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Mirai Cruise Report

MR18-06 leg 4

Central Pacific and Northwestern Pacific

March. 5, 2019 - March 25, 2019

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

Content

I. Cruise Information

1. Cruise ID

MR18-06 leg 4

2. Name of Vessel

R/V *Mirai*

3. Title of Project

East/central Pacific International Campaign (EPIC)

4. Title of Cruise

MR18-06 R/V *Mirai*

5. Ports of Departure/call/arrival/

Departure: Papeete, French Polynesia at March. 5, 2019
Arrival: Shimizu, Japan at March 25, 2019

6. Research Area

Central and Northwestern Pacific

7. Research Map

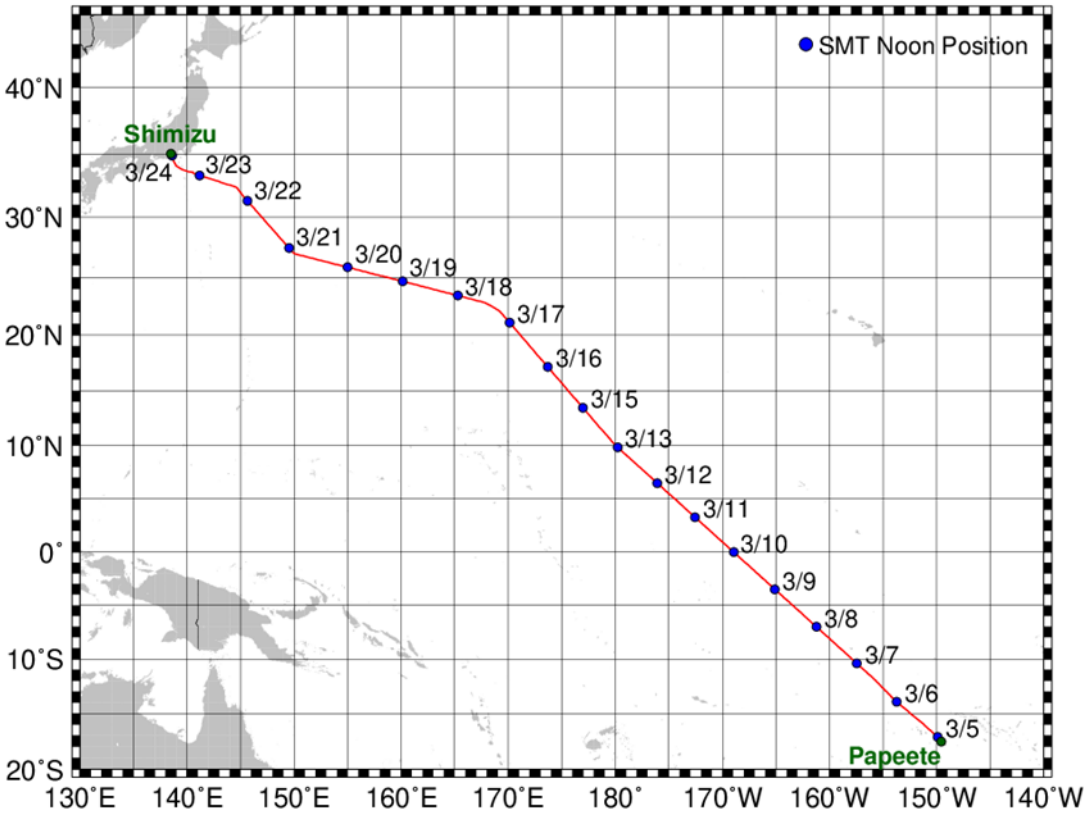


Fig. 7.1 Cruise track for the 4th leg of MR18-06.

II. Researchers

1. Chief Scientist

Fumikazu Taketani（JAMSTEC）

2. List of Participants

Name	Affiliation	Position
Kazuhiko Matsumoto	JAMSTEC	Research Scientist
Kaori Kawana	JAMSTEC	Postdoctoral Researcher
Masanori Murakami	NME	Technical Staff
Kazuho Yoshida	NME	Technical Staff
Shinichiro Yokogawa	MWJ	Technical Staff
Hiroshi Hoshino	MWJ	Technical Staff
Masahiro Orui	MWJ	Technical Staff

JAMSTEC: Japan Agency for Maine Science and Technology
NME: Nippon Marine Enterprises, Ltd
MWJ: Marine Works Japan, Ltd

III. Observation

1. Cruise Narrative

The MR18-06 cruise by the R/V *Mirai* was conducted for the following two themes, which were selected from 17 proposals based on the report created in the JAMSTEC long-term cruise planning workshop: “An explorative study on connectivity between poor nutrients environment in the South-East Pacific gyre and ecosystem” and “Research into the world only-one subduction zone in the active ridge: Chile triple junction”. For these themes, biological, oceanographic, geologic and geophysical surveys were made in the area off Chile and the central and southeastern Pacific Ocean.

The fourth leg of MR18-06 was done for the period from 5 March 2019 at Pateete Port, French Polynesia to 25 March 2019 at Shimizu Port, Japan. We started bucket seawater sampling and underway observations such as gas aerosol, marine weather, geophysics and bio-geochemistry monitoring soon after departure from the Pateete Port, French Polynesia.

On the way to Shimizu port, Japan, we entered the EEZ of New Zeeland where no permission for ocean and atmosphere observation was taken. For the EEZ, we stopped the observations or removed the data obtained in the area. We experienced almost no serious malfunctions of the observation devices during the cruise. Unfortunately, one of observation device which is C-band Weather Radar had malfunction on 13 March due to the motor trouble. We terminated the observations of C-band Weather Radar around 00:11 on 13 March (UTC). The other observations were terminated at just before Shimizu Port, Japan.

2. Cruise track and Log

The cruise track and log of MR18-06Leg4 are shown in Figure 2.1 and Table 2.1 respectively.

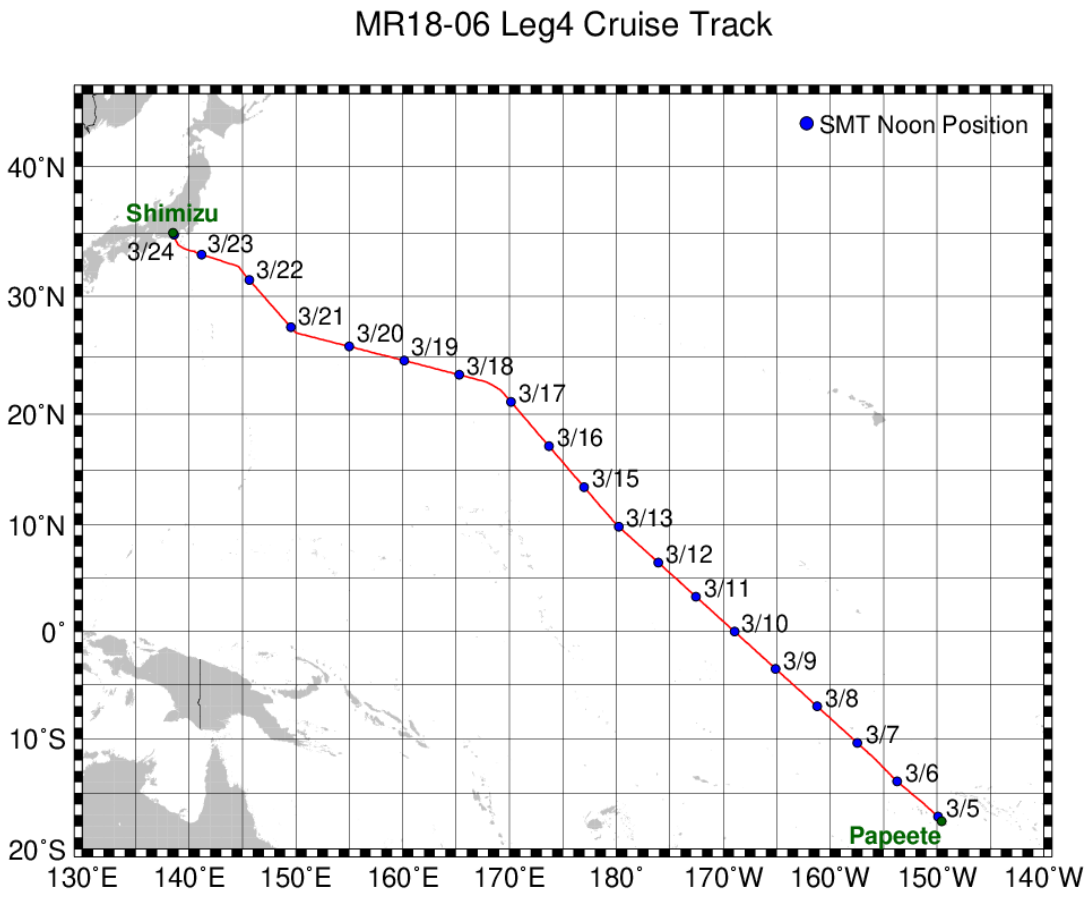


Figure 2.1 Cruise track of MR18-06 Leg4.

Table 2.1 Log of MR18-06 Leg4.

U.T.C.		S.M.T.		Position		Event logs
Date	Time	Date	Time	Lat.	Lon.	
3.5	19:10	3.5	09:10	17-32.20S	149-34.20W	Departure from Papeete
	20:35		10:35	17-22.00S	149-42.62W	Start Sea water pump
	21:10		11:10	17-16.24S	149-47.13W	Exit the Territorial Water of French Polynesia
	21:26		11:26	17-13.63S	149-49.17W	Start TSG observation
	21:35		11:35	17-12.19S	149-50.40W	Start MBES observation
3.6	02:00		16:00	15-51.37S	151-22.42W	Start Doppler Rader observation
	19:00	3.6	09:00	14-15.00S	153-22.08W	Surface water (Bucket) sampling #01
	19:20		09:20	14-14.58S	153-22.37W	Calibration for magnetometer #01
3.7	07:40		21:40	12-30.00S	155-12.00W	Exit the EEZ of French Polynesia
	11:36	3.7	01:36	11-53.98S	155-48.05W	Pause MBES observation Pause Doppler Rader observation
	11:39		01:39	11-53.52S	155-48.51W	Pause TSG observation
	12:02		02:02	11-50.00S	155-52.00W	Enter the EEZ of New Zealand
3.9	00:22	3.8	14:22	06-40.27S	161-36.17W	Exit the EEZ of New Zealand
	00:30		14:30	06-39.16S	161-37.40W	Restart TSG observation Restart Doppler Rader observation
	00:40		14:40	06-37.70S	161-39.02W	Restart MBES observation
	00:56		14:56	06-35.88S	161-41.08W	Surface water (Bucket) sampling #02
	00:57		14:57	06-35.89S	161-41.10W	XCTD #01
	08:00		22:00	-	-	Time adjustment -1 hour (SMT=UTC-11h)
	19:58	3.9	08:58	03-53.80S	164-39.77W	Surface water (Bucket) sampling #03
	19:59		08:59	03-53.80S	164-39.78W	XCTD #02
3.10	22:57	3.10	11:57	00-00.03S	168-57.03W	Surface water (Bucket) sampling #04
				00-00.04S	168-56.95W	XCTD #03
3.11	20:00	3.11	09:00	02-54.25N	172-08.35W	Surface water (Bucket) sampling #05
				02-54.25N	172-08.36W	XCTD #04
3.12	19:57	3.12	08:57	06-05.20N	175-39.35W	Surface water (Bucket) sampling #06
				06-05.21N	175-39.35W	XCTD #05
3.13	00:11		13:11	06-37.20N	176-14.77W	Stop Doppler Rader observation
	09:00		22:00	-	-	Time adjustment -1 hour (SMT=UTC-12h)
3.13	20:57	3.13	08:57	09-25.36N	179-21.49W	Surface water (Bucket) sampling #07
3.14	01:26		13:26	09-59.75N	180-00.00	Crossing the International Date Line (SMT=UTC+12h)
	21:00	3.15	09:00	13-00.99N	177-21.45E	Surface water (Bucket) sampling #08 XCTD #06
3.15	20:58	3.16	08:58	16-43.30N	174-04.38E	Surface water (Bucket) sampling #09
3.16	20:58	3.17	08:58	20-35.19N	170-35.35E	Surface water (Bucket) sampling #10
	20:59		08:59			XCTD #07
3.17	10:00		22:00	-	-	Time adjustment -1 hour (SMT=UTC+11h)
	22:00	3.18	09:00	23-17.25N	165-55.81E	Surface water (Bucket) sampling #11
	22:01		09:01	23-17.26N	165-55.75E	XCTD #08
3.18	21:58	3.19	08:58	24-30.25N	165-45.40E	Surface water (Bucket) sampling #12 XCTD #09
3.19	21:58	3.20	08:58	25-42.83N	155-38.84E	Surface water (Bucket) sampling #13
	21:59		08:59			XCTD #10
3.20	11:00	3.20	22:00	-	-	Time adjustment -1 hour (SMT=UTC+10h)
	22:56	3.21	08:56	27-00.05N	150-00.04E	Surface water (Bucket) sampling #14 XCTD #11
3.21	12:00		22:00	-	-	Time adjustment -1 hour (SMT=UTC+9h)
3.22	00:00	3.22	09:00	30-56.48N	146-01.85E	Surface water (Bucket) sampling #15 XCTD #12
	00:25		09:25	30-58.65N	145-59.25E	Calibration for magnetometer #01
	10:24		19:24	32-25.09N	144-37.10E	Surface water (Bucket) sampling #16
				32-25.09N	144-37.11E	XCTD #13
3.23	06:55	3.23	15:55	33-32.02N	140-33.41E	Finish MBES observation
	07:01		16:01	33-32.02N	140-33.44E	Finish TSG observation Finish Sea water pump
3.24	23:10	3.25	08:10	35-02.34N	138-30.59E	Arrival at Shimizu

3. Underway Observation

3.1 Swath Bathymetry

(1) Personnel

Fumikazu Taketani	*JAMSTEC: Principal investigator*
Masanori Murakami	*Nippon Marine Enterprises LTD. (NME)*
Kazuho Yoshida NME	
Yoichi Inoue	*MIRAI crew*

(2) Objectives

The objective of Multi-Beam Echo Sounding system (MBES) is collecting continuous bathymetric data along ship's track to make a contribution to geological and geophysical investigations and global data sets.

(3) Apparatus

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 XCTD and Argo float data by the equation in Del Grosso (1974).

Table 3.1.1 SEABEAM 3012 System configuration and performance

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

(4) Preliminary Results

The results will be published after primary processing.

(5) Data archives

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

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

(6) Remarks

1. The following period, acquisition of data was stopped due to entering the Territorial Water of French Polynesia.

19:10UTC 5th Mar. 2019 (Departure from Papeete) - 21:10UTC 5th Mar. 2019

2. The following period, acquisition of data was stopped due to entering the EEZ of New Zealand.

11:40UTC 7th Mar. 2019 - 00:29UTC 9th Mar. 2019

3.2 Surface Meteorological Observations

(1) Personnel

Fumikazu Taketani		*JAMSTEC: Principal investigator*
Masanori Murakami		*Nippon Marine Enterprises LTD. (NME)*
Kazuho Yoshida	*NME*	
Yoichi Inoue		*MIRAI crew*

(2) Objectives

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

(3) Apparatus

Surface meteorological parameters were observed throughout the MR18-06 Leg4 cruise. During this cruise, we used two systems for the observation.

i. MIRAI Surface Meteorological observation (SMet) system

Instruments of SMet system are listed in Table 3.2.1 and measured parameters are listed in Table 3.2.2. 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) Portable Radiation Package (PRP) designed by BNL – short and long wave downward radiation.
b) Analog meteorological data sampling with CR1000 logger manufactured by Campbell Inc. Canada – wind, pressure, and rainfall (by a capacitive rain gauge) measurement.
c) Digital meteorological data sampling from individual sensors - air temperature, relative humidity and rainfall (by optical rain gauge (ORG)) measurement.
d) Photosynthetically Available Radiation (PAR) 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 PRP, 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 3.2.3 and measured parameters are listed in Table 3.2.4.

