization.

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

2.4.3 Nutrient

Masahide WAKITA (JAMSTEC): Principal Investigator
Yuko MIYOSHI (MWJ): Operation Leader
Kengo FUJITA (MWJ)

(1) Objectives

The objective of this document is to show the present status of the nutrient measurement during the R/V MIRAI MR24-07Leg1 cruise (EXPOCODE: 49NZ20241002) in the North Pacific Ocean and Bering Sea.

(2) Parameters

The parameters are nitrate, nitrite, silicate, phosphate, and ammonia in seawater.

(3) Instruments and methods

The analytical platform was replaced from QuAAtro 2-HR to QuAAtro 39 in March 2021. However, since this replacement, several issues for the QuAAtro 39 system have been reported (see the cruise report of MR21-05C). In July 2022, to improve those issues and the analytical precisions, (1) their pumps were replaced from the 13-tube pump (model number: 166+B214-01, BL TEC K.K.) to the 14-tube pump (model number: TRA+B014-02, BL TEC K.K.), (2) their motor brackets were replaced to the new type that is a stainless model (model number: Motor-Braket-01-Rev-1 and Motor-Braket-02-Rev-1, BL TEC K.K.), and (3) their light source units were fixed firmly to reduce vibration. The modified platform is called “QuAAtro 39-J” and was employed in this cruise.

The modification of analytical methods for four parameters, nitrate, nitrite, silicate, and phosphate, which were employed in this cruise, are compatible with the methods described in the GO-SHIP repeat hydrography nutrients manual (Hydes et al., 2010; Becker et al., 2019). The analytical method of ammonium is compatible with the method using a vaporization membrane permeability method (Kimura, 2000).

(4.1) Nitrate + nitrite and nitrite

Nitrate + nitrite and nitrite were analyzed by the following methodology that was modified from the original method of Grasshoff (1976). The flow diagrams are shown in Fig. 2.4.3.1 for nitrate + nitrite and Fig. 2.4.3.2 for nitrite. For the nitrate + nitrite analysis, the samples were mixed with the alkaline buffer (Imidazole) and then the mixture was pushed through a cadmium coil which was coated with a metallic copper. This step was conducted due to the reduction from nitrate to nitrite in the sample, which allowed us to determine nitrate + nitrite in the seawater sample. For the nitrite analysis, the sample was mixed with reagents without this reduction step. In the flow system, the seawater sample with or without the reduction step was mixed with an acidic sulfanilamide reagent through a mixing coil to produce a diazonium ion. And then, the mixture was mixed with the N-1-naphthylethylenediamine dihydrochloride (NED) to produce a red azo dye. The azo dye compound was injected into the spectrophotometric

detection to monitor the signal at 545 nm. Thus, for the nitrite analysis, the sample was determined without passing through the Cd coil. Nitrate was computed by the difference in concentrations between nitrate + nitrite and nitrite.

Reagents

a) 50 % Triton solution: 50 mL of Triton® X-100 (CAS No. 9002-93-1) was mixed with 50 mL of ethanol (99.5 %).
b) Imidazole (buffer), 0.06 M (0.4 % w/v): Dissolved 4 g of the imidazole (CAS No. 288-32-4) in 1000 mL ultra-pure water, and then added 2 mL of the hydrogen chloride (CAS No. 7647-01-0). After mixing, 1 mL of the 50 % triton solution was added.
c) Sulfanilamide, 0.06 M (1 % w/v) in 1.2 M HCl: Dissolved 10 g of 4-aminobenzenesulfonamide (CAS No. 63-74-1) in 900 mL of ultra-pure water, and then add 100 mL of the hydrogen chloride (CAS No. 7647-01-0). After mixing, 2 mL of the 50 % triton solution was added.
d) NED, 0.004 M (0.1 % w/v): Dissolved 1 g of N-(1-naphthalenyl)-1,2-ethanediamine dihydrochloride (CAS No. 1465-25-4) in 1000 mL of ultra-pure water and then added 10 mL of hydrogen chloride (CAS No. 7647-01-0). After mixing, 1 mL of the 50 % triton solution was added. This reagent was stored in a dark bottle.

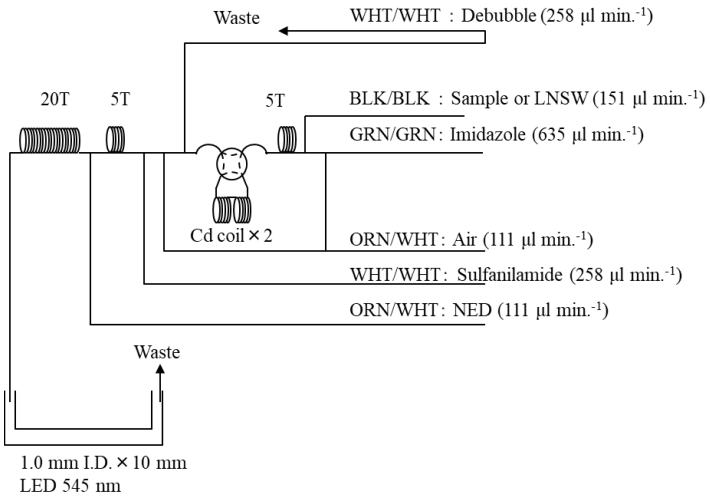


Figure 2.4.3.1 NO_3+NO_2 (1ch.) flow diagram.

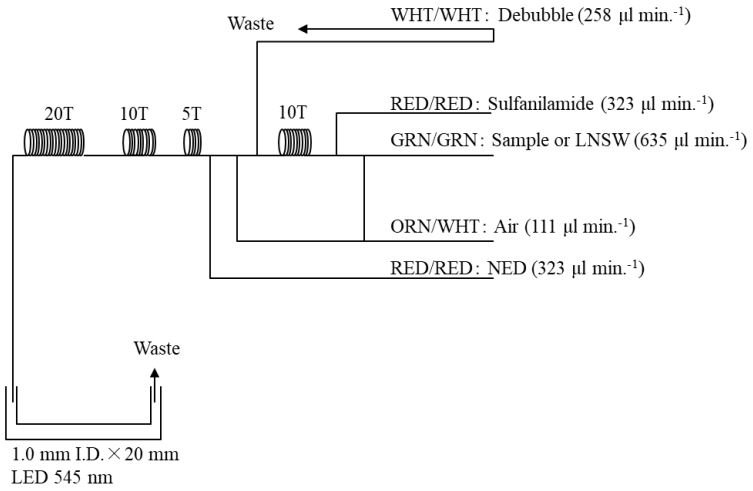


Figure 2.4.3.2 NO_2 (2ch.) flow diagram.

(4.2) Silicate

The method for silicate is analogous to that described for phosphate (4.3). The method is essentially that of Grasshoff et al. (1999). The flow diagrams are shown in Fig. 2.4.3.3. Silicomolybdic acid compound was first formed by mixing silicate in the sample with the molybdic acid. The silicomolybdic acid compound was then reduced to silicomolybdous acid, "molybdenum blue," using L-ascorbic acid as the reductant. And then the signal was monitored at 630 nm.

Reagents

a) 15 % Sodium dodecyl sulfate solution: 75 g of sodium dodecyl sulfate (CAS No. 151-21-3) was mixed with 425 mL ultra-pure water.
b) Molybdic acid, 0.03 M (1 % w/v): Dissolved 7.5 g of sodium molybdate dihydrate (CAS No. 10102-40-6) in 980 mL ultra-pure water, and then added 12 mL of 4.5M sulfuric acid. After mixing, 20 mL of the 15 % sodium dodecyl sulfate solution was added. Note that the amount of sulfuric acid was reduced from the previous report (MR19-03C) since we have modified the method of Grasshoff et al. (1999).
c) Oxalic acid, 0.6 M (5 % w/v): Dissolved 50 g of oxalic acid (CAS No. 144-62-7) in 950 mL of ultra-pure water.
d) Ascorbic acid, 0.01 M (3 % w/v): Dissolved 2.5 g of L-ascorbic acid (CAS No. 50-81-7) in 100 mL of ultra-pure water. This reagent was freshly prepared every day.

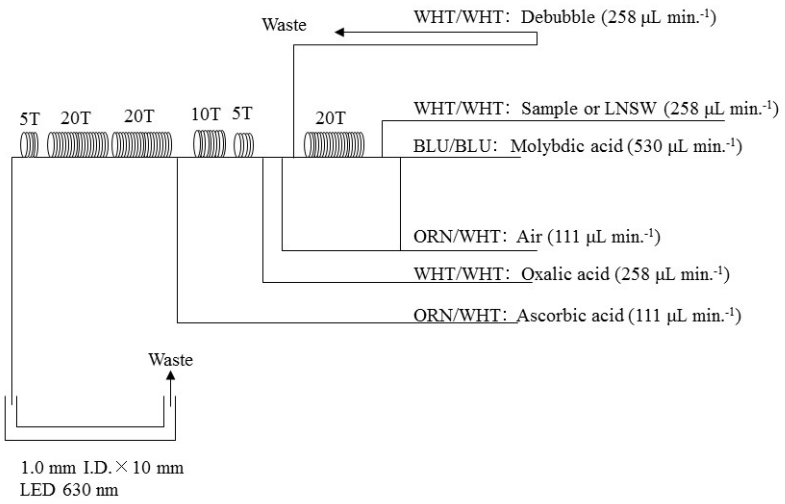


Figure 2.4.3.3 SiO_2 (3ch.) flow diagram.

(4.3) Phosphate

The methodology for the phosphate analysis is a modified procedure of Murphy and Riley (1962). The flow diagrams are shown in Fig. 2.4.3.4. Molybdic acid was added to the seawater sample to form the phosphomolybdic acid compound, and then it was reduced to phosphomolybdous acid compound using L-ascorbic acid as the reductant. And then the signal was monitored at 880 nm.

Reagents

a) 15 % Sodium dodecyl sulfate solution: 75 g of sodium dodecyl sulfate (CAS No. 151-21-3) was mixed with 425 mL of ultra-pure water.
b) Stock molybdate solution, 0.03 M (0.8 % w/v): Dissolved 8 g of sodium molybdate dihydrate (CAS No. 10102-40-6) and 0.17 g of antimony potassium tartrate trihydrate (CAS No. 28300-74-5) in 950 mL of ultra-pure water, and then added 50 mL of sulfuric acid (CAS No. 7664-93-9).
c) PO_4 color reagent: Dissolved 1.2 g of L-ascorbic acid (CAS No. 50-81-7) in 150 mL of the stock molybdate solution. After mixing, 3 mL of the 15 % sodium dodecyl sulfate solution was added. This reagent was freshly prepared before every measurement.

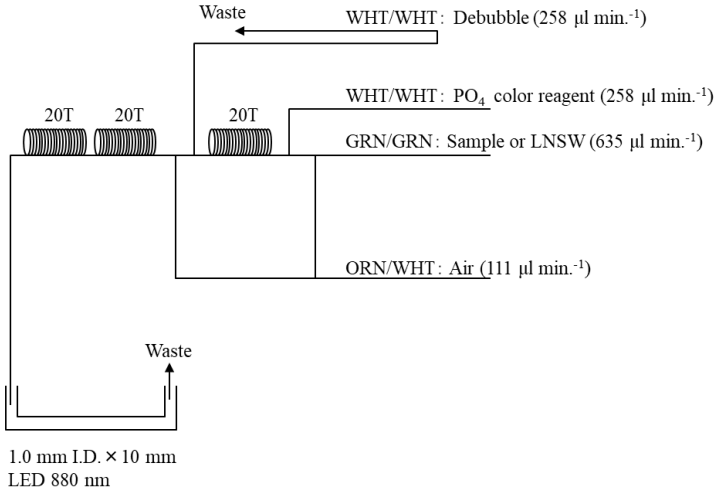


Figure 2.4.3.4 PO_4 (4ch.) flow diagram.

(4.4) Ammonia

The ammonia in seawater was determined using the flow diagrams shown in Fig. 2.4.3.5. The sample was mixed with an alkaline solution containing EDTA, which ammonia as a gas state was formed from seawater. The ammonia (gas) is absorbed in a sulfuric acid by way of a 0.5 µm pore-size membrane filter (ADVANTEC PTFE) at the dialyzer attached to the analytical system. And then the ammonia absorbed in sulfuric acid was determined by coupling with phenol and hypochlorite to form indophenols blue, and the signal was determined at 630 nm.

Reagents

a) 30 % Triton solution: 30 mL of the Triton® X-100 (CAS No. 9002-93-1) was mixed with 70 mL ultra-pure water.
b) EDTA: Dissolved 41 g of tetrasodium;2-[2-[bis(carboxylatomethyl)amino]ethyl-(carboxylatemethyl)amino]acetate;tetrahydrate (CAS No. 13235-36-4) and 2 g of boric acid (CAS No. 10043-35-3) in 200 mL of ultra-pure water. After mixing, 1 mL of the 30 % triton solution was added. This reagent is prepared every week.
c) NaOH liquid: Dissolved 1.5 g of sodium hydroxide (CAS No. 1310-73-2) and 16 g of tetrasodium;2-[2-[bis(carboxylatomethyl)amino]ethyl-(carboxylatemethyl)amino]acetate;tetrahydrate (CAS No. 13235-36-4) in 100 mL of ultra-pure water. This reagent was prepared every week. Note that we reduced the amount of sodium hydroxide from 5 g to 1.5 g because pH of C standard solutions has been lowered 1 pH unit due to the change of recipe of B standards solution (the details of those standard solutions, see 6.4).
d) Stock nitroprusside: Dissolved 0.25 g of sodium nitroferricyanide dihydrate (CAS No. 13755-

38-9) in 100 mL of ultra-pure water, and then added 0.2 mL of 1M sulfuric acid. Stored in a dark bottle and prepared every month.

e) Nitroprusside solution: Added 4 mL of the stock nitroprusside and 4 mL of 1M sulfuric acid in 500 mL of ultra-pure water. After mixing, 2 mL of the 30 % triton solution was added. This reagent was stored in a dark bottle and prepared every 2 or 3 days.

f) Alkaline phenol: Dissolved 10 g of phenol (CAS No. 108-95-2), 5 g of sodium hydroxide (CAS No. 1310-73-2) and 2 g of sodium citrate dihydrate (CAS No. 6132-04-3) in 200 mL of ultra-pure water. Stored in a dark bottle and prepared every week.

g) NaClO solution: Mixed 3 mL of sodium hypochlorite (CAS No. 7681-52-9) in 47 mL of ultra-pure water. Stored in a dark bottle and fleshly prepared before every measurement. This reagent needs to be 0.3 % available chlorine.

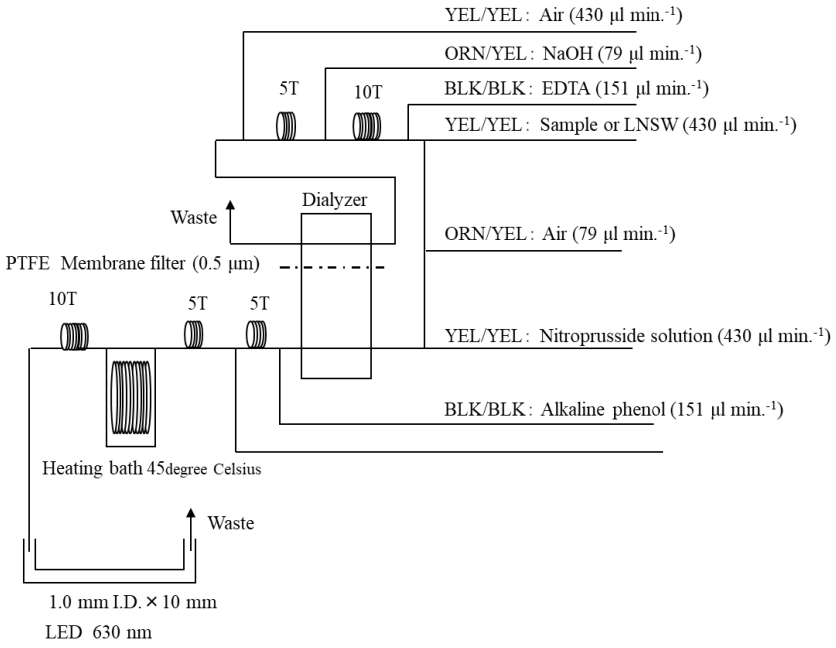


Figure 2.4.3.5 NH_4 (5ch.) flow diagram.

(4.5) Sampling procedures

Sampling for the nutrient samples was conducted after the sampling for other gas parameters. The seawater samples were collected into two bottles of new polyacrylate vials (10 mL) without any sample drawing tube that is usually used for the oxygen samples. Each vial was rinsed three times before filling and then was sealed without any head space immediately after the collection. The vials were put into a water bath at 21.0 degree Celsius for more than 30 minutes before measuring. The seawater sample in the vial was not transferred to another container and the vial was placed on an autosampler (AIM 4000, BL TEC K.K.) tray directly. The seawater samples were analyzed within 24 hours after collection.

(4.6) Data processing

Raw data from QuAAtro 39-J were processed as follows:

a) Checked if there were any baseline shifts.
b) Checked the shape of each peak and positions of peak values. If necessary, a change was made for the positions of peak values.
c) Conducted carry-over correction and baseline drift correction followed by sensitivity correction to apply to the peak height of each sample.
d) Conducted baseline correction and sensitivity correction using linear regression. Conducted baseline correction and sensitivity correction using linear regression.
e) Using the salinity (determined in bottle sampling on board) and the laboratory room temperature (20 degree Celsius), the density of each sample was calculated. The obtained density was used to calculate the final nutrient concentration with the unit of μmol kg^{-1}.
f) Calibration curves to obtain the nutrient concentrations were assumed second-order equations.

(5) Certified Reference Material of nutrients in seawater

Certified reference materials produced by KANSO Co., Ltd. were used to ensure the comparability and traceability of nutrient measurements during this cruise. The KANSO CRMs are for inorganic nutrients (nitrate, nitrite, silicate, phosphate, and ammonia) in seawater and have been produced using autoclaved natural seawater based on the quality control system under ISO Guide 34 (JIS Q 0034). KANSO Co., Ltd. has been accredited under the accreditation System of the National Institute of Technology and Evaluation (ASNITE) as a CRM producer since 2011. (ASNITE 0052 R)

The certified values were the arithmetic means of the results of 30 bottles from each batch (measured in duplicates) analyzed by both KANSO Co., Ltd. and Japan Agency for Marine-Earth Science and Technology (JAMSTEC) using the colorimetric method (continuous flow analysis, CFA, method). The salinity of the calibration standards solution to obtain each calibration curve was adjusted to the salinity of the used CRMs within ± 0.5.

Each certified value of nitrate, nitrite, and phosphate of KANSO CRMs was calibrated using one of the Japan Calibration Service System (JCSS) standard solutions for each nitrate ion, nitrite ion, and phosphate ion. JCSS standard solutions were calibrated using the secondary solution of JCSS for each of these ions. The secondary solution of JCSS was calibrated using the specified primary solution produced by the Chemicals Evaluation and Research Institute (CERI), Japan. CERI-specified primary solutions were calibrated using the National Metrology Institute of Japan (NMIJ) primary standards solution of nitrate ions, nitrite ions, and phosphate ions, respectively. The certified value of silicate of KANSO CRM was calibrated using a newly established silicon standards solution named “exp31” and “exp64” produced by JAMSTEC and KANSO and Lot. AA produced by KANSO. This silicon standard solution was produced by a dissolution technique with an alkaline solution. The mass fraction of Si in the produced solution was calibrated based on NMIJ CRM 3645-a Si standard solution by a technology consulting

system of the National Institute of Advanced Industrial Science and Technology (AIST), and this value is traceable to the International System of Units (SI).

12 sets of CRM lots CQ, CU, CP, CM, and CN were used in this cruise (Table 2.4.3.1). Each CRM's serial number was randomly selected. The CRM bottles were stored in a room named "BIOCHEMICAL LABORATORY" on the ship, where the temperature was maintained around 18.39 degree Celsius – 23.55 degree Celsius.

Table 2.4.3.1 Certified concentration and the uncertainty (k=2) of CRMs (μmol kg^{-1}).

Lot	Nitrate	Nitrite*	Silicate	Phosphate	Ammonia**
CQ	0.06 ± 0.03	0.074 ± 0.07	2.20 ± 0.07	0.030 ± 0.009	1.76 ± 0.07
CU	3.06 ± 0.05	0.04 ± 0.04	7.77 ± 0.09	0.262 ± 0.011	1.02 ± 0.04
CP	24.8 ± 0.3	0.318 ± 0.07	61.1 ± 0.3	1.753 ± 0.018	0.87
CM	33.2 ± 0.3	0.028 ± 0.006	100.5 ± 0.5	2.38 ± 0.03	0.59
CN	43.6 ± 0.4	0.020 ± 0.004	152.7 ± 0.8	2.94 ± 0.03	0.46

* For Nitrite concentration, there is a trend that the value has been increased 0.004 ± 0.002 μmol kg^{-1} per year. Nitrite concentration values except for CU were determined by JAMSTEC in June 2023.

** Ammonia values are all reference value. The value of CQ, CR and CU were reported by KANSO. The other values were determined by JAMSTEC.

(6) Standards

To obtain the calibration curves, we prepared in-house standard solutions because (1) the concentrations nitrate, silicate and phosphate of CRM lot CN were lower than the maximum concentrations in sweater samples, (2) the concentration range of nitrite of the CRMs is not available for the calibration curves, and (3) the concentrations of ammonia of the CRMs are not certified values.

(6.1) Volumetric laboratory-ware of in-house standards

All volumetric glassware and polymethylpentene (PMP)-ware used were gravimetrically calibrated. Plastic volumetric flasks were gravimetrically calibrated at the water temperature of use within 0.9 K at around 21.0 degree Celsius. Volumetric flasks of “Class A” quality are used because their nominal tolerances are 0.05 % or less over the size ranges likely to be used in this work. Since Class A flasks are made of borosilicate glass, the standard solutions were transferred to plastic bottles as quickly as possible after the solutions were made up to volume and well mixed to prevent the excessive dissolution of silicate from the glass. PMP volumetric flasks were gravimetrically calibrated and used only within 3.0 K of the calibration temperature. The computation of volume contained by the glass flasks at various temperatures other than the calibration temperatures was conducted by using the coefficient of linear expansion of borosilicate crown glass. The coefficients of cubical expansion of each glass and PMP volumetric flask were determined by the measurements in 2023. The coefficient of cubical expansion of the glass volumetric flask (SHIBATA HARIO) was 0.00000975 to 0.0000110 K^{-1} and that of the PMP volumetric flask (NALGEN PMP) was 0.00038 to 0.00042 K^{-1}. The weights obtained in the calibration weightings were corrected for the density of water and air buoyancy. All glass pipettes have nominal calibration tolerances of 0.1 % or better. These were gravimetrically calibrated to verify and improve upon this nominal tolerance.

(6.2) Reagents

For nitrate standard, "potassium nitrate 99.995 suprapur®" provided by Merck, Batch B1983565, CAS No. 7757-79-1, was used. For nitrite standard solution, we used nitrite ion standard solutions (NO_2^- 1000) provided by Wako Chemicals, Lot ACH2582, Code. No. 146-06453. These standard solutions were certified by Wako Chemicals. The calibration result is 1002 mg L^{-1} at 20 degree Celsius. Expanded uncertainty of calibration (k=2) is 0.8 % for the calibration result. For the silicate standard solution, we used Si standard solutions Lot. AA produced by KANSO. The mass fraction of Si in the Lot. AA solution was calibrated based on NMIJ CRM 3645-a Si standard solution. For the phosphate standard, we used potassium dihydrogen phosphate anhydrous 99.995 suprapur®" provided by Merck, Batch B2024308, CAS No.: 7778-77-0. For the ammonia standard, ammonium chloride (CRM 3011-a) provided by NMIJ, CAS No. 12125-02-9 was used. The purity of this standard was reported as >99.9 % by the manufacturer. Expanded uncertainty of calibration (k=2) was 0.026 %.

(6.3) Low nutrients seawater (LNSW)

Surface water with low nutrient concentrations was taken and filtered using a 0.20 μm pore capsule cartridge filter around 13ºN and 136ºE during the MR21-03 cruise in June 2021. Obtained seawater was drained into multiple 20 L Cubitainer (flexible containers) and stored in a cardboard box. These have been used as the low nutrients seawater (LNSW) for nutrients measurement. The concentrations of each LNSW were measured in June 2022. The averaged nutrient values in the LNSW were 0.01, 0.003, 1.08, 0.075, and 0.01 μmol L^{-1} for nitrate, nitrite, silicate, phosphate, and ammonia, respectively. The concentrations of nitrate, nitrite, and ammonia were lower than the detection limit.

(6.4) Standard solutions and calibration curves

Concentrations of nutrients for standard solutions A, B, C, and D are shown in Table 2.4.3.2. We used the KANSO Si standard solution for A standard of silicate, which doesn't need to be neutralized by the hydrochloric acid. B standard was diluted from A standard with the following recipes shown in Table 2.4.3.3. To match the salinity and the density of the B standard solution to those of the LNSW, 15.00 g of sodium chloride powder was dissolved in the B standard solution, and then the final volume was adjusted to 500 mL. The C standard solution was prepared in the LNSW following the recipes shown in Table 2.4.3.4. Then the actual concentrations of nutrients in each standard solution were calculated based on the solution temperature, together with the determined factors of volumetric laboratory wares. The calibration curves for each run for nitrate, nitrite and phosphate were obtained using 6 levels, C-2, C-3, C-4, C-6, C-7, and C-8. For silicate, for samples from station 002 and 003, the calibration curves were obtained using 5 levels, C-2, C-3, C-4, C-6 and C-7 although that was obtained using 3 levels, C-6, C-7 and C-8 for high concentration samples (> C-6). Besides for samples from station 004-008, the calibration curves were obtained using 6 levels, C-2, C-3, C-4, C-6, C-7 and C-8. For ammonia, that was obtained using 3 levels, C-1, C-5, C-8. C-1 was LNSW, C-2, C-3, C-4, C-6 and C-7 were the CRM of nutrients in seawater, and C-5 and C-8 were diluted using the B standard solution. The D standard

solutions, which were for calculating the reduction rate of the Cd coil, was diluted from the A standard solution into the pure water. The in-house standard solutions were remade by each "renewal time" shown in Table 2.4.3.5.

Table 2.4.3.2 Nominal concentrations of nutrients for A, D, B and C standards (μmol L^{-1}).

	A	B	D	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8
NO_3	45000	900	900	-	CQ	CU	CP	-	CM	CN	53.8
NO_2	21800	26	870	-	CQ	CU	CP	-	CM	CN	1.6
SiO_2	35600	2840*		-	CQ	CU	CP	-	CM	CN	171.4*
PO_4	6000	60		-	CQ	CU	CP	-	CM	CN	3.7
NH_4	2000	100		LNSW	-	-	-	3.0	-	-	6.0

*For samples from stations 002 and 003, silicate concentration for B standard was 4260 μmol L^{-1} and for C-8 was 256.4μmol L^{-1}.

Table 2.4.3.3 B standard recipes. Final volume was 500 mL.

	A Std.
NO_3	10 mL
NO_2*	15 mL
SiO_2**	40 mL
PO_4	5 mL
NH_4	25 mL

*NO_2 was D standard solution which was diluted from A standard.
**For samples from station 002 and 003, the recipe of SiO_2 was 60mL

Table 2.4.3.4 Working calibration standard recipes. Final volume was 500 mL.

C Std.	B Std.
C-5	15 mL
C-8	30 mL

Table 2.4.3.5 Renewal times of in-house standards.

Standard	Renewal time
A-1 Std. (NO_3)	maximum a month
A-2 Std. (NO_2)	commercial prepared solution
A-3 Std. (SiO_2)	commercial prepared solution
A-4 Std. (PO_4)	maximum a month
A-5 Std. (NH_4)	maximum a month
D-1 Std.	maximum 8 days
D-2 Std.	maximum 8 days
B Std. (mixture of A-1, D-2, A-3, A-4 and A-5 Std.)	maximum 8 days
C Std.	every 24 hours
36 μM NO_3 (diluted D-1 Std. for reduction estimate)	when C Std. renewed
35 μM NO_2 (diluted D-2 Std. for reduction estimate)	when C Std. renewed

(7) Data quality

During this cruise, a total of the 12 runs were conducted to measure the samples collected by 12 casts at 7 stations. The total number of seawater samples was 632. The samples were collected into two vials and measured independently (replicate measurement).

(7.1) Precision

The highest-concentration standard solution (C-8) was repeatedly determined every 6 to 14 samples to obtain the analytical precision of the nutrient analyses during this cruise. During each run, the total number of the C-8 determinations was 5-15 times depending on the run. We obtained the analytical precision based on these C-8 results for each run. The overall precisions throughout this cruise were calculated based on the analytical precisions obtained from all of the runs (Table 2.4.3.6). During this cruise, overall median precisions were 0.13, 0.23, 0.14, 0.13, and 0.47 % for nitrate, nitrite, silicate, phosphate, and ammonia, respectively. These were comparable to those obtained during the past cruises conducted in 2009 - 2024.

Table 2.4.3.6 Overall precisions based on the replicate analyses (k=1)

	Nitrate CV %	Nitrite CV %	Silicate CV %	Phosphate CV %	Ammonia CV %
Median	0.13	0.23	0.14	0.13	0.47
Mean	0.12	0.21	0.13	0.14	0.50
Maximum	0.17	0.28	0.18	0.20	0.75
Minimum	0.06	0.11	0.04	0.03	0.20
n	12	12	12	12	12

(7.2) Comparability

CRM lots CN was measured every run to evaluate the comparability throughout the measurement in this cruise. All of the measured concentrations were within the uncertainty of certified values for nitrate, nitrite, silicate, and phosphate (Table 2.4.3.7).

Table 2.4.3.7 CRM lot CN measurements (μmol kg^{-1}).

	Nitrate	Nitrite	Silicate	Phosphate	Ammonia
Median	43.69	0.021	152.88	2.940	0.96
Mean	43.66	0.021	152.82	2.939	0.99
STDEV	0.12	0.002	0.36	0.009	0.28
n	12	12	12	12	12

(7.3) Carryover

We also summarized the magnitudes of carry over, which is a sample-to-sample contamination during the flow analysis. To evaluate carryover in each run, we measured the C-8 standard solution and consecutively the LNSW solution two times. The difference from LNSW-1 to LNSW-2 was used to estimate the Carryover (%) by the following equation (1) where [ ] means concentration.

$$\text{Carryover (\%)} = ([\text{LNSW-1}] - [\text{LNSW-2}]) / ([\text{C-8}] - [\text{LNSW-2}]) * 100 \quad (1)$$

The carryover (%) is shown in Table 2.4.3.8. Overall results were low % of carryover. The low % indicates that there is no significant issue during this cruise.

Table 2.4.3.8 Carryovers (%)

	Nitrate	Nitrite	Silicate	Phosphate	Ammonia
Median	0.20	0.09	0.23	0.20	0.80
Mean	0.20	0.14	0.23	0.22	0.78
Maximum	0.25	0.46	0.28	0.38	1.02
Minimum	0.17	0.00	0.20	0.07	0.31
n	12	12	12	12	12

(7.4) Uncertainty (Repeatability)

Empirical equations of (2), (3) and (4) were obtained based on 12 measurements of 12 sets of CRMs (Table 2.4.3.1) to estimate the uncertainty (repeatability) of measurements of nitrate, silicate, and phosphate, respectively (Figs. 2.4.3.6-8).

$$\text{Uncertainty of measurement of nitrate (\%)} = 0.15813 + 1.3556 * (1 / C_{NO3}) \quad (2)$$

$$\text{Uncertainty of measurement of silicate (\%)} = 0.17203 + 1.5193 * (1 / C_{SiO2}) \quad (3)$$

$$\text{Uncertainty of measurement of phosphate (\%)} = 0.090726 + 0.36297 * (1 / C_{PO4}) \quad (4)$$

where C_{NO3}, C_{SiO2}, and C_{PO4} are nitrate, silicate, and phosphate concentrations of sample (μmol kg^{-1}), respectively.

Empirical equations, eq. (5) and (6) were obtained based on duplicate measurements of the samples to estimate the uncertainty (repeatability) of measurements of nitrite and ammonia (Figs. 2.4.3.9-10).

$$\text{Uncertainty of measurement of nitrite (\%)} = 4.1188 + 0.22152 * (1 / C_{NO2}) \quad (5)$$

$$\text{Uncertainty of measurement of ammonia (\%)} = 4.1963 + 0.69713 * (1 / C_{NH4}) + 0.0042456 * (1 / C_{NH4}) * (1 / C_{NH4}) \quad (6)$$

where C_{NO2} and C_{NH4} are nitrite and ammonia concentrations of sample (μmol kg^{-1}), respectively.

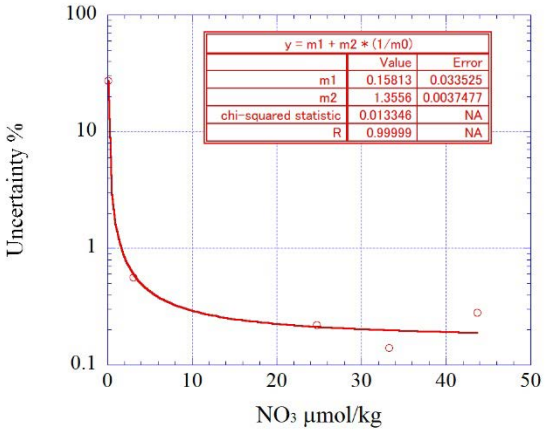


Figure 2.4.3.6 Uncertainty for NO_3.

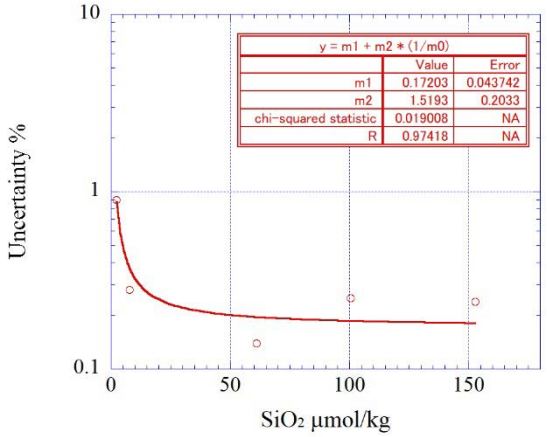


Figure 2.4.3.7 Uncertainty for SiO_2.

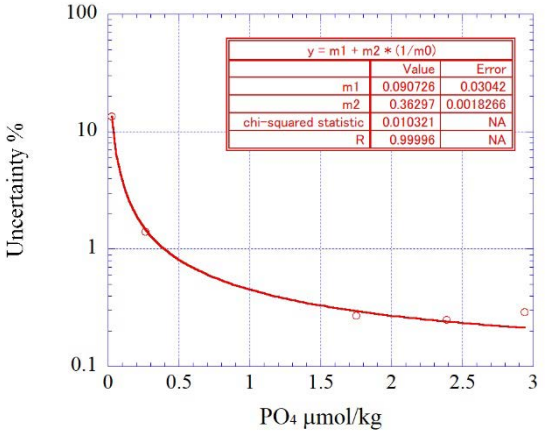


Figure 2.4.3.8 Uncertainty for PO_4.

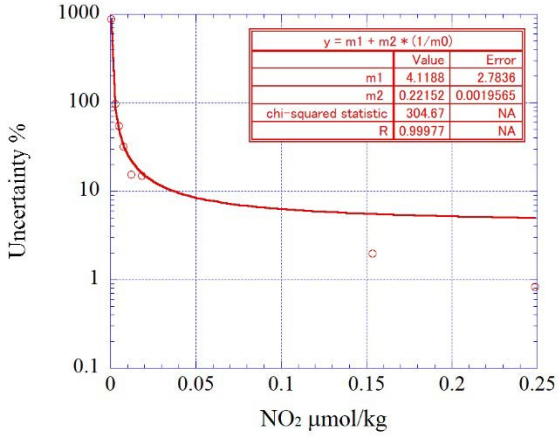


Figure 2.4.3.9 Uncertainty for NO_2.

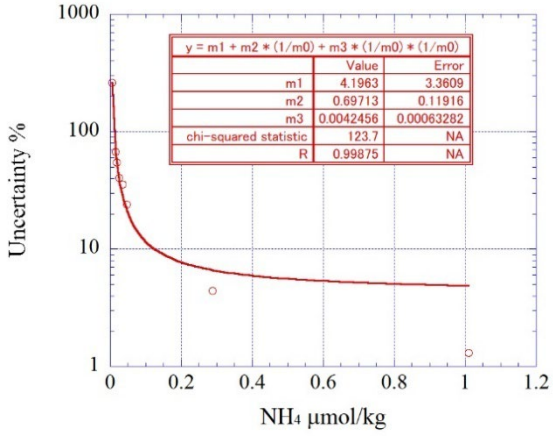


Figure 2.4.3.10 Uncertainty for NH_4.

(7.5) Detection limit and quantitative determination

The LNSW was measured every 6 to 14 samples to estimate the detection limit of the nutrient analyses during this cruise. During each run, the total number of the LNSW determination was 6-14 times depending on the run. The detection limit was calculated based on the LNSW results from all the runs by the following equation (7).

Detection limit = 3 * standard deviation of repeated measurement of LNSW (7)

The estimated detection limit is shown in Table 2.4.3.9. The quantitative determination of nutrient analyses is the concentration of which uncertainty is 33 % in the empirical equations, eq. (2) to (6). The estimated quantitative determination is also shown in Table 2.4.3.9.

Table 2.4.3.9 Detection limit and quantitative determination.

	Nitrate μmol kg^{-1}	Nitrite μmol kg^{-1}	Silicate μmol kg^{-1}	Phosphate μmol kg^{-1}	Ammonia μmol kg^{-1}
Detection limit	0.02	0.01	0.08	0.008	0.03
Quantitative determination	0.04	0.01	0.05	0.011	0.03

Replicate samples were taken at most of the layers. The summary of average and standard deviation of the difference between each replicate pair of analysis was shown in Table 2.4.3.10.

Table 2.4.3.10 Average and standard deviation of the difference between each replicate pair of analysis.

	Nitrate μmol kg^{-1}	Nitrite μmol kg^{-1}	Silicate μmol kg^{-1}	Phosphate μmol kg^{-1}	Ammonia μmol kg^{-1}
Average	0.05	0.003	0.16	0.006	0.02
Standard deviation	0.04	0.003	0.12	0.004	0.01
n	249	256	247	242	243

(8) Problems

There is no significant issue for this data set.

(9) List of reagents

List of reagents used in this cruise is shown in Table 2.4.3.11.

Table 2.4.3.11 List of reagents used in this cruise.

IUPAC name	CAS Number	Formula	Compound Name	Manufacture	Grade
4-Aminobenzenesulfonamide	63-74-1	$C_6H_8N_2O_2S$	Sulfanilamide	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Ammonium chloride	12125-02-9	NH_4Cl	Ammonium Chloride	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Antimony potassium tartrate trihydrate	28300-74-5	$K_2(SbC_4H_2O_6)_2 \cdot 3H_2O$	Bis[(+)-tartrato]diantimonate(III) Dipotassium Trihydrate	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Boric acid	10043-35-3	H_3BO_3	Boric Acid	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Hydrogen chloride	7647-01-0	HCl	Hydrochloric Acid	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Imidazole	288-32-4	$C_3H_4N_2$	Imidazole	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
L-Ascorbic acid	50-81-7	$C_6H_8O_6$	L-Ascorbic Acid	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
N-(1-Naphthalenyl)-1,2-ethanediamine, dihydrochloride	1465-25-4	$C_{12}H_{16}Cl_2N_2$	N-1-Naphthylethylenediamine Dihydrochloride	FUJIFILM Wako Pure Chemical Corporation	for Nitrogen Oxides Analysis
Oxalic acid	144-62-7	$C_2H_2O_4$	Oxalic Acid	FUJIFILM Wako Pure Chemical Corporation	Wako Special Grade
Phenol	108-95-2	C_6H_6O	Phenol	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Potassium nitrate	7757-79-1	KNO_3	Potassium Nitrate	Merck KGaA	Suprapur®
Potassium dihydrogen phosphate	7778-77-0	KH_2PO_4	Potassium dihydrogen phosphate anhydrous	Merck KGaA	Suprapur®
Sodium chloride	7647-14-5	NaCl	Sodium Chloride	FUJIFILM Wako Pure Chemical Corporation	TraceSure®
Sodium citrate dihydrate	6132-04-3	$Na_3C_6H_5O_7 \cdot 2H_2O$	Trisodium Citrate Dihydrate	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Sodium dodecyl sulfate	151-21-3	$C_{12}H_{25}NaO_4S$	Sodium Dodecyl Sulfate	FUJIFILM Wako Pure Chemical Corporation	for Biochemistry
Sodium hydroxide	1310-73-2	NaOH	Sodium Hydroxide for Nitrogen Compounds Analysis	FUJIFILM Wako Pure Chemical Corporation	for Nitrogen Analysis
Sodium hypochlorite	7681-52-9	NaClO	Sodium Hypochlorite Solution	Kanto Chemical co., Inc.	Extra pure
Sodium molybdate dihydrate	10102-40-6	$Na_2MoO_4 \cdot 2H_2O$	Disodium Molybdate(VI) Dihydrate	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Sodium nitroferricyanide dihydrate	13755-38-9	$Na_2[Fe(CN)_5NO] \cdot 2H_2O$	Sodium Pentacyanonitrosylferrate(III) Dihydrate	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
Sulfuric acid	7664-93-9	H_2SO_4	Sulfuric Acid	FUJIFILM Wako Pure Chemical Corporation	JIS Special Grade
tetrasodium;2-[2-[bis(carboxylatomethyl)amino]ethyl-(carboxylatomethyl)amino]acetate;tetrahydrate	13235-36-4	$C_{10}H_{12}N_2Na_4O_8 \cdot 4H_2O$	Ethylenediamine-N,N,N',N'-tetraacetic Acid Tetrasodium Salt Tetrahydrate (4NA)	Dojindo Molecular Technologies, Inc.	-
Synonyms: t-Octylphenoxypolyethoxyethanol 4-(1,1,3,3-Tetramethylbutyl)phenyl-polyethylene glycol Polyethylene glycol tert-octylphenyl ether	9002-93-1	$(C_2H_4O)_nC_{14}H_{22}O$	Triton®X-100	MP Biomedicals, Inc.	-

(10) Data archives

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

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2.4.4 Dissolved inorganic carbon

Masahide WAKITA (JAMSTEC MIO): Principal Investigator
Nagisa FUJIKI (MWJ): Operation Leader
Tomoki Nakamura (MWJ)

(1) Objective

Onboard total dissolved inorganic carbon (DIC) concentration measurement of seawater collected in sampling bottles

(2) Methods, Apparatus and Performance

(2)-1 Seawater sampling

Seawater samples were collected by 12-liter sampling bottles mounted on the CTD/Carousel Water Sampling System and a bucket at 7 stations. Seawater was sampled in a 250 mL glass bottle (SHOTT DURAN) that was previously soaked in 5 % alkaline detergent solution (decon 90, Decon Laboratories Limited) at least 3 hours and was cleaned by fresh water for 5 times and Milli-Q deionized water for 3 times. A sampling silicone rubber tube with PFA tip was connected to the sampling bottle when sampling was carried out. The glass bottles were filled from its bottom gently, without rinsing, and were overflowed for 30 seconds. They were sealed using the polyethylene inner lids with their diameter of 29 mm with care not to leave any bubbles in the bottle. Within about one hour after collecting the samples on the deck, the glass bottles were carried to the laboratory to be poisoned. Small volume (3 mL) of the sample (1 % of the bottle volume) was removed from the bottle and 100 μL of over saturated solution of mercury (II) chloride was added. Then the samples were sealed by the polyethylene inner lids with its diameter of 31.9 mm and stored in a refrigerator at approximately 5 °C. About one hour before the analysis, the samples were taken from refrigerator and put in the water bath kept about 25 °C.

(2)-2 Seawater analysis

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

The seawater dispensing unit has an auto-sampler (6 ports), which dispenses the seawater from a glass bottle to a pipette of nominal 15 mL volume. The pipette was kept at 25.00 °C ± 0.05 °C by a water jacket, in which water circulated through a thermostatic water bath (NESLAB RTE10, Thermo Fisher Scientific).

The CO_2 dissolved in a seawater sample is extracted in a stripping chamber of the CO_2 extraction unit by adding 10 % phosphoric acid solution. The stripping chamber is made approx. 25 cm long and has a fine frit at the bottom. First, a constant volume of acid is added to the

stripping chamber from its bottom by pressurizing an acid bottle with nitrogen gas (99.9999 %). Second, a seawater sample kept in a pipette is introduced to the stripping chamber by the same method. The seawater and phosphoric acid are stirred by the nitrogen bubbles through a fine frit at the bottom of the stripping chamber. The stripped CO_2 is carried to the coulometer through two electric dehumidifiers (kept at 2 °C) and a chemical desiccant (magnesium perchlorate) by the nitrogen gas (flow rate of 140 mL min^{-1}).

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

(3) Preliminary result

A few replicate samples were taken at most of the stations and difference between each pair of analyses was plotted on a range control chart (fig. 2.4.4-1). The average of the differences was provisionally 0.9 μmol kg^{-1}, with its standard deviation of 0.8 μmol kg^{-1} (n = 33), which indicate the analysis was sufficiently accurate (< 1.5 μmol kg^{-1}) according to Dickson et al. (2007).

(4) Data archive

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

(5) Reference

Dickson, A. G., Sabine, C. L. & Christian, J. R. (Eds.). (2007). *Guide to best practices for ocean CO2 measurements, PICES Special Publication 3*: North Pacific Marine Science Organization.

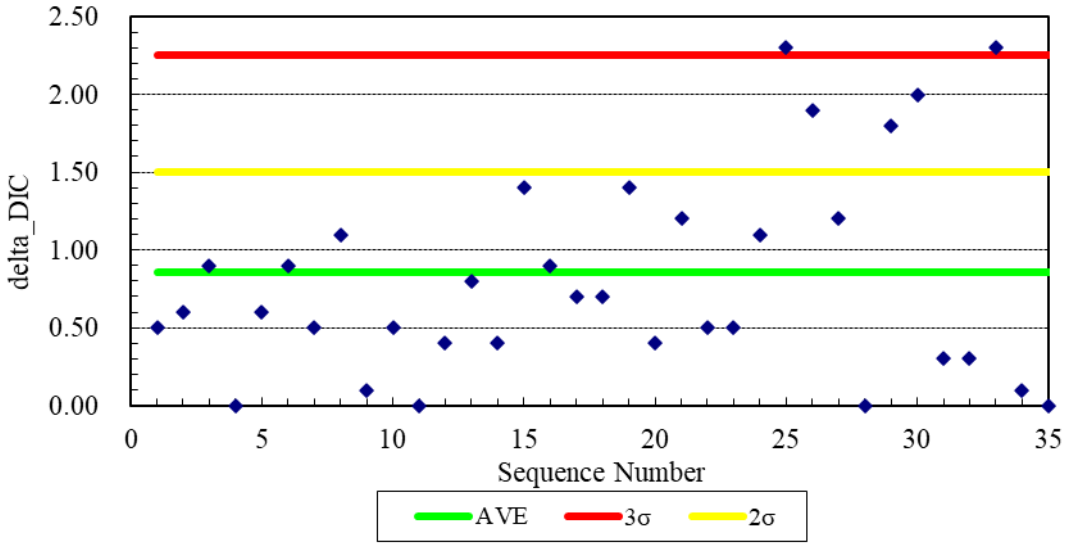

Figure 2.4.4-1 Range control chart of the absolute differences of replicate measurements of DIC carried out during this cruise. AVE represents the average of absolute difference, 3σ the upper control limit (standard deviation of AVE × 3), and 2σ upper warning limit (standard deviation of AVE × 2).

2.4.5. Total Alkalinity

Masahide WAKITA (JAMSTEC MIO): Principal Investigator
Nagisa FUJIKI (MWJ): Operation Leader
Tomoki NAKAMURA (MWJ)

(1) Objective

Onboard total alkalinity measurement of seawater corrected in sampling bottles

(2) Methods, Apparatus and Performance

(2)-1 Seawater sampling

Seawater samples were collected by 12 L sampling bottles mounted on the CTD/Carousel Water Sampling System and a bucket at 7 stations. The seawater from the sampling bottle was filled into the 250 mL borosilicate glass bottles (SHOTT DURAN) using a sampling silicone rubber tube with PFA tip. The water was filled into the bottle from the bottom smoothly, without rinsing, and overflowed for 2 times bottle volume (10 seconds). These bottles were pre-washed in advance by soaking in 5 % alkaline detergent (decon90, Decon Laboratories Limited) for more than 3 hours, and then rinsed 5 times with tap water and 3 times with Milli-Q deionized water. The samples were stored in a refrigerator at approximately 5 °C before the analysis, and were put in the water bath with its temperature of about 25 °C for one hour just before analysis. Within an hour of collecting the samples on deck at stations 6 (cast 8), 7, and 8, the glass bottles were transported to the laboratory for preservation. A 3 mL portion of the sample (1% of the bottle's volume) was removed, and 100 μL of a mercury (II) chloride solution was added. The samples were stored in a refrigerator at ~5 °C and placed in a water bath at ~25 °C about one hour prior to analysis.

(2)-2 Seawater analyses

Total alkalinity of seawater samples except for station 6 cast 8, station 7 and station 8 was measured using a spectrophotometric system (Nihon ANS, Inc.) using a scheme of Yao and Byrne (1998). The calibrated volume of sample seawater (ca. 42 mL) was transferred from a sample bottle into the titration cell with its light path length of 4 cm long via dispensing unit. The TA is calculated by measuring two sets of absorbance at three wavelengths (730, 616, and 444) nm applied by the spectrometer (TM-UV/VIS C10082CAH, Hamamatsu Photonics). One is the absorbance of seawater sample before injecting an acid with indicator solution (bromocresol green sodium salt) and another 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 equipped with periodically renewed TYGON tube 5 minutes before the measurement. Nitrogen bubbles were introduced into the titration cell for degassing CO_2 from the mixed solution

sufficiently.