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

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

(4) Preliminary results

Figure 3.2.1 shows the time series of the following parameters;
Wind (SOAR)
Air temperature (SMet)
Relative humidity (SMet)
Precipitation (SOAR, ORG)

Short wave radiation (SOAR)
Long wave radiation (SMet)
Barometric Pressure (SMet)
Sea surface temperature (SMet)
Significant wave height (SMet)

(5) Data archives

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

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

(6) Remarks

1. The following period, acquisition of data was stopped due to entering the Territorial Water of French Polynesia.

19:10UTC 5th Mar. 2019 (Departure from Papeete) - 21:10UTC 5th Mar. 2019

2. The following period, acquisition of data was stopped due to entering the EEZ of New Zealand.

11:40UTC 7th Mar. 2019 - 00:29UTC 9th Mar. 2019

3. The following period, SST (Sea Surface Temperature) data of SMet was available.

21:26UTC 5th Mar. 2019 - 07:01UTC 23th Mar. 2019

4. The following period, capacitive rain gauge data of SMet was invalid due to transmitting for MF/HF radio.

23:57UTC 6th Mar. 2019 - 00:28UTC 7th Mar. 2019

5. PAR and UV data was not acquired in this cruise, due to the system maintenance.

6. FRSR data was not available in this cruise, due to FRSR sensor failure.

7. The following period, long wave radiation (PIR) data of SOAR was invalid due to Tcase data contained noise.

21:10UTC 5th Mar. 2019 - 01:00UTC 19th Mar. 2019

Table 3.2.1 Instruments and installation locations of MIRAI Surface Meteorological observation 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
Rain gauge	50202	R. M. Young, USA	compass deck (19 m)
Optical rain gauge	ORG-815DR	Osi, USA	compass deck (19 m)
Radiometer (short wave)	MS-802	Eko Seiki, Japan	radar mast (28 m)
Radiometer (long wave)	MS-202	Eko Seiki, Japan	radar mast (28 m)
Wave height meter	WM-2	Tsurumi-seiki, Japan	bow (10 m)

Table 3.2.2 Parameters of MIRAI Surface Meteorological observation 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 side)	degC	6sec. averaged
11 Air temperature (port side)	degC	6sec. averaged
12 Dewpoint temperature (starboard side)	degC	6sec. averaged
13 Dewpoint temperature (port side)	degC	6sec. averaged
14 Relative humidity (starboard side)	%	6sec. averaged
15 Relative humidity (port side)	%	6sec. averaged
16 Sea surface temperature	degC	6sec. averaged
17 Rain rate (optical rain gauge)	mm/hr	hourly accumulation
18 Rain rate (capacitive rain gauge)	mm/hr	hourly accumulation
19 Down welling shortwave radiation	W/m^2	6sec. averaged
20 Down welling infra-red radiation	W/m^2	6sec. averaged
21 Significant wave height (bow)	m	hourly
22 Significant wave height (aft)	m	hourly
23 Significant wave period (bow)	second	hourly
24 Significant wave period (aft)	second	hourly

Table 3.2.3 Instruments and installation locations of SOAR system

Sensors (Meteorological)	Type	Manufacturer	Location (altitude from surface)
Anemometer	05106	R.M. Young, USA	foremast (25 m)
Barometer 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 (PRP)	**Type**	**Manufacturer**	**Location (altitude from surface)**
Radiometer (short wave)	PSP	Epply Labs, USA	foremast (25 m)
Radiometer (long wave)	PIR	Epply Labs, USA	foremast (25 m)
Fast rotating shadowband radiometer		Yankee, USA	foremast (25 m)
Sensor (PAR&UV)	**Type**	**Manufacturer**	**Location (altitude from surface)**
PAR&UV sensor	PUV-510	Biospherical Instruments Inc., USA	Navigation deck (18m)

Table 3.2.4 Parameters of SOAR system

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

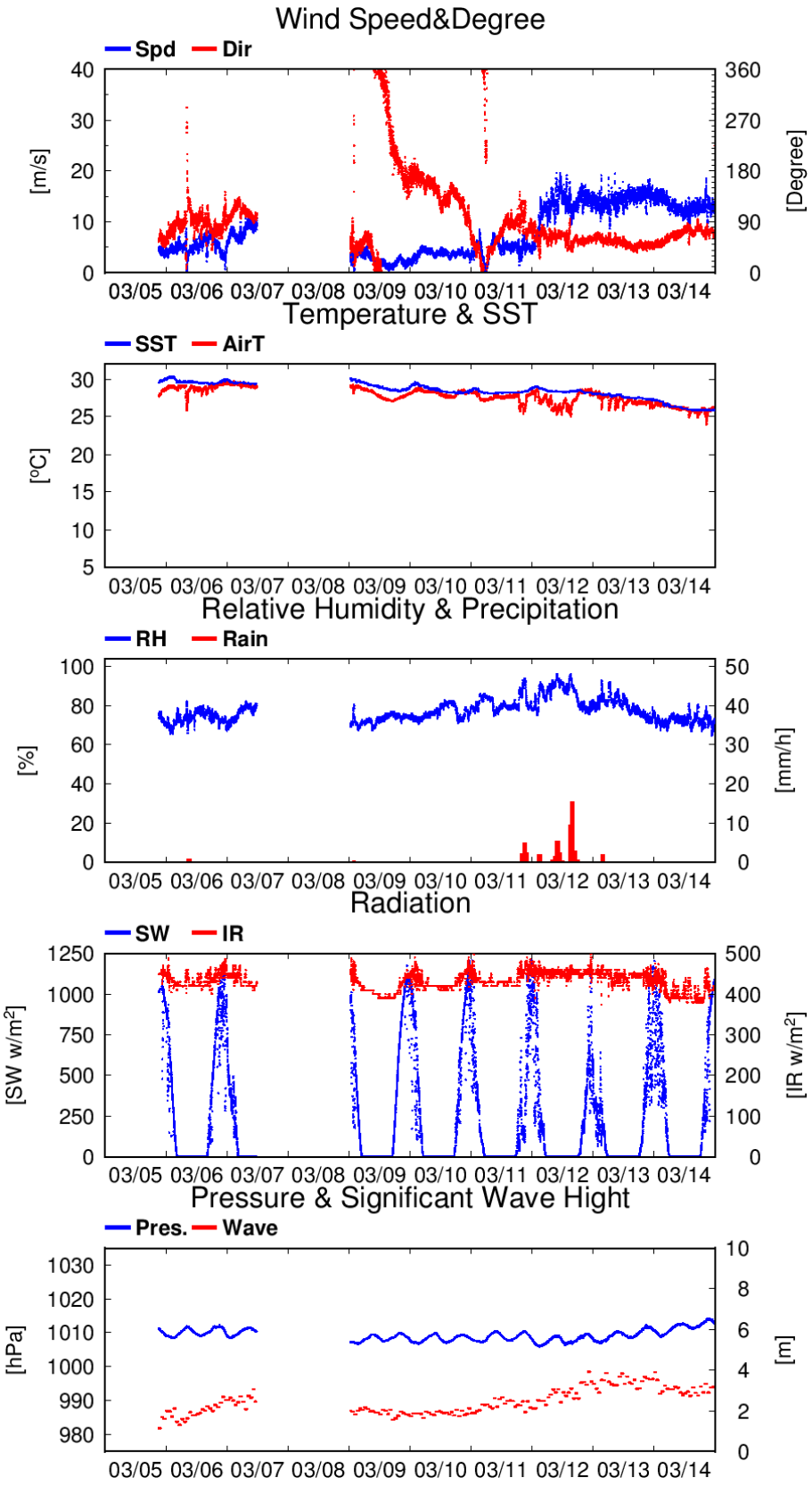


Fig. 3.2.1 Time series of surface meteorological parameters during the cruise

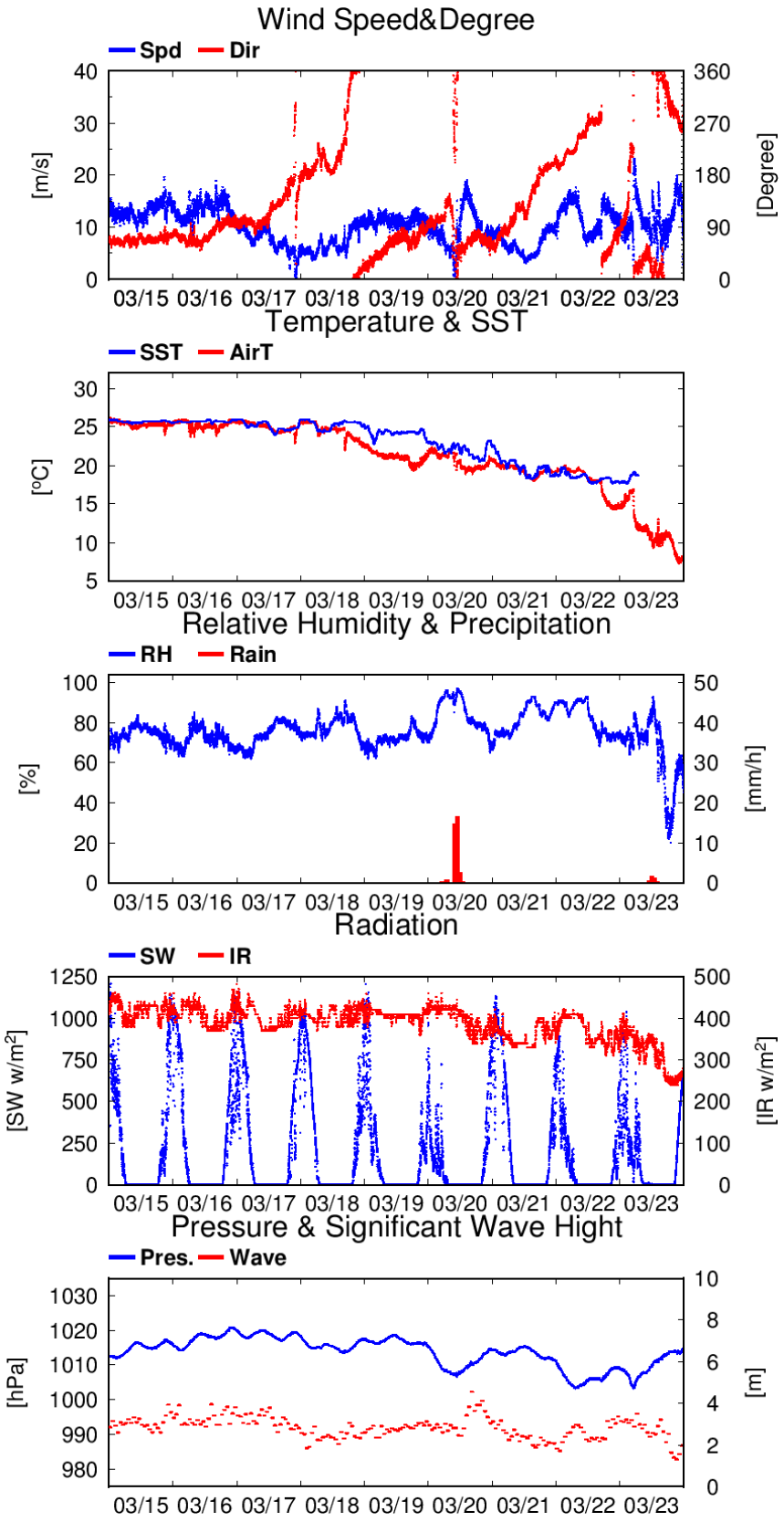


Fig. 3.2.1 (Continued)

3.3 Sea Surface Water Monitoring

3.3.1 Thermo-Salinograph (TSG) Measurement

(1) Personnel

Fumikazu Taketani (JAMSTEC): Principal Investigator
Hiroshi Hoshino (MWJ): Operation leader

(2) Objective

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

(3) Parameters

Temperature
Salinity
Dissolved oxygen
Fluorescence
Turbidity
Total dissolved gas pressure

(4) Instruments and Methods

The Continuous Sea Surface Water Monitoring System (Marine Works Japan Co. Ltd.) has five sensors and automatically measures temperature, salinity, dissolved oxygen, fluorescence, turbidity and total dissolved gas pressure in near-sea surface water every one minute. This system is located in the "sea surface monitoring laboratory" and connected to shipboard LAN-system. Measured data, time, and location of the ship were stored in a data management PC. Sea water was continuously pumped up to the laboratory from an intake placed at the approximately 4.5 m below the sea surface and flowed into the system through a vinyl-chloride pipe. The flow rate of the surface seawater was adjusted to 4 dm^3 min^{-1}.

a. Instruments

Software

SeaMoni Ver.1.1.0.0

Sensors

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

Temperature and Conductivity sensor

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

Bottom of ship thermometer

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

Dissolved oxygen sensor

Model:	RINKO II, JFE ADVANTECH CO. LTD.
Serial number:	13
Measuring range:	0 mg L^{-1} - 20 mg L^{-1}
Resolution:	0.001 mg L^{-1} - 0.004 mg L^{-1} (25 ^{o}C)
Accuracy:	Saturation ± 2 % F.S. (non-linear) (1 atm, 25 ^{o}C)

Fluorescence & Turbidity sensor

Model:	C3, TURNER DESIGNS
Serial number:	2300384
Measuring range:	Chlorophyll in vivo 0 μg L^{-1} – 500 μg L^{-1}
Minimum Detection Limit:	Chlorophyll in vivo 0.03 μg L^{-1}
Measuring range:	Turbidity 0 NTU - 1500 NTU
Minimum Detection Limit:	Turbidity 0.05 NTU

Total dissolved gas pressure sensor

Model:	HGTD-Pro, PRO OCEANUS
Serial number:	37-394-10
Temperature range:	-2 °C - 50 °C
Resolution:	0.0001 %
Accuracy:	0.01 % (Temperature Compensated)
Sensor Drift:	0.02 % per year max (0.001 % typical)

(5) Observation log

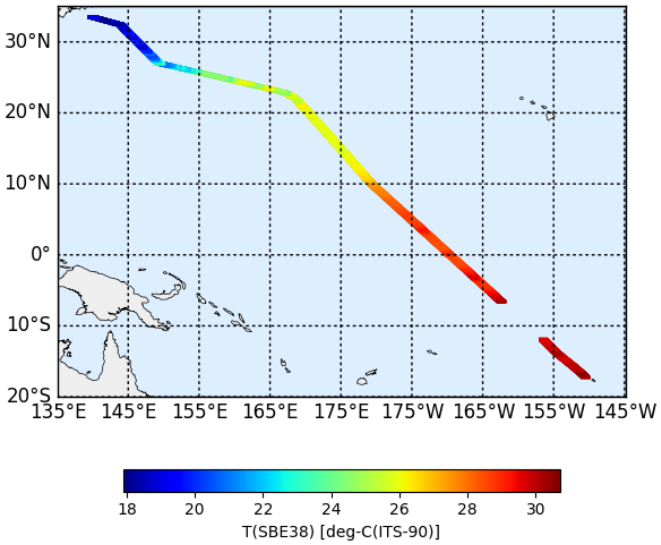
Periods of measurement, maintenance, and problems during this cruise are listed in Table 3.3.1-1.

Table 3.3.1-1 Events list of the Sea surface water monitoring during MR18-06 Leg4

System Date [UTC]	System Time [UTC]	Events	Remarks
2019/03/06	07:31-07:42	Adjust flow rate	Dissolved oxygen, Gas pressure, fluorescence data were affected.
2019/03/06	09:09-09:10	Adjust flow rate	
2019/03/07	11:40	All the measurements stopped.	New Zealand EEZ in
2019/03/09	00:30	All the measurements started.	New Zealand EEZ out
2019/03/10	21:37-21:40	Adjust flow rate	Gas pressure data were affected.
2019/03/14	01:10-01:22	Filter Cleaning	All data except for SBE38 were affected
2019/03/15	05:25-05:29	Adjust flow rate	Gas pressure data were affected.
2019/03/22	08:26-08:29	Adjust flow rate	Gas pressure data were affected.
2019/03/22	22:23-22:27	Adjust flow rate	Gas pressure data were affected.
2019/03/23	07:01	All the measurements stopped.	

We took the surface water samples from this system once a day to compare sensor data with bottle data of salinity and dissolved oxygen, and chlorophyll *a*. The results are shown in fig. 3.3.1-2. All the salinity samples were analyzed by the Model 8400B “AUTOSAL” manufactured by Guildline Instruments Ltd., and dissolve oxygen samples were analyzed by Winkler method (see 3.4.2), chlorophyll *a* were analyzed by 10-AU manufactured by Turner Designs (see 3.4.3).