The TA is calculated based on the following equation:

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

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

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

At stations 6 (cast 8), 7, and 8, total alkalinity was measured in the laboratory using potentiometric techniques with a total alkalinity titration analyzer (ATT-15, Kimoto Electric Co., Ltd.), following the procedure described by Wakita et al. (2021). Measurements were completed within one month after the cruise.

(3) Preliminary result

The repeatability of this system was provisionally 1.8 μmol kg^{-1} (n = 13) which was estimated from standard deviation of measured KRM value during this cruise. 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 fig. 2.4.5-1). The average of the difference was provisionally 0.8 μmol kg^{-1} (n = 33) with its standard deviation of 0.7 μmol kg^{-1}.

(4) Data archive

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

(5) References

Dickson, A. G., Sabine, C. L. & Christian, J. R. (Eds.). (2007). *Guide to best practices for ocean CO2 measurements, PICES Special Publication 3*: North Pacific Marine Science Organization.

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

Wakita, M., Sasaki, K., Nagano, A., Abe, H., Tanaka, T., Nagano, K., et al. (2021). Rapid reduction of pH and $CaCO_3$ saturation state in the Tsugaru Strait by the intensified Tsugaru Warm Current during 2012–2019. *Geophysical Research Letters*, 48, e2020GL091332. https://doi.org/10.1029/2020GL091332

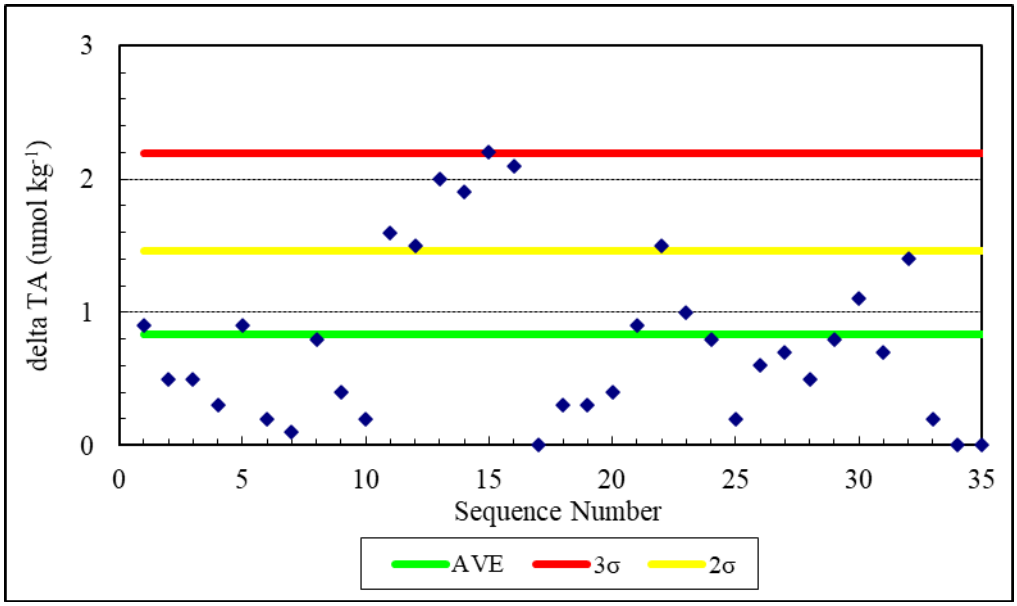

Figure 2.4.5-1 Range control chart of the absolute differences of replicate measurements of TA carried out during this cruise. AVE represents the average of absolute difference, 3σ the upper control limit (standard deviation of AVE × 3), and 2σ upper warning limit (standard deviation of AVE × 2).

2.4.6. DIC, TA, Nutrients-UV

Yoshiyuki NAKANO (JAMSTEC Engineering Department)

(1) Objective

When measuring DIC in seawater, mercury (II) chloride is usually added to the sample to kill organisms in the seawater. However, mercury (II) chloride is a highly poisonous chemical that requires careful handling, and liquid waste disposal must be entrusted to a waste disposal company. Furthermore, it is highly likely that the use of mercury (II) chloride will be discontinued in a few years due to international mercury control treaties, so alternative sterilization methods are needed. Therefore, we have been developing a water sampling sterilization device that utilizes a new ultraviolet (UV) light source. Our objective in this cruise is to test the water sampling sterilization device using each layer water sampling of Niskin bottles.

(2) Method

We utilize a UV Luminous Array Film (UV-LAFi) for the water sampling sterilization device. UV-LAFi is a new deep-UV light source featuring surface emission and broad wavelength, and it can be expected to have higher bactericidal effect than UV-LED at the same output. UV-LAFi technologies were developed by Shikoh Tech Co., Ltd. The Basic structure for UV-C light source is based on mercury-free plasma emission technology. We wound the UV-LAFi onto a 230 mm long, Φ50 mm quartz tube. The mechanism of the water sampling sterilization device is that while seawater passes through the quartz tube, it is irradiated with UV-C from all directions, killing organisms in the seawater.

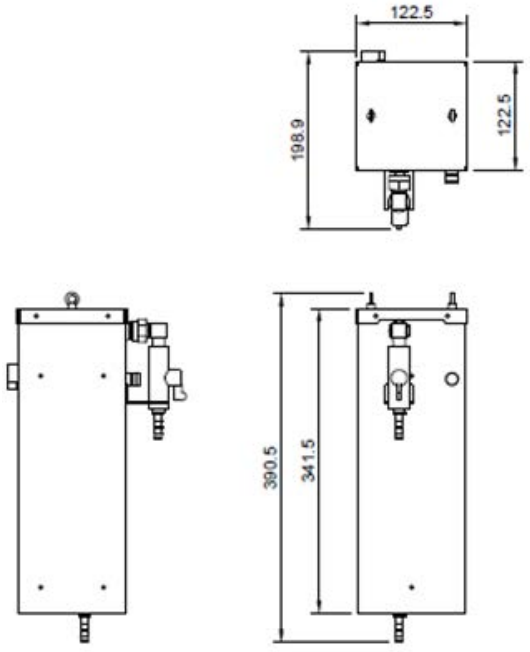

Fig. 2.4.6-1. Dimensions of the water sampling sterilization device.

(3) Observation log

Station	Date (m/d/y)	Sampling depth (dbar)
2	10/7/2024	Chl*a*. Max (20), 100, 200, 1000

(4) Data Archive

All data will be submitted to JAMSTEC Data Management Office (DMO) and is currently under its control.

Reference

Kosako, T., Guo, B., Tanaka, H., Hirakawa, H., Awamoto, K., Shinoda, T. (2013) Progress in Luminous Array Film (LAFi) with Plasma Tube Technology for Seamless Tilling Super-large-area Display. SID Dig., 44(1), pp. 49-52.

Awamoto. K., Hirakawa, H., Takahashi, J., Hidaka, T. and Shinoda, T. (2016) Development of the Flexible Surface Light Source Using Luminous Array Film Technology. Proceeding of IDW ’16, pp. 504-507.

Awamoto. K., Hirakawa, H., Hidaka, T. Takahashi, J., Makino, T. and Shinoda, T. (2018) Development of the Mercury Free Deep UV Surface Light Source with Plasma Technologies. Proceeding of the 2018 IEICE Society Conference, pp. 158.

2.4.7 Dissolved organic carbon and total dissolved nitrogen

Masahide WAKITA (MIO, JAMSTEC)

(1) Objectives

Variabilities in the concentration of dissolved organic carbon (DOC) in seawater have a potentially great impact on the carbon cycle in the marine system, because DOC is a major global carbon reservoir. A change by < 10% in the size of the oceanic DOC pool, estimated to be ~ 700 GtC (IPCC, 2013), would be comparable to the annual primary productivity in the whole ocean. In fact, it was generally concluded that the bulk DOC in oceanic water, especially in the deep ocean, is quite inert based upon ^{14}C-age measurements. Nevertheless, it is widely observed that in the ocean DOC accumulates in surface waters at levels above the more constant concentration in deep water, suggesting the presence of DOC associated with biological production in the surface ocean. This study presents the distribution of DOC in the western subarctic North Pacific.

(2) Sampling

Seawater samples of DOC and TDN were collected by surface bucket sampling and 12 L Niskin bottles mounted on the CTD/Carousel Water Sampling System and brought the total to ~230. Seawater from the Niskin bottle or surface water monitoring was transferred into 60 ml High Density Polyethylene bottle (HDPE) for DOC/TDN and rinsed with same water three times. Water taken from the surface to bottom is filtered using precombusted (450°C) GF/F inline filters as they are being collected from the Niskin bottle or surface bucket sampling. After collection, samples are frozen upright and preserved at ~ -20 °C cold until analysis in our land laboratory. Before use, all glassware was muffled at 550 °C for 5 hrs.

(3) Analysis

Prior to analysis, samples are returned to room temperature and acidified to pH < 2 with concentrated hydrochloric acid. DOC/TDN analysis was basically made with a high-temperature catalytic oxidation (HTCO) system improved a commercial unit, the Shimadzu TOC-L with a TNM-L units (Shimadzu Co.). In this system, the non-dispersive infrared was used for carbon dioxide produced from DOC during the HTCO process (temperature: 720 °C, catalyst: 0.5% Pt-Al_2O_3). Non-purgeable dissolved nitrogen compounds are combusted and converted to NO which, when mixed with ozone, chemiluminesces for detection by a photomultiplier. The consensus reference material for DOC and TDN (Hansell 2005) was analyzed during the sample measurements.

(3) Preliminary result

The distributions of DOC and TDN will be determined as soon as possible after this cruise.

(4) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.4.8 Chl.*a*

Tetsuichi Fujiki **(JAMSTEC): Principal Investigator**
Masahide Wakita **(JAMSTEC)**
Misato Kuwahara **(MWJ): Operation Leader**
Yasuhiro Arii **(MWJ)**
Takuya Izutsu **(MWJ)**

(1) Objective

Phytoplankton biomass can be estimated by measuring the concentration of chlorophyll *a*, as all oxygenic photosynthetic plankton contain chlorophyll *a*. The objective of this study is to investigate the vertical distribution of phytoplankton biomass, as indicated by chlorophyll *a*, using fluorometric determination.

(2) Parameters

Total chlorophyll *a*

(3) Instruments and Methods

Seawater samples (250 mL) for total chlorophyll *a* were collected from depths ranging from 12 to 18, between the surface and 300 dbar, including the chlorophyll *a* maximum layer. The chlorophyll *a* maximum layer was determined by a Chlorophyll Fluorometer (Seapoint Sensors, Inc.) attached to the CTD system.

Seawater samples were vacuum-filtrated (< 0.02 MPa) through glass microfiber filters (Whatman GF/F, 25mm in diameter). Phytoplankton pigments retained on the filters were immediately extracted in polypropylene tubes with 7 mL of N,N-dimethylformamide (FUJIFILM Wako Pure Chemical Corporation Ltd.) (Suzuki and Ishimaru, 1990). The tubes were stored at -20 °C in the dark at least for 24 hours to allow chlorophyll *a* extraction.

Chlorophyll *a* concentrations were measured using a fluorometer (10-AU, TURNER DESIGNS), which has been calibrated against pure chlorophyll *a* (Sigma-Aldrich Co., LLC). The fluorometric “Non-acidification method” (Welschmeyer, 1994) was applied to estimate chlorophyll *a* concentrations.

(4) Preliminary Results

A total of 177 samples were collected. The sampling casts were shown in Table 2.4.8.1. Total chlorophyll *a* concentrations at each station were shown in Figure 2.4.8.1 to 2.4.8.3. The results of replicate sample measurements were shown in Table 2.4.8.2.

(5) Data Archives

The data obtained during this cruise will be submitted to the Data Management Group of JAMSTEC, and will be made publicly available through the “Data Research System for Whole Cruise Information in JAMSTEC (DARWIN)” on JAMSTEC website.

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

(6) References

Suzuki, R., and T. Ishimaru (1990), An improved method for the determination of phytoplankton chlorophyll using N, N-dimethylformamide, *J. Oceanogr. Soc. Japan*, 46, 190-194.

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

Table 2.4.8.1. Number of samples and casts.

	Number of samples	Number of casts
Total chlorophyll *a*	177	10

Table 2.4.8.2. Results of the replicate sample measurements.

	All samples
Number of replicate sample pairs	20
Standard deviation (μg L^{-1})	0.01

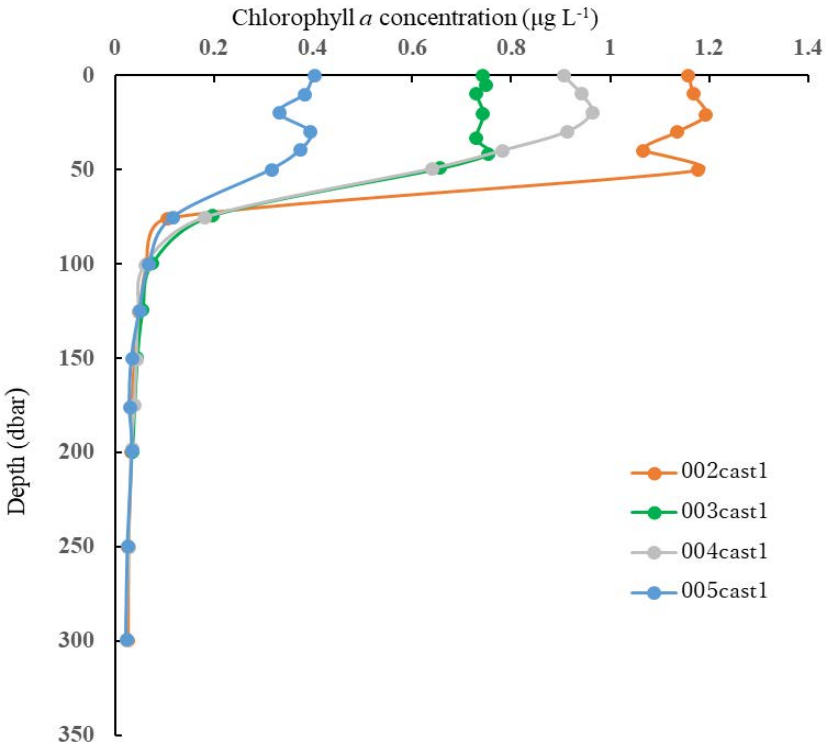

Figure 2.4.8.1. Vertical distribution of chlorophyll *a* at Stn.002 to Stn.005.

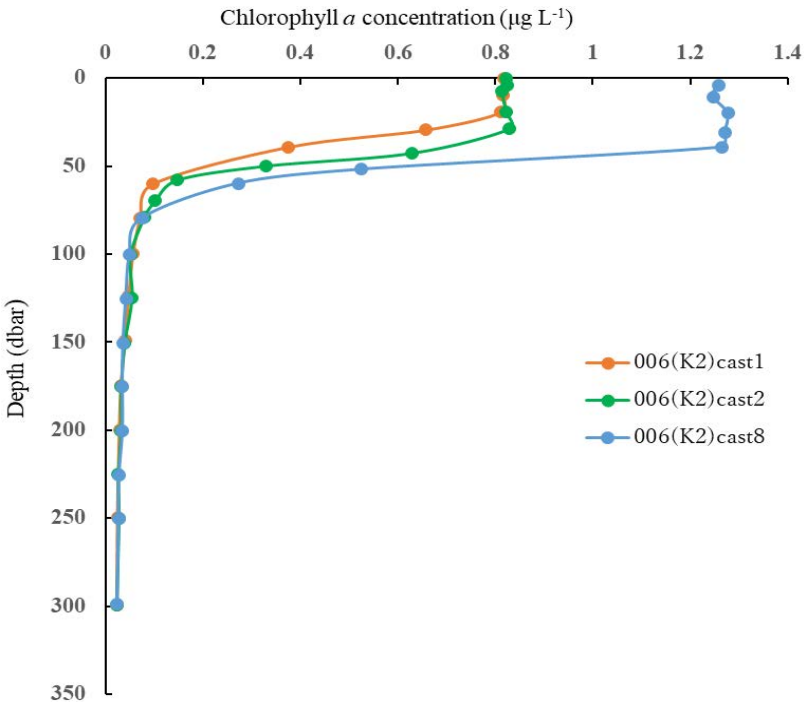

Figure 2.4.8.2. Vertical distribution of chlorophyll *a* at Stn.006.

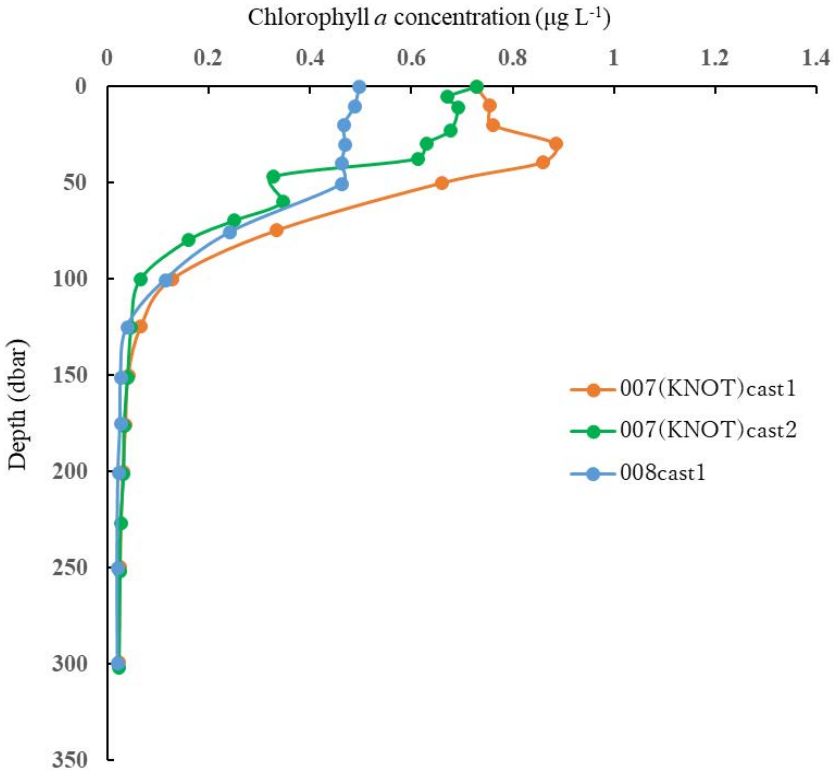

Figure 2.4.8.3. Vertical distribution of chlorophyll *a* at Stn.007 to Stn.008.

2.4.9 pH

Hiroshi UCHIDA (JAMSTEC RIGC)

(1) Objective

The objective of this study is to understand pH change in the western North Pacific.

(2) Instruments and method

Seawater pH for water samples was measured with a glass electrode pH meter (F-72 [serial no. A23C0014], Horiba, Japan) with the long glass electrode (9680S [serial no. 9Z3A0104], Horiba).

The water samples were collected in 100-mL aluminum bottles (Mini Bottle Can, Daiwa Can Company, Japan). Each bottle was rinsed three times with sample water and was filled without air space after overflowed the sample water two times of volume of the bottle (about 5 seconds) by using a plastic drawing tube (PFA tubing connected to silicon rubber tubing).

Before measurements, the sample bottles were immersed in a water bath whose temperature was controlled to about 25 °C by a thermostat (HT-90D, AS ONE), whose temperature was set to 25.8 °C. The pH measurements were conducted at 25 °C in a refrigerated temperature control bath (TRL-108H, THOMAS KAGAKU Co., Ltd.), whose temperature was set to 25.6 °C.

Two buffers (*2-aminophyridine*, AMP [016-28183, lot TPH2930, expiration date: August 2024, Fujifilm Wako Chemicals Co.], and *2-amino-2-hydroxy-1,3-propanediol*, TRIS, [013-28193, lot TPG2979, expiration date: October 2024, Fujifilm Wako Chemicals]) and Multiparametric Standard Seawater (MSSW, lot PRE20, KANSO TECHNOS Co., Ltd.) (see Uchida et al., 2020) were used as references.

Actual temperature measured by the glass electrode were slightly different from 25 °C. It's mean ± SD was 24.96±0.06 °C (minimum of 24.7 °C and maximum of 25.1 °C). Voltage changes due to this slight temperature deviation from 25 °C were corrected by using temperature dependencies of the voltage for AMP, TRIS, and PRE20 measurements (Fig. 2.4.9-1). The temperature coefficients were 0.68 mV/°C, 1.07 mV/°C, and 0.16 mV/°C for AMP, TRIS, and PRE20, respectively. For seawater samples, the temperature coefficients were assumed to be the same as that of the standard seawater (PRE20). The temperature coefficient of the standard seawater was smaller than that of AMP and TRIS. The magnitude of the correction for seawater samples was within ±0.001 pH units for temperature deviation of ±0.3 °C.

Since the measured pH (7.6756±0.0034 [total scale]) of PRE20 calibrated by AMP (6.6866 in pH units of total scale at 25 °C) and TRIS (8.0936 in pH units of total scale at 25 °C) based on a method by Dickson et al. (2007) was largely different from the calculated pH (7.6400 in pH units of total scale) estimated from Practical Salinity (34.2768), dissolved inorganic carbon (2191.4 μmol/kg), total alkalinity (2301.3 μmol/kg), phosphate (1.991 μmol/kg), silicate (61.44 μmol/kg), temperature (25 °C), and pressure (0 dbar) by using CO2SYS program developed by Lewis and Wallace (1998) (K1, K2 from Lueker et al., 2000), the pH of seawater samples were calibrated by AMP and PRE20 whose pH value was assumed to be 7.6400. The voltage values of AMP and TRIS measured at the beginning and the end of the measurements for each day were

used to estimate time drift of the pH meter, and the time drift was corrected linearly for each day of measurements.

The seawater samples were measured usually within a few hours after water sampling.

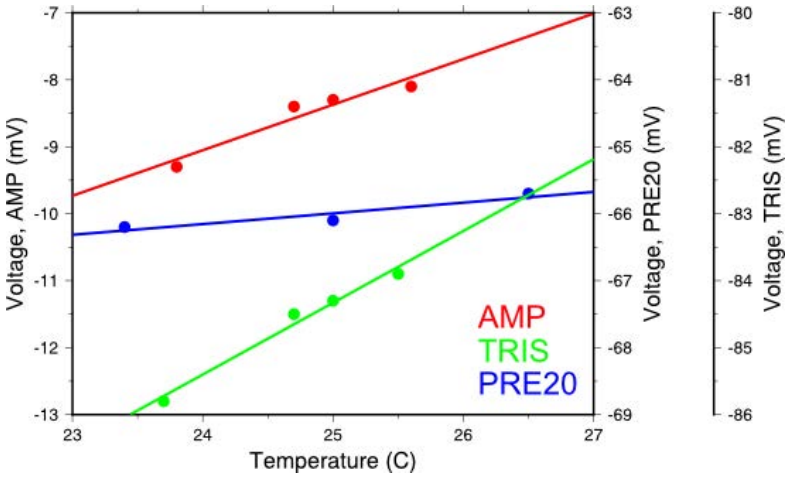

Figure 2.4.9-1. Temperature dependencies of the voltage for AMP, TRIS, and PRE20 measurements

(3) Results

A total of 14 pairs of replicate samples was measured and SD of the replicate samples was 0.0011.

PRE20 was used as the reference of pH measurements in the cruises MR23-05, MR23-07, and MR24-07. Therefore, the pH values obtained in these cruises are comparable (Fig. 2.4.9-2).

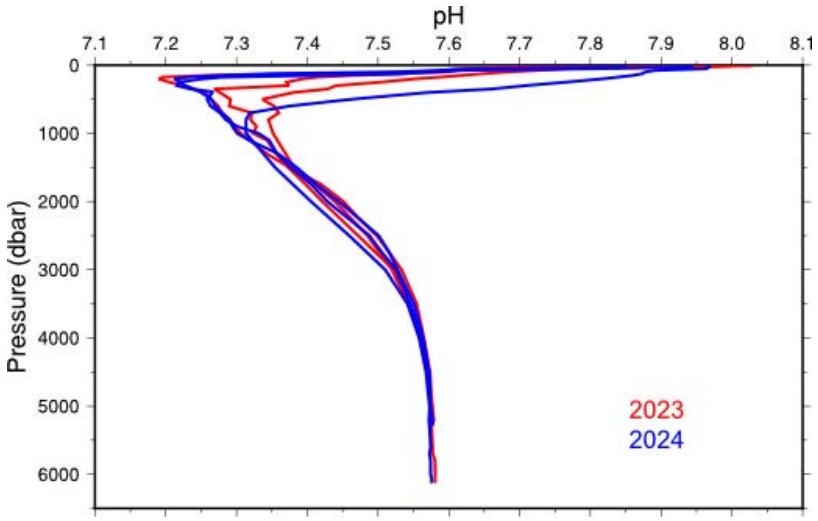

Figure 2.4.9-2. Vertical profiles of pH for stations 006 (K2), 007 (KNOT), and 008 (CT) obtained in the cruises MR23-05 (red lines) and MR24-07 (blue lines).

MSSW lots PRE19, PRE20, and PRE21 were measured in the cruise MR24-07 leg 2, and the results are shown in Table 2.4.9-1.

Table 2.4.9-1. Results of pH measurements for MSSW lots PRE19, PRE20, PRE21.

Lot no.	Serial no.	pH (total scale)	Note
PRE20	002	7.6400	
PRE20	041	7.6401	
PRE20	044	7.6387	
PRE20	082	7.6405	
PRE20	123	7.6407	
		Average ± *SD*: 7.6400±0.0008	Reference of the measurements
PRE19	132	7.7551	
PRE19	222	7.7520	
PRE19	276	7.7547	
		Average ± *SD*: 7.7539±0.0017	
PRE21	023	7.8479	
PRE21	078	7.8449	
PRE21	155	7.8485	
PRE21	211	7.8471	
PRE21	287	7.8455	
		Average ± *SD*: 7.8468±0.0015	Stored at room temperature
PRE21	024	7.8481	
PRE21	079	7.8484	
PRE21	156	7.8453	
PRE21	212	7.8437	
PRE21	288	7.8440	
		Average ± *SD*: 7.8459±0.0022	Stored at 40°C for 1 month

(4) References

Dickson, A. G., C. L. Sabine, and J. R. Christian (Eds.) (2007): Determination of the pH of sea water using a glass/reference electrode cell. In Guide to best practices for ocean CO2 measurements. PICES Special Publication 3, IOCCP report no. 8.

Lewis, E., and D. W. R. Wallace (1998): Program developed for CO2 system calculations. Report 105, 33 pp., Oak Ridge, TN: Oak Ridge National Laboratory. Retrieved from https://cdiac.esd.ornl.gov/oceans/co2rprt.html.

Uchida, H., T. Kawano, T. Nakano, M. Wakita, T. Tanaka and S. Tanihara (2020): An updated batch-to-batch correction for IAPSO standard seawater. J. Atmos. Oceanic Technol., 37, 1507-1520, doi:10.1175/JTECH-D-19-0184.1.

(5) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.4.10. Automated water sampling robot

Yoshiyuki NAKANO (JAMSTEC Engineering Department)

(1) Objective

In recent years, the number of onboard researchers in Japan has been decreasing and aging, and there are concerns about whether the current level of observation by research vessels can be maintained. Observation of seawater parameters by water sampling is a fundamental part of oceanographic observation, but there is a possibility that the water sampling process, which is one of the most labor-intensive aspects of shipboard observation, cannot be maintained at the current level. Therefore, we are developing an automated water sampling robot that can automatically take routine samples from a Niskin water sampler. Our objective in this cruise is to perform water sampling from the Niskin water sampler using the newly developed automated water sampling robot and compare the data with samples taken by researchers.

(2) Observation log

Station	Date (m/d/y)	Sampling depth (dbar)
5	10/11/2024	1000, 2000
6	10/17/2024	Chl*a*. Max (19), 100, 200, 300
6	10/18/2024	1000, 2000, 3000, 4000, 5000
6	10/21/2024	20

Sampling item

Dissolved inorganic carbon (DIC), Total Alkalinity (TA), Salinity, Nutrients, Chlorophyll *a*

(3) Data Archive

Water sampling data by the automated water sampling robot will not be made public because it is test data.

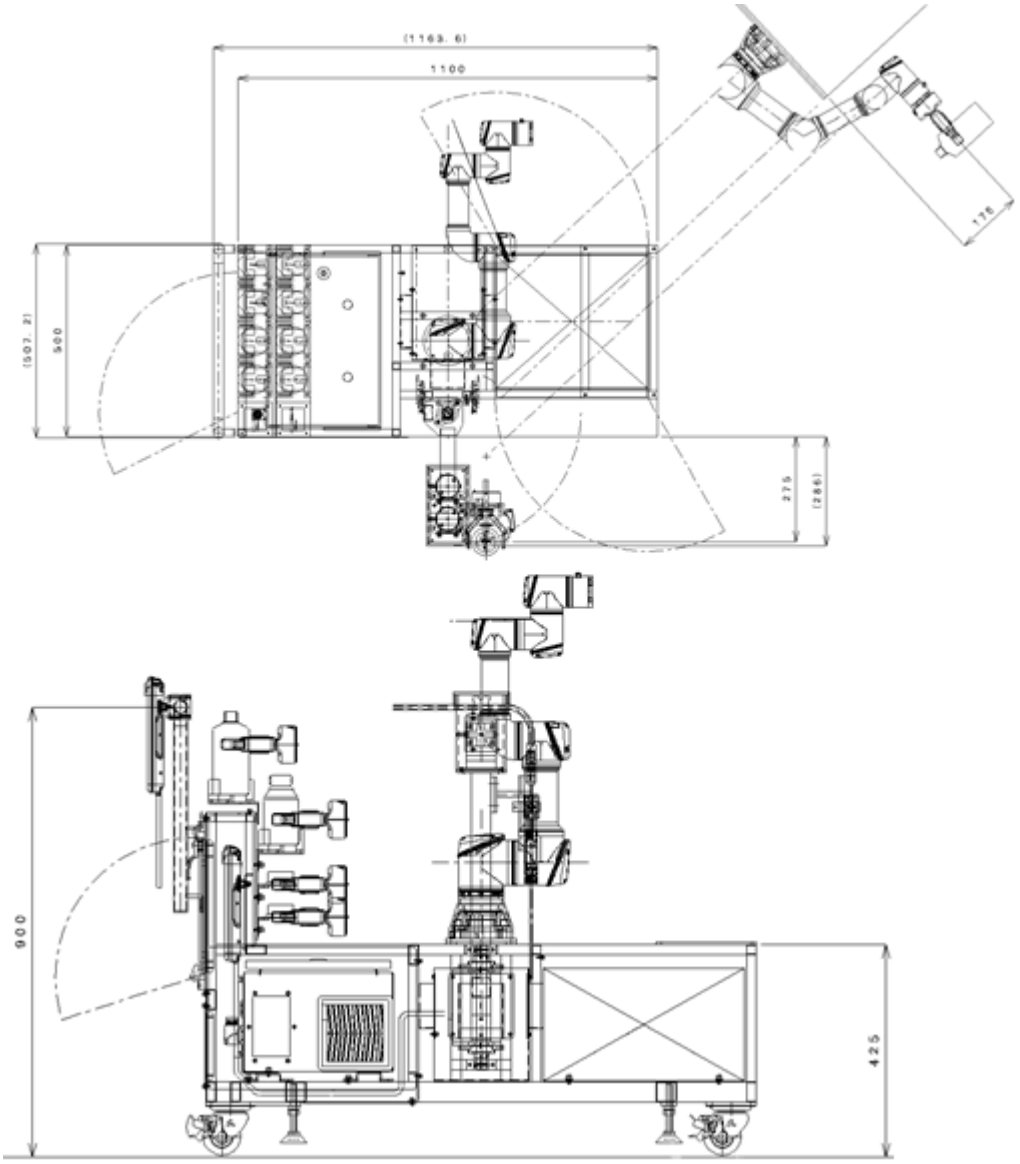

Fig. 2.4.10-1. Dimensions of the Automated water sampling robot.

2.4.11 pH/pCO_2 and Gamma-ray sensor vertical

Kiminori SHITASHIMA (Tokyo University of Marine Science and Technology) PI

pH/pCO_2 sensor

(1) Objective

The measurement of pH in the marine system is important because the pH of seawater reflects the oceanic carbon cycles and the exchange of CO_2 between the atmosphere and the ocean. Furthermore, pH relates to and the biological and chemical processes occurring in the ocean. Concerning the global warming, change of pH and pCO_2 in seawater should preferably be observed continually in a long term and a wide area (vertically and horizontally) to monitor air-sea CO_2 exchange and oceanic carbon cycle. In-situ measurement with a sensor is the most suitable for such observations.

The objective of this study is to develop high performance pH/pCO_2 sensor for in situ measurement in the deep sea and apply it for chemical oceanography

(2) Instruments and methods

The in-situ pH sensor employs an Ion Sensitive Field Effect Transistor (ISFET) as a pH electrode, and the Chloride ion selective electrode (Cl-ISE) as a reference electrode. The ISFET is a semiconductor made of p-type Si coated with SiO_2 and Si_3N_4 that can measure H^+ ion concentration in aqueous phase. New ISFET-pH electrode specialized for oceanographic use was developed. The Cl-ISE is a pellet made of several chlorides having a response to the chloride ion, a major element in seawater. The electric potential of the Cl-ISE is stable in the seawater, since it has no inner electrolyte solution. The in-situ pH sensor has a quick response (less than a second), high accuracy (±0.003pH) and pressure-resistant performance. The pCO_2 sensor was devised to incorporate the above-mentioned newly developed in-situ pH sensor to measure the in-situ pCO_2 in seawater. The principle of pCO_2 measurement by the pCO_2 sensor is as follows. Both the ISFET-pH electrode and the Cl-ISE of the pH sensor are sealed in a unit with a gas permeable membrane whose inside is filled with inner electrolyte solution with 1.5 % of NaCl. The pH sensor can detect pCO_2 change as pH change of inner solution caused by permeation of carbon dioxide gas species through the membrane. An amorphous Teflon membrane (Teflon AF™) manufactured by DuPont was used as the gas permeable membrane. The in-situ (3,000m, 1.8ºC) response time of the pCO_2 sensor was less than 60 seconds. The diode on ISFET can measure the temperature of seawater simultaneously. ISFET and Cl-ISE are connected to pH converter circuit in the pressure housing through the underwater cable connector. The pressure housing includes pH converter circuit, A/D converter, data logger RS-232C interface and Li ion battery.

Two pH/pCO_2 sensors were installed to the CTD-CMS, and in-situ data of pH and pCO_2 ware measured every 1 second during descent and ascent of the CTD-CMS. Before and after the observation, the pH sensor was calibrated using two different standard buffer solutions, 2-aminopyridine (AMP; pH 6.7866) and 2-amino-2-hydroxymethil-1,3-propanediol (TRIS; pH 8.0893) described by Dickson and Goyet, for the correction of electrical drift of pH data. In this cruise, the calibration of the pCO_2 sensor was conducted using two different seawaters, surface and deep seawaters which measured pCO_2 concentration, before and after the observation. The recorded data (pH, pCO_2, temperature) is stored in the data logger. After recovery of the sensor, the data is transferred from the data logger into a personal computer (PC) connected with RS-232C cable, and the in-situ pH and pCO_2 are calculated using calibration data of each standards in a PC.

(3) Parameters

In-situ pH and pCO_2

(4) Observation log

Station	UTC (m/d/y)	Cast
ST2	10/6/2024	Cast 1
ST3	10/8/2024	Cast 1
ST4	10/9/2024	Cast 1
ST5	10/10/2024	Cast 1
ST6	10/16/2024	Cast 1
ST7	10/23/2024	Cast 1
ST8	10/25/2024	Cast 1

(5) Data archives

All data will be archived at Tokyo University of Marine Science and Technology after checking data quality and submitted to Data Management Group (DMG) of JAMSTEC.

Fig. 2.4.11.1 Photo of pH/pCO_2 sensors on the frames of CTD-CMS.

Gamma-ray sensor (Radioactivity)

(1) Objective

Underwater in-situ gamma-ray measurement is an important scientific priority for oceanography, especially for survey and monitoring of the concentration distributions of natural and anthropogenic gamma-ray. The sensor was applied to observe and monitor natural gamma-ray in the deep open ocean.

(2) Instruments and methods

A plastic scintillator is made from polystyrene that doped NaI(Tl) and it absorbs gamma-ray like as liquid or crystal scintillator. The plastic scintillator was coated by light-resistant paint and used as a part of pressure housing. Therefore, the sensor can expect high sensitivity in comparison with NaI(Tl) crystal sealed in a container because the plastic scintillator contacts seawater directly. This sensor consists of plastic scintillator, photomultiplier tube, preamplifier unit, high-voltage power supply, data logger and lithium-ion battery, and all parts are stored in a pressure housing. The sensor was installed to the CTD-CMS frame and in-situ data of radon was measured every 1 second during descent and ascent of the CTD-CMS system.

(3) Parameters

In-situ gamma-ray

(4) Observation log

Station	UTC (m/d/y)	Cast
ST2	10/6/2024	Cast 1
ST3	10/8/2024	Cast 1
ST5	10/11/2024	Cast 2
ST6	10171/2024	Cast 2
ST6	10/19/2024	Cast 5
ST7	10/23/2024	Cast 2

(5) Data archives

All data will be archived at Tokyo University of Marine Science and Technology after checking of data quality and submitted to Data Management Group (DMG) of JAMSTEC.

Fig. 2.4.11.2 Photo of gamma-ray sensors on the frames of CTD-CMS.

2.4.12 Environmental DNA

Masahide WAKITA (MIO, JAMSTEC)
Akihide KASAI (Hokkaido University)

(1) Objectives

To depict the aquatic biodiversity is essential to reveal the substantial impacts of climate change on the marine ecosystems. Fishes are one of the major components of the ecosystem and can be very susceptible to global warming. Because they are important for the economy, their ecological changes will also influence human activity.

Analyzing environmental DNA (eDNA) is an emerging method to assess aquatic community composition. eDNA originated from aquatic organisms in various forms (e.g., cells, feces, gametes) can be retrieved from seawater and used in quantitative PCR (qPCR) assay or metabarcoding to identify organisms present in the study site. Because the eDNA approach has successfully been applied to various environments (river, lake, coastal area), it can also be considered a promising tool for marine ecosystems. This cruise's primary aim is to collect eDNA samples to analyze the fish community in the western subarctic North Pacific.

(2) Sampling

Seawater surface samples of eDNA were collected by the surface bucket sampling at St. 2, 3, 4, 5 (K2-east), 6 (K2), 7 (KNOT), and 8 (CT). The subsurface samples were and 12 L Niskin bottles mounted on the CTD/Carousel Water Sampling System at the depths of 10m, 50m, and 100m at 6 (K2), and brought the total to 34. Seawater from bucket or Niskin bottle was transferred into 5 L polyethylene bag rinsed with same water three times. Seawater sample is vacuum-filtered using 0.45 μm Sterivex^{TM}-HV PVDF filters (Millipore) with a suction filtration pump (Merck, Ez-Stream). After filtrating, filters are filled with 1.6 ml of RNAlater and preserved at ~ -20 °C cold until analysis in our land laboratory. Before use, all equipment were washed using bleach solution. These samples will be the subject of metabarcoding analysis to clarify the species composition of fishes.

(3) Preliminary result

The vertical distributions of eDNA will be determined as soon as possible after this cruise.

(4) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.4.13 FDOM

Hiroshi UCHIDA, (JAMSTEC RIGC)
Masahito SHIGEMITSU (JAMSTEC RIGC) (not onboard)
Masahide WAKITA (JAMSTEC MIO)

(1) Objective

The objective of this study is to collect calibration data for in situ fluorometer (e.g. Shigemitsu et al., 2020), and to examine spatial distribution and temporal change of fluorescent dissolved organic matter (FDOM).

(2) Instruments and method

Seawater samples for FDOM were collected in 40 ml pre-combusted glass vials with acid-washed Teflon-lined caps. Filtrations were carried out by connecting the spigot of the Niskin bottle through a silicone tube to an inline plastic filter holder. The samples were stored frozen in the dark until laboratory analysis. The samples were immersed in a water jacket bath connected to a refrigerated temperature control bath (TRL-108H, THOMAS KAGAKU Co., Ltd.), whose temperature was set to 21 °C, before measurements to acclimate the sample temperature to about 20 °C.

A benchtop fluorometer (Aqualog, Horiba Scientific, Japan, HGS no. U54CX17C) was used to measure EEM fluorescence spectra. Emission scans from 248–829 nm will be obtained at 2.33 nm intervals for sequential excitations from 240–560 nm at 5 nm intervals, with an integration time of 12 s and using the high Charge-Coupled Device (CCD) gain mode. The glass cell folder also serves as a water jacket and was connected to a refrigerated temperature control bath (NCB-1220B, TOKYO RIKAKIKAI Co., Ltd.), whose temperature was set to 20 °C, to maintain the sample temperature to 20 °C during measurement (about 15 minutes).

(3) Results

The samples were collected at stations 004, 006 (K2), and 008 (CT), and measured in the cruise MR24-07 leg 2. MSSW lot PRE21 was measured as a reference. One bottle of MSSW (serial no. 237) was divided into three pre-combusted glass vials, and measured one glass vial at each measurement day. Moreover, five bottles of MSSW PRE21 (serial no. 025, 080, 157, 213, and 289) stored at room temperature and five bottle of MSSW PRE21 (serial no. 026, 081, 158, 214, and 290) stored at 40°C for 1 month were also measured to check homogeneity and stability of MSSW lot PRE21 for FDOM measurement.

(4) Reference

Shigemitsu, M., Uchida, H., Yokokawa, T., Arulananthan, K., and Murata, A., 2020,
Determining the distribution of fluorescent organic matter in the Indian Ocean using in situ fluorometry. Front. Microbiol. 11:589262. doi:10.3389/fmicb.2020.589262.

(6) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.5 Biological oceanography
2.5.1 Primary Productivity

Maki Noguchi JAMSTEC
Chiho Sukigara JAMSTEC

(1) Objectives

Primary production in the ocean not only supports all marine life but is also the starting point for the carbon storage in the middle and deep ocean. To clarify the spatial distribution of primary productivity in the subarctic North Pacific, primary productivity was measured at three stations (St.3, K2 and KNOT, Table 2.5.1.1) by the on-deck incubation method (the simulated *in situ* method).

(2) Methods

i. Sampling

Water samples were collected at 6 depths based on 56, 35, 11, 4, 2, and 1% of surface light intensity at each station using Niskin-X bottles installed acid-cleaned O-ring and at surface (100% of surface light intensity) using a bucket. The sampling depths (Table 2.5.1.2) were determined from the profile of PAR (photosynthetically active radiation) of the CTD observation on the previous day. Seawater for incubation at each depth was transferred into acid-cleaned, four transparent polycarbonate bottles and a dark polyethylene bottle.

ii. Incubation

Just before the incubation, $NaH^{13}CO_3$ dissolved in water was added to each bottle to a final concentration of 0.2mM, increasing the bicarbonate concentration by approximately 10 %. Water sample for the time-zero were filtered immediately after the addition of $NaH^{13}CO_3$ solution. The incubation was conducted in the on-deck bath cooled by a surface seawater overflow or by an immersion cooler, depending on the water temperature at each sampling depth. The light intensity for each depth was adjusted by coating the culture cylinder with blue film and by covering it with a light-shielding sheets. The incubation time was 24 hours.

iii. Measurement

After incubation, water samples were immediately filter through pre-combusted (450ºC, 5 hours) GF/F filter. The filters were exposed to HCL vapor for 30 minutes to remove particulate inorganic carbon and then dried in an oven for at least 20 hours. The incorporation of 13C contents of the particulate fraction will be measured with an isotope ratio mass spectrometer system (EcovisION; Elementar Japan, K.K.) based on the method of Hama et al. (1983) on land.

iv. Phytoplankton composition

To provide information on the influence of the chemotaxonomic composition of the phytoplankton community on primary productivity, analyses of phytoplankton pigments are performed using an Agilent high-performance liquid chromatography (HPLC) system.

For HPLC measurements of marine phytoplankton pigments, 2.4-L seawater samples were filtered through a 47 mm GF/F filter. The filters with moisture wiped off and vacuum dried at 0 °C within a few hours are stored in a deep-freezer (−80 °C) until analysis on land. Pigment concentrations will be quantified as described by Van Heukelem and Thomas (2001).

(3) Data archive

The data obtained will be submitted to the JAMSTEC Data Management Group (DMG).

(4) References

Hama T. et al. (1983), Measurement of photosynthetic production of a marine phytoplankton population using a stable 13C isotope. *Marine Biology* 73: 31-36.

Van Heukelem, L., and C. S. Thomas (2001), Computer-assisted high-performance liquid chromatography method development with applications to the isolation and analysis of phytoplankton pigments, *J. Chromatogr. A*, 910(1), 31-49.

Table 2.5.1.1: Sampling times and locations

Station	Time					Location	
	YYYY	MM	DD	HH:MM		Latitude	Longitude
St.3	2024	10	08	11:25	UTC	52-47.97N	175-44.01E
St.6 (K2)	2024	10	17	18:00	UTC	46-59.92N	159-59.96E
St.7 (KNOT)	2024	10	23	09:30	UTC	44-00.08N	155-00.01E

Table 2.5.1.2: Sampling depths

Light intensity	Depth [m]		
	St.3	St.6 (K2)	St.7 (KNOT)
100%	0	0	0
56%	5	4	6
35%	10	7	11
11%	21	19	23
4%	34	29	38
2%	42	43	47
1%	50	58	60

2.5.2 Transparent exopolymer particles

Kazuhiko Matsumoto (JAMSTEC)
Maki Noguchi (JAMSTEC)

(1) Objectives

Transparent exopolymer particles (TEP), i.e., polysaccharide-rich microgels that are produced primarily by the abiotic coagulation of phytoplankton exudates, are identifying as organic gels in the ocean interior. TEP is very sticky, and it aggregates with other suspended particles, resulting in the formation of sinking marine snow. In addition, TEP becomes enriched in the surface microlayer and expected to produce marine organic aerosol directly at the sea surface due to the interaction between wind and waves. To understand the processes of settling particles and organic aerosol formation, the concentrations of TEP are measured.

(2) Sampling and measurement procedure

Seawater samples were collected with Niskin-X bottles and a bucket vertically at Station K2. Samples were fixed with 1% (v/v) formalin and stored in refrigerator. The analyses will be conducted after the cruise on land as follows. The water samples of 200 mL are filtered onto 0.4-μm polycarbonate filters, and the filters are stained with 1 mL alcian blue solution which adjusted to pH 2.5 and rinsed with 1 mL of Milli-Q water. Stained filter samples are stored in freezer until analysis. Filter samples are soaked for 2 - 5 h in 80% sulfuric acid (H_2SO_4) to elute the dye and then the absorbance of the solution is measured at 787 nm in a 1 cm cuvette. The calibration curve is produced by using a xanthan gum solution (XG, Sigma-Aldrich), and the TEP concentrations are represented as XG equivalent (Passow and Alldredge, 1995).

(3) Data archive

The data obtained during this cruise will be submitted to the JAMSTEC Data Management Group (DMG).

(4) Reference

Passow, U., and A. L. Alldredge (1995), A dye-binding assay for the spectrophotometric measurement of transparent exopolymer particles (TEP) in the ocean, *Limnol. Oceanogr.*, 40(7): 1326-1335.

2.5.3 Zooplankton

2.5.3.1 Planktic foraminifers and thecosomatous pteropods

Katsunori Kimoto (RIGC, JAMSTEC)
Keisuke Shimizu (RIGC, JAMSTEC)
Maki Noguchi (RIGC , JAMSTEC)
Takuya Sagawa (Kanazawa University)
Yusei Miyamoto (Chiba University)

(1) Objectives

The ocean has already absorbed about 30% of the total anthropogenic CO_2 (approximately 155 GtC) since the industrial revolution (IPCC AR5, 2013). This reduces ocean pH (Ocean acidification, OA) and causes wholescale shift in seawater carbonate chemistry. OA also give several impacts to the biological processes; one well-known effect is the lowering of calcium carbonate saturation state, which give negative impact to shell-forming marine organisms such as pteropods and planktic foraminifers etc. OA also affect zooplankton other than the shell-forming organisms, and characteristics of the zooplankton community will be changed. Therefore, we are observing long-term change of zooplankton biomass at K2 and adjacent areas in the North Pacific by using the plankton collecting apparatus and performing some biological/geochemical analysis to evaluate the biological impact to OA.

In this cruise, for better understanding of biological responses to carbonate saturation status, we aimed for following themes,

a) Analysis of plankton communities in each layer at depths shallower than 1000m using VMPS net

b) Understanding the vertical distribution of pteropod and planktonic foraminiferal communities and changes in shell density with depth

c) Elucidating the relationship between population dynamics of planktonic foraminifera and biogeochemical cycles with depth using protein concentrations in the North Pacific

d) Understanding the phenotypic and genetic variation of pteropods in the mixed layer and their population structure

e) Relationships between morphology and geochemistry of planktonic foraminiferal shells

(2) Methods

Zooplankton sampling was conducted at 8 stations (See Table 2.5.3-1) by using the Vertical Multi-depth Plankton Sampler (VMPS-3K, Tsurumi Seiki co., Ltd, Fig. 2.5.3-1). VMPS-3K equipped 2 or 3 plankton nets (63 μm mesh, NXX25), magnetic flow-meter, fluorometer (Wet Lab Inc.) and CTD sensors (Sea-bird Electrics), and was hauled vertically at a speed of 0.5 m/sec. Opening/closing of each net is electrically controlled from the lab on the ship, we can collect vertically stratified sample sets together with the environmental sensing data. For shallow depths (0-100 m), in addition to the VMPS nets, sample collection by single NORPAC net (Aperture 45cm, 63μm mesh, NXX25, 2m length) was performed. Additionally, during this cruise, we

collected plankton samples from surface water using a water pump onboard R/V Mirai, filtered them through a 63 μm mesh, and stored the samples in microtubes (Table 2.5.3-2).