(a)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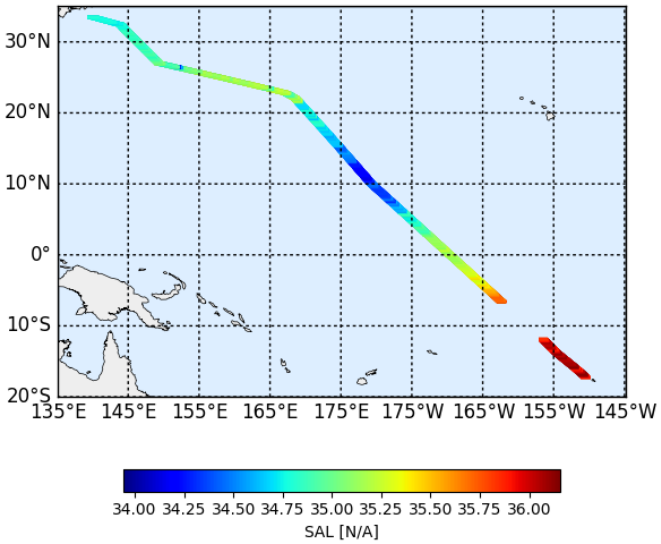
20°N
10°N
0°
10°S
20°S
135°E 145°E 155°E 165°E 175°E 175°W 165°W 155°W 145°W
18 20 22 24 26 28 30
T(SBE38) [deg-C(ITS-90)]

(b)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20°N
10°N
0°
10°S
20°S
135°E 145°E 155°E 165°E 175°E 175°W 165°W 155°W 145°W
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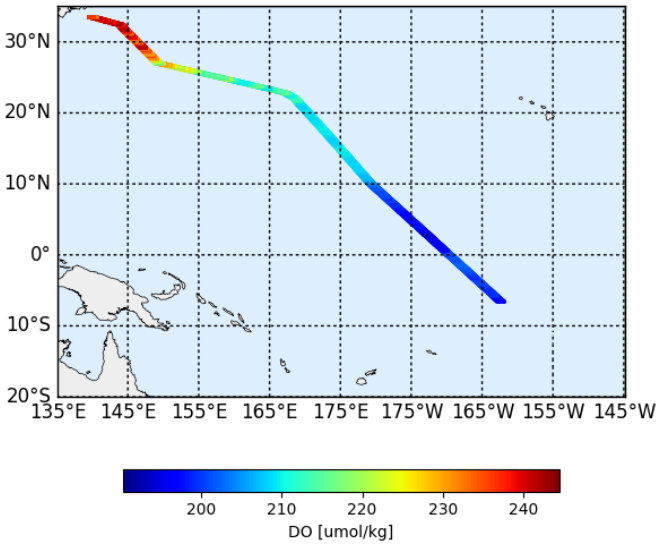
SAL [N/A]

(c)



(d)

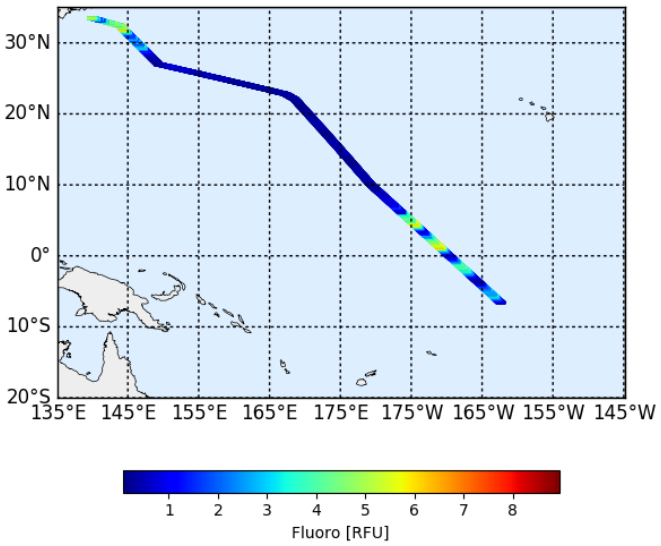


Fig. 3.3.1-1 Spatial and temporal distribution of (a) temperature, (b) salinity, (c) dissolved oxygen, and (d) fluorescence in MR18-06 Leg4 cruise.

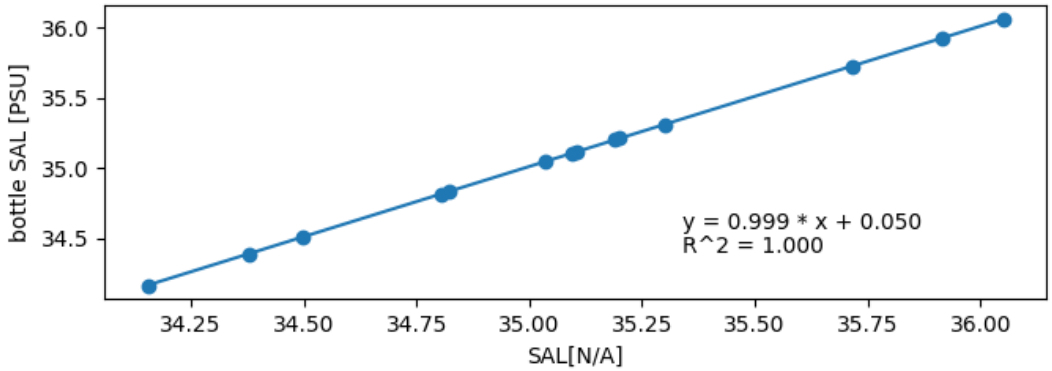


Fig. 3.3.1-2-1 Correlation of salinity between sensor data and bottle data.

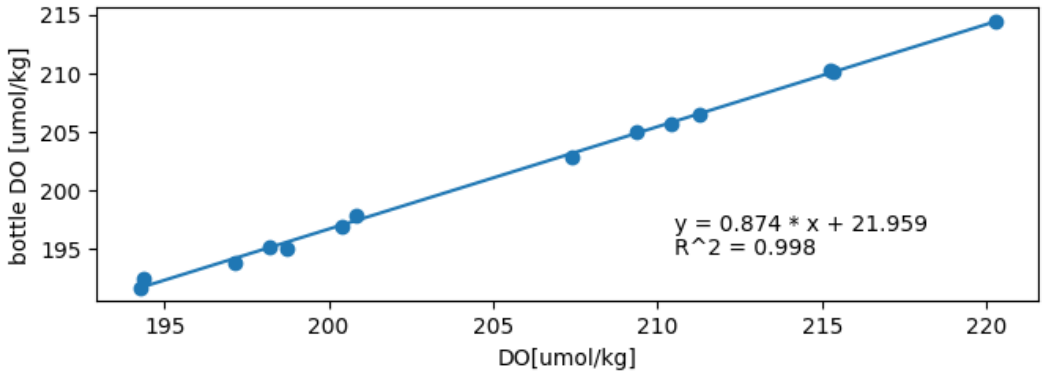


Fig. 3.3.1-2-2 Correlation of dissolved oxygen between sensor data and bottle data.

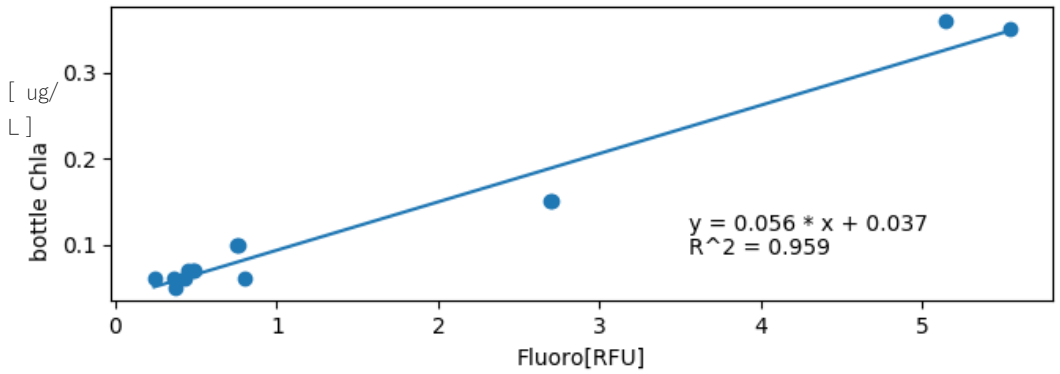


Fig. 3.3.1-2-3 Correlation of fluorescence between sensor data and bottle data.

(6) Data archives

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

3.3.2 pCO_2

(1) Personnel

Fumikazu Taketani (JAMSTEC): Principal Investigator
Masahiro Orui (MWJ): Operation Leader

(2) 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 Pacific in order to quantify how much CO_2 is absorbed in the region.

(3) Apparatus

Concentrations of CO_2 in the atmosphere and the sea surface were measured continuously during the cruise using an automated system with a non-dispersive infrared (NDIR) analyzer (Li-COR LI-7000). The automated system (Nippon ANS) was operated by about one and a half hour cycle. In one cycle, standard gasses, marine air and an air in a headspace of an equilibrator were analyzed subsequently. The nominal concentrations of the standard gas were 270, 330, 390 and 420 ppmv. The standard gases will be calibrated after the cruise.

The marine air taken from the bow was introduced into the NDIR by passing through a mass flow controller, which controlled the air flow rate at about 0.6 – 0.8 L/min, and a cooling unit.

A fixed volume of the marine air taken from the bow was equilibrated with a stream of seawater that flowed at a rate of 4.0 – 5.0 L/min in the equilibrator. The air in the equilibrator was circulated with a pump at 0.7-0.8L/min in a closed loop passing through the cooling unit as used for marine air sample.

(4) Results

Concentrations of CO_2 (xCO_2) of marine air and surface seawater are shown in Fig. 3.3.2, together with SST.

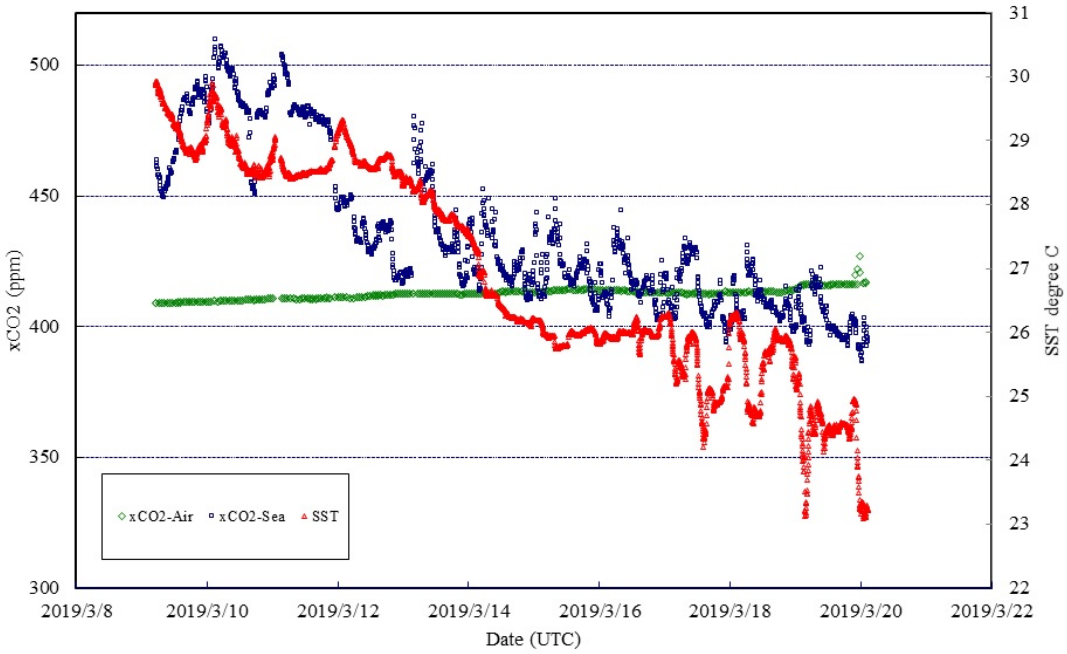


Fig. 3.3.2. Preliminary results of concentrations of CO_2 (xCO_2) in atmosphere (green) and surface seawater (blue), and SST (red) observed during the leg 4 of MR18-06.

3.3.3 DIC

(1) Personnel

Fumikazu Taketani (JAMSTEC): Principal Investigator
Hiroshi Hoshino (MWJ): Operation Leader

(2) Objective

Our purpose is in-situ measurement of total dissolved inorganic carbon (DIC) concentration in near-sea surface water.

(3) Parameters

DIC

(4) Instruments and Methods

Surface seawater was continuously collected from 10th March 2019 to 21th March 2019 (UTC) during this cruise. Surface seawater was taken from an intake placed at the approximately 4.5 m below the sea surface by a pump, and was filled in a 250 mL glass bottle (SCHOTT DURAN) from the bottom, without rinsing, and overflowed for more than 3 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 (AC-150-A25, Thermo 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, 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 1.5 % CO_2 standard gas in a nitrogen base, system blank (phosphoric acid blank), and seawater samples (6 samples) were programmed to repeat. Both CO_2 standard gas and blank signals were used to correct the signal drift results from chemical alternation of coulometer solutions. The coulometer solutions were renewed every about 2 days, and a certified reference material (CRM: batch 166) was measured each time to correct systematic difference between measurements.

(5) Observation log

Cruise track during underway DIC observation is shown in fig. 3.3.3-1.

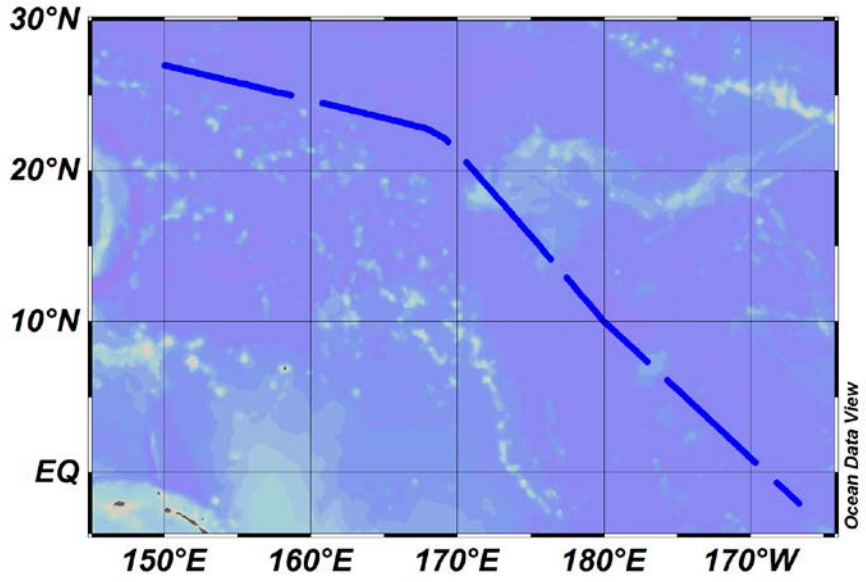


Figure 3.3.3-1 Observation map

(6) Results

The 6 sets of measurement were combined and time-series variation of sea surface DIC concentrations are plotted in the fig. 3.3.3-2. The standard deviation of the absolute differences of CRM was 1.3 µmol kg^{-1} (n=2).

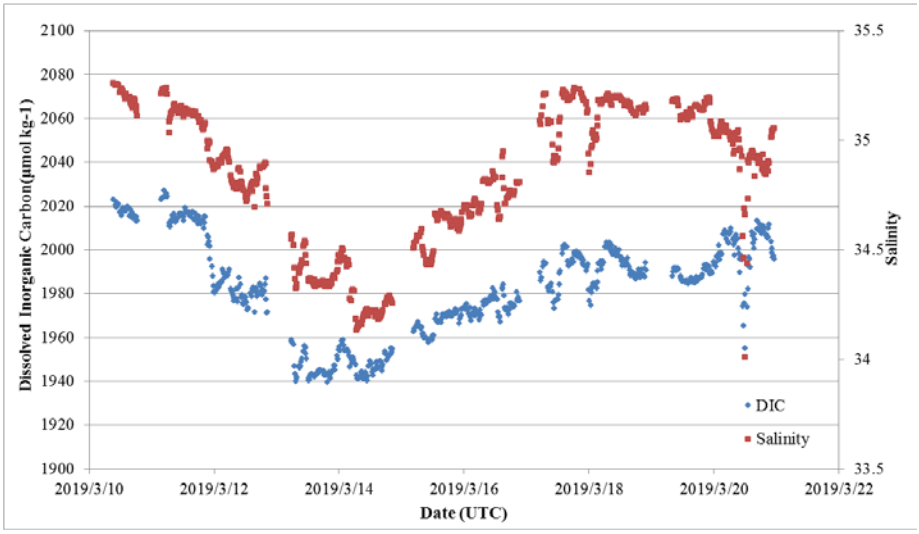


Figure 3.3.3-2 Temporal variations of underway DIC. Blue and red dots represent surface DIC and salinity, respectively.

(7) Date archives

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

(8) References

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.

3.4 Bucket sampling

3.4.1 Nutrients

(1) Personnel

Fumikazu Taketani (JAMSTEC): Principal Investigator
Shinichiro YOKOGAWA (MWJ): Operation Leader

(2) Objectives

The objectives of nutrients analyses during the R/V Mirai MR18-06 Leg4 cruise in the Pacific Ocean.

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

(3) Parameters

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

(4) Instruments and methods

(4.1) Analytical detail using QuAAtro 2-HR systems (BL TEC K.K.)

Nitrate + nitrite and nitrite are analyzed following a modification of the method of Grasshoff (1976). The sample nitrate is reduced to nitrite in a cadmium tube the inside of which is coated with metallic copper. The sample stream after reduction is treated with an acidic, sulfanilamide reagent to produce a diazonium ion. N-1-Naphthylethylenediamine Dihydrochloride added to the sample stream to produce a red azo dye. With reduction of the nitrate to nitrite, both nitrate and nitrite react and are measured; without reduction, only nitrite reacts. Thus, for the nitrite analysis, no reduction is performed and the alkaline buffer is not necessary. Nitrate is computed by difference.