Collected samples were fixed for each research purpose. For morphologic analysis, samples were immediately fixed by ethanol (99.5 %) and stored at the room temperature (ca. 20~25 °C). For genetic analysis, they were stored in the RNA storage solution and kept in the deep freezer (-80°C). Planktonic foraminifera for measuring protein biomass were picked up from those samples and transferred into a bath of micro-filtered seawater, cleaned with a brush to remove all particles stuck to the specimen including organic matter. Each planktonic foraminifera were individually stored in an 1.5 ml micro tube, and frozen at -80 ℃.

(3) Onshore study in the future

Thecosomatous pteropod and planktonic foraminiferal shells will be analyzed by the Micro-focus X-ray CT (MXCT) equipped in JAMSTEC HQ in order to elucidate relationships between the multiple stressors and individual shell morphology/density. For the population analysis of pteropods, DNA extraction from the preserved specimens and amplifying of gene sequences for the COI region of mtDNA will be performed. After the sequence alignments, population genetic analysis will be performed. Also planktonic foraminiferal samples separated into the microtubes will be individually measured for protein content and correlated with their shell size. Then, we will determine the total biomass of planktonic foraminifera in this area from the correlation between protein content and shell size.

(4) Data Archive

All data will be submitted to JAMSTEC Data Management Office (DMO).

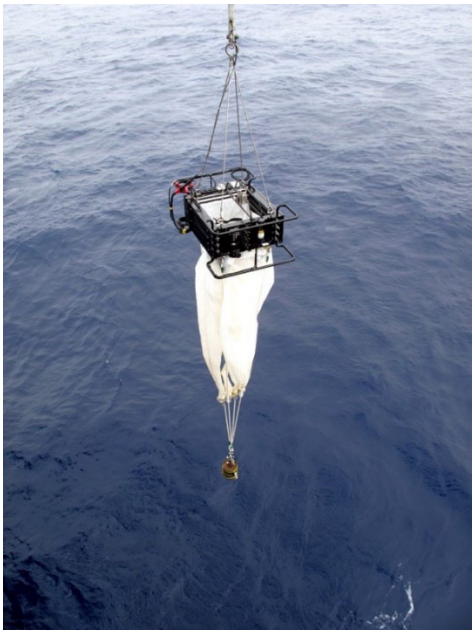

Fig. 2.5.3-1 The overview of VMPS (Vertical Multi-layer Plankton Sampler).

Table 2.5.3-1 Sampled locations for zooplankton during the MR24-07 Leg1.

Station	Apparatus	Area	Latitude			Longitude			depth (m)	Date			Time (UTC)
St2	Plankton net (VMPS)	Bering Sea	52	47.00	N	177	42.20	W	0-50	2024	10	6	0:35
St2	Plankton net (VMPS)	Bering Sea	52	47.00	N	177	42.20	W	50-150	2024	10	6	0:35
St2	Plankton net (VMPS)	Bering Sea	52	47.00	N	177	42.20	W	150-300	2024	10	6	0:35
St2	Plankton net (VMPS)	Bering Sea	52	47.00	N	177	42.20	W	300-500	2024	10	6	0:35
St2	Plankton net (VMPS)	Bering Sea	52	47.00	N	177	42.20	W	500-700	2024	10	6	0:35
St2	Plankton net (VMPS)	Bering Sea	52	47.00	N	177	42.20	W	700-1000	2024	10	6	0:35
St3	Plankton net (VMPS)	Bering Sea	52	47.48	N	175	43.48	W	0-50	2024	10	7	11:38
St3	Plankton net (VMPS)	Bering Sea	52	47.48	N	175	43.48	E	50-150	2024	10	7	11:38
St3	Plankton net (VMPS)	Bering Sea	52	47.48	N	175	43.48	E	150-300	2024	10	7	11:38
St3	Plankton net (VMPS)	Bering Sea	52	47.48	N	175	43.48	E	300-500	2024	10	7	11:38
St3	Plankton net (VMPS)	Bering Sea	52	47.48	N	175	43.48	E	500-700	2024	10	7	11:38
St3	Plankton net (VMPS)	North Pacific	52	47.48	N	175	43.48	E	700-1000	2024	10	7	11:38
St4	Plankton net (VMPS)	North Pacific	51	05.48	N	173	31.36	E	0-50	2024	10	8	8:17
St4	Plankton net (VMPS)	North Pacific	51	05.48	N	173	31.36	E	50-150	2024	10	8	8:17
St4	Plankton net (VMPS)	North Pacific	51	05.48	N	173	31.36	E	150-300	2024	10	8	8:17
St4	Plankton net (VMPS)	North Pacific	51	05.48	N	173	31.36	E	300-500	2024	10	8	8:17
St4	Plankton net (VMPS)	North Pacific	51	05.48	N	173	31.36	E	500-700	2024	10	8	8:17
St4	Plankton net (VMPS)	North Pacific	51	05.48	N	173	31.36	E	700-1000	2024	10	8	8:17
St5	Plankton net (VMPS)	North Pacific	47	00.00	N	170	00.00	E	0-50	2024	10	11	17:07
St5	Plankton net (VMPS)	North Pacific	47	00.00	N	170	00.00	E	50-150	2024	10	11	17:07
St5	Plankton net (VMPS)	North Pacific	47	00.00	N	170	00.00	E	150-300	2024	10	11	17:07
St5	Plankton net (VMPS)	North Pacific	47	00.00	N	170	00.00	E	300-500	2024	10	11	17:07
St5	Plankton net (VMPS)	North Pacific	47	00.00	N	170	00.00	E	500-700	2024	10	11	17:07
St5	Plankton net (VMPS)	North Pacific	47	00.00	N	170	00.00	E	700-1000	2024	10	11	17:07

Table 2.5.3-1(continued) Sampled locations for zooplankton during the MR24-07 Leg1.

Station	Apparatus	Area	Latitude			Longitude			depth (m)	Date			Time (UTC)
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	0-50	2024	10	17	3:04
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	50-150	2024	10	17	3:04
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	150-300	2024	10	17	3:04
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	300-500	2024	10	17	3:04
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	500-700	2024	10	17	3:04
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	700-1000	2024	10	17	3:04
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	0-50	2024	10	19	19:05
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	50-150	2024	10	19	19:05
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	150-300	2024	10	19	19:05
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	300-500	2024	10	19	19:05
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	500-700	2024	10	19	19:05
St6	Plankton net (VMPS)	North Pacific	47	00.00	N	160	00.00	E	700-1000	2024	10	19	19:05
St7	Plankton net (VMPS)	North Pacific	44	00.00	N	155	00.00	E	0-50	2024	10	23	4:40
St7	Plankton net (VMPS)	North Pacific	44	00.00	N	155	00.00	E	50-150	2024	10	23	4:40
St7	Plankton net (VMPS)	North Pacific	44	00.00	N	155	00.00	E	150-300	2024	10	23	4:40
St7	Plankton net (VMPS)	North Pacific	44	00.00	N	155	00.00	E	300-500	2024	10	23	4:40
St7	Plankton net (VMPS)	North Pacific	44	00.00	N	155	00.00	E	500-700	2024	10	23	4:40
St7	Plankton net (VMPS)	North Pacific	44	00.00	N	155	00.00	E	700-1000	2024	10	23	4:40
St2	Plankton net (NORPAC)	Bering Sea	52	47.00	N	177	42.20	W	0-50	2024	10	6	0:35
St3	Plankton net (NORPAC)	North Pacific	52	47.48	N	175	43.48	E	700-1000	2024	10	7	11:38
St4	Plankton net (NORPAC)	North Pacific	51	05.48	N	173	31.36	E	300-500	2024	10	8	8:17
St5	Plankton net (NORPAC)	North Pacific	47	00.00	N	170	00.00	E	300-500	2024	10	11	17:07
St6	Plankton net (NORPAC)	North Pacific	47	00.00	N	160	00.00	E	500-700	2024	10	17	6.04
St6	Plankton net (NORPAC)	North Pacific	47	00.00	N	160	00.00	E	300-500	2024	10	19	19:05
St7	Plankton net (NORPAC)	North Pacific	44	00.00	N	155	00.00	E	500-700	2024	10	23	8:40

Table 2.5.3-2 Sampling locations by water pump during the MR24-07 Leg1.

Station	Apparatus	Latitude			Longitude			depth (m)	Date			Time	
st 02	sea water pump	55	37.2418	N	167	22.6863	W	5	2024	10	3	3:02	UTC
st 02	sea water pump	56	10.9359	N	167	42.0263	W	5	2024	10	3	5:59	UTC
st 02	sea water pump	58	8.0123	N	168	50.3926	W	5	2024	10	3	15:14	UTC
st 02	sea water pump	59	0.2502	N	169	21.9977	W	5	2024	10	3	19:13	UTC
st 02	sea water pump	59	51.6941	N	169	55.0746	W	5	2024	10	3	23:25	UTC
st 02	sea water pump	60	27.6983	N	169	59.9948	W	5	2024	10	4	2:15	UTC
st 02	sea water pump	60	58.9042	N	170	0.0992	W	5	2024	10	4	4:38	UTC
st 02	sea water pump	60	32.0628	N	169	56.929	W	5	2024	10	4	16:59	UTC
st 02	sea water pump	60	46.5245	N	169	52.5788	W	5	2024	10	4	20:05	UTC
st 02	sea water pump	60	14.0183	N	170	13.2079	W	5	2024	10	4	23:02	UTC
st 02	sea water pump	59	53.4	N	170	53.2632	W	5	2024	10	5	1:38	UTC
st 02	sea water pump	59	38.8605	N	172	7.3299	W	5	2024	10	5	5:02	UTC
st 02	sea water pump	59	27.619	N	173	15.5007	W	5	2024	10	5	8:13	UTC
st 02	sea water pump	58	46.4967	N	176	3.6542	W	5	2024	10	5	17:13	UTC
st 02	sea water pump	57	52.8174	N	176	19.7721	W	5	2024	10	5	21:35	UTC
st 02	sea water pump	56	50.7994	N	176	37.235	W	5	2024	10	6	2:34	UTC
st 02	sea water pump	55	48.3391	N	176	52.7083	W	5	2024	10	6	7:30	UTC
st 02	sea water pump	53	31.1894	N	177	31.0919	W	5	2024	10	6	18:17	UTC
st 02	sea water pump	52	47.0837	N	177	44.4443	W	5	2024	10	7	13:19	UTC
st 03	sea water pump	52	14.0375	N	174	43.3421	E	5	2024	10	8	21:05	UTC
st 03	sea water pump	51	5.8155	N	173	31.721	E	5	2024	10	9	5:03	UTC
st 04	sea water pump	49	9.6857	N	171	48.9221	E	5	2024	10	10	0:28	UTC
st 05	sea water pump	46	57.3367	N	170	0.1551	E	5	2024	10	11	5:50	UTC
st 05	sea water pump	46	59.2003	N	170	2.159	E	5	2024	10	12	6:20	UTC
st 05	sea water pump	46	54.9513	N	164	2.7677	E	5	2024	10	13	5:40	UTC
st 06	sea water pump	46	58.0341	N	159	41.5753	E	5	2024	10	14	8:47	UTC
st 06	sea water pump	46	53.0526	N	159	42.1249	E	5	2024	10	14	22:13	UTC
st 06	sea water pump	46	54.0683	N	159	42.0531	E	5	2024	10	15	7:40	UTC
st 06	sea water pump	46	58.3961	N	159	59.1467	E	5	2024	10	16	3:24	UTC
st 06	sea water pump	46	59.6526	N	160	0.5392	E	5	2024	10	17	1:46	UTC
st 06	sea water pump	46	35.0775	N	159	43.9078	E	5	2024	10	19	22:25	UTC
st 06	sea water pump	46	19.3197	N	159	26.0452	E	5	2024	10	20	7:39	UTC
st 06	sea water pump	46	45.9992	N	159	29.8396	E	5	2024	10	20	22:42	UTC
st 06	sea water pump	46	57.2526	N	160	10.0778	E	5	2024	10	21	10:17	UTC
st 07	sea water pump	46	34.7216	N	159	16.1022	E	5	2024	10	22	5:59	UTC
st 07	sea water pump	44	15.5779	N	155	24.5398	E	5	2024	10	22	22:34	UTC
st 07	sea water pump	43	44.955	N	154	42.5532	E	5	2024	10	23	11:19	UTC
st 07	sea water pump	42	21.837	N	152	27.7738	E	5	2024	10	23	22:53	UTC
st 07	sea water pump	41	10.3483	N	150	11.6735	E	5	2024	10	24	8:56	UTC
st 07	sea water pump	40	47.6779	N	146	55.6424	E	5	2024	10	25	0:08	UTC
st 07	sea water pump	41	53.3472	N	146	18.5791	E	5	2024	10	25	7:52	UTC
st 07	sea water pump	40	3.907	N	142	59.4742	E	5	2024	10	26	2:21	UTC
st 07	sea water pump	38	41.0767	N	141	57.3124	E	5	2024	10	26	9:38	UTC
st 07	sea water pump	35	5.9632	N	140	33.5973	E	5	2024	10	27	2:38	UTC

2.5.4 Bacteria

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Kiminori SHITASHIMA (Tokyo University of Marine Science and Technology)

(1) Objective

The deep sea is a low-temperature, high-pressure environment, and many kinds of psychrophiles and piezophiles inhabit the deep sea. The final purpose of this study is to search for novel enzymes that degrade various ester compounds from psychrophiles and piezophiles, and to apply them to environmental conservation and industry.

In this voyage, the purpose is to isolate the psychrophiles and piezophiles inhabit in seawater collected from various depths of the survey area, and to search for novel ester-degrading enzymes.

(2) Methods

Seawater collected at each depth was kept at a low temperature and transferred to our laboratory. In order to concentrate bacteria in each seawater sample, the seawater samples were filtered with a membrane filter of 0.2 μm-pore size under decompression. A part of the concentrated liquid was smeared on nutrient marine agar MA media and cultured at a low temperature of 4°C to 10°C. For the rest of the concentrated liquid, glycerin was added and the mixture was cryopreserved at -80°C. Prepare a marine agar medium containing an ester-substrate EMA was prepared: the ester was used to examine the activity of degrading enzyme. Bacterial colonies obtained on the MA media were planted to the EMA media and cultured at low temperatures. Strains with clear zones around colonies were screened as candidates for strains with degradation activity of the objective ester.

The physiological properties of each candidate strain are analyzed. Each candidate strain is cultured in a liquid medium and centrifuged to obtain supernatant containing the enzyme. The enzymatic properties such as temperature characteristics, pressure characteristics, and substrate specificity of the candidate enzymes are determined and compared to each other. From these results, novel useful enzymes are selected.

(3) Parameters

Novel useful enzymes in seawater.

(4) Observation log

Station	UTC (m/d/y)	Sampling depth (dbar)
K2-C1	10/17/2024	0, 100, 200, 400, 600, 800, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000, B-10
CT-C1	10/25/2024	0, 200, 400, 800, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 5700, 6000, 6130

(5) Data archives

All data will be archived at Tokyo University of Marine Science and Technology after checking of data quality and submitted to Data Management Office (DMO) of JAMSTEC.

2.6 Mooring

2.6.1 Recovery and Deployment of mooring systems

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(1) Overview

The Hybrid Profiling Buoy (HPB) is a biogeochemical (BGC) mooring system designed to provide continuous monitoring of oceanic environmental changes and the associated low-trophic level organisms throughout the year. During the MR24-07 Leg1 cruise, we successfully recovered the HPB system, which had been moored at Station K2 (47°00'N, 160°00'E, 5,200m) during the MR23-05 Leg2 cruise, 2023 and subsequently redeployed it during this expedition. Additionally, we deployed a new sediment trap BGC surface mooring system (K2-OA) near Station K2 in the subarctic gyre, specifically to monitor ocean acidification (OA). The following are the specifications of both mooring systems. For detailed information on deployment of HPB and K2-OA BGC moorings, please refer to chap. 2.6.2.

Table 2.6.1-1. Mooring positions of respective mooring systems.

	Recovery	Deployment
Mooring Number	K2H230809	K2H241022
Working Date	Aug. 09 2023	Oct. 22 2024
Latitude	47 ° 00.24 N	47 ° 00.2546’ N
Longitude	159 ° 58.36 E	159 ° 58.3446’ E
Sea Beam Depth	5,213 m	5,187 m

The deployment Hybrid profiling buoy consists of a top buoy with 24lbs (11kg) buoyancy, underwater winch, instruments, wire and ropes, recovery buoy with 496lbs (225kg) buoyancy, glass floats (Benthos 17" glass ball), dual releasers (Edgetech) and 4,911lbs (2,228kg) sinker. An ARGOS compact mooring locator was mounted on underwater winch, and a submersible recovery strobe was mounted on the top buoy. This mooring system was planned to keep the following time-series observational instruments are mounted approximately 130 m below sea surface. On the Hybrid profiling buoy, three Sediment Traps are installed on the 500 m, 1,000 m and 4,800 m. two Auto Sampling Systems (RAS) are installed on the 200 m and 300m. four Backscatter Meter are mounted on the SUS frame (175 m) and RAS(300m),, CTD (SBE-37) and Do Sensor (RINKO and Optode) are mounted on the dual acoustic releaser and inline SUS frame (175 m, 250 m and 780 m), Sediment Trap, RAS, underwater winch, top buoy. Details for each instrument are also described below.

Table 2.6.1-2. Information of recovery of the Hybrid profiling buoy system.

Mooring Number	K2H230809			
Project	Time-Series	Depth	5,186.8	m
Area	North Pacific	Planned Depth	5,220	m
Station	K2	Length	5,089.8	m
Target Position	**47°00.35' N**	Depth of Buoy	160	m
	159°58.32' E	Period	1	year
ACOUCTIC RELEASERS				
Type	Edgetech	Edgetech		
Serial Number		27815		
Receive F.	11.0 kHz	11.0	kHz	
Transmit F.	14.0 kHz	14.0	kHz	
RELEASE C.	**335704**	**344657**		
Enable C.	377142	361035		
Disable C.	377161	361073		
Battery	4.5 years (lithiumBattery)	2 years		
Release Test	OK	OK		
RECOVERY				
Recorder	Masaki Furuhata	Start	1.5	NM
Ship	R/V MIRAI	Overrun	-	m
Cruise No.	**MR24-07 Leg1**	Recovery Start	19:54	
Date	2024/10/15-16	Recovery End	02:01	
Weather	C			
Wave Hight	2.0 m	Pos. of Start	47-05.01	N
SeaBeam Depth	5,213 m		159-58.30	E
Ship Heading	180 deg	Pos. of Drop. Anc.	46-59.97	N
Ship Ave.Speed	- knot		159-58.34	E
Wind	< 301 deg > 0.7 m/s	Pos. of Mooring	47-00.2411	N
Current	< 283 deg > 0.1 cm/s		159-58.3616	E

Table 2.6.1-3. Deployment Hybrid profiling buoy system record.

Mooring Number	K2H241022			
Project	Time-Series	Depth	5,187.0	m
Area	North Pacific	Planned Depth	5,220.0	m
Station	K2	Length	5,089.8	m
Target Position	**47°00.2546' N**	Depth of Buoy	170	m
	159°58.3446' E	Period	1	year
ACOUCTIC RELEASERS				
Type	Edgetech	Edgetech		
Serial Number	27864	34040		
Receive F.	11.0 kHz	11.0 kHz		
Transmit F.	14.0 kHz	14.0 kHz		
RELEASE C.	**344421**	**233770**		
Enable C.	357724	221130		
Disable C.	357762	221155		
Battery	4.5 years (lithiumBattery)	4.5 years (lithiumBattery)		
Release Test	OK	OK		
DEPLOYMENT				
Recorder	Masaki Furuhata	Start	5.6	NM
Ship	R/V MIRAI	Overrun	-	m
Cruise No.	**MR24-07 Leg1**	Let go Top Buoy	22:15	
Date	2024/10/21-22	Let go Anchor	11:49	
Weather	C	Sink Top Buoy	12:30	
Wave Hight	2.8 m	Pos. of Start	47-03.60	N
SeaBeam Depth	5,213 m		160-06.30	E
Ship Heading	230 deg	Pos. of Drop.Anc	47-03.60	N
Ship Ave.Speed	- knot		160-06.30	E
Wind	< 223 deg > 7.8 m/s	Pos. of Mooring	47-00.2546'	N
Current	< 028 deg > 0.5 cm/s		159-58.3446'	E

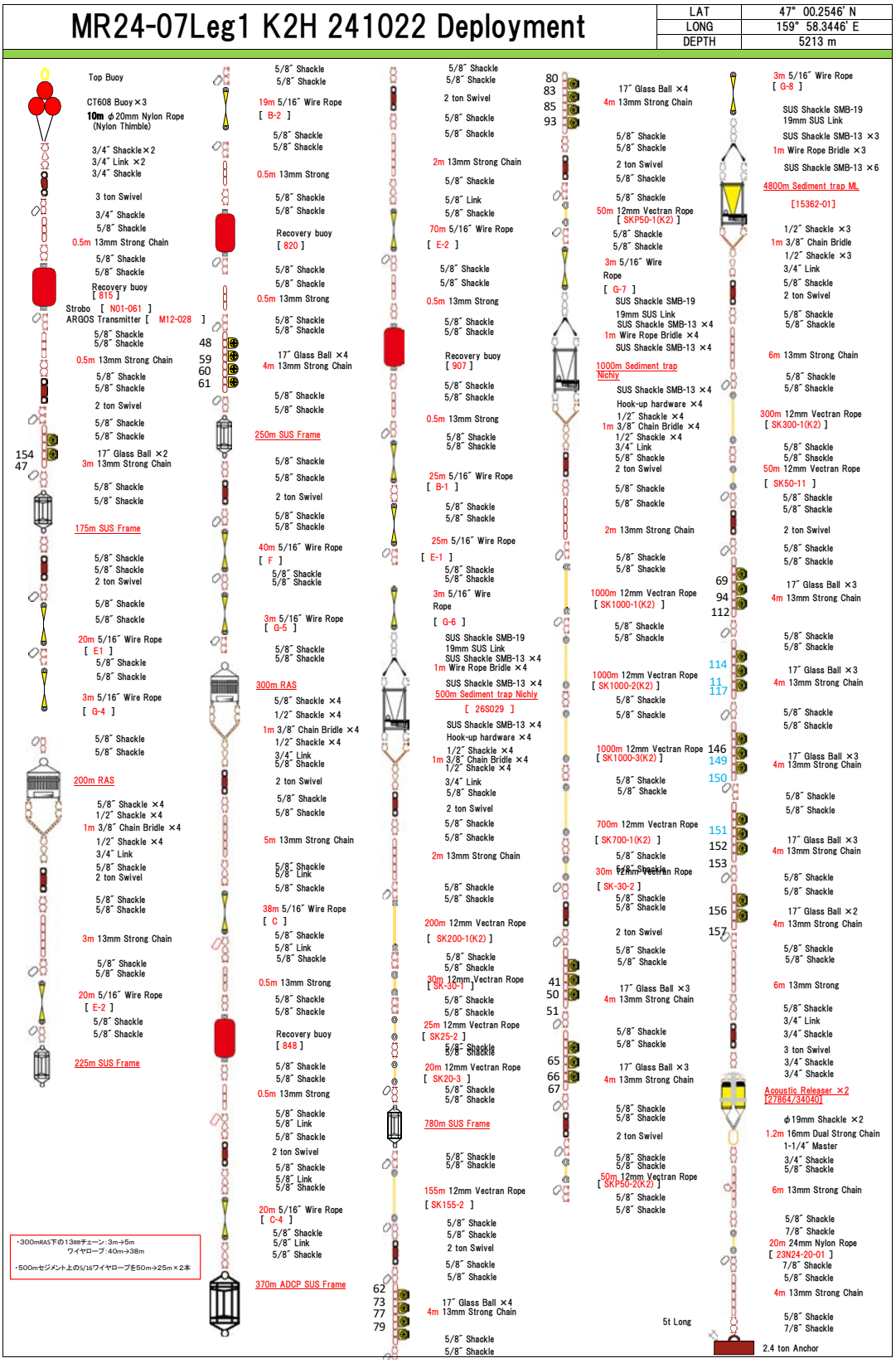

Figure 2.6.1-1. Hybrid profiling buoy system redeployed in this cruise.

Table 2.6.1-4 Summary for sensors/samplers attached to the Hybrid profiling buoy mooring.

Deployment：October.22.2024 (MR24-07Leg1)
Recovery： 2025（Mirai cruise）

Mooring depth (m)	Sensor/sampler	S/N	-	Investigator	Collected data/sample	Remarks
170	***[Recovery buoy]***	***815***				
	Argos transmitter	M12-028	MetOcean/NOVATECH	Fujiki, T.	-	ID:260740
	Storobo	N01-061	MetOcean/NOVATECH	Fujiki, T.	-	
175	***[SUS frame]***					
	SBE37	1892	SeaBird	Uchida, H./Wakita, M.	CTD	
	OPTODE	6	JFE Advantec	Uchida, H./Wakita, M.	DO	
200	***[RAS200]***					
	RAS	11241-09	McLane	Wakita, M.	time-series sampling of seawater	
	SBE37	2239	SeaBird	Uchida, H./Wakita, M.	CTD	
	OPTODE	50	JFE Advantec	Uchida, H./Wakita, M.	DO	
	HpHS	60100364001	Kimoto Electric	Nakano, Y./Wakita, M.	pH, Temp.	メインシリンダーのS/N
	DEFI-D	0AGG026	JFE Advantec	Kitamura, M.	Depth	
	UV fluorometer + RBR data logger	6238, 205142	Seapoint	Uchida, H./Wakita, M.	CDOM	
225	***[SUS frame]***					
	SBE37	2730	SeaBird	Uchida, H./Wakita, M.	CTD	
	RINKO	0004	JFE Advantec	Uchida, H./Wakita, M.	DO	
250	***[SUS frame]***					
	SBE37	2756	SeaBird	Uchida, H./Wakita, M.	CTD	
	RINKO	0092	JFE Advantec	Uchida, H./Wakita, M.	DO	
300	***[RAS300]***					
	RAS	11241-07	McLane	Wakita, M.	time-series sampling of seawater	
	SBE37	2289	SeaBird	Uchida, H./Wakita, M.	CTD	
	RINKO	051	JFE Advantec	Uchida, H./Wakita, M.	DO	
370	***[ADCP]***					
	ADCP, Workhorse LongRanger	1434	Teledyne RD Instruments	Fujiki, T.	current, backscattering strength	
	SBE37	2288	SeaBird	Uchida, H./Wakita, M.	CTD	
	OPTODE	9	JFE Advantec	Uchida, H./Wakita, M.	DO	
500	***[Trap 500]***					
	Sediment trap, NGK	26S029	Nichiyu Giken Kogyo	Kitamura, M.	sinking particles	
	SBE37	2287	SeaBird	Uchida, H./Wakita, M.	CTD	
	OPTODE	10	JFE Advantec	Uchida, H./Wakita, M.	DO	
780	***[SUS frame]***					
	SBE37	2738	SeaBird	Uchida, H./Wakita, M.	CTD	
	OPTODE	5	JFE Advantec	Uchida, H./Wakita, M.	DO	
1000	***[Trap1000]***					
	Sediment trap, MARK78H-21	26S003	McLane	Kitamura, M.	sinking particles	
	SBE37	2285	SeaBird	Uchida, H./Wakita, M.	CTD	
	OPTODE	7	JFE Advantec	Uchida, H./Wakita, M.	DO	
4800	***[Trap4800]***					
	Sediment trap, MARK78H-21	15362-01	McLane	Kitamura, M.	sinking particles	
	SBE37	2742	SeaBird	Uchida,H	CTD	
	OPTODE	2	JFE Advantec	Uchida, H.	DO	
	Chlorophyll/turbidity meter	0002	JFE Advantec	Uchida,H	FDOM,turbidity	
30m from bottom	***[Acoustic releasers]***	***27864/34040***				
	Chlorophyll/turbidity meter	0003	JFE Advantec	Uchida,H	FDOM,turbidity	
	OPTODE	08	JFE Advantec	Uchida, H.	DO	
	SBE37	2731	SeaBird	Uchida, H.	CTD	

Table 2.6.1-5. Deployment record of K2-OA surface BGC mooring system.

Mooring Number K2OA				
Project	Time-Series	Depth	5,116.0	m
Area	North Pacific	Planned Depth	5,150.0	m
Station	K2	Length	5,090.0	m
Target Position	**46° 53.5787' N**	Depth of Buoy	60	m
	159° 40.2137' E	Period	1	year
ACOUCTIC RELEASERS				
Type	Edgetech	Edgetech		
Serial Number	27824	28533		
Receive F.	11.0 kHz	11.0 kHz		
Transmit F.	14.0 kHz	14.0 kHz		
RELEASE C.	**344674**	**223307**		
Enable C.	361121	201054		
Disable C.	361167	201077		
Battery	4.5 years (lithiumBattery)	4.5 years (lithiumBattery)		
Release Test	OK	OK		
DEPLOYMENT				
Recorder	Masaki Furuhata	Start	6.6	NM
Ship	R/V MIRAI	Overrun	-	m
Cruise No.	**MR24-07 Leg1**	Let go Top Buoy	02:20	
Date	2024/10/15	Let go Anchor	05:03	
Weather	BC	Sink Top Buoy	05:41	
Wave Hight	3.2 m	Pos. of Start	46-19.50'	N
SeaBeam Depth	5,155 m		159-48.02'	E
Ship Heading	184 deg	Pos. of Drop. Anc.	46-53.82'	N
Ship Ave.Speed	- knot		159-39.90'	E
Wind	< 301 deg > 9.4 m/s	Pos. of Mooring	46-53.5758'	N
Current	< 184 deg > 0.3 cm/s		159-40.2137'	E

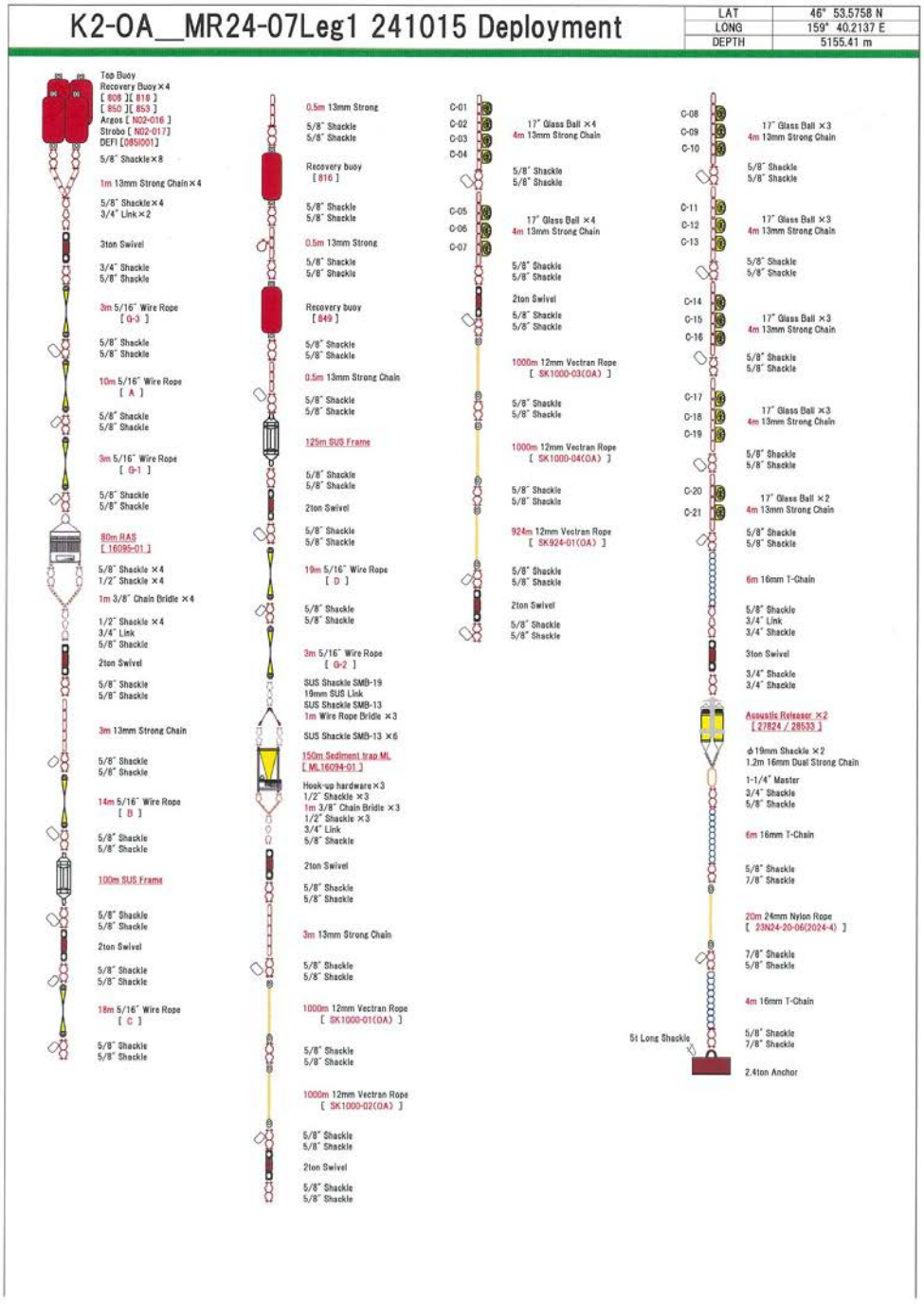

Figure 2.6.1-2. K2-OA Sediment trap mooring system deployed in this cruise.

Table 2.6.1-6 Summary for sensors/samplers attached to the K2-OA Surface BGC mooring

Summary for sensors/samplers attached to the K2 SurfaceBGC mooring
Deployment : Oct,15 2024 (MR24-07Leg1) Recovery :
Summer 2025 (Mirai cruise)

Mooring depth (m)	Sensor/sampler	Serial No.	Manufacturer	Investigator	Collected data/sample	Sampling			Purpose	Remarks
						Time interval	Duration	Depth (m)		
60	*[Top of the mooring]*									
	Argos transmitter	N02-016	metocean	Fujiki.T.						ID:261208
	ACTW-WF-L	0049	JFE Advantec	Uchida/Wakita	CT	60 min.	2 years	60		
	DEFI-D50HG	085I001	JFE Advantec	Wakita, M.	Depth	10 min.	1 year	60		
	Strobo	N02-017	metocean	Fujiki.T.						
80	*[RAS80]*									
	RAS-500	16095-01	McLane	Wakita	seawater	10 days *1	2 years	80	time-series of water sampling	
	ACTW-WF-L	0050	JFE Advantec	Uchida/Wakita	CT	60 min.	2 years	80	environmental sensing	
	AROW-WF-L	0040	JFE Advantec	Uchida/Wakita	DO	60 min.	2 years	80	environmental sensing	
	HpHS	505963001	Kimoto Electric	Nakano/Wakita	pH, Temp.	4 hours	16 months	80	environmental sensing	
	DEFI-D50HG	082U009	JFE Advantec	Wakita, M.	Depth	10 min.	1 year	80		
	Backscatter	0891	SeaBird	Honda	particle			80	environmental sensing	
100	*[SUS frame]*									
	SBE37	8836	SeaBird	Uchida/Wakita	CTD	60 min.	2 years	100	environmental sensing	
	RINKO (AROD-USB)	0009	JFE Advantec	Uchida/Wakita	DO	60 min.	2 years	100	environmental sensing	
125	*[SUS frame]*									
	SBE37	8839	SeaBird	Uchida/Wakita	CTD	60 min.	2 years	125	environmental sensing	
	RINKO (AROD-USB)	0010	JFE Advantec	Uchida/Wakita	DO	60 min.	2 years	125	environmental sensing	
150	*[Trap 150]*									
	Sediment trap, Model78H-21	ML16094-01	McLane	Kimoto	sinking particles			150	environmental sensing	
	SBE37	8840	SeaBird	Uchida/Wakita	CTD	60 min.	2 years	150	environmental sensing	
	RINKO (ARO-USB)	0017	JFE Advantec	Uchida/Wakita	DO	60 min.	2 years	150	environmental sensing	
	Backscatter	1742	SeaBird	Honda	particle			150	environmental sensing	
	ISFET pH/pCO2 sensor	-		Shitashima/Kimoto	pH,pCO2					

2.6.2. Sediment trap

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(1) Objective

To evaluate magnitude and efficiency of the biological carbon pump in the Western Subarctic Gyre of the North Pacific, the sediment trap experiment has been carried out since 2005 at the time-series station K2.

(2) Description of deployed instruments (K2H241022 and K2OA)

In this cruise, we installed two kinds of moorings K2H241022 and K2OA at station K2 (47º00'N, 159º58'E and 46º53'N, 159º40'E, respectively). The former has been used for routine observations since 2005 and contains three traps at depths of 500 m, 1,000 m, and 4,800 m. The latter is a new mooring with one trap at depth of 150 m. Two sediment traps were manufactured by NiGK Corporation (SMD26S-029 and SMD26S-003) with 26 sampling bottles were installed at depths of 500 m and 1,000 m of K2H241022 (table 2.6.6.-1). The sediment trap was manufactured by Mclane Research Laboratories (ML15362-01) with 21 sampling bottles was also installed at depths of 4800 m of K2H241022 too (table 2.6.6.-1). All sampling bottles were filled with 10% formaldehyde solution with excess sodium tetraborate dissolved in filtered seawater using 0.22 μm pore-size filter. In new moorings K2-OA, one sediment trap was manufactured by Mclane Research Laboratories (ML16094-01) with 21 sampling bottles was installed at depths of 150 m (table 2.6.6.-1). Internal clock of each sediment trap was set in UTC, and sampling schedules of the recovered and deployed sediment traps were summarized in the tables (table 2.6.6.-3). Sample collection interval was set 7 or 14 days, except for initial and last bottles.

Table 2.6.6-1. Specifications of sediment traps

	SMD26S-6000	MARK78H-21_old model	MARK78H-21_new model
Company	NiGK Corporation	McLane Research Lab.	McLane Research Lab.
Max. depth (m)	6000	7000	7000
Dimensions (diameter × height, cm)	104×160	91×164	91×164
Mouth area (m2)	0.5	0.5	0.5
Weights (kg)	86 in air, 46 in water	72 in air, 39 in water	72 in air, 39 in water
No. of sampling bottles	26	21	21
Volume of sampling bottles (ml)	270	250	250
Battery	Alkaline/Lithium pack	14 Alkaline batteries	14 Alkaline batteries
Communication cables	RMG4-USB	RMG3-Serial port-USB	SUBCOM6-USB (Cable model: M4787)
Software	N-SMD	Crosscut	MacLanePro
OS	Win 7	Win 7	Win 10

Table 2.6.6-2. Serial numbers and battery types

Mooring ID	Depth	Model	S/N	Battery
K2H230809	500 m	NiGK, SMD26S-6000	26S001	Alkaline/Lithium pack
K2H230809	1000 m	McLane, MARK78H-21_new	ML15362-02 14	Alkaline batteries
K2H230809	4810 m	McLane, MARK78H-21_old	ML11241-22	Alkaline batteries
K2H241022	500 m	NiGK, SMD26S-6000	26S029	Alkaline/Lithium pack
K2H241022	1000 m	NiGK, SMD26S-6000	26S003	Alkaline/Lithium pack
K2H241022	4810 m	McLane, MARK78H-21_old	ML15362-01	Alkaline batteries
K2OA	150 m	McLane, MARK78H-21_new	ML16094-01	Alkaline batteries

Table 2.6.6-3. Sampling schedules of the deployed sediment trap.

(a) 500 m and 1000 m (K2H241022)

Bottle No.	Sampling (UTC, yyyy/mm/dd) Start	End	Interval (days)
1	2024/10/23 0:00	2024/11/3 0:00	11
2	2024/11/3 0:00	2024/11/17 0:00	14
3	2024/11/17 0:00	2024/12/1 0:00	14
4	2024/12/1 0:00	2024/12/15 0:00	14
5	2024/12/15 0:00	2024/12/29 0:00	14
6	2024/12/29 0:00	2025/1/12 0:00	14
7	2025/1/12 0:00	2025/1/26 0:00	14
8	2025/1/26 0:00	2025/2/9 0:00	14
9	2025/2/9 0:00	2025/2/23 0:00	14
10	2025/2/23 0:00	2025/3/9 0:00	14
11	2025/3/9 0:00	2025/3/23 0:00	14
12	2025/3/23 0:00	2025/4/6 0:00	14
13	2025/4/6 0:00	2025/4/20 0:00	14
14	2025/4/20 0:00	2025/5/4 0:00	14
15	2025/5/4 0:00	2025/5/18 0:00	14
16	2025/5/18 0:00	2025/5/25 0:00	7
17	2025/5/25 0:00	2025/6/1 0:00	7
18	2025/6/1 0:00	2025/6/8 0:00	7
19	2025/6/8 0:00	2025/6/15 0:00	7
20	2025/6/15 0:00	2025/6/22 0:00	7
21	2025/6/22 0:00	2025/6/29 0:00	7
22	2025/6/29 0:00	2025/7/6 0:00	7
23	2025/7/6 0:00	2025/7/13 0:00	7
24	2025/7/13 0:00	2025/7/20 0:00	7
25	2025/7/20 0:00	2025/7/27 0:00	7
26	2025/7/27 0:00	2025/8/1 0:00	5

(b) 4800 m (K2H241022)

Bottle No.	Sampling (UTC, yyyy/mm/dd) Start	End	Interval (days)
1	2024/10/23 0:00	2024/11/03 0:00	11
2	2024/11/03 0:00	2024/11/17 0:00	14
3	2024/11/17 0:00	2024/12/01 0:00	14
4	2024/12/01 0:00	2024/12/15 0:00	14
5	2024/12/15 0:00	2024/12/29 0:00	14
6	2024/12/29 0:00	2025/01/12 0:00	14
7	2025/01/12 0:00	2025/01/26 0:00	14
8	2025/01/26 0:00	2025/02/09 0:00	14
9	2025/02/09 0:00	2025/02/23 0:00	14
10	2025/02/23 0:00	2025/03/09 0:00	14
11	2025/03/09 0:00	2025/03/23 0:00	14
12	2025/03/23 0:00	2025/04/06 0:00	14
13	2025/04/06 0:00	2025/04/20 0:00	14
14	2025/04/20 0:00	2025/05/04 0:00	14
15	2025/05/04 0:00	2025/05/18 0:00	14
16	2025/05/18 0:00	2025/06/01 0:00	14
17	2025/06/01 0:00	2025/06/15 0:00	14
18	2025/06/15 0:00	2025/06/29 0:00	14
19	2025/06/29 0:00	2025/07/13 0:00	14
20	2025/07/13 0:00	2025/07/27 0:00	14
21	2025/07/27 0:00	2025/08/01 0:00	5

(c) 150 m (K2OA)

Bottle No.	Sampling (UTC, yyyy/mm/dd) Start	End	Interval (days)
1	2024/10/20 0:00	2024/11/3 0:00	14
2	2024/11/3 0:00	2024/11/17 0:00	14
3	2024/11/17 0:00	2024/12/1 0:00	14
4	2024/12/1 0:00	2024/12/15 0:00	14
5	2024/12/15 0:00	2024/12/29 0:00	14
6	2024/12/29 0:00	2025/1/12 0:00	14
7	2025/1/12 0:00	2025/1/26 0:00	14
8	2025/1/26 0:00	2025/2/9 0:00	14
9	2025/2/9 0:00	2025/2/23 0:00	14
10	2025/2/23 0:00	2025/3/9 0:00	14
11	2025/3/9 0:00	2025/3/23 0:00	14
12	2025/3/23 0:00	2025/4/6 0:00	14
13	2025/4/6 0:00	2025/4/20 0:00	14
14	2025/4/20 0:00	2025/5/4 0:00	14
15	2025/5/4 0:00	2025/5/18 0:00	14
16	2025/5/18 0:00	2025/6/1 0:00	14
17	2025/6/1 0:00	2025/6/15 0:00	14
18	2025/6/15 0:00	2025/6/29 0:00	14
19	2025/6/29 0:00	2025/7/13 0:00	14
20	2025/7/13 0:00	2025/7/27 0:00	14
21	2025/7/27 0:00	2025/8/1 0:00	5

(3) Preliminary result (K2H230809)

In the recovered K2H230809 mooring, three sediment traps were installed at depths of 500 m, 1,000 m and 4,810 m at station K2 in 2023 were operated as scheduled (table 2.6.6.-4). The sediment trap with 26 sampling bottles at a depth of 4,810 m was set to run only 14 times due to technical trouble, thus the remaining 12 sampling bottles (bottle #15 – #26) were not used. After the recovery, the pH of the formaldehyde solution in each bottle was measured onboard and was mostly about pH 8.0-8.5 (table 2.6.6.-5). Only one bottle (#26 at depth of 500 m) had a much lower pH (pH 6.34), probably because it contained a rotting squid that had been stuck in the turntable. Average pH of samples at depth of 500 m, 1000 m, and 4810 m were pH 8.39 ± 0.17 (excluded bottle #26), 8.10 ± 0.24, and 8.19 ± 0.13, respectively. Amount of the collected material in each bottle was also measured (Figure 2.6.6.-1). A distinct peak in the particle flux collected at the depth of 500, 1,000, and 4,800 m was observed in summer. However, the

particle flux collected at the depth of 4800m showed a slight delay in the timing of the peak compared to the other samples.

Table 2.6.6-4. Sampling schedules of the recovered sediment trap (K2H230809).

(a) 500 m

Bottle No.	Sampling (UTC, yyyy/mm/dd) Start	End	Interval (days)
1	2023/8/11 0:00	2023/8/21 0:00	10
2	2023/8/21 0:00	2023/8/31 0:00	10
3	2023/8/31 0:00	2023/9/20 0:00	20
4	2023/9/20 0:00	2023/10/10 0:00	20
5	2023/10/10 0:00	2023/10/30 0:00	20
6	2023/10/30 0:00	2023/11/19 0:00	20
7	2023/11/19 0:00	2023/12/9 0:00	20
8	2023/12/9 0:00	2023/12/29 0:00	20
9	2023/12/29 0:00	2024/1/18 0:00	20
10	2024/1/18 0:00	2024/2/7 0:00	20
11	2024/2/7 0:00	2024/2/27 0:00	20
12	2024/2/27 0:00	2024/3/18 0:00	20
13	2024/3/18 0:00	2024/4/7 0:00	20
14	2024/4/7 0:00	2024/4/27 0:00	20
15	2024/4/27 0:00	2024/5/17 0:00	20
16	2024/5/17 0:00	2024/6/6 0:00	20
17	2024/6/6 0:00	2024/6/16 0:00	10
18	2024/6/16 0:00	2024/6/26 0:00	10
19	2024/6/26 0:00	2024/7/6 0:00	10
20	2024/7/6 0:00	2024/7/16 0:00	10
21	2024/7/16 0:00	2024/7/26 0:00	10
22	2024/7/26 0:00	2024/8/5 0:00	10
23	2024/8/5 0:00	2024/8/15 0:00	10
24	2024/8/15 0:00	2024/8/25 0:00	10
25	2024/8/25 0:00	2024/9/14 0:00	20
26	2024/9/14 0:00	2024/10/4 0:00	20

(b) 1000 m

Bottle No.	Sampling (UTC, yyyy/mm/dd) Start	End	Interval (days)
1	2023/8/11 0:00	2023/8/31 0:00	20
2	2023/8/31 0:00	2023/9/20 0:00	20
3	2023/9/20 0:00	2023/10/10 0:00	20
4	2023/10/10 0:00	2023/10/30 0:00	20
5	2023/10/30 0:00	2023/11/19 0:00	20
6	2023/11/19 0:00	2023/12/9 0:00	20
7	2023/12/9 0:00	2023/12/29 0:00	20
8	2023/12/29 0:00	2024/1/18 0:00	20
9	2024/1/18 0:00	2024/2/7 0:00	20
10	2024/2/7 0:00	2024/2/27 0:00	20
11	2024/2/27 0:00	2024/3/18 0:00	20
12	2024/3/18 0:00	2024/4/7 0:00	20
13	2024/4/7 0:00	2024/4/27 0:00	20
14	2024/4/27 0:00	2024/5/17 0:00	20
15	2024/5/17 0:00	2024/6/6 0:00	20
16	2024/6/6 0:00	2024/6/26 0:00	20
17	2024/6/26 0:00	2024/7/16 0:00	20
18	2024/7/16 0:00	2024/8/5 0:00	20
19	2024/8/5 0:00	2024/8/25 0:00	20
20	2024/8/25 0:00	2024/9/14 0:00	20
21	2024/9/14 0:00	2024/10/4 0:00	20

(c) 4800 m

Bottle No.	Sampling (UTC, yyyy/mm/dd) Start	End	Interval (days)
1	2023/8/11 0:00	2023/9/12 0:00	32
2	2023/9/12 0:00	2023/10/14 0:00	32
3	2023/10/14 0:00	2023/11/15 0:00	32
4	2023/11/15 0:00	2023/12/17 0:00	32
5	2023/12/17 0:00	2024/1/18 0:00	32
6	2024/1/18 0:00	2024/2/19 0:00	32
7	2024/2/19 0:00	2024/3/22 0:00	32
8	2024/3/22 0:00	2024/4/23 0:00	32
9	2024/4/23 0:00	2024/5/25 0:00	32
10	2024/5/25 0:00	2024/6/26 0:00	32
11	2024/6/26 0:00	2024/7/28 0:00	32
12	2024/7/28 0:00	2024/8/29 0:00	32
13	2024/8/29 0:00	2024/9/30 0:00	32
14	2024/9/30 0:00	-	-
15	-	-	-
16	-	-	-
17	-	-	-
18	-	-	-
19	-	-	-
20	-	-	-
21	-	-	-

Table 2.6.6-5. pH of the recovered samples.