The silicate method is analogous to that described for phosphate. The method used is essentially that of Grasshoff et al. (1999). Silicomolybdic acid is first formed from the silicate in the sample and molybdic acid. The silicomolybdic acid is reduced to silicomolybdous acid, or "molybdenum blue," using ascorbic acid.

The phosphate analysis is a modification of the procedure of Murphy and Riley (1962). Molybdic acid is added to the seawater sample to form phosphomolybdic acid which is in turn reduced to phosphomolybdous acid using L-ascorbic acid as the reductant.

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

The details of modification of analytical methods for four parameters, Nitrate, Nitrite, Silicate and Phosphate, used in this cruise are also compatible with the methods described in nutrients section in GO-SHIP repeat hydrography manual (Hydes et al., 2010), while an analytical method of ammonium is compatible with Determination of ammonia in seawater using a vaporization membrane permeability method (Kimura, 2000). The flow diagrams and reagents for each parameter are shown in Figures 3.4.1-1 to 3.4.1-5.

(4.2) Nitrate + Nitrite Reagents

50 % Triton solution

50 mL Triton™ X-100 provided by Sigma-Ardrich Japan G. K. (CAS No. 9002-93-1), were mixed with 50 mL Ethanol (99.5 %).

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

Dissolve 4 g Imidazole (CAS No. 288-32-4), in 1000 mL Ultra-pure water, add 2 mL Hydrogen chloride (CAS No. 7647-01-0). After mixing, 1 mL 50 % Triton solution is added.

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

Dissolve 10 g 4-Aminobenzenesulfonamide (CAS No. 63-74-1), in 900 mL of Ultra-pure water, add 100 mL Hydrogen chloride (CAS No. 7647-01-0). After mixing, 2 mL 50 % Triton solution is added.

NED, 0.004 M (0.1 % w/v)

Dissolve 1 g N-(1-Naphthalenyl)-1,2-ethanediamine, dihydrochloride (CAS No. 1465-25-4), in 1000 mL of Ultra-pure water and add 10 mL Hydrogen chloride (CAS No. 7647-01-0). After mixing, 1 mL 50 % Triton solution is added. This reagent was stored in a dark bottle.

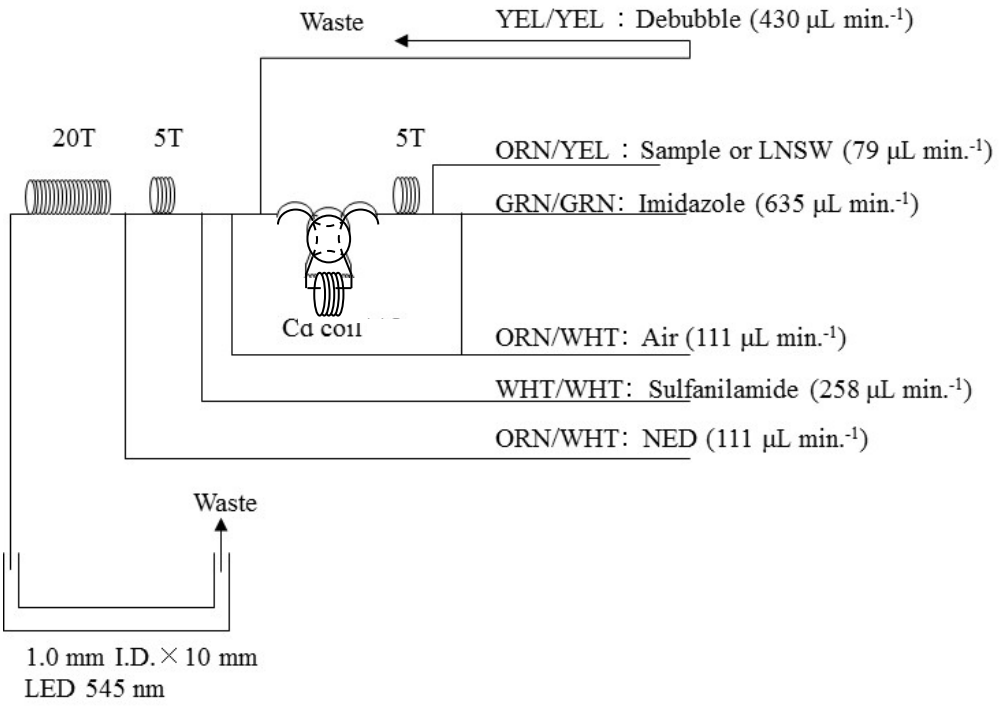


Figure 3.4.1-1 NO_3+NO_2 (1ch.) Flow diagram.

(4.3) Nitrite Reagents

50 % Triton solution

50 mL Triton™ X-100 provided by Sigma-Ardrich Japan G. K. (CAS No. 9002-93-1), were mixed with 50 mL Ethanol (99.5 %).

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

Dissolve 10 g 4-Aminobenzenesulfonamide (CAS No. 63-74-1), in 900 mL of Ultra-pure water, add 100 mL Hydrogen chloride (CAS No. 7647-01-0). After mixing, 2 mL 50 % Triton solution is added.

NED, 0.004 M (0.1 % w/v)

Dissolve 1 g N-(1-Naphthalenyl)-1,2-ethanediamine, dihydrochloride (CAS No. 1465-25-4), in 1000 mL of Ultra-pure water and add 10 mL Hydrogen chloride (CAS No. 7647-01-0). After mixing, 1 mL 50 % Triton solution is added. This reagent was stored in a dark bottle.

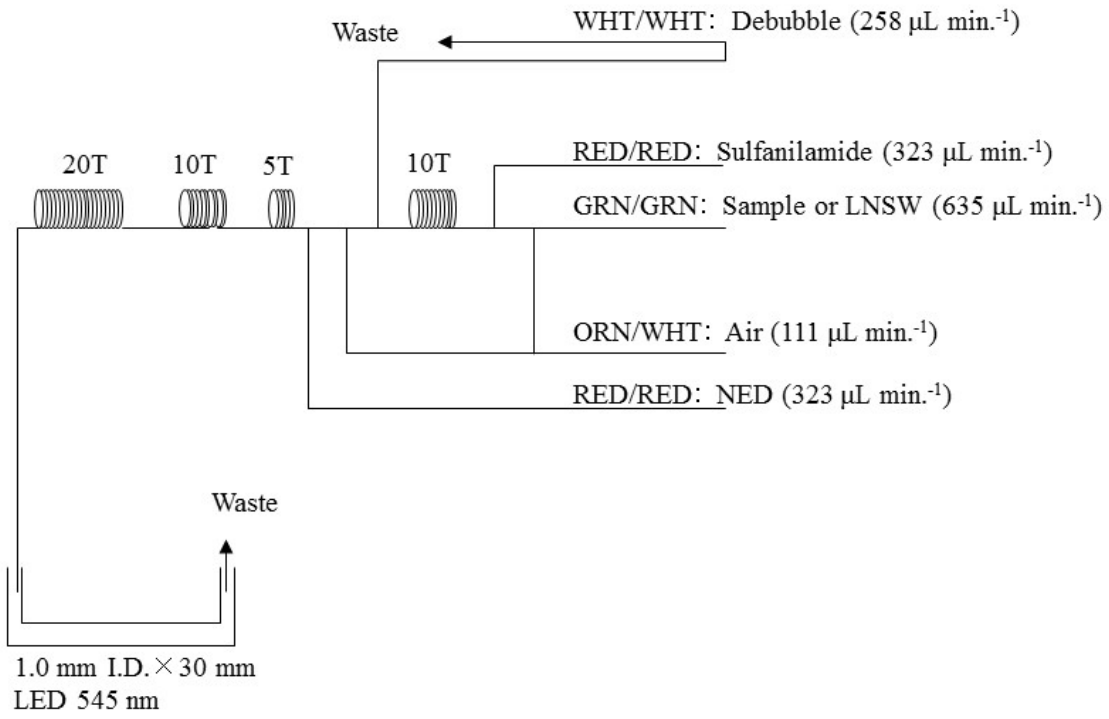


Figure 3.4.1-2 NO_2 (2ch.) Flow diagram.

(4.4) Silicate Reagents

15 % Sodium dodecyl sulfate solution

75 g Sodium dodecyl sulfate (CAS No. 151-21-3) were mixed with 425 mL Ultra-pure water.

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

Dissolve 15 g Sodium molybdate dihydrate (CAS No. 10102-40-6), in 980 mL Ultra-pure water, add 8 mL Sulfuric acid (CAS No. 7664-93-9). After mixing, 20 mL 15 % Sodium dodecyl sulfate solution is added.

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

Dissolve 50 g Oxalic acid (CAS No. 144-62-7), in 950 mL of Ultra-pure water.

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

Dissolve 2.5 g L-Ascorbic acid (CAS No. 50-81-7), in 100 mL of Ultra-pure water. This reagent was freshly prepared at every day.

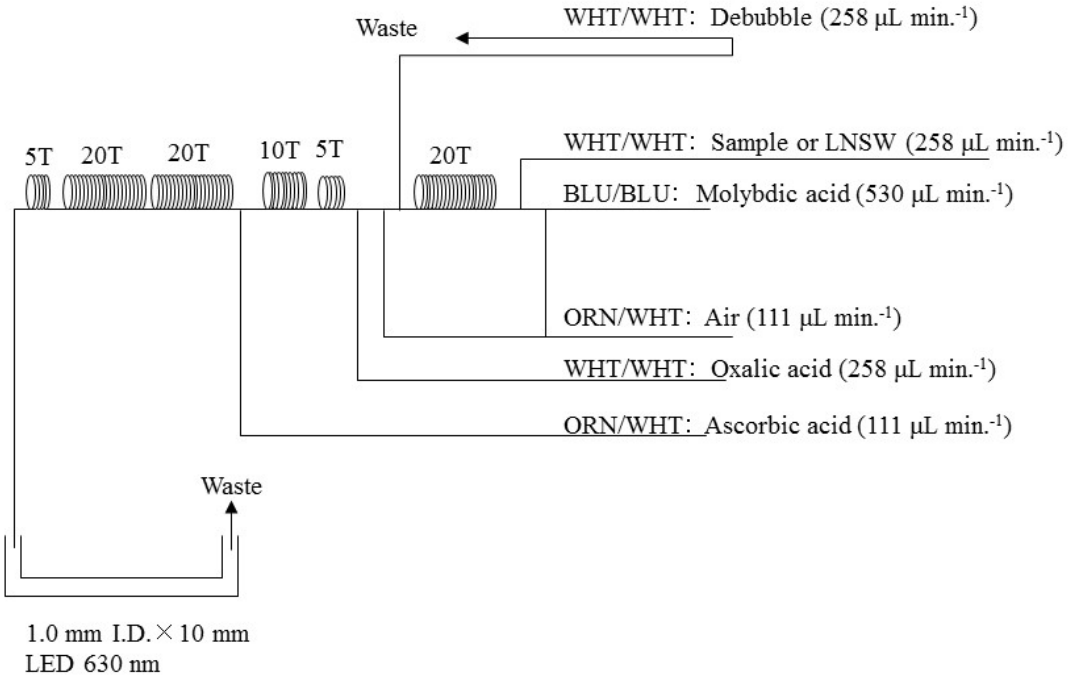


Figure 3.4.1-3 SiO_2 (3ch.) Flow diagram.

(4.5) Phosphate Reagents

15 % Sodium dodecyl sulfate solution

75 g Sodium dodecyl sulfate (CAS No. 151-21-3) were mixed with 425 mL Ultra-pure water.

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

Dissolve 8 g Sodium molybdate dihydrate (CAS No. 10102-40-6), and 0.17 g Antimony potassium tartrate trihydrate (CAS No. 28300-74-5), in 950 mL of Ultra-pure water and added 50 mL Sulfuric acid (CAS No. 7664-93-9).

PO_4 color reagent

Dissolve 1.2 g L-Ascorbic acid (CAS No. 50-81-7), in 150 mL of stock molybdate solution. After mixing, 3 mL 15 % Sodium dodecyl sulfate solution is added. This reagent was freshly prepared before every measurement.

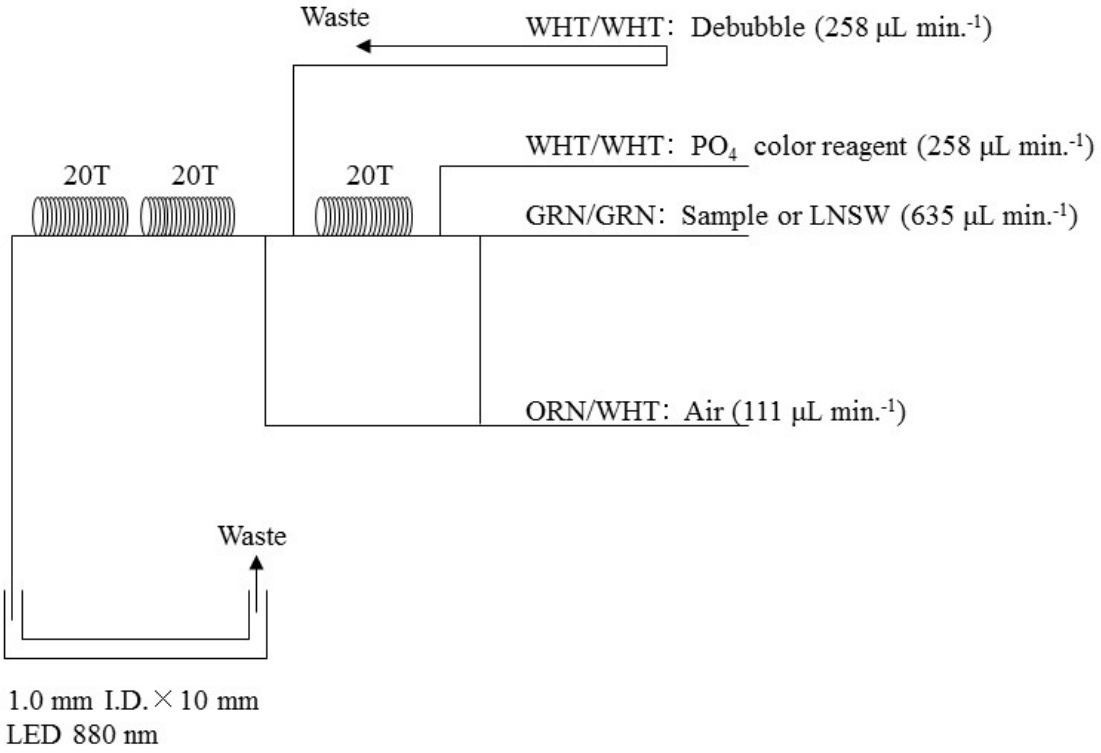


Figure 3.4.1-4 PO_4 (4ch.) Flow diagram.

(4.6) Ammonia Reagents

30 % Triton solution

30 mL Triton™ X-100 provided by Sigma-Ardrich Japan G. K. (CAS No. 9002-93-1), were mixed with 70 mL Ultra-pure water.

EDTA

Dissolve 41 g tetrasodium;2-[2-[bis(carboxylatomethyl)amino]ethyl-(carboxylateme-thyl)amino]acetate;tetrahydrate (CAS No. 13235-36-4), and 2 g Boric acid (CAS No. 10043-35-3), in 200 mL of Ultra-pure water. After mixing, 1 mL 30 % Triton solution is added. This reagent is prepared at a week about.

NaOH liquid

Dissolve 5 g Sodium hydroxide (CAS No. 1310-73-2), and 16 g tetrasodium;2-[2-[bis(carboxylatomethyl)amino]ethyl-(carboxylatomethyl)amino]acetate;tetrahydrate (CAS No. 13235-36-4) in 100 mL of Ultra-pure water. This reagent is prepared at a week about.

Stock nitroprusside

Dissolve 0.25 g Sodium nitroferricyanide dihydrate (CAS No. 13755-38-9) in 100 mL of Ultra-pure water and add 0.2 mL 1M Sulfuric acid. Stored in a dark bottle and prepared at a month about.

Nitroprusside solution

Mix 4 mL stock nitroprusside and 5 mL 1M Sulfuric acid in 500 mL of Ultra-pure water. After mixing, 2 mL 30 % Triton solution is added. This reagent is stored in a dark bottle and prepared at every 2 or 3 days.

Alkaline phenol

Dissolve 10 g Phenol (CAS No. 108-95-2), 5 g Sodium hydroxide (CAS No. 1310-73-2) and 2 g Sodium citrate dihydrate (CAS No. 6132-04-3), in 200 mL Ultra-pure water. Stored in a dark bottle and

prepared at a week about.

NaClO solution

Mix 5 mL Sodium hypochlorite (CAS No. 7681-52-9) in 45 mL Ultra-pure water. Stored in a dark bottle and fleshly prepared before every measurement. This reagent is prepared 0.3 % available chlorine.

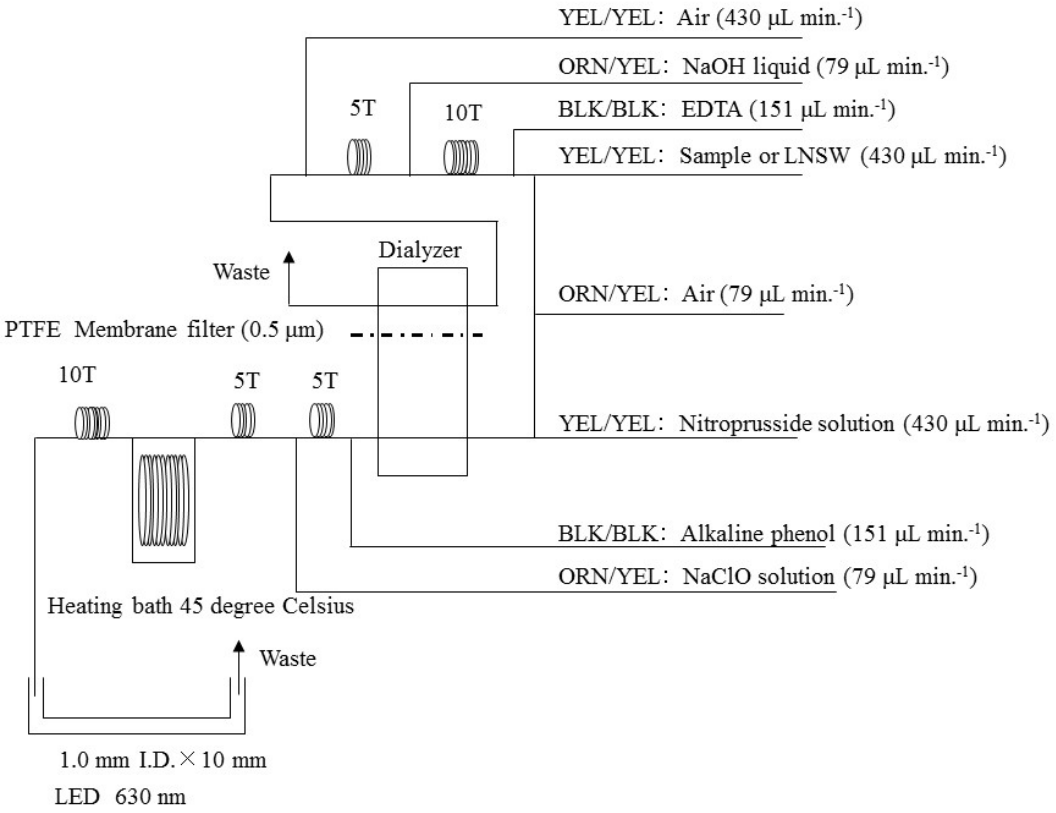


Figure 3.4.1-5 NH_4 (5ch.) Flow diagram.

(4.7) Sampling procedures

Samples were drawn into a virgin 10 mL polyacrylates vials without sample drawing tubes. These were rinsed three times before filling and vials were capped immediately after the drawing. The vials are put into water bath adjusted to ambient temperature, 20. 3 degree Celsius, in about 30 minutes before use to stabilize the temperature of samples.

No transfer was made and the vials were set an auto sampler tray directly.

(4.8) Data processing

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

- Check baseline shift.
- Check the shape of each peak and positions of peak values taken, and then change the positions of peak values taken if necessary.
- Carry-over correction and baseline drift correction were applied to peak heights of each samples followed by sensitivity correction.
- Baseline correction and sensitivity correction were done basically using liner regression.
- Calibration curves to get nutrients concentration were assumed second order equations.

(4.9) Summary of nutrients analysis

We made 2 QuAAtro runs for the water columns sample collected by sea surface water and rain

water during this cruise. The total amount of layers of the sample reached to 89.

(5) Certified Reference Material of nutrients in seawater

KANSO CRMs (Lot: CK, CJ, BZ) were used to ensure the comparability and traceability of nutrient measurements during this cruise. The details of CRMs are shown below.

Production

KANSO CRMs are certified reference material (CRM) for inorganic nutrients in seawater. These were produced by KANSO Co.,Ltd. This certified reference material has been produced using autoclaved natural seawater on the basis of quality control system under ISO Guide 34 (JIS Q 0034).

KANSO Co.,Ltd. has been accredited under the Accreditation System of National Institute of Technology and Evaluation (ASNITE) as a CRM producer since 2011. (Accreditation No.: ASNITE 0052 R)

Property value assignment

The certified values are arithmetic means of the results of 30 bottles from each batch (measured in duplicates) analysed by 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 calibration solutions were adjusted to the salinity of this CRM ± 0.5.

Metrological Traceability

Each certified value of nitrate, nitrite, and phosphate of KANSO CRMs were calibrated versus one of Japan Calibration Service System (JCSS) standard solutions for each nitrate ions, nitrite ions, and phosphate ions. JCSS standard solutions are calibrated versus the secondary solution of JCSS for each of these ions. The secondary solution of JCSS is calibrated versus the specified primary solution produced by Chemicals Evaluation and Research Institute (CERI), Japan. CERI specified primary solutionsare calibrated versus the National Metrology Institute of Japan (NMIJ) primary standards solution of nitrate ions, nitrite ions and phosphate ions, respectively.

For a certified value of silicate of KANSO CRM was determined by one of Merck KGaA silicon standard solution 1000 mg L^{-1} Si traceable to National Institute of Standards and Technology (NIST) SRM of silicon standard solution (SRM 3150).

The certified values of nitrate, nitrite, and phosphate of KASNO CRM are thus traceable to the International System of Units (SI) through an unbroken chain of calibrations, JCSS, CERI and NMIJ solutions as stated above, each having stated uncertainties. The certified values of silicate of KANSO CRM are traceable to the International System of Units (SI) through an unbroken chain of calibrations, Merck KGaA and NIST SRM 3150 solutions, each having stated uncertainties.

As stated in the certificate of NMIJ CRMs each certified value of dissolved silica, nitrate ions, and nitrite ions was determined by more than one method using one of NIST (National Institute of Standards and Technology) SRM of silicon standard solution and NMIJ primary standards solution of nitrate ions and nitrite ions. The concentration of phosphate ions as stated information value in the certificate was determined NMIJ primary standards solution of phosphate ions. Those values in the certificate of NMIJ CRMs are traceable to the International System of Units (SI).

One of analytical methods used for certification of NMIJ CRM for nitrate ions, nitrite ions, phosphate ions and dissolved silica was colorimetric method (continuous mode and batch one). The colorimetric method is same as the analytical method (continuous mode only) used for certification of KANSO CRM. For certification of dissolved silica, exclusion chromatography/isotope dilution-inductively coupled plasma mass spectrometry and Ion exclusion chromatography with post-column detection were used. For certification of nitrate ions, Ion chromatography by direct analysis and Ion chromatography after halogen-ion separation were used. For certification of nitrite ions, Ion chromatography by direct analysis was used.

NMIJ CRMs were analysed at the time of certification process for CRM and the results were confirmed within expanded uncertainty stated in the certificate of NMIJ CRMs.

(5.1) CRM for this cruise

These CRM assignments were completely done based on random number. The CRM bottles were stored at a room in the ship, BIOCHEMICAL LAB., where the temperature was maintained around 20.1 degree Celsius - 24.5 degree Celsius.

(5.2) CRM concentration

We used nutrients concentrations for CRM lots CK, CJ, and BZ as shown in Table 3.4.1-1.

Table 3.4.1-1 Certified concentration and uncertainty (k=2) of CRMs.

unit: μmol kg^{-1}

Lot	Nitrate	Nitrite	Silicate	Phosphate	Ammonia*
CK	0.02 ± 0.03	0.01 ± 0.01	0.73 ± 0.08	0.048 ± 0.012	0.84
CJ	16.20± 0.20	0.03 ± 0.01	38.50 ± 0.40	1.190 ± 0.020	0.77
BZ	43.35 ± 0.33	0.22 ± 0.01	161.00 ± 0.93	3.056 ± 0.033	0.49

*For ammonia values are references

(6) Nutrients standards

(6.1) Volumetric laboratory ware of in-house standards

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

(6.1.1) Volumetric flasks

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

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

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

(6.1.2) Pipettes

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

(6.2) Reagents, general considerations

(6.2.1) Specifications

For nitrate standard, “potassium nitrate 99.995 suprapur®” provided by Merck, Lot. B1452165, CAS No. 7757-79-1, was used.

For nitrite standard solution, we used “nitrite ion standard solution (NO_2^- 1000) provided by Wako, Lot APR5598, Code. No. 140-06451.” This standard solution was certified by Wako using Ion chromatograph method. Calibration result is 1003 mg L^{-1} at 20 degree Celsius. Expanded uncertainty of calibration (k=2) is 0.7 % for the calibration result.

For the silicate standard, we use “Silicon standard solution SiO_2 in NaOH 0.5 M CertiPUR®” provided by Merck, Code. No. 170236, of which lot number is HC68513536 are used. The silicate concentration is certified by NIST-SRM3150 with the uncertainty of 0.7 %. HC68513536 is certified as 1000 mg L^{-1}.

For phosphate standard, “potassium dihydrogen phosphate anhydrous 99.995 suprapur®” provided by Merck, Lot. B1144508, CAS No.: 7778-77-0, was used.

For ammonia standard, “Ammonium Chloride” provided by NMIJ, CAS No. 12125-02-9. We used NMIJ CRM 3011-a. The purity of this standard was greater than 99.9 %. Expanded uncertainty of calibration (k=2) is 0.065 %.

(6.2.2) Ultra-pure water

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

(6.2.3) Low nutrients seawater (LNSW)

Surface water having low nutrient concentration was taken and filtered using 0.20 μm pore capsule cartridge filter at MR16-09 cruise on March, 2017. This water is stored in 20 L cubitainer with cardboard box.

LNSW concentrations were assigned to February, 2018 in JAMSTEC.

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

Concentrations of nutrients for A, D, B and C standards are set as shown in Table 3.4.1-2. The C standard is prepared according recipes as shown in Table 3.4.1-3. All volumetric laboratory tools were calibrated prior the cruise as stated in chapter (6.1) Then the actual concentration of nutrients in each fresh standard was calculated based on the ambient, solution temperature and determined factors of volumetric laboratory wares.

The calibration curves for each run were obtained using 5 levels, C-1, C-2, C-3, C-4 and C-5.

Table 3.4.1-2 Nominal concentrations of nutrients for A, D, B and C standards.

	A	D	B	C-1	C-2	C-3	C-4	C-5
NO_3 (μM)	45000	1800	900	LNSW	9	18	35	54
NO_2 (μM)	21800	870	26	LNSW	0.26	0.52	1.04	1.56
SiO_2 (μM)	34800		2845	LNSW	29	58	114	172
PO_4 (μM)	6000		60	LNSW	0.7	1.3	2.5	3.7
NH_4 (μM)	4000		160	LNSW	1.6	3.2	6.4	9.6

Table 3.4.1-3 Working calibration standard recipes.

C Std.	B Std.
C-2	5 mL
C-3	10 ml
C-4	20 ml
C-5	30 ml

(6.2.5) Renewal of in-house standard solutions

In-house standard solutions as stated in paragraph (6.2) were renewed as shown in Table 3.4.1-4 to 4.3.1-6.

Table 3.4.1-4 Timing of renewal of in-house standards.

NO_3, NO_2, SiO_2, PO_4, NH_4	Renewal
A-1 Std. (NO_3)	maximum a month
A-2 Std. (NO_2)	commercial prepared solution
A-3 Std. (SiO_2)	commercial prepared solution
A-4 Std. (PO_4)	maximum a month
A-5 Std. (NH_4)	maximum a month
D-1 Std.	maximum 8 days
D-2 Std.	maximum 8 days
B Std. (mixture of A-1, D-2, A-3, A-4 and A-5 std.)	maximum 8 days

Table 3.4.1-5 Timing of renewal of working calibration standards.

Working standards	Renewal
C Std. (dilute B Std.)	every 24 hours

Table 3.4.1-6 Timing of renewal of in-house standards for reduction estimation.

Reduction estimation	Renewal
36 μM NO_3 (dilute D-1 Std.)	when C Std. renewed
35 μM NO_2 (dilute D-2 Std.)	when C Std. renewed

(7) Quality control

(7.1) Precision of nutrients analyses during the cruise

Precision of nutrients analyses during this cruise was evaluated based on the 7 to 8 measurements, which are measured every 8 to 12 samples, during a run at the concentration of C-5 std. Summary of precisions are shown in Table 3.4.1-7. The precisions for each parameter are generally good considering the analytical precisions during the R/V Mirai cruses conducted in 2009 - 2017. During in this cruise, analytical precisions were 0.13 % for nitrate, 0.13 % for nitrite, 0.12 % for silicate, 0.10 % for phosphate and 0.17 % for ammonia in terms of median of precision, respectively. Then we can conclude that the analytical precisions for nitrate, nitrite, silicate, phosphate and ammonia were maintained throughout this cruise.

Table 3.4.1-7 Summary of precision based on the replicate analyses.

	Nitrate CV %	Nitrite CV %	Silicate CV %	Phosphate CV %	Ammonia CV %
Mean	0.13	0.14	0.12	0.15	0.19
Maximum	0.14	0.14	0.14	0.18	0.26
Minimum	0.11	0.13	0.09	0.11	0.12
N	2	2	2	2	2

(7.2) Carry over

We can also summarize the magnitudes of carry over throughout the cruise. These are small enough within acceptable levels as shown in Table 3.4.1-8

Table 3.4.1-8 Summary of carry over throughout this cruise.

	Nitrate %	Nitrite %	Silicate %	Phosphate %	Ammonia %
Mean	0.13	0.17	0.21	0.16	0.47
Maximum	0.15	0.24	0.21	0.19	0.47
Minimum	0.11	0.09	0.21	0.12	0.46
N	2	2	2	2	2

(8) Problems / improvements occurred and solutions.

Nothing happened during this cruise.

(9) List of reagent

List of reagent is shown in Table 3.4.1-9.

Table 3.4.1-9 List of reagent in this cruise.

IUPAC name	CAS Number	Formula	Compound Name	Manufacture	Grade
4-Aminobenzenesulfonamide	63-74-1	$C_6H_8N_2O_2S$	Sulfanilamide	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Ammonium Chloride	12125-02-9	NH_4Cl	Ammonium Chloride	National Institute of Advanced Industrial Science and Technology	Certified Reference Material
Antimony potassium tartrate trihydrate	28300-74-5	$K_2(SbC_4H_2O_6)_2 \cdot 3H_2O$	Bis[(+)-tartrato]diantimonate(III) Dipotassium Trihydrate	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Boric acid	10043-35-3	H_3BO_3	Boric Acid	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Hydrogen chloride	7647-01-0	HCl	Hydrochloric Acid	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Imidazole	288-32-4	$C_3H_4N_2$	Imidazole	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
L-Ascorbic acid	50-81-7	$C_6H_8O_6$	L-Ascorbic Acid	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
N-(1-Naphthalenyl)-1,2-ethanediamine, dihydrochloride	1465-25-4	$C_{12}H_{16}Cl_2N_2$	N-1-Naphthylethylenediamine Dihydrochloride	Wako Pure Chemical Industries, Ltd.	for Nitrogen Oxides Analysis
Oxalic acid	144-62-7	$C_2H_2O_4$	Oxalic Acid	Wako Pure Chemical Industries, Ltd.	Wako Special Grade
Phenol	108-95-2	C_6H_6O	Phenol	Wako Pure Chemical Industries, Ltd.	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 citrate dihydrate	6132-04-3	$Na_3C_6H_5O_7 \cdot 2H_2O$	Trisodium Citrate Dihydrate	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Sodium dodecyl sulfate	151-21-3	$C_{12}H_{25}NaO_4S$	Sodium Dodecyl Sulfate	Wako Pure Chemical Industries, Ltd.	for Biochemistry
Sodium hydroxide	1310-73-2	NaOH	Sodium Hydroxide for Nitrogen Compounds Analysis	Wako Pure Chemical Industries, Ltd.	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	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Sodium nitroferricyanide dihydrate	13755-38-9	$Na_2[Fe(CN)_5NO] \cdot 2H_2O$	Sodium Pentacyanonitrosylferrate(III) Dihydrate	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Sulfuric acid	7664-93-9	H_2SO_4	Sulfuric Acid	Wako Pure Chemical Industries, Ltd.	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	Sigma-Aldrich Japan G.K.	-

(10) Data archives

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

(11) References

Grasshoff, K. 1976. Automated chemical analysis (Chapter 13) in Methods of Seawater Analysis. With contribution by Almgreen T., Dawson R., Ehrhardt M., Fonselius S. H., Josefsson B., Koroleff F., Kremling K. Weinheim, New York: Verlag Chemie.

Grasshoff, K., Kremling K., Ehrhardt, M. et al. 1999. Methods of Seawater Analysis. Third, Completely Revised and Extended Edition. WILEY-VCH Verlag GmbH, D-69469 Weinheim (Federal Republic of Germany).

Hydes, D.J., Aoyama, M., Aminot, A., Bakker, K., Becker, S., Coverly, S., Daniel, A., Dickson, A.G., Grosso, O., Kerouel, R., Ooijen, J. van, Sato, K., Tanhua, T., Woodward, E.M.S., Zhang, J.Z., 2010.

Determination of Dissolved Nutrients (N, P, Si) in Seawater with High Precision and Inter-Comparability Using Gas-Segmented Continuous Flow Analysers, In: GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines. IOCCP Report No. 14, ICPO Publication Series No 134.

Kimura, 2000. Determination of ammonia in seawater using a vaporization membrane permeability method. 7th auto analyzer Study Group, 39-41.

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

3.4.2 Dissolved Oxygen

(1) Personnel

Fumikazu Taketani (JAMSTEC): Principal Investigator
Masahiro Orui (MWJ): Operation Leader

(2) Objective

Determination of dissolved oxygen in seawater by Winkler titration.

(3) Parameters

Dissolved Oxygen(DO)

(4) 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-610) 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;
DOT15X_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

We collected samples for Dissolved Oxygen from surface layer. Seawater for oxygen measurement was transferred from the bottle to a volume calibrated flask (ca. 100 cm^3), and three times volume of the flask was overflowed. Temperature was simulteneously measured by digital thermometer during the overflowing. After transfering 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 . 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 TSG, flask volume, and titrated volume of sodium thiosulfate solution without the blank. During this cruise, 1 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.

(5) Observation log

Standardization and determination of the blank

Table 3.4.2-1 shows results of the standardization and the blank determination during this cruise.

Table 3.4.2-1 Results of the standardization and the blank determinations during cruise

Date (yyyy/mm/dd)	Potassium iodate ID	Sodium thiosulfate ID	DOT-15X (No.9)		Stations
			E.P. (cm^3)	Blank (cm^3)	
2019/3/7	K1805C06	T1806E	3.965	0.004	B02,B03, B04,B05,B06
2019/3/13	K1805C07	T1806E	3.966	0.003	B07,B08,B09, B10,B11
2019/3/18	K1805C08	T1806E	3.967	0.003	B12,B13,B14, B15,B16
2019/3/23	K1805C09	T1606K	3.969	0.003	

(6) Data archives

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

(7) 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.

3.4.3. Chlorophylls

(1) Personnel

Kazuhiko Matsumoto (JAMSTEC): Principal Investigator
Masahiro Orui (Marine Works Japan Ltd.; MWJ): Operation leader

(2) Objective

We measured total chlorophyll a in seawater by using the fluorometric method.

(3) Parameters

Total chlorophyll *a*

(4) Instruments and methods

We collected samples for total chlorophyll *a* from surface layer.

Seawater samples for total chlorophyll *a* were vacuum-filtrated (< 0.02 MPa) through Whatman GF/F filter (25mm-in diameter).

Phytoplankton pigments retained on the filters were immediately extracted in a polypropylene tube with 7 ml of *N*,*N*-dimethylformamide (Wako Pure Chemical Industries Ltd.) (Suzuki and Ishimaru, 1990). The tubes were stored at -20 °C under the dark condition to extract chlorophyll *a* at least for 24 hours.

Chlorophyll *a* concentrations were measured by the fluorometer (10-AU-005-CE, TURNER DESIGNS), which was previously calibrated against a pure chlorophyll *a* (Sigma-Aldrich Co., LLC). To estimate the chlorophyll *a* concentrations, we applied to the fluorometric "Non-acidification method" (Welschmeyer, 1994).

(5) Station list

The stations and the sampling positions were shown in table 3.4.3-1.

(6) Data archives

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

(7) Reference

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

Table 3.4.3-1. Stations and the sampling positions.

Stations	Latitude	Longitude
B02	06-35.92415S	161-41.01619W
B03	03-53.81231S	164-39.74420W
B04	00-00.02183S	168-56.91509W
B05	02-54.24774N	172-08.34723W
B06	06-05.18919N	175-39.33400W
B07	09-25.32391N	179-21.47288W
B08	13-00.98085N	177-21.44485E
B09	16-43.27767N	174-04.36829E
B10	20-35.18585N	170-35.35107E
B11	23-17.25109N	165-55.81385E
B12	24-30.22359N	160-45.40363E
B13	25-42.79834N	155-38.81058E
B14	27-00.02569N	150-00.02142E
B15	30-56.48599N	146-01.88798E
B16	32-25.09030N	144-37.09563E

3.4.4 Marine gel particles

(1) Personnel

Kazuhiko Matsumoto (JAMSTEC)
Kaori Kawana (JAMSTEC)
Fumikazu Taketani (JAMSTEC)

(2) Objectives

Marine organic aerosol is produced directly at the sea surface due to the interaction between wind and waves. Organic matter becomes enriched in the surface microlayer with the organic gels. Transparent exopolymer particles (TEP), i.e., polysaccharide-rich microgels that are produced primarily by the abiotic coagulation of phytoplankton exudates, and Coomassie stainable particles (CSP) containing proteinaceous polymers released during cell lysis and decomposition are identifying as organic gels in the ocean interior. To understand the processes of organic aerosol formation, the concentration of marine gel particles at the sea surface are measured along the cruise track.

(3) Methods and Instruments

i. Sampling

Seawater samples were collected at the sea surface using a bucket at the stations B02 ~ B16 (Table 3.4.4-1). To estimate the phytoplankton group composition, the samples for high-performance liquid chromatography (HPLC) and flow cytometry (FCM) were collected concurrently (Table 3.4.4-1). Water samples of 2000 mL were filtered (<0.02MPa) through 47mm-diameter Whatman GF/F filter for HPLC, and the filters were frozen immediately at -80 °C. Water samples of about 2 mL were fixed with glutaraldehyde and frozen immediately at -80 °C for FCM. The analyses of HPLC and FCM will be conducted after the cruise.

ii. Staining and measurement procedure

(a) Transparent exopolymer particle (TEP)

TEP is very sticky, and it aggregates with other suspended particles, resulting in the formation of sinking marine snow. TEP is formed by coagulation of colloidal TEP precursors present in the phytoplankton released dissolved organic matter. The water samples of 200 mL were filtered onto 0.4-μm polycarbonate filters, and the filters were stained with 1 mL alcian blue solution and rinsed thrice with 1 mL of Milli-Q water. Stained filter samples were stored in freezer until analysis. Filter samples were soaked for 2 - 5 h in 6 mL of 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.

(b) Coomassie stainable particles (CSP)

CSP is protein-containing transparent particle that can be stained with Coomassie brilliant blue (CBB). The water samples of 200 mL were filtered onto 0.4-μm polycarbonate filters, and the filters were stained with 1 mL CBB solution and rinsed five times with 1 mL of Milli-Q water. Stained filter samples were stored in freezer until analysis. Filter samples were soaked for 2 h in 4 mL of 3% sodium dodecyl sulfate (SDS) in 50% isopropyl alcohol with sonication to elute the dye and then the absorbance of the solution is measured at 615 nm in a 1 cm cuvette.

(4) Data archive

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

Table 3.4.4-1: Sampling locations at the surface

Station	Date					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC/JST	Deg.	Min.	N/S	Deg.	Min.	E/W
B02	2019	03	09	0:55	UTC	6	35.92415	S	161	41.01619	W
B03	2019	03	09	19:58	UTC	3	53.81231	S	164	39.7442	W
B04	2019	03	10	22:56	UTC	0	0.02183	S	168	56.91509	W
B05	2019	03	11	20:00	UTC	2	54.24774	N	172	8.34723	W
B06	2019	03	12	19:56	UTC	6	5.18919	N	175	39.334	W
B07	2019	03	13	20:56	UTC	9	25.32391	N	179	21.47288	W
B08	2019	03	14	20:59	UTC	13	0.98085	N	177	21.44485	E
B09	2019	03	15	20:58	UTC	16	43.27767	N	174	4.36829	E
B10	2019	03	16	20:59	UTC	20	35.18585	N	170	35.35107	E
B11	2019	03	17	22:00	UTC	23	17.25109	N	165	55.81385	E
B12	2019	03	18	21:58	UTC	24	30.22359	N	160	45.40363	E
B13	2019	03	19	21:58	UTC	25	42.79834	N	155	38.81058	E
B14	2019	03	20	22:56	UTC	27	0.02569	N	150	0.02142	E
B15	2019	03	21	23:59	UTC	30	56.48599	N	146	1.88798	E
B16	2019	03	22	10:24	UTC	32	25.0903	N	144	37.09563	E

3.4.5 Particulate Organic Matter and Dissolved Organic Carbon

(1) Personnel

Maki Noguchi Aita (JAMSTEC) *not on board*
Kazuhiko Matsumoto (JAMSTEC)
Fumikazu Taketani (JAMSTEC)

(2) Objectives

Evidence suggests that analysis of Stable Isotopes (SI) have the potential to reveal complex interactions, including trophic interactions and energy or mass flow through ecological communities. To examine how different water properties (*i.e.*, nutrients and temperature) affect $\delta^{15}N$ and $\delta^{13}C$ in marine food webs, and to verify the contribution of the atmospheric N deposition to the marine ecosystems, we collected particulate organic matter (POM) samples in this cruise.

(3) Methods

Samples for $\delta^{15}N$ and $\delta^{13}C$ analysis of particulate organic matter (POM) were collected at the sea surface using a bucket (Table 3.4.5-1). POM samples of 30.0 ~ 40.0 L water were filtered with a pre-combusted Whatman GF/F filter (diameter, 47mm). Samples were immediately frozen at -80 °C and will be analyzed using elemental analyzer / isotope-ratio mass spectrometer at onshore laboratory. To estimate the concentrations of dissolved organic carbon (DOC) concurrently, seawater samples were collected using a bucket. DOC samples were transferred into 60 ml high density polyethylene bottle with filtering by a pre-combusted (450 °C) GF/F inline filter. The samples were frozen at -20 °C until analysis at onshore laboratory.

(4) Data archive

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

Table 3.4.5-1: Sampling locations of POM and DOC at the surface

Station	Date					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC/JST	Deg.	Min.	N/S	Deg.	Min.	E/W
B02	2019	03	09	0:55	UTC	6	35.92415	S	161	41.01619	W
B03	2019	03	09	19:58	UTC	3	53.81231	S	164	39.7442	W
B04	2019	03	10	22:56	UTC	0	0.02183	S	168	56.91509	W
B05	2019	03	11	20:00	UTC	2	54.24774	N	172	8.34723	W
B06	2019	03	12	19:56	UTC	6	5.18919	N	175	39.334	W
B07	2019	03	13	20:56	UTC	9	25.32391	N	179	21.47288	W
B08	2019	03	14	20:59	UTC	13	0.98085	N	177	21.44485	E
B09	2019	03	15	20:58	UTC	16	43.27767	N	174	4.36829	E
B10	2019	03	16	20:59	UTC	20	35.18585	N	170	35.35107	E
B11	2019	03	17	22:00	UTC	23	17.25109	N	165	55.81385	E
B12	2019	03	18	21:58	UTC	24	30.22359	N	160	45.40363	E
B13	2019	03	19	21:58	UTC	25	42.79834	N	155	38.81058	E
B14	2019	03	20	22:56	UTC	27	0.02569	N	150	0.02142	E
B15	2019	03	21	23:59	UTC	30	56.48599	N	146	1.88798	E
B16	2019	03	22	10:24	UTC	32	25.0903	N	144	37.09563	E

3.4.6. Biological particles in seawater

(1) Personnel

Kaori Kawana (JAMSTEC)
Fumikazu Taketani (JAMSTEC)
Kazuhiko Matsumoto (JAMSTEC)
Yugo Kanaya(JAMSTEC) *not on board*

(2) Objectives

To investigate the abundance of biological particles from marine surface to atmosphere , we measured the fluorescent particles in seawater samples as well as in atmospheric samples in chapter 3.12.

(3) Methods

Seawater at the sea surface were collected using a bucket. These sampling logs are listed in Table 3.4.6-1. By measurement of fluorescent particles in the samples with/without dyeing reagents of DAPI and Hoechst using a bioplorer (KB-VKH01, Koyo Sangyo Co., Ltd), the number concentration of alive/dead particles in sea surface were obtained.

(4) Data archive

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

Table 3.4.6-1: Logs of seawater sampling for biological particle analysis.

Station	Date					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC/JST	Deg.	Min.	N/S	Deg.	Min.	E/W
B02	2019	03	09	0:55	UTC	6	35.92415	S	161	41.01619	W
B03	2019	03	09	19:58	UTC	3	53.81231	S	164	39.7442	W
B04	2019	03	10	22:56	UTC	0	0.02183	S	168	56.91509	W
B05	2019	03	11	20:00	UTC	2	54.24774	N	172	8.34723	W
B06	2019	03	12	19:56	UTC	6	5.18919	N	175	39.334	W
B07	2019	03	13	20:56	UTC	9	25.32391	N	179	21.47288	W
B08	2019	03	14	20:59	UTC	13	0.98085	N	177	21.44485	E
B09	2019	03	15	20:58	UTC	16	43.27767	N	174	4.36829	E
B10	2019	03	16	20:59	UTC	20	35.18585	N	170	35.35107	E
B11	2019	03	17	22:00	UTC	23	17.25109	N	165	55.81385	E
B12	2019	03	18	21:58	UTC	24	30.22359	N	160	45.40363	E
B13	2019	03	19	21:58	UTC	25	42.79834	N	155	38.81058	E
B14	2019	03	20	22:56	UTC	27	0.02569	N	150	0.02142	E
B15	2019	03	21	23:59	UTC	30	56.48599	N	146	1.88798	E
B16	2019	03	22	10:24	UTC	32	25.0903	N	144	37.09563	E

3.5 Shipboard ADCP

(1) Personnel

Fumikazu Taketani	*JAMSTEC: Principal investigator*
Masanori Murakami	*Nippon Marine Enterprises LTD. (NME)*
Kazuho Yoshida NME	
Yoichi Inoue	*MIRAI crew*

(2) Objective

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

(3) Apparatus

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

1. R/V MIRAI has installed the Ocean Surveyor for vessel-mount ADCP (frequency 76.8 kHz; Teledyne RD Instruments, USA). It has a phased-array transducer with single ceramic assembly and creates 4 acoustic beams electronically. We mounted the transducer head rotated to a ship-relative angle of 45 degrees azimuth from the keel.
2. For heading source, we use ship's gyro compass (Tokyo Keiki, Japan), continuously providing heading to the ADCP system directory. Additionally, we have Inertial Navigation System (Phins, Ixblue, France) which provide high-precision heading, attitude information, pitch and roll. They are stored in ".N2R" data files with a time stamp.
3. Differential GNSS system (StarPack-D, Fugro, Netherlands) providing precise ship's position.
4. We used VmDas software version 1.49(TRDI) for data acquisition.
5. To synchronize time stamp of ping with Computer time, the clock of the logging computer is adjusted to GPS time server continuously by the application software.
6. Fresh water is charged in the sea chest to prevent bio fouling at transducer face.
7. The sound speed at the transducer does affect the vertical bin mapping and vertical velocity measurement, and that is calculated from temperature, salinity (constant value; 35.0 PSU) and depth (6.5 m; transducer depth) by equation in Medwin (1975).

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

(4) Parameters

Major parameters for the measurement, Direct Command, are shown in Table 3.5.1.

Table 3.5.1 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)

Water-Track Commands

WA = 255 False Target Threshold (Max) (0-255 count)

WC = 120 Low Correlation Threshold (0-255)
WD = 111 100 000 Data Out (V; C; A; PG; St; Vsum; Vsum^2; #G; P0)
WE = 1000 Error Velocity Threshold (0-5000 mm/s)
WF = 0800 Blank After Transmit (cm)
WN = 100 Number of depth cells (1-128)
WP = 00001 Pings per Ensemble (0-16384)
WS = 800 Depth Cell Size (cm)
WV = 0390 Mode 1 Ambiguity Velocity (cm/s radial)

(5) Preliminary results

Horizontal velocity along the ship's track is presented in Fig.3.5.1. In vertical direction, the data are averaged from 35 to 100m.

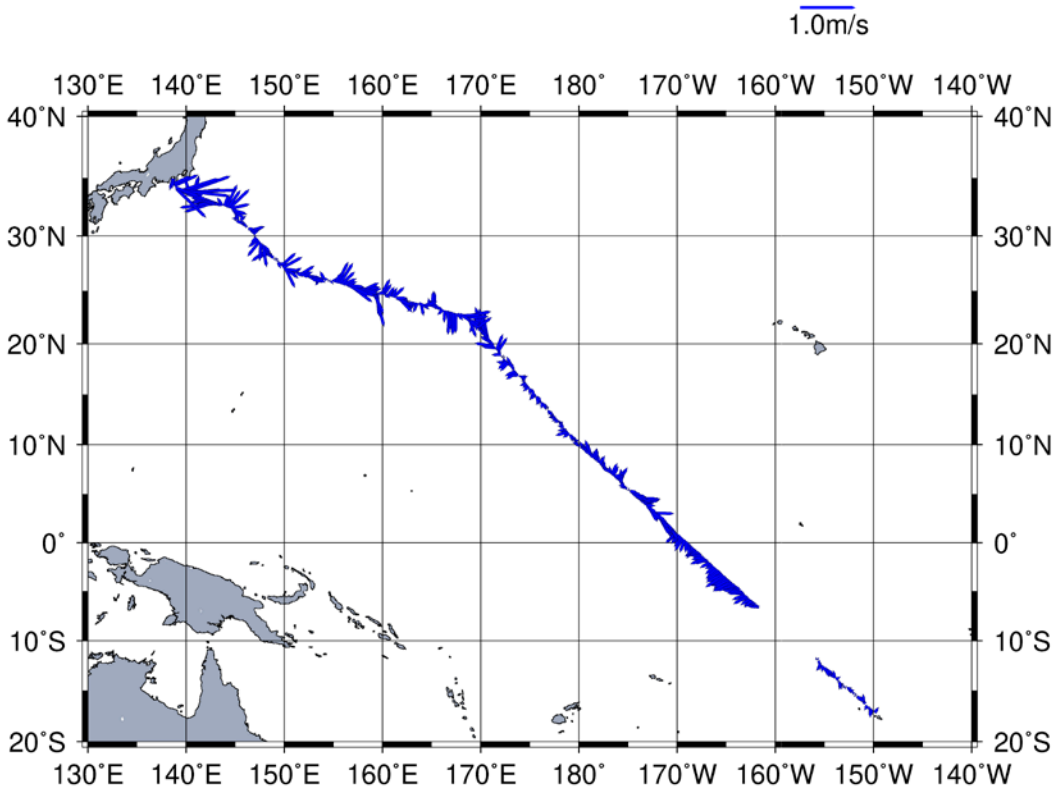


Fig.3.5.1 Horizontal Velocity along the ship's track. (60min. Average / Layer: 35-100m)

(6) Data Archives

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

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

(7) Remarks

1. The following period, acquisition of data was stopped due to entering the Territorial Water of French Polynesia.

19:10UTC 5th Mar. 2019 (Departure from Papeete) - 21:10UTC 5th Mar. 2019

2. The following period, acquisition of data was stopped due to entering the EEZ of New Zealand.

11:40UTC 7th Mar. 2019 - 00:29UTC 9th Mar. 2019

3.6 XCTD

(1) Personnel

Fumikazu Taketani	*JAMSTEC: Principal investigator*
Kazuhiko MATSUMOTO	*JAMSTEC*
Masanori Murakami	*Nippon Marine Enterprises LTD. (NME)*
Kazuho Yoshida NME	
Yoichi Inoue	*MIRAI crew*

(2) Objective

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

(3) Apparatus

We observed the vertical profiles of the sea water temperature and conductivity measured by XCTD-1 manufactured by Tsurumi-Seiki Co. (TSK). The signal was converted by MK-150N(TSK) and was recorded by AL-12B software (Ver.1.1.4, TSK). We launched 3 probes by using the automatic launcher. The summary of XCTD observation log is shown in Table 3.6.1.

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

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

Table 3.6.1 XCTD observation log

No.	Date [YYYY/MM/DD]	Time [hh:mm]	Latitude [deg-min]	Longitude [deg-min]	Depth [m]	SST [deg-C]	SSS [PSU]	Probe S/N	Probe Type
1	2019/03/09	00:56	6-35.8688S	161-41.1023W	5225	30.437	35.776	18043373	XCTD-1
2	2019/03/09	19:59	3-53.7959S	164-39.7759W	3068	28.745	35.330	18043374	XCTD-1
3	2019/03/10	22:57	0-00.0037S	168-56.9512W	5615	28.554	35.199	18043375	XCTD-1
4	2019/03/11	20:00	2-54.2533N	172-08.3563W	5394	28.566	35.062	18043376	XCTD-1
5	2019/03/12	19:57	6-05.2053N	175-39.3484W	5558	28.598	34.782	18106787	XCTD-1
6	2019/03/14	21:00	13-00.9913N	177-21.4524E	5720	26.140	34.264	18106788	XCTD-1
7	2019/03/16	20:59	20-35.1931N	170-35.3546E	5631	25.941	34.810	18106789	XCTD-1
8	2019/03/17	22:01	23-17.2623N	165-55.7520E	6144	25.151	35.182	18106790	XCTD-1
9	2019/03/18	21:58	24-30.2463N	160-45.4013E	4870	25.826	35.143	18106791	XCTD-1
10	2019/03/19	21:59	25-42.8331N	155-38.8402E	5882	24.900	35.193	18106792	XCTD-1
11	2019/03/20	22:56	27-00.0450N	150-00.0355E	5802	23.497	35.056	18106793	XCTD-1
12	2019/03/22	00:00	30-56.4808N	146-01.8486E	5580	19.133	34.855	18043300	XCTD-1
13	2019/03/22	10:24	32-25.0984N	144-37.1105E	5675	19.117	34.795	18043299	XCTD-1

SST: Sea Surface Temperature [deg-C] measured by TSG (Thermo Salino Graph).
SSS: Sea Surface Salinity [PSU] measured by TSG.

(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.

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

3.7 C-band Weather Radar

(1) Personnel

Fumikazu Taketani (JAMSTEC)
Masaki Katsumata (JAMSTEC) *not*
Biao Geng (JAMSTEC) *not*

(2) Objective

The objective of weather radar observations is to investigate the structures and evolutions of precipitating systems over the tropical ocean.

(3) Radar specifications

The C-band weather radar the R/V Mirai was used. 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 S.A.S)

(4) Available radar variables

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

Radar reflectivity:	Z
Doppler velocity:	Vr
Spectrum width of Doppler velocity:	SW
Differential reflectivity:	Z_{DR}
Differential propagation phase:	Φ_{DP}
Specific differential phase:	K_{DP}
Co-polar correlation coefficients:	ρ_{HV}

(5) Operational methodology

The antenna was 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 laser gyro. The Doppler velocity was also corrected by subtracting the ship movement in beam direction.

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

During the cruise, the radar was operated as in Table 3.7-1. A dual PRF mode was used for a volume scan. For RHI, vertical point, and surveillance PPI scans, a single PRF mode was used.

(6) Data and preliminary results

The C-band weather radar observations were conducted through the cruise, except in the EEZs and territorial waters without permission, and in the area where the operations were prohibited by Japanese license.

The obtained data will be analyzed after the cruise. Unfortunately, C-band Weather Radar had malfunction on 13 March due to the motor trouble. We terminated the observations of C-band Weather Radar around 00:11 on 13 March (UTC).

(7) Data archive

All data from the C-band weather radar observations during this cruise will be submitted to the JAMSTEC Data Management Group (DMG).

Table 3.7-1 Parameters for scans.

	Surveillance PPI Scan	Volume Scan						RHI Scan	Vertical Point Scan
Repeated Cycle (min.)	30	6						12	
Times in One Cycle	1	1						3	3
Pulse Width (long / short, in microsec)	200 / 2	64 / 1		32 / 1		32 / 1		32 / 1	32 / 1
Scan Speed (deg/sec)	18	18		24		36		9	36
PRF(s) (Hz)	400	dual PRF (ray alternative)						1250	2000
		667	833	938	1250	1333	2000		
Pulses / Ray	16	26	33	27	34	37	55	32	64
Ray Spacing (deg.)	0.7	0.7		0.7		1.0		0.2	1.0
Azimuth (deg)	Full Circle							Option	Full Circle
Bin Spacing (m)	150								
Max. Range (km)	300	150		100		60		100	60
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	90

3.8 Ceilometer

(1) Personnel

Fumikazu Taketani	*JAMSTEC: Principal investigator*
Masanori Murakami	*Nippon Marine Enterprises LTD. (NME)*
Kazuho Yoshida NME	
Yoichi Inoue	*MIRAI crew*

(2) Objectives

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

(3) Apparatus

Cloud base height and backscatter profile were observed by ceilometer (CL51, VAISALA, Finland). Measured parameters and major specifications for the measurement configuration are shown in Table 3.8.1 and Table 3.8.2 respectively. On the archive dataset, cloud base height and backscatter profile are recorded with the resolution of 10 m.

Table 3.8.1 Measured parameters

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

Table 3.8.2 Major specifications for the measurement configuration

Property	Description / Value
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 meter 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

(4) Preliminary results

Figure 3.8-1 shows the time series of cloud-base heights derived from the ceilometer during this cruise.

(5) Data archives

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

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

(6) Remarks

1. The following period, acquisition of data was stopped due to entering the Territorial Water of French Polynesia.

19:10UTC 5th Mar. 2019 (Departure from Papeete) - 21:10UTC 5th Mar. 2019

2. The following period, acquisition of data was stopped due to entering the EEZ of New Zealand.

11:40UTC 7th Mar. 2019 - 00:29UTC 9th Mar. 2019

3. Window cleaning

00:04UTC 9th Mar. 2019
21:03UTC 15th Mar. 2019
22:40UTC 18th Mar. 2019

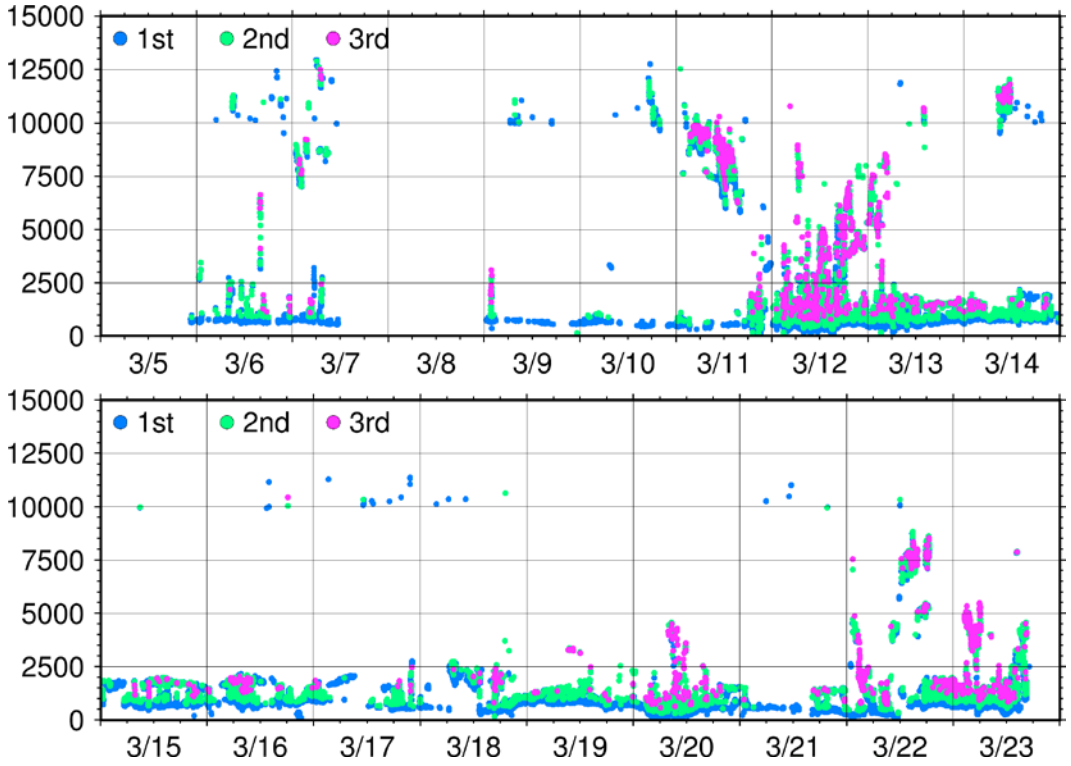


Figure 3.8-1 Time series of cloud base height during this cruise

3.9 Micro Rain Radar

(1) Personnel

Fumikazu Taketani (JAMSTEC)
Masaki Katsumata (JAMSTEC) *not*

(2) Objectives

The micro rain radar (MRR) is a compact vertically-pointing Doppler radar, to detect vertical profiles of rain drop size distribution. The objective of this observation is to understand detailed vertical structure of the precipitating systems.

(3) Instruments and Methods

The MRR-2 (METEK GmbH) was utilized. The specifications are in Table 3.9-1. The antenna unit was installed at the starboard side of the anti-rolling systems (see Fig. 3.9-1), and wired to the junction box and laptop PC inside the vessel.

The data was averaged and stored every one minute. The vertical profile of each parameter was obtained every 100 meters in range distance (i.e. height) up to 3100 meters, i.e. well beyond the melting layer. The recorded parameters were; Drop size distribution, radar reflectivity, path-integrated attenuation, rain rate, liquid water content and fall velocity.

Fig. 3.9-1: Photo of the antenna unit of MRR

Table 3.9-1: Specifications of the MRR-2.

Transmitter power	50 mW
Operating mode	FM-CW
Frequency	24.230 GHz (modulation 1.5 to 15 MHz)
3dB beam width	1.5 degrees
Spurious emission	< -80 dBm / MHz
Antenna Diameter	600 mm
Gain	40.1 dBi

(4) Preliminary Results

The data have been obtained all through the cruise, except EEZs and territorial waters without permission. The further analyses will be after the cruise.

(5) Data Archive

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

(6) Acknowledgment

The operations are supported by Japan Aerospace Exploration Agency (JAXA) Precipitation Measurement Mission (PMM).

3.11 Rain Water Sampling

(1) Personnel

Fumikazu Taketani (JAMSTEC)
Yugo Kanaya (JAMSTEC) *not*
Kazuhiko Matsumoto (JAMSTEC)

(2) Objectives

To obtain the information of nutrients input from atmosphere to Ocean surface by wet deposition process, we collected rain water.

(3) Instrumentations and Methods

Rain Water Sampling is installed on the compass deck. Rain water was corrected by plastic infundibulum. There are 24 bottles in the sampler. The sampling was carried out every 2 hours from 9th March 2:00. Sampled rain water was stored to refrigeration room. Time-profile of rain fall were shown in Figure 3.12-1. The sampling log is listed in Table 3.11-1. All samples are going to be analyzed in laboratory.

(4) Data Archive

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

Figure 3.11-1 Time-profile of rain fall in MR18-06Leg4

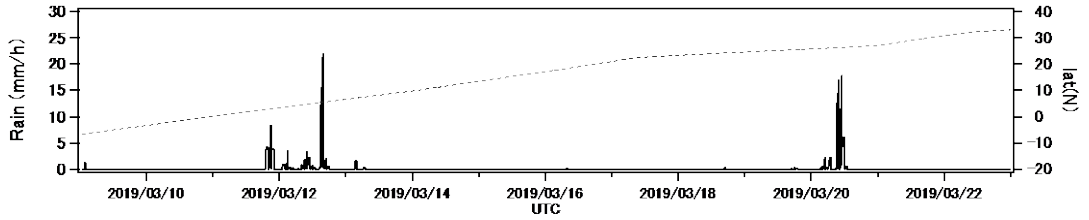


Table 3.11-1. Rain sampling log in MR18-06Leg4

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC/JST	Deg.	Min.	N/S	Deg.	Min.	E/W
Rain-001	2019	03	11	16:00	UTC	3	14.28	N	172	30.89	W
Rain-002	2019	03	11	18:00	UTC	3	25.7	N	72	55.22	W
Rain-003	2019	03	12	0:00	UTC	3	40	N	172	59	W
Rain-004	2019	03	12	2:00	UTC	3	41.45	N	173	0.47	W
Rain-005	2019	03	12	8:00	UTC	4	29.83	N	173	54.19	W
Rain-006	2019	03	12	10:00	UTC	4	45.76	N	174	11.47	W
Rain-007	2019	03	12	14:00	UTC	5	17.26	N	174	46.29	W
Rain-008	2019	03	12	16:00	UTC	5	33.23	N	175	4.47	W
Rain-009	2019	03	18	16:00	UTC	24	16.67	N	161	51.6	E
Rain-013	2019	03	20	4:00	UTC	26	0.52	N	154	18.6	E
Rain-014	2019	03	20	6:00	UTC	26	7.04	N	153	50.05	E
Rain-015	2019	03	20	8:00	UTC	26	13.31	N	153	22.09	E
Rain-016	2019	03	20	10:00	UTC	26	19.91	N	152	55.19	E

3.12 Tropospheric gases and particles observation at the marine atmosphere

(1) Personnel

Fumikazu Taketani (JAMSTEC)	
Kaori Kawana (JAMSTEC)	
Kazuhiko Matsumoto (JAMSTEC)	
Yugo Kanaya (JAMSTEC)	*not*
Takuma Miyakawa (JAMSTEC)	*not*
Zhu Chunmao (JAMSTEC)	*not*

(2) Objectives

- To investigate roles of aerosols in the marine atmosphere in relation to climate change
- To investigate processes of biogeochemical cycles between the atmosphere and the ocean.

(3) Instrumentations and Methods

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

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

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

Size distribution of aerosol particles: The size distribution of particles was measured by a handheld optical particle counter (OPC) (KR-12A, Rion) installed at compass deck.

Ambient air sampling: Ambient air samplings were carried out by air samplers installed at compass deck. Ambient particles were collected on the quartz filter (size: 8” × 10”) using a high-volume air sampler (HVS, 120SL, KIMOTO operated at flow rate of 740L/min. To avoid collecting particles emitted from the funnel of the own vessel, the sampling period was controlled automatically by using a “wind-direction selection system”. To investigate the morphology of particles by the electron microscope, temporal samplings (5 – 10min) are carried out using hand-made air sampler operated at flow rate of 1 L/min. These sampling logs are listed in Table 3.13-1. All samples are going to be analyzed in laboratory.

Ambient air sampling for fluorescent particles: Ambient aerosol sampling for bioaerosol analysis were conducted by two methods. Aerosols (≥0.9 μm) were introduced to vial bottle in the downstream of PM1 cyclone with a flow rate of 20 L/min. This collection was also controlled by a “wind-direction selection system” as above. Additionally, temporal collection of aerosols on the membrane filter directly was conducted with a flow rate of 1 L/min. These sampling logs are listed in Table 3.12-3. By measurement of the fluorescent particles in the samples with/without dyeing reagents of DAPI and Hoechst using a bioplorer (KB-VKH01, Koyo Sangyo Co., Ltd), alive/dead particles in the marine atmosphere were obtained.

CO and O3: Ambient air was continuously sampled on the compass deck and drawn through ~20-m-long Teflon tubes connected to CO analyzer (Model 48C, Thermo Fisher Scientific) and a UV photometric ozone analyzer (Model 49C, Thermo Fisher Scientific). The data will be used for characterizing air mass origins.

(4) Preliminary results

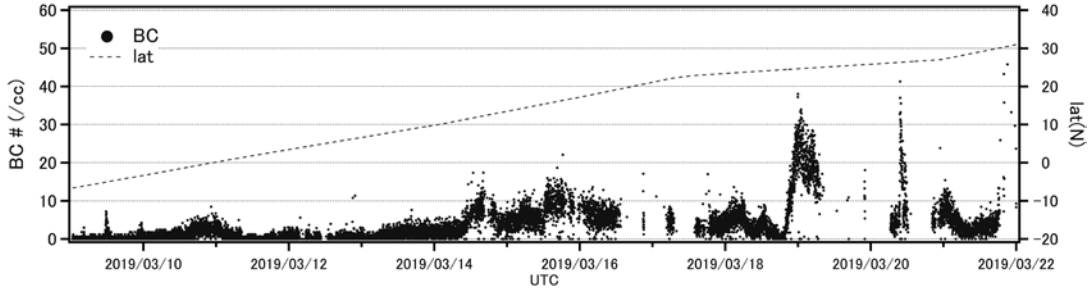


Figure 3.12-1. Temporal profile of BC number concentration measured by SP2 instrument along the ship track

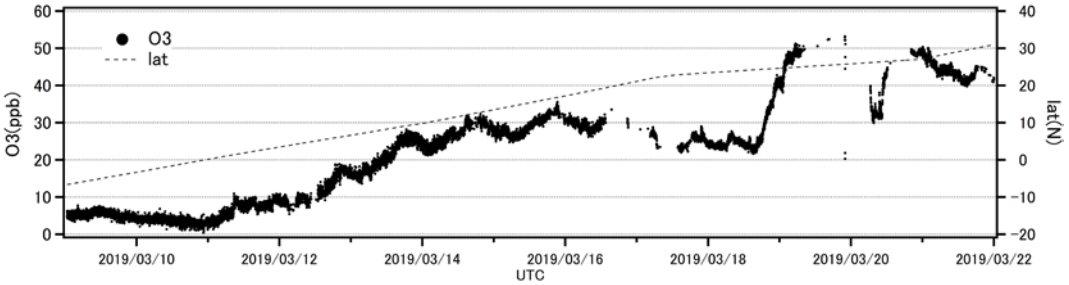


Figure 3.13-2. Temporal profile of O3 concentration measured by O3 instrument along the ship track

(5) Data Archive

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

Table 3.12-1: Logs of Ambient aerosol particles sampling.

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC/JST	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1806Leg4-HV-001	2019	03	05	21:45	UTC	17	10.3	S	149	52.33	W
MR1806Leg4-HV-002	2019	03	09	0:37	UTC	6	38.23	S	161	38.45	W
MR1806Leg4-HV-003	2019	03	10	20:33	UTC	0	20.67	S	168	34.43	W
MR1806Leg4-HV-004	2019	03	13	0:56	UTC	6	43.08	N	176	21.54	W
MR1806Leg4-HV-005	2019	03	16	1:53	UTC	17	28.25	N	173	24.41	E
MR1806Leg4-HV-006	2019	03	18	2:30	UTC	23	31.59	N	164	55.85	E
MR1806Leg4-HV-007	2019	03	19	2:25	UTC	24	43.97	N	159	49.66	E
MR1806Leg4-HV-008	2019	03	20	2:38	UTC	25	55.92	N	154	37.59	E
MR1806Leg4-HV-009	2019	03	21	3:58	UTC	27	46.44	N	149	13.32	E
MR1806Leg4-HV-010	2019	03	22	5:09	UTC	31	39.84	N	145	17.64	E

Table 3.13-2: Logs of Ambient aerosol particles sampling for TEM analysis.

On board ID	Date Collected					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC/JST	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1806Leg4_TEM_001	2019	03	10	1:05	UTC	3	12.35	S	165	25.6	W
MR1806Leg4_TEM_002	2019	03	11	1:52	UTC	0	25.93	N	169	25.7	W
MR1806Leg4_TEM_003	2019	03	12	0:34	UTC	3	29.62	N	172	47.44	W
MR1806Leg4_TEM_004	2019	03	13	1:21	UTC	6	46.26	N	176	25.03	W
MR1806Leg4_TEM_005	2019	03	14	2:19	UTC	10	8.86	N	179	52.06	E
MR1806Leg4_TEM_006	2019	03	15	1:52	UTC	13	46.46	N	176	41.54	E
MR1806Leg4_TEM_007	2019	03	16	2:37	UTC	17	37.42	N	173	16.14	E
MR1806Leg4_TEM_008	2019	03	18	4:07	UTC	23	36.26	N	164	34.23	E
MR1806Leg4_TEM_009	2019	03	19	4:00	UTC	24	48.5	N	159	27.53	E
MR1806Leg4_TEM_010	2019	03	21	0:46	UTC	27	22.2	N	149	38.47	E

Table 3.12-3: Logs of Ambient aerosol particles sampling for bioaerosol analysis.

ID	Date					Latitude			Longitude		
	YYYY	MM	DD	hh:mm:ss	UTC/JST	Deg.	Min.	N/S	Deg.	Min.	E/W
MR1806L04-cyclone-01	2019	3	5	21:45	UTC	17	10.30	S	149	52.33	W
MR1806L04-cyclone-02	2019	3	9	0:37	UTC	6	38.23	S	161	38.45	W
MR1806L04-cyclone-03	2019	3	10	0:07	UTC	3	21.41	S	165	15.95	W
MR1806L04-cyclone-04	2019	3	10	20:33	UTC	0	20.67	S	168	34.43	W
MR1806L04-cyclone-05	2019	3	12	1:25	UTC	3	27.90	N	172	45.62	W
MR1806L04-cyclone-06	2019	3	14	2:00	UTC	10	4.84	N	179	55.48	E
MR1806L04-cyclone-07	2019	3	15	1:35	UTC	13	42.67	N	176	44.81	E
MR1806L04-cyclone-08	2019	3	16	1:53	UTC	17	28.25	N	173	24.41	E
MR1806L04-cyclone-09	2019	3	17	1:25	UTC	21	17.09	N	169	55.88	E
MR1806L04-cyclone-10	2019	3	18	2:30	UTC	23	31.59	N	164	55.85	E
MR1806L04-cyclone-11	2019	3	20	2:38	UTC	25	55.92	N	154	37.59	E
MR1806L04-cyclone-12	2019	3	21	3:58	UTC	27	46.44	N	149	13.32	E
MR1806L04-cyclone-13	2019	3	22	5:09	UTC	31	39.84	N	145	17.64	E
MR1806L04-chip-01	2019	3	7	2:04	UTC	13	19.10	S	154	22.00	W
MR1806L04-chip-02	2019	3	9	0:37	UTC	6	38.23	S	161	38.45	W
MR1806L04-chip-03	2019	3	10	0:10	UTC	3	21.41	S	165	38.96	W
MR1806L04-chip-04	2019	3	10	20:02	UTC	0	24.78	S	168	30.04	W
MR1806L04-chip-05	2019	3	12	0:20	UTC	3	27.90	N	172	45.62	W
MR1806L04-chip-06	2019	3	15	1:30	UTC	13	42.67	N	176	44.81	E
MR1806L04-chip-07	2019	3	16	2:00	UTC	17	28.25	N	173	24.41	E
MR1806L04-chip-08	2019	3	18	0:05	UTC	23	23.34	N	165	28.67	E
MR1806L04-chip-09	2019	3	18	23:55	UTC	24	35.18	N	160	24.16	E
MR1806L04-chip-10	2019	3	21	3:57	UTC	27	46.44	N	149	13.32	E

3.13 Aerosol optical characteristics measured by ship-borne sky radiometer

(1) Personnel

Fumikazu Taketani (JAMSTEC)
Kazuma Aoki (University of Toyama) *not*
Masanori Murakami (NME)
Kazuho Yoshida (NME)

(2) Objective

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.

(3) 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.

(4) Instruments and Methods

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.

(5) Data archives

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

3.14 Lidar

(1) Personnel

Fumikazu Taketani (JAMSTEC)
Masaki Katsumata (JAMSTEC) *not*
Kyoko Taniguchi (JAMSTEC) *not*
Masanori Murakami (NME)
Kazuho Yoshida (NME)

(2) Objective

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

(3) Instrumentations and Methods

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 parallel and perpendicular 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.

(4) Results

The lidar system observed the lower atmosphere throughout the cruise, except on EEZs and territorial waters without permission. All data will be reviewed after the cruise to maintain data quality.

(5) Data Archive

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

3.15 GNSS precipitable water

(1) Personnel

Fumikazu Taketani (JAMSTEC)	
Masaki Katsumata (JAMSTEC)	*not*
Mikiko Fujita (JAMSTEC)	*not*

(2) Objective

Getting the GNSS satellite data to estimate the total column integrated water vapor content of the atmosphere.

(3) Method

The GNSS satellite data was archived to the receiver (Trimble NetR9) with 5 sec interval. The GNSS antenna (Margrin) was set on the roof of aft wheel house. The observations were carried out all thru the cruise.

(4) Results

The data have been obtained all through the cruise, except in the EEZs and territorial waters without permission. We will calculate the total column integrated water from observed GNSS satellite data after the cruise.

(5) Data archive

Raw data is recorded as T02 format and stream data every 5 seconds. These raw datasets are available from Mikiko Fujita of JAMSTEC. Corrected data will be submitted to JAMSTEC Marine-Earth Data and Information Department and will be archived there.

3.16 Sea Surface Gravity

(1) Personnel

Fumikazu Taketani *JAMSTEC: Principal investigator*
Kazuho Yoshida *Nippon Marine Enterprises LTD. (NME)*
Masanori Murakami *NME*
Yoichi Inoue *MIRAI crew*

(2) Objective

The local gravity is an important parameter in geophysics and geodesy. We collected gravity data during this cruise.

(3) Apparatus

We measured relative gravity using LaCoste and Romberg air-sea gravity meter S-116 (Micro-g LaCoste, LLC) during the cruise. To convert the relative gravity to absolute one, we measured gravity, using portable gravity meter (Scintrex gravity meter CG-5), at Shimizu and Valparaiso port as the reference points. The parameters for gravity calculation are as follows;

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

(4) Preliminary Results

Absolute gravity table is shown in Table 3.16-1

Table 3.16-1 Absolute gravity table of the MR18-06Leg4 cruise

No.	Date & Time (UTC)	Port	Absolute Gravity [mGal]	Sea Level [cm]	Ship Draft [cm]	* Gravity at Sensor [mGal]	S-116 Gravity [mGal]
#1	03-Mar-2019 20:52	Papeete	978699.41	118	610	978699.95	10983.46
#2	26-Mar-2019 05:55	Shimizu	979729.49	262	607	979730.46	12013.29

* Gravity at Sensor = Absolute Gravity + Sea Level*0.3086/100 + (Draft-530)/100*0.2654

(5) Data archives

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

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

(6) Remarks

1. The following period, acquisition of data was stopped due to entering the Territorial Water of French Polynesia.

19:10UTC 5th Mar. 2019 (Departure from Papeete) - 21:10UTC 5th Mar. 2019

2. The following period, acquisition of data was stopped due to entering the EEZ of New Zealand.

11:40UTC 7th Mar. 2019 - 00:29UTC 9th Mar. 2019

3.17 Sea Surface Magnetic Field

(1) Personnel

Fumikazu Taketani	*JAMSTEC: Principal investigator*
Masanori Murakami	*Nippon Marine Enterprises LTD. (NME)*
Kazuho Yoshida NME	
Yoichi Inoue	*MIRAI crew*

(2) Objective

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

(3) Apparatus

A shipboard three-component magnetometer system (SFG2018, Tierra Tecnica) is equipped R/V MIRAI. Three-axes flux-gate sensors with ring-cored coils are fixed on the fore mast. Outputs from the sensors are digitized by a 20-bit A/D converter (1 nT/LSB), and sampled at 8 times per second. Yaw (heading), Pitch and Roll are measured by the Inertial Navigation System (INS) for controlling attitude of a Doppler radar. Ship's position (Differential GNSS), speed over ground and gyro data are taken from LAN every second.

The relation between a magnetic-field vector observed , Hob, (in the ship's fixed coordinate system) and the geomagnetic field vector, F, (in the Earth's fixed coordinate system) is expressed as:

$$\mathbf{H}_{ob} = \bar{\mathbf{A}}\,\bar{\mathbf{R}}\,\bar{\mathbf{P}}\,\bar{\mathbf{Y}}\,\mathbf{F} + \mathbf{H}_p \qquad \text{(a)}$$

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

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

where $\bar{\mathbf{B}} = \bar{\mathbf{A}}^{-1}$, and $\mathbf{H}_{bp} = -\bar{\mathbf{B}}\,\mathbf{H}_p$. The magnetic field, $\mathbf{F}$, can be obtained by measuring , $\bar{\mathbf{R}}$, $\bar{\mathbf{P}}$, $\bar{\mathbf{Y}}$ and $\mathbf{H}_{ob}$, if $\bar{\mathbf{B}}$ and $\mathbf{H}_{bp}$ are known. Twelve constants in $\bar{\mathbf{B}}$ and $\mathbf{H}_{bp}$ can be determined by measuring variation of $\mathbf{H}_{ob}$ with $\bar{\mathbf{R}}$, $\bar{\mathbf{P}}$, and, $\bar{\mathbf{Y}}$ at a place where the geomagnetic field, $\mathbf{F}$, is known.

(4) Preliminary Results

The results will be published after the primary processing.

(5) Data archives

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

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

(6) Remarks

1. The following period, acquisition of data was stopped due to entering the Territorial Water of French Polynesia.

19:10UTC 5th Mar. 2019 (Departure from Papeete) - 21:10UTC 5th Mar. 2019

2. The following period, acquisition of data was stopped due to entering the EEZ of New Zealand.

11:40UTC 7th Mar. 2019 - 00:29UTC 9th Mar. 2019

3. The following periods, calibration data were collected.

19:20UTC 6th Mar. 2019 - 19:46UTC 6th Mar. 2019 (14-15.60S, 153-22.38W)
00:25UTC 22nd Mar. 2019 - 00:50UTC 22nd Mar. 2019 (30-58.77N, 145-59.75E)

IV. Notice on Using

This cruise report is a preliminary documentation as of the end of cruise.
This report is not necessarily corrected even if there is any inaccurate description (i.e. taxonomic classifications). This report is subject to be revised without notice. Some data on this report may be raw or unprocessed. If you are going to use or refer the data on this report, it is recommended to ask the Chief Scientist for latest status.
Users of information on this report are requested to submit Publication Report to JAMSTEC.

http://www.godac.jamstec.go.jp/darwin/explain/1/e#report
E-mail: submit-rv-cruise@jamstec.go.jp

V. Acknowledgments

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Chief Scientists of MR18-06 leg 4
Fumikazu Taketani