Bottle No.	Depth 500m	1000m	4800m
1	8.37	8.13	8.02
2	8.37	8.18	8.14
3	8.09	8.19	8.18
4	8.27	8.12	8.23
5	8.20	8.23	8.28
6	8.13	7.98	8.35
7	8.26	8.15	8.30
8	8.41	8.30	8.32
9	8.49	8.37	8.32
10	8.54	8.40	8.05
11	8.56	8.43	7.89
12	8.54	8.24	8.17
13	7.89	8.18	8.25
14	8.52	7.98	8.09
15	8.54	8.09	-
16	8.49	7.79	-
17	8.57	7.52	-
18	8.43	8.01	-
19	8.49	7.54	-
20	8.49	8.10	-
21	8.47	8.23	-
22	8.48	-	
23	8.45	-	
24	8.29	-	
25	8.46	-	
26	6.34	-	

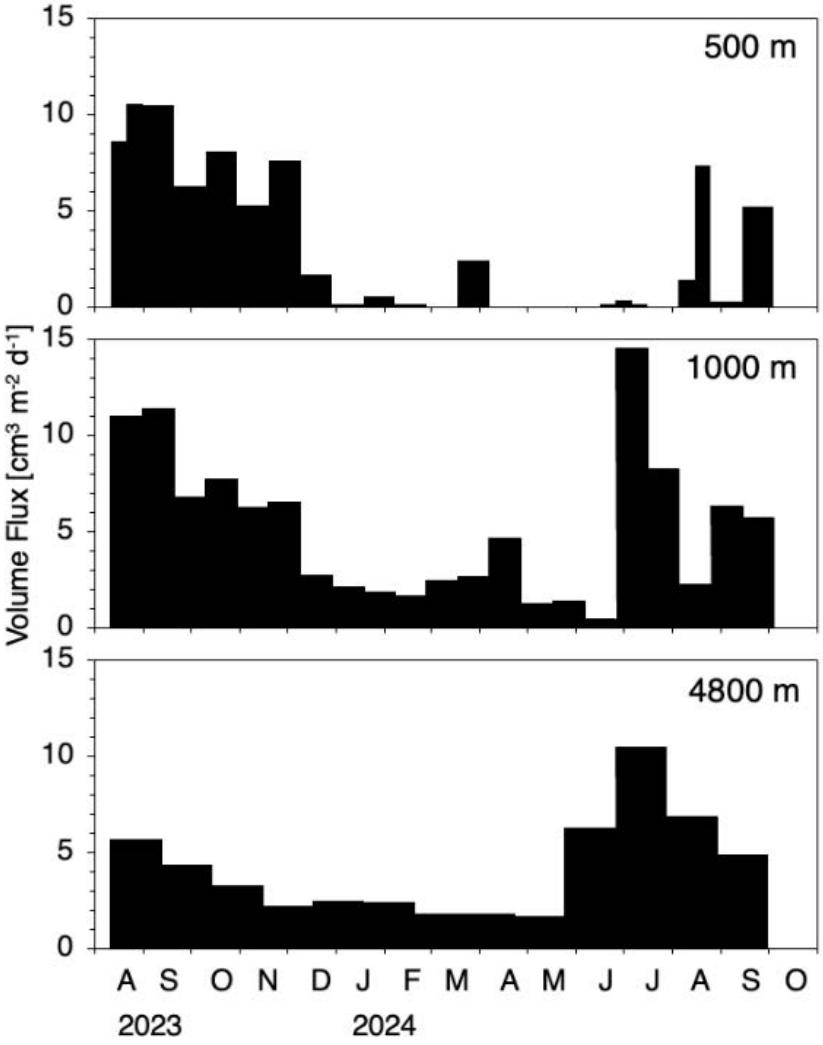

Figure 2.6.6-1. Seasonal changes of volume fluxes at 500, 1000 and 4810 m in the station K2.

(4) Sample archives

All samples are stored in JAMSTEC/Yokosuka. Each sample will be divided into ten aliquots and these subsamples will be distributed to co-researchers for further analysis. The obtained data will be submitted to JAMSTEC Data Management Group (DMG).

2.6.3. Remote Automatic Sampler (RAS)

Masahide WAKITA (JAMSTEC)
Hiroshi UCHIDA (JAMSTEC)
Yoshihisa MINO (Nagoya University)

(1) Objectives and Sampling

In order to investigate the seasonal variation of pH in the winter mixed layer and intermediate layer, and the vertical gradients of biogeochemical properties which affects vertical diffusion flux across the boundary with the thermocline, RAS on 80m, 200m and 300m (Fig.2.6.3-1) will work following schedule (Table 2.6.3-1) and collect samples of dissolved inorganic carbon (DIC), total alkalinity (TA), nutrients (Phosphate, Nitrate + Nitrite, Silicate), $^{15}NO_3$ and salinity. We will compare these properties from 12 L Niskin bottles mounted on the CTD/Carousel Water Sampling System for calibration on RAS samples at K2.

Salinity of RAS seawater samples were measured by salinometer (Model 8400B "AUTOSAL" Guildline Instruments). Salinity measured by salinometer were slightly lower than that observed by SBE-37 sensor (CTD). RAS samples (~400ml) were diluted with 2.5 ml of 25% saturated $HgCl_2$ solution for preservative. For chemical properties, the dilutions of RAS samples by $HgCl_2$ must be corrected by a ratio of salinity by SBE-37 to that by salinometer. We will correct measurements of DIC, TA and nutrients. We used coulometric technique and spectrophotometric system to measure DIC and TA, respectively. Nutrient (silicate, phosphate, and nitrate) concentrations were measured with a continuous flow analyzer. $^{15}NO_3$ will be measured by Tokai University.

Fig. 2.6.3-1 Remote Automatic Samplers deployed on 80m (left), 200m (center) and 300m (right).

Table 2.6.3-1 Sampling schedule of RAS in 80m, 200m and 300m on the moorings at station K2.

	RAS 80m		RAS 200m		RAS 300m		
RAS	S/N: 16095-01		ML11241-09		ML11241-07		Memo
No.	Interval 7 days		Interval 7 days		Interval 7 days		Sample volume 400ml / 25%
#	mm/dd/yyyy	Time (UTC)	mm/dd/yyyy	Time(UTC)	mm/dd/yyyy	Time(UTC)	saturated HgCl2
1	10/20/2024	00:00:00	10/23/2024	00:00:00	10/23/2024	00:00:00	繰返し精度確認
2	10/20/2024	01:00:00	10/23/2024	01:00:00	10/23/2024	01:00:00	
3	10/27/2024	00:00:00	10/27/2024	00:00:00	10/27/2024	00:00:00	
4	11/03/2024	00:00:00	11/03/2024	00:00:00	11/03/2024	00:00:00	
5	11/10/2024	00:00:00	11/10/2024	00:00:00	11/10/2024	00:00:00	
6	11/17/2024	00:00:00	11/17/2024	00:00:00	11/17/2024	00:00:00	
7	11/24/2024	00:00:00	11/24/2024	00:00:00	11/24/2024	00:00:00	
8	12/01/2024	00:00:00	12/01/2024	00:00:00	12/01/2024	00:00:00	
9	12/08/2024	00:00:00	12/08/2024	00:00:00	12/08/2024	00:00:00	
10	12/15/2024	00:00:00	12/15/2024	00:00:00	12/15/2024	00:00:00	
11	12/22/2024	00:00:00	12/22/2024	00:00:00	12/22/2024	00:00:00	繰返し精度確認
12	12/22/2024	01:00:00	12/22/2024	01:00:00	12/22/2024	01:00:00	
13	12/29/2024	00:00:00	12/29/2024	00:00:00	12/29/2024	00:00:00	
14	01/05/2025	00:00:00	01/05/2025	00:00:00	01/05/2025	00:00:00	
15	01/12/2025	00:00:00	01/12/2025	00:00:00	01/12/2025	00:00:00	
16	01/19/2025	00:00:00	01/19/2025	00:00:00	01/19/2025	00:00:00	
17	01/26/2025	00:00:00	01/26/2025	00:00:00	01/26/2025	00:00:00	
18	02/02/2025	00:00:00	02/02/2025	00:00:00	02/02/2025	00:00:00	
19	02/09/2025	00:00:00	02/09/2025	00:00:00	02/09/2025	00:00:00	
20	02/16/2025	00:00:00	02/16/2025	00:00:00	02/16/2025	00:00:00	
21	02/23/2025	00:00:00	02/23/2025	00:00:00	02/23/2025	00:00:00	繰返し精度確認
22	02/23/2025	01:00:00	02/23/2025	01:00:00	02/23/2025	01:00:00	
23	03/02/2025	00:00:00	03/02/2025	00:00:00	03/02/2025	00:00:00	
24	03/09/2025	00:00:00	03/09/2025	00:00:00	03/09/2025	00:00:00	
25	03/16/2025	00:00:00	03/16/2025	00:00:00	03/16/2025	00:00:00	
26	03/23/2025	00:00:00	03/23/2025	00:00:00	03/23/2025	00:00:00	
27	03/30/2025	00:00:00	03/30/2025	00:00:00	03/30/2025	00:00:00	
28	04/06/2025	00:00:00	04/06/2025	00:00:00	04/06/2025	00:00:00	
29	04/13/2025	00:00:00	04/13/2025	00:00:00	04/13/2025	00:00:00	
30	04/20/2025	00:00:00	04/20/2025	00:00:00	04/20/2025	00:00:00	
31	04/27/2025	00:00:00	04/27/2025	00:00:00	04/27/2025	00:00:00	繰返し精度確認
32	04/27/2025	01:00:00	04/27/2025	01:00:00	04/27/2025	01:00:00	
33	05/04/2025	00:00:00	05/04/2025	00:00:00	05/04/2025	00:00:00	
34	05/11/2025	00:00:00	05/11/2025	00:00:00	05/11/2025	00:00:00	
35	05/18/2025	00:00:00	05/18/2025	00:00:00	05/18/2025	00:00:00	
36	05/25/2025	00:00:00	05/25/2025	00:00:00	05/25/2025	00:00:00	
37	06/01/2025	00:00:00	06/01/2025	00:00:00	06/01/2025	00:00:00	
38	06/08/2025	00:00:00	06/08/2025	00:00:00	06/08/2025	00:00:00	
39	06/15/2025	00:00:00	06/15/2025	00:00:00	06/15/2025	00:00:00	
40	06/22/2025	00:00:00	06/22/2025	00:00:00	06/22/2025	00:00:00	
41	06/29/2025	00:00:00	06/29/2025	00:00:00	06/29/2025	00:00:00	繰返し精度確認
42	06/29/2025	01:00:00	06/29/2025	01:00:00	06/29/2025	01:00:00	
43	07/06/2025	00:00:00	07/06/2025	00:00:00	07/06/2025	00:00:00	
44	07/13/2025	00:00:00	07/13/2025	00:00:00	07/13/2025	00:00:00	
45	07/20/2025	00:00:00	07/20/2025	00:00:00	07/20/2025	00:00:00	
46	07/27/2025	00:00:00	07/27/2025	00:00:00	07/27/2025	00:00:00	繰返し精度確認
47	07/27/2025	01:00:00	07/27/2025	01:00:00	07/27/2025	01:00:00	
48	08/03/2025	00:00:00	08/03/2025	00:00:00	08/03/2025	00:00:00	

2.6.4. Hybrid pH sensor

Yoshiyuki NAKANO (JAMSTEC Engineering Department)

(1) Objective

We have developed newly stable and accurate *in situ* system for pH measurement using hybrid technique (potentiometric and spectrophotometric). In this cruise, we aim to long-term monitoring of accurate in-situ pH by the Hybrid pH sensor (HpHS) in the open sea. We recovered one HpHS at K2 which were deployed at MR23-05 with Hybrid mooring (Remote Automatic Sampler (RAS), 200m). A HpHS was installed to the RAS (80m) of the K2-OA mooring. A HpHS was installed to the RAS (200m) of the K2 Hybrid mooring. In-situ data of pH will be measured every 4 hours during mooring observation in both moorings.

(2) Method

The HpHS is constituted two types of pH sensors (i.e. potentiometric pH sensor and spectrophotometric pH sensor). The spectrophotometric pH sensor can measure pH correctly and stably, however, it needs large power consumption and a lot of reagents over a long period of observation. On the other hand, although the potentiometric pH sensor has low power consumption and high-speed response (within 20 seconds), drifts in the pH of the potentiometric measurements may occur for a long observation period. The HpHS can measure in situ pH correctly and stably combining the advantage of both pH sensors. The HpHS is correcting the value of the potentiometric pH sensor (measuring frequently) by the value of the spectrophotometric pH sensor (measuring less frequently). It is possible to calibrate in situ with standard solution (Tris buffer) on the spectrophotometric pH sensor. Therefore, the drifts in the value of potentiometric pH measurements can be compensated using the pH value obtained from the spectrophotometric pH measurements. Thereby, the sensor can accurately measure the pH value over a long period of time with low power consumption.

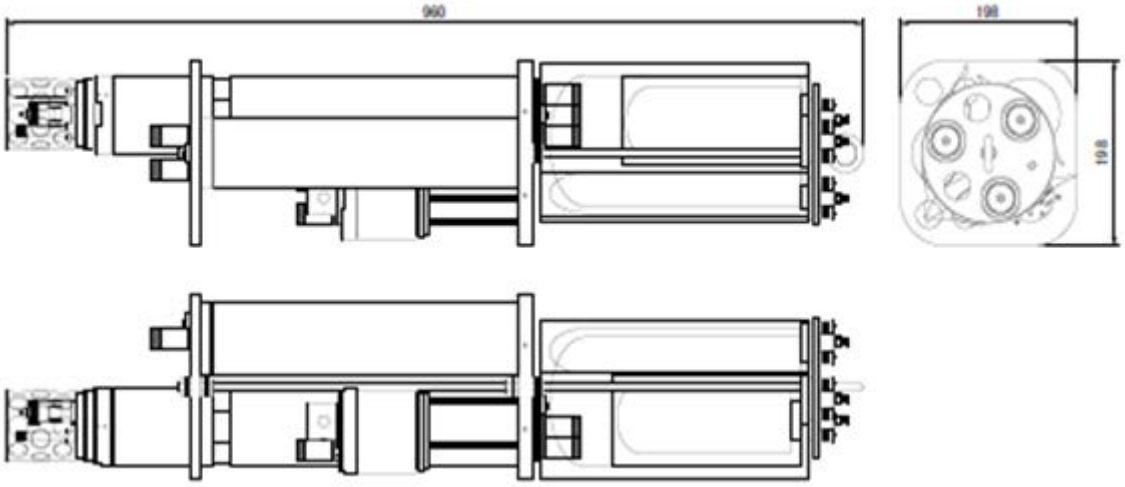

Fig. 2.6.4-1. Side view of HpHS.

Table 2.6.4-1. Specification of HpHS

	Potentiometry	Spectrophotometry
Range	6.0～8.3 pH	7.2～8.2 pH
Initial Accuracy	0.01 pH	0.002 pH
Analytical Method	Glass Electrode	m-cresol purple
Response speed	20 sec (90%, 25 deg C)	1 min (90%)
Resolution	0.001 pH	
Sample rate	1 sec	
Temperature range	0～40 deg C (Resolution: 0.01 deg C)	
Dimension	198×198×960 mm	
Weight	10 kg（in air）	
Depth rating	3,000 m	

(3) Preliminary results

We succeeded in recovering the HpHS with RAS in K2 Hybrid mooring and obtaining long term (about one year) pH data every four hours.

(4) Data Archive

All data will be submitted to JAMSTEC Data Management Office (DMO) and is currently under its control.

Reference

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LIU, X., PATSAVAS, M.C. and BYRNE, R.H. (2011) Purification and characterization of meta-cresol purple for spectrophoto-metric seawater pH measurements. Environ. Sci. Technol., 45, pp. 4862-4868.

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2.6.5 ADCP

Akira NAGANO (JAMSTEC CCOAR)
Tetsuichi FUJIKI (JAMSTEC ESS)
Masahide WAKITA (JAMSTEC MIO)
Masaki FURUHATA, Kango FUKUYAMA (MWJ)

(1) Objectives

The objective of this study is to collect a time series of the current velocity vector profile at station K2 in the western subarctic North Pacific by an acoustic Doppler current profiler (ADCP). We obtain knowledge on vertical mixing by combined use of the ADCP and CTD data, as in Nagano et al. (2021).

(2) Instruments and methods

Current velocity vector profiles were measured at intervals of 1 h by a Work Horse ADCP (Teledyne RD Instruments, Inc., Poway, California) attached upward to the mooring system at a depth of 370 m. We replaced old ADCP to new one.

The configuration of the recovered ADCP is as follows:

Serial number: 1533
Bin size: 8.0 m
Number of bins: 60
Pings per ensemble: 1

The configuration of the replaced ADCP is as follows:

Serial number: 1413
Bin size: 8.0 m
Number of bins: 60
Pings per ensemble: 1

(3) Preliminary result

Current velocity data were obtained from near surface to approximately 300m. As of this recovery, we obtained approximately 10-year time series of current velocity vector profile at K2.

Obtained data will be corrected with sound speed estimated from CTD data and the difference between true north and geo- magnetic north based on the 12-th generation of the international geomagnetic reference field (Thèbault et al., 2015).

(4) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG).

(5) References

Nagano, A., M. Wakita, T. Fujiki, and H. Uchida (2021) El Niño-related vertical mixing enhancement under the winter mixed layer at western subarctic North Pacific station K2, Journal of Geophysical Research, 126, e2020JC016913. https://doi.org/10.1029/2020JC016913

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2.6.7 CTD/DO sensors

Hiroshi UCHIDA (JAMSTEC RIGC)
Masahide WAKITA (JAMSTEC MIO)

(1) Objective

The objective of this study is to grasp variability of temperature, salinity, oxygen etc. at the K2 mooring site.

(2) Instruments and method

Pressure, temperature, and salinity are measured by CTDs (SBE37SM, Sea-Bird Scientific, Bellevue, Washington, USA). Dissolved oxygen is measured by optical oxygen sensors (Oxygen Optode model 3830, Aanderaa Data Instruments AS, Bergen, Norway, and RINKO-I [ARO-USB] or RINKO-I DSP [AROD-USB], JFE Advantech Co. Ltd., Japan). The Oxygen Optode sensor was attached to a datalogger with an internal battery and memory in a titanium housing (Compact-OPTODE, Alec Electronics Co., Ltd., Japan). Fluorescent dissolved organic matter (FDOM) is measured by UV fluorometer (Seapoint Sensors Inc.). The UV fluorometer was connected to a datalogger (RBRduo^3 V.V, RBR Ltd., Canada). Chlorophyll, turbidity and temperature are measured by chlorophyll-turbidity meters (ACLD70-USB, JFE Advantech).

A sampling interval was set to 1 hour for all sensors. Sensors used in the K2 mooring observation are summarized in Table 2.6.7-1.

Table 2.6.7-1 Serial number of the sensors deployed in the K2 mooring.

Planned depth	Serial number (Instrument)	Note
175 m frame	1892 (SBE37SM), 0006 (CompactOPTODE)	SUS
200 m	2239 (SBE37SM), 0050 (CompactOPTODE) 6238 (UV fluorometer)+205142 (RBR data logger)	RAS
225 m frame	2730 (SBE37SM), 0004 (RINKO-IDSP)	SUS
250 m frame	2756 (SBE37SM), 0092 (RINKO-I)	SUS
300 m	2289 (SBE37SM), 0051 (RINKO-I)	RAS
370 m	2288 (SBE37SM), 0009 (CompactOPTODE)	ADCP
500 m	2787 (SBE37SM), 0010 (CompactOPTODE)	Trap
780 m frame	2738 (SBE37SM), 0005 (CompactOPTODE)	SUS
1000 m	2285 (SBE37SM), 0007 (CompactOPTODE)	Trap
4800 m	2742 (SBE37SM), 0002 (CompactOPTODE), 0002 (ACLD70)	Trap
30 m above bottom	2731 (SBE37SM), 0008 (CompactOPTODE), 0003 (ACLD70)	Releasers

(3) Results

All sensor data deployed in 2023 was recovered with some problems. The refractive index density senser installed at 4800 m stopped recording data on December 19th, 2023 due to a problem with the internal software. The chlorophyll-turbidity meters installed at 4800 m and 30 m above bottom also stopped recording data on August 1st, 2024, and June 3rd, 2024, respectively, due to a dead battery. Time series of temperature measured by the moored CTDs is shown in Fig. 2.6.7-1.

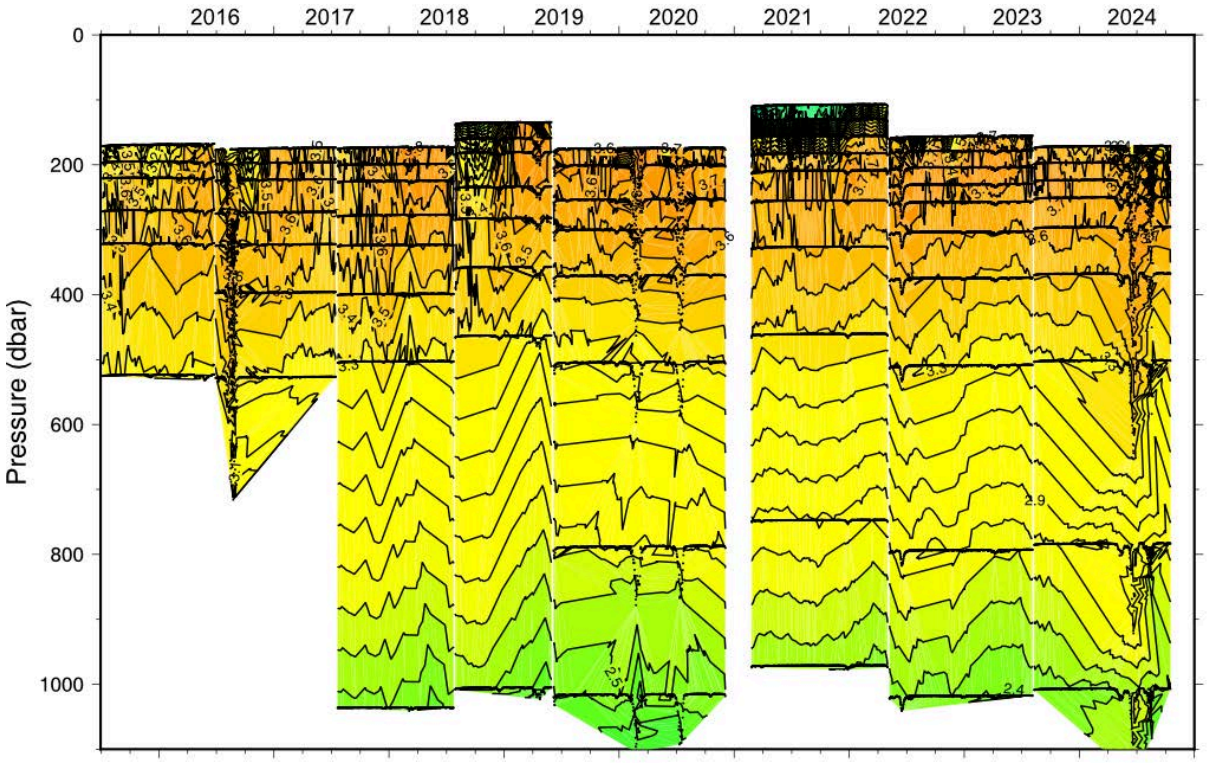

Figure 2.6.7-1. Time series of temperature measured by the moored CTDs.

(4) Data archive

These obtained data will be submitted to JAMSTEC Data Management Group (DMG) after recovery of the instruments.

2.6.8 pH/pCO_2 sensor experiment

Kiminori SHITASHIMA (Tokyo University of Marine Science and Technology) PI
Katsunori KIMOTO (JAMSTEC)

(1) Objective

The objective of this study is to long-term monitoring of in-situ pH and pCO_2 by sensor.

(2) Instruments and methods

A pH/pCO_2 sensor (see 2.3.7) was installed to the McLane sediment trap (150 m) of the K2-OA mooring, and in-situ data of pH and pCO_2 ware measured every 15 minutes during mooring observation.

(3) Parameters

In-situ pH and pCO_2

(4) Data archives

All data will be archived at Tokyo University of Marine Science and Technology after checking of data quality and submitted to Data Management Group (DMG) of JAMSTEC.

2.7 Float and drone observations

2.7.1 BGC Argo Float

Tetsuichi FUJIKI (JAMSTEC RIGC)
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Kanako SATO (JAMSTEC RIGC)
Mizue HIRANO (JAMSTEC RIGC)
Tun Htet AUNG (MWJ)
Rei ITO (MWJ)

(1) Objectives

The objective of this study is to clarify the mechanisms behind climate and oceanic environmental variability, understand changes in the Earth system through estimates of heat and material transports, and improve long-term climate change forecasts by conducting global ocean monitoring. To achieve this, long-term, automated measurements of physical and biogeochemical (BGC) parameters are carried out using BGC Argo floats deployed in the western North Pacific.

Two BGC Argo floats (BGC Navis) have been deployed in the subarctic western North Pacific (Fig. 2.7.1-1) to measure biogeochemical parameters, temperature, and salinity down to a depth of 2000 dbar. The primary goal of these observations is to identify changes in the phytoplankton community in relation to environmental parameters. In collaboration with shipboard and mooring observations, these measurements will capture the long-term and spatial variability of biogeochemical process in the western North Pacific. The deployed float will also contribute to the international BGC Argo project, which aims to construct a global array.

The data from BGC Argo floats will be integrated into the ESTOC system, a 4D-VAR data assimilation model used to estimate the state of the global ocean and investigate the mechanisms behind long-term oceanic changes.

Fig. 2.7.1-1 BGC Argo float

(2) Parameters

Water temperature, salinity, pressure, dissolved oxygen, backscattering, CDOM[FDOM], chlorophyll, and nitrate

(3) Methods

i) Biogeochemical Argo profiling float deployment

We deployed BGC Navis floats manufactured by Sea-Bird Scientific. Each float is equipped with an SBE41 CTD sensor, an SBE63 optical DO sensor, and a Deep SUNA nitrate sensor, all produced by manufactured by Sea-Bird Scientific. Additionally, the floats are equipped with FLBBCD backscattering, CDOM, and chlorophyll sensors, manufactured by WET Labs.

The float drifts at a depth of 1000 dbar (referred to as the parking depth) until the next vertical measurement. It then ascends from a depth of 2000 dbar to the sea surface. During the ascent, physical and biogeochemical parameters are measured every 2 dbar or at depths according to a predefined depth table. Upon surfacing, which lasts for several minutes, the float transmits all collected data to land via the Iridium satellite communication system using the Rudics protocol. The float observations will be sustained for a few years, depending on the internal battery lifetime. The float status and launch details are provided in Table 2.7.1-1.

Table 2.7.1-1 Status and launches of BGC floats

BGC Navis Float (2000dbar) (WMO ID: 2903762, 2903763)

Float Type	BGC Navis float manufactured by Sea-Bird Scientific
CTD sensor	SBE41 manufactured by Sea-Bird Scientific
Oxygen sensor	SBE63 optical DO sensor by Sea-Bird Scientific
Backscatter CDOM Chlorophyll sensors	FLBBCD manufactured by WET Labs Backscattering: wavelength: 700nm CDOM[FDOM]: ex/em→ 370/460nm Chlorophyll: ex/em→ 470/695nm
Nitrate sensor	Deep SUNA manufactured by Sea-Bird Scientific
Cycle	Every 5 days
Iridium transmit type	Router-Based Unrestricted Digital Internetworking Connectivity Solutions (RUDICS)
Target Parking Pressure	1000 dbar
Sampling layers	2 dbar or given depth interval from 2000 dbar to surface

Launch

Float S/N	WMOID	Date and Time of Launch (UTC)	Location of Launch	Station
F1655	2903763	2024/10/10 16:53	47-00.15 [N] 170-00.03 [E]	Stn. 5 (K2 east)
F1653	2903762	2024/10/17 00:57	46-59.91 [N] 159-59.76 [E]	Stn. 6 (K2)

(4) Data archive

The Argo float data, with real-time quality control, are provided to meteorological organizations, research institutes, and universities via Global Data Assembly Center (GDAC: http://www.usgodae.org/argo/argo.html, http://www.coriolis.eu.org/) and Global Telecommunication System (GTS) within 24 hours, following the procedures established by the Argo data management team. For physical parameters, delayed-mode quality control is performed within 6 months to 1 year to ensure data accuracy for research use. For BGC parameters, the methods for delayed-mode quality control are still under deployment. The data are freely available online and are used not only for research but also for weather forecasts and other applications.

2.7.2 VM drone

Kensuke Watari (K-program, JAMSTEC)

(1) Objective

Although prediction using sophisticated numerical models is the most important issue in controlling typhoons, it is also important to obtain more accurate initial values (assimilated data), and to understand the current status of typhoons in as much detail as possible. I need to know. In addition, in order to know the control effects, it is necessary to accurately understand the typhoon situation after the control is implemented. Although the VM drone is not a device for typhoon control, it contributes to typhoon prediction and typhoon monitoring necessary for control. The current observation system in the tropical northwest Pacific Ocean, where typhoons occur, is weak, and there is no on-site observation of atmospheric pressure, wind, temperature, etc. at the center of the typhoon, which determines the strength of working models, and the on-site measurements are only estimated using satellite observations. do not have. Furthermore, even with satellite observations, it is impossible to obtain the internal structure of the ocean surface layer, which is one of the keys to the mechanism of typhoon development. Therefore, we aim to develop a buoy that moves autonomously using natural energy and establish a method to efficiently collect this unknown data. During this cruise, we will confirm the operation of the prototype and collect observation data and data from the Mirai ship.

(2) Methods

The VM drone is a yacht-shaped platform with a total length of 3m, total height of 3.6m, total width of 0.8m, and weight of 160kg. It is equipped with a naca0018 type sail with a total length of 2.6m and obtains propulsion from wind power. The prototype launched this time is equipped with a CTD sensor at the bottom of the hull to measure surface seawater temperature and salinity. In addition, a composite weather sensor is installed at the rear of the main unit to measure wind direction, wind speed, temperature, atmospheric pressure, and humidity. The main body is equipped with a 9-axis gyro to measure the attitude of the main body. Additionally, two-way communication is possible through Wi-Fi and Iridium communications. In addition, in case of trouble, it is equipped with an iridium beacon powered separately to track location information.

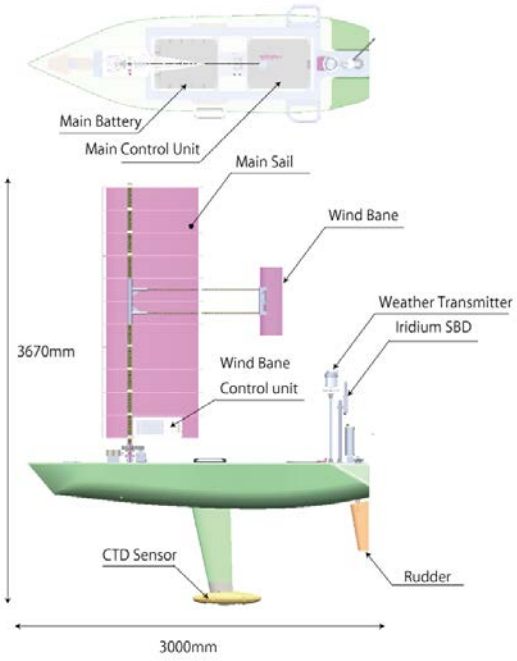
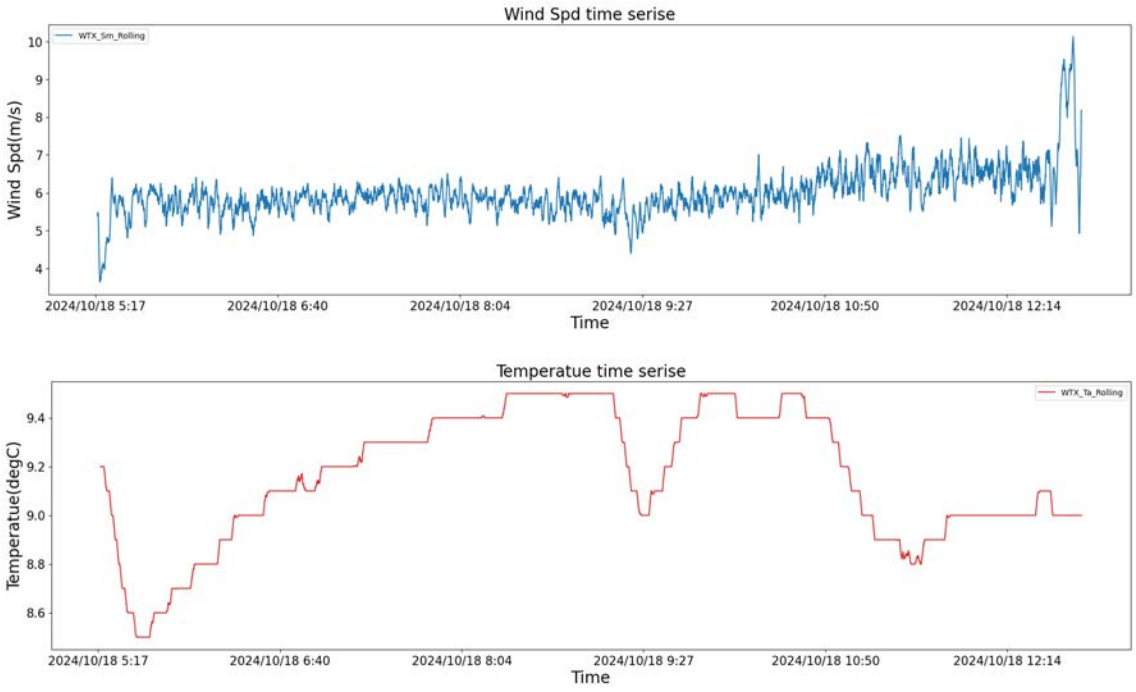


Fig.2.7.2-1 Prototype of Uncrewed sailing vessel

(3) Preliminary result on shipboard analysis

The uncrewed sailing vessel was launched at 5:20 UTC on Oct 18, 2024 at 47.0003232N, 160.0017616E. It then headed north through the surrounding waters and was recovered at approximately 13:30 UTC on Oct 18 at 46.8164433N, 160.0595865E. Fig 2.7.2-3 shows some of the data on the surrounding environment. During the observations, tests were conducted in various environments, including strong winds with a maximum instantaneous wind speed of over 13m and rain. Although the vessel tilted significantly due to strong winds and rough waves, it was safely recovered and observation data was successfully acquired. Comparison with data acquired by Mirai is expected to provide important knowledge.

Fig.2.7.2-2 Uncrewed sailing vessel in testing



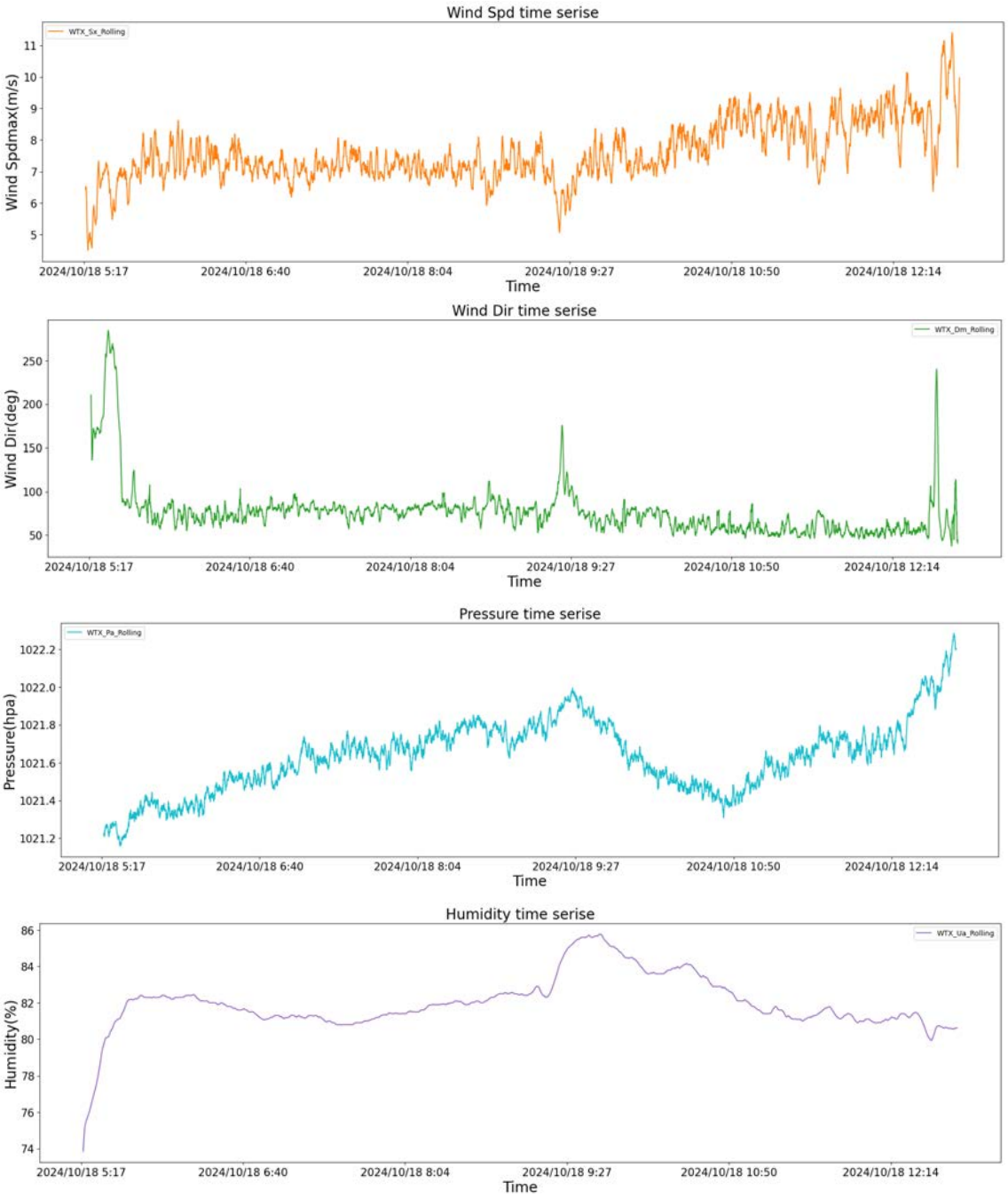


Fig2.7.2-3 Uncrewed Sailing Vessel observation data (Environment)

(4) Data archive

Planktic foraminifers and radiolarians sample is stored at JAMSTEC. Molecular phylogenetic analyses and morphological observations will be conducted.

3. Art - Science collaboration

Rina GOTO (Intermedia Art, Tokyo University of the Arts)

(1) Purpose, background

Logbook, SNS and drawing

As an artist creating artworks, I research the ocean and plankton, exploring the essence of nature. By participating in a research expedition and conducting fieldwork, I gain a lot of insights through hands-on experience. Based on these findings, I set out to create artworks, produce a booklet documenting these insights, and exhibit the works to spread oceanography to the public. Additionally, I decided to collaborate with the belief that crossing into other fields could make effective use of the role art plays in society.

(2) Activities

Career exploration, hands-on experience, and assistance

Each day during the cruise, I observed the workings of the ship, the research conducted by the researchers on board, and the duties of the ship's crew. Furthermore, I assisted with CTD water sampling and plankton sample collection（Fig.3-1）.

Fig.3-1 CTD water sampling

(3) Methods and instruments

Documentary booklets, and Instagram posts

I mainly used text and photographs to communicate the daily life of the cruise, as well as the content of the interviews and observation. This information was edited using Adobe Photoshop and InDesign, and proofread, printed, and bound weekly on the ship's printer so that it could be read as a booklet on board.

In addition, the daily posts, confirmed by the Operations Department of JAMSTEC, were posted on Instagram so that the daily activities could be viewed by those on land as well.

(5) Drawing

Among the improvisational works created after boarding the ship were drawings created using the waves. These were drawn for 30 seconds to 40 minutes each day throughout Legs 1 and 2.

Even though the person thought of drawing along the waves, the person's ego plays a small role, so the trajectory of the waves is not completely recorded, but is influenced by the body and mental state of the person drawing.

In this sense, the act of drawing one line as if conversing with the waves was carried out.

The way the line appears is considered to vary depending on which vessel is used to conduct the work.

(6) Results

Documentary booklets, and Instagram posts

The 'Fieldwork Notebook' booklets, Vol.1 (46p), Vol.2 (56p), Vol.3 (60p) and Vol.4 (44p), which summarize the one-month cruise record, have been completed (Fig.3-2). It was pointed out that this is written in a more casual style than academic archives and can be enjoyed by non-specialists as well.

Fig.3-2 'Fieldwork Notebook' booklets Vol. 1 ~ Vol. 4

Drawing

Data for 23 days were gathered from October 4 to October 28 (Table.1). Furthermore, I held a workshop, and wave drawing was performed by JAMSTEC researchers, observation technician and a student (Fig.3-3). In fact, doing it, it is expected to provide stress relief and mental distraction by clearing one's mind. It helps foster communication with people from diverse backgrounds. Even people who do not usually draw pictures can easily draw and enjoy a refreshing experience.

Fig.3-3 Workshop with researchers

(7) Future plans

In the future, I would like to create a piece of work for my graduation work and exhibit it as an installation along with the documentation of this project. Most recently, booklets Vol. 1 and 2 were exhibited at the Toride Arts Festival in November, 2024. Subsequently, this project will be presented at the Ocean and Earth Symposium in March, 2025 and at my solo exhibition. In addition, there are plans to present the project through group exhibitions and art fairs. Based on the research related to the ocean, including this cruise, an exhibition involving other artists and researchers is being planned for 4 or 5 years from now.

Table3-1. Summary of sea wave Drawing sampling.

Latitude	Longtitude	Bow Wave Height (m) / Prd(s)	Stern Wave Height (m) / Prd(s)	True Wind Dir(deg) / Spd(m/s)	Relative Wind Dir(deg) / Spd(m/s)	Current Dir(deg) / Spd(kt)	Date (on ship)	Time	Drawing
59-31.0129N	172-52.8355W	4.47 / 10.31	3.52 / 9.42	353 / 18.0	78 / 18.3	68 / 0.2	2024.10.4 Unkown	40 min	
56-36.3632N	176-41.4224W	4.94 / 14.54	3.50 / 15.42	327 / 18.2	116 / 14.1	320 / 0.5	2024.10.5 22:04-22:44	40 min	
52-47.0339N	177-42.1945W	3.87 / 8.85	2.89 / 8.92	328 / 9.0	6 / 9.2	10 / 0.1	2024.10.6 22:04-22:44	40 min	
52-54.4065N	176-45.4329E	1.91 / 7.53	1.70 / 5.98	196 / 12.2	318 / 16.3	142 / 0.3	2024.10.7 19:12-19:42	40 min	
51-05.7756N	173-31.7026E	2.10 / 7.17	1.62 / 7.16	205 / 6.6	18 / 6.8	27 / 0.7	2024.10.8 22:24-22:44	20 min	
47-46.9907N	170-39.0540E	2.54 / 9.20	1.54 / 9.08	318 / 11.6	76 / 11.3	16 / 0.3	2024.10.9 19:37-20:17	40 min	
46-59.0049N	169-56.0391E	3.12 / 8.99	2.40 / 9.20	61 / 9.6	107 / 9.4	277 / 0.4	2024.10.11 19:37-20:17	40 min	
46-59.4402N	169-00.8680E	4.68 / 16.38	3.98 / 13.59	120 / 17.0	227 / 11.7	338 / 0.3	2024.10.12 20:15-20:45	30 min	
46-57.5808N	165-50.2057E	5.66 / 11.79	4.42 / 11.00	250 / 16.5	344 / 21.8	314 / 0.3	2024.10.13 8:55-9:35	40min	
46-57.9819N	159-40.5650E	5.17 / 9.42	3.68 / 8.43	294 / 17.1	6 / 17.7	230 / 0.5	2024.10.14 20:13-20:43	30 min	
46-53.8190N	159-48.1580E	2.93 / 8.41	2.53 / 7.88	257 / 8.2	238 / 7.9	140 / 0.8	2024.10.15 21:22-21:52	30 min	
46-57.6937N	159-57.4634E	1.62 / 7.38	1.62 / 6.55	169 / 12.2	82 / 12.2	357 / 0.7	2024.10.16 21:22-21:52	30 min	
47-00.1024N	160-03.4413E	2.16 / 8.53	2.11 / 7.47	303 / 6.8	250 / 6.7	90 / 0.7	2024.10.17 19:39-19:40	1 min	
46-56.2472N	159-58.2829E	2.37 / 7.56	1.75 / 7.14	315 / 7.9	108 / 7.8	268 / 1.1	2024.10.18 21:23-21:46	23 min	
46-52.7601N	160-00.0894E	2.43 / 6.73	1.62 / 5.96	160 / 18.4	331 / 18.9	79 / 0.9	2024.10.19 20:36-20:37	1 min	
46-55.0134N	160-15.8237E	3.73 / 8.14	2.79 / 7.69	248 / 12.1	319 / 14.2	143 / 0.8	2024.10.21 23:02-23:03	1 min	
45-46.1065N	157-54.0663E	1.81 / 5.95	1.61 / 5.89	175 / 10.5	328 / 15.6	311 / 0.6	2024.10.22 22:42-22:56	12 min	
43-36.9262N	154-42.6916E	2.78 / 8.53	2.20 / 7.16	146 / 12.7	320 / 16.9	64 / 0.7	2024.10.23 22:04-22:06	2 min	
40-50.4722N	149-24.4633E	2.36 / 10.06	1.73 / 8.01	286 / 13.3	14 / 9.6	26 / 0.6	2024.10.24 22:04-22:06	2 min	
41-49.2000N	146-18.4144E	2.55 / 12.48	2.11 / 10.92	145 / 6.2	311 / 8.0	143 / 2.0	2024.10.25 22:05-22:19	10 min	
38-02.3026N	141-38.1131E	1.77 / 14.21	1.67 / 12.84	37 / 5.6	3 / 1.4	222 / 0.3	2024.10.26 21:49-21:57	8 min	
34-36.6829N	138-44.3474E	1.77 / 14.21	1.67 / 12.84	37 / 5.6	3 / 1.4	54 / 1.0	2024.10.27 21:49-21:57	8 min	
35-01.9354N	138-30.3036E	0.26 / 5.81	0.40 / 4.66	61 / 5.7	84 / 5.7	91 / 0.1	2024.10.28 22:19- 22:29	10 min	

4 Sampling of source seawater for KANSO CRM of nutrients

Hiroshi UCHIDA (JAMSTEC RIGC)
Hiroyuki FUJIWARA (JAMSTEC RIGC)
Yoshiyuki NAKANO (JAMSTEC MarE3)
Yuko MIYOSHI (MWJ)
Kengo FUJITA (MWJ)
Shiori ARIGA (MWJ)

(1) Objective

The objective is to collect deep seawater based on the agreement between KANSO TECHNOS Co., Ltd. and Japan Agency for Marine-Earth Science and Technology (JAMSTEC) for the manufacture and sale of high concentration CRM of nutrients and provision of source seawater.

(2) Instruments and method

Deep seawater was collected by using the CTD/water sampling system:

Station: 006 (K02) cast 5
Location and water depth: 47° 00.01'N, 160° 00.01'E, 5188 m
Sampling date and time: October 19, 2024, 03:36 - 03:42 (UTC)
Sampling depth: 1088.4 ± 0.2 m

The deep seawater was collected from 36 × 12-L Niskin bottles into 18 × 20-L thin polyethylene containers by using a UV Luminous Array Film (UV-LAFi) for the water sampling sterilization device. After washing three times with the seawater to be sampled, the container was filled with the sampled seawater without air space. While collecting the seawater in the 11th container, it was found that the sterilization device was not working because of the protective function that was activated due to the rising temperature. Therefore, for the 11th container onwards, the seawater was collected directly without using the sterilization device.

The 18 containers were each placed in a cardboard box and stored in a refrigerated room (about 4°C) on the ship. The container number 18 was used to monitor stability of nutrients concentrations (Table 4.1), and the other containers were unloaded from the ship on October 29th and shipped to KANSO TECHNOS by refrigerated delivery for the manufacture of high concentration CRM.

Table 4-1. Stability of nutrients concentrations during cold storage (about 4°C) for container no. 18. The seawater was collected on October 19th. Salinity of the sample is 34.460 in Practical Salinity. The measurements were conducted at ambient temperature of about 22 °C.

Date of measurement	NO_3	NO_2	SiO_2	PO_4	NH_4	Note
20 October 2024	43.348	0.004	160.508	3.084	0.045	Leg 1
24 October 2024	43.367	0.001	160.323	3.065	0.040	Leg 1
5 November 2024	43.133	−0.002	159.776	3.062	0.036	Leg 2
9 November 2024	43.261	0.044	160.340	3.088	0.063	Leg 2
11 November 2024	43.375	0.007	160.565	3.075	0.030	Leg 2
14 November 2024	43.221	−0.003	160.750	3.111	0.054	Leg 2

